SOLAR TECHNICIAN (ELECTRICAL)

NSQF LEVEL - 3

TRADE THEORY

SECTOR: POWER

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector : Power

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai has now come up with instructional material to suit the revised curriculum for **Solar Technician (Electrical) - Trade Theory - NSQF Level - 3 (Revised 2022) in Power Sector under Yearly Pattern.** The NSQF Level - 3 (Revised 2022)Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 3 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 3 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Addl. Secretary/ Director General of training
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032

EXECUTIVE DIRECTOR

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Solar Technician (Electrical)** under **Power** Sector for ITIs.

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NIMI records its appreciation for the Data Entry, CAD, DTP operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks the invaluable efforts rendered by all other NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course of the **Solar Technician (Electrical)** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF Level -3 (Revised 2022) syllabus are covered.

Module 1	-	Safety Practice and Hand Tools
Module 2	-	Electrical Wire Joints, Soldering and Crimping
Module 3	-	Characteristics of Electrical and Magnetic Circuits
Module 4	-	Measuring instruments and Power, Energy, Calculation Electrical Circuits
Module 5	-	National planetary movements and sunlight's path
Module 6	-	Characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers and DC appliances of solar PV
Module 7	-	Connect, test, under take maintenance and disposal of solar batteries
Module 8	-	Basic circuits of solar panel, Charge controller,Battery bank and Inverter
Module 9	-	Connect and Test Solar Panel
Module 10	-	Bill of Materials for Solar PV Projects
Module 11	-	Tests and Measurement of PV Modules and Installation
Module 12	-	Installation Solar PV Plant and Hybrid Plant
Module 13	-	Operation & Maintenance of PV System
Module 14	-	Manufacturing of Solar Panel

The skill training in the shop floor is planned through a series of practical exercises centered around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI, looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Solar Technician (Electrical)** Trade Theory NSQF Level - 3 (Revised 2022) in **Power** . The contents are sequenced according to the practical exercise contained in NSQF Level - 3 (Revised 2022) syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self-learning and should be considered as supplementary to class room instruction.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No.	Learning Outcome	Ref.Ex.No
1	Prepare profile with an appropriate accuracy as per drawing following safety precautions	1.1.01 - 10
2	Prepare electrical wire joints, carry out soldering and crimping.	1.2.11 - 14
3	Construct and test various characteristics of electrical and magnetic circuits.	1.3.15 - 28
4	Assemble, install and test wiring system	1.3.29 - 37
5	Use instruments for measurement of various electrical parameters.	1.4.38 - 40
6	Perform basic electric energy calculations and understand transmission and distribution of electrical power.	1.4.41 - 46
7	Verify natural planetary movements and sunlight's path.	1.5.47 - 57
8	Demonstrate characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers.	1.6.58 - 82
9	Construct and demonstrate Solar DC appliances.	1.6.83 - 88
10	Connect, test, under take maintenance and disposal of solar	1.7.89 - 96
11	Connect and test solar panel, Charge controller, Battery bank and Inverter.	1.8.97 - 104 1.9.105 - 110
12	Prepare Bill of materials for small, medium and mega solar PV projects	1.10.111 - 116
13	Perform various tests and measurement pertaining to PV Modules and their installation as per IEC standards.	1.11.117 - 121 1.12.122
14	Assist in Installation and commissioning of Solar PV plant and Hybrid plant.	1.12.123 - 157 1.13.158
15	Perform Operation & Maintenance of PV system with best practices.	1.13.159 - 163
16	Perform manufacturing of solar panel, prepare and commission marketable solar products.	1.13.164 - 169 1.14.170 - 176

SYLLABUS

Duration	Reference Learning Outcome	Professional Skill (Trade Practical) (With inidcative hour)	Professional Knowledge (Trade Theory)
Professional Skill 60 Hrs; Professional Knowledge 15 Hrs	Prepare profile with an appropriate accuracy as per drawing following safety precautions	1. Visit of various sections of the institutes and identification of danger, warning, caution & safety signs. (05 hrs) 2. Preventive measures for electrical accidents and use of fire extinguishers.(05hrs) 3. Practice elementary first aid and artificial respiration. (06hrs) 4. Disposal procedure of waste materials. (03hrs) 5. Use of personal protective equipments. (05hrs) 6. Familiarization with signs and symbols of electrical Accessories. (04hrs)	Scope of the trade. Safety rules and safety signs. Types and working of fire extinguishers. First aid safety practice. Hazard identification and prevention. Response to emergencies, e.g. power failure, system failure and fire etc. (05 hrs)
		7. Workshop practice on filing and hacksawing.(07hrs) 8. Practice sawing, planing, drilling and assembling formaking a wooden switchboard. (07hrs) 9. Workshop practice on drilling, chipping, internal and external threading of different sizes. (12hrs) 10. Prepare an open box from metal sheet. (05hrs)	Concept of Standards and advantages of BIS/ISI. Trade tools specifications. Electrical symbols. Introduction to National Electrical Code-2011. (10 hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Prepare electrical wire joints, carry out soldering and crimping.	11. Practice on skinning, twisting and crimping. (06 hrs) 12. Identify various types of cables and measure conductor size using SWG and micrometer. (06hrs) 13. Make joints on single strand conductors. (06 hrs) 14. Practice in crimping and soldering of joints / lugs. (07 hrs)	Fundamentals of electricity. Concept of current, voltage, power, resistors and capicitors. Generation of DC electricity. Electrical conductors and insulators. Differentiate between AC and DC current. Types of joints and techniques of soldering. (05 hrs)
Professional Skill 60 Hrs; Professional Knowledge 12 Hrs	Construct and test various characteristics of electrical and magnetic circuits	15. Measure parameters in combinational DC circuits by applying Ohm's Law for different resistor values and voltage sources. (05 hrs) 16. Measure current and voltage in DC circuits to verify Kirchhoff's Law. (04 hrs)	Ohm's Law; Simple electrical circuits and problems. Kirchoff's Laws and applications. Series and parallel circuits. Open and short circuits in series and parallel networks.

		17. Verify laws of series and parallel circuits with voltage source in different combinations. (04 hrs) 18. Measure current and voltage and analyse the effects of shorts and opens in series and parallel circuits. (05 hrs) 19. Verify the characteristics of series parallel combination of resistors. (04 hrs) 20.Determine the poles and plot the field of a magnet bar. (04 hrs) 21. Identify various types of capacitors, charging / discharging and testing. (04 hrs) 22. Test AC circuit with resistive load like lamp, heater, etc. (04 hrs) 23. Test AC circuit with inductive load like fan, pump, etc. (04 hrs) 24. Measure power, energy for lagging and leading power factors in single phase circuits. (04 hrs) 25. Measure Current, voltage,power, energy and power factor in three phase circuits. (05 hrs) 26. Ascertain use of neutral by identifying wires of a 3- phase 4 wire system and find the phase sequence. (04 hrs) 27. Determine the relationship between Line and Phase values for star and delta connections. (04 hrs) 28. Measure the Power of three phase circuit for balanced and unbalanced loads. (05 hrs)	Series and parallel combinations of resistors. Magnetic terms, magnetic materials and properties of magnet. Electrostatics: CapacitorDifferent types, functions, grouping and uses. Inductive and capacitive reactance and their effect on AC circuit. Comparison and Advantages of DC and AC systems. Sine wave, phase and phase difference. Related terms frequency,Instantaneous value, R.M.S. value Average value, Peak factor, form factor, power factor and Impedance etc. Active and Reactive power Single Phase and threephase system. Advantages of AC polyphase system. Concept of three-phase Star and Delta connection. Line and phase voltage, current and power in a 3 phase circuits with balanced and unbalanced load. (12 hrs)
Professional Skill 45 Hrs; Professional Knowledge 07 Hrs	Assemble, install and test wiring system.	29. Identify various conduits and different electrical accessories. (04 hrs) 30. Practice cutting, threading of different sizes & laying Installations. (05 hrs) 31. Prepare test boards / extension boards and mount accessories like lamp holders, various switches, sockets, fuses, relays, MCB, ELCB, MCCB etc. (05 hrs) 32. Drawing layouts and practice in PVC Casingcapping, Conduit wiring with minimum to number of points as per IE rules. (06 hrs) 33. Wire up PVC conduit wiring to control one lamp from two different places using two way switch. (06 hrs)	I.E. rules on electrical wiring. Types of domestic and industrial wirings. Study of wiring accessories e.g. switches, fuses, relays, MCB, ELCB, MCCB, switchgears etc. Grading of cables and current ratings. Principle of laying out of Domestic wiring. Voltage drop concept. PVC conduit and Casing-capping wiring system. Different types of wiring Power, control, Communication and entertainment wiring.

		34. Practice testing / fault detection of domestic and industrial wiring installation and repair. (05 hrs) 35. Practice control panel wiring using wiring accessories and mounting of control elements, e.g. meters, fuses, relays, switches, push buttons, MCB, ELCB etc. (05 Hrs) 36. Prepare different types of earthing and measure earth resistance by earth tester / megger. (05 hrs) 37. Practice Installation of lightening arrestor. (04 hrs)	Wiring circuits planning, permissible load in subcircuit and main circuit. Importance of Earthing. Plate earthing and pipe earthing methods and IEE regulations. Earth resistance and earth leakage circuit breaker. Lightening arrestor. (07 hrs)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Use instruments for measurement of various electrical parameters.	38. Identify and practice of various analog and digital measuring Instruments. (05 hrs) 39. Practice on measuring instruments in single and three phase circuits e.g. multi-meter, Wattmeter, Energy meter, Phase sequence meter and Frequency meter etc. (15 hrs) 40. Test single phase energy meter for its errors. (05 hrs)	Classification of electrical instruments and essential forces required in indicating instruments. PMMC and Moving iron instruments. Range extension Wattmeter, PF meter, Energy meter, Megger, Earth tester, Frequency meter, Phase sequence meter, Multimeter, Tong tester etc. Instrument transformers – CT and PT. (05 hrs)
Professional Skill 45 Hrs; Professional Knowledge 10 Hrs	Perform basic electric energy calculations and understand transmission and distribution of electrical power	41. Measure power consumption for different loads with various times of use and calculate watthour. (07 Hrs) 42. Find out power ratings from product label and prepare a load calculation chart. (06 hrs) 43. Verify terminals, identify components and calculate the transformation ratio of single phase transformers. (04hrs) 44. Perform OC and SC test to determine and efficiency of single phase transformer. (05 hrs) 45. Visit to transmission / distribution substation. (15 hrs) 46. Draw actual circuit diagram of substation visited and indicate various components. (08 hrs)	Calculation of total watt hour of all loads per day and daily average watt hour from twelve months electricity bill. Working principle of transformer. Electric power demand, supply and gap in city, state and national level. Conventional energy Generation by thermal (coal, gas diesel) and hydel power plant. (small and large) Advantages of high voltage transmission. Transmission network of India. Study of distribution of power and substation. Overhead v/s underground distribution system. (10 hrs)

Professional Skill 60 Hrs; Professional Knowledge 12 Hrs	Verify natural planetary movements and sunlight's path.	47. Plot sun chart and locate the sun at your location for a given time of the day. (04 hrs) 48. Find out relations between sunlight and earth motion by globe model. (04 hrs) 49. Observe and compare sunlight and angle of inclination during 12 hours of a day on different days. (13 hrs) 50. Locate magnetic poles (North and South) with the help of magnetic compass. (05 hrs) 51. Observe on Globe, which countries are in the Northern hemisphere and which on the Southern hemisphere. (05 hrs) 52. Prepare a list of places around India, their latitude and longitude. (05 hrs) 53.Measure intensity of solar radiation using Pyranometer and radiometers. (05 hrs) 54.Analyse shadow effect on incident solar radiation and find out contributors. (05 hrs) 55.Plot curve of radiation measured with respect to time for a location. (05 hrs) 56.Draw a solar map by collecting data of solar radiation in a location for one year. (05 hrs) 57. Compare the effects of direct radiation, diffused radiation and reflected radiation and prepare reports. (04 hrs)	Non-renewable and Renewable energy concept. Advantages over non renewable energy; brief discussion main renewable energy resources viz. solar (PV and thermal), wind, Biofuel, Biomass, small hydro, Tidal power, Wave power, Geo thermal energy etc. Solar energy fundamentals. Study of Sun path (east to west, North to south and south to north movement). Study of daily and seasonal changes of sunlight. Angle of inclination of radiant light and its relation with latitude and longitude of different locations on Earth. Definition of key earth-sun angles. Equation of time, solar constant etc. Definition of GHI & DNI Definition of tracking (single axis and double axis) Solar radiation over India (measurements, satellite data and maps) (10-12 years historical data) Application of sunchart on shadow identification. Sunlight spectrum. (12 hrs)
Professional Skill 100 Hrs; Professional Knowledge 19 Hrs	Demonstrate characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers.	58. Test an LED and a Photodiode to verify the photo emitting effect and light sensitivity. (04 hrs) 59. Test a Photo voltaic cell for different illumination levels and verify photovoltaic property. (04 hrs) 60. Plot I-V curve for photovoltaic cell based on the illumination at constant temperature. (04 hrs) 61. Plot I-V curve for photovoltaic cell based on temperature at constant illumination. (04 hrs) 62. Test photovoltaic cell in sunlight at various angles of inclination and direction. (04 hrs) 63. Test different rated Photovoltaic modules (Panels) and plot I-V curve. (04 hrs)	Semiconductor properties and types. P-type and N-type semiconductors, PN junction, etc. Conversion of solar radiation to electricity. Main materials used to develop solar cells (Silicon, Cadmium tellurides, etc.) Light sensitive properties of PN junction. Difference of photo electric and photo voltaic effects of a PN junction. PV cell characteristics, I–V curve, effects of temperature. Photovoltaic effect. Photo voltaic module: minimal functional

		64. Record specification of different solar panels and compare specifications to select a panel. (04 hrs) 65. Test different types of PV panels such as, mono crystalline, poly crystalline, amorphous silicon and thin film modules. Prepare a report on panels. (04 hrs) 66. Determine the relation between number of cells and maximum voltage per module. (04 hrs) 67. Connect suitably rated wires in the terminal box of a solar panel and connect end terminals using MC 4 connectors. (04 hrs)	specification, cells per module, max watts per module, maximum voltage at max power, maximum current at max power. Standard test conditions (STC) of a PV module. Terminal box and connectors of a Solar PV module. Identification of various test standards of PV module. Measurement of area of the cells and compare with the module area in data sheet. Identification of faulty PV module. (14 hrs)
		68. Connect solar panels in series and measure voltage and current. Repeat with different rated panels. (04 hrs) 69. Connect solar panels in parallel and measure voltage and current. Repeat with different rated panels. (04 hrs) 70. Shift the panels to rooftop or the place of installation using safe handling practices. (03 Hrs) 71. Check the structural and area requirement for installation of 1 KW solar panel. (04 hrs) 72. Identify different solar panels as per specification. (04 hrs) 73. Compare different types of solar panels and prepare a report. (04 hrs) 74. Charge a solar battery rated 12V, 100 Ah using Battery charger by CV and CC method and Tabulate the observations during charging cycle. (05hrs) 75. Discharge a solar battery rated 12V, 100 Ah using DC load under Constant Current and tabulate the observations during discharging cycle. (04 hrs) 76. Verify Voltage, ampere hour (Ah), state of charge (SOC), depth of discharge (DOD), Efficiency, C-rating of battery from 5 different manufacturers. Compare and select suitable solar battery. (04 hrs) 77. Connect the charge controller (12V, 10A) with Solar battery (12V, 100Ah), Solar panel (75W) and DC load (12V such as LED light 3W & 5W, DC Fan & FM radio). (05 hrs)	Solar PV array; series and parallel calculation. Handling of PV modules. Module mounting; structures requirement. Photovoltaic cell and PV modules: types - mono crystalline, poly crystalline, amorphous silicon and thin film PV cells and their comparison. Recent thin film technologies (CdTe, GIGS, CIS etc.) Safe handling of panels. **Battery fundamentals;** Storage batteries: Various types of Batteries- Lead acid battery, nickel cadmium battery, lithium ion battery. Battery construction, working, charge/discharge and applications. Safe working with battery. Solar Rechargeable SMF Battery; energy, storage capacity specifications, voltage, ampere hour (Ah), state of charge (SOC), depth of discharge (DOD), Efficiency, C-rating, cycle life, self-discharge etc. Deep discharge and shallow cycle. Block diagram of a charge controller. Tools required for working with battery. Charge controllers, fuses, blocking diodes, bypass diode, LED indicators, low voltage disconnect, high voltage disconnect.

		78. Test the charge controller working with the above circuit and study the performance. (04 hrs) 79. Construct home lighting system using solar panel. (04 hrs) 80. Construct and test a solar powered mobile handset charger. (04 hrs) 81. Construct a dusk to dawn charge controller (12V, 10A) with Solar battery (12V, 100Ah), Solar panel (75W) and LED light (12V DC, 5W). (04 hrs) 82. Construct a home lighting system with manual control. (04 hrs)	Solar DC home lighting, Solar mobile Handset charger, Solar FM radio, Solar DC fan and other solar DC devices. Power packs for decentralized energy supply. Troubleshooting of batteries and charge controllers. (09 hrs)
Professional Skill 45 Hrs; Professional Knowledge 07 Hrs	Construct and demonstrate Solar DC appliances.	83. Construct a solar lantern using Solar PV panel (15W), Charge controller (6V, 5A), Output control circuit for variable illumination, Rechargeable battery (6V, 7Ah) and DC LED lamp (5W). (08hrs) 84. Construct a Solar Day lighting using manual charge controller (12V, 10A), Solar battery (12V, 100Ah), Solar panel (75 W) and 4X LED light (12V DC,5W). (08hrs) 85.Construct a Solar Garden light using dusk to dawn charge controller (12V, 10 A), Solar battery (12V, 100 Ah), Solar panel (75 W) and 4X LED light (12V DC, 5W). (07 Hrs) 86. Construct a Solar Street light using dusk to dawn charge controller (12V, 10 A), Solar battery (12V, 100 Ah), Solar panel (75 W) and 4X LED light (12V DC, 5W). (07 Hrs) 87. Construct a Solar Security system using a Manual charge controller rated (12V, 10 A), Solar battery (12V, 100 Ah), Solar panel (75 W) and Security camera & CCTV/Intruder alarm (12 V DC). (08 hrs) 88. Construct a Solar water pump using a DC pump (24 V), Solar Panel (250 W), Charge controller (24 V, 10 A). (07 hrs)	Solar DC domestic application: Making of solar lantern. Solar Day lighting. Solar Garden Lights. Safety in DC system. Quality standards List out the inventory list of equipments and tools for construction of a DC system. Solar DC industrial application: Solar street light. Solar home lighting system. Solar Security system. Solar DC water pump. Differentiate AC and DC solar pumps and their PV requirements for various HP capacity. (07 hrs)
Professional Skill 45 Hrs; Professional Knowledge 07 Hrs	Connect, test, under take maintenance and disposal of solar batteries.	89. Prepare connecting wires for grouping of solar batteries. (06hrs) 90. Connect two solar batteries (12V, 100Ah each) in series to a 24 V DC pump and Test the Voltage and current in the circuit. (06 hrs) 91. Connect two solar batteries (12V, 100 Aheach) in parallel to a parallel group of 12 Volts DC LED lights and Test the Voltage and current in the circuit. (06 hrs)	Battery bank: Series and parallel connections. Specific gravity. Use of hydrometer Safety aspects in handling batteries. Charging/ Discharging of batteries.

		92. Check the condition of electrolyte in a solar battery using hydrometer and add distilled water to the required level in the solar battery. (06 hrs) 93. Remove complete electrolyte from a lead acid battery and refill. (06 hrs) 94. Shift 12V 100Ah battery on a trolley to different location following safe handling practices. (05 hrs) 95. Plan for rack system of battery bank storage. (05 hrs) 96. Prepare a report on maintenance and disposal of solar batteries (05 hrs)	Maintenance of battery. Risk of batteries. Ventilation requirements. Requirement of connecting only similar batteries. Disposal procedure of batteries. Common defects in batteries. Procedure for capacity testing. (07 hrs)
Professional Skill 60 Hrs; Professional Knowledge 12 Hrs	Connect and test solar panel, Charge controller, Battery bank and Inverter.	97. Connect MC 4 connectors to a solar panel using crimping tool. (04 hrs) 98. Connect the PWM controller with solar panel & solar battery and note input /output current and battery voltage at different time intervals. (04 hrs) 99. Connect the MPPT controller with solar panel & solar battery and note input and output current and battery voltage, at different time intervals. (04 hrs) 100 Compare the results of the above. (03hrs) 101.Open PWM and MPPT Charge controllers and identify components wired to understand mechanism. (04 hrs) 102.Connect solar panels to an Array Junction box. (05 hrs) 103.Connect and test a 12V DC/230V AC normal inverter. (05 hrs) 104.Connect a Solar panel (10W), Solar charge controller (12V, 10A), Solar battery (12V, 100 Ah) and a normal inverter and convert to a solar inverter. (05 hrs) 105 Prepare a comparative chart by collecting data sheets of different solar PCU and normal inverters. (05 hrs) 106 Practice procedural switching 'ON' and Shutdown of solar PCU. (05 hrs) 107 Connect a 1 KW Solar PCU to 1 KW Solar panel installation using a suitable battery bank and test the performance. (04 hrs) 108 Check of front panel features of a Solar PCU. (04 hrs)	Solar panel terminal wires and MC-4 connectors. Choice of wires (DC cables) used in the solar PV Electrical system. Array junction box (AJB) or combiner box. Protection devices in AJB. PWM charge controller. MPPT charge controller. Block diagram of charge controller. Overview of Sequence of connection (step wise) in an off grid system. Inverter: working, front panel controls and back panel controls. Normal and solar inverter. Solar charge controller for a normal inverter. Selection of solar inverter or Power Conditioning Unit (PCU). Switching ON and shut down procedure of a solar inverter Types of Inverter:- Standalone, Grid Tied (MPPT/Central/String), Micro inverter. IEC Std followed for Inverter in solar projects. Block diagram of Solar Photo voltaic electrical system. Classification of inverters- Stand alone or off-grid inverter, Hybrid inverter, Grid-tie inverter. Wall mount or array mount inverter. Inverter room planning for mega projects. Integration of inverters in large PV projects. Overview of PV System Software. (21 hrs)

		109 Check of back panel features of a Solar PCU. (04 hrs) 110. Demonstrate Solar PV e-learning software. (04 hrs)	
Professional Skill 45 Hrs; Professional Knowledge 07 Hrs	Prepare Bill of materials for small, medium and mega solar PV projects.	111 Prepare bill of material for a 1 KW solar PV installation. (08 hrs) 112 Prepare bill of material for a 5 KW solar PV installation. (08 hrs) 113 Prepare a Bill of materials for a 10 KW solar PV installation. (07 hrs) 114 Prepare a Bill of materials for a 20 KW solar PV installation. (07 Hrs) 115 Prepare a Bill of materials for a 100 KW solar PV installation. (09hrs) 116 Estimate cost of a 1 KW solar PV installation and prepare a quotation. (09hrs)	Single Line Diagram (SLD) and identifying different component symbols in SLD. System sizing: Selection of components of the Solar Photovoltaic Electrical system. Load calculation and system sizing. Battery sizing. Solar panel sizing. Sizing small and medium solar PV projects and their SLDs. System types based on: Backup requirements, Grid availability, Budget and space. Various skill requirements during solar PV plant installation. Guidance for Solar Installation by MNRE (07 hrs)
Professional Skill 20 Hrs; Professional Knowledge 05 Hrs	Perform various tests and measurement pertaining to PV Modules and their installation as per IEC standards.	117 Carry out visual inspection of PV modules. (05 hrs) 118 Measure Insulation resistance and Wet Leakage Current of PV Modules. (03 hrs) 119 Perform Bypass Diode test -Pmax at STC and Pmax at low irradiance. (04 hrs) 120 Measure Ground Continuity, Impulse Voltage, Reverse current and Partial Discharge. (03 hrs) 121 Practice to undertake precautions against Module breakage. (03 hrs) 122 Demonstrate hot spot on modules through audio visual aids. (02 hrs)	Performance standards IEC 62125/ 61646 (Diagnostic, Electrical, Performance, Thermal, Irradiance, Environmental, Mechanical) Safety Standards IEC 61730-1,2 (Electrical Hazards, Mechanical Hazards, Thermal Hazards, Fire Hazards) Hot spot on modules and method to detect them at site. (05 hrs)
Professional Skill 145 Hrs; Professional Knowledge 28 Hrs	Assist in Installation and commissioning of Solar PV plant and Hybrid plant.	123 Create a rough layout of the rooms showing existing Grid meter line, MCB, nearest shaded & dry place for a solar PCU and place for panels. (03 hrs) 124 Prepare a layout of roof showing open areas and occupied areas and mark obstructions that can cause shadows. Take site photographs. (03 hrs) 125 Mark locations for components of solar PV electrical system on site. (03 hrs) 126 Perform shadow analysis in the rooftop of a 1 KW Solar PV plant. Use sun path diagram for the latitude and solar pathfinder. (04 hrs)	**Site survey:** Inspection of field, Selection of site, Shadow analysis. Types of roofs, Weather monitoring. Solar path finder and sun path diagram. Wind Load conditions on Solar PV Panels like Wind Speed, Height of Panel above roof and Relative Location of Panels on roof. Identifying challenges' in the placement of modules/PCU in the site. (Portrait/ landscape placement, number of tables etc.). Roof area, shadow free area, structure, type& age of the building, usable area, O&M challenges, and integration issues.

		127 Install a roof top Solar panel mounting structure for 1 KW installation that uses Solar panels 250 W x 4 Nos. (05 hrs) 128 Mount Solar panels 250 W x 4 Nos. on the Mounting structure. (04 hrs) 129 Wire Solar panels 250 W x 4 Nos. (04 Hrs) 130 Connect the array junction box to the above installation and draw wires up to PCU. (04 hrs) 131 Perform different angle of inclination of Solar panel mounting for various cities considering their latitude. (04 hrs) 132 Perform Cable laying in the field. (04hrs) 133 Perform finishing work on mounting structure. Perform concrete foundation making over mounting pole base. (03hrs) 134 Perform setting of seasonal angles on mounting structure. (03hrs)	Wire (cable) requirement/ estimation. Special tools and material handling equipment required during installation. Solar panel mounting structures. Solar plant foundation planning. Installation of solar panels. Solar panel facing direction. Changing the angle of inclination as per location and seasonal setting. MMS systems or using trackers. Solar plant, civil works: drilling, digging, finishing, Mixing concrete. (07 hrs)
		135 Wire a battery bank for 1 KW installation, using 4X 12V, 100 Ah Solar batteries. (04 Hrs) 136 Wire the above installation panels, battery etc. to a 1 KW Solar PCU. (04 hrs) 137 Group and distribute the loads as per economical planning. (04 hrs) 138 Wire the AC mains connection to the Solar PCU (Do not switch ‘ON’). (04 hrs) 139 Prepare a Checklist for finding out errors during above installation. (04 hrs) 140 Check as per the checklist and prepare a clearance certificate before commissioning. (04 hrs) 141 Perform Procedural first switch ON, observe No load test results and record. (04 hrs) 142 Perform ‘ON Load’ test, progressively add load till full load and record observation. (05 hrs) 143 Perform Overload test and record observation. (05 hrs) 144 Prepare a First inspection report onthe solar plant installation. (05 hrs) 145 Prepare a list of Do’s and Don’ts in the installation. (05 hrs) 146 Prepare a report on Customer orientation. (04 hrs) 147 Prepare a report on visible and audio annunciations, alarms or alerts in a solar PCU. (05 hrs)	Battery Bank wiring, load wiring and distribution panel. Switching loads, economical planning of load distribution. Inverter wiring, Interface with the existing electrical system. Commissioning skills: Preparation of check off list. Safety precautions before initial starting. Observation of parameters pre and post operation. Operational test before connecting to Load. Progressive load connecting and on load testing. Overload testing. First inspection report generation. Customer orientation. Documentation and record. Do’s and Don’ts in the installation. Types of installation for solar array mounts based roof types: Manual Mount: Raft/rack mounts Pillar or Pole mount Building integrated mount Ballast roof mounts RCC rooftop mount Tracking mounts: Manual track Automatic track Single axis and dual axis Safety at heights. Condition monitoring and report generation. (12 hrs)

		148 Perform shutting down procedure of the above solar plant. (06hrs)	
		149 Prepare a ballast foundation for tiled roof. (04 hrs) 150 Prepare a rack mount for a tilted roof. (04 hrs) 151 Plan and prepare a report on building integrated solar mount. (04 hrs) 152 Prepare a foundation for a single Pillar mount. (04 hrs) 153 Visit a Mega project and prepare a report including strings, array, inverter room, output transformers, plant layout and SCADA room. (04 hrs) 154 Prepare a report on site suitable for windmill. (04 hrs) 155 Observe the presence of obstacles in a site suitable for windmill. (04 hrs) 156 Evaluate windiness of a place using an anemometer. (04 hrs) 157 Prepare a report on wind mill energy conversion system through sufficient audio visual sessions. (04 hrs) 158 Test with a blower and model windmill & record the observations. (04 hrs)	Maintenance of a solar plant. Alarms & security. Data logger and SCADA room. Introduction to wind power Components of wind turbine generator (WTG). Windmill; principle of operation and types. Elements of a wind mill. Minimum threshold, nominal speed during operation and out of service, high speeds of wind energy. Speed governor and control of transmission of energy. Electrical generator and Charge controller for windmill. Small (mini) hydro electricity generation and charge controller. Basics of other renewable energy resources for power generation, such as bio gas plant. Windmill suitable for integration with solar PV plant and its integration. (14hrs)
Professional Skill 20 Hrs; Professional Knowledge 05 Hrs	Perform Operation & Maintenance of PV system with best practices.	159 Demonstrate Standard Operating Procedures of PV system. (05 hrs) 160 Demonstrate Electrical Maintenance of Inverters/Cables/Junction Boxes, Fault Indications of Inverters/PCU. (05 hrs) 161 Demonstration of Solar Panel Maintenance: - Cleaning, DC Array Inspection, Precautions While Cleaning. (05 hrs) 162 Demonstration of Battery Maintenance- Checking of Electrolyte Level, Specific Gravity Using Hydrometer, Physical Damage, Terminal Voltage, Cleaning of Battery Terminals. (05 hrs) 163 Inspection of Mounting Structure of Solar Modules, Procedure of replacement of defective Fixtures. (05 hrs)	SOP (Standard Operation Procedures) of PV system. Types of Maintenance (Preventive/ Corrective/Condition Based). Electrical maintenance /Solar Panel maintenance/ Battery maintenance/ Charge Controller maintenance / Solar Panel maintenance. (05 hrs)
Professional Skill 50 Hrs; Professional Knowledge 14 Hrs	Perform manufacturing of solar panel, prepare and commission marketable solar products.	164 Verify the I-V curve of solar cells. (04hrs) 165 Perform the incoming inspection of Solar PV cells and categorise according to the quality. (04hrs) 166 Construct a cell string. (03hrs) 167 Assemble a solar panel using the above cell string. (04hrs)	Solar panel manufacturing: Skills for incoming inspection of PV cells. Making of cell string. Parts of solar panel. Assembly of panel parts. Framework and sealing of panel. Testing and certification. Quality standards. Manual and automatic

		168 Perform the framework and seal the Solar panel. (04hrs) 169 Determine the I-V curve of finished solar PV panel and prepare a model certificate. (03hrs) 170 Visit a solar panel manufacturing industry and prepare a report. (or through an audio visual session) (04hrs) 171 Prepare a report on automatic manufacturing of solar panels through audio visual sessions. (04hrs) 172 Assemble, install and commission a solar street light. (04hrs) 173 Assemble, install and commission a model of solar fertilizer sprayer. (04hrs) 174 Prepare a report on possible innovative solar products for marketing. (04hrs) 175 Assemble, install and commission a solar water pump. (04hrs) 176 Assemble, install and commission a solar traffic light. (04hrs)	manufacturing. Solar water treatment plant Solar air conditioning Solar refrigeration. Solar agricultural products – sowing, digging, fertilizer or pesticide spraying. Introduction to solar energy technologies for decentralized (thermal) energy supply; Solar cookers for domestic and community cooking. Solar Sprinklers for drip irrigation, Solar water pumping, Solar dryer, Solar air Heater. Solar Traffic Light, Solar distillation, Solar pond. National and international energy policies. National Solar Mission, Renewable Purchase Obligation. Implementation at state level. Loan and promotional schemes. Incentives, subsidies & concessions. Solar rooftop business models. Administrative processes. Details of various websites and mobile apps where policies can be accessed. (14hrs)

Scope of the trade

Objectives: At the end of this lesson you shall be able to

- **explain the duties of Solar Technician - electrical and their NCO**
- **state the key skills and carrier pathway for Solar Technician - electrical**
- **list out the job opportunities and self employment opportunities.**

Welcome to the Solar Technician - electrical trade

Solar Technician - electrical trade under craftsman training scheme (CTS) is one of the new age trade delivered nationwide through the network of ITIs. This trade is of one year duration. It mainly consists of domain area and core areas. In domain area trade practical (Professional Skill) and trade theory (Professional Knowledge) and core area (Core Skills) workshop calculation and science, Engineering drawing and employability skills which imparts soft and life skills.

There are four professional classifications in **Solar Technician - electrical** trade based on National Code of Occupation (NCO) as

a 7421.1401 – Solar Panel Installation Technician

b 7421.1402 – Solar Photo Voltaic System Installation Technician

c 7421.1403 – PV System Installation Engineer

d 8212.2301 – Module Assembly Technician

Duties of Solar Panel Installation Technician: (also known as 'Panel Installer'): the Solar Panel Installation Technician is responsible for installing solar panels at the customers' premises. The individual at work checks the installation site, understands the layout requirement as per design, assesses precautionary measures to be taken, installs the solar panel as per customer's requirement and ensures effective functioning of the system post installation.

Solar Photo Voltaic System Installation Technician and Solar PV System Maintenance Technician; is responsible for installing, maintenance and effective functioning of the solar panels. Testing the solar plant after installation, maintaining quality, data collection, status reporting etc. The individual at work cleans the installed solar modules, checks the photovoltaic system for uninterrupted power output and identifies faults in the PV system.

Module Assembly Technician; is responsible for fixing frames and junction box in the solar module. The individual at work prepares the solar module for final assembly, frames the module and fixes the junction box with cables on the rear side of the module. The individual is also responsible for connecting the tabbing wire from the module to the junction box and soldering them.

Solar PV System Installation Engineer; is responsible for designing and installing the solar photovoltaic system at the customer's premises to meeting their power requirement. The individual at work evaluates the installation site, designs the installation, plans and arranges for materials, and ensures smooth installation process. The individual also supervises the installation technicians' work.

Key skills:

During the course the trainee learns about safety and environment, use of fire extinguishers, artificial respiratory resuscitation to begin with. He gets the idea of trade tools & its standardization, identifies different types of conductors, cables & their skinning & joint making. Basic electrical laws and their application in different combinations of electrical circuit are practiced along with laws of magnetism. Performs testing by various Electrical Instruments like Wattmeter, Energy meter, etc. Performs basic Electric energy calculations and understand transmission and distribution of electrical power.

Job Opportunities: There are good numbers of job opportunities for a Solar Technician - Electrical

- Technician in local electricity boards, railways, Telephone department, airport and other government and semi-government establishments
- Technician in factories (Public/Private) Install, test and maintain Solar panels and inverters in off grid Solar power plants, in buildings, malls and cinema etc and in on grid solar plants
- Assembler of components on accessories such as array junction boxes, control panels, SCADA systems etc in Solar equipment manufacturing factories.
- Assembler in the domestic solar appliances manufacturing factories
- Service technician for domestic solar appliances in reputed companies.
- Skilled worker in Solar panel manufacturing

Self-employment opportunities

Placement, Self employment, direct sale in market (trade), Entrepreneurship (Business opportunity) and maintenance in renewable energy industries such as

- Solar panel manufacturing
- Solar PV plant integration companies
- Solar DC products such as lantern, mobile charger, DC fan, FM radio etc

- Solar inverter and battery industries
- Solar agricultural products
- Solar water heater
- Solar cooker
- Structures for mounting panels
- Accessories

After the training, the trainee will be able to

- Design SPV system in small capacity
- Test and troubleshoot SPV system
- Maintain SPV system
- Promote small, medium and mega SPV projects
- Analyze Government energy policies and draw a solar project plan
- Explore business opportunities in Renewable energy sector
- Select institution assisting entrepreneurship
- Prepare project report for startup initiatives
- Arrange for loans
- Manage a small business
- Start a small scale industry
- Identify the components of Solar PV (SPV) Electrical system
- Perform Installation of SPV system
- Test SPV system
- Commission SPV system
- Prepare documents and records of installation and commissioning
- Design hybrid electrical system
- Test and troubleshoot hybrid system
- Maintain hybrid system
- Orient the customer to optimum use of hybrid electrical system
- Perform analysis of different methods of Renewable Energy Harnessing
- Site survey of renewable energy sources
- Comparison of methods of generating electricity
- Estimate cost effective benefits of renewable energy sources

Progression pathways

- Can join industry as Technician and will progress further as Senior Technician, Supervisor and can rise up to the level of Manager.
- Can become Entrepreneur in the related field.
- Can join Apprenticeship Programmes in different types of industries leading to a National Apprenticeship Certificate (NAC).
- Can join Crafts Instructor Training Scheme (CITS) in the trade for becoming an instructor in ITIs.
- Can join Advanced Diploma (Vocational) courses under DGT as applicable.

Safety rules - Safety signs - Hazards

Objectives: At the end of this lesson you shall be able to

- **explain the necessity of adopting the safety rules**
- **list the safety rules to be followed by the electrician**
- **explain how to treat a person for electric shock/injury.**

Necessity of safety rules: Safety consciousness is one of the essential attitudes required for any job. A skilled electrician always should strive to form safe working habits. Safe working habits always save men, money and material. Unsafeworking habits always end up in loss of production and profits, personal injury and even death. The safety hints given below should be followed by Electrician to avoid accidents and electrical shocks as his job involves a lot of occupational hazards.

The listed safety rules should be learnt, remembered and practised by every electrician. Here a electrician should remember the famous proverb, **"Electricity is a good servant but a bad master".**

Safety rules

- Only qualified persons should do electrical work.
- Keep the workshop floor clean, and tools in good condition, and keep proper places.
- Do not work on live circuits; if unavoidable, use rubber gloves rubber mats, etc.
- Use wooden or PVC insulated handle screwdrivers when working on electrical circuits.
- Do not touch bare conductors
- When soldering, place the hot soldering irons in their stand. Never lay switched 'ON' or heated soldering iron on a bench or table as it may cause a fire to break out.
- Use only correct capacity fuses in the circuit. If the capacity is less it will blow out when the load is connected. If the capacity is large, it gives no protection and allows excess current to flow and endangers men and machines, resulting in loss of money.
- Replace or remove fuses only after switching off the circuit switches.

- Use extension cords with lamp guards to protect lamps against breakage and to avoid combustible material coming in contact with hot bulbs.
- Use accessories like sockets, plugs, switches and appliances only when they are in good condition and be sure they have the mark of BIS (ISI). Necessity of using BIS(ISI) marked accessories is explained under standardisation.
- Never extend electrical circuits by using temporary wiring.
- Stand on a wooden stool, or an insulated ladder while repairing live electrical circuits/ appliances or replacing fused bulbs. In all the cases, it is always good to open the main switch and make the circuit dead.
- Stand on rubber mats while working/operating switch panels, control gears etc.
- Position the ladder, on firm ground.
- While using a ladder, ask the helper to hold the ladder against any possible slipping.
- Always use safety belts while working on poles or high rise points.
- Never place your hands on any moving part of rotating machine and never work around moving shafts or pulleys of motor or generator with loose shirt sleeves or dangling neck ties.
- Only after identifying the procedure of operation, operate any machine or apparatus.
- Run cables or cords through wooden partitions or floor after inserting insulating porcelain tubes.
- Connections in the electrical apparatus should be tight. Loosely connected cables will heat up and end in fire hazards.
- Use always earth connection for all electrical appliances along with 3-pin sockets and plugs.
- While working on dead circuits remove the fuse grips; keep them under safe custody and also display 'Men on line' board on the switchboard.
- Do not meddle with interlocks of machines/switch gears.
- Do not connect earthing to the water pipe lines.
- Do not use water on electrical equipment.
- Discharge static voltage in HV lines/equipment and capacitors before working on them.
- Use safety belt and hook while working on roof top
- Do not step on Solar Array/panels
- Ensure proper electrical bonding between solar panels
- Do not hold hot solar panel frames with bare hands.
- Avoid spillage of electrolyte while working on Battery.

Safety signs (Road signals)

Objectives: At the end of this lesson you shall be able to
- **list three kinds of road sign**
- **describe the "marking" on the road**
- **describe the various police traffic hand signal and light signal**
- **list the causes for collision.**

In olden days road locomotive carrying a red flag by day and red lantern by night. Safety is the prime motive of every traffic.

Kinds of road signs

- Mandatory
- Cautionary and
- Informatory

Mandatory signs (Fig 1)

Violation of mandatory sign can lead to penalties. Eg. Stop, give way, limits, prohibited, no parking and compulsory sign.

Cautionary signs (Fig 2)

Cautionary/ warning signs are especially safe. Do's and don'ts for pedestrians, cyclists, bus passengers and motorists.

Information signs (Fig 3)

Information signs as especially benefit to the passengers and two wheelers.

Fig 1

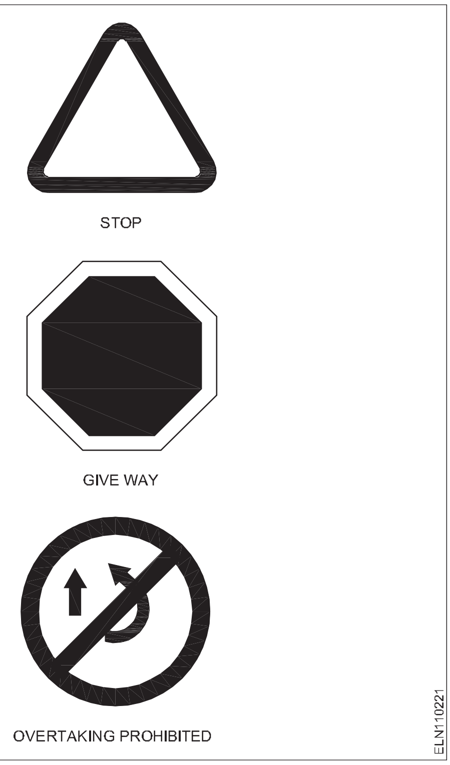
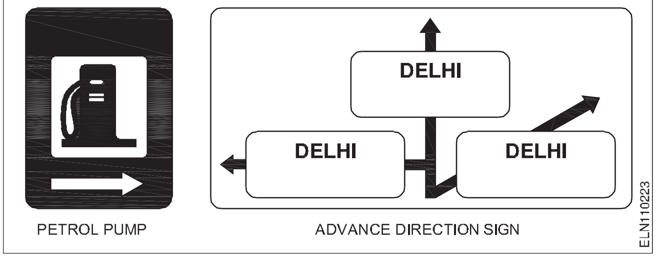


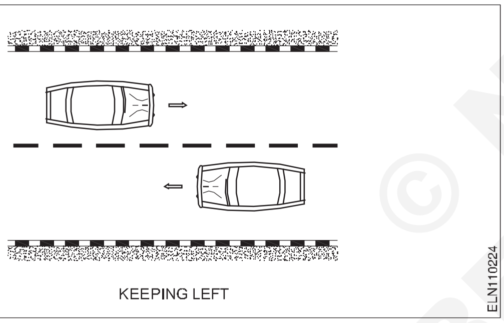
Fig 2

Fig 3



Marking lines on road (Fig 4)

Fig 4



- Marking lines are directing or warning to the moving vehicles, cyclist and pedestrians to follow the law.
- Single and short broken lines in the middle of the road allow the vehicle to cross the dotted lines safely overtake whenever required.
- When moving vehicle approaching pedestrian crossing, be ready to slow down or stop to let people cross.
- Do not overtake in the vicinity of pedestrian crossing.

Police signals (Fig 5)

To stop a vehicle approaching from behind. (Fig 5/1)

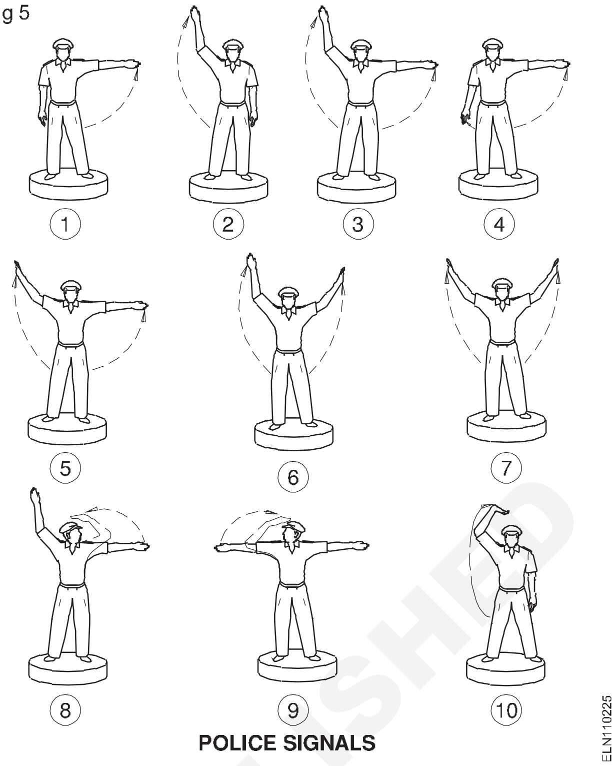
To stop a vehicle coming from front. (Fig 5/2)

To stop vehicles approaching simultaneously from front and behind. (Fig 5/3)

To stop traffic approaching from left and wanting to turn right. (Fig 5/4)

To stop traffic approaching from the right to allow traffic from left to turn right. (Fig 5/5)

Fig 5



To allow traffic coming from the right and turning right by stopping traffic approaching from the left. (Fig 5/6)

Warning signal closing all traffic. (Fig 5/7)

Beckoning on vehicles approaching from left. (Fig 5/8)

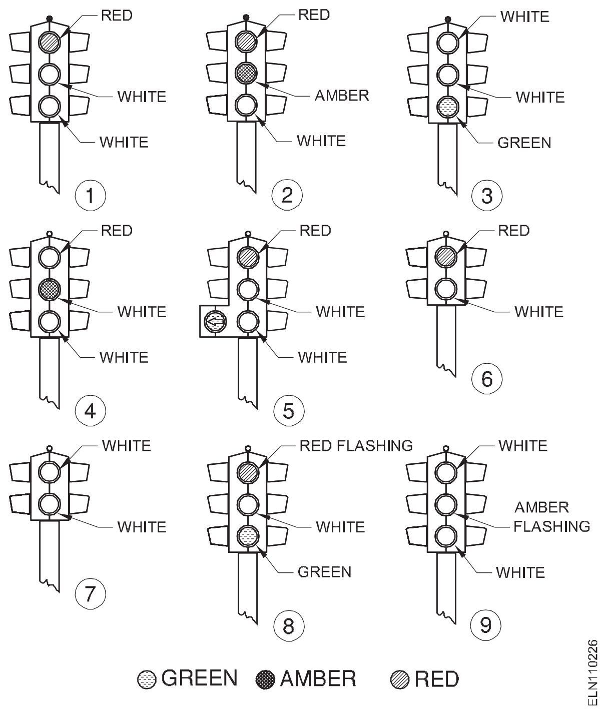
Beckoning on vehicles approaching from right. (Fig 5/9)

Beckoning on vehicles from front. (Fig 5/10)

Traffic light signals (Fig 6)

Red means stop. Wait behind the stop line on the carriage way. (Fig 6/1)

Fig 6



Red and amber also means stop. Do not pass through or start until green shows. (Fig 6/2)

Green means you may go on if the way is clear. Take special care if you mean to turn left or right and give way to pedestrians who are crossing. (Fig 6/3)

Amber means stop at the stop line. you may only go on if the amber appears after you have crossed the stop line or so close to it that to pull up may not be possible. (Fig 6/4)

Green arrow means that you may go in the direction shown by the arrow. You may do this whatever other lights may be showing. (Fig 6/5)

Pedestrians - do not cross. (Fig 6/6)

Pedestrians - cross now. (Fig 6/7)

Flashing red means stop at the stop line and if the way is clear proceed with caution. (Fig 6/8)

Flashing amber means proceed with caution. (Fig 6/9)

Safety practice - Safety signs

Objectives: At the end of this lesson you shall be able to
- **state the responsibilities of employer and employees**
- **state the safety attitude and list the four basic categories of safety signs.**

Responsibilities

Safety doesn't just happen - it has to be organised and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf.

Employer's responsibilities

The effort a firm puts into planning and organising work, training people, engaging skilled and competent workers, maintaining plant and equipment, and checking, inspecting and keeping records - all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what the employees are asked to do, and the training given.

Employee's responsibilities

You will be responsible for the way you use the equipment, how you do your job, the use you make of your training, and your general attitude to safety.

A great deal is done by employers and other people to make your working life safer; but always remember you are responsible for your own actions and the effect they have on others. You must not take that responsibility lightly.

Rules and procedure at work

What you must do, by law, is often included in the various rules and procedures laid down by your employer. They may be written down, but more often than not, are just the way a firm does things - you will learn these from other workers as you do your job.

They may govern the issue and use of tools, protective clothing and equipment, reporting procedures, emergency drills, access to restricted areas, and many other matters. Such rules are essential; they contribute to the efficiency and safety of the job.

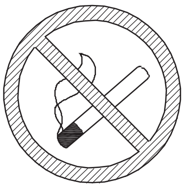
Safety signs

As you go about your work on a construction site you will see a variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others you may not have seen before. It is up to you to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

Safety signs fall into four separate categories. These can be recognised by their shape and colour. Sometimes they may be just a symbol; other signs may include letters or figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

The four basic categories of signs are as follows:

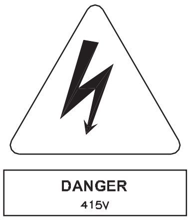
- prohibition signs (Fig 1 & Fig 5)
- mandatory signs (Fig 2 & Fig 6)
- warning signs (Fig 3 & Fig 7)
- information signs (Fig 4)

Prohibition signs	SHAPE	Circular.
Fig 1 	COLOUR	Red border and cross bar. Black symbol on white background.
	MEANING	Shows it must not be done.
	Example	No smoking.

Mandatory signs	SHAPE	Circular.
Fig 2 	COLOUR	White symbol on blue background
	MEANING	Shows what must be done.
	Example	Wear hand protection.

Warning signs

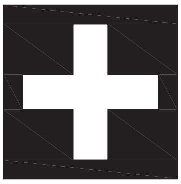
Fig 3



SHAPE	Triangular.
COLOUR	Yellow background with black border and symbol.
MEANING	Warns of hazard or danger.
Example	Caution, risk of electric shock.

Information signs

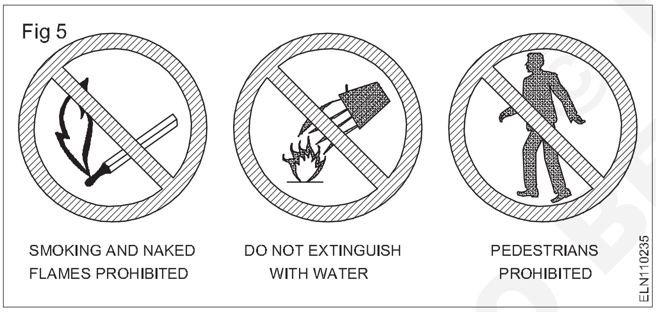
Fig 4



SHAPE	Square or oblong.
COLOUR	White symbols on green background.
MEANING	Indicates or gives information of safety provision.
Example	First aid point.

Prohibition signs

Fig 5

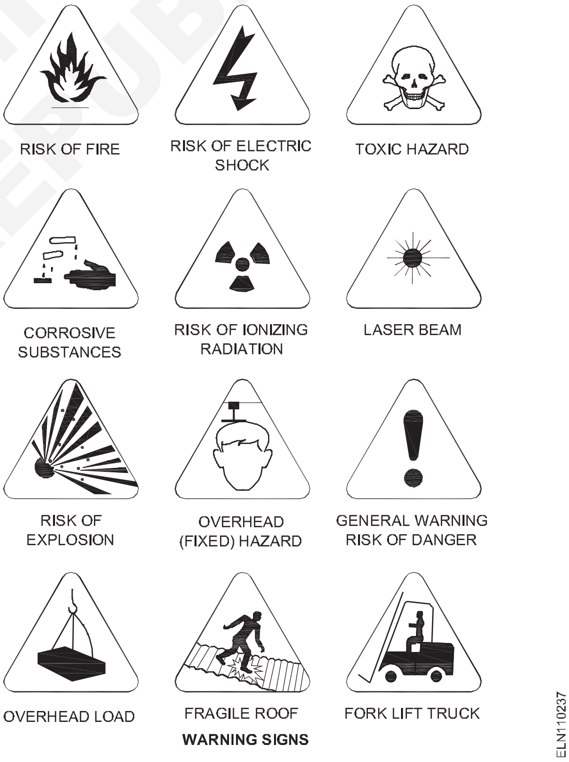


Mandatory signs

Fig 6

Warning signs

Fig 7



Fire - Types - Extinguishers

Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire break out and causes of fire in a workshop**
- **distinguish the different types of fire extinguishers**
- **state the classification of fires and basic ways for extingushing the fire**
- **determine the correct type of fire extinguisher to be used based on the class of fire**
- **describe the general procedure to be adopted in the event of fire**
- **state the method of operation of fire extinguisher and extinguishing of fire.**

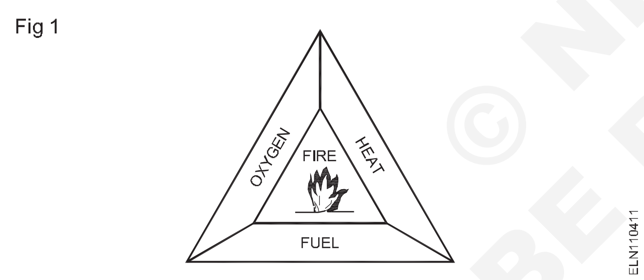
Fire

Fire is the burning of combustible material. A fire in an unwanted place and on an unwanted occasion and in an uncontrollable quantity can cause damage or destroy property and materials. It might injure people, and sometimes cause loss of life as well. Hence, every effort must be made to prevent fire. When a fire outbreak is discovered, it must be controlled and extinguished by immediate corrective action.

Is it possible to prevent fire? Yes, fire can be prevented by eliminating anyone of the three factors that causes fire.

The following are the three factors that must be present in combination for a fire to continue to burn. (Fig 1)

Fig 1



Fuel: Any substance, liquid, solid or gas will burn, if there is oxygen and high enough temperatures.

Heat: Every fuel will begin to burn at a certain temperature. It varies and depends on the fuel. Solids and liquids give off vapour when heated, and it is this vapour which ignites. Some liquids do not have to be heated as they give off vapour at normal room temperature say 15^{0}C, *eg.* petrol.

Oxygen: Usually exists in sufficient quantity in air to keep a fire burning.

Extinguishing of fire: Isolating or removing any of these factors from the combination will extinguish the fire. There are three basic ways of achieving this.

- **Starving** the fire of fuel removes this element.
- **Smothering** - ie. isolate the fire from the supply of oxygen by blanketing it with foam, sand etc.
- **Cooling** - use water to lower the temperature.

Removing any one of these factors will extinguish the fire.

Preventing fires: The majority of fires begin with small outbreaks which burn unnoticed until they have a secure hold. Most fires could be prevented with more care and by following some simple common sense rules.

Accumulation of combustible refuse (cotton waste soaked with oil, scrap wood, paper, etc.) in odd corners are a fire risk. Refuse should be removed to collection points.

The cause of fire in electrical equipment is misuse or neglect. Loose connections, wrongly rated fuses, overloaded circuits cause overheating which may in turn lead to a fire. Damage to insulation between conductors in cables causes fire.

Clothing and anything else which might catch fire should be kept well away from heaters. Make sure that the heater is shut off at the end of the working day.

Highly flammable liquids and petroleum mixtures (thinner, adhesive solutions, solvents, kerosene, spirit, LPG gas etc.) should be stored in the flammable material storage area.

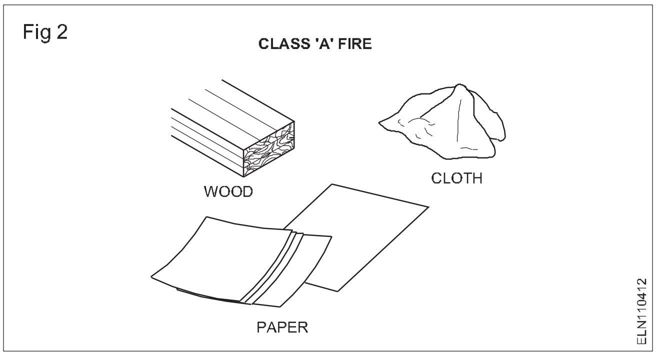
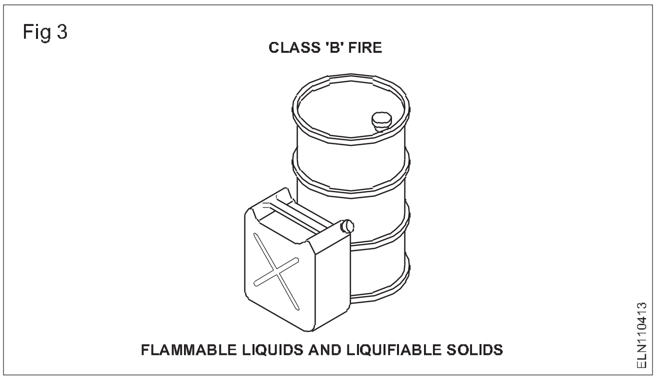
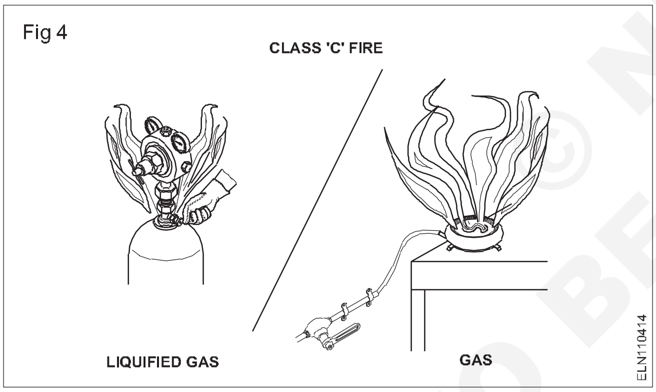
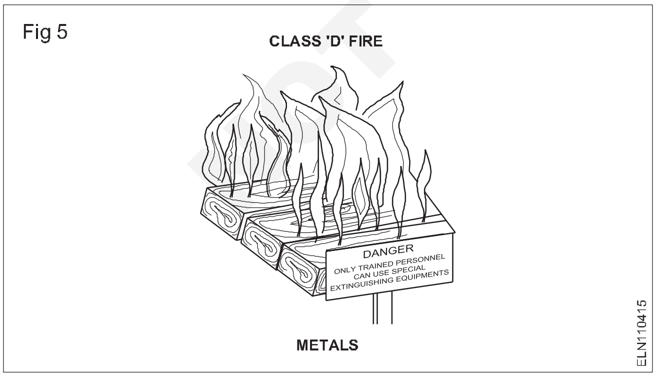
Blowlamps and torches must not be left burning when they are not in use.

Classification of fires: Fires are classified into four types in terms of the nature of fuel.

Different types of fires (Fig 2, Fig 3 Fig 4 & Fig 5) have to be dealt with in different ways and with different extinguishing agents.

An extinguishing agent is the material or substance used to put out the fire, and is usually (but not always) contained in a fire extinguisher with a release mechanism for spraying into the fire.

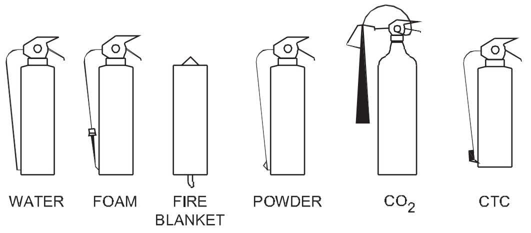
It is important to know the right type of agent for extinguishing a particular type of fire; using a wrong agent can make things worse.There is no classification for 'electrical fires' as such, since these are only fires in materials where electricity is present.

Fire Classification and Fuel	Extinguishing Method
Fig 2 	Most effective ie., cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
Fig 3 	**Should be smothered** :- The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire.
Fig 4 	Water should never be used on burning liquids. Foam, dry powder or CO_2 may be used on this type of fire. Extreme caution is necessary in dealing with liquefied gases. There is a risk of explosion and sudden outbreak of fire in the entire vicinity. If an appliance fed from a cylinder catches fire - shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel.
Fig 5 	Dry powder extinguishers are used on this type of fire. Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire. The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires. Fire on electrical equipment. Halon, Carbon dioxide, dry powder and vapourising liquid (CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (eg. water) extinguishers must not be used on electrical equipment under any circumstances.

Types of Fire Extinguisher

Many types of fire extinguishers are available with different extinguishing ‘agents’ to deal with different classes of fires. (Fig 1)

Fig 1

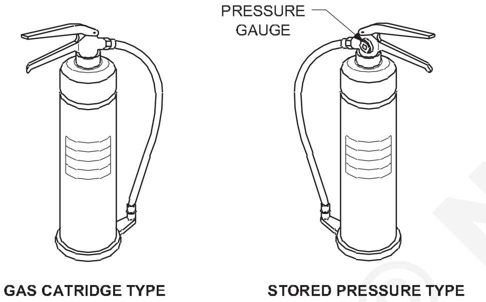


Water-filled extinguishers: There are two methods of operation. (Fig 2)

- Gas cartridge type
- Stored pressure type

With both methods of operation the discharge can be interruted as required, conserving the contents and preventing unnecessary water damage.

Fig 2



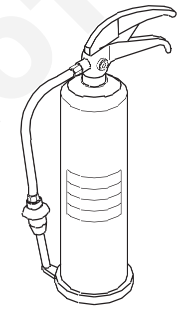
Foam extinguishers (Fig 3): These may be of stored pressure or gas cartridge types. Always check the operating instructions on the extinguisher before use.

Most suitable for

- flammable liquid fires
- running liquid fires

Must not be used on fires where electrical equipment is involved.

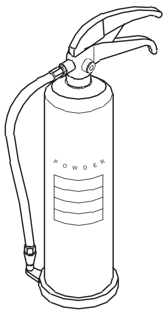
Fig 3



FOAM EXTINGUISHERES

Dry powder extinguishers (Fig 4): Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type. Appearance and method of operation is the same as that of the water-filled one. The main distinguishing feature is the fork shaped nozzle. Powders have been developed to deal with class D fires.

Fig 4



DRY POWDEER EXTINGUSHERS

Carbon dioxide (CO_2): This type is easily distinguished by the distinctively shaped discharge horn. (Fig 5).

Fig 5

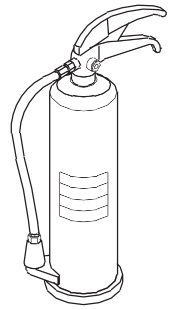
CARBAN DIOXIDE(CO_2)

Suitable for Class B fires. Best suited where contamination by deposits must be avoided. Not generally effective in open air.

Always check the operating instructions on the container before use. Available with different gadgets of operation such as - plunger, lever, trigger etc.

Halon extinguishers (Fig 6): These extinguishers may be filled with carbon-tetrachloride and Bromochlorodifluoro methene (BCF). They may be either gas cartridge or stored pressure type.

Fig 6



HALON EXTINGUISHERS

Response to emergencies, e.g. power failure, system failure and fire etc

Objectives: At the end of this lesson you shall be able to
- **state the effects of a fire break out and causes of fire in a workshop**
- **state the method of operation of fire extinguisher and extinguishing of fire.**

Power failure

Electricity drives most of the necessities and conveniences in our homes and offices. You never know when a natural disaster or a man-made one will disrupt our everyday routine. Disasters may come when we least expect them. It is best to be prepared. There are general safety tips and information to help you prepare for and cope with sudden loss of power or an electrical blackout.

What can you do to be prepared for an unplanned power failure?

Prepare a contingency plan. Is all data backed up frequently enough? What actions will you need to take if power is lost or equipment stops working?

Plan with Facilities and Services well in advance if you have critical power issues.

Plug equipment needed during a prolonged power failure into emergency power outlet.

Use surge protectors on computer systems and other surge-sensitive equipment.

Use an uninterruptable power supply for equipment, which will not tolerate any power loss, even if it is short duration.

Purchase and install alarms that notify you of a power loss or equipment malfunction on critical systems and equipment.

Back up data frequently and save often for work in progress.

Establish procedures to continue critical functions if power is lost.

Do you have a plan to mitigate losses during a power failure?

Do you have a backup freezer arrangement for critical frozen specimens?

Do you have a plan to continue critical functions, if power is out for an hour? For a day?

Budget electrical back up items into your research or program budget proposals.

Request an electrical audit for critical electrical systems.

What can you do to be prepared for rolling power failure?

Avoid experiments, which could be affected by 60 minute repeated power failure.

Turn off equipment sensitive to power failure or a shut off / restart cycle.

Do not overload emergency circuits by adding additional equipment.

Inform your colleague of the possible loss of power so they are prepared and remain calm.

Take note of the location of stairwells and avoid use of elevators in buildings subject to rolling blackouts.

Keep a flashlight and batteries in key locations throughout your work areas. Most cell phones will offer temporary illumination by activating the key pad.

Dress comfortably in consideration of loss of indoor temperature control.

If a power failure occurs in your building:

Remain calm.

Turn off electronic equipment and appliances, including sensitive laboratory/research units.

Laboratory personnel should secure all experiments; turn off all gases; store chemicals in original locations; close all fume hood sashes; avoid opening cold storage or cryogenic equipment.

Use flashlights and cell phone for emergency light source. Avoid use of any type of open flame.

If instructed to evacuate, proceed to nearest exit and assist persons with disabilities or notify emergency responders.

If you are on an elevator when power outage occurs, remain calm and press the emergency button and/or telephone to alert NMSU Police. Follow directions from responding NMSU Police and Facilities and Services personnel.

After the power loss, check all equipment to make sure everything restarted properly

Rescue operation - First aid treatment - Artificial respiration

Objectives: At the end of this lesson you shall be able to
- **explain how to rescue a person who is in contact with a live wire.**
- **state the first aid and its key aims.**
- **explain ABC of the first aid.**
- **brief how to give first aid treatment for a victim.**
- **explain how to treat a person affected due to electric shock/injury.**

The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that the electric current has been disconnected. If the victim is still in contact with the supply - break the contact either by switching off or by removing the plug or pulling the cable free.

If not, stand on some insulating material such as dry wood, rubber or plastic or newspaper and then pull his shirt sleeves. However, you have to insulate yourself and break the contact by pushing or pulling the person free. (Figs1 & 2)

Fig 1

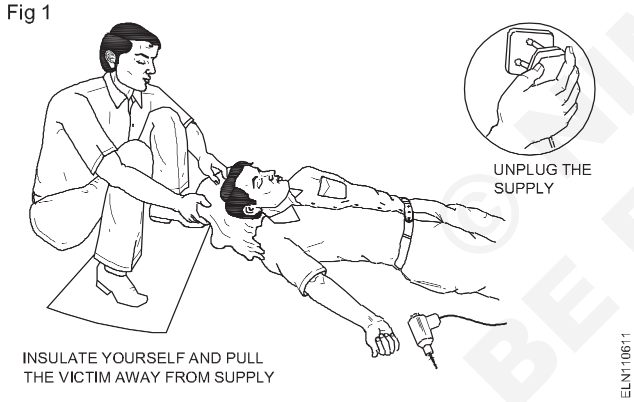
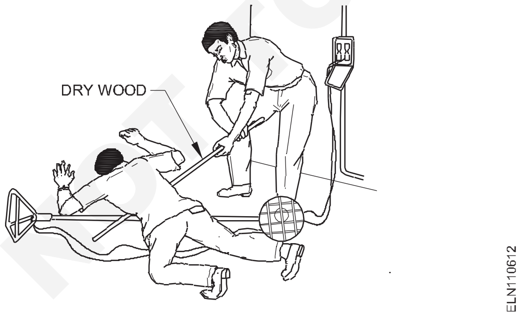


Fig 2



In any case avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

If the victim is at a height, efforts must be taken to prevent him from falling or to make him fall safe.

Electric burns on the victim may not cover a big area but may be deep seated. All you can do is to cover the area with a clean, sterile dressing and treat for shock. Get expert help as quickly as possible.

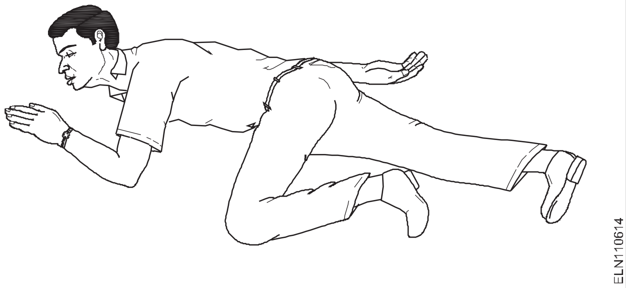
If the casualty is unconscious but is breathing, loosen the clothing about the neck, chest and waist (Fig 3) and place the casualty in the recovery position.

Fig 3

Keep a constant check on the breathing and pulse rate.

Keep the casualty warm and comfortable in the recover position. Send for help.(Fig 4)

Fig 4



Do not give an unconscious person anything to eat or drink.

Do not leave an unconscious person unattended.

If the casualty is not breathing - **Act at once to resuscitate the victim** - do not waste time.

Basic first-aid treatment

First aid is defined as the immediate care and support given to an acutely injured or ill person, primarily to save life, prevent further deterioration or injury, plan to shift the victim to safer place, provide best possible comfort and finally help them to reach the medical centre/ hospital through all available means. It is an immediate life-saving procedure using all resources available within reach.

Imparting knowledge and skill through institutional teaching at younger age group in schools, colleges, entry point at industry level is now given much importance. Inculcating such habits at early age, helps to build good healthcare habits among people.

First aid procedure often consists of simple and basic life saving techniques that an individual performs with proper training and knowledge.

The key aims of first aid can be summarized in three key points:

- **Preserve life:** If the patient was breathing, a first aider would normally then place them in the recovery position, with the patient leant over on their side, which also has the effect of clearing the tongue from the pharynx. It also avoids a common cause of death in unconscious patients, which is choking on regurgitated stomach contents.

  The airway can also become blocked through a foreign object becoming lodged in the pharynx or larynx, commonly called choking. The first aider will be taught to deal with this through a combination of 'back slaps' and 'abdominal thrusts'. Once the airway has been opened, the first aider would assess to see if the patient is breathing.

- **Prevent further harm:** Also sometimes called prevent the condition from worsening, or danger of further injury, this covers both external factors, such as moving a patient away from any cause of harm, and applying first aid techniques to prevent worsening of the condition, such as applying pressure to stop a bleed becoming dangerous.

- **Promote recovery:** First aid also involves trying to start the recovery process from the illness or injury, and in some cases might involve completing a treatment, such as in the case of applying a plaster to a small wound.

Training

Basic principles, such as knowing to use an adhesive bandage or applying direct pressure on a bleed, are often acquired passively through life experiences. However, to provide effective, life-saving first aid interventions requires instruction and practical training.

This is especially true where it relates to potentially fatal illnesses and injuries, such as those that require **Cardio Pulmonary Resuscitation (CPR)**; these procedures may be invasive, and carry a risk of further injury to the patient and the provider. As with any training, it is more useful if it occurs before an actual emergency, and in many countries, emergency ambulance dispatchers may give basic first aid instructions over the phone while the ambulance is on the way.

Training is generally provided by attending a course, typically leading to certification. Due to regular changes in procedures and protocols, based on updated clinical knowledge, and to maintain skill, attendance at regular refresher courses or re-certification is often necessary. First aid training is often available through community organization such as the Red cross.

ABC of first aid

ABC stands for **A**irway, **B**reathing and **C**irculation.

- **Airway:** Attention must first be brought to the airway to ensure it is clear. Obstruction (choking) is a life-threatening emergency.
- **Breathing:** Breathing if stops, the victim may die soon. Hence means of providing support for breathing is an important next steps. There are several methods practiced in first aid.
- **Circulation:** Blood circulation is vital to keep person alive. The first aiders now trained to go straight to chest compressions through CPR methods.

Golden hours

India have best of technology made available in hospitals to treat devastating medical problem viz. head injury, multiple trauma, heart attack, strokes etc, but patients often die poorly because they don't gain access to that technology in time.

The risk of dying from these conditions, is greatest in the first 30 minutes, often instantly. This period is referred to as **Golden period**. By the time the patient reach the hospital, they would have passed that critical period. First aid care come handy to save lives.

Maintain the hygiene

Most important, the first aider need to wash hands and dry before giving any first aid treatment to the patient or wear gloves in order to prevent infection.

Cleaning and dressing

Always clean the wound thoroughly before applying the bandage gently wash the wound with clean water.

Not to use local medications on cuts or open wounds

They are more irritating to tissue than it is helpful. Simple dry cleaning or with water and some kind of bandage are best.

CPR (Cardio-Pulmonary Resuscitation) can be life-sustaining

CPR can be life sustaining. If one is trained in PR and the person is suffering from choking or finds difficulty in breathing, immediately begin CPR. However, if one is not trained in CPR, do not attempt as you can cause further injury. But some people do it wrong.

Declaring death

It is not correct to declare the victim's death at the accident site. It has to be done by qualified medical doctors.

How to report an emergency?

Reporting an emergency is one of those things that seems simple enough, until actually when put to use in emergency situations. A sense of shock prevail at the accident sites. Large crowd gather around only with inquisitive nature, but not to extend helping hands to the victims. This is common in road side injuries.

The first aiders need to adapt multi-task strategy to control the crowd around, communicate to the rescue team, call ambulance etc., all to be done simultaneously. The mobile phones helps to a greater extent for such emergencies.

- **Call emergency service**

  The emergency number varies - 100 for Police & Fire, 108 for Ambulance.

- **Report your location**

  The first thing the emergency dispatcher will ask is where you are located, so the emergency services can get there as quickly as possible. Give the exact street address, if you're not sure of the exact address, give approximate information.

- **Give the dispatcher your phone number**

  This information is also imperative for the dispatcher to have, so that he or she is able to call back if necessary.

- **Describe the nature of the emergency**

  Speak in a calm, clear voice and tell the dispatcher why you are calling. Give the most important details first, then answer the dispatcher's follow-up question as best as you can.

- **Do not hang up the phone** until you are instructed to do so. Then follow the instructions you were given.

Do basic first aid

Important guideline for first aiders

Evaluate the situation

Are there things that might put the first aider at risk. When faced with accidents like fire, toxic smoke, gasses, an unstable building, live electrical wires or other dangerous scenario, the first aider should be very careful not to rush into a situation, which may prove to be fatal.

Remember A-B-Cs

The ABCs of first aid refer to the three critical things the first aiders need to look for.

- **A**irway
- **B**reathing
- **C**irculation

Avoid moving the victim

Avoid moving the victim unless they are immediate danger. Moving a victim will often make injuries worse, especially in the case of spinal cord injuries.

Call emergency services

Call for help or tell someone else to call for help as soon as possible. If alone at the accident scene, try to establish breathing before calling for help, and do not leave the victim alone unattended.

Determine responsiveness

If a person is unconscious, try to rouse them by gently shaking and speaking to them.

If the person remains unresponsive, carefully roll them on the side (recovery position) and open his airway.

Fig 5

- Keep head and neck aligned.
- Carefully roll them onto their back while holding his head.
- Open the airway by lifting the chin (Fig 5).

Look, listen and feel for signs of breathing

Look for the victim's chest to raise and fall, listen for sounds of breathing.

If the victim is not breathing, see the section below

- If the victim is breathing, but unconscious, roll them onto their side, keeping the head and neck aligned with the body. This will help drain the mouth and prevent the tongue or vomit from blocking the airway.

Check the victim's circulation

Look at the victim's colour and check their pulse (the carotid artery is a good option; it is located on either side of the neck, below the jaw bone). If the victim does not have a pulse, start CPR.

Treat bleeding, shock and other problems as needed

After establishing that the victim is breathing and has a pulse, next priority should be to control any bleeding. Particularly in the case of trauma, preventing shock is the priority.

- **Stop bleeding:** Control of bleeding is one of the most important things to save a trauma victim. Use direct pressure on a wound before trying any other method of managing bleeding.

- **Treat shock:** Shock may causes loss of blood flow from the body, frequently follows physical and occasionally psychological trauma. A person in shock will frequently have ice cold skin, be agitated or have an altered mental status, and have pale colour to the skin around the face and lips. Untreated, shock can be fatal. Anyone who has suffered a severe injury or life-threatening situation is at risk for shock.
- **Choking victim:** Choking can cause death or permanent brain damage within minutes.
- **Treat a burn:** Treat first and second degree burns by immersing or flushing with cool water. Don't use creams, butter or other ointments, and do not pop blisters. Third degree burns should be covered with a damp cloth. Remove clothing and jewellery from the burn, but do not try to remove charred clothing that is stuck to burns.
- **Treat a concussion:** If the victim has suffered a blow to the head, look for signs of concussion. Common symptoms are: loss of consciousness following the injury, disorientation or memory impairment, vertigo, nausea, and lethargy.
- **Treat a spinal injury victim:** If a spinal injury is suspected, it is especially critical, not move the victim's head, neck or back unless they are in immediate danger.

Stay with the victim until help arrives

Try to be a calming presence for the victim until assistance can arrive.

Unconsciousness (COMA)

Unconscious also referred as Coma, is a serious life threatening condition, when a person lie totally senseless and do not respond to calls, external stimulus. But the basic heart, breathing, blood circulation may be still intact, or they may also be failing. If unattended it may lead to death.

The condition arises due to interruption of normal brain activity. The causes are too many.

Causes for COMA Stage

- Shock (Cardiogenic, Neurogenic)
- Head injury (Concussion, Compression)
- Asphyxia (obstruction to air passage)
- Extreme of body temperature (Heat, Cold)
- Cardiac arrest (Heart attack)
- Stroke (Cerbro-vascular accident)
- Blood loss (Haemorrhage)
- Dehydration (Diarrohea & vomiting)
- Diabetes (Low or high sugar)
- Blood pressure (Very low or very high)
- Over dose of alcohol, drugs
- Poisoning (Gas, Pesticides, Bites)
- Epileptic fits (Fits)
- Hysteria (Emotional, Psychological)

DO NOT

- Do not give an unconscious person any food or drink.
- Do not leave the person alone.
- Do not place a pillow under the head of an unconscious person.
- Do not slap an unconscious person's face or splash water on the face and try to revive him.

Loss of consciousness may threaten life if the person is on his back and the tounge has dropped to the back of the throat, blocking the airway. Make certain that the person is breathing before looking for the cause of unconsciousness. If the injuries permit, place the casualty in the recovery position with the neck extended. Never give any thing by mouth to an unconscious casualty.

Hazard identification and prevention

Objectives: At the end of this lesson you shall be able to
- **explain the Need of occupational health and safety**
- **explain the types of occupational hazards.**

Quality of PPE'sSSS

PPE must meet the following criteria with regard to its quality-provide absolute and full protection against possible hazard and PPE's be so designed and manufactured out of materials that it can withstand the hazards against which it is intended to be used.

Selection of PPE's requires certain conditions

- Nature and severity of the hazard
- Type of contaminant, its concentration and location of contaminated area with respect to the source of respirable air
- Expected activity of workman and duration of work, comfort of workman when using PPE
- Operating characteristics and limitations of PPE
- Easy of maintenance and cleaning
- Conformity to Indian/ International standards and availability of test certificate.

Proper use of PPEs

Having selected the proper type of PPE, it is essential that the workman wears it. Often the workman avoids using PPE. The following factors influence the solution to this problem.

- The extent to which the workman understands the necessity of using PPE
- The ease and comfort with which PPE can be worn with least interference in normal work procedures
- The available economic, social and disciplinary sanctions which can be used to influence the attitude of the workman
- The best solution to this problem is to make 'wearing of PPE' mandatory for every employee.
- In other places, education and supervision need to be intensified. When a group of workmen are issued PPE for the first time.

Occupational health hazard and safety

Safety

Safety means freedom or protection from harm, danger, hazard, risk, accident, injury or damage.

Occupational health and safety

- Occupational health and safety is concerned with protecting the safety, health and welfare of people engaged in work or employment.
- The goal is to provide a safe work environment and to prevent hazards.
- It may also protect co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are affected by the workplace environment.
- It involves interactions among many related areas, including occupational medicine, occupational (or industrial) hygiene, public health, and safety engineering, chemistry, and health physics.

Need of occupational health and safety

- Health and safety of the employees is an important aspect of a company's smooth and successful functioning.
- It is a decisive factor in organizational effectiveness. It ensures an accident-free industrial environment.
- Proper attention to the safety and welfare of the employees can yield valuable returns.
- Improving employee morale
- Reducing absenteeism
- Enhancing productivity
- Minimizing potential of work-related injuries and illnesses
- Increasing the quality of manufactured products and/or rendered services.

Occupational (Industrial) hygiene

- Occupational hygiene is anticipation, recognition, evaluation and control of work place hazards (or) environmental factors (or) stresses
- This is arising in (or) from the workplace.
- Which may cause sickness, impaired health and well being (or) significant discomfort and inefficiency among workers.

Anticipation (Identification): Methods of identification of possible hazards and their effects on health

Recognition (Acceptance): Acceptance of ill-effects of the identified hazards

Evaluation (Measurement & Assessment): Measuring or calculating the hazard by Instruments, Air sampling and Analysis, comparison with standards and taking judgement whether measured or calculated hazard is more or less than the permissible standard.

Control of workplace hazards: Measures like Engineering and Administrative controls, medical examination, use of Personal Protective Equipment (PPE), education, training and supervision

Occupational hazards

"Source or situation with a potential for harm in terms of injury or ill health, damage to property, damage to the workplace environment, or a combination of these".

Standard and standardisation

Objectives: At the end of this lesson you shall be able to
- **state what is meant by standardisation and standard**
- **state the names of various standard organisation**
- **read and interpret the basic concept of electrical code 2011**
- **state the types of injury caused by the improper lifting method**
- **describe the procedure to be followed for moving heavy equipments**

Standardisation can be defined as the process of formulating and applying rules for an orderly approach to specific activity for the benefit of the user and the manufacturer, and in particular for the promotion of optimum overall economy taking due account of functional conditions and safety requirement.

It is based on the consolidated results of science, technique and experience. It determines not only the basis for the present but also for future development, and to keep pace with progress.

The materials/tools/equipment produced in any country should be of certain standard. To meet this requirement, the international organisation for standarization(ISO) is started and specifies the units of measurement, technology and symbols, products and processes, safety of persons and goods through a number of booklets coded with ISO number.

Standard can be defined as a formulation established verbally, in writing or by any other graphical method or by means of a model, sample or other physical means of representation to serve during a certain period of time for defining designating or specifying certain features of a unit or basis of measurement, physical object, an action, process, method, practice, capacity, function, duty, right of responsibility, a behaviour, an attitude a concept or a conception.

To sell Indian goods in the local and international market certain standardization methods are essential. The standard is specified by the **B**ureau of **I**ndian **S**tandard **BIS**(ISI) for various goods through their booklets. The BIS only certifies a good often the product meets the specification and passes necessary tests. The manufacturer allows to use the BIS(ISI) mark on the product only after BIS certification.

These are a number of organisation for standardisation throughout the world in different countries.

The standard organisation and the respective countries are given below:

BIS - Bureau of Indian Standard (ISI) - India

ISO - International standard Organisation

JIS - Japanese Industrial Standard - Japan

BSI - British Standards Institution BS(S) - Britain

DIN - Deutche Industrie Normen - Germany

GOST - Russian

ASA - American standards association - America

Advantages of BIS(ISI) certification marks scheme:

A number of advantages accrue to different sectors of economy from the BIS(ISI) certification marks scheme.

To manufacturers

- Streamlining of production processes and introduction of quality control system.
- Independent audit of quality control system by BIS
- Reaping of production economics accruing from standardization
- Better image of products in the market, both internal and overseas
- Winning for whole-salers, retailers and stockists consumer confidence and goodwill
- Preference for ISI-marked products by organised purchasers, agencies of Central and State Governments, local bodies, public and private sector undertakings etc. Some organised purchasers offer even higher price for ISI-marked goods.
- Financial incentives offered by the Industrial Development Bank of India (IDBI) and nationalised banks.

To consumers

- Conformity with Indian Standards by an independent technical, National Organisation
- Help in choosing a standard product
- Free replacement of ISI-marked products in case of their being found to be of substandard quality
- Protection from exploitation and deception
- Assurance of safety against hazards to life and property

To organised purchasers

- Convenient basis for concluding contracts
- Elimination of the need for inspection and testing of goods purchased, saving time, labour and money
- Free replacement of products with ISI-mark, found to be sub-standard

To exporters

- Exemption from pre-shipment inspection, wherever admissible
- Convenient basis for concluding export contracts

To export inspection authorities

- Elimination of the need for exhaustive inspection of consignments exported from the country, saving expenditure, time and labour.

Introduction to National Electrical Code - 2011

National Electrical Code - 2011

National electrical code describes several indian standards deciding with the various aspects relating to electrical installation practice. It is there fore recommended that individual parts/ sections of the code should be read in conjunction with the relevant indian standards.

There are 8 parts and each part contains number of sections. Each section refers the description of the electrical item/ devices, equipment etc.

Here, 20 sections of the part - 1 are described which aspect it covers

In part 1, 20 sections are there. Each sections reference is given below.

Section 1 part 1/ section 1 of the code describes the scope of the NEC.

Section 2 covers definition of items with references.

Section 3 covers graphical symbols for diagrams, letter symbols and signs which may be referred for further details.

Section 4 covers of guidelines for preparation of diagrams, chart and tables in electro technology and for marking of conductors.

Section 5 covers units and systems of measurement in electro technology.

Section 6 covers standard values of AC and DC distribution voltage prefereres values of current ratings and standard systems frequency.

Section 7 enumerates the fundamental principles of design and execution of electrical installation.

Section 8 covers guidelines for assessing the characteristics of buildings and the electrical installation there in.

Section 9 Covers the essential design and constructional requirement for electrical wiring installation.

Section 10 covers guidelines and general requirements associated with circuit calculators.

Section 11 covers requirements of installation work relating to building services that use electrical power.

Section 12 covers general criteria for selection of equipment.

Section 13 covers general principles of installation and guide lines on initial testing before commissioning.

Section 14 covers general requirements associated with earthing in electrical installations. Specific requirements for earthing in individual installations are covered in respective parts of the code.

Section 15 covers guidelines on the basic electrical aspects of lightning protective systems for buildings and the electrical installation forming part of the system.

Section 16 covers the protection requirements in low voltage electrical installation of buildings.

Section 17 covers causes for low power factor and guidelines for use of capacitors to improve the same in consumer installations.

Section 18 covers the aspects to be considered for selection of equipment from energy conservation point of view and guidance on energy audit.

Section 19 covers guidelines on safety procedures and practices in electrical work.

Section 20 gives frequently referred tables in electrical engineering work.

The above description is part 1 only you can refer remaining parts and section for other electrical installation, items devices and equipments.

NEC applies to:

- Standby generating plants
- Building substations
- Domestic dwellings
- Office buildings
- Shopping and commercial centres
- Institutions
- Recreation and other public premises
- Medical establishments
- Hotels
- Sports buildings
- Industrial premises
- Temporary and permanent outdoor installations
- Agricultural premises
- Installations in hazardous areas
- Solar Photovoltaic installations

NEC does not apply to:

- Traction, motor vehicles, installations in rolling-stock, on board-ships, aircraft or installations in underground mines
- Systems of distribution of energy to public
- Power generation and transmission for such systems

- Guidelines on the payment for electrical work done in installations

Few highlights:

Alphanumeric Notation, Graphical Symbols and Colours

1 Supply ac systems

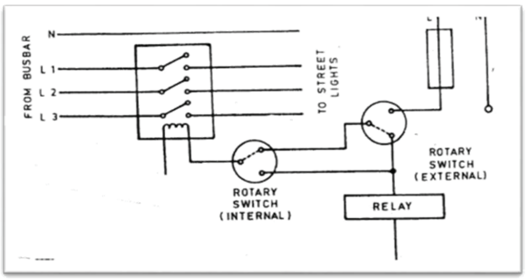
Phase 1	L1	Red
Phase 2	L2	Yellow
Phase 3	L3	Blue
Neutral	N	Black

2 Symbols

Alternating current	
Winding- Delta	
Winding- Star	
Contactor	
Lamp	
Star-Delta Starter	

3 Typical wiring for Remote/Auto Control

Fig 1



NEC CONTENTS are:

Part 1	General and Common Aspects (20 Sections)
Part 2	Electrical installations in stand by generating stations and captive substations
Part 3	Electrical installations in non-industrial buildings (7 sections)
Part 4	Electrical installations in industrial buildings
Part 5	Outdoor installations (3 sections)
Part 6	Electrical installations in agricultural premises
Part 7	Electrical installations in Hazardous area
Part 8	Solar Photovoltaic (PV) power supply systems

- New areas/enhancement of the scope of some areas
- Solar Photovoltaic (PV) power supply systems
- Protection against voltage surge _ Electronic Items
- Capacitor bank- Energy efficiency – Project on APFC Penal on LV side
- Wiring - Revision of IS 732 – Wiring of Electric Installation under progress o Lighting – National Lighting Code (NLC)
- In view of the importance of decentralized and distributed applications of solar photovoltaic energy and the potential of solar lighting systems following have been considered important:
- Solar water pumps and other solar power-based rural applications in changing the face of India's rural economy
- Growing usage of SPV in a number of products under various schemes of the MNRE o Initiative by BIS
- Solar Photovoltaic Energy systems sectional committee, ETD 28 has taken up formulation of specific product standards covering the various products in vogue having SPV applications including Solar Lantern as well as Solar water pumps.
- The standards are already under development addressing LED based solar lanterns.

Trade hand tools - specification - standards - NEC code 2011 - lifting of heavy loads

Objectives: At the end of this lesson you shall be able to
- **list the tools necessary for an electrician**
- **specify the tools and state the use of each tool**
- **explain the care and maintenance of electrician hand tools.**

It is important that the electrician uses proper tools for his work. The accuracy of workmanship and speed of work depend upon the use of correct tools. If the tools are properly used, and maintained, the electrician will find the working efficiency increases and the skills becomes a work habit.

Listed below are the most commonly used tools by electrician.

Their specifications and BIS number are given for your reference. Proper method of care and maintenance will result in prolonged tool life and improved working efficiency.

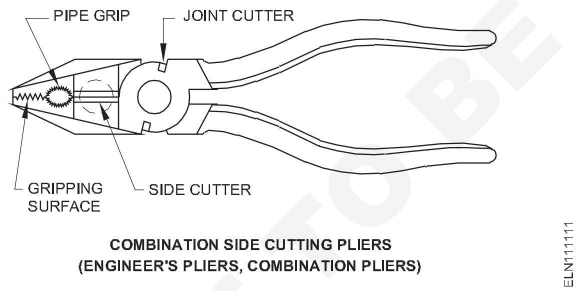
Pliers

They are specified with their overall dimensions of length in mm. The pliers used for electrical work will be of insulated grip.

1 **Combination pliers with pipe grip, side cutter and insulated handle**. BIS 3650 (Fig 1)

Size 150 mm, 200 mm etc.

Fig 1



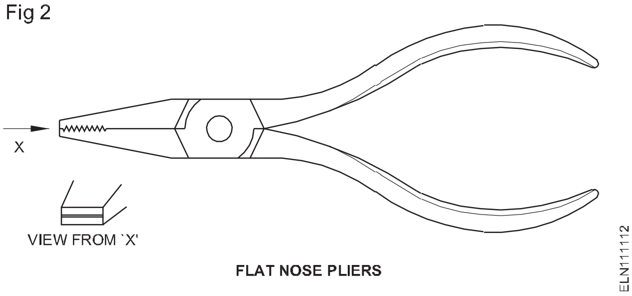
COMBINATION SIDE CUTTING PLIERS
(ENGINEER'S PLIERS, COMBINATION PLIERS)

It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work. A non-insulated type is also available. Insulated pliers are used for work on live lines.

2 **Flat nose pliers** BIS 3552 (Fig 2)

Size 100 mm, 150 mm, 200 mm etc.

Fig 2



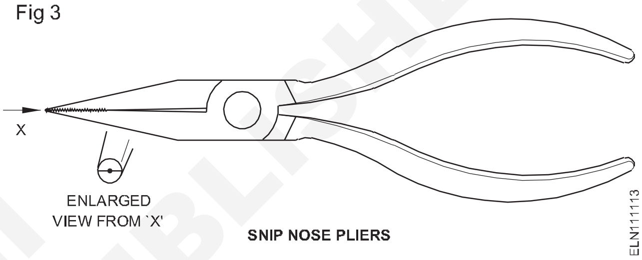
FLAT NOSE PLIERS

Flat nose pliers are used for holding flat objects like thin plates etc.

3 **Long nose pliers** or (snip nose pliers) with side cutter. BIS 5658 (Fig 3)

Size 100 mm, 150 mm etc.

Fig 3

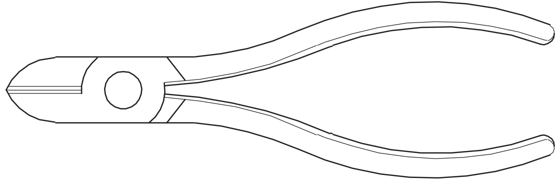


SNIP NOSE PLIERS

Long nose pliers are used for holding small objects in places where fingers cannot reach.

4 **Side cutting pliers** (Diagonal cutting pliers) BIS 4378 (Fig 4) Size 100 mm, 150 mm etc.

Fig 4



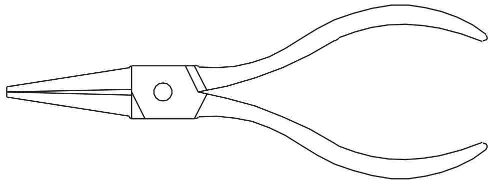
DIAGONAL CUTTING PLIERS/NIPPER

It is used for cutting copper and aluminium wires of smaller diameter (less than 4mm dia).

5 **Round nose pliers** BIS 3568 (Fig 5)

Size 100 mm, 150 mm etc.

Fig 5



ROUND NOSE PLIERS

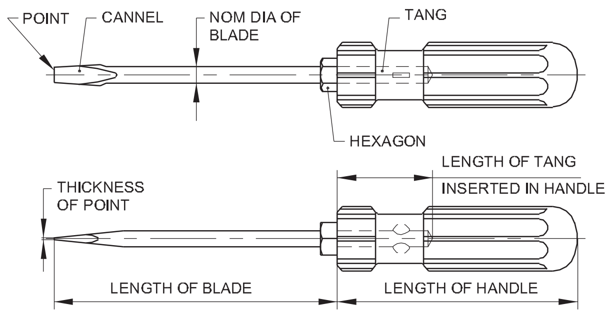
Wire hooks and loops could be made using the round nose pliers.

Care and maintenance of pliers

- Do not use pliers as hammers.
- Do not use pliers to cut large sized copper or aluminium wires and hard steel wires of any size.
- While using the pliers avoid damages to the insulation of hand grips.
- Lubricate hinged portions.

6 **Screwdriver BIS 844** (Fig 6)

Fig 6



NOMENCLATURE FOR SCREWDRIVERS

The screwdrivers used for electrical works generally have plastic handles and the stem is covered with insulating sleeves. The size of the screw driver is specified by its blade length in mm and nominal screwdriver's point size (thickness of tip of blade) and by the diameter of the stem.

eg. 75 mm x 0.4 mm x 2.5 mm

150 mm x 0.6 mm x 4 mm

200 mm x 0.8 mm x 5.5 mm

7 **Neon tester** BIS 5579 - 1985 (Fig 7)

It is specified with its working voltage range 100 to 250 volts but rated to 500 V.

It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amps at the maximum voltage, a high value resistance is connected in series with one of the electrodes. It may have a tip like a probe or screwdriver at one end. The presence of supply is indicated by the glow of the lamp when the tip is touched on the live supply and the brass contact in the other end of neon tester is touched by hand.

8 **Electrician's knife (Double blade) (Fig 8)**

The size of the knife is specified by its largest blade length eg. 50 mm, 75 mm.

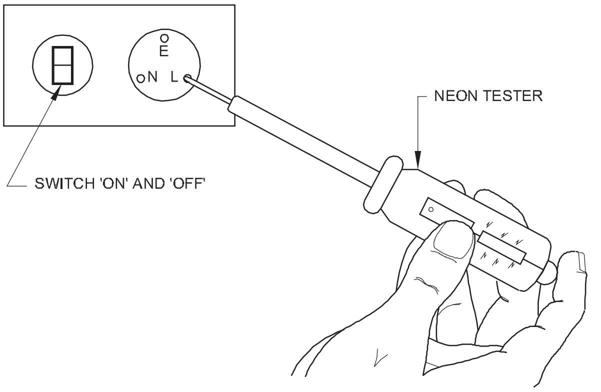
It is used for skinning the insulation of cables and cleaning the wire surface.

9 **Hammer ball pein** (Fig 9)

The size of the hammer is expressed in weight of the metal head. Eg.125 gms, 250 gms etc.

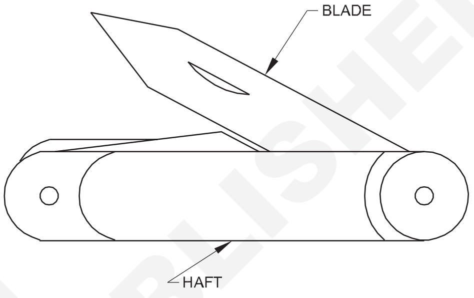
The hammer is made out of special steel and the striking face is tempered. Used for nailing, straightening, and bending work. The handle is made of hard wood.

Fig 7



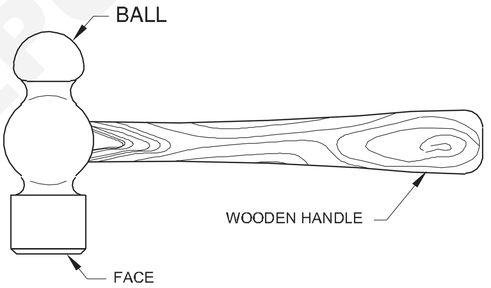
NEON TESTER

Fig 8



ELECTRICIAN'S KNIFE

Fig 9



BALL PEIN HAMMER

10 **Try-square** (Engineer's square) (Fig 10) BIS 2103

This is specified by its blade length.

Eg. 50 mm x 35 mm

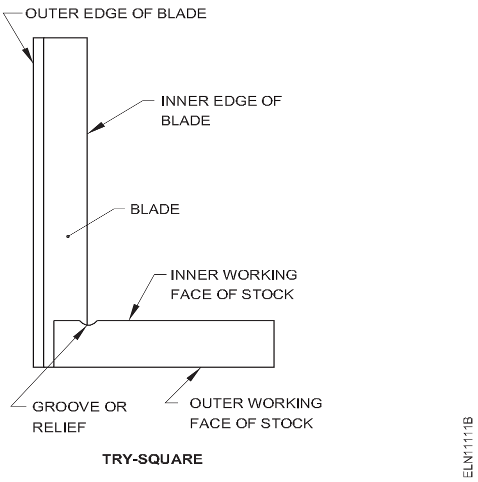
100 mm x 70 mm

150 mm x 100 mm etc.

There are two types; one is the bevelled edge with stock and the other is the flat edge without stock. It is used to check whether the object is plane, perpendicular and at right angle. Two straight blades set at right angles to each other constitute the try-square. The steel blade is riveted to the stock. The stock is made of cast iron. The stock should be set against the edge of the job.

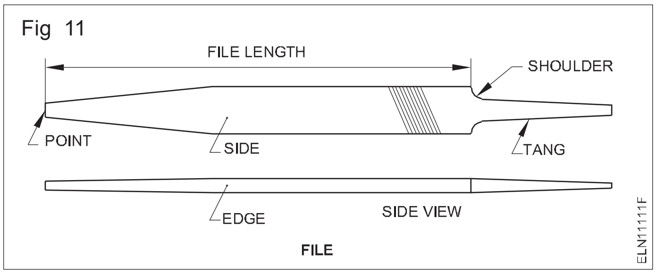
Do not use it as a hammer.

Fig 10



11 **Files** (Fig 11) BIS 1931

Fig 11



These are specified by their nominal length.

Eg.150 mm, 200 mm, 250 mm 300 mm etc.

These files have different numbers of teeth designed to cut only in the forward stroke. They are available in different lengths and sections (Eg.flat, half round, round, square, triangular), grades like rough, bastard second cut and smooth and cuts like single and double cut.

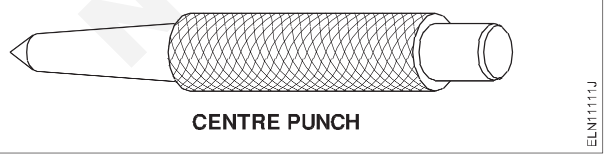
These files are used to remove fine chips of material from metals. The body of the file is made of cast steel and hardened except the tang.

Care and maintenance

- Never use the file as a hammer.
- Do not use the file without the handle.
- Do not throw a file since the teeth get damaged.

12 **Centre punch (Fig 12) BIS 7177**

Fig 12



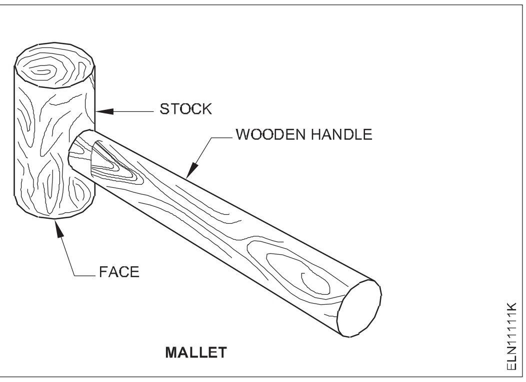
The size is given by its length and diameter of the body.

Eg. 100 mm x 8 mm. The angle of the tip of the centre punch is 90°.

It is used for marking and punching pilot holes on metals. It is made of tool steel and the ends are hardened and tempered.

13 **Mallet (Fig 13)**

Fig 13



The mallet is specified by the diameter of the head or by the weight.

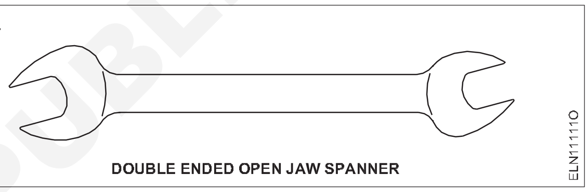
eg. 50 mm x 150 mm

75 mm x 150 mm or 500gms, 1 Kg.

It is made out of hard wood or nylon. It is used for driving the firmer chisel, and for straightening and bending of thin metallic sheets. Also it is used in motor assembly work.

14 **Spanner: double ended (Fig 14) BIS 2028**

Fig 14



The size of a spanner is indicated so as to fit on the nuts. They are available in many sizes and shapes.

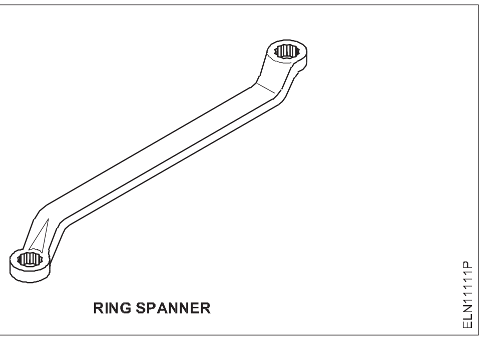
The sizes, indicated in double-ended spanners are

10-11 mm, 12-13 mm, 14-15 mm, 16-17 mm, 18-19 mm, 20-22 mm.

For loosening and tightening of nuts and bolts, spanner sets are used. It is made out of cast steel. They are available in many sizes and may have single or double ends.

15 **Ring spanner set (Fig 15) BIS 2029**

Fig 15

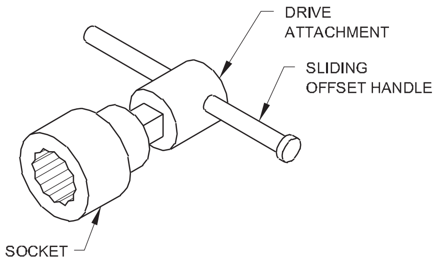


The ring spanner is used in places where the space is restricted and where high leverage is required.

16 **Socket (box) spanner (Fig 16) BIS 7993, 7991, 6129**

These spanners are useful at places where the nut or bolt is located in narrow space or at depth.

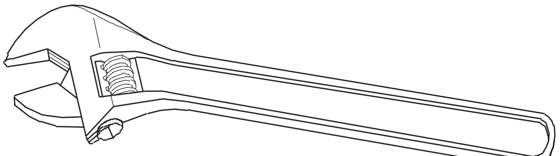
Fig 16



SOCKET SPANNER

17 **Single ended open jaw adjustable spanner (Fig 17) BIS 6149**

Fig 17

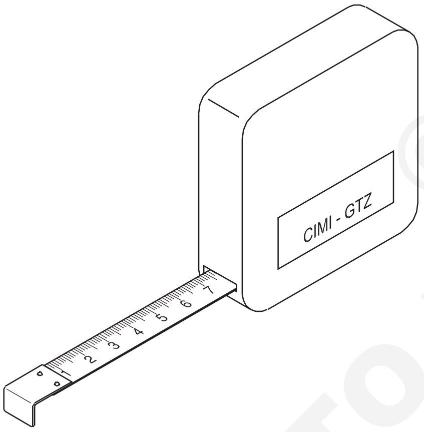


ADJUSTABLE SPANNER

It saves time and working. The movable jaw is made adjustable by operating a screw. It is known as a monkey wrench also. Available in 150,200,250mm etc.

18 **Measuring steel tape (Fig 18)**

Fig 18



MEASURING STEEL TAPE

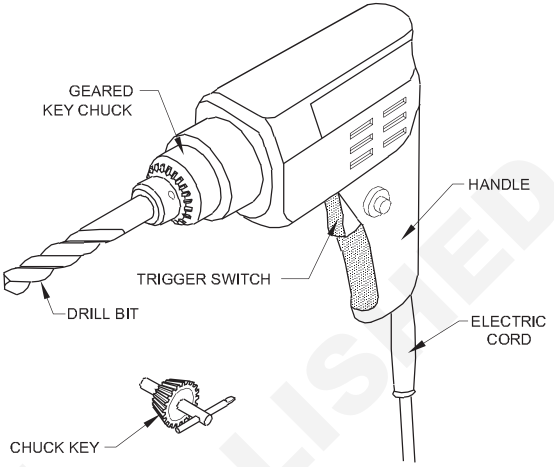
The size will be the maximum length it can measure. Eg.Blade 12 mm wide 2 metres long.

The measuring tape is made of thin steel blade, bearing dimensions on it.

It is used for measuring the dimension of the wiring installation and general measurements.

19 **Portable Electric drilling machine (Fig 19)**

Fig 19



ELECTRIC DRILLING MACHINE

When power is available, a power drilling machine is a more convenient and accurate tool for drilling holes on wooden and metal articles.

Care and maintenance

- Lubricate all the moving parts of the machine.
- Fix the drill bit firmly in the jaws.
- Before drilling, mark the job with a centre punch.
- For taking out the drill bit move the chuck in the reverse direction.
- Do not apply excess pressure on small bits.
- In the case of an electric drilling machine it must be properly earthed and the insulation should be sound.

Fitting tools - marking tools - specification - grades - uses

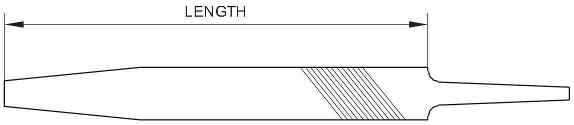
Objectives : At the end of this lesson you shall be able to
- **state the different types of files and their grades, shapes, specification and application.**
- **state the different cuts of files and their uses**
- **state the parts of file**

File : File is a filing tool, which is used to file the rough surface & smooth surface on metals

File specification: Files are specified according to their

- length
- grade
- cut
- shape

Fig 1



Length is the distance from the tip to the heel (Fig 1). It may be 300mm, 250mm, 200mm,150mm or 100mm.

Rough, bastard, second cut, smooth and dead smooth are the different **grades** of files commonly available.

A rough file is used for removing more quantity of metal quickly. (Fig 2a)

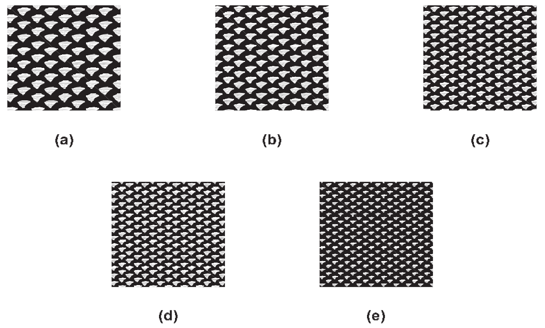
A bastard file is used for ordinary filing purposes. (Fig 2b)

A second cut file is used for good finishing purposes. (Fig 2c)

A smooth file is used for removing less metal and for giving good surface finish. (Fig 2d)

A dead smooth file is used for high degree finishing. (Fig 2e)

Fig 2



GRADES OF FILES

Cut of file: The rows of teeth determine the cut of a file.

Types of cut

Single cut, double cut, rasp cut and curved cut are the different types of cuts of files.

Single cut: A single cut file has a single row of teeth in one direction on the face of the file at an angle of 60° and this file is used for filing soft material such as lead, tin, aluminium etc. (Figs 3 & 4)

Fig 3

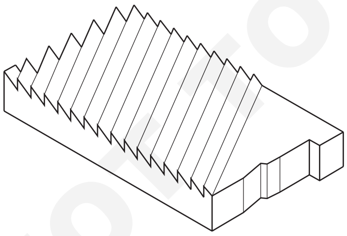
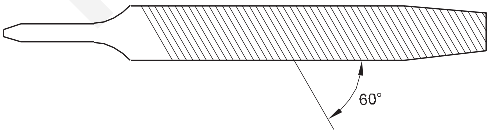


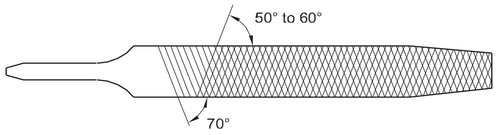
Fig 4



SINGLE CUT FILE

Double cut: A double cut file has rows of teeth in two directions across each other, one at an angle of 50° to 60°, another row at 70° which is used to file hard materials such as steel, brass, bronze, etc. (Fig 5)

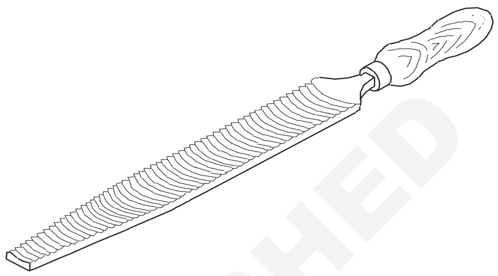
Fig 5



DOUBLE CUT FILE

Curved cut: These files have deeper cutting action, and are useful for filing soft materials like - aluminium, tin, copper and plastic. These are available only in flat shape. (Fig 6)

Fig 6

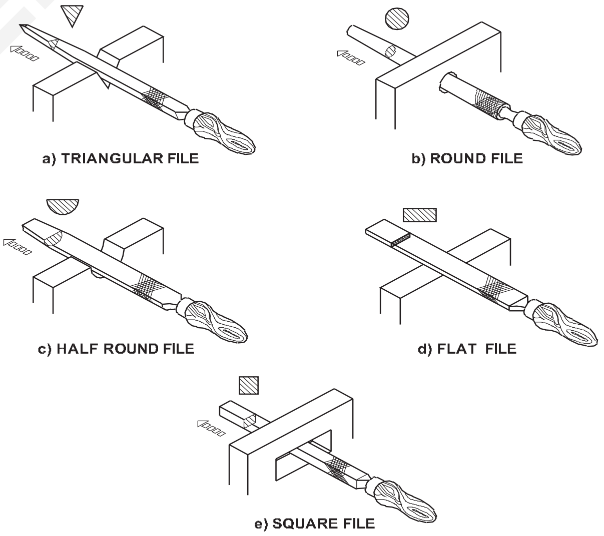


CURVED CUT FILE

The selection of the type of cut is based on the material to be filed. Single cut files are used for filing soft materials. But certain special files, for example - those used for sharpening saws, are also of single cut.

Shape: The various shapes of files with their application are shown below. The cross-section drawn in the file refers to the shape of the file. (Fig 7)

Fig 7



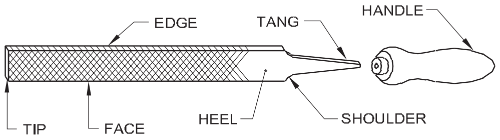
a) TRIANGULAR FILE
b) ROUND FILE
c) HALF ROUND FILE
d) FLAT FILE
e) SQUARE FILE

Parts of file

File : A file is a cutting tool with multiple cutting edges used for filing different materials.

Parts of a file (Refer Fig 1 below)

Fig 8



PARTS OF A FILE

Tip or point: This is the end of the file opposite to tang.

Face or side: The broad part of the file with teeth cut on it.

Edge: The thin part of the file with a simple row of parallel teeth.

Heel: It is the broad part of the file without teeth.

Shoulder : It is the curved part of a file separating the tang from the body.

Tang: Narrow and thin part of a file which fits into the handle.

Handle: The part fitted to the tang to hold and use the file.

Bench vice

Objectives: At the end of this lesson you shall be able to
- **name the parts and state the uses of a bench vice**
- **specify the size of a bench vice**
- **state the uses of vice clamps.**

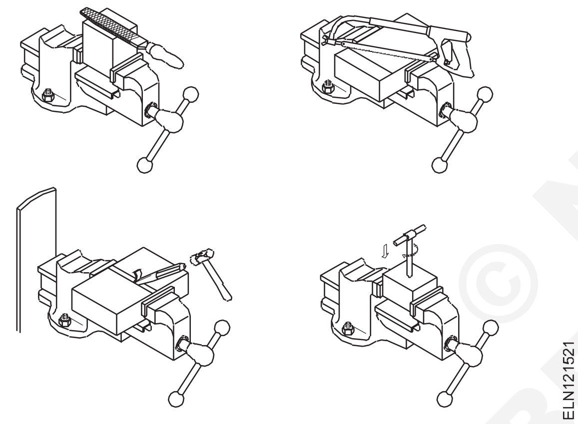
Bench vice: Vices are used for holding workpieces. They are available in different types.

The vice used for bench work is the bench vice (Engineer's vice).

A bench vice is made of cast iron or cast steel, and it is used to hold work for filing, sawing, threading and other hand operations. (Fig 1)

The size of the vice is stated by the width of the jaws.

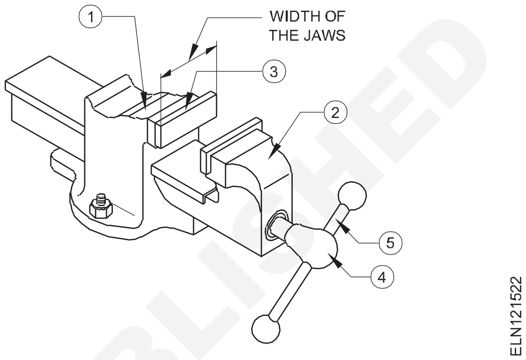
Fig 1



Parts of a bench vice (Fig 2)

- Fixed jaw (1)
- Movable jaw (2)
- Hard jaw (3)

Fig 2

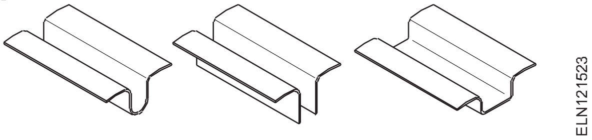


- Spindle (4)
- Handle (5)
- Box nut (6)
- Spring (7)

The box nut and the spring are the internal parts.

Vice clamps or soft jaws: To hold a finished work use soft jaws (vice clamps), (Fig 3) made of aluminium over the regular hard jaws. This will protect the work surface from damage. Do not over-tighten the vice so as to prevent damage to the spindle.

Fig 3



Hammer

Objectives: At the end of this lesson you shall be able to
- **state the uses of an engineer's hammer**
- **name the parts of an engineer's hammer and state their functions**
- **name the types of engineer's hammers with specifications.**

Hammer: Engineer's hammer is a hand tool used for various striking purposes like punching, bending, straightening, chipping, forging and riveting. (Fig 1)

Major parts of a hammer (Fig 2)

- Head
- Handle

The head is made of drop-forged carbon steel, and the wooden handle must be capable of absorbing shock.

The parts of the hammer head are:

- face
- peen
- cheek
- eyehole

Face: Face is the striking portion. A slight convexity is given to it, to avoid digging of the edge.

Fig 1

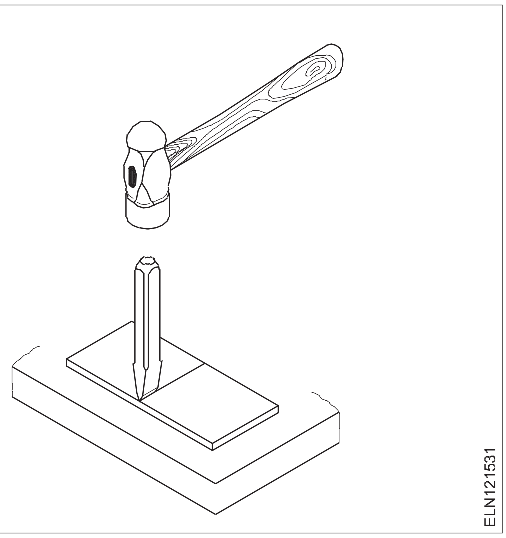
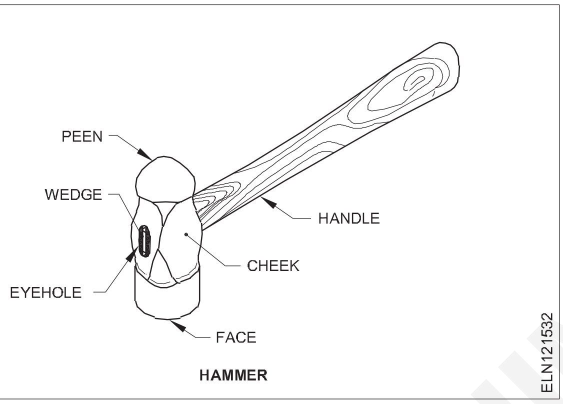


Fig 2



Peen: Peen is the other end of the head. It is used for shaping and forming work like riveting and bending. The peen is of different shapes. (Fig 3) They are:

- ball peen
- cross-peen
- straight peen

Cheek: Cheek is the middle portion of the hammer head. The weight of the hammer is stamped here.

Eyehole: Eyehole is meant for fixing the handle. It is shaped to fix the handle rigidly. The wedge fixes the handle in the eyehole. (Fig 4)

Fig 3

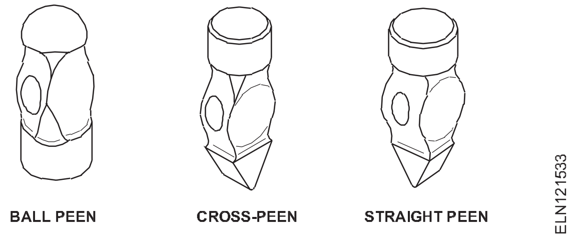
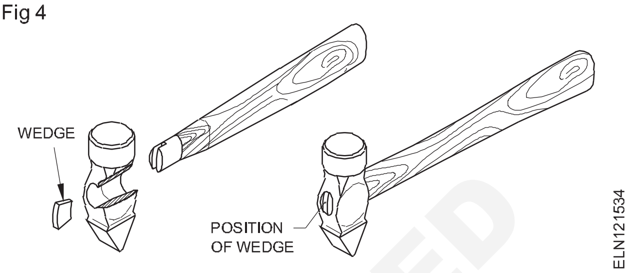


Fig 4



Specifications: The face and peen are hardened.

The cheek is left soft.

Engineer's hammers are specified by the weight of the head and shape of the peen. The weight varies from 125 gms to 1.5 kg.

The weight of the engineer's hammer used for marking purposes is 250 gms.

The ball peen hammer is used for general work in machine fitting shops.

Before using a hammer:

- make sure the handle is properly fitted
- select the correct weight of hammer suitable for the type of work
- check the head and handle for any crack
- ensure the face of the hammer is free from oil or grease.

Drill bits - Types and sizes

Objectives: At the end of this lesson you shall be able to
- **state the different types of drill bits, and their uses**
- **state the parts of a drill bit.**
- **state the different types of nails, wood screws and their uses**

For marking round holes in different types of materials, such as metal, wood, plastic etc. drills are used.

Types of drill bits

The most common drill bits are (a) twist drill and (b) flat drill.

Twist drills may be:

- parallel shank
- taper shank drills. (Fig 1)

Parallel or straight shank drills are held in the drill chuck. (Fig 2a)

Taper shank drills are held in taper sockets in the drilling machine. (Fig 2b)

Parts of a twist drill: A twist drill consists of a body, point, neck and shank. The point comprises the cutting elements, while the body guides the drill in operation. (Fig 2c)

Fig 1

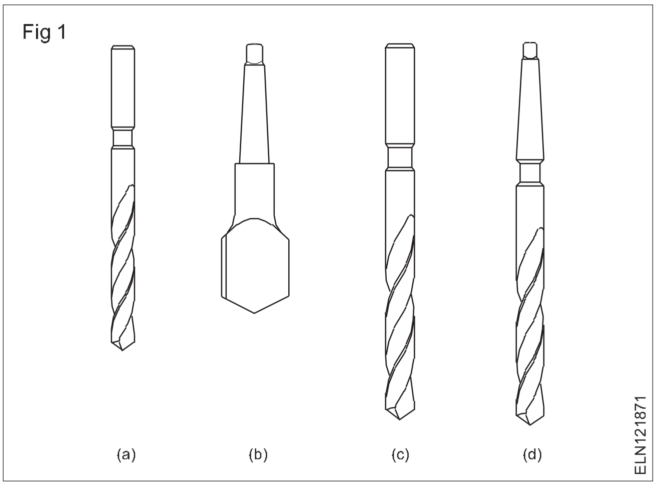
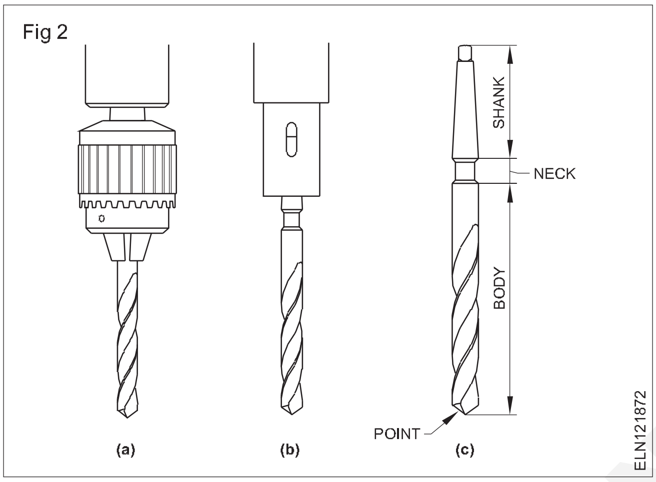


Fig 2

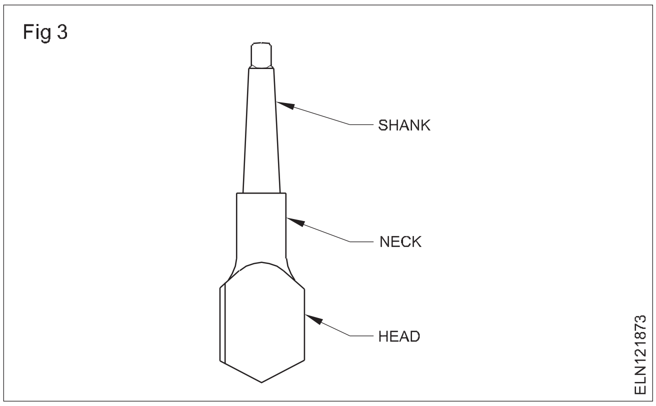


Parts of a flat drill: The flat drill consists of a head, neck and shank. It has a tapered shank. (Fig 3)

Flat drill is used for drilling shallow holes in heavy works.

Sizes of the drill bits: Drills are available in various sizes. The size of the drill is indicated on the plain portion of its shank.

Fig 3

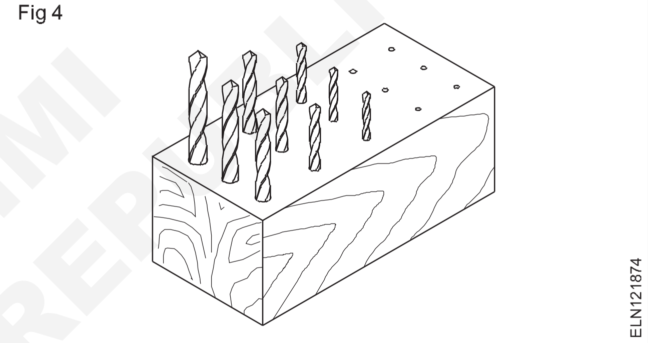


Parallel shank drills are available in small sizes up to 12mm diameter.

Taper shank drills are available in sizes from 3mm to 50mm dia.

To protect the twist drill bits from damage, place them separately in small boxes/containers. (Fig 4)

Fig 4



Types of nails and wood screws

These chill bits are attached to either hand drilling machine or electric drilling machine to drill holes.

Both nails and screws are used as fasteners in woodwork. Nails are used for cheaper types of work, and screws are used for a better class of work where additional strength and durability is a must.

Specification of nails: Nails are specified stating their

- length,
- type, and
- gauge number.

Length in the case of nail includes the head of the nail. (Fig 1)

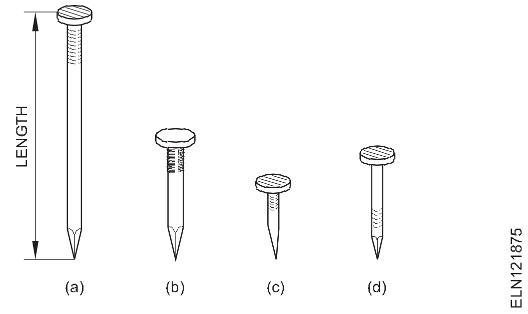
`Type' includes shape of the head, cross-section, purpose, and the metal the nail is made of.

Gauge is indicated by a number in accordance with the standard wire gauge, where higher gauge number indicates a smaller diameter of nail and vice versa.

Types of nails: There are different types of nails made for different purposes. Those that are generally used in electrical work are:

- wire nail (Fig 1a)
- wire clout nail (Fig 1b)

Fig 1

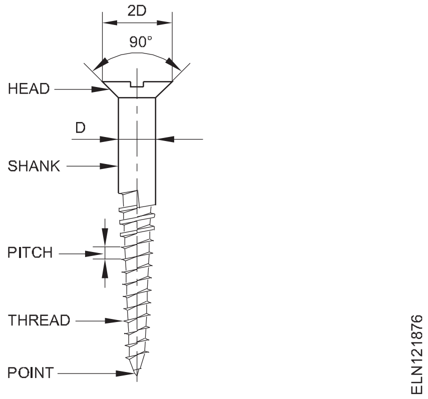


- cut tack or stud (Fig 1c)
- wire tack. (Fig 1d)

Specification of screws: Screws also are specified in a similar way as nails are i.e. stating their length, designation number, type and the metal they are made of.

Parts of a wood screw: The parts of a wood screw are shown in Fig 2.

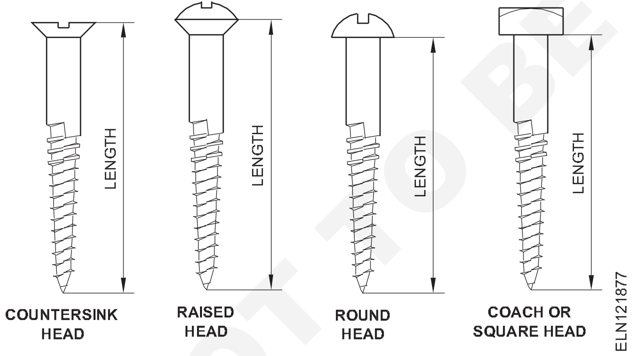
Fig 2



Head	:	Uppermost part
Shank	:	Plain or unthreaded portion of 1/3 of the length of the screw.
Pitch	:	It is the distance between adjacent threads
Point	:	The sharp edge of the screw end.
Thread	:	A special ridge around the core.

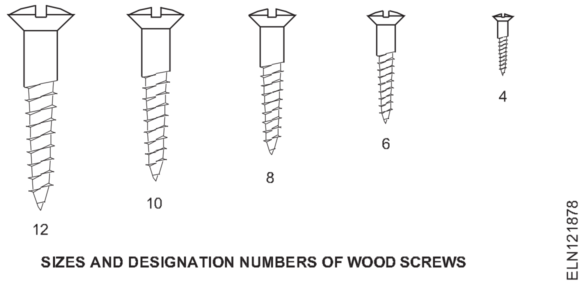
Length is measured from the point of the screw to the portion it can enter the timber. (Fig 3)

Fig 3



The designation number of a screw indicates the diameter of the unthreaded shank. The screw number and the corresponding diameter of the shank are given in IS 6739, 6736 and 6760. The screw number is the screw designation. It is different from the SWG of wire nails. (Fig 4)

Fig 4



SIZES AND DESIGNATION NUMBERS OF WOOD SCREWS

Types of screws

According to the shape of the head, screws are classified into:

- **slotted countersunk (flat) head wood screw (Fig 3a)**
  - used for general purpose (IS:6760-1972)
- **slotted countersunk raised head wood screw (Fig 3b)**
  - used for fixing thick sheets to woods (IS:6736-1972)
- **slotted round head screw (Fig 3c)**
  - It is used for fixing thin sheets to woodwork. (IS:6739-1972)
- **coach or square head screw (Fig 3d)**
  - is used for heavy duty work. It is tightened using spanner.

Availability: Wood screws are generally made of mild steel, aluminium and brass, and are from 8 mm to 200 mm length, with the screw numbers ranging from 0 to 24.

The chart of preferred lengths and screw number combinations for wood screws is available in the relevant IS.

The screws commonly used by electricians are from screw No. 4 to 12 and 12 mm to 50 mm in length.

Wood screws are available in packets of 100 and 200 numbers. The size and number of the screw are indicated on the packet.

Mild steel screws are most commonly used for general work. Brass and aluminium screws are used to match the metal fitting and also to prevent rust under damp conditions.

Electrical symbols

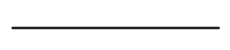
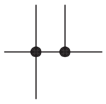
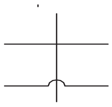
Objectives: At the end of this lesson you shall be able to
- **define electrical symbols.**

Electrical symbols are a graphical representation of basic electrical and electronic devices or components. These

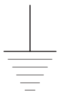
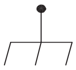
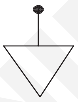
Symbols are used in circuit and electrical diagrams to recognize a component. It is also called a schematic symbol. Each component has typical functionality according to its operational characteristics.

An electronic circuit or schematic drawing uses a wired path between electronic components to complete the circuit.

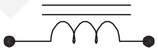
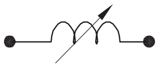
Wire Symbols

Electrical wire		Conductor of electrical current
Connected wires		Connected crossing
Not Connected wires		Wires are not connected

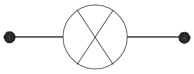
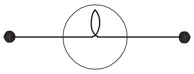
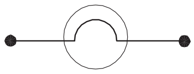
Ground Symbols

Earth Ground		An earth ground means protection against electrical shock.
Chassis Ground		There can be Chassis ground common to a circuit.
Digital/Common Ground		A common ground stands common to all analog and digitalcircuits. Used for zero potential reference and electrical shock protection.

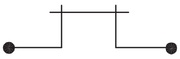
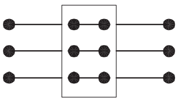
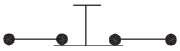
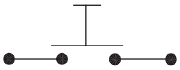
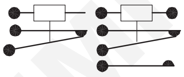
Inductor/Coil Symbols

Inductor		**Definition of an Inductor :** It is a device thattemporarily stores energy in theform of a magnetic field. Coil / solenoid that generates magnetic field
Iron Core Inductor		
Variable Inductor		

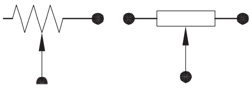
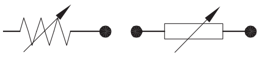
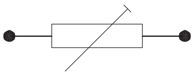
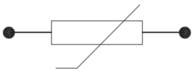
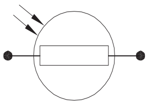
Lamp/Light Bulb Symbols

Lamp / light bulb		**Generates light when current flows through**
Lamp / light bulb		
Lamp / light bulb		

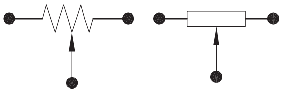
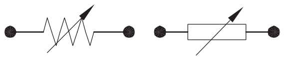
Switch and Relay Symbols

SPST Toggle Switch		Disconnects current when open
SPDT Toggle Switch		Selects between two connections
Jumper		Close connection by jumper insertion on pins
DIP Switch		DIP switch is used for onboard configuration
Pushbutton Switch (N.C)		Momentary switch - normally closed
Pushbutton Switch (N.O)		Momentary switch - normally open
SPST Relay/SPDT Relay		Definition of a Relay: It controls circuits by opening and closing contacts in another circuit. Relays switches are used to open and close circuits electromechanically or electronically.
Solder Bridge		Relay open / close connection by an electromagnet Solder to close connection

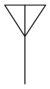
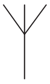
Resistor Symbols

Resistor (IEEE)/ Resistor (IEC)		**Definition of a Resistor:** As the name suggests, they resist the flow of excessive electrical power or voltage passing through the circuit, in a precise and controlled manner. Resistor reduces the current flow. Potentiometer is adjustable resistor - has 3 terminals. Variable Resistor is adjustable resistor - has 2 terminals
Potentiometer (IEEE)/(IEC)		
Variable Resistor / Rheostat (IEEE/IEC)		
Trimmer Resistor/ Preset resistor		
Thermistor		Thermal resistor - change resistance when temperature changes
Photoresistor / Light-dependent resistor (LDR)		Photo-resistor - change resistance with light intensity change

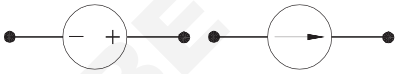
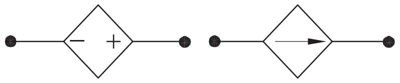
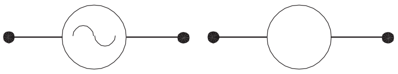
Capacitor symbols

Capacitor		**Definition of a Capacitor:** It is a device that is used to store electrical energy in an electric field. It is a passive electronic component. Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC
Polarized Capacitor Electrolytic capacitor		
Variable Capacitor Adjustable capacitance		

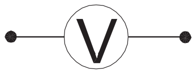
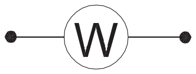
Antenna symbols

Antenna / aerial		Antenna is an electrical device that converts electric power into radio waves and vice versa.
Antenna / aerial		
Dipole Antenna		

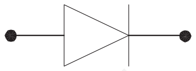
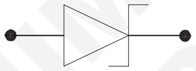
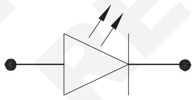
Power Supply symbols

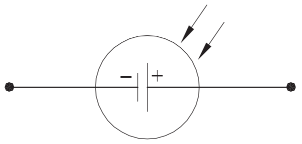
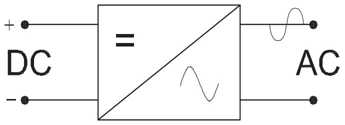
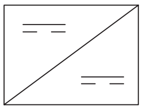
Voltage Source/ Current Source		Generates constant voltage Generates constant current
Battery Cell/ Battery		Generates constant voltage
Controlled voltage source/Controlled Current source		Generates voltage as a function of voltage or current of other circuit element
AC voltage source/Generator		Electrical voltage is generated by mechanical rotation of the generator

Meter symbols

Voltmeter		Measures voltage. Has very high resistance. Connected in parallel
Ammeter		Measures electric current. has near zero resistance. Connected serially
Ohmmeter		Measures resistance
Wattmeter		Measures resistance

Diode/LED symbols

Diode		Diode allows current flow in one direction only - left (anode) to right (cathode).
Zener Diode		Allows current flow in one direction, but also can flow in the reverse direction when above breakdown voltage
Light Emitting Diode		LED is a semiconductor device that emits light when an electric current is passed through it

solar cells	
inverters	
charge controller	

There are several other Electrical Wiring Symbols used in Residential and Commercial Wiring, but the above list of symbols is the important ones.

Fundamental of electricity - conductors - insulators - wire size measurement - crimping

Objectives: At the end of this lesson you shall be able to
- **define electricity and atom**
- **explain about the atomic structure**
- **define the fundamental terms and definition of electricity**
- **state the type of supply, polarity and the effects of electric current**
- **state the conductors, insulators, wires - size measurement methods**

Introduction

Electricity is one of the today's most useful sources of energy. Electricity is of utmost necessity in the modern world of sophisticated equipment and machinery.

Electricity in motion is called electric current. Whereas the electricity that does not move is called static electricity.

Examples of static electricity

- Shock received from door knobs of a carpeted room.
- Attraction of tiny paper bits to the comb.

Structure of matter

Electricity is related to some of the most basic building blocks of matter that are atoms (electrons and protons). All matter is made of these electrical building blocks, and, therefore, all matter is said to be 'electrical'.

Atom

Matter is defined as anything that has mass and occupies space. A matter is made of tiny, invisible particles called molecules. A molecule is the smallest particle of a substance that has the properties of the substance. Each molecule can be divided into simpler parts by chemical means. The simplest parts of a molecule are called atoms.

Basically, an atom contains three types of sub-atomic particles that are of relevance to electricity. They are the electrons, protons and neutrons. The protons and neutrons are located in the centre, or nucleus, of the atom, and the electrons travel around the nucleus in orbits.

Atomic structure

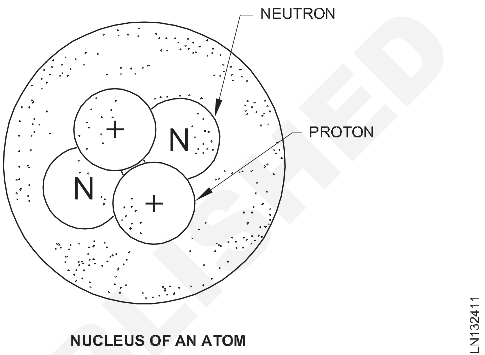
The Nucleus

The nucleus is the central part of the atom. It contains the protons and neutrons in equlal numbrs shown in Fig 1.

Protons

The proton has a positive electrical charge. (Fig 1) It is almost 1840 times heavier than the electron and it is the permanent part of the nucleus; protons do not take an active part in the flow or transfer of electrical energy.

Fig 1

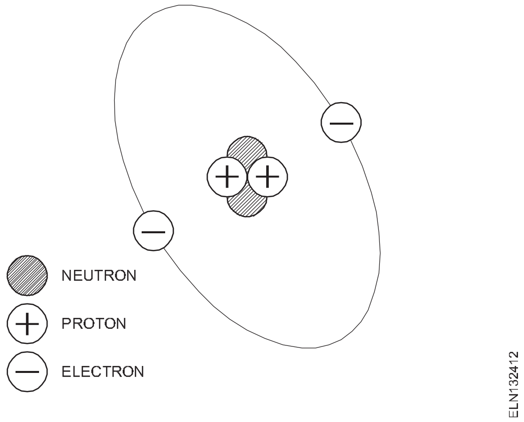


NUCLEUS OF AN ATOM

Electron

It is a small particle revolving round the nucleus of an atom (as shown in Fig 2). It has a negative electric charge. The electron is three times larger in diameter than the proton. In an atom the number of protons is equal to the number of electrons.

Fig 2



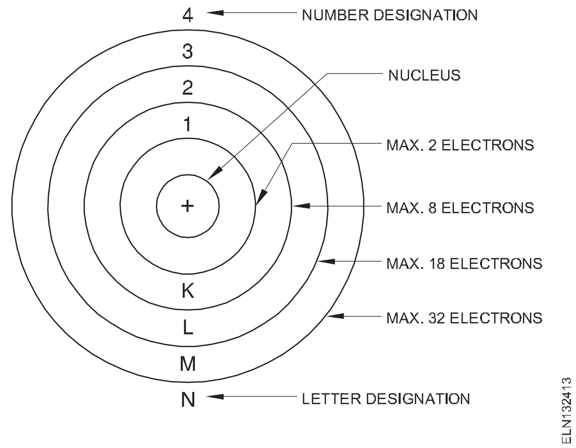
Neutron

A neutron is actually a particle by itself, and is electrically neutral. Since neutrons are electrically neutral, they are not too important to the electrical nature of atoms.

Energy shells

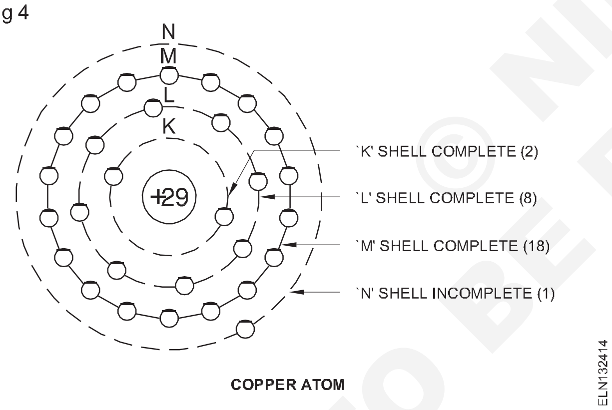
In an atom, electrons are arranged in shells around the nucleus. A shell is an orbiting layer or energy level of one or more electrons. The major shell layers are identified by numbers or by letters starting with 'K' nearest the nucleus and continuing alphabetically outwards. There is a maximum number of electrons that can be contained in each shell. Fig 3 illustrates the relationship between the energy shell level and the maximum number of electrons it can contain.

Fig 3



If the total number of electrons for a given atom is known, the placement of electrons in each shell can be easily determined. Each shell layer, beginning with the first, is filled with the maximum number of electrons in sequence. For example, a copper atom which has 29 electrons would have four shells with a number of electrons in each shell as shown in Fig 4.

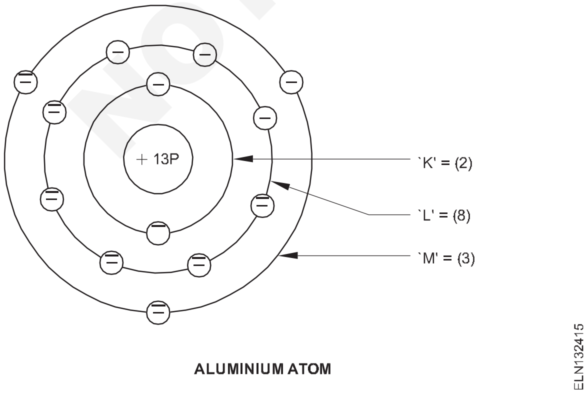
Fig 4



COPPER ATOM

Similarly an aluminium atom which has 13 electrons has 3 shells as shown in Fig 5.

Fig 5



ALUMINIUM ATOM

Electron distribution

The chemical and electrical behaviour of atoms depends on how completely the various shells and sub-shells are filled.

Atoms that are chemically active have one electron more or one less than a completely filled shell. Atoms that have the outer shell exactly filled are chemically inactive. They are called inert elements. All inert elements are gases and do not combine chemically with other elements.

Metals possess the following characteristics.

- They are good electric conductors.
- Electrons in the outer shell and sub-shells can move more easily from one atom to another.
- They carry charge through the material.

The outer shell of the atom is called the valence shell and its electrons are called valence electrons. Because of their greater distance from the nucleus, and because of the partial blocking of the electric field by electrons in the inner shells, the attracting force exerted by nucleus on the valence electrons is less. Therefore, valence electrons can be set free most easily. Whenever a valence electron is removed from its orbit it becomes a free electron. Electricity is commonly defined as the flow of these free electrons through a conductor. Though electrons flow from negative terminal to positive terminal, the conventional current flow is assumed as from positive to negative.

Conductors, insulators and semiconductors

Conductors

A conductor is a material that has many valance electrons permitting electrons to move through it easily. Generally, conductors have many valence shells of one, two or three electrons. Most metals are conductors.

Some common good conductors are Copper, Aluminium, Zinc, Lead, Tin, Eureka, Nichrome, are conductors, where as silver and gold are very good conductors

Insulators

An insulator is a material that has few, if any, free electrons and resists the flow of electrons. Generally, insulators have full valence shells of five, six or seven electrons. Some common insulators are air, glass, rubber, plastic, paper, porcelain, PVC, fibre, mica etc.

Semiconductors

A semiconductor is a material that has some of the characteristics of both the conductor and insulator. Semiconductors have valence shells containing four electrons.

Common examples of pure semiconductor materials are silicon and germanium. Specially treated semiconductors are used to produce modern electronic components such as diodes, transistors and integrated circuit chips.

Simple electrical circuit and its elements

Objectives: At the end of this lesson you shall be able to
- **describe a simple electric circuit**
- **explain the current, its units and method of measurement (ammeter)**
- **explain the emf, potential difference, their units and method of measurement (voltmeter)**
- **explain resistance and its unit, and quantity of electricity.**

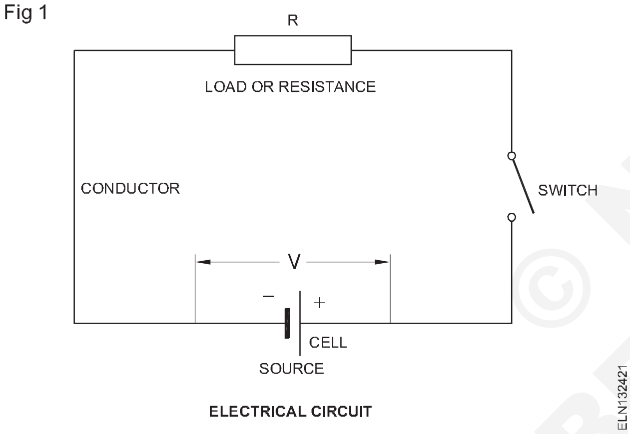
Simple electric circuit

A simple electrical circuit is one in which the current flows from the source to a load and reaches back the source to complete the path.

As shown in Fig 1, the electrical circuit should consist of the following.

- An energy source (cell) to provide the voltage needed to force the current through the circuit.
- Conductors through which the current can flow.
- A load (resistor 'R') to control the amount of current and to convert the electrical energy to other forms.
- A control device (switch 'S') to start or stop the flow of current.

Fig 1



ELECTRICAL CIRCUIT

In addition to the above, the circuit may have insulators (PVC or rubber) to confine the current to the desired path, and a protection device (fuse 'F') to interrupt the circuit in case of malfunction of the circuit (excess current).

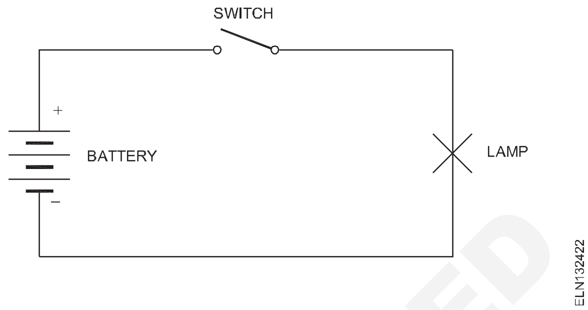
Electric current

Fig 2 shows a simple circuit which consists of a battery as the energy source and a lamp as the resistance. In this circuit, when the switch is closed, the lamp glows because of the electric current flows from the +ve terminal of the source (battery) via the lamp and reaches back the –ve terminal of the source.

Flow of electric current is nothing but the flow of free electrons. Actually the electrons flow is from the negative terminal of the battery to the lamp and reaches back to the positive terminal of the battery.

However direction of current flow is taken conventionally from the +ve terminal of the battery to the lamp and back to the –ve terminal of the battery. Hence, we can conclude that conventional flow of current is opposite to the direction of the flow of electrons. Throughout the Trade Theory book, the current flow is taken from the +ve terminal of source to the load and then back to the –ve terminal of the source.

Fig 2



Ampere

The unit of current (abbreviated as **I**) is an ampere (symbol A). If 6.24 x 10^{18} electrons pass through a conductor per second having one ohm resistance with a potential difference of one volt causes one ampere current has passed through the conductor.

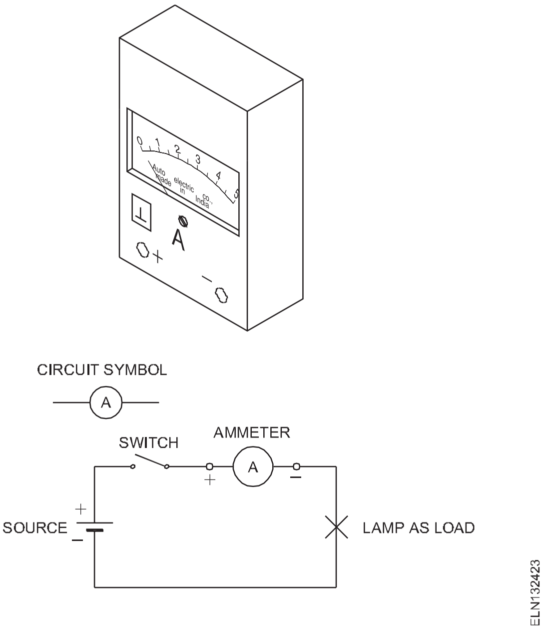
Ammeter

We know the electrons cannot be seen and no human being can count the electrons. As such an instrument called ammeter is used to measure the current in a circuit.

As an ammeter measures the flow of current in amperes it should be connected in series with the resistance (Load).

as shown in Fig 3. For the decimal and decimal sub-multiples of the ampere we use the following expressions.

Fig 3



1 kilo-ampere = 1 kA = 1000 A = 1 x 10^{3}A

1 milli-ampere = 1 mA = 1/1000 A = 1 x 10^{-3}A

1 micro-ampere = 1 μA = 1/1000000 A = 1 x 10^{-6}A

Electro Motive Force (EMF)

In order to move the electrons in a circuit- that is to make the current to flow, a source of electrical energy is required. In a torch light, the battery is the source of electrical energy.

The terminals of the battery are indicated in the circuit symbol by two lines, the longer line for the positive and the shorter for the negative terminal.

Within the battery the negative terminal contains an excess of electrons whereas the positive terminal has a deficit of electrons. The battery is said to have an electromotive force (emf) which is available to drive the free electrons in the closed path of the electrical circuit. The difference in the distribution of electrons between the two terminals of the battery produces this emf.

In Simple,

Electromotive force (EMF) is the electrical force, which is initially available in elecrical source, cause to move the free electrons in a conductor

Its unit is 'Volt'

It is denoted by letter 'E'

It cannot be measured by any meter. It can be only calculated by using the formula

E = Potential Difference (P.D) + V. drop

= p.d + V.drop

E = V + IR

Electromotive force is essential to drive the electrons in circuit

This force is obtained from the source of supply i.e. Torch lights, dynamo

System International (SI) unit of electromotive force is Volts (symbol 'E')

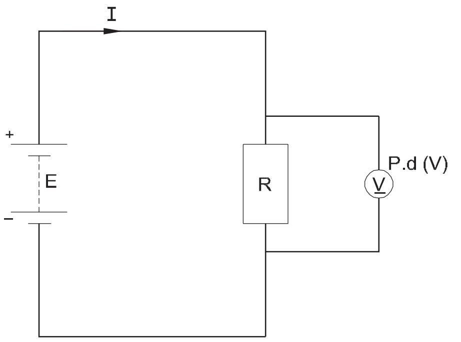
Potential Difference (PD)

The difference of volatge and pressure across two points in a circuit is called a potential difference (p.d) and is measured in volts.

In a circuit, when a current flows, there will be a potential difference across the terminals of the resistor/load. In the circuit shown in Fig 4, when the switch is in open conidition, the voltage across the terminals of the cell is called electromotive force (E) whereas when the switch is in the closed position, the voltage across the cell is called potential difference (p.d) which wil be lesser in value than the electromotive force earlier measured. This is due to the fact that the internal resistance of the cell drops a fer volts when the cell supplies current to the load.

The force which causes current to flow in the circuit is called emf. Its symbol is E and its unit is Volts (V). It can be calculated as

Fig 4



ELECTROMOTIVE FORCE

EMF = voltage at the terminal of source of supply + voltage drop in the source of supply

or emf = V_T + IR

Terminal voltage (p.d)

It is the voltage available at the terminal of the source of supply. Its symbol is V_T. Its unit is also the volt and is also measured by a voltmeter. It is given by the emf minus the voltage drop in the source of supply, i.e.

V_T = EMF - IR

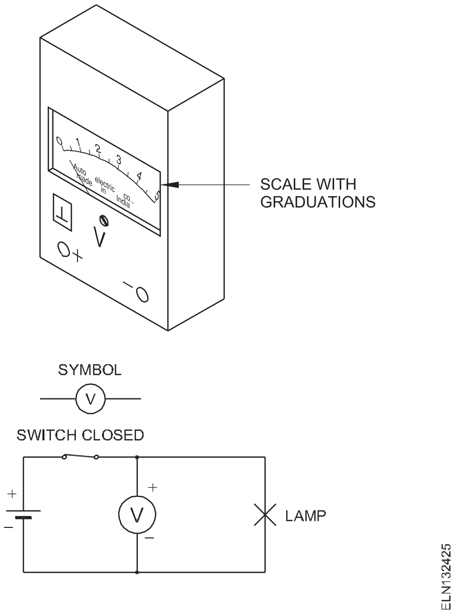
where I is the current and R is the resistance.

Hence EMF is always greater than p.d [E.M.F>p.d]

Voltmeter

Electrical voltage is measured with a voltmeter. In order to measure the voltage of a source, the terminals of the voltmeter must be connected to the terminals of the source. Positive to the positive terminal and negative to the negative terminal, as shown in Fig 5. The voltmeter connection is across or it is a parallel connection.

Fig 5



For the decimal or decimal sub-multiples of the volt, we use the following expressions.

1 kilo-volt = 1 KV = 1000 V

= 1 x 10^{3}V

1 milli-volt = 1 mV = 1/1000 V

= 1 x 10^{-3}V

1 micro-volt = 1 μV = 1/1000000

V = 1 x 10^{-6}V

Resistance (R)

In addition to the current and voltage there is a third quantity which plays a role in a circuit, called the electrical resistance. Resistance is the property of a material by which it opposes the flow of electric current.

The resistance is the property of opposition to the flow of the current offered by the circuit elements like resistance of the conductor or load is limit the flow of current

In absence of resistance in a circuit, the current will reach an abnormal high value endangering the circuit itself

Ohm

The unit of electrical resistance (abbreviated as R) is ohm (symbol Ω).

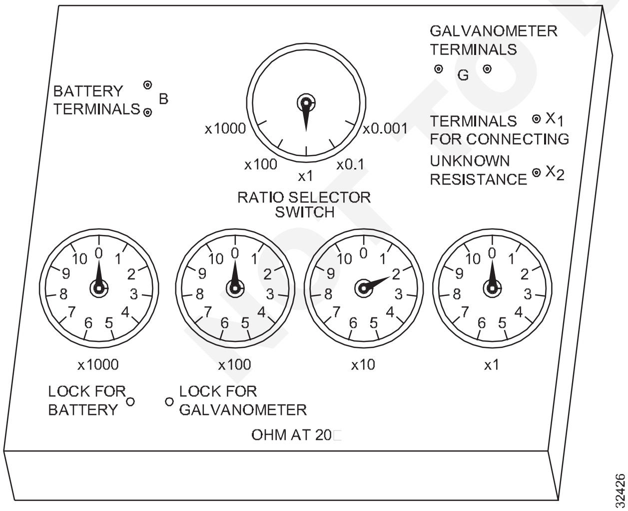
For the decimal multiples or decimal sub-multiples of the ohm we use the following expressions:

1 megohm	= 1 MΩ	= 1000000Ω	= 1 x 10^{6}Ω
1 kilo-ohm	= 1 kΩ	= 1000Ω	= 1 x 10^{3}Ω
1 milli-ohm	= 1 mΩ	= 1/1000Ω	= 1 x 10^{-3}Ω
1 micro-ohm	= 1 μΩ	= 1/1000000Ω	= 1 x 10^{-6}Ω

Meter to measure resistance

Ohmic value of a medium resistance is measured by an ohmmeter or a Wheatstone bridge. (Fig 6) There is a provision to measure the ohmic value of a resistance in a multimeter. There are various methods to determine the ohmic value of resistance. Some of these methods will be explained later in this book.

Fig 6



WHEATSTONE BRIDGE

International Ohm

It is defined as that resistance offered to an unvarying current (DC) by a column of mercury at the temperature of melting ice (i.e. 0°C), 14.4521 g in mass, of constant cross-sectional area (1 sq. mm) and 106.3 cm in length.

International ampere

One international ampere may be defined as that unvarying current (DC) which when passed through a solution of silver nitrate in water, deposits silver at the rate of 1.118 mg per second at the cathode.

Internation volt

It is defined as that potential difference which when applied to a conductor whose resistance is one international ohm produces a current of one international ampere. Its value is equal to 1.00049V.

Conductance

The property of a conductor which conducts the flow of current through it is called conductance. In other words, conductance is the reciprocal of resistance. Its symbol is G (G = 1/R) and its unit is mho represented by ℧. Good conductors have large conductances and insulators have small conductances. Thus if a wire has a resistance of R Ω, its conductance will be 1/R

Quantity of electricity

As the current is measured in terms of the rate of flow of electricity, another unit is necessary to denote the quantity of electricity (Q) passing through any part of the circuit in a certain time. This unit is called the coulomb (C). It is denoted by the letter Q. Thus

Quantity of electricity = current in amperes (I)
x time in seconds (t)

or Q = I x t

Coulomb

It is the quantity of electricity transferred by a current of one ampere in one second. Another name for the above unit is the ampere-second. A larger unit of the quantity of electricity is the ampere-hour (A.h) and is obtained when the time unit is in hours

1 A.h = 3600 Asec or 3600 C

Types of electrical supply

Objectives: At the end of this lesson you shall be able to
- **explain the difference types of electrical supply**
- **differentiate between alternating current and direct current**
- **explain the method of identification of polarity in DC source**
- **state the effect of electric current**

There are various types of instruments working on different principles. Each instrument is designed to measure a particular electrical quantity or more than one quantity with suitable modification and necessary instruction. Further they may be designed to measure AC or DC supply quantities or can be used in either supply.

To enable proper use of the instruments, the technician should be able to identify the type of supply with the help of the details given below.

Type of electrical supply (Voltage)

There are two types of electrical supply in use for various technical requirements. The alternating current supply (AC) and the direct current supply (DC).

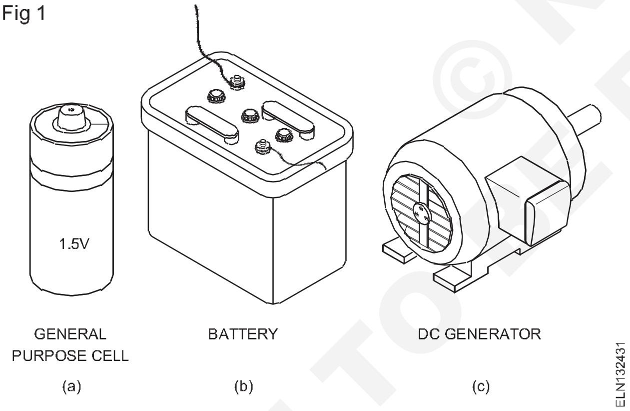
___ DC is represented by this symbol.

AC is represented by this symbol.

DC Supply

The most common sources of DC supply are the cells/ batteries (Figs 1a and 1b) and DC generators (dynamos). (Fig 1C)

Fig 1



Direct voltage is of constant magnitude (amplitude). It remains at the same amplitude from the moment of switching on to the moment of switching off. The polarity of the voltage source does not change. (Fig 2)

The polarity of direct voltage (commonly known as DC voltage) is positive (+ve) and negative (–ve). The direction of conventional flow of current is taken as from the positive to the negative terminal outside the source. (Fig 3)

Direct Current (D.C) (Fig 4)

Voltage is the cause of electrical current. If a direct current flows through a circuit, the movement of electrons in the circuit is unidirectional.

Thus direct current remains at the same value from the moment of switching on to the moment of switching off. (Direct current in common usage is known as DC current.)

Fig 2

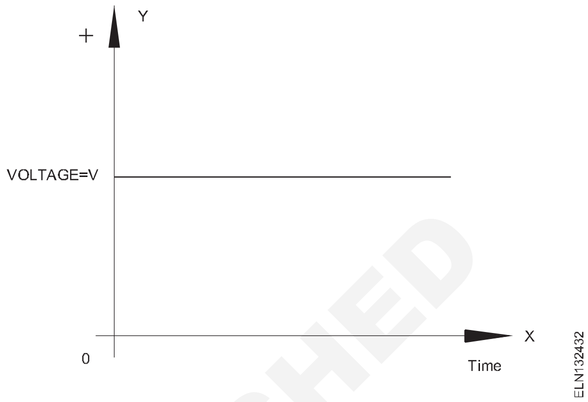


Fig 3

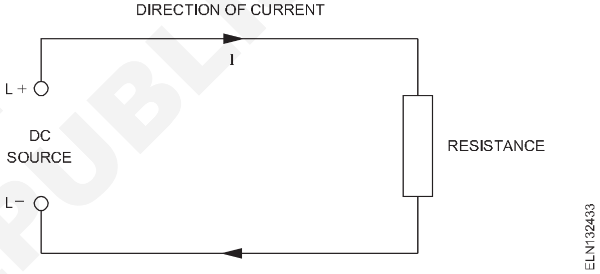
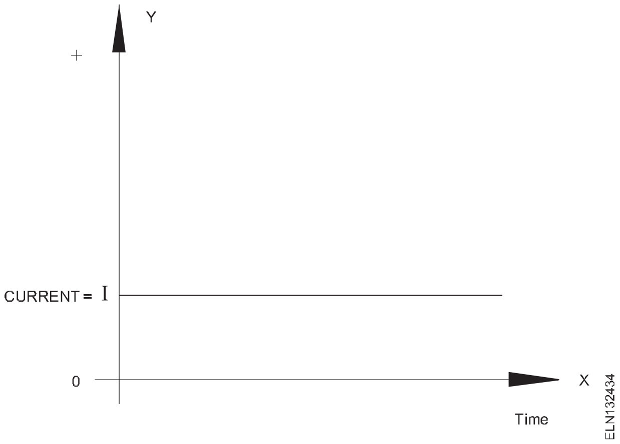


Fig 4



AC Supply

The source of AC supply is AC generators (alternators). (Fig 5a) The supply from a transformer (Fig 5b) is also AC.

Alternating voltage

AC supply sources change their polarity constantly, and consequently the direction of voltage also magnitude. The voltage supplied to our homes by power plants is alternating. Fig 6 shows a sinusoidal alternating voltage over time (wave-form).

AC supply is expressed by the effective value of the voltage, and the number of times it changes in one second is known as frequency. Frequency is represented by 'F' and its unit is in Hertz(Hz).

For example, the AC supply used for lighting is 240V 50 Hz. (Alternating voltage in common use is known as AC voltage.) AC supply terminals are marked as phase/ line(L) and neutral(N).

Fig 5

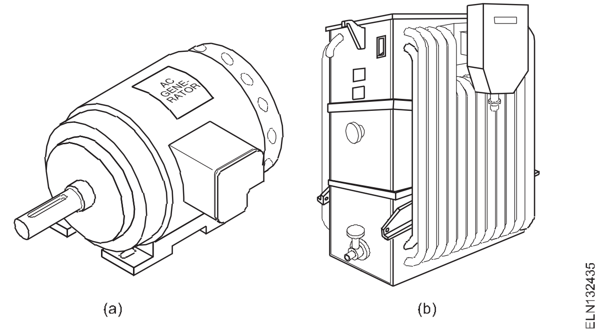
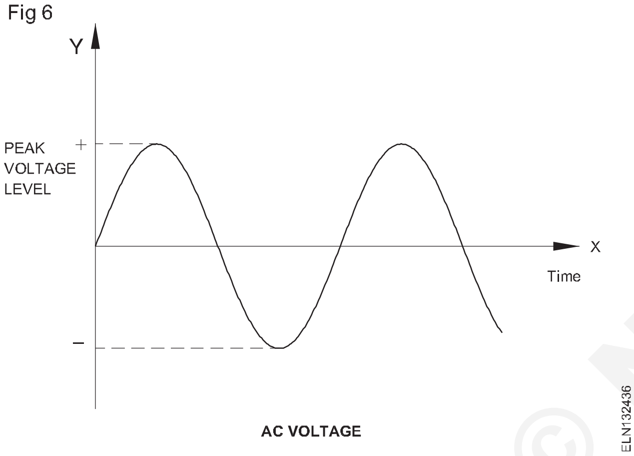


Fig 6

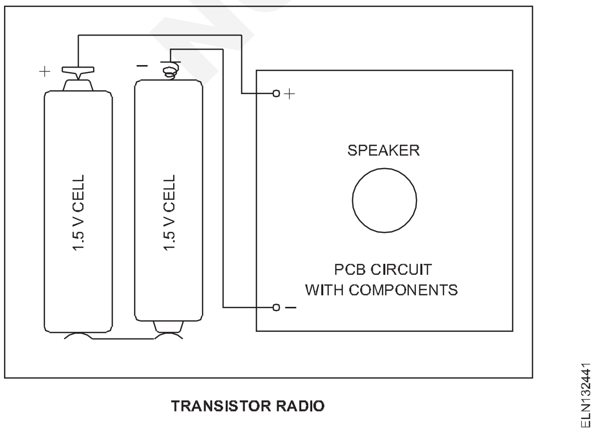


Polarity test in DC

Polarity

The polarity of a DC supply source should be identified as positive or negative. We can also use the term to indicate how an electric device is to be connected to the supply. For example, when putting new cells in a transistor radio we must put the cells correctly such that the positive terminal of one cell connects to the positive terminal of the radio and the negative terminal of the other cell connects to the negative terminal of the radio as shown in Fig 1.

Fig 1



Current is caused in an electric circuit due to the application of voltage. If an alternating voltage is applied to an electrical circuit, an alternating current (commonly known as AC current) will flow. (Figs 7 and 8)

Fig 7

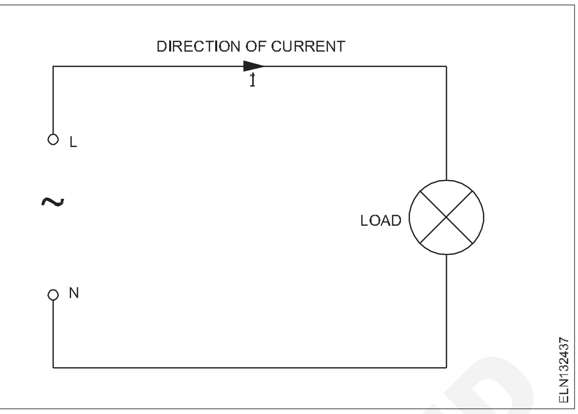
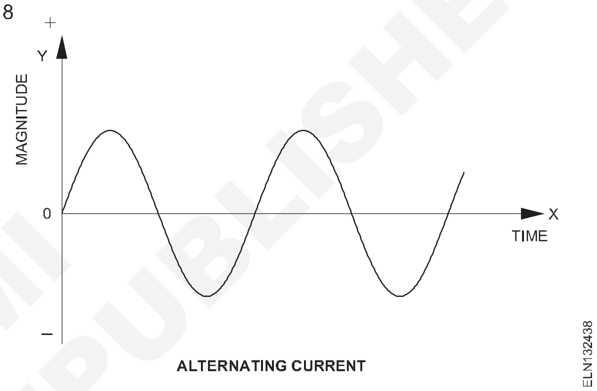


Fig 8



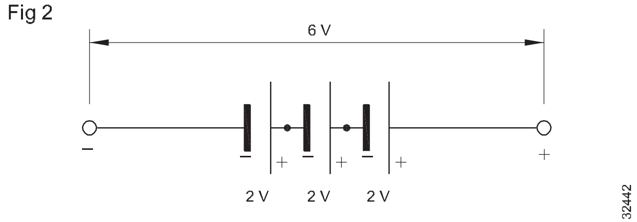
Importance of the polarity

Direct current supply has fixed polarity, positive and negative marked as + and –. Electric devices which have positive and negative identifications on their terminals are said to be polarised. When connecting such devices to a source of voltage (such as a battery or DC supply)

We must observe the correct polarity markings. That is the positive terminal of the device must be connected to the positive terminal of the source, and the negative to the negative. If the polarity is not observed correctly (that is, if +ve is connected to –ve) the device will not function and may be damaged.

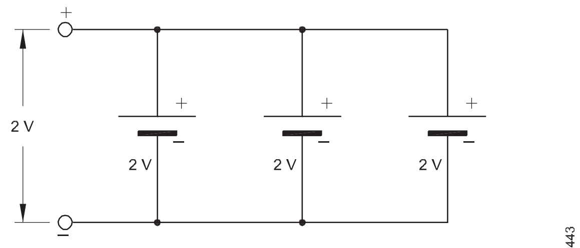
To get more voltage, current and power, the voltage sources like cells, batteries and generator are often connected in series, or in parallel or in series/parallel combination circuit. To connect them in such a manner we must know the correct polarity of the source. Fig 2 shows the method of connecting 3 cells in series to get more voltage. Fig 3 shows connection of 3 cells in parallel for getting more current.

Fig 2



CELL IN SERIES FOR GETTING MORE VOLTAGE

Fig 3



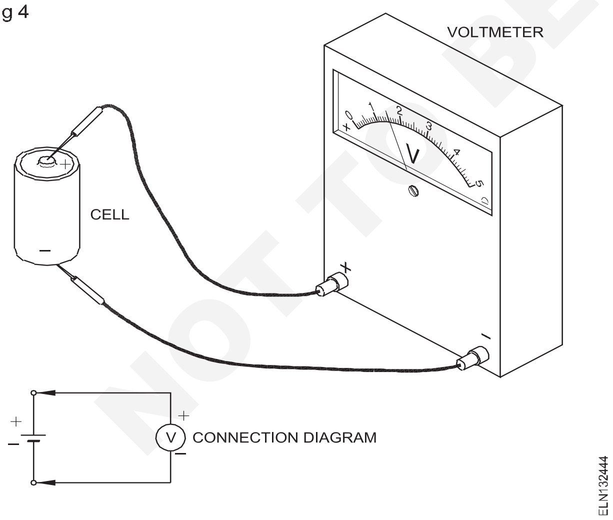
CELLS IN PARALLEL FOR GETTING MORE CURRENT.

Testing polarity by MC meter

The polarity of a cell is determined by the use of a moving coil volt-meter. The terminals of the MC meter are marked as +ve and –ve. MC meters are called as polarised as they have to be connected as per the polarity marking. By using a low range (0-10V) MC voltmeter we can find out the voltage of a cell.

The connections are made as per Fig 4 the voltmeter reads 1.5 volts. The polarity of the cell is correct as per the marked polarity on the meter terminals. If the pointer of the voltmeter deflects as in Fig 5, below zero, the polarity is not correct. From this we conclude that the meter reads in forward direction only if the instrument is connected with correct polarity as per the markings on the instrument terminals.

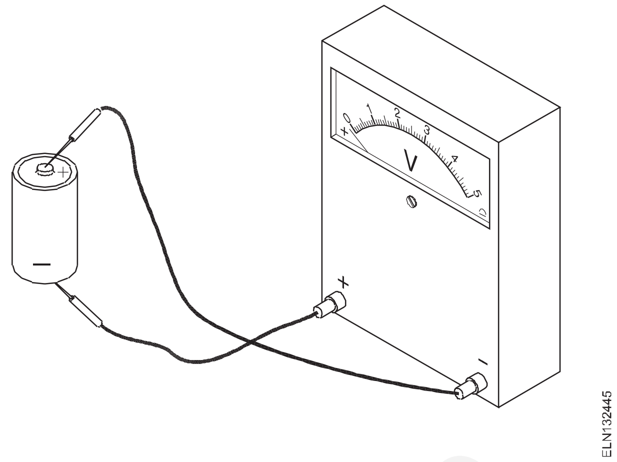
Fig 4



Polarity of the battery

To determine the polarity of the terminals of an unmarked battery, that is +ve and –ve we can use a low range MC voltmeter. If the voltmeter reads positive reading, say 10 or 12 volts then the polarity of the terminals are correct as per the markings on the meter terminals. If the meter reading is negative, that is below zero, the battery polarity is not correct with respect to the meter.

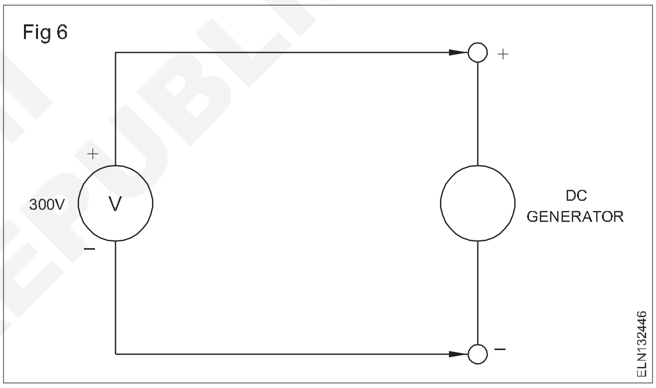
Fig 5



Polarity of DC supply

In the same way to find out the polarity of DC generator or a DC source it is advisable to use a moving coil type voltmeter with a suitable range, of say 0-300 volts (Fig 6). To protect the meters, always use higher range meters above the rated voltage of the generator or DC source supply.

Fig 6

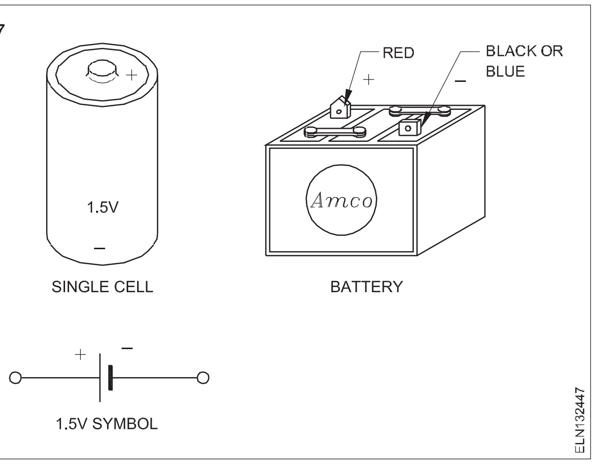


Marking made in practice

Generally in DC source the +ve terminal of the supply lead is Red in colour and –ve terminal of the supply lead is Blue or Black in colour. Battery terminals are marked as +ve and –ve on the body or on the terminal post.

- For cells on top of the cell is marked as +ve and the bottom is marked as –ve
- The battery terminal is marked as + and is Red in colour, and the other terminal is marked as – and Black or Blue in colour. (Fig 7)

Fig 7



Neon polarity indicator

To check the polarity, a neon lamp in series with a 220k ohms resistor could be used (as shown in Fig 8). Touch the probes of the neon lamp circuit across the circuit to be tested. The lamp will light when voltage is present. If both electrodes in the lamp glow, you have an AC power source. If only one electrode glows, the voltage is DC and the lighted electrode will be on the side of the negative polarity of the source.

Fig 8

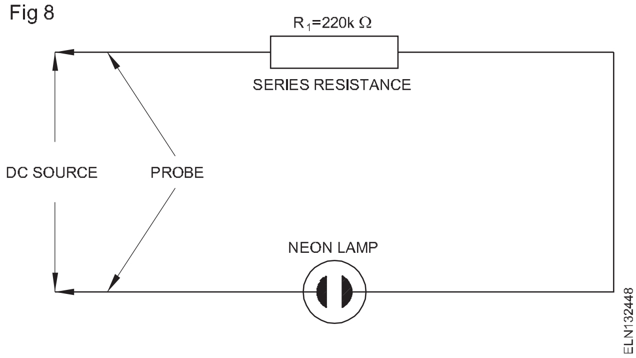
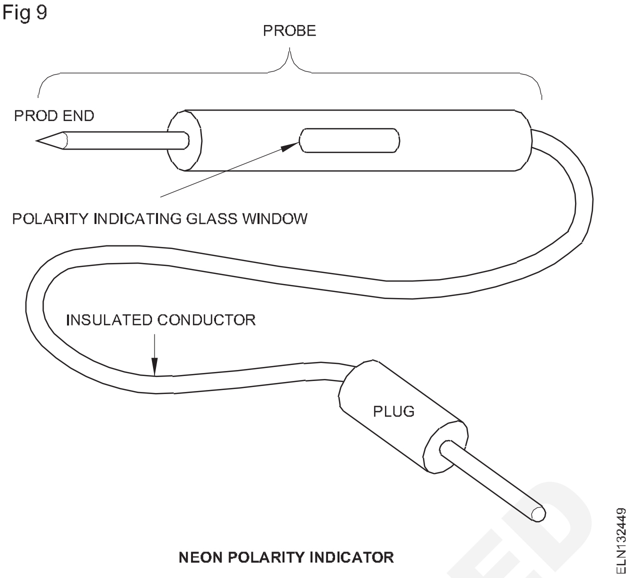


Fig 9



NEON POLARITY INDICATOR

Therefore, you also have a polarity check on DC circuits. (Fig 8) A commercial neon polarity indicator is shown in Fig 9. It has an indicating glass window in which the polarity touched by the pointed end of the indicator will be displayed as +ve or –ve through neon signs.

Conductors - insulators - wires - types

Objectives: At the end of this lesson you shall be able to
- **differentiate between conducting and insulating materials**
- **state the electrical properties of conducting materials**
- **state the terms used in electrical cables**
- **state the characteristics of copper and aluminium conductors**
- **state the types and propertites of insulating materials.**
- **describe the method of measurement of wire size using SWG**
- **explain the method of measure wire size by outside micrometer**

Conductors and insulators

Material with high electron mobility (many free electrons) are called conductor.

Materials that contain many free electrons and are capable of carrying an electric current are known as conductors.

Examples - silver, copper, aluminium and most other metals.

Materials with low electron mobility (few (or) no free electron) are called insulators

Materials that have only a few electrons and are incapable of allowing the current to pass through them are known as insulators.

Examples - wood, rubber, PVC, porcelain, mica, dry paper and fibreglass.

Conductors

The use of conductors and their insulation is regulated by I E regulations and BIS (ISI) code of practice.

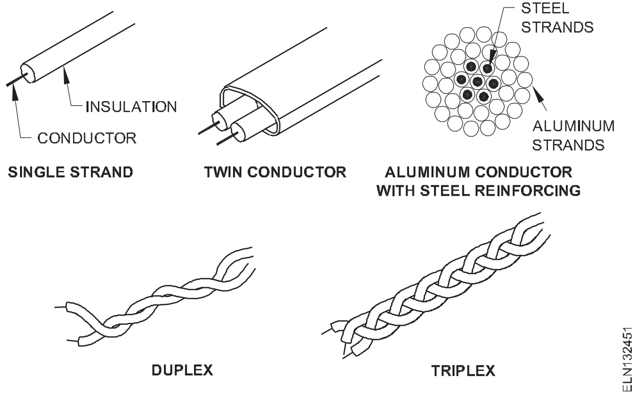
The I E regulations and I S cover all electrical conductors listing the minimum safety precautions needed to safeguard people, buildings and materials from the hazards of using electricity.

Wires and cables are the most common forms of conductors. They are made in a wide variety of forms to suit many different applications. (Fig 1)

Conductors form an unbroken line carrying electricity from the generating plant to the point where it is used. Conductors are usually made of copper or aluminium.

Current passing through a conductor generates heat. The amount of heat generated depends on the square of the current that passes through the conductor and the resistance of the conductor.

Fig 1



SINGLE STRAND

TWIN CONDUCTOR

ALUMINUM CONDUCTOR WITH STEEL REINFORCING

DUPLEX

TRIPLEX

As the heat developed in the conductor depends upon the resistance of the conductor the cross-sectional area of the conductor must have a large enough area to give it a low resistance. But the cross- sectional area must also be small enough to keep the cost and weight as low as possible.

The best cross-sectional area depends upon how much current the conductor can carry without much voltage drop in the line and heat generation in the conductor.

There is a limit to the temperature each kind of insulation can safely withstand and also the type of insulation which can withstand the physical chemical and temperature zones of the surroundings.

BIS (ISI) code specifies the maximum current considered safe for conductors of different sizes, having different insulation and installed in different surroundings.

Size of conductors

The size is specified by the diameter in mm or the cross-sectional area. Typical sizes are 1.5 sq.mm, 2.5 sq.mm, 6 sq.mm etc.

Still in India the old method of specifying the diameter by the standard wire gauge number is in use.

Classfication of conductors

Wires and cables can be classified by the type of covering they have.

Bare conductors

They have no covering. The most common use of bare conductors is in overhead electrical transmission and distribution lines. For earthing also bare conductors are used.

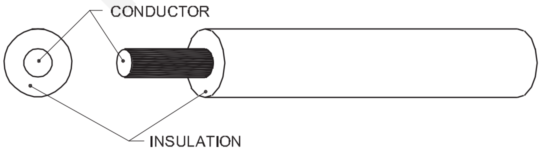
Insulated conductors

They have a coating of insulation. The insulation separates the conductor electrically from other conductors and from the surroundings. It allows conductors to be grouped without danger. Additional covering over the insulation adds mechanical strength and protection against weather, moisture and abrasion.

Solid and stranded conductors

A solid conductor is one in which there will be only one conductor in the core as shown in Fig 2. A stranded conductor is one in which there will be a number of smaller sized conductors twisted to form the core as shown in Fig 3.

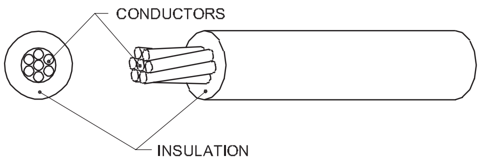
Fig 2



INSULATED SOLID CONDUCTOR

The number of conductors ranges from 3 to 162 and the conductor size varies from 0.193 mm to 3.75 mm diameter depending upon the current carrying capacity and also upon whether these conductors are used in cables or overhead lines.

Fig 3



INSULATED CONDUCTOR

Normally stranded conductors are designated as 10 sq. mm cable of size 7/1.40 where 10 sq.mm gives the area of the cross-section, in the size, numerator (7) gives the number of conductors and the denominator 1.40 gives the diameter of the conductor in mm. Alternatively 7/1.40 cable is the same as 7/17 whereas in the latter case the denominator is expressed in Standard Wire Gauge (SWG) number.

Stranded conductors are more flexible and have better mechanical strength. According to recent stipulation, the cable size should be expressed in sq. millimetres or they can be expressed in terms of the number of conductors in the cable and the diameter of the conductor in mm.

Cable

A cable is a length of single, insulated conductor (single or stranded), or two or more such conductors - each provided with its own insulation, and are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

Cable (armoured)

An armoured cable is provided with a wrapping of metal (usually in the form of tape or wire), serving as a mechanical protection.

Cable (flexible)

A flexible cable contains one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

Core

All cables have one central core or a number of cores of stranded conductors farming high conductivity; generally there are one, two, three, three and half and four cores. Each core is insulated separately and there is overall insulation around the cores.

Wire

A solid substance (conductor) or an insulated conductor (solid or stranded) subjected to tensile stress with or without screen is called a wire.

Copper and aluminium

In electrical work, mostly copper and aluminium are used for conductors. Though silver is a better conductor than copper, it is not used for general work due to higher cost.

Copper used in electrical work is made with a very high degree of purity, say 99.9 percent.

Characteristics of copper

1 It has the best conductivity next to silver.

2 It has the largest current density per unit area compared

to other metals. Hence the volume required to carry a given current is less for a given length.

3 It can be drawn into thin wires and sheets.

4 It has a high resistance to atmospheric corrosion: hence, it can serve for a long time.

5 It can be joined without any special provision to prevent electrolytic action.

6 It is durable and has a high scrap value.

Next to copper, aluminium is the metal used for electrical conductors.

Characteristics of aluminium

1 It has good conductivity, next to copper. When compared to copper, it has 60.6 percent conductivity. Hence, for the same current capacity, the cross-section for the aluminium wire should be larger than that for the copper wire.

2 It is lighter in weight.

3 It can be drawn into thin wires and sheets. But loses its tensile strength on reduction of the cross-sectional area.

4 A lot of precautions needs to be followed while joining aluminium conductors.

5 The melting point of aluminium is low, hence it may get damaged at points of loose connection due to heat developed.

6 It is cheaper than copper.

Table 1 shows the properties of copper compared with those of aluminium.

Properties of insulating materials

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. They are entirely different from each other and measured in different ways.

Insulation resistance

It is the electrical resistance of the insulation against the flow of current. Megohmmeter (Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megohms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Dielectric strength

It is the measure of how much potential difference the insulation layer can withstand without breaking down. The potential difference that causes a breakdown is called the breakdown voltage of the insulation.

Every electrical device is protected by some kind of insulation. The desirable characteristics of insulation materials are:

- high dielectric strength
- resistance to temperature
- flexibility
- mechanical strength.

No single material has all the characteristics required for every application. Therefore, many kinds of insulating materials have been developed.

Insulating tapes

Various tapes are used for insulating electrical equipments, conductors and components. Some of these are adhesive. The tapes commonly used include friction, rubber, plastic and varnished cambric tapes.

Rubber tape

Rubber tapes are used for insulating joints. The tape is applied under slight tension. Pressure causes the layers to bend together. Application of this restores insulation but will not be mechanically strong.

Friction tape

This is used over rubber tape insulation. This is made up of cotton cloth impregnated with an adhesive. It does not stretch like the rubber tape. The friction tape does not have insulating qualities of the rubber tape, hence should not be used by itself for insulation.

Plastic tape (PVC tape)

This is used more than the other tapes. PVC tapes have the following advantages.

- High dielectric strength
- Very thin
- Stretches to conform to contours of joints

Varnished cambric tapes

These tapes are made of cloth impregnated with varnish. It usually has no adhesive coating. Available in sheets and rolls and are ideal for insulating motor connecting leads.

Measurement of wire sizes - standard wire gauge - outside micrometer

Necessity of measuring the wire sizes

To execute a wiring job proper planning is necessary. After considering the requirements of the house owner, the electrician prepares a layout plan of the wiring and an estimate of the cost of the wiring materials and labour.

A proper estimate involves determination of current in different loads, correct selection of the type of cable, size of the cable and the required quantity. Any error will result in defective wiring, fire accidents and bring unhappiness to both the house owner and the electrician.

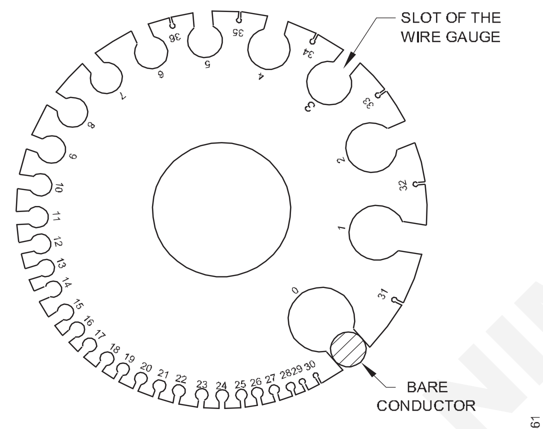
To measure the size of conductors, a electrician can use normally a standard wire gauge or an outside micrometer for more accurate results.

The size of wires are designed more carefully by the manufacturers. Though the Bureau of Indian Standards (BSI) specifies the cables by the area of the cross-section in square millimetres, the manufacturers still produce the cable with the diameter of each wire and number of wires in the stranded cables. Sometimes the indicated size of cable by the manufacturer may not be correct and the electrician has to ascertain the size by measurement.

Standard Wire Gauge (SWG)

The size of the conductor is given by the standard wire gauge number. According to the standards each number has an assigned diameter in inch or mm. This is given in Table 1. The standard wire gauge, shown in Figure 1 could measure the wire size in SWG numbers from 0 to 36. It should be noted that the higher the number of wire gauge the smaller is the diameter of the wire.

Fig 1

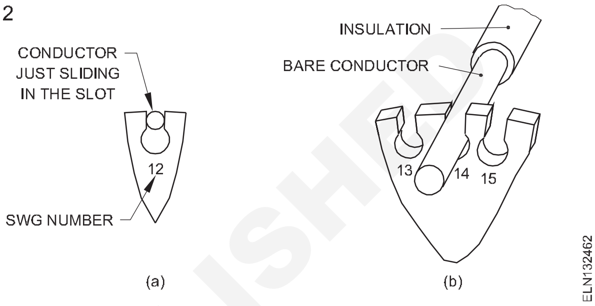


STANDARD WIRE GAUGE

For example, SWG No. 0 (zero) is equal to 0.324 inch or 8.23 mm in diameter whereas SWG No.36 is equal to 0.0076 inch or 0.19 mm in diameter.

While measuring the wire, the wire should be cleaned and then inserted into the slot of the wire gauge to determine the SWG number (Fig 2). The slot in which the wire just slides in is the correct slot and the SWG number could be read in the gauge directly. In most of the wire gauges to save the trouble of referring to the table, the wire diameter is inscribed on the reverse of the gauge.

Fig 2



American Wire Gauge (AWG)

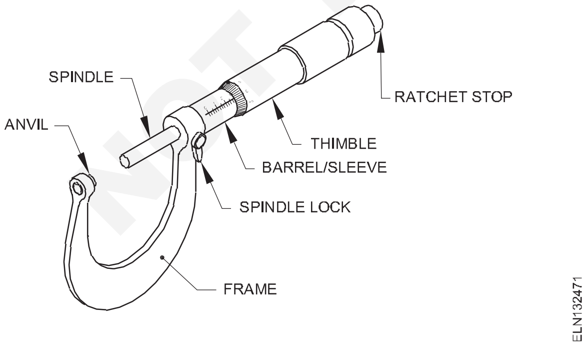
The American wire gauge is different from the British standard wire gauge. In an American wire gauge (AWG) the diameter is represented in mils rather than inch or mm. One mil is one thousandth part of an inch. Please note there is no direct conversion from AWG to SWG.

Measurement of wire size by Outside micrometers

A micrometer is a precision instrument used to measure a job, generally within an accuracy of 0.01 mm.

Micrometers used to take the outside measurements are known as outside micrometers. (Fig 1)

Fig 1



The parts of a micrometer

Frame

The frame is made of drop-forged steel or malleable cast iron. All other parts of the micrometer are attached to this.

Barrel/sleeve

The barrel or sleeve is fixed to the frame. The datum line and graduations are marked on this.

Thimble

The thimble is attached to the spindle and on the bevelled surface of the thimble, the graduation is marked.

While selecting the cable sizes, the electrician has to take into consideration the proposed connected load, future changes in load, the length of the cable run and the permissible voltage drop in the cable.

A sound knowledge about the area of the cross-section of the core, the diameter of the single strand of the conductor and the number of conductors in each core of the stranded conductor is essential for a wireman to be successful in his carreer.

Table 1 - Conversion table SWG to mm/inch

SWG No.	mm	inch
7/0	12.7	0.500
6/0	11.38	0.464
5/0	10.92	0.432
4/0	10.16	0.400
3/0	9.44	0.372
2/0	8.83	0.348
0	8.23	0.324
1	7.62	0.300
2	7.01	0.276
3	6.40	0.252
4	5.89	0.234
5	5.38	0.212
6	4.88	0.192
7	4.47	0.176
8	4.06	0.160
9	3.66	0.144
10	3.25	0.128
11	2.95	0.116
12	2.64	0.104
13	2.34	0.092
14	2.03	0.080
15	1.83	0.072
16	1.63	0.064
17	1.42	0.056
18	1.22	0.048
19	1.02	0.040
20	0.91	0.036
21	0.81	0.032
22	0.71	0.028

SWG No.	mm	inch
23	0.61	0.024
24	0.56	0.022
25	0.51	0.020
26	0.46	0.018
27	0.42	0.0164
28	0.38	0.0148
29	0.34	0.0136
30	0.31	0.0124
31	0.29	0.0116
32	0.27	0.0108
33	0.25	0.0100
34	0.23	0.0092
35	0.21	0.0084
36	0.19	0.0076
37	0.17	0.0068
38	0.15	0.0060
39	0.13	0.0052
40	0.12	0.0048
41	0.11	0.0044
42	0.10	0.0040
43	0.09	0.0036
44	0.08	0.0032
45	0.07	0.0028
46	0.06	0.0024
47	0.05	0.0020
48	0.04	0.0016
49	0.03	0.0012
50	0.02	0.0010

Generation of DC electricity

Objectives: At the end of this lesson you shall be able to

- **Construction of DC generator.**
- **E.M.F. equation of DC generator.**
- **Types of DC generator.**

DC generators produce electrical power based on the principle of faraday's law of electromagnetic induction. Based on this law, when a conductor moves in a magnetic field, the magnetic lines of force are cut. This leads to an electromagnetic force induction in the conductor.

In general, Electric generators work on the principle of electromagnetic induction. A conductor coil (a copper coil tightly wound onto a metal core) is rotated rapidly between the poles of a horseshoe type magnet. The conductor coil along with its core is known as an armature.

Basically, A DC generator is an electrical device used for generating electrical energy. The main function of this device is to change mechanical energy into electrical energy. There are several types of mechanical energy sources available such as hand cranks, internal combustion engines, water turbines, gas and steam turbines.

Difference between AC and DC Generator

Before we can discuss the difference between AC & DC generator, we have to know the concept of generators. Generally, generators are classified into two types like AC and DC. The main function of these generators is to change the power from mechanical to electrical. An AC generator generates an alternating current whereas the DC generator generates direct power.

Both generators use Faraday's law to generate electrical power. This law tells that once a conductor shifts within a magnetic field then it slashes magnetic lines of force to stimulate an EMF or electromagnetic force within the conductor. This induced emf's magnitude mainly depends on the magnetic line force connection through the conductor. Once the circuit of the conductor is closed then the emf can cause flow of current. The main parts of a dc generator are the magnetic field & conductors that move within the magnetic field.

The main differences between AC & DC generators are one of the most important electrical topics. These differences can assist students to study about this topic but before that, one should know about the AC generators as well as dc generators in every detail so that differences are very simple to understand.

Differentiate between AC and DC current

Objectives: At the end of this lesson you shall be able to

- **Differentiate AC current and DC current**

Direct current (DC) is the flow of electric charge in only one direction. It is the steady state of a constant-voltage circuit. Most well-known applications, however, use a time-varying voltage source. Alternating current (AC) is the flow of electric charge that periodically reverses direction.

Electric current flows in two ways as an alternating current (AC) or direct current (DC). In alternating current, current keeps switching directions periodically – forward and backward. While in the direct current it flows in a single direction steadily. The main difference between AC and DC lies in the direction in which the electrons flow. In DC, the electrons flow steadily in a single direction while electrons keep switching directions, going forward and then backwards in AC. Let us learn more differences between them in the next few sections.

What is an Alternating Current (AC)?

In alternating current, the electric charges flow changes its direction periodically. AC is the most commonly used and most preferred electric power for household equipment, office, and buildings, etc. It was first tested, based on the principles of Michael Faraday in 1832 using a Dynamo Electric Generator.

Alternating current can be identified in waveform called a sine wave, in other words, it can be said as the curved line. These curved lines represent electric cycles and are measured per second. The measurement is read as Hertz or Hz. AC is used to powerhouses and buildings etc because generating and transporting AC across long distances is relatively easy. AC is capable of powering electric motors which are used on refrigerators, washing machine, etc

What is Direct Current (DC)?

Unlike alternating current, the flow of direct current does not change periodically. The current electricity flows in a single direction in a steady voltage. The major use of DC is to supply power for electrical devices and also to charge batteries. Example: mobile phone batteries, flashlights, flat-screen television, and electric vehicles. DC has the combination of plus and minus sign, a dotted line or a straight line.

Everything that runs on a battery and uses an AC adapter while plugging into a wall or uses a USB cable for power relies on DC. Examples would be cell phones, electric vehicles, flashlights, flat-screen TVs (AC goes into the TV and is converted into DC).

The major differences between Alternating Current and Direct Current are given in the table below:

Alternating Current	Direct Current
AC is safe to transfer longer distance even between two cities, and maintain the electric power.	DC cannot travel for a very long distance. It loses electric power.
The rotating magnets cause the change in direction of electric flow.	The steady magnetism makes DC flow in a single direction.
The frequency of AC is depended upon the country. But, generally, the frequency is 50 Hz or 60 Hz.	DC has no frequency of zero frequency.
In AC the flow of current changes its direction backwards periodically.	It flows in a single direction steadily.
Electrons in AC keep changing its directions – backward and forward	Electrons only move in one direction – that is forward.

Following are the advantages of alternating current over direct current:

- AC is less expensive and easy to generate than DC.
- The distance covered by AC is more than that of the DC.
- The power loss during transmission in AC is less when compared to the DC. There are two reasons why the use of AC voltage is preferred over DC voltage:
- The loss of energy during the transmission in AC voltage is less when compared with the DC voltage and this makes its installations easy when the transformers are at distance.
- AC voltage has the advantage of stepping up and stepping down as per the requirement.

Skinning, Crimping, Joining and Sololering of Cables

Objective: At the end of this lesson you shall be able to
- **state the method of skinning of cable.**

Skinning of Cables:

The installation technique for aluminium cables is the same as that for copper cables. Certain additional precautions are necessary as aluminium has low mechanical strength, less current carrying capacity for the same area of cross-section, low melting point, and is quicker in forming oxides on the surface than copper.

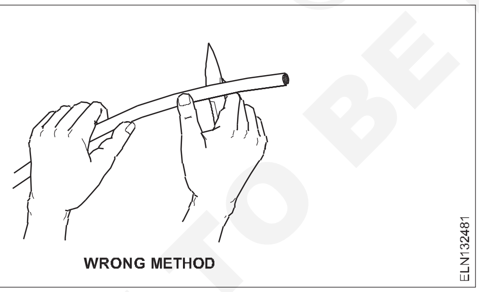
Accordingly, while, using aluminium cables proper care is to be taken regarding the following.

- Handling
- Skinning of the cables
- Connecting the cable ends

Handling: Remember that aluminium conductors when compared to copper conductors have less tensile strength and less resistance to fatigue. As such, bending or twisting of aluminium conductors while laying the cables should be avoided as far as possible.

Skinning of cables: While skinning the insulation from the cables, knicks and scratches should be avoided. As shown in Fig 1, the insulation should not be ringed as there is a danger of nicking the aluminium conductor while ringing the insulation with a knife.

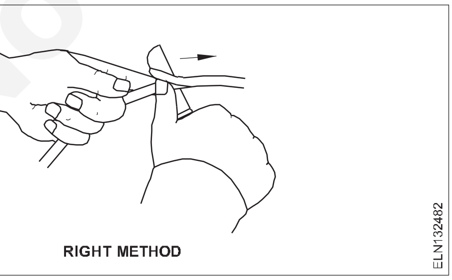
Fig 1



WRONG METHOD

Using the knife as shown in Fig 2 at an angle of 20° to the axis of the core will avoid knicking of the conductor.

Fig 2



RIGHT METHOD

Connecting the cable ends

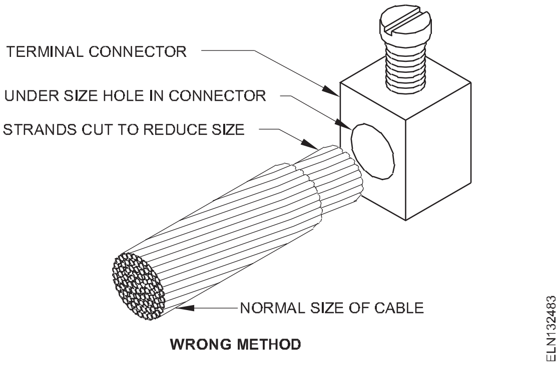
The following problems are encountered while connecting aluminium cables to the accessories.

The termination holes in the accessories may be undersized.

This normally happens in old accessories as they are designed for copper cable ends. Hence, while selecting accessories, a thorough check is necessary of all accessories to ensure whether the holes in the terminating connectors as shown in Fig 4 are suitable to accommodate the specified aluminium conductors. In any case, the strands should not be cut or the conductor filed as shown in Fig 3 to enable insertion in the undersized hole as this operation results in the heating of the cable end on load condition.

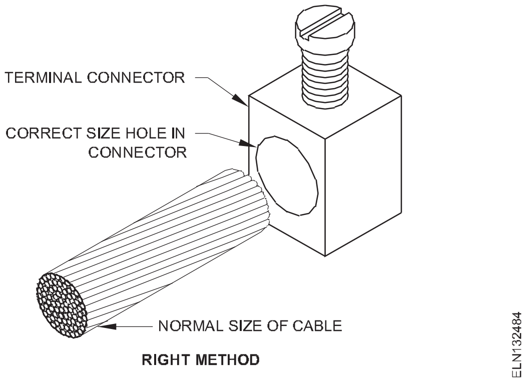
Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.

Fig 3



WRONG METHOD

Fig 4



RIGHT METHOD

Cable end termination - crimping tool

Objectives: At the end of this lesson you shall be able to:
- **state the necessity of proper termination**
- **list the different types of terminations**
- **describe the parts and their functions of crimping tool**
- **state the advantages of crimping termination.**

Necessity of termination

Cables are terminated at electrical appliances, accessories and equipment etc. for providing electrical connections. All terminations must be made to provide good electrical continuity, and made in such a manner as to prevent contact with other metallic parts and other cables.

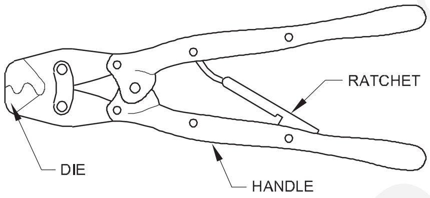
Loose terminations will lead to overheating of cables, plugs and other connecting points due to higher resistance at those terminations. Fires may also be started due to the excess heat. Wrong termination like excess or extended conductor touching metallic part of the equipment may lead to giving shock to the person who comes in contact with the equipment.

Touching of strands projecting from one terminal with other terminal leads to short circuit. To conclude, we can state that wrong termination will lead to overheating of terminating points and cables, short circuits and earth leakage.

Types of termination

Crimp connection: In this type of connection the conductor is inserted into a crimp terminal and is then crimped with a crimping tool (Fig 1).

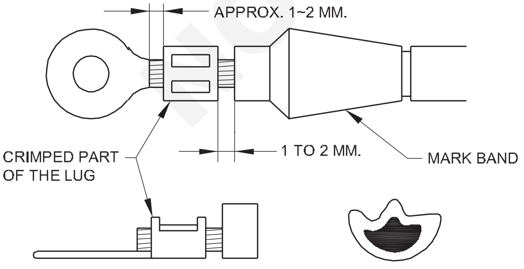
Fig 1



CRIMPING TOOL

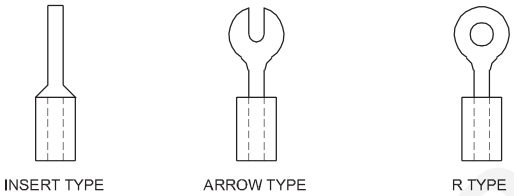
It is important to choose a crimp terminal that matches the conductor diameter and the dimensions of the connecting screw terminal. (Figs 2 and 3)

Fig 2



CRIMP TERMINAL CONNECTION

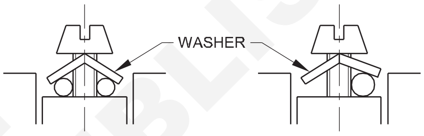
Fig 3



VARIOUS KINDS OF CRIMP TERMINALS

Insert screw setting: The conductor is inserted between the terminal block and the special form of washer (Fig 4), and then the screw is tightened.

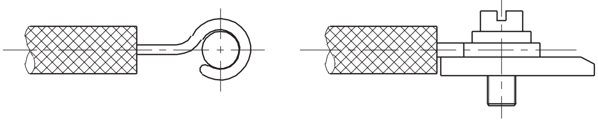
Fig 4



INSERT AND SCREW SETTING

Screw on terminals with loop/ring conductor: A loop is formed clockwise in the bare portion of the conductor to match the size of the screw diameter. Then the loop is inserted to the screw and tightened. (Fig 5) In the case of a stranded conductor, soldering of the loop is essential to prevent strands getting fray.

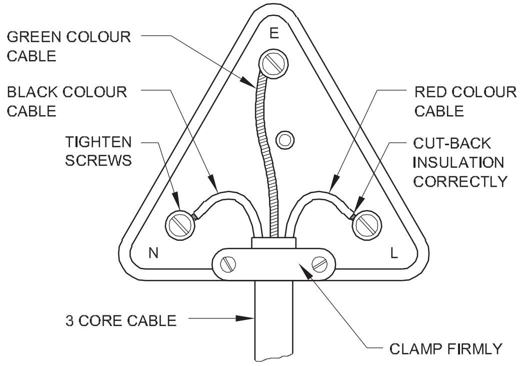
Fig 5



RING MAKE-UP SCREW SETTING

While connecting the plug and socket for extension of the cable, Line (L), the Neutral (N) and Earth (E) terminals must be properly identified by markings on them .(Fig 6)

Fig 6



INSIDE VIEW OF A 3-PIN PLUG

The colour code while connecting 3 core cable must be properly followed. Red wire to L, black/blue to N, green wire or yellow with green line to E terminal. The earth terminal in a 3 pin plug is bigger than the other two.

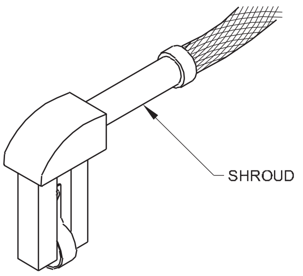
Connections and terminals

There is an electrical fire risk if:

- the current-carrying capacity of the cable is inadequate
- the capacity of the plug is inadequate
- the insulation is cut back too far
- the conductor is damaged while cutting back the insulation
- the connections are not right
- the cable is not adequately supported at the point of entry to the plug or to the appliance.

When a reinforcing rubber shroud is provided, ensure that it is used. (Fig 7)

Fig 7



Crimping and crimping tool

The ends of cables can be prepared for termination with lugs by the soldering process or by mechanical means - compression or crimp fitting.

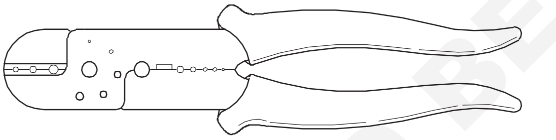
In crimp compression fitting, a ring-tongued terminal (lug) is to be compressed to the bared end of an insulated multi-strand cable. The process is called crimping and the tool used is called crimping pliers or crimping tool.

Compression type connectors apply and maintain pressure by compressing the connector around the conductor.

Crimping tools

The crimping pliers illustrated in Fig 1 is of a type which crimps from 0.5 to 6 mm cables.

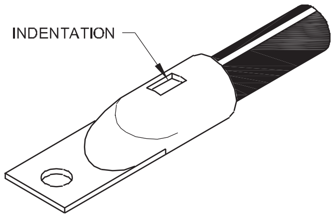
Fig 1



HAND CRIMPING PLIERS

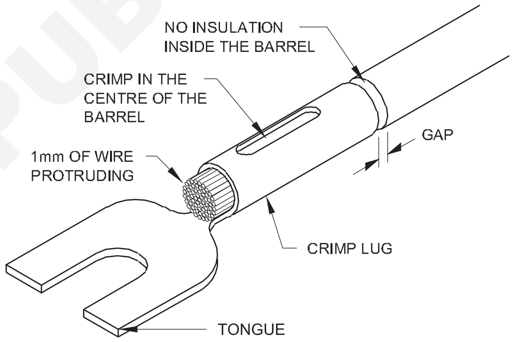
The tool is operated by squeezing the handles. The jaws move together, grip and then crimp the fitting. Using the crimping tool that matches the specific crimp lug will give the correct crimping force for a properly executed crimp. Properly executed crimp will indent the top of the lug and the indentation will hold the conductor securely as shown in Fig 2.

Fig 2



If the terminal has too deep a crimp, the strength of the joint is reduced. With too shallow a crimp, the electrical contact has a high resistance. Selection of the correct crimping tool is essential. A properly crimped terminal is shown in Fig 3.

Fig 3



A PROPERLY CRIMPED TERMINAL

Terminal lug crimping pliers are available in lengths ranging from 180 to 300 mm. Crimping tools are available in sets. For higher capacity cables crimping tools are operated by hydraulic force.

Fig 4 shows another type of crimping tool which crimps from 26 to 10 SWG.

The head and jaws, may be removed, by unscrewing the screws S_1 and S_2. A head with different shaped jaws may then be secured to the tool. The shape of the jaws determines the shape of the crimp (indent). Some crimp sections are shown in Fig 5.

Safety

When using this type of crimping tool care must be taken not to trap the finger, as the operating cycle of the tool is non-reversible i.e. once the handles are squeezed together the jaws can only be released by applying further pressure to the handles as shown in Fig 4.

Fig 4

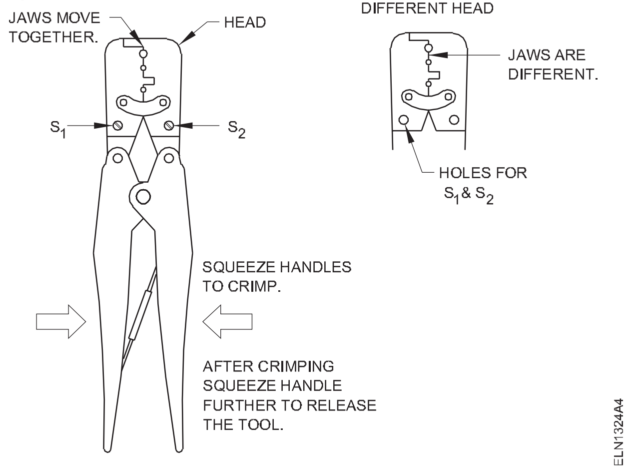
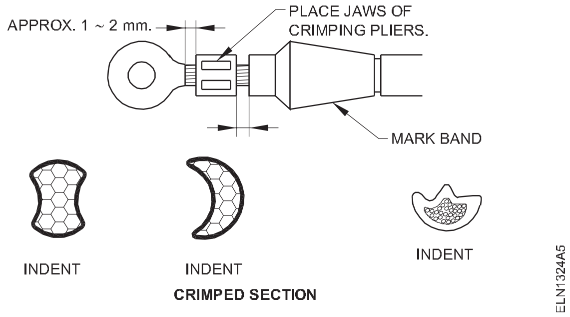


Fig 5



Terminal types

It is important to consider both the mechanical and electrical requirements when selecting a lug connector.

The factors are:

- the type of tongue, i.e. rectangular, ring, spade, etc.
- the mechanical size, i.e. tongue size and thickness, hole size etc. for the cable selected
- the electrical considerations such as the current carrying capacity, that may also determine some of the mechanical dimensions.

The electrical and mechanical requirements for the lug and the base material of the lug are decided by the cable material, and the place of connection will determine the minimum tongue size and the barrel size. The most commonly used base materials are copper and brass. Nickel, aluminium and steel are also used, but less frequently.

Fig 6

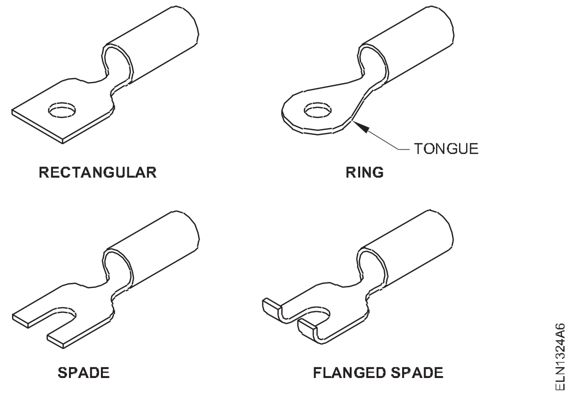


Fig 6 shows some lug connectors normally used in practice terminals. They are ring, rectangular, spade, flanged spade etc. Ring and rectangular terminals are not intended for frequent removal to disconnect the terminal whereas in spade and flanged spade lugs (terminals) the screw need not be removed to disconnect.

Advantages of crimping terminations

1 A properly made crimp is better in electrical conductivity and mechanical strength.

2 Less costly.

3 When the same size cables are to be terminated through lug connectors, the crimping process is faster than soldering.

4 The crimping operation surely needs good skill but soldering operation needs advanced skills.

5 Heat generated in the conductor sometimes melts the solder and the connection is open circuited. But crimped connection will not open that easily.

Wire joints - Types - Soldering methods

Objective: At the end of this lesson you shall be able to
- **state the different types of wire joints and their uses**
- **state the necessity of soldering and types of soldering**
- **state the purpose and types of fluxes**
- **explain the different method of soldering and techniques of soldering**
- **explain the type of solder and flux used for soldering aluminium conductor**

Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.

Definition of joint: A joint in an electrical conductor means connecting/tying or interlaying together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

Types of joints: In electrical work, different types of joints are used, based on the requirement. The service to be performed by a joint determines the type to be used.

Some joints may require to have good electrical conductivity. They need not necessarily be mechanically strong.

Example : The joints made in junction boxes and conduit accessories.

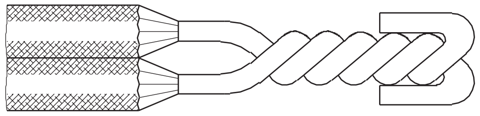
On the other hand, the joints made in overhead conductors, need to be not only electrically conductive but also mechanically strong to withstand the tensile stress due to the weight of the suspended conductor and wind pressure.

Some of the commonly used joints are listed below.

- Pig-tail or rat-tail
- twisted joints
- Married joint
- Tee joint
- Britannia straight joint
- Britannia tee joint
- Western union joint
- Scarfed joint
- Tap joint in single stranded conductor

Pig-tail/Rat-tail/Twisted joint (Fig 1): This joint is suitable for pieces where there is no mechanical stress on the conductors, as found in the junction box or conduit accessories box. However, the joint should maintain good electrical conductivity.

Fig 1



RAT TAIL JOINT

Married joint (Fig 2): A married joint is used in places where appreciable electrical conductivity is required, along with compactness.

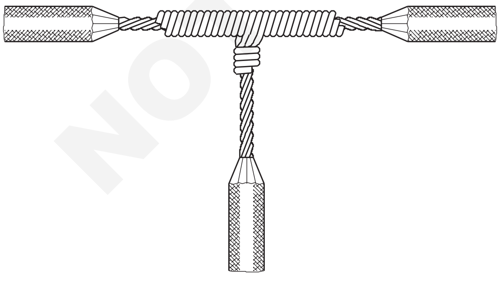
Fig 2

MARRIED JOINT

As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3): This joint could be used in overhead distribution lines where the electrical energy is to be tapped for service connections.

Fig 3

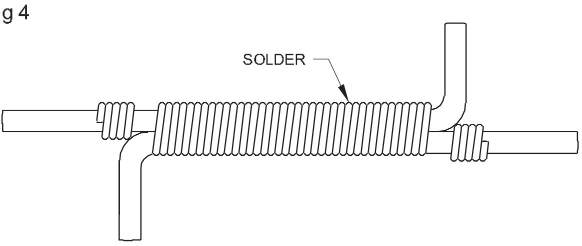


TEE JOINT

Britannia joint (Fig 4): This joint is used in overhead lines where considerable tensile strength is required.

It is also used both for inside and outside wiring where single conductors of diameter 4 mm or more are used.

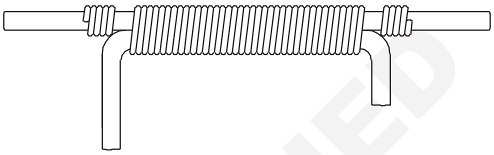
Fig 4



BRITANNIA JOINT

Britannia tee joint: This joint (shown in Fig 5) is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

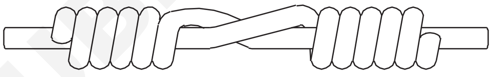
Fig 5



BRITANNIA TEE JOINT

Western union joint (Fig 6): This joint is used in overhead lines for extending the length of wire where the joint is subjected to considerable tensile stress.

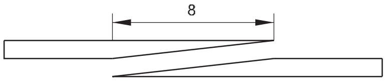
Fig 6



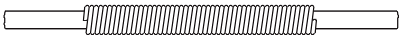
WESTERN UNION JOINT

Scarfed joint (Fig 7): This joint is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring.

Fig 7



(a) SCARFED JOINT



(b) SCARFED JOINT

Tap joints in single stranded conductors of diameter 2 mm or less

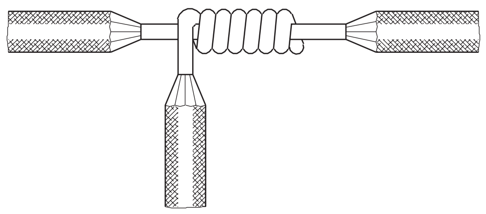
By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

The following types of taps are commonly used.

- – Plain
- – Aerial
- – Knotted
- – Cross - Double - Duplex

Plain tap joint (Fig 8): This joint is the most frequently used, and is quickly made. Soldering makes the joint more reliable.

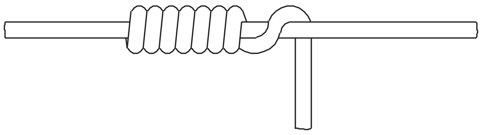
Fig 8



PLAIN TAP JOINT

Aerial tap joint (Fig 9): This joint is intended for wires subjected to considerable movement, and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap joint except that it has a long or easy twist to permit the movement of the tap wire over the main wire.

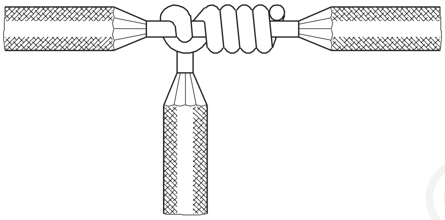
Fig 9



AERIAL TAP JOINT

Knotted tap joint (Fig 10): A knotted tap joint is designed to take considerable tensile stress.

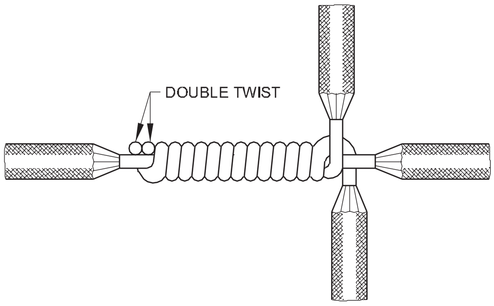
Fig 10



KNOTTED TAP JOINT

Duplex cross-tap joint (Fig 11): This joint is used where two wires are to be tapped at the same time. This joint could be made quickly.

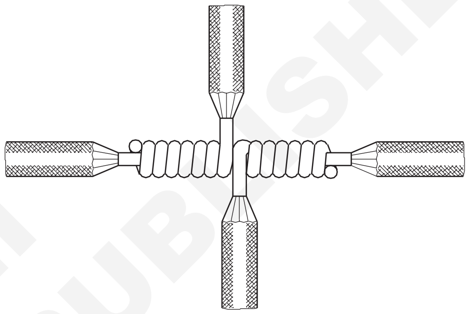
Fig 11



DUPLEX-CROSS TAP JOINT

Double-cross tap joint (Fig 12): This joint (shown in Fig 12) is simply a combination of two plain taps.

Fig 12



DOUBLE-CROSS TAP JOINT

Soldering - types of solders, flux and methods of soldering

Soldering: Soldering is the process of joining two metal plates or conductors without melting them, with an alloy called solder whose melting point is lower than that of the metals to be soldered. The molten solder is added to the two surfaces to be joined so that they are linked by a thin film of the solder which has penetrated into the surfaces.

Necessity of soldering: Wire and cable joints should have the same electrical conductivity and mechanical strength as that of the parent conductor. This cannot be achieved by a mere mechanical joint. As such cable joints are soldered to have good mechanical strength, electrical conductivity and also to avoid corrosion.

Solders

The following are the general proportions of tin and lead used in the solders.

Designation Uses		**Compo-**	**Working sitiontemp.**
Plumbing/ Tinman's solder	Tin-50% Lead-50%	212°C.or 413.6°F.	Heavy duty soldering
Electrician's solder	Tin-60% Lead-40%	185°C. or 365°F.	Tinning and soldering electrical joints etc.
Fine solder	Tin-63% Lead-37%	183°C.or 361°F.	Tinning/ Electrical/ Electronic Compound

Solder used for copper: The metal alloy used as a bonding agent in soldering is called a solder. The solders used for soft soldering consist of an alloy (mixture) of mostly tin and lead.

Factors influencing the choice of a solder

The factors that influence the choice of a solder are:

- place of use
- melting point
- solidification range
- strength
- hardness
- sealability
- price.

Flux: Flux is a substance used to dissolve oxides on the surface of conductors and to protect against de-oxidisation during the soldering process.

General properties of flux

The purpose of the flux is to

- dissolve oxides, sulphides etc. thereby making the soldering surface free of oxides and dirt
- prevent re-oxidation during the soldering operation thereby making the solder adhere to the surface to be soldered.
- facilitate the flow of the solder through surface tension so as to make the solder flow into the surface to be soldered.

The state of the flux can be solid or liquid.

The activity of the flux can be weak or strong, and is classified with regard to the corrosive properties, as slightly corrosive or highly corrosive.

The type of solder often determines the flux to be used for soldering.

The following table lists the fluxes used for soldering.

Table

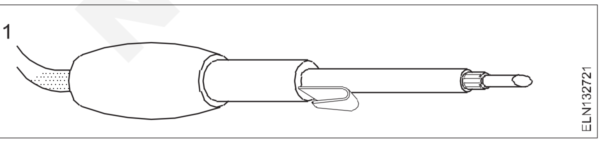
Sl. No.	Suitable flux	Metals/job - used for	Type of solder
1	Zinc chloride (acidic)	Cast iron, wrought iron, mild steel,cast steel, brass, bronze, copper etc. for soldering at low temperature	Tinman's solder Fine solder
2	Hydrochloric acid 10% diluted with water 90%	Zinc Galvanised iron	Coarse solder
3	Sal ammonia rosin (Not fully acid-free)	Copper, brass, tin plate, gun-metal: for clean and finer soldering work.	Coarse solder
4	Rosin	Joining electrical conductors	Electrician's solder
5	Tallow - (turpentine, acid free)	For joining electrical conductors, for soldering.	Electrician's fine solder

Fluxes shown under 1, 2 and 3 are not recommended for electrical purposes as they are highly corrosive, hygroscopic (absorb moisture), and the residues are electricity conductive.

Soldering methods

Soldering with a soldering iron: The most common method of soldering is with a soldering iron as shown in Fig 1. This is widely used for most kinds of soft soldering work.

Fig 1

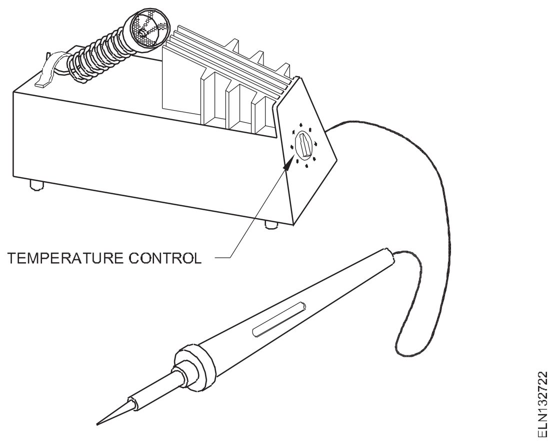


This tool is simple and inexpensive. Soldering irons are available in a wide range of sizes and models. Heating is generally by electrical means, though non-electrical irons are also used.

Temperature controlled soldering

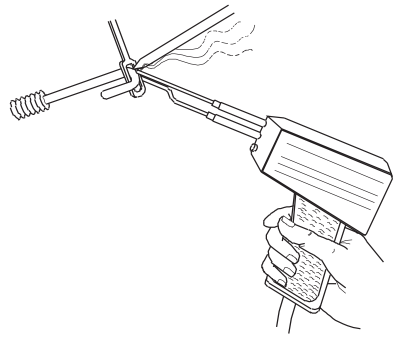
For soldering miniature components on printed circuit boards, a temperature-controlled soldering iron is used as shown in Fig 2. The electrical supply given to the soldering iron is of low voltage, and is completely isolated from the main supply. Low voltage does not endanger the life of the user and will also not spoil the sensitive electronic components. Controlled temperature makes the job easy for the user.

Fig 2



Soldering with a soldering gun: This method, shown in Fig 3, is used for individual soldering, e.g. for servicing and repair work.

Fig 3



SOLDERING WITH A SOLDERING GUN

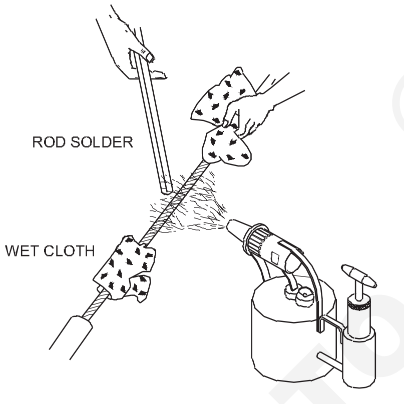
The principle of this method is that an electric current flows through a wire coil heating it. The temperature is difficult to check, and overheating can easily occur. This is the disadvantage.

Soldering with a flame: Soldering with a flame is used when the heat capacity of a soldering iron is insufficient.

This method, shown in Fig 4, permits rapid heating and is used primarily for larger jobs, such as piping and cable work, vehicle body repairs and some applications in the building trade.

This method requires skilful management of the flame.

Fig 4

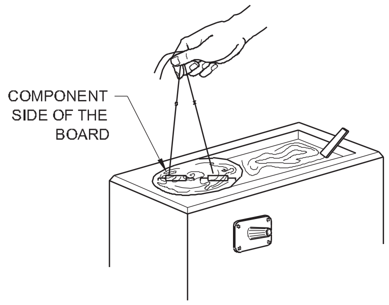


SOLDERING WITH BLOWLAMP

Dip soldering: This method, shown in Fig 5, is used for quantity production and for tinning work similar to component soldering on Printed Circuit Boards (P.C.B.). Components to be soldered or tinned are dipped into a bath of molten solder, which is heated electrically.

The solder is kept in motion by an agitator in order to obtain an even temperature and to keep the surface free from oxides. If no agitator is provided, the surface must be protected or skimmed at regular intervals to remove the oxides.

Fig 5



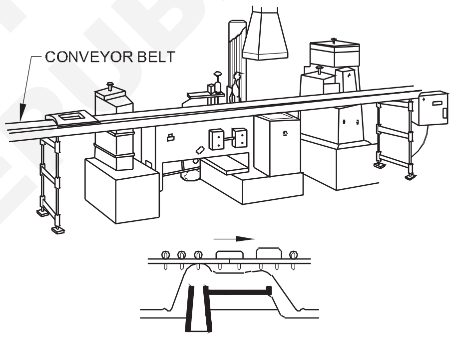
DIP SOLDERING

The temperature can be controlled very accurately.

Machine soldering: This method, shown in Fig 6, is used for quantity production, and is based on the principle that molten solder or a mixture of oil and molten solder is set in rapid motion, thus breaking up the oxide film. The solder comes into direct contact with the component ends to be soldered.

Soldering machines of different designs are used for wave soldering, cascade soldering and jet soldering.

Fig 6



MACHINE SOLDERING

Equipment for machine soldering is expensive and the cost of production is high.

Accurate temperature control can be arranged.

Apart from these, any one of the following methods can also be used for soldering.

- Resistance soldering
- Induction soldering
- Oven soldering
- Soldering in vegetable oil
- Soldering by hot gas

Soldering - Techniques - pot and laddle

Soldering with electric soldering iron: In this method, the joining surface is first cleaned and then the flux is applied over the surface. The joint is then heated, and the solder is kept over the surface to be soldered, and heat is applied by keeping the soldering iron tip over it. The solder melts and spreads on the surface evenly.

The electric soldering iron: The heating element in the iron is heated by an electric current passing through it.

The bit is heated by the heating element.

The face of the bit is the part of the iron, used to make contact with the surfaces to be soldered.

Soldering irons of the following voltages and input power (wattage) are available (I.S.950-1980).

Ratings

Voltage	6	12	24	50	110	230 or 240
Wattage	25	25	25	25	25,75, 250	5,10,25,75, 125,250,500

Select an iron with adequate power to suit the size of the work.

The bit: Most bits are made of copper because it is a good conductor of heat. The face of the bit may be either:

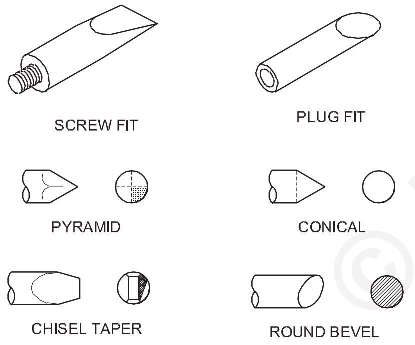
- un-plated or
- iron-plated.

Iron-plated faces do not wear out as rapidly as un-plated faces.

Most irons are so constructed that the bit can be changed.

Different shapes of bits are available as shown in Fig 1.

Fig 1

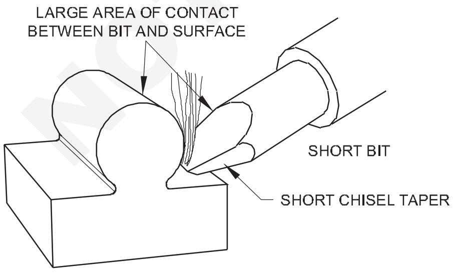


SHAPES OF SOLDERING BITS

Selecting the bit (Fig 2): Select the bit to give a compromise between:

- the best approach to the work
- the shortest bit and bit taper
- the ideal contact with the surfaces.

Fig 2



SELECT CORRECT SOLDERING BIT FOR THE JOB

Care of the bit (Fig 3)**:** Un-plated bits become pitted quickly and get covered in oxide. If the iron is in constant use, this will occur within a few hours.

To make a good soldered joint, the bit must be maintained clean, smooth and correctly shaped.

Fig 3

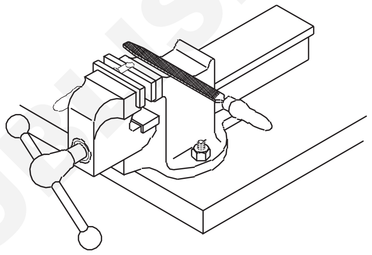
SOLDERING BITS

Dressing the bit (Fig 4): To dress an un-plated bit follow the procedure stated below.

- Switch off, unplug the iron and allow it to cool.
- Remove the bit from the iron, if possible.
- Mount the bit in a vice.
- File to shape.

Do not file the bit in an electronic assembly area. Copper dust from the bit may settle in the equipment and cause a short circuit. Iron-plated bits must not be filed. Renew when worn out.

Fig 4

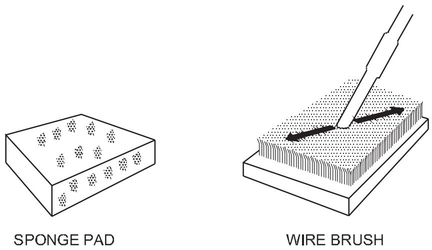


FILING THE SOLDERING BIT

Cleaning the bit (Fig 5): The bit should be cleaned frequently. To clean the bit, rub the face of the un-plated bits on a wire brush or special sponge pad when the iron is hot.

Iron-plated bits must not be cleaned on a wire brush. Rub on a sponge pad.

Fig 5



CLEANING THE SOLDERING BIT

Wetting (soldering): To make a good joint, the solder must flow evenly over and between the surfaces to be soldered. Wetting is a term used to describe the extent to which this occurs.

Good wetting results can be obtained if:

- the surfaces are clean
- sufficient flux of the correct type is used
- the surfaces are hot enough
- the surfaces have been tinned.

Techniques of soldering

Soldering involves the following main operations.

- Tinning the soldering iron
- Cleaning the parts to be soldered
- Applying the solder

Tinning the soldering iron: To make the solder adhere to the tip of the soldering iron, the surface of the tip must be coated with the solder, and this operation is known as tinning.

First the tip is cleaned with a cloth and heated either directly or indirectly. The tip is then filed to remove the scales, and is wiped again with a cloth.

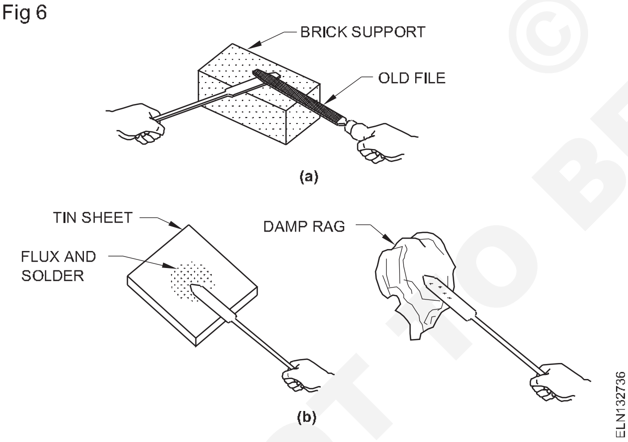
The right temperature for tinning could be judged by the change of colour of the tip when heated. If the surface of the copper tip tarnishes immediately, the temperature is high and needs to be cooled slightly by withdrawing the source of heat temporarily. A correctly heated tip tarnishes slowly.

After the soldering iron tip attains the correct temperature, place a small quantity of solder and the flux on a tin plate and rub the bit on the mixture. The solder should stick to the surface of the tip evenly. Wipe out the superfluous solder with a clean damp cloth.

The whole process of tinning is shown in Figures 6a and 6b.

The surface should present a bright silvery appearance when properly tinned.

Fig 6

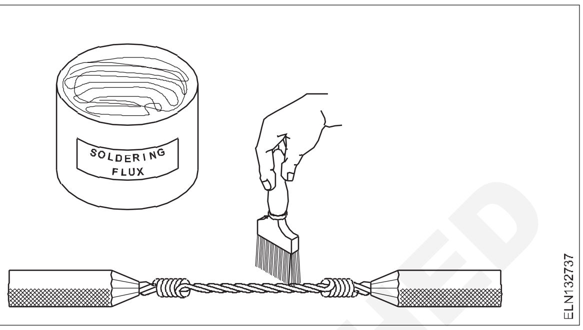


Cleaning the surface to be soldered: The parts to be soldered should be well cleaned for perfect soldering. The scales, dirt, oil and grease should be completely removed either by wiping or by rubbing with a sandpaper. Immediately after cleaning, the flux should be applied on the surface to avoid oxidization.

Applying the flux: The rosin which is recommended as a flux may be sprinkled over the surface to be soldered or may be applied with a brush as shown in the Fig 7.

Applying the solder: The quantity of the solder to be applied depends upon the size of the job. For small jobs like printed circuit boards soldering or soldering joints in wires of diameter 2 mm or lower, an electric soldering iron is used whereas for soldering joints of large sized cables, pot and ladle are used.

Fig 7



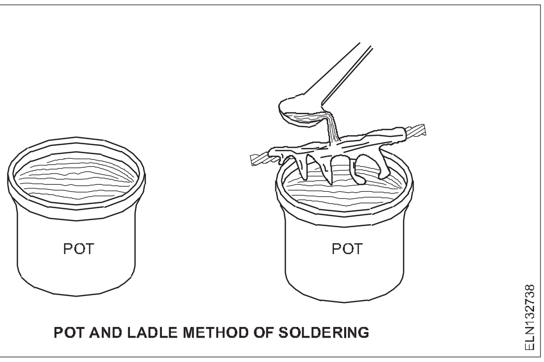
Soldering precautions: Remove the iron as soon as the solder has flowed over the surfaces.

Excessive heating may damage:

- the wire and its insulation
- the component being soldered
- the adjoining components.

Soldering with pot and ladle (Fig 8): For larger sized jobs like underground cable jointing, a melting pot and ladle are used. The solder is kept in the pot and heated either by a blowlamp or by charcoal. Initially the surface to be soldered is cleaned and a coat of flux is given.

Fig 8



POT AND LADLE METHOD OF SOLDERING

Then the surface to be soldered is heated by pouring molten solder over it in quick succession. The dripping solder is collected in a clean tray. After several pourings, the surface attains the same temperature as that of the molten solder. The flux is again applied and the solder is slowly poured on the surface as it forms an even layer. Superfluous solder collected in the tray is re-melted in the pot.

Ohm's law

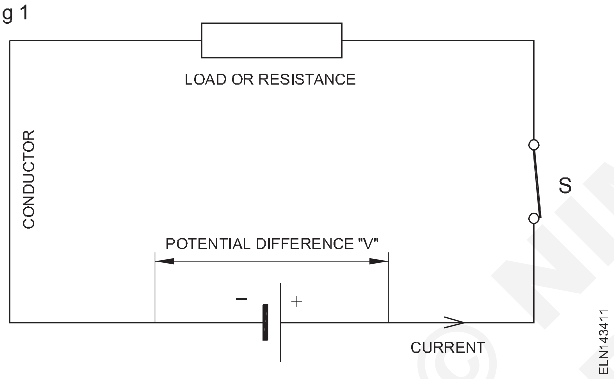
Objectives: At the end of this lesson you shall be able to
- **describe the essential factors in an electrical circuit**
- **state the relation between circuit factors through Ohm's law**
- **apply Ohm's law in an electric circuit.**
- **define electrical power and energy and calculate related problems.**

Simple electric circuit

In the simple electric circuit shown in Fig 1, the current completes its path from the positive terminal of the battery via the switch and the load back to the negative terminal of the battery.

The circuit shown in Fig 1 is a closed circuit. In order to make a circuit to function normally the following three factors are essential.

Fig 1



- Electromotive force (EMF) to drive the electrons through the circuit.
- Current (I), the flow of electrons.
- Resistance (R) - the opposition to limit the flow of electrons.

Ohm's law

In 1826 George Simon Ohm discovered that for metallic conductor, there is a substantially constant ratio of the potential difference between the ends of the conductor

Ohm's law gives the relation between the voltage, current and resistance of a circuit.

Ohm's law states that the ratio of the voltage (V) across any two points of a circuit to the current (I) flowing through is constant provided physical conditions, namely temperature etc. remain constant. This constant is denoted as resistance (R) of the circuit.

(or)

In simple,

Ohm's law states that in any electrical closed circuit, the current (I) is directly proportional to the voltage (V), and it is inversely proportional to the resistance 'R' at constant temperature.

(ie) I α V (When 'R' is kept constant)

I α R (When 'V' is kept constant)

I α V/R (Relation between I,V and R)

$$I \propto \frac{V}{R}$$

It means I = V/R

V = Voltage applied to the circuit in 'Volt'

I = Current flowing through the circuit in 'Amp'

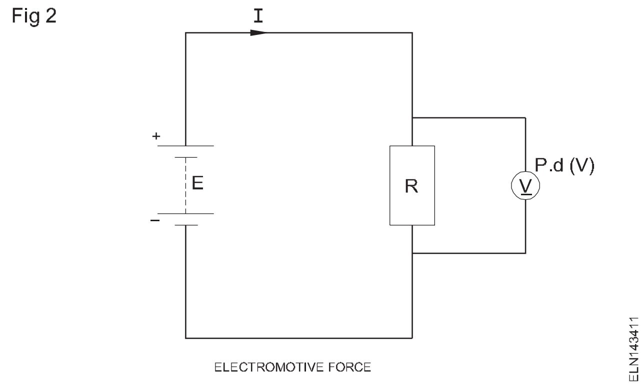
R = Resistance of the circuit in Ohm (Ω)

The above relationship can be referred to in a **triangle** as shown in Fig 2. In this triangle whatever the value you want to find out, place the thumb on it then the position of the other factors will give you the required value.

For example for finding 'V' close the value 'V' then readable values are IR, so V = IR.

Again for finding 'R', close the value R, then readable values are V/I so R = V/I, like that $I = \frac{V}{R}$.

Fig 2



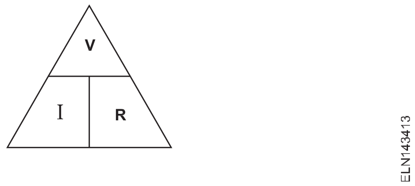
Written as a mathetical expression, Ohm's Law is

$$\text{Resistance} = \frac{\text{Voltage (V)}}{\text{Current (I)}} \text{ (Refer Fig 3)}$$

$$\text{(or) } R = \frac{V}{I} \text{ (Refer Fig 3)}$$

Of course, the above equation can be rearranged as:

Fig 3

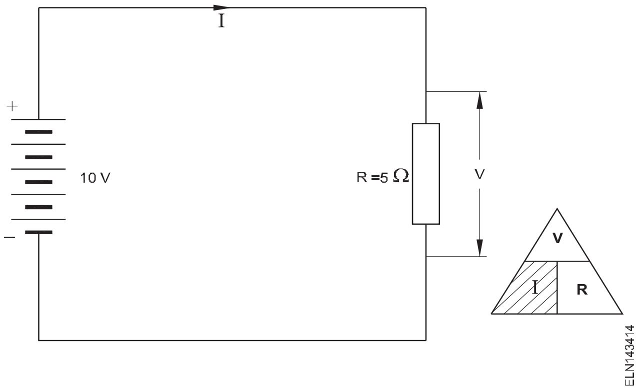


$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

$$\text{(or) } I = \frac{V}{R} \text{ (Refer Fig 4)}$$

In the same way, ‘V’ can be found by covering ‘V’

Fig 4

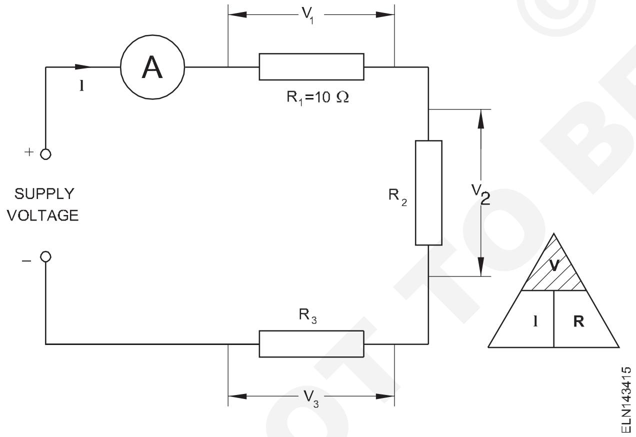


Voltage (V) = Current (I) x Resistance (R)

or V - IR (Refer Fig 5)

Application of Ohm’s law in circuits

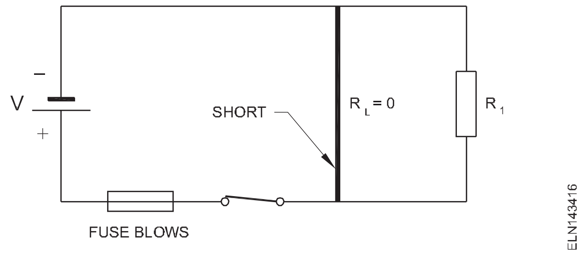
Fig 5



Example 1

Let us take a circuit shown in Fig 6 having a source of 10V battery and a load of 5 Ohms resistance. Now we can find out the current through the conductor.

Fig 6



$$I \propto \frac{V}{R}$$

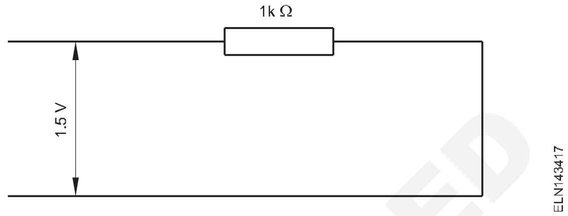
$$I = \frac{V}{R}$$

$$I = \frac{10}{5} = 2 \text{ amp}$$

Example 2

How much current (I) flows in the circuit shown in Fig 7

Fig 7



Given:

Voltage (V) = 1.5 Volts

Resistance (R) = 1 kOhm

= 1000 Ohms

Find : Current (I)

Known

$$I = \frac{V}{R}$$

Solution:

$$I = \frac{1.5 \text{ V}}{1000 \text{ Ohms}} = 0.0015 \text{ amp}$$

Answer:

The current in the circuit is 0.0015 A

or

the current in the circuit is 1.5 milliampere (mA)

(1000 milliamps = 1 ampere)

Problem

Find the value of voltage across a 10 Ohms resistor in the circuit shown in Fig 8. When the current of 2 Amps flows through the 10 Ohm resistor

Solution

Voltage across 10 Ohm

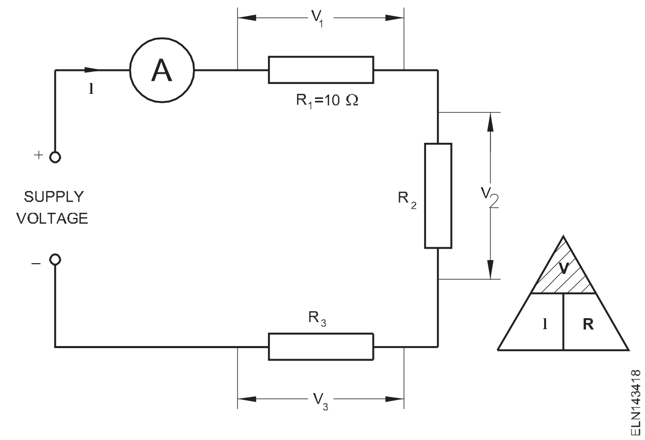
V= I x R

= 2 x 10

= 20 Volt

Similarly if the value of the other resistance is known we can find the voltage drop across them.

Fig 8



Extreme circuit conditions

Two important extreme conditions can occur in a circuit.

Open circuit

In an open circuit, there is an infinitely high resistance in the circuit. This condition can happen in a circuit when the switch is open. Therefore, no current of flow.

For example, a generator is said to be in an open circuit when the switch is open and running without supplying current to the circuit. A wall socket, too, is an open circuit if the control switch of the wall socket is 'OFF'or 'ON' position provided there is no appliance plugged to the wall socket.

Short circuit

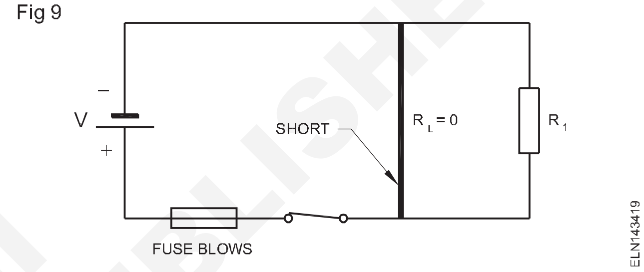
The other important extreme condition is the short circuit. A short circuit will occur, for example, when the two terminals of a cell are joined (Fig 9). A short circuit may also occur if the insulation between the two cores of a cable is defective.

The resulting negligible resistance will cause large currents which can become a hazard. A fuse, if provided in the circuit as shown in Fig 9, could then blow and automatically open the circuit.

Practical application

The knowledge gained by this exercise can be applied to calculate the current drawn by a particular load resistance when the supply voltage is known. This will enable the technician to select a proper size of cable for the circuit.

Fig 9



Simple electrical circuits and problems

Objectives: At the end of this lesson you shall be able to
- **describe the essential factors in an electrical circuit**
- **state the relation between circuit factors through Ohm's law**
- **apply Ohm's law in an electric circuit.**
- **define electrical power and energy and calculate related problems**

Electrical Power (P) & Energy (E)

The product of voltage (V) and current (I) is called electrical power. Electrical power (P) = Voltage x Current P=V x I

The unit of Electrical power is 'Watt' It is denoted by the letter 'P' It is measured by Watt meter. The following formulae can also be derived from formula of power (P) as

(i) $P = V X I$

$= IR x I$

$P = I^2 R$

(ii) $P = V X I$

$$= V x \frac{V}{R}$$

$$P = \frac{V^2}{R}$$

Electrical Energy (E)

The product of power (P) and time (t) is called as electrical energy (E)

Electrical Energy (E) = Power x time

$E = P x t$

$= (V x I) x t$

$E = V x I x t$

The unit of electrical energy is "Watt hour" (Wh)

The commercial unit of Electrical energy is "Kilo watt hour" (KWH) or unit

B.O.T (Board of Trade) unit / KWH/Unit

One B.O.T (Board of Trade) unit is defined as that one thousand watt lamp is used for one hour time, it consumes energy of one kilowatt hour (1kWH). It is also called as **"unit"**

Energy = 1000W x 1Hr = 1000WH (or) 1kWH

Example - 1

How much electrical energy is consumed in an electric iron rated as 750W/250V used for 90 Minutes

Given:

Power (P) = 750W

Voltage (V) = 250V

Time = 90min (or) 1.5Hr

Find:

Electrical Energy (E) = ?

Solution:

Electrical Energy (E) = P x t

=750 w x 1.5Hr

= 1125 WH (or)

E = 1.125 kWH

Example 2

Calculate the power of a lamp, which takes a current of 0.42 Amp at 240 V supply

Given:

Voltage (V) = 240 V

Current (I) = 0.5 A

Find:

Power(P) = ?

Solution:

P = V X I

= 240 x 0.42

= 100.8W

Hence, Power (P) = 100 W (approx)

Example 3:

Calculate the hot resistance (R) of the 200W/250V rated bulb?

Given:

Power (P) = 200 W

Voltage (V) = 250 V

Find:

Resistance (R) = ?

Solution:

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{250\ X\ 250}{200}$$

(R) Resistance = 312.5 Ohm (Ω)

Example 4

In a house, the following electrical loads are daily used:-

(i) 5 Nos of 40W Tube Lights used for 5 hours/day

(ii) 4 Nos of 80W fans used for 8 hours/day

(iii) 1 No of 120W T.V. receiver used for 5 hours/day

(iv) 4 No of 60W lamps used for 4 hours/day

Calculate the total energy consumed in unit's per day and also the cost of electric bill for the month of January If the cost of energy is 1.50/unit

Given

Load details per day

Electric Device	Power	Numbers	Time in hours
(i) Tube light	40W	5	5 hr/day
(ii) Fans	80W	4	8 hr/day
(iii) T.V.	120W	1	6 hr/day
(iv) Lamps	60W	4	4 hr/day

cost of energy - Rs.1.50/unit

Find:

(i) Energy consumption in unit per day = ?

(ii) Cost of energy for the month of January = ?

Solution

Energy consumption/day

1 Tube light = 40W x 5 x 5 hr /day

$$= \frac{1000\text{ wh}}{1000} = 1\text{Kwh/day}$$

2 Fans = 80W x 4x8 hr/day

$$= \frac{2560}{1000} = 2.56\text{Kwh/day}$$

3 T.V. = 120W x 1x6 hr/day

$$= \frac{720\text{ wh}}{1000} = 0.72\text{Kwh/day}$$

4 Lamp = 60W x 4x4 hr/day

$$= \frac{960}{1000} = \text{Kwh} = \frac{0.96\,\text{kwh/day}}{5.24\,\text{kwh/day}}$$

(i) Total energy consumption in unit per day = 5.24 unit

(ii) Total energy consumption for the month of January (i.e 31 days)

= 5.24 x 31

= 162.44 units

Cost of energy = Rs. 1.50/unit

Total electric bill for the month of January =162.44 x 1.50

= Rs.243.66

Electricity Bill for the month = Rs. 244/-

Assignment :

> **Note : The instructor may ask the trainees to prepare electric bill for the current month for his house (or) any building.**

Work, Power and Energy

Work is said to be done, when a force (F) displaces a body from one distance (s) to another (or)

Work done = Force x distance moved

w.d = F x S

It is generally denoted as “W”

The unit of work done is

(i) In Foot Pound Second (F.P.S) System is “Foot Pound (lb.ft)”

(ii) In Centimetre Gram Second (C.G.S) System “Gram Centimetre (gm.cm)”

or

1 gm.cm = 1 dyne

1 dyne = 10^7 ergs

The smallest unit of work done is **“Erg”**

(iii) In Metre - Kilogram - Second (M.K.S.) System is “Kilogram Metre (Kg-M)’

1 Kilogram = 9.81Newton

(iv) In system of international unit (S.I. Unit) is ‘Joule’

1 Joule = 1 Newton Metre (Nw-M)

Power (P)

The rate of doing work is called as Power (P)

Power (P) = work done / time taken

$$P = \frac{F \text{ x } S}{t}$$

It’s unit is Lb.ft/sec in FPS system

gm-cm/sec is in C.G.S. System

(or)

Dyne/sec

(or)

Kg-M/sec in M.K.S System (or) NW - M/ sec

(1kg = 9.81 Newton)

Joule/sec in (S.I)

1 Joule/Sec = 1 watt

Electrical Power = VI Watt

The unit of Mechanical power is “Horse Power” (H.P)

Horse Power (HP) further classified into two:

They are:-

Indicated Horse Power - (IHP)

Brake Horse Power - (BHP)

Indicated Horse Power (IHP)

The power developed inside the engine (or) pump (or) motor is called Indicated Horse Power (IHP)

Brake Horse Power (BHP)

The useful Horse Power which is available at the shaft of the engine/motor/pump is called Brake Horse Power (BHP)

So, IHP is always greater than

BHP due to friction losses

IHP > BHP

The relation between Mechanical and Electrical Power

(ie) 1 HP (British) = 746 Watt

1 HP (Metric) = 735.5 Watt

One HP (Metric)

The amount of Mechanical Power required to move/ displace a body/substance by force of 75 Kg to one metre distance in one second is called as one HP (metric)

HP (Metric) = 75kg - M/Sec

One HP (British)

The amount of Mechanical power required to move/ displace a body/substance of force 550lb to one foot (ft) distance in one second is called as one HP (British)

1 HP (British) = 550 lb.ft/sec

Energy

The capacity for doing work is called as electrical Energy

(or)

The product of power and time is known as Electrical energy

(ie) Energy = Power x time

$$t = \frac{\text{workdone}}{\text{time}} \text{xtime}$$

Electric - energy = Power x time

= VI x t

S.I unit of energy is “Joule”

(ie) Energy = (Joule/sec) x sec

$$= \frac{\text{Joulle}}{\text{Sec}} \times \text{Sec} = \text{joule}$$

(ie) The S.I of unit of work done and energy is same (Joule)

The energy can be divided into two main categories (ie)

(i) Potential Energy (eg. Loaded gun, energy (stored in spring etc)

(ii) Kinetic Energy (eg. Moving of car, raining etc).

Kirchhoff's law and its applications

Objectives: At the end of this lesson you shall be able to
- **state Kirchhoff's first law**
- **apply Kirchhoff's first law to find the circuit current**
- **state Kirchhoff's second law and apply the same to find the voltage drop in branches**
- **solve problems by applying Kirchhoff's laws.**

Kirchoff's laws are used in determinig the equivalent resistance of a complex network and the current flowing in the various conductors.

Kirchhoff's laws

Kirchhoff's first law: At each junction of currents, the sum of the incoming currents is equal to the sum of the outgoing currents. (Figs 1 & 2) (or) The algebric sum of all branch currents meeting at a point/node is zero

Fig 1

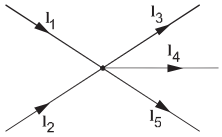
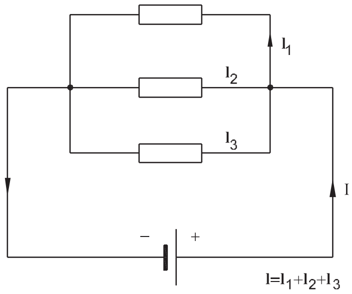


Fig 2



If all inflowing currents have positive signs and all outflowing currents have negative signs, then we can state that

$$I_1 + I_2 = I_3 + I_4 + I_5$$

$$+ I_1 + I_2 - I_3 - I_4 - I_5 = 0$$

In the above example the sum of all the currents flowing at the junction (node) is equal to zero.

$$\Sigma I = 0$$

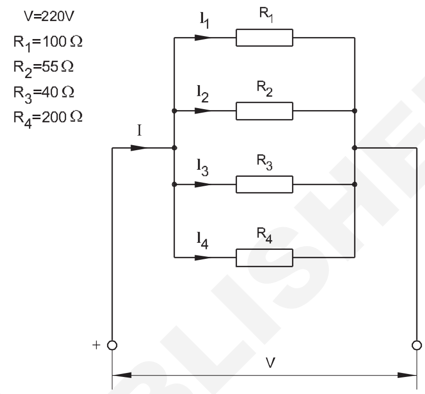
$$I = I_1 + I_2 + I_3 + \ldots\ldots\ldots\ldots\ldots$$

Example: Apply Kirchhoff's First Law to find the current shown in circuit Fig 3.

Find current

$$I, I_1, I_2, I_3, I_4$$

Fig 3



Solution

$$H = \frac{M.M.F}{\text{Length of coil in meters}} = \frac{NI}{\ell}$$

NI

mmf

$$I = I_1 + I_2 + I_3 + I_4$$

$$= 2.2A + 4A + 5.5A + 1.1A = 12.8A$$

Checking the calculation

$$S = \frac{\ell}{\mu} \text{ or } S = \frac{\ell}{\mu_0\mu a}$$

emf

$$R = \frac{\rho L}{A}$$

$$\frac{di}{dt}$$

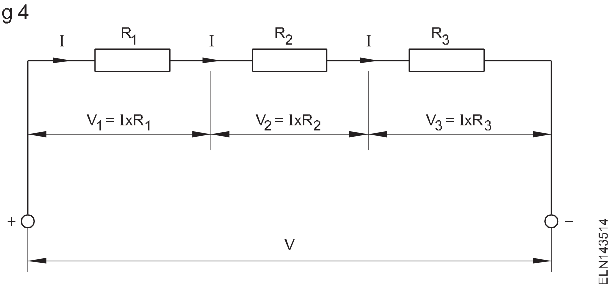
R_{TOT} = 17.19 ohms

$L \times \frac{N\phi}{I}$

Kirchhoff's second law

A simple case: In closed circuits, the applied terminal voltage V is equal to the sum of the voltage drops V_1+V_2 and so forth. (Fig 4)

Fig 4



If all the generated voltages are taken as positive, and all the consumed voltages are taken as negative, then it can be stated that:

in each closed circuit the sum of all voltages is equal to zero.

$\Sigma V = 0$

Example

Given

$V = 220V$
$R_1 = 36$ ohms
$R_2 = 40$ ohms
$R_3 = 60$ ohms
$R_4 = 50$ ohms

Find

$R, I, I_1, I_2,$

$V_1, V_{2||3}, V_4$

Solution

Apply Kirchhoff's First Law to find the voltage drops in the branches (Fig 5).

Calculate the total resistance R of the series circuit according to Kirchhoff's Second Law. (Fig 6)

First simplify by calculating the equivalent resistance for R_2, R_3 according to Kirchhoff's First Law.

Fig 5

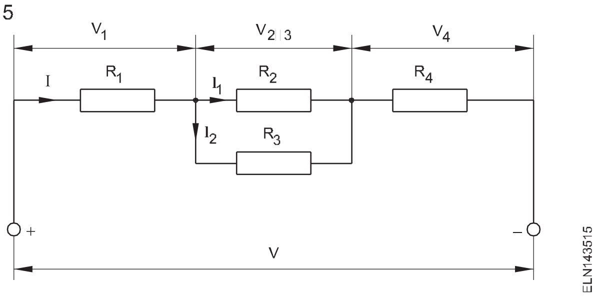
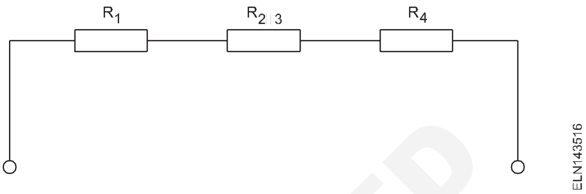


Fig 6



$$R_{2||3} = \frac{R_2 > R_3 \quad 40 \text{ ohm} > 60 \text{ ohms}}{R_2 + R_3 \quad (40 + 60) \text{ ohms}}$$

$= 24$ ohms

$R_{TOT} = R_1 + R_{2||3} + R_4$

$= 36$ ohms $+ 24$ ohms $+ 50$ ohms

$= 110$ ohms

The total current I can now be calculated by means of Ohm's Law:

$$\frac{\phi}{I} = N \times \frac{N\mu_0\mu_r\ a}{L}$$

The partial voltages are accordingly:

$V_1 = I \times R_1 = 2A \times 36 \text{ ohms} = 72\ V$

$V_{2||3} = I \times R_{2||3} = 2A \times 24 \text{ ohms} = 48\ V$

$V_4 = I \times R_4 = 2A \times 50 \text{ ohms} = 100\ V$

Checking the calculation

$V = V_1 + V_{2||3} + V_4$

$220\ V = 72V + 48V + 100\ V$

$220\ V = 220\ V$

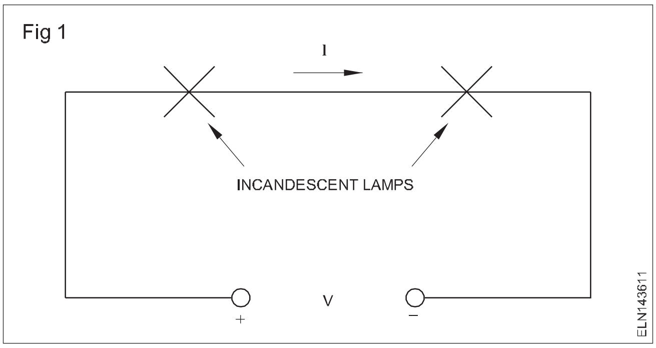
DC series and parallel circuits

Objectives: At the end of this lesson you shall be able to
- **state the characteristics of series circuit and determine the current and voltage across each resistors**
- **determine the total voltage sources in series circuit**
- **state the relation between EMF potential difference and terminal voltage**
- **determine the polarity of voltage drops with respect to ground**

The series circuit

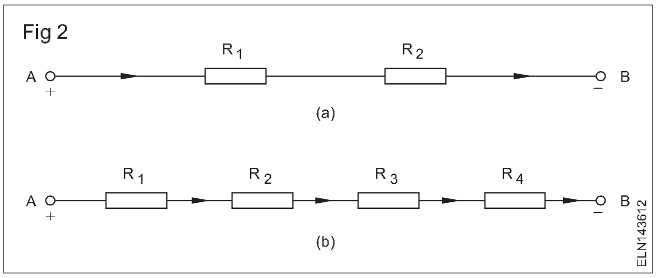
If more than one resistors are connected one by one like a chain and if the current has only one path is called as series circuit. It is possible to connect two incandescent lamps in the way shown in Fig 1. This connection is called a series connection, in which the same current flows in the two lamps.

Fig 1



The lamps are replaced by resistors in Fig 2. Fig 2 (a) shows two resistors are connected in series between point A and point B. Fig 2(b) shows four resistors are in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

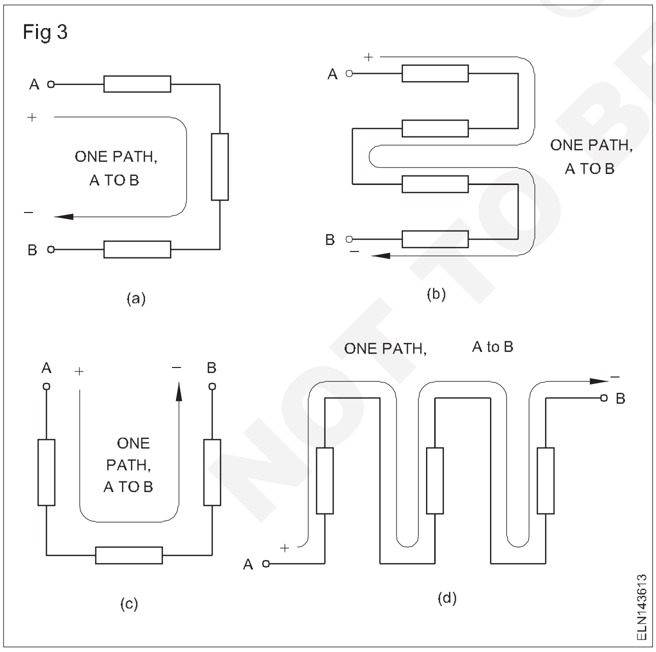
Fig 2



Identifying series connections

In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, Fig 3(a), 3(b), 3(c) & 3(d) shows series resistors drawn in different ways. In all the above circuits we find there is only one path for the current to flow.

Fig 3



Current in series circuits

The current will be the same at any point of the series circuit. This can be verified by measuring the current in any two points of a given circuit . The ammeters will show the same reading.

The current relationship in a series circuit is

$$I = I_{R1} = I_{R2} = I_{R3}.$$

We can conclude that there is only one path for the current to flow in a series circuit. Hence, the current is the same throughout the circuit.

Total resistance in series circuit

You know how to calculate the current in a circuit, by Ohm's law, if resistance and voltage are known. In a circuit consisting of two resistors R_1 and R_2 we know that the resistor R_1 offers some opposition to the current flow. As the same current should flow through R_2 in series it has to overcome the opposition offered by R_2 also.

If there are a number of resistors in series, they all oppose the flow of current through them.

The second characteristic of a DC series circuit could be written as follows (R).

The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$$R = R_1 + R_2 + R_3 + ...R_n$$

where R is the total resistance

R_1, R_2 , R_3,.......R_n are the resistors connected in series.

When a circuit has more than one resistor of the same value in series, the total resistance is R = r x N

where 'r' is the value of each resistor and N is the number of resistors in series.

Voltage in series circuits

In DC circuit voltage divides up across the load resistors, depending upon the value of the resistor so that the sum of the individual load voltages equals the source voltage.

The 3rd characteristic of a DC circuit can be written as follows.

As the source voltage divides/drops across the series resistance depending upon the value of the resistances

$$V = V_{R1} + V_{R2} + V_{R3} + ...V_{RH}$$

the total voltage of a series circuit must be measured across the voltage source.

Voltages across the series resistors could be measured using one voltmeter at different positions.

When Ohm's law is applied to the complete circuit having an applied voltage V, and total resistance R, we have the current in the circuit as

$$I = \frac{V}{R}$$

Application of Ohm's law to DC series circuits

Applying to Ohm's law to the series circuit, the relation between various currents could be stated as below

$$I = I_{R1} = I_{R2} = I_{R3}$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots\ldots\ldots\ldots \frac{1}{L_n}$$

This could be stated as

You can use any of the above formulae to calculate current in a series circuit.

We know the total supply voltage

$V = V_{R1} + V_{R2} + V_{R3}$

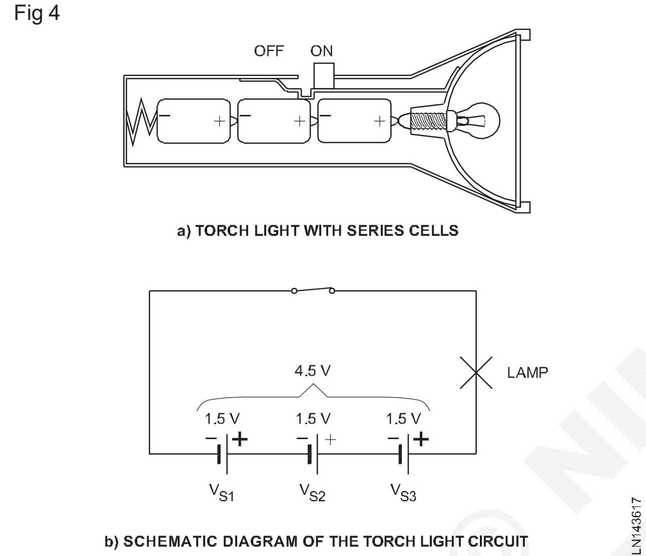
i.e.$IR = R_1 I_{R1} + R_2 I_{R2} + R_3 I_{R3}$

and Total resistance $R = R_1 + R_2 + R_3$.

Voltage sources in series

When cells are placed in a torch light, they are connected in series to produce a higher voltage as shown in Fig 4.

Fig 4

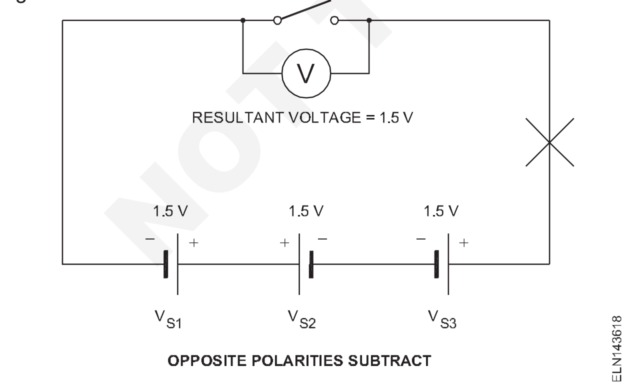


a) TORCH LIGHT WITH SERIES CELLS

b) SCHEMATIC DIAGRAM OF THE TORCH LIGHT CIRCUIT

Series voltage sources are added when their polarities are in the same direction and or subtracted when their polarities are in the opposite direction. For example, if one of the ends of the cell, say V_{S2} in a torch light is wrongly placed in polarity as indicated in the schematic of Fig 5 its voltage to be subtracted as follows.

Fig 5



OPPOSITE POLARITIES SUBTRACT

$V_{Total} = V_{S1} – V_{S2} + V_{S3}$

$= 1.5\ V – 1.5\ V + 1.5\ V$

$= 1.5\ V$

Use of series connection

1 Cells in torch light, car batteries, etc.

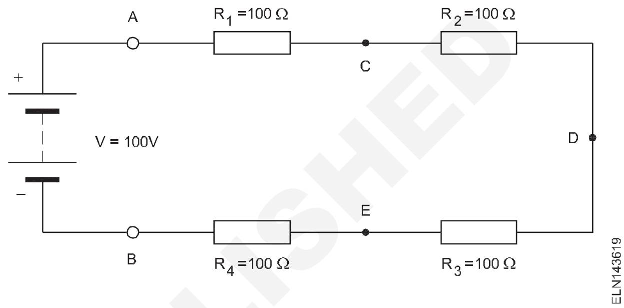
2 Cluster of mini-lamps used for decoration purposes.

3 Fuse in circuit.

4 Overload coil in motor starters.

5 Multiplier resistance of a voltmeter.

Fig 6



Polarity of IR voltage drops

Definitions

Electromotive force (emf)

We have seen that the electromotive force (emf) of a cell is the open circuit voltage, and the potential difference (PD) is the voltage across the cell when it delivers a current. The potential difference is always less than the emf.

Potential difference

PD = emf – voltage drop in the cell

Potential difference can also be called by another term, the terminal voltage, as explained below.

Terminal voltage

It is the voltage available at the terminal of the source of supply. Its symbol is V_T. Its unit is also the volt. It is given by the emf minus the voltage drop in the source of supply,

i.e. $V_T = emf – IR$

where I is the current and R the resistance of the source.

Voltage drop (IR drop)

The voltage lost by resistance in a circuit is called the Voltage drop or IR drop.

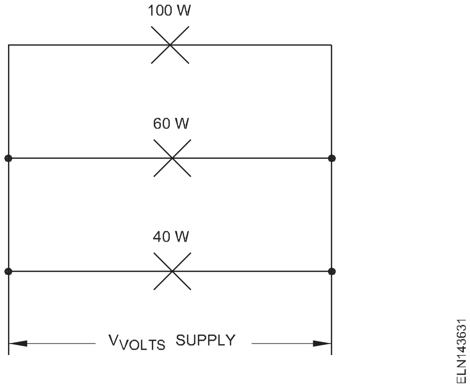
DC parallel circuit

Objectives: At the end of this lesson you shall be able to
- **explain a parallel circuit**
- **determine the voltages in a parallel circuit**
- **determine the current in a parallel circuit**
- **determine the total resistances in a parallel circuit**
- **state the application of a parallel circuit.**

In an electrical circuit, if the current has more than one paths and equal voltage in each branch is called parallel circuit.

It is possible to connect three incandescent lamps as shown in Fig 1. This connection is called parallel connection in which, the same source voltage is applied across all the three lamps.

Fig 1



Voltage in parallel circuit

The lamps in Fig 1 are replaced by resistors in Fig 2. Again the voltage applied across the resistors is the same and also equal to the supply voltage.

We can conclude that the voltage across the parallel circuit is the same as the supply voltage.

Fig 2

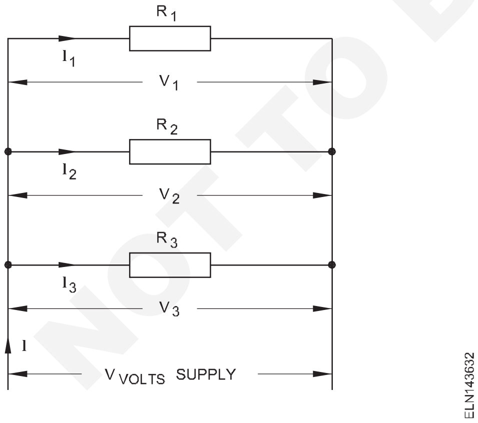


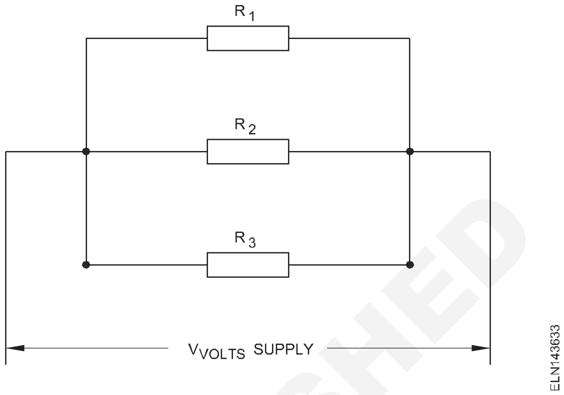
Fig 2 could also be drawn as shown in Fig 3.

Mathematically it could be expressed as V = $V_1 = V_2 = V_3$.

Current in parallel circuit

Again referring to Fig 2 and applying Ohm's law, the individual branch currents in the parallel circuit could be determined.

Fig 3



Current in resistor

$$\frac{di}{dt} = \frac{5A - 2A}{0.1s}$$

$$R_2 = I_2 = \frac{V_2}{R_2} = \frac{V}{R_2}.$$

Current in resistor

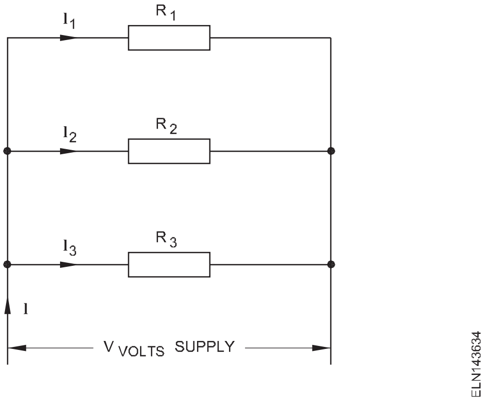
$$R_3 = I_3 = \frac{V_3}{R_3} = \frac{V}{R_3}.$$

Current in resistor

as $V_1 = V_2 = V_3$.

Refer to Fig 4 in which the branch currents I_1, I_2 and I_3 are shown to flow into resistance branches R_1, R_2 and R_3 respectively.

Fig 4



The total current I in the parallel circuit is the sum of the individual branch currents.

Mathematically it could be expressed as $I = I_1 + I_2 + I_3 + \ldots . I_n$.

Open and short circuit in series and parallel network

Objectives: At the end of this lesson you shall be able to

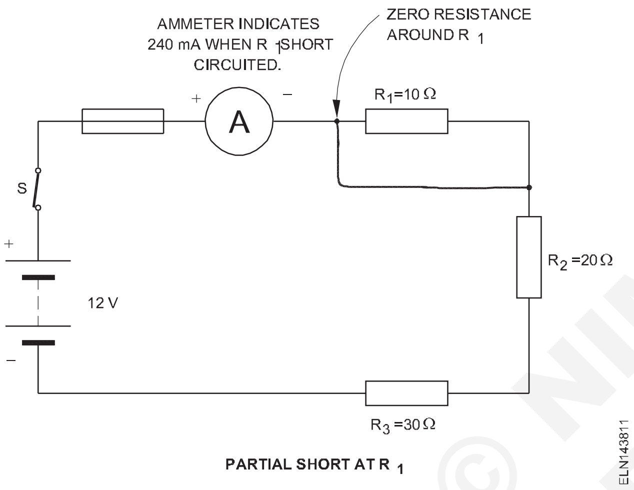
- **state about short circuit in series circuit and its effect in series circuit**
- **state the effect of an open circuit in series circuit and its causes**
- **state the effect of shorts and open in parallel circuit.**

Short circuits

A short circuit is a path of zero or very low resistance compared to the normal circuit resistance.

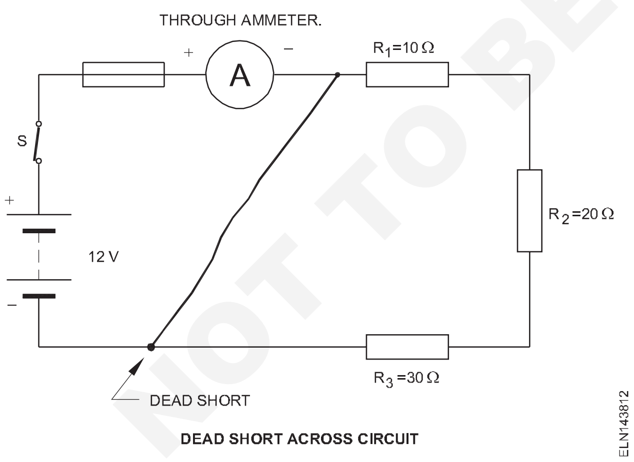
In a series circuit, short circuits may be partial or full (dead short) as shown in Fig 1 and Fig 2 respectively.

Fig 1



PARTIAL SHORT AT R 1

Fig 2



DEAD SHORT ACROSS CIRCUIT

Short circuits cause an increase in current that may or damage the series circuit.

Effects due to short circuit

Excess current due to short circuit can damage the circuit components, power sources, or burn the insulation of connecting wires. Fire is also caused due to intense heat generated in the conductors.

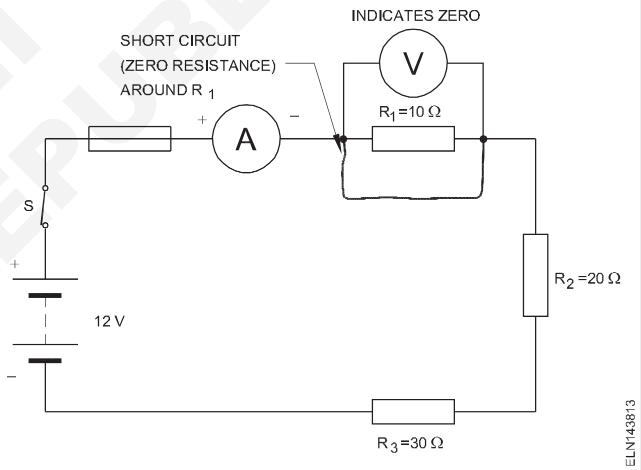
Protection against dangers of short circuit

Dangers of short circuit can be prevented by means of fuses and circuit breakers in series with the circuit.

Detecting short circuit

When the ammeter in the circuit indicates excessive current then it indicates a short circuit in the circuit. The location of short in a circuit can be detected by connecting a voltmeter across each of the elements (resistors) and circuit source. If the voltmeter indicates zero volts or reduced voltage across the element, it is short circuited as shown in Fig 3.

Fig 3



Methods used to protect the circuit in case of a short circuit

As heavy currents flow through the short circuit, the circuit cables should be protected against the large currents. If the short circuit current is allowed to flow through the circuit, the cables which are rated for normal circuit current, will get heated up and become potential fire hazards.

To open the circuit automatically in cases of short circuits, fuses or circuit breakers are used in the circuit. The rating of the fuse wire or setting of the overload relay in circuit breakers will be selected depending upon the lowest rating of any one of the following used in the circuit.

i Load current in the circuit

ii Cable rating of the circuit

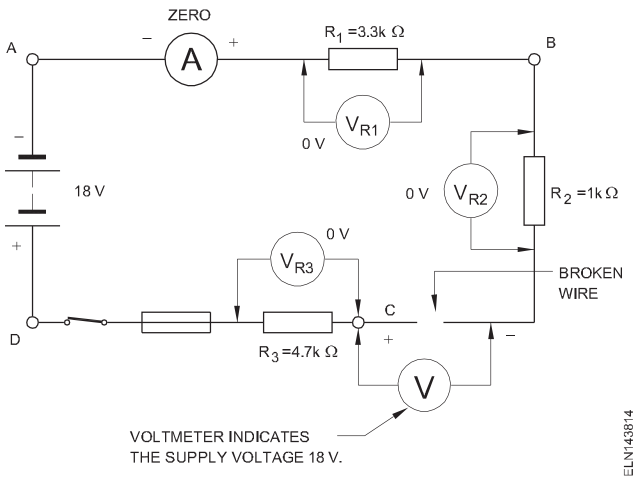
iii Series meter (ammeter etc.) rating of the circuit.

Open circuit in series circuit

An open circuit results whenever a circuit is broken or is incomplete, and there is no continuity in the circuit.

In a series circuit, open circuit means that there is no path for the current, and no current flows through the circuit. Any ammeter in the circuit will indicate no current as shown in Fig 4.

Fig 4



Causes for open circuit in series circuit

Open circuits, normally, happen due to improper contacts of switches, burnt out fuses, breakage in connection wires and burnt out resistors etc.

Effect of open in series circuit

a No current flows in the circuit.

b No device in the circuit will function.

c Total supply voltage/ source voltage appear across the open.

Determination the location of break in the circuit has occurred

Use a voltmeter on a range that can accommodate the supply voltage; connect it across each connecting wire in turn. If one of the wires is open as shown in Fig 4, the full supply voltage is indicated on the voltmeter. In the absence of a current, there is no voltage drop across any of the resistors. Therefore, the voltmeter must be reading full supply voltage across the open. part of the circuit

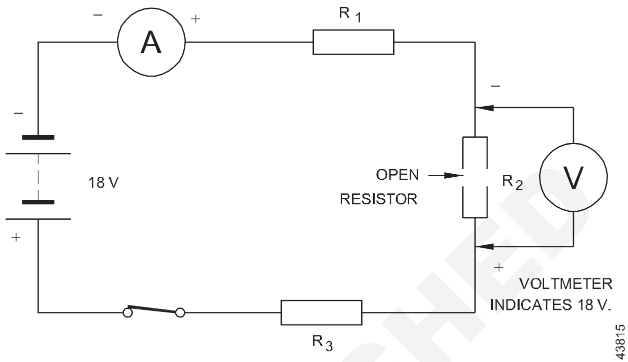
Voltmeter reading

$= 18\ V – V_{R1} – V_{R2} – V_{R3}$

$= 18\ V – O\ V – O\ V – O\ V = 18\ V.$

If the circuit was open due to a defective resistor, as shown in Fig 5 (resistors usually open when they burn out), the voltmeter would indicate 18 V when connected across this resistor, R_2.

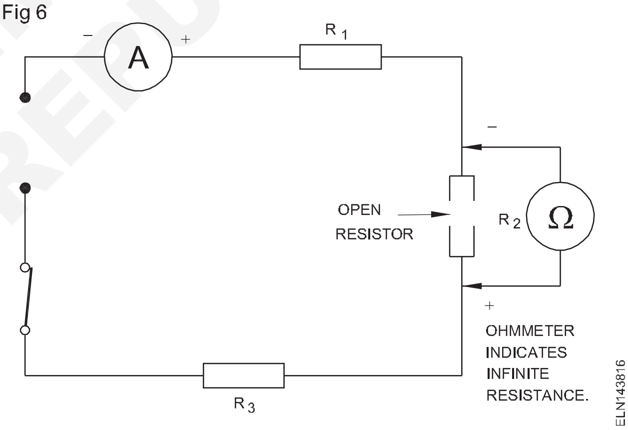
Fig 5



OPEN CIRCUIT DUE TO OPEN RESISTOR R₂

Alternatively, the open circuit may be found using an ohmmeter. With the voltage removed, the ohmmeter will show no continuity (infinite resistance), when connected across the broken wire or open resistor. (Fig 6)

Fig 6



Practical application

With the knowledge gained from this exercise:

- locate open and short circuit faults in a series circuit
- repair series-connected decoration bulb sets.

Shorts and opens in parallel circuits

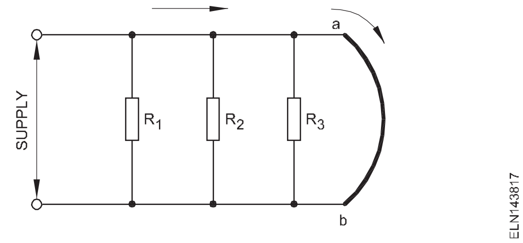
The two possible defects that can occur in an electrical circuit they are:

- short circuit
- open circuit

Shorts in parallel circuit:

Fig 7 shows a parallel circuit with short between points ‘a’ and ‘b’.

Fig 7



This causes reduction of circuit resistance almost to zero.

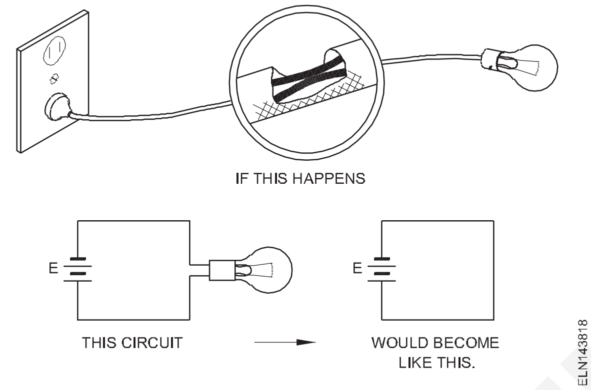
Therefore, the voltage drop across 'ab' will be almost zero (by Ohms law).

Thus current through the resistors R_1, R_2, R_3 will be negligible and not their normal current.

The result is that a very high current in the order of hundred times of the normal current will flow through the short circuit.

A short circuit exists when current can flow from the positive terminal of the power source through connecting wires and back to the negative terminal of the power source without going through any load. (Fig 8)

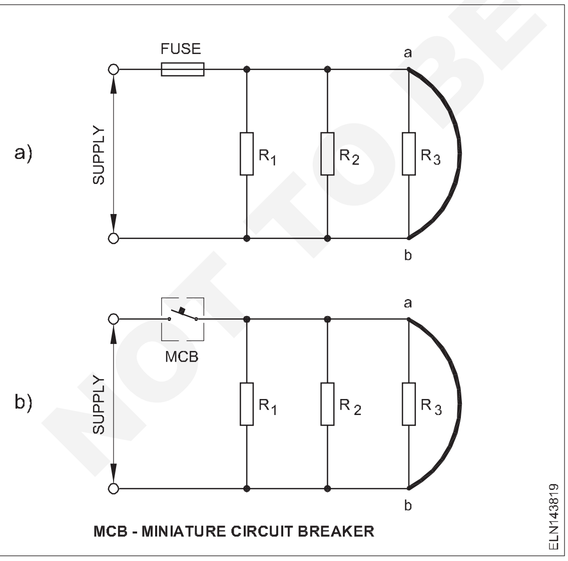
Fig 8



Short circuit may cause burning of the circuit elements like cables, switches etc.

To avoid burning of circuit components safety devices like **'**fuse', circuit breakers etc. are used to open the circuit. (Figs 9a and 9b).

Fig 9



For a fuse to protect a parallel circuit, it should be placed in the circuit where the total current flows or else each branch must have a fuse. (Fig 10 (a&b))

Fig 10

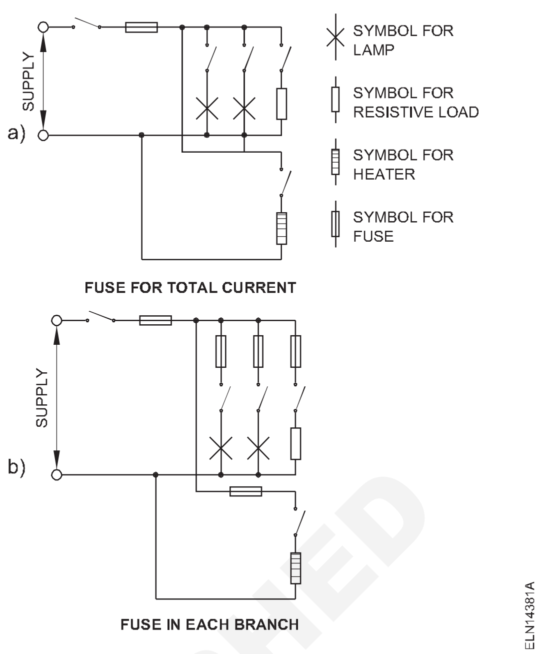
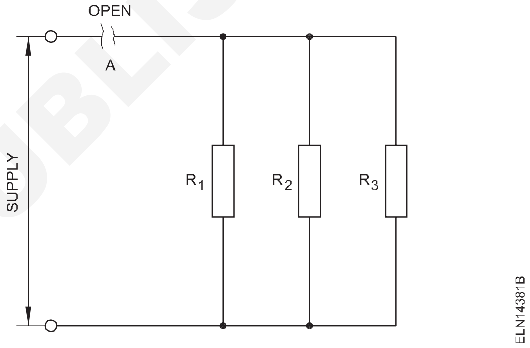


Fig 11



Opens in parallel circuit

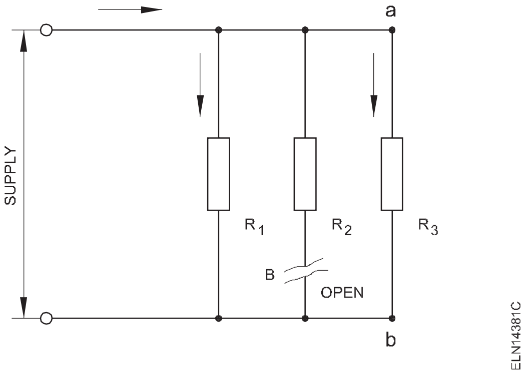
An open in the common line at point A as shown in

Fig 11 causes no current flow in that circuit whereas an open in the branch at point B causes no current flow only in that branch. (Fig 12)

However, the current in branches R_1 and R_3 will continue to flow so long as they are connected to the voltage source.

Full voltage of the source will be available at open circuit terminals. It is dangerous to meddle with the terminals which are open.

Fig 12



Practical application

Knowledge gained in this exercise can be applied to identify open circuits or short circuits in wiring installations.

Laws of resistance and various types of resistors

Objectives: At the end of this lesson you shall be able to
- **state the laws of resistance, compare resistances of different materials**
- **state the relationship between the resistance and diameter of a conductor**
- **calculate the resistance and diameter of a conductor from the given data (i.e. dimensions etc.)**
- **explain various types of resistors.**

Laws of resistance: The resistance R offered by a conductor depends on the following factors.

- The resistance of the conductor varies directly with its length (L).
- The resistance of the conductor is inversely proportional to its cross-sectional area (a).
- The resistance of the conductor depends on the material with which it is made of.
- It also depends on the temperature of the conductor.

Ignoring the last factor for the time being, we can say that

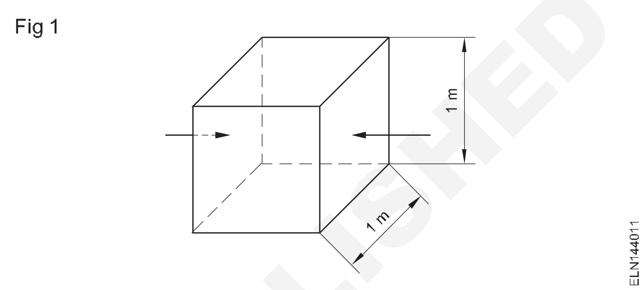
$$R = P\frac{L}{a}$$

where ‘ρ’ (rho - Greek alphabet) - is a constant depending on the nature of the material of the conductor, and is known as its **specific resistance** or **resistivity.**

If the length is one metre and the area, ‘a’ = 1 m^2, then R = r.

Hence, specific resistance of a material may be defined as `the resistance between the opposite faces of a metre cube of that material’. (or, sometimes, the unit cube is taken in centimetre cube of that material) (Fig 1).

Fig 1



Hence the unit of specific resistance is ohm metre (Ωm).

Resistors

Objectives: At the end of this lesson you shall be able to
- **explain the construction and characteristics of various types of resistors**
- **explain the functions and applications of the resistors in electrical and electronic circuits.**

Resistors : These are the most common passive component used in electrical and electronic circuits. A resistor is manufactured with a specific value of ohms (resistance). The purpose of using a resistor in circuit is either to limit the current to a specific value or to provide a desired voltage drop (IR). The power rating of resistors may be from fractional walts to hundreds of Watts.

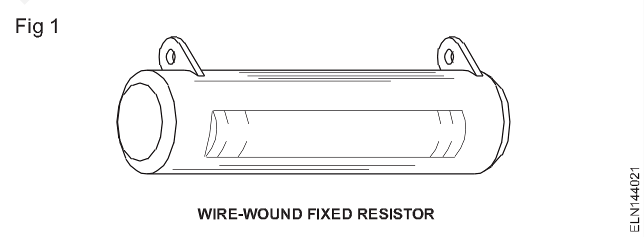
There are five types of resistors

1 Wire-wound resistors
2 Carbon composition resistors
3 Metal film resistors
4 Carbon film resistors
5 Special resistors

1 Wire-wound resistors

Wire-wound resistors are manufactured by using resistance wire (nickel-chrome alloy called Nichrome) wrapped around an insulating core, such as ceramic porcelain, bakelite pressed paper etc. Wire wound resistors are used for high current application as shown in Fig 1.

Fig 1



WIRE-WOUND FIXED RESISTOR

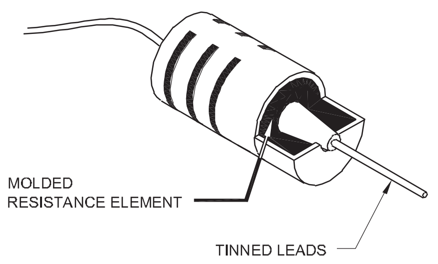
They are available in wattage ratings from one watt to 100 watts or more. The resistance can be less than 1 ohm and go up to few thousand ohms.

2 Carbon composition resistors

These are made of fine carbon or graphite mixed with powdered insulating material as a binder in the proportion needed for the desired resistance value. Carbon-resistance elements are fixed with metal caps with leads of tinned copper wire for soldering the connection into a circuit. Fig 2 shows the construction of carbon composition resistor.

Carbon resistor are available in values of 1 ohm to 22 megohms and of different power ratings, generally 0.1, 0.125, 0.25, 0.5, 1.0 and 2 watts.

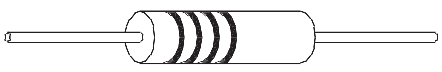
Fig 2



CARBON COMPOSITION RESISTOR

3 Metal film resistors (Fig 3)

Fig 3



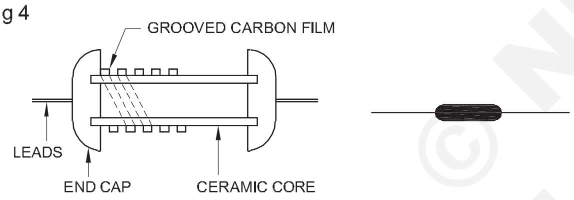
METAL FILM RESISTOR

Metal film resistors are manufactured by two processes. Thick film resistors are pasted with metal compound and powdered glass which are spread on the ceramic base and then backed.

Thin film resistors are processed by depositing a metal vapour on a ceramic base. Metal film resistors are available from 1 ohm to 10 MΩ, upto 1W. Metal film resistors can work from 120°C to 175°C.

4 Carbon film resistors (Fig 4)

Fig 4



(a) CONSTRUCTION (b) A CARBON-FILM RESISTOR

CARBON – FILM RESISTOR

In this type, a thin layer of carbon film is deposited on the ceramic base/tube. A spiral groove is cut over the surface to increase the length of the foil by a specialised process.

Carbon film resistors are available from 1 ohm to 10 meg ohm and up to 1 W and can work from 85°C to 155°C.

All the above four types of resistors are coated with synthetic resin to protect them against mechanical damages and climatic influences, It is therefore, difficult to distinguish them from each other externally.

Specification of resistors : Resistors are specified normally with the four important parameters

1 Type of resistor

2 Nominal value of the resistors in ohm (or) kilo ohm (or) mega ohm.

3 Tolerance limit for the resistance value in percentage.

4 Loading capacity of the components in wattage

Example

100 ± 10% , 1W, where as nominal value of resistance is 100Ω.

The actual value of resistance may be between 90Ω to 110 Ω, and the loading capacity is maximum 1 watt.

The resistors can also be classified with respect to their function as

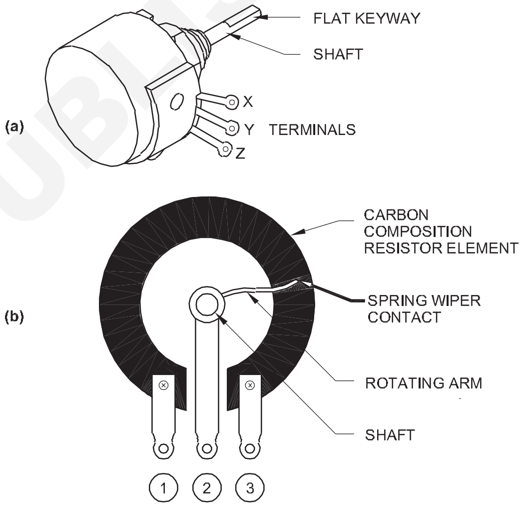
1 Fixed resistors

2 Variable resistors

Fixed resistors : The fixed resistors is one in which the is nominal value of resistance is fixed. These resistors are provided with pair of leads. (Fig 1 to 4)

Variable resistors (Fig 5): Variable resistors are those whose values can be changed. Variable resistors includes those components in which the resistance value can be set at the different levels with the help of sliding contacts. These are known as potentio meter resistors or simply as a potentio meters.

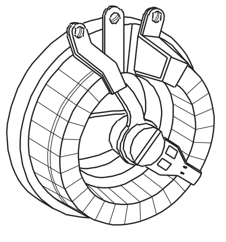
Fig 5



VARIABLE CARBON-RESISTANCE (a) EXTERNAL VIEW
(b) INTERNAL VIEW OF CIRCULAR RESISTANCE ELEMENT

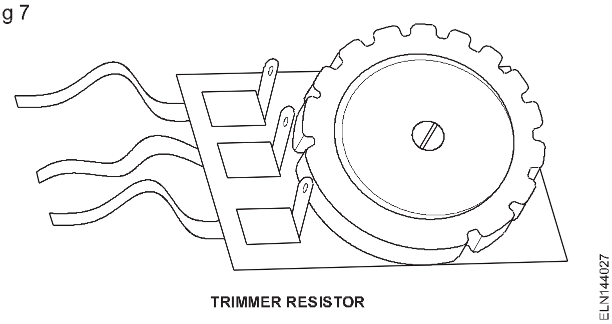
It is provided with 3 terminals as shown in Fig 5. They are available with carbon tracks (Fig 6) and wire wound (Fig 7) types. Trimmer potentio meters (or) resistor which can be adjusted with the help of a small screw drivers. (Fig 7).

Fig 6



WIRE-WOUND VARIABLE RESISTOR

Fig 7



TRIMMER RESISTOR

Resistance depends upon temperature, voltage, light : Special resistors are also produced whose resistance varies with temperature, voltage, and light.

PTC resistors (Sensistors) : Since, different materials have different crystal structure, the rate at which resistance increases with raising temperature varies from material to material. In PTC resistor (positive Temp. coefficient resistor), as the temp increases, the resistance increases non linearly. For example, the resistance of PTC at room temperature may be of nominal value 100 Ω when the temperature rises say 10°C, it may increase to 150 Ω and with further increase of another 10°C, it may increases to 500 Ω.

NTC Resistors (Thermistors) : In case of NTC resistors (Negative temperature co-efficient resistors) as the temperature increases, the value of resistance decreases non-linearly, For example, NTC resistor, which has nominal value of resistance is 500 Ω at room temperature may decrease to 400 Ω with the rise of 10°C temperature and further decrease to 150 Ω when the temperature rises to another 10°C.

The PTC and NTC resistors can perform switching operation at specific temperature. They are also used for measurements and temperature compensators.

VDR (Varistors) : The VDR (Voltage dependent resistor) resistance falls non-linearly with increasing voltage. For example, a VDR, may have 100 Ω resistance at 10 V, and it may decrease to 90 Ω at rise in 5V. By further increasing the voltage to another 5V, the resistance may fall to 50 Ω. The VDRS are used in voltage stabilisation, arc quenching and over voltage protection.

Light dependent resistor (LDR) : The LDRs are also known as photo- conductors. In LDRs the resistance falls with increase in intensity of illumination. The phenomena is explained as the light energy frees some electron in the materials of the resistors, which are then available as extra conducting electrons. The LDR shall have exposed surface to sense the light. These are used for light barriers in operating relays. These are also used for measuring the intensity of light.

Marking codes for resistors

Objectives: At the end of this lesson you shall be able to
- **interpret the coded marking of colours on the resistors**
- **interpret the letter and digit codes for resistance values**
- **state the tolerance value for resistors.**

Resistance and tolerance value of colour coded resistors

Commercially, the value of resistance and tolerance value are marked over the resistors by colour codes (or) letter and digital codes.

The colour codes for indicating the values to two significant figure and tolerances are given in Table 1 as per IS 8186.

Table 1

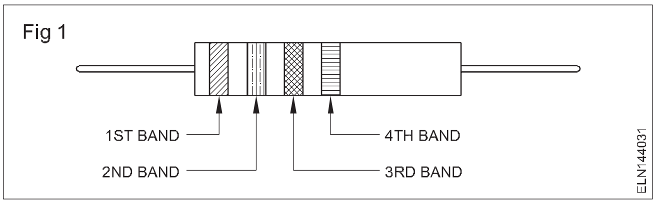
Values to two significant figures and tolerances corresponding to colours

Colour	First Band/ Dot	Second Band/ Dot	Third Band/ Dot	Fourth Band/ Dot
	First Figure	Second Figure	Multiplier	Tolerance
Silver	—	—	10^{-2}	± 10 %
Gold	—	—	10^{-1}	± 5 %
Black —-	—	0	1	
Brown	1	1	10	± 1 %
Red	2	2	10^{2}	± 2 %
Orange	3	3	10^{3}	—-
Yellow	4	4	10^{4}	—-
Green	5	5	10^{5}	—-
Blue	6	6	10^{6}	—-
Violet	7	7	10^{7}	—-
Grey	8	8	10^{8}	—-
White	9	9	10^{9}	—-
None	—	—	—	± 20 %

The two significant figures and tolerances colour coded resistors have 4 bands of colours coated on the body as in Fig.1.

The first band shall be the one nearest to one end of the component resistor. The second, third and four colour bands are shown in Fig 1.

Fig 1



The first two colour bands indicate the first two digits in the numeric value of resistance. The third colour band indicates the multiplier. The first two digits are multiplied by the multiplier to obtain the actual resistance value. The forth colour band indicates the tolerance in percentage.

Example

Resistance value : If the colour band on a resistor are in the order- Red, Green, Orange and Gold, then

First colour	Second colour	Third colour	Fourth colour
Red	Violet	Orange	Gold
2	7	1000(10^3)	±5%

the value of the resistor is 27,000 ohms with +5% tolerance.

Tolerance value : The fourth band (tolerance) indicates the resistance range within which is the actual value falls. In the above example, the tolerance is ±5%. ±5% of 27000 is 1350 ohms. Therefore, the value of the resistor is any value between 25650 ohms and 28350 ohms. The resistors with lower value of tolerance (precision) are costlier than normal value of resistors.

Series and parallel combination circuit

Objectives: At the end of this lesson you shall be able to
- **compare the characteristics of series and parallel circuits**
- **solve series-parallel circuit problems**

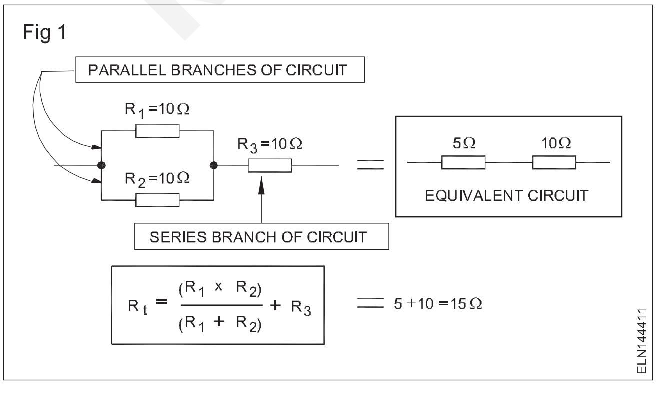
Comparison of characteristics of DC series and parallel ciruits

Sl. No.	Series circuit	Parallel circuit
1	The sum of voltage drops across the individual resistances equals the applied voltage.	The applied voltage is the same across each branch.
2	The total resistance is equal to the sum of the individual resistances that make up the circuit. $R_t = R_1+R_2+R_3+...$ etc combination.	The reciprocal of the total resistance equals the sum of the reciprocal of the resistances. The resultant resistance is less than the smallest resistance of the parallel
3	Current is the same in all parts of the circuit. resistance of each branch.	The current divides in each branch according to the resistance of each branch
4	Total power is equal to the sum of the power dissipated by the individual resistances.	(Same as series circuit) Total power is equal to the sum of the power dissipated by the individual resistances.

Formation of series parallel circuit

Apart from the series circuit and parallel circuits, the third type of circuit arrangement is the series-parallel circuit. In this circuit, there is at least one resistance connected in series and two connected in parallel. The two basic arrangements of the series-parallel circuit are shown here. In one, resistor R_1 and R_2 are connected in parallel and this parallel connection, in turn, is connected in series with resistance R_3. (Fig 1)

Fig 1



Thus, R_1 and R_2 form the parallel component, and R_3 the series component of a series-parallel circuit. The total resistance of any series-parallel circuit can be found by merely reducing it into a simple series circuit. For example, the parallel portion of R_1 and R_2 can be reduced to an equivalent 5-ohm resistor(two 10-ohm resistors in parallel).

Then it has an equivalent circuit of a 5-ohm resistor in series with the 10-ohm resistor(R_3), giving a total resistance of 15 ohms for the series-parallel combination.

A second basic series-parallel arrangement is shown in Fig 2 where basically it has two branches of a parallel circuit. However, in one of the branches it has two resistances in series R_2 and R_3. To find the total resistance of this series -parallel circuit, first combine R_2 and R_3 into an equivalent 20-ohm resistance. The total resistance is then 20 ohms in parallel with 10 ohms, or 6.67 ohms.

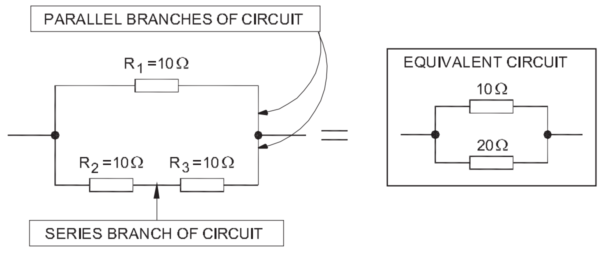
Combination circuits

A series-parallel combination appears to be very complex.

However, a simple solution is to break down the circuit into series/or parallel groups, and while solving problems, each may be dealt with individually. Each group may be replaced by one resistance, having the value equal to the sum of all resistances.

Each parallel group may be replaced by one resistance value equivalent to the combined resistance of that group. Equivalent circuits are to be prepared for determining the current, voltage and resistance for each component.

Fig 2



$$R_t = \frac{R_1 \times (R_2 + R_3)}{R_1 + (R_2 + R_3)} = \frac{200}{30} = 6.67\,\Omega$$

ELN144412

Magnetic terms, magnetic material and properties of magnet

Objectives: At the end of this lesson you shall be able to

- **state the different kinds of magnets and state the classification of magnetic material.**
- **state the molecular theory of magnetism**
- **describe the earth as a magnet**
- **state the classifications of magnets.**

Magnetism and magnets: Magnetism is a force field that acts on some materials and not on other materials. Physical devices which possess this force are called magnets. Magnets attract iron and steel, and when free to rotate, they will move to a fixed position relative to the north pole.

Classification of magnets

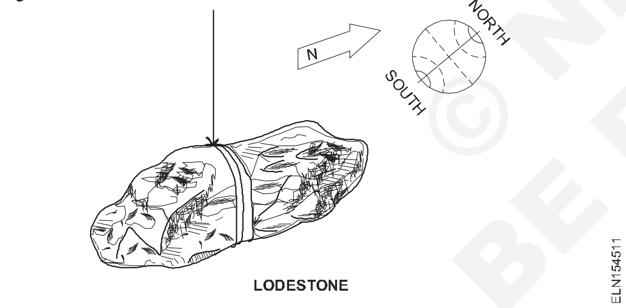
Magnets are classified into two groups.

- Natural magnets
- Artificial magnets

Lodestone (an iron compound) is a natural magnet which was discovered centuries ago. (Fig 1)

There are two types of artificial magnets. Temporary and permanent magnets.

Fig 1



Temporary magnets or electromagnets: If a piece of magnetic material, say, soft iron is placed in a strong magnetic field of a solenoid it becomes magnetised by induction. The soft iron itself becomes a temporary magnet as long as the current continues to flow in the solenoid. As soon as the source producing the magnetic field is removed, the soft iron piece will loose its magnetism.

Permanent magnets: If steel is substituted for soft iron in the same inducing field as in the previous case, due to the residual magnetism, the steel will become a permanent magnet even after the magnetising field is removed. This property of retention is termed retentiveness. Thus, permanent magnets are made from steel, nickel, alnico, tungsten all of which have higher retentiveness.

Molecular theory of magnetism: In magnetic materials such as iron, steel, nickel, cobalt and their alloys, which are ferromagnetic materials, the molecules themselves are tiny magnets, each of them having a north pole and south pole. This is basically due to their special crystalline structure and to the continuous movements of electrons in their atoms.

Under ordinary conditions, these molecules arrange themselves in a disorderly manner, the north and south pole of these tiny magnets pointing in all directions and neutralizing one another. Thus a non-magnetized ferromagnetic bar is one in which there is no definite arrangement of the magnetic poles as shown in Fig 2. When iron or steel is magnetized, the molecules are moved into a new arrangement as shown in Fig 3, which is caused by the force used to magnetize them.

Fig 2

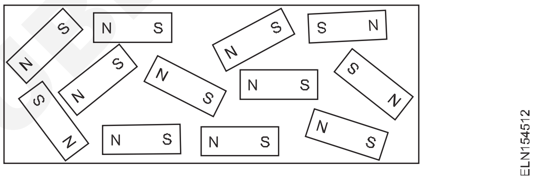
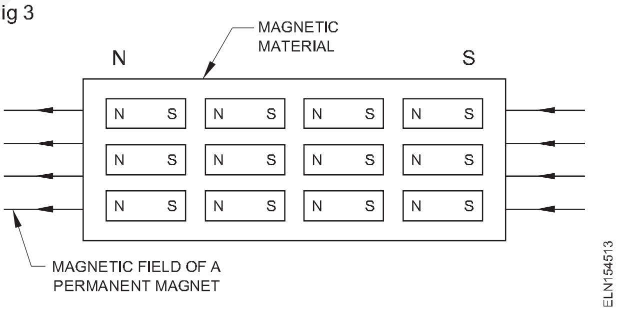
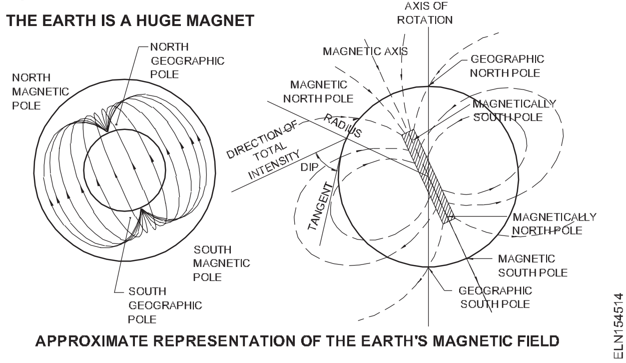


Fig 3



The earth's magnetic field: Since the earth itself is a large spinning mass, it too produces a magnetic field. The earth acts as though it has a bar magnet extending through its centre, with one end near the north geographic pole and the other end near the south geographic pole. (Fig 4)

Fig 4



Classification of magnetic substances

Materials can be classified into three groups as follows.

Ferromagnetic substances: Those substances which are strongly attracted by a magnet are known as ferromagnetic substances. Some examples are iron, nickel, cobalt, steel and their alloys.

Paramagnetic substances: Those substances which are slightly attracted by a magnet of common strength are called paramagnetic substances. Their attraction can easily be observed with a powerful magnet. In short, paramagnetic substances are similar in behaviour to ferromagnetic materials. Some examples are aluminium, manganese, platinum, copper etc.

Diamagnetic substances: Those substances which are slightly repelled by a magnet of powerful strength only are known as diamagnetic substances. Some examples are bismuth, sulphur, graphite, glass, paper, wood, etc. Bismuth is the strongest of the diamagnetic substances.

There is no substance which can be properly called non-magnetic. It may also be noted that water is a diamagnetic material, and air is a paramagnetic substance.

Magnetic terms and properties of magnet

Objectives: At the end of this lesson you shall be able to
- **define the terms magnetic field, magnetic line, magnetic axis, magnetic neutral axis and unit pole**
- **explain the properties of a magnet**
- **describe magnetic shielding**
- **describe the shape of magnets and the method of magnetizing**
- **state the application, care and maintenance of a permanent magnet.**

Magnetic fields: The force of magnetism is referred to as a magnetic field. This field extends out from the magnet in all directions, as illustrated in Fig 1. In this figure, the lines extending from the magnet represent the magnetic field.

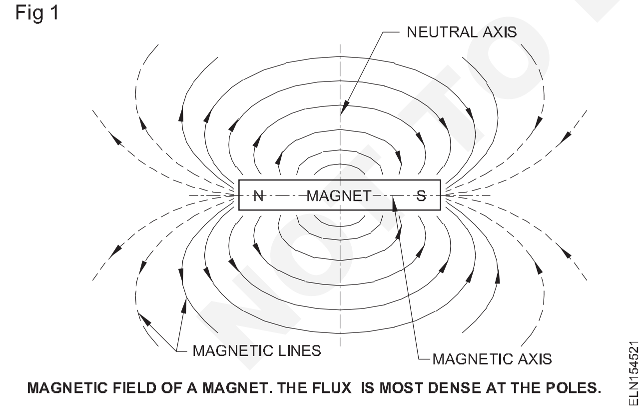
The space around a magnet in which the influence of the magnet can be detected is called the magnetic field.

Magnetic lines: Magnetic lines of force (flux) are assumed to be continuous loops, the flux lines continuing on through the magnet. They do not stop at the poles.

The magnetic lines around a bar magnet are shown in Fig 1.

Magnetic axis: The imaginary line joining the two poles of a magnet are called the magnetic axis. It is also known as the magnetic equator.

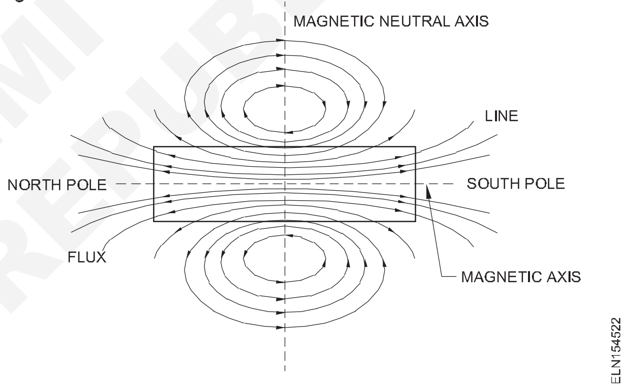
Fig 1



MAGNETIC FIELD OF A MAGNET. THE FLUX IS MOST DENSE AT THE POLES.

Magnetic neutral axis (Fig 2): The imaginary lines which are perpendicular to the magnetic axis and pass through the centre of the magnet are called the magnetic neutral axis.

Fig 2



Unit pole: A unit pole may be defined as that pole which, when placed one metre apart from an equal and similar pole, repels it with a force of 10 newtons.

Properties of a magnet

The following are the properties of magnets.

- Attractive property
- Directive property:
- Induction property
- Ies-existing property
- Demagnetising property
- Property of strengthSaturation property
- Property of attraction and repulsion
- Assumed physical properties of magnetic lines of force
- Magnetic shielding

Shapes of magnets: Magnets are available in various shapes, with the magnetism concentrated at their ends known as poles. The common shapes are listed here.

- Bar magnet
- Horseshoe magnet
- Ring magnet
- Cylindrical type magnet
- Specially shaped magnets

Specially shaped magnets: Permanent magnets for special purposes like, for the use of magnet in automobiles, cycle dynamos, electrical instruments and energy meters, are made to special shapes depending upon the purpose for which they are needed.

Methods of magnetizing: There are three principal methods of magnetizing a material.

- Touch method
- By means of electric current
- Induction method.

Touch method: This method can be further divided into:

- single touch method
- double touch method, and
- divided touch method

The magnetic circuits - self and mutually induced emfs

Objectives: At the end of this lesson you shall be able to

- **define the magnetic terms in a magnetic circuit (like M.M.F., reluctance, flux, field strength, flux density, permeability, relative permeability)**
- **state hysterisis and explain hysterisis loop**
- **describe pulling power of magnet.**

Magnetro Motive Force (MMF): The amount of flux density set up in the core is dependent upon five factors - the current, number of turns, material of the magnetic core, length of core and the cross-sectional area of the core. More current and the more turns of wire we use, the greater will be the magnetising effect. We call this product of the turns and current the magnetomotive force (mmf), similar to the electromotive force (emf). (Fig 1 & 2)

Fig 1

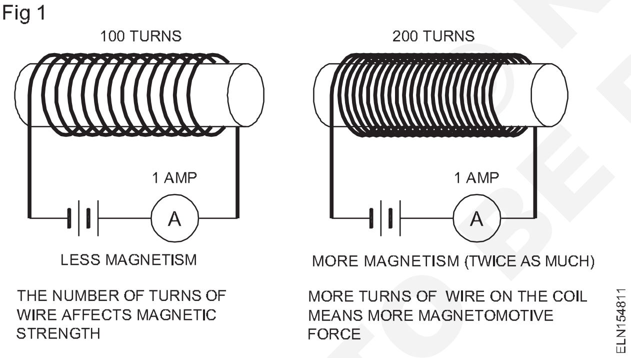
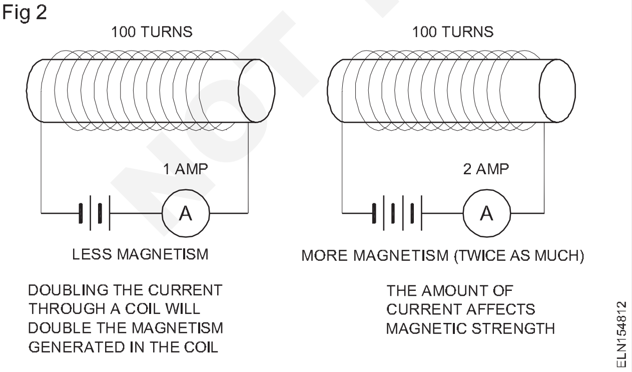


Fig 2



MMF = NI ampere-turns

where mmf - is the magnetomotive force in ampere turns

N - is the number of turns wrapped on the core

I - is the current in the coil, in amperes, A.

If one ampere current is flowing through a coil having 200 turns then the mmf is 200 ampere turns.

Reluctance: In the magnetic circuit there is something analogous to electrical resistance, and is called reluctance, (symbol S). The total flux is inversely proportional to the reluctance and so if we denote mmf by ampere turns. we can write

$$S = \frac{MMF}{\phi} = \frac{L}{\mu a} = \frac{L}{\mu_0 \mu_r a}$$

Where ϕ is flux and reluctances

where S - reluctance

L - length of the magnetic path in metres

μ_o - permeability of free space

μ_r - relative permeability

a - cross-sectional area of the magnetic path in sq.mm.

The unit of reluctance is ampere turns/Wb.

Magnetic flux:The magnetic flux in a magnetic circuit is equal to the total number of lines existing on the cross-section of the magnetic core at right angle to the direction of the flux. Its symbol is Ø and the SI unit is weber.

$$\phi = \left(\mu_0 \frac{N}{L} I \right) a$$

(or)

ϕ = Ba

where

ϕ - total flux

N - number of turns

I - current in amperes

S - reluctance

μ_o - permeability of free space

μ_r - relative permeability

a - magnetic path cross-sectional area in m^2

ℓ - length of magnetic path in metres.

Magnetic field strength: This is also known sometimes as field intensity, magnetic intensity or magnetic field, and is represented by the letter H. Its unit is ampere turns per metre.

$$H = \frac{B}{\mu}(a)H = \frac{N}{L}\left(\frac{A}{M}\right)$$

Flux density (B): The total number of lines of force per square metre of the cross- sectional area of the magnetic core is called flux density, and is represented by the symbol B. Its SI unit (in the MKS system) is tesla (weber per metre square).

$$B = \frac{\phi}{a}(N) \Rightarrow B = \mu_0 \frac{N}{L} \text{ Weber/ } m^2$$

where ϕ - total flux in webers

a - area of the core in square metres

B - flux density in weber/metre square.

Permeability: The permeability of a magnetic material is defined as the ratio of flux created in that material to the flux created in air, provided that mmf and dimensions of the magnetic circuit remain the same. It's symbol is μ and

$$\mu = B/H$$

where B is the flux density

H is the magnetic field strength.

Being a ratio it has no unit and it is expressed as a mere number. The permeability of air μ air = unity. The relative permeability μr of iron and steel ranges from 50 to 2000. The permeability of a given material varies with its flux density.

Electromagnet applications - Electromagnetic induction

Objectives: At the end of this lesson you shall be able to
- **compare the magnetic circuit and electric circuit**
- **state the applications of an electromagnet (Bell & Buzzer tubelight choke)**
- **state the principle and laws of electromagnetic induction**
- **explain the energy stored in induction coil**
- **explain about the series and parallel connection of inductors and types of inductors**
- **state function of choke in a flourscent light circuit**
- **state the factors that contribute to induced voltage**
- **explain about the counter EMF-induced reactance-time constant.**

Practical applications of electromagnets: Electromagnets are used in the manufacture of all types of electrical machines, such as motors, generators, transformers, convertors, some electrical measuring instruments, protective relays, for medical purposes (like removing iron pieces from eyes) and in many other electrical devices like bells, buzzers, circuit-breakers, relays, telegraphic circuits, lifts and other industrial uses.

a Bells
b Buzzers
c Circuit-breakers
d Relays
e Telegraphic circuits
f Lifts
g Industrial uses

Principles and laws of electromagnetic induction

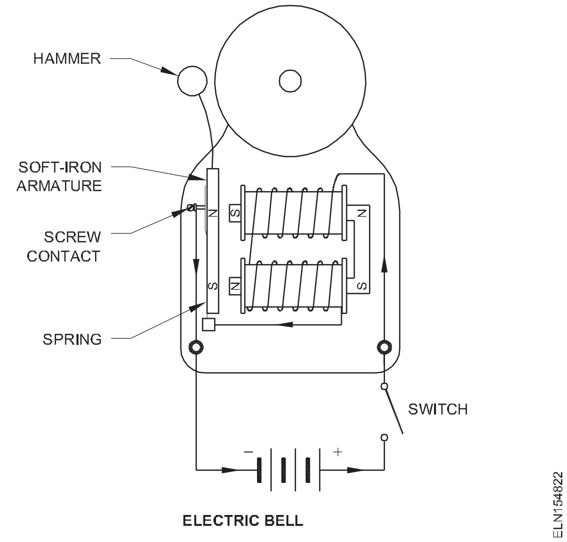
Faraday's Laws of Electromagnetic Induction are also applicable for conductors carrying alternating current.

Faradays' Laws of Electromagnetic Induction

Faraday's First Law states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in it.

The Second Law states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

Fig 1



Dyanamically Induced EMF

Accordingly induced emf can be produced either by moving the conductor in a stationery magnetic field or by changing magnetic flux over a stationery conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Ex. generators.

Statically Induced EMF

When changing flux produces emf the emf is called as statically induced emf as explained below. Ex: Transformer.

Statically induced emf: When the induced emf is produced in a stationery conductor due to changing magnetic field, obeying Faraday's laws of electro magnetism, the induced emf is called as statically induced emf.

There are two types of statically induced emf as stated below:-

1 **Self induced emf** produced with in the same coil

2 **mutually induced emf** produced in the neighbouring coil

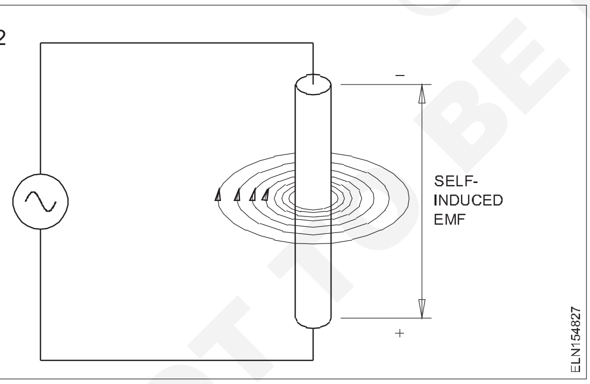
Self-induction: The production of an electromotive force in a circuit, when the magnetic flux linked with the circuit changes as a result of the change in a current inducing in the same circuit.

At any instant, the direction of the magnetic field is determined by the direction of the current flow.

With one complete cycle, the magnetic field around the conductor builds up and then collapses. It then builds up in the opposite direction, and collapses again. When the magnetic filed begins building up from zero, the lines of force or flux lines expand from the centre of the conductor outward. As they expand outward, they can be thought of as cutting through the conductor.

According to Faraday's Laws, an emf is induced in the conductor. Similarly, when the magnetic field collapses, the flux lines cut through the conductor again, and an emf is induced once again. This is called self-induction. (Fig 2)

Fig 2



Mutual Inductance: When two or more coils one magnetically linked together by a common magnetic flux, they are said to have the property of mutual inductance. It is the basic operating principal of the transformer, motor generaters and any other electrical component that interacts with another magnetic field. It can define mutual induction on the current flowing in one coil that induces a voltage in an adjacement coil.

In the Fig 3 current flowing in coil L1 sets up a magnetic field around it self with some of its magnetic field line passing through coil L2 giving in mutual inductance coil one L on has a current of I, and N, turns while coil two L2, has N2 turns therefore mutual inductance M, of coil two that exists with respect to coil one L, depend on their position with inspect to each other.

The mutual inductance M that exists between the two coils can be greately measured by positioning them on a common soft iron cone or by measuring the number of turns of either coil on would he found in a transformer.

The two coils are tightly wound one on top of the other over a common soft iron core unity in said to exist between them as any losses due to the leakage of flux will be extremely small. Then assuring a perfect flux leakage between the two coils the mutual inductance M that exists between them can be given on:

Value $$M = \frac{M_o M_r N_1 N_2 A}{L}$$

M_o is the permeability of free space $(4\pi \times 10^{-7})$

M_r - is the relative permability of soft iron cone

N is the no. of turns of coil

A is the cross sectional area in m^2

I is the coil length in meters

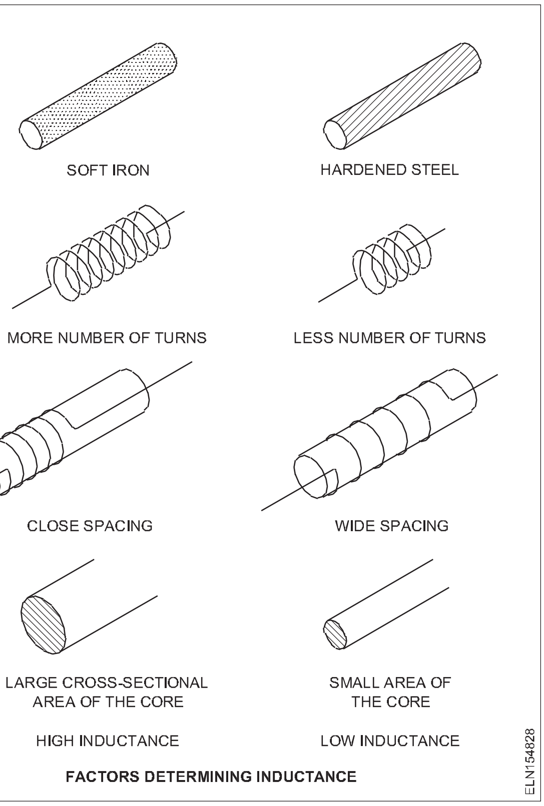
Inductance: Inductance (L) is the electrical property of an electrical circuit or device to oppose any change in the magnitude of current flow in a circuit.

Devices which are used to provide inductance in a circuit are called inductors. Inductors are also known as chokes, coils, and reactors. Inductors are usually coils of wire.

Factors determining inductance: The inductance of an inductor is primarily determined by four factors.

- Type of core permeability of the core m_r.
- Number of turns of wire in the coil 'N'.
- Spacing between turns of wire (Spacing factor).
- Cross-sectional area (diameter of the coil core) 'a' or 'd'.

Fig 3



FACTORS DETERMINING INDUCTANCE

Electrostatics: Capacitor- Different types, functions, grouping and uses

Objectives: At the end of this lesson you shall be able to
- **describe capacitor its construction and charging**
- **explain capacitance and the factors determining**
- **state the different types and application of capacitors**
- **state the testing and defects of capacitors.**

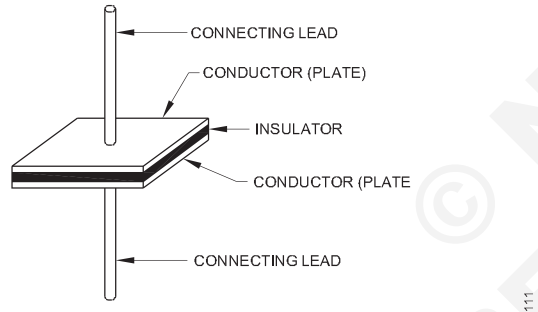
Capacitor:

Capacitor is a passive two terminal electrical/electronic component that stores potential energy in the form of electrostatic field

The effect of capacitor is called as capacitance. It consists of two conducting plates separated by an insulating material called as dielectric. In simple, capacitor is a device designed to store electric charge.

Construction: A capacitor is an electrical device consisting of two parallel conductive plates, separated by an insulating material called the dielectric. Connecting leads are attached to the parallel plates. (Fig 1)

Fig 1



SIMPLE CAPACITOR. THE PLATES OF A CAPACITOR ARE ALWAYS INSULATED FROM EACH OTHER

Function: In a capacitor the electric charge is stored in the form of an electrostatic field between the two conductors or plates, due to the ability of dielectric material to distort and store energy while it is charged and keep that charge for a long period or till it is discharged through a resistor or wire. The unit of charge is coulomb and it is denoted by the letter `C'.

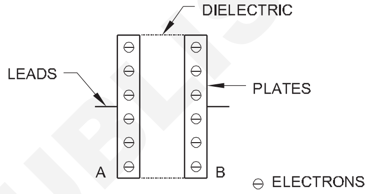
How a capacitor stores charge?: In the neutral state, both plates of a capacitor have an equal number of free electrons, as indicated in Fig 2a. When the capacitor is connected to a voltage source through a resistor, the electrons (negative charge) are removed from plate A, and an equal number are deposited on plate `B'. Plate A becomes positive with respect to plate B as shown in Fig 2b.

The current enters and leaves the capacitor, but the insulation between the capacitor plates prevents the current from flowing through the capacitor.

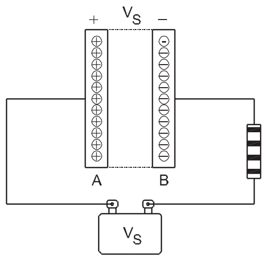
As electrons flowing into the negative plate of a capacitor have a polarity opposite to that of the battery supplying the current, the voltage across the capacitor opposes the battery voltage. The total circuit voltage, therefore, consists of two series-opposing voltages.

As the voltage across the capacitor increases, the effective circuit voltage, which is the difference between the battery voltage and the capacitor voltage, decreases. This, in turn, causes a decrease in the circuit current.

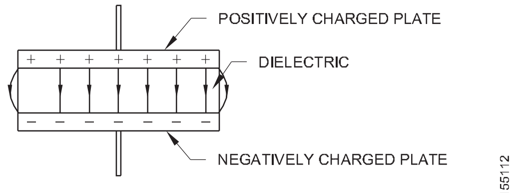
Fig 2



(a) NEUTRAL (UNCHARGED) CAPACITOR (SAME CHARGE ON BOTH PLATES)



(b) CAPACITOR CHARGED TO V NO MORE ELECTRONS FLOW



(c) ELECTRIC FIELD OF A CHARGED CAPACITOR

When the voltage across the capacitor equals the battery voltage, the effective voltage in the circuit is zero, and so the current flow stops. At this point, the capacitor is fully charged, and no further current can flow in the circuit.

Capacitance : The ability or capacity to store energy in the form of electric charge is called capacitance. The symbol used to represent capacitance is C.

Unit of capacitance: The base unit of capacitance is the **Farad.** The abbreviation for **Farad** is **F**. One farad is that amount of capacitance which stores 1 coulomb of charge when the capacitor is charged to 1 V. In other words, a Farad is a coulomb per volt (C/V).

Farad

A farad is the unit of capacitance (C), and a coulomb is the unit of charge(Q), and a volt is the unit of voltage(V). Therefore, capacitance can be mathematically expressed as $C = \frac{Q}{V}$

Example 1: What is the capacitance of a capacitor that requires 0.5 C to charge it to 25V?

Given: Charge(Q) = 0.5C

Voltage(V) = 25V

Find : =

Capacitance(C)

$$C = \frac{Q}{V} \quad \frac{0.5}{25} = 0.02$$

Solution

Answer: The capacitance is 0.02F.

Capacitive reactance

Similar to resistors and inductors, a capacitor also offers opposition to the flow of AC current. This opposition offered to the flow of current by a capacitor is called **capacitive reactance** abbreviated as X_C.

Recall expressions,

$$I = \frac{Q}{t} = \text{and } Q = CV$$

Substituting Q = CV in I = Q/t

$$I = \frac{CV}{t}$$

This means,

$I \alpha C$, $I \alpha V$ and $I \alpha f$ (Because, 1/t = f)

From the above equation, the amount of AC current that a capacitor conducts depends on;

- the frequency (f) of the applied voltage
- the capacitance (C) of the capacitor
- the amplitude of the applied voltage(V).

Fig 2a shows the graph of variation of current(I) through a capacitor with frequency or capacitance when the applied voltage is kept constant.

Since current flow through a capacitor is directly proportional to frequency and capacitance, the opposition to current flow by the capacitor is inversely proportional to these quantities.

Capacitive reactance, X_C can be mathematically represented as;

$$X_c = \frac{1}{2\pi fc}$$

where

X_C is the capacitive reactance in ohms

f is the frequency of the applied voltage in Hz

and C is the capacitance in farads.

Capacitive reactance, X_C, expressed in ohms, acts just like a resistance in limiting the AC current flow.

Sub-units of a farad: Most capacitors that you will use in electronics work, have capacitance values in microfarads (μF) and picofarads (pF). A microfarad is one-millionth of a farad (1μF = 1 x 10^{-6} F), and a picofarad is one-trillionth of a farad (1 PF = 1 x $10^{-12}{}_{P}$F) one nano farad (1nF = 1 x 10^{-9} F).

Factors determining capacitance: The capacitance of a capacitor is determined by four factors.

- Area of the plates ($C \alpha A$)
- Distance between the plates ($C \alpha d$)
- Type of dielectric material
- Temperature
- Resistance of the plates

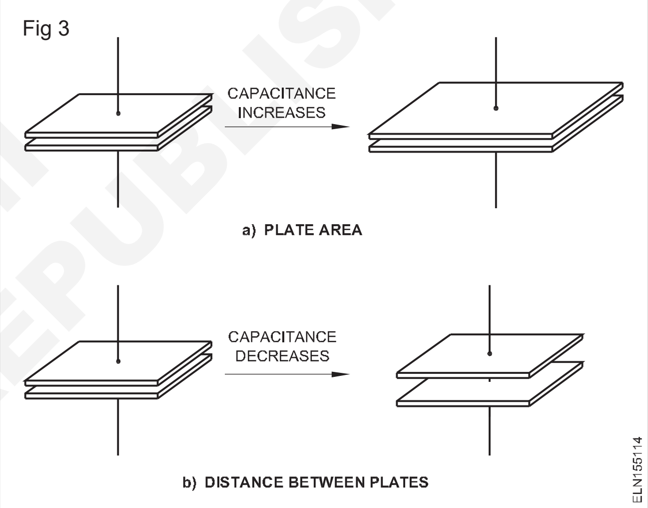


Fig 3

Types of capacitors: Capacitors are manufactured in a wide variety of types, sizes and values. Some are fixed in value, in others the value is variable.

Fixed capacitors

Ceramic capacitors: These discs are made by using ceramic as an insulator with a silver deposit on each side of the plates.

Ceramic capacitors are typically available in capacitance values ranging from 1μF to 2.2μ F with voltage ratings up to 6 KV. A typical temperature coefficient for ceramic capacitors is 200,000 PPM/°C.

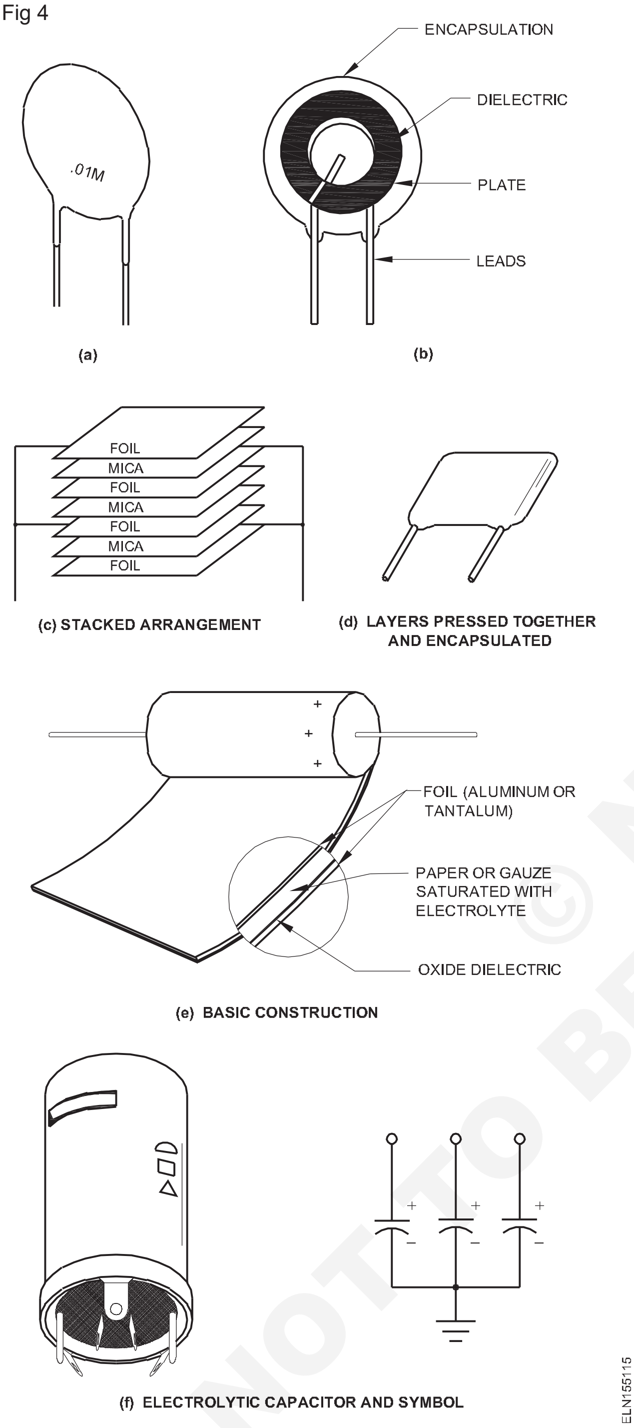
Mica capacitors: It consists of alternate layers of metal foil and thin sheets of mica.

Mica capacitors are available with capacitance values ranging from 1 pF to 0.1 pF and voltage ratings from 100 to 2500 V DC. Temperature coefficients from −20 to +100 PPM/°C are common. Mica has a typical dielectric constant of 5.

Electrolytic capacitors: Electrolytic capacitors are polarized so that one plate is positive and the other negative.

These capacitors are used for high capacitance values up to over 200,000µ F, but they have relatively low breakdown voltages (350 V is a typical maximum) and high amounts of leakage.

Fig 4



(a) (b)

(c) STACKED ARRANGEMENT

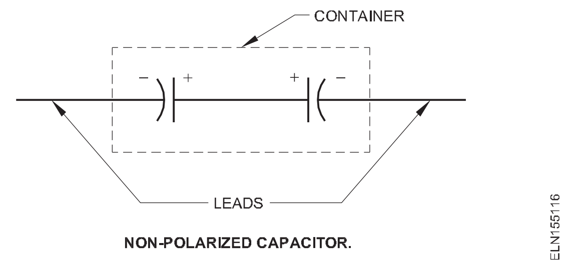
(d) LAYERS PRESSED TOGETHER AND ENCAPSULATED

(e) BASIC CONSTRUCTION

(f) ELECTROLYTIC CAPACITOR AND SYMBOL

Special electrolytic capacitors are manufactured for use in AC circuits. These capacitors are usually listed in catalogues as `non-polarised' or `AC' electrolytic capacitors. An AC electrolytic capacitor is really two electric capacitors packaged in a single container.(Fig 5) The two internal capacitors are in series, with their positive ends connected together. Regardless of the polarity on the leads of the AC electrolytic capacitor, one of the two internal capacitors will be correctly polarized.

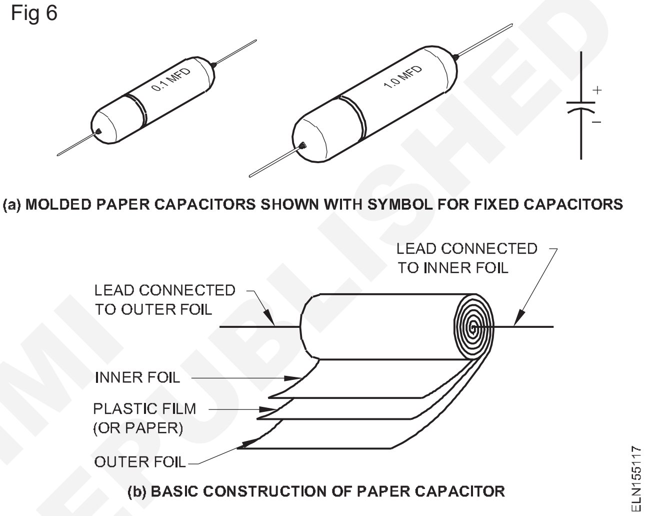
Fig 5



NON-POLARIZED CAPACITOR.

Paper/plastic capacitors: Polycarbonate, parylene, polyester, polystyrene, polypropylene, mylar, and paper are some of the more common dielectric materials used. Some of these types have capacitance values up to 100µF. (Fig 6)

Fig 6



(a) MOLDED PAPER CAPACITORS SHOWN WITH SYMBOL FOR FIXED CAPACITORS

(b) BASIC CONSTRUCTION OF PAPER CAPACITOR

Common defects in capacitors

Short circuited capacitors: In the course of normal usage, capacitors can become short-circuited/shorted. This is because of the deterioration of the dielectric used due to ageing.

Short-circuiting of capacitors is more common in paper and electrolytic capacitors than in the other types.

A shorted capacitor cannot store energy.

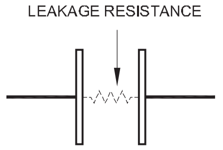
Open capacitors: A capacitor may become open due to loose/broken lead connections or due to the electrolyte. After a few years of usage, the electrolyte may dry up resulting in open-circuit of the capacitor. An open capacitor cannot store energy.

Leaky capacitors/leakage resistance: Theoretically, the current that flows in a pure capacitive circuit results from the charge and discharge currents of the capacitors. The dielectric, which is an insulator, should prevent any current flow between the plates. However, even the best dielectric conduct very small current.

The dielectric, that has some high value of resistance, known as leakage resistance. This leakage resistance, as shown in Fig 7, allows some leakage current to flow. This leakage current tends to reduce the capacitance value.

In a good capacitor, the leakage resistance is generally of the order of several tens of megohms and hence can be considered negligible for most applications. As the capacitor ages, the leakage resistance could reduce. Generally, the leakage resistance is lower with high value capacitors than with low value capacitors.

Fig 7



The reason for this is that, larger capacitors have larger plate areas that are closer together. Therefore their dielectrics must have large areas and be thin. Recall, resistance reduces as the -sectional area is increased or when the length or thickness is decreased.

So, larger the capacitor, lower the leakage resistance, and higher is the leakage current.

Normal leakage resistance across a good capacitor has to be very high. Depending upon the type of dielectric used, the normal resistance varies.

For paper, plastic, mica and ceramic capacitors the normal resistance will be of the order of 500 to 1000 M or more. For electrolytic capacitors the normal resistance will be of the order of 200 KΩ to 500 KΩ.

A capacitor is said to have become leaky when the resistance across it is less than normal when read with any average quality ohmmeter.

Checking capacitors: The two simple methods to check a capacitor is by carrying out,

i capacitor action-normal resistance test, using a ohm-meter/multimeter (This test is also referred as quick test)

ii charging-holding test, using a battery and voltmeter/multimeter.

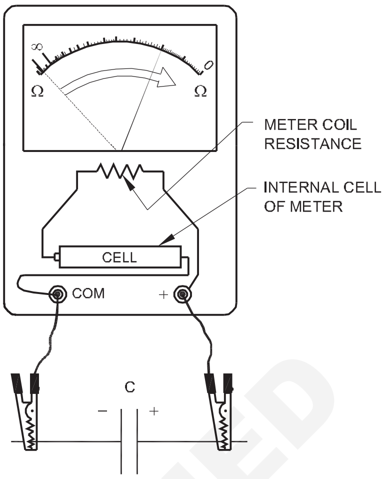
Capacitor action-normal charging test: When an ohmmeter is connected across a fully discharged capacitor, initially, the battery insider the meter charges the capacitor. During this charging, at the first instance, a reasonably high charging current flows.

Since more current through the ohm meter means less resistance, the meter pointer moves quickly towards zero ohms of the meter scale as shown in Fig 8a.

As the initial charging, the charging current to the capacitor slowly decreases (as the voltage across the capacitor increases towards the applied voltage). Since less and less current through the ohmmeter means high and higher resistance the meter pointer slowly moves towards infinite resistance of the meter scale as shown is Fig 8b. Finally, when the capacitor is completely charged to the ohmmeter internal battery voltage, the charging current is almost zero and the ohmmeter reads the normal resistance of the capacitor which is a result of just the small leakage current through the dielectric.

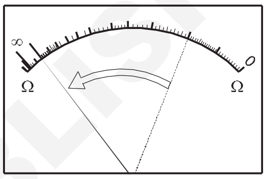
This changing effect commonly known as Capacitor action indicates, whether the capacitor can store charge, whether the capacitor is excessively leaky, whether the capacitor is fully short-circuited or whether the capacitor is fully open-circuited.

Fig 8a



CAPACITOR UNDER TEST

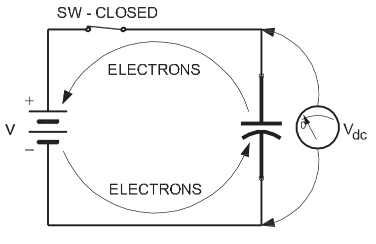
Fig 8b



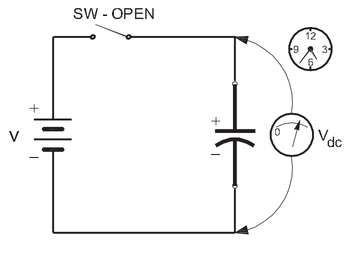
The capacitor-action test is most suitable for high value capacitors and specially electrolyte capacitors. When small value capacitors such as ceramic disc or paper capacitors are tested for capacitor-action, due to the extremely low charging current the capacitor-action can not be observed on the meter dial. For such small capacitors the capacitor-charging-holding test is preferred. However, if small capacitors are subjected for the capacitor-action test, if the meter shows high resistance the capacitor can be taken as not shorted and hence may be taken as good.

Charging-holding test on capacitors: In this test, a given capacitor is charged to some voltage level using an external battery as shown in Fig 9a.

Fig 9



a) CAPACITOR ON CHARGING



b) CAPACITOR RETAINING CHARGE

Once the capacitor is charged to the applied voltage level, the battery is disconnected and the voltage across the capacitor is monitored as shown in Fig 9b. The voltage is monitored for a period of time to confirm whether he capacitor is able to hold the charge atleast for a small period of time (of the order of few seconds).

In this test, when the capacitor is tried for charging, if the capacitor does not charge at all even after connecting the battery for a considerable period of time, it can be concluded that the capacitor is either short-circuited or fully open circuited.

If the capacitor is unable to hold the charge even for a considerably small period of time, then it can be concluded that the capacitor is excessively leaky.

Grouping of capacitors

Objectives: At the end of this lesson you shall be able to
- **state the necessity of grouping capacitors and method of connection**
- **state the conditions for connecting capacitors in parallel and in series**
- **explain the values of capacitance and voltage in parallel and series combination**

Necessity of grouping of capacitors: In certain instances, we may not be able to get a required value of capacitance and a required voltage rating. In such instances, to get the required capacitances from the available capacitors and to give only the safe voltage across capacitor, the capacitors have to be grouped in different fashions. Such grouping of capacitors is very essential.

Methods of grouping: There are two methods of grouping.

- Parallel grouping
- Series grouping

Parallel grouping

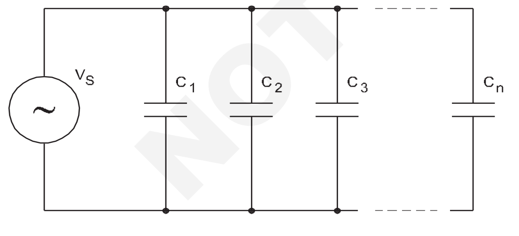
Conditions for parallel grouping

- Voltage rating of capacitors should be higher than the supply voltage Vs.
- Polarity should be maintained in the case of polarised capacitors (electrolytic capacitors).

Necessity of parallel grouping: Capacitors are connected in parallel to achieve a higher capacitance than what is available in one unit.

Connection of parallel grouping: Parallel grouping of capacitors is shown in Fig 1 and is analogous to the connection of resistance in parallel or cells in parallel.

Fig 1

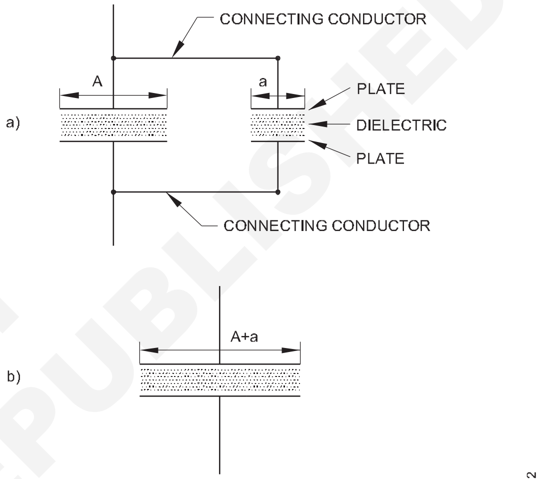


CAPACITORS IN PARALLEL

Total capacitance: When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitances, because the effective plate area increases. The calculation of total parallel capacitance is analogous to the calculation of total resistance of a series circuit.

By comparing Figs 2a and 2b, you can understand that connecting capacitors in parallel effectively increases the plate area.

Fig 2



CAPACITORS IN PARALLEL. THE EQUIVALENT CAPACITANCE IN (b) IS EQUAL TO THE SUM OF THE CAPACITANCES IN (a).

General formula for parallel capacitance: The total capacitance of parallel capacitors is found by adding the individual capacitances.

$C_T = C_1 + C_2 + C_3 + \ldots\ldots\ldots\ldots + C_n$

where C_T is the total capacitance,

C_1, C_2, C_3 etc. are the parallel capacitors.

The voltage applied to a parallel group must not exceed the lowest breakdown voltage for all the capacitors in the parallel group.

Example: Suppose three capacitors are connected in parallel, where two have a breakdown voltage of 250 V and one has a breakdown voltage of 200 V, then the maximum voltage that can be applied to the parallel group without damaging any capacitor is 200 volts.

The voltage across each capacitor will be equal to the applied voltage.

Charge stored in parallel grouping: Since the voltage across parallel-grouped capacitors is the same, the larger capacitor stores more charge. If the capacitors are equal in value, they store an equal amount of charge. The charge stored by the capacitors together equals the total charge that was delivered from the source.

$Q_T = Q_1 + Q_2 + Q_3 + \ldots.. + Q_n$

where Q_T is the total charge

Q_1, Q_2, Q_3.....etc. are the individual charges of the capacitors in parallel.

Using the equation Q = CV,

the total charge $Q_T = C_T V_S$

where V_S is the supply voltage.

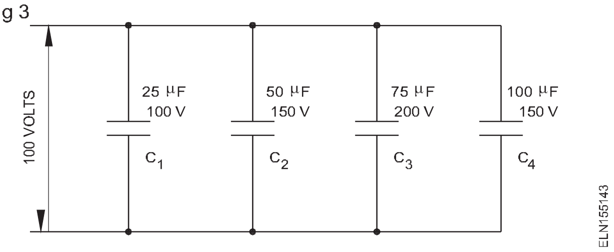
Again $C_T V_S = C_1 V_S + C_2 V_S + C_3 V_S$

Because all the V_S terms are equal, they can be cancelled.

Therefore, $C_T = C_1 + C_2 + C_3$

Example: Calculate the total capacitance, individual charges and the total charge of the circuit given in Fig 3.

Fig 3



Solution

Total capacitance = C_T

$C_T = C_1 + C_2 + C_3 + C_4$

C_T = 250 micro farads.

Individual charge = Q = CV

$Q_1 = C_1V$

$= 25 \times 100 \times 10^{-6}$

$= 2500 \times 10^{-6}$

$= 2.5 \times 10^{-3}$ coulombs.

$Q_2 = C_2V$

$= 50 \times 100 \times 10^{-6}$

$= 5000 \times 10^{-6}$

$= 5 \times 10^{-3}$ coulombs.

$Q3 = C_3V$

$= 75 \times 100 \times 10^{-6}$

$= 7500 \times 10^{-6}$

$= 7.5 \times 10^{-3}$ coulombs.

$Q_4 = C_4V$

$= 100 \times 100 \times 10^{-6}$

$= 10000 \times 10^{-6}$

$= 10 \times 10^{-3}$coulombs.

Total charge $= Q_t = Q_1 + Q_2 + Q_3 + Q_4$

$= (2.5 \times 10^{-3}) + (5 \times 10^{-3})$

$+ (7.5 \times 10^{-3}) + (10 \times 10^{-3})$

$= (2.5+5+7.5+10) \times 10^{-3}$

$= 25 \times 10^{-3}$ coulombs.

or $Q_T = C_TV$

$= 250 \times 10^{-6} \times 100$

$= 25 \times 10^{-3}$ coulombs.

Series grouping

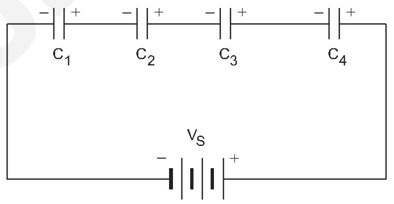
Necessity of grouping of capacitors in series: The necessity of grouping capacitors in series is to reduce the total capacitance in the circuit. Another reason is that two or more capacitors in series can withstand a higher potential difference than an individual capacitor can. But, the voltage drop across each capacitor depends upon the individual capacitance. If the capacitances are unequal, you must be careful not to exceed the breakdown voltage of any capacitor.

Conditions for series grouping

- If different voltage rating capacitors have to be connected in series, take care to see that the voltage drop across each capacitor is less than its voltage rating.
- Polarity should be maintained in the case of polarised capacitors.

Connection in series grouping: Series grouping of capacitors, as shown in Fig 4 is analogous to the connection of resistances in series or cells in series.

Fig 4



SERIES CONNECTION OF CAPACITORS

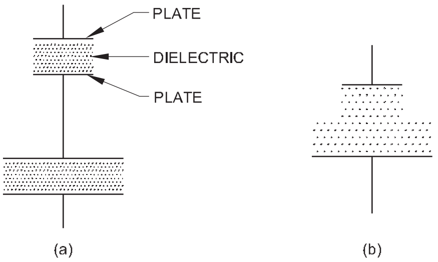
Total capacitance: When capacitors are connected in series, the total capacitance is less than the smallest capacitance value, because

- the effective plate separation thickness increases
- and the effective plate area is limited by the smaller plate.

The calculation of total series capacitance is analogous to the calculation of total resistance of parallel resistors.

By comparing Figs 5a and 5b you can understand that connecting capacitors in series increases the plate separation thickness, and also limits the effective area so as to equal that of the smaller plate capacitor.

Fig 5



THE EQUIVALENT CAPACITANCE IN (b) IS LESS THAN THE LOWER OF THE TWO CAPACITANCES IN (a).

Inductive and capacitive reactance and their effect on AC circuit

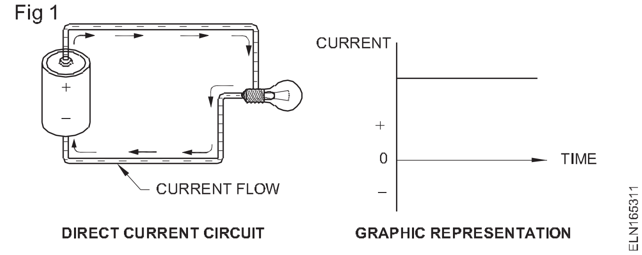
Objectives: At the end of this lesson you shall be able to

- **state the features of direct current**
- **list out the advantages of DC over AC**
- **compare the features of DC and AC**
- **explain the generation of alternating current and terms used**
- **state the advantages of AC over DC**

Direct current (DC): Electric current can be defined as the flow of electrons in a circuit. Based on the electron theory, electrons flow from the negative (–) polarity to the positive (+) polarity of a voltage source.

Direct current (DC) is the current that flows only in one direction in a circuit. (Fig 1) The current in this type of circuit is supplied from a DC voltage source. Since the polarity of a DC source remains fixed, the current produced by it flows in one direction only.

Fig 1

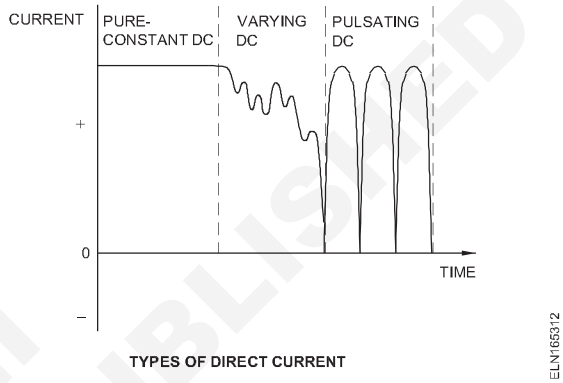


Dry cells are commonly used as a DC voltage source. Both the voltage and polarity of the dry cell are fixed. When connected to a load, the current produced flows in one direction at some steady or constant value.

A direct current flow need not necessarily be constant, but it must travel in the same direction at all times. There are several types of direct current, and all of them depend upon the value of the current in relation to time. (Fig 2)

A constant DC current shows no variation in value over a period of time. Both varying and pulsating DC currents have a changing value when plotted against time. The pulsating DC current variations are uniform, and repeat at regular intervals.

Fig 2



Advantages of DC over AC

1 DC needs only two wires of transmission, while a 3 phase AC may need upto 4 wires.

2 The corona loss associated with DC is negligible while for AC it increases with its frequency.

3 The skin effect is also observed in AC leading to problems in transmission conductor designs.

4 No inductive and capacitive losses.

5 No proximity effect.

Comparison of AC and DC

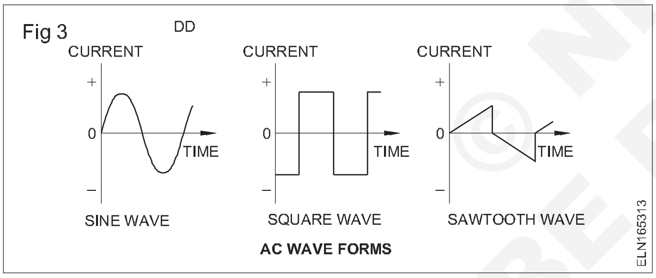
	Alternating current	Direct current
Amount of energy that can be carried	Safe to transfer over longer city distances and can provide more power.	Voltage of DC cannot travel very far until it begins to lose energy.
Cause of the direction of flow of electrons	Rotating magnet along the wire.	Steady magnetism along the wire.
Frequency	The frequency of alternating current is 50Hz or 60Hz depending upon the country.	The frequency of direct current is zero.
Direction	It reverse its direction while flowing in a circuit.	It flows in one direction in the circuit.

	Alternating current	Direct current
Current	It is the current of magnitude varying with time.	It is the current of constant magnitude.
Flow of electrons	Electrons keep switching directions - forward and backward.	Electrons move steadily in one direction or ‘forward’.
Obtained from	AC generator and mains.	Cell or battery.
Passive parameters	Impedence.	Resistance only.
Power factor	Lies between 0 to 1.	It is always 1.
Types	Sinusoidal, trapezoidal, triangular, square	Pure and pulsating.

Alternating current (AC): An alternating current (AC) circuit is one in which the direction and amplitude of the current flow change at regular intervals. The current in this type of circuit is supplied from an AC voltage source. The polarity of an AC source changes at regular intervals resulting in a reversal of the circuit current flow.

Alternating current usually changes in both value and direction. The current increases from zero to some maximum value, and then drops back to zero as it flows in one direction. This same pattern is then repeated as it flows in the opposite direction. The wave-form or the exact manner in which the current increases and decreases is determined by the type of AC voltage source used. (Fig 3)

Fig 3



AC WAVE FORMS

Alternating current generation: Alternating current is used wherever a large amount of electrical power is required. Almost all of the electrical energy supplied for domestic and commercial purposes is alternating current.

AC voltage is used because it is much easier and cheaper to generate, and when transmitted over long distances, the power loss is low.

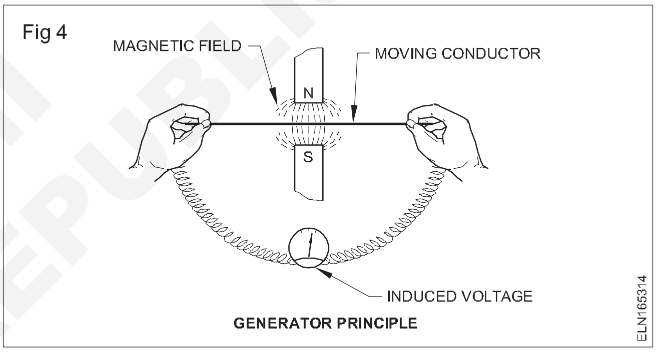
AC equipment is generally more economical to maintain and requires less space per unit of power than the DC equipment.

Alternating current can be generated at higher voltages than DC, with fewer problems of heating and arcing. Some standard values of voltages are 1.1KV, 2.2.KV, 3.3KV for low capacity and 6.6KV (6600V), 11KV(11000V) and 33KV(33000V) for high capacity requirements. The values are increased to 66 000, 110 000, 220 000, 400 000 volts for transmission over long distances. At the load area, the voltage is decreased to working values of 240V and 415V.

The basic method of obtaining AC is by the use of an AC generator. A generator is a machine that uses magnetism to convert mechanical energy into electrical energy. The generator principle, simply stated, is that a voltage is induced in a conductor whenever the conductor is moved through a magnetic field so as to cut the lines of magnetic force.

Fig 4 shows the basic generator principle. A change in a magnetic field around a conductor tends to set electrons in motion. The mere existence of a magnetic field is not enough; there must be some form of change in the field.

Fig 4



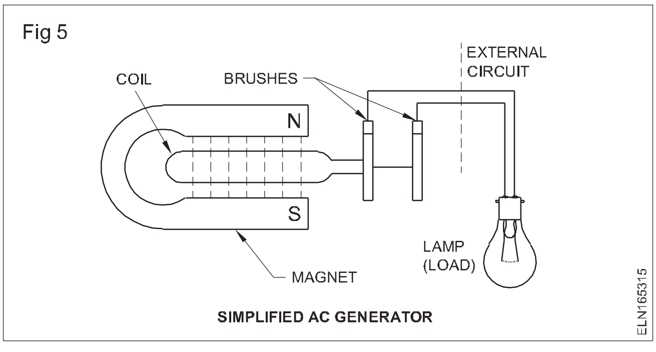
GENERATOR PRINCIPLE

If we move the conductor through the magnetic field, a force is exerted by the magnetic field on each of the free electrons within the conductor. These forces add together and the effect is that voltage is generated or induced into the conductor.

An AC generator produces an AC voltage by causing a loop of wire to turn within a magnetic field. This relative motion between the wire and the magnetic field causes a voltage to be induced between the ends of the wire. This voltage changes in magnitude and polarity as the loop is rotated within the magnetic field. (Fig 5)

The force required to turn the loop can be obtained from various sources. For example, very large AC generators are turned by steam turbines or by the movement of water.

Fig 5



SIMPLIFIED AC GENERATOR

The voltage produced by a single loop generator is too weak to be of much practical value. A practical AC generator has many more turns of wire wound on an armature. The armature is made up of a number of coils wound on an iron core.

The AC voltage induced in the armature coils is connected to a set of slip rings from which the external circuit receives the voltage through a set of brushes. An electromagnet is used to produce a stronger magnetic field.

The sine wave: The shape of the voltage wave-form generated by a coil rotating in a magnetic field is called a sine wave. The generated sine wave voltage varies in both voltage value and polarity.

If the coil is rotated at a constant speed, the number of magnetic lines of force cut per second varies with the position of the coil. When the coil is moving parallel to the magnetic field, it cuts no lines of force.

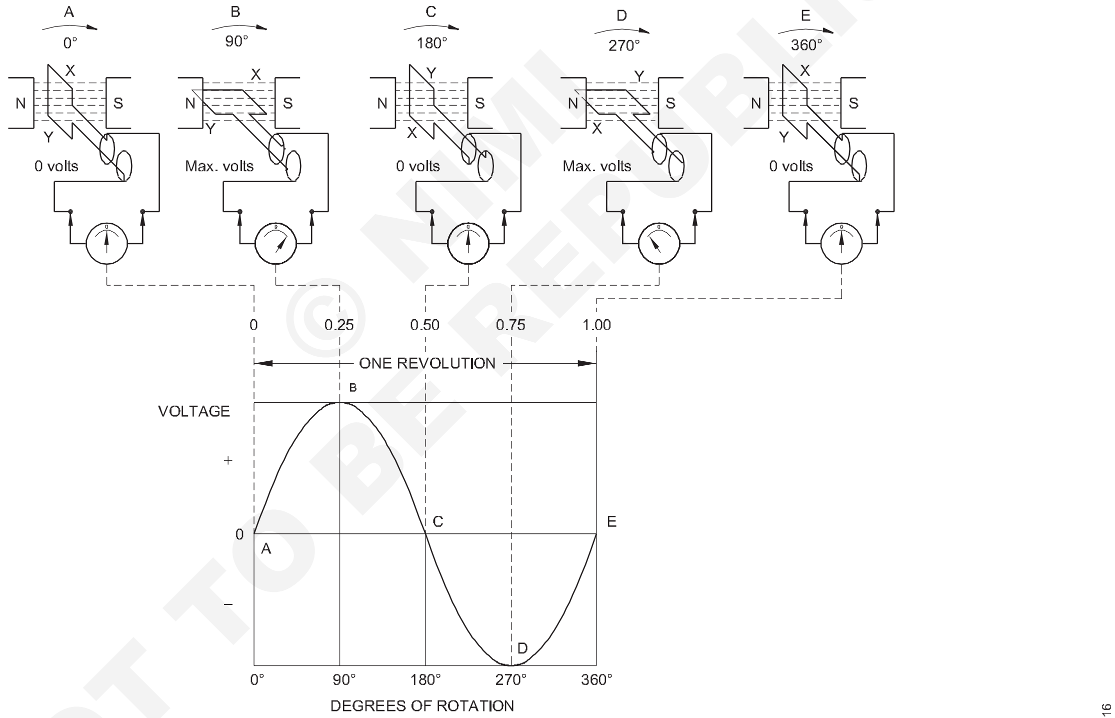
Therefore, no voltage is generated at this instant. When the coil is moving at right angles to the magnetic field, it cuts the maximum number of lines of force. Therefore, maximum or peak voltage is generated at this instant. Between these two points the voltage varies in accordance with the sine of the angle at which the coil cuts the lines of force.

The coil is shown in five specific positions in Fig 6. These are intermediate positions which occur during one complete revolution of the coil position. The graph shows how the voltage increases and decreases in amount during one rotation of the loop.

Note that the direction of the voltage reverses each half-cycle. This is because, for each revolution of the coil, each side must first move down and then up through the field.

The sine wave is the most basic and widely used AC wave-form. The standard AC generator (alternator) produces a voltage of sine wave-form. Some of the important electrical characteristics and terms used when referring to AC sine wave voltage or current are as follows.

Fig 6

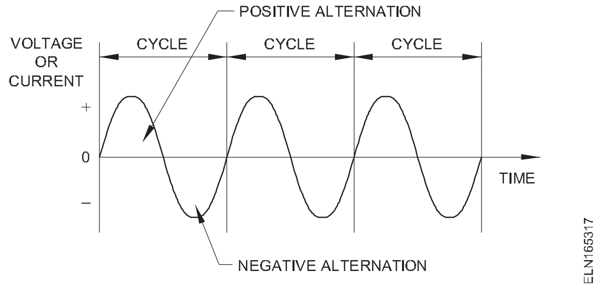


GENERATION OF AN ALTERNATING VOLTAGE: AS THE LOOP ROTATES THROUGH THE MAGNETIC FIELD. THE AMOUNT AND POLARITY OFTHE VOLTAGE CHANGES WITH ANGLE AND DIRECTION OF MOTION.

Cycle: One cycle is one complete wave of alternating voltage or current. During the generation of one cycle of output voltage, there are two changes or alternations in the polarity of the voltage.

These equal but opposite halves of a complete cycle are referred to as alternations. The terms positive and negative are used to distinguish one alternation from the other. (Fig 7)

Fig 7

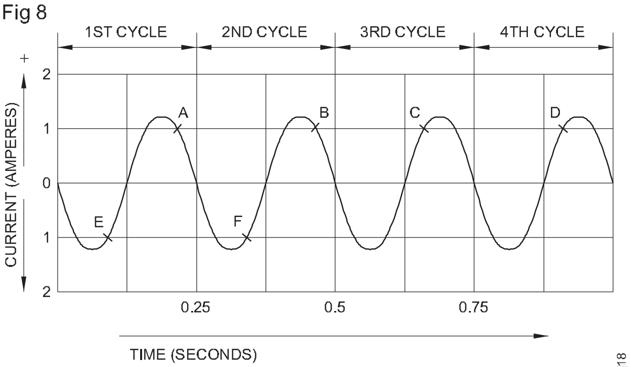


Period: The time required to produce one complete cycle is called the period of the wave-form. In Fig 8, it takes 0.25 seconds to complete one cycle. Therefore, the period (T) of that wave-form is 0.25 seconds.

The period of a sine wave (any symmetrical wave-form) need not necessarily be measured between the zero crossings at the beginning and the end of a cycle. It can be measured from any point in a given cycle to the corressponding point in the next cycle. (See Fig 8-AB, CD or EF.)

Frequency: The frequency of an AC sine wave is the number of cycles produced per second.(Fig 8) The SI unit of frequency is the hertz (Hz). For example, the 240V AC at your home has a frequency of 50 Hz.

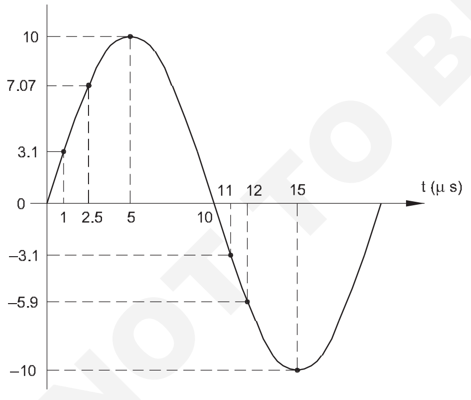
Fig 8



CYCLE, PERIOD, AND FREQUENCY. THE WAVEFORM HAS A PERIOD OF 0.25 SECONDS AND FOUR CYCLES PER SECOND.

Instantaneous value: The value of an alternating quantity at any particular instant is called instantaneous value. The instantaneous values of a sine wave voltage is shown in Fig 9. It is 3.1 volts at 1μs, 7.07 V at 2.5μs, 10V at 5μs, 0V at 10μs, 3.1 volt at 11 μs and so on.

Fig 9

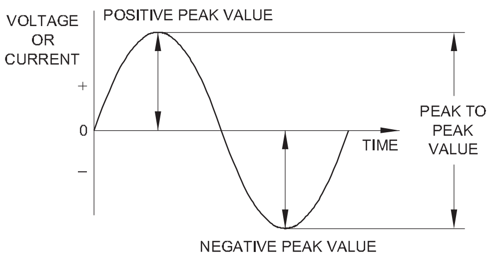


EXAMPLE OF INSANTANEOUS VALUES OF A SINE WAVE VOLTAGE

AC voltage and current values: Since the value of a sine wave of voltage or current continuously changes, one must be specific, while referring to and describing the values of the wave-form . There are several ways of expressing the value of a sine wave.

Peak value or maximum value: Each alternation of the sine wave is made up of a number of instantaneous values. These values are plotted at various heights above and below the horizontal line to form a continuous wave-form. (Fig 10)

Fig 10



PEAK TO PEAK VALUE OF A SINE WAVE

The peak value of a sine wave refers to the maximum voltage or current value. Note that two equal peak values occur during one cycle.

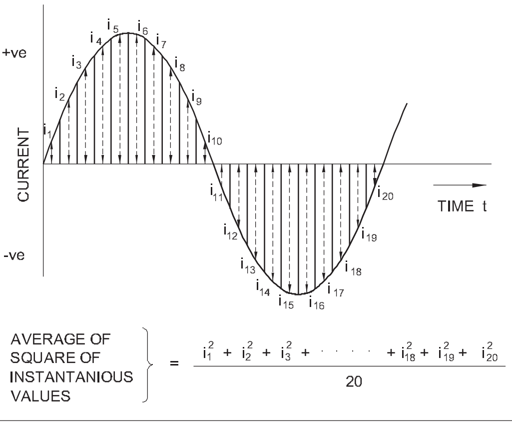
Peak-to-peak value: The peak-to-peak value of a sine wave refers to its total overall value from one peak to the other. (Fig 10) It is equal to two times the peak value.

Effective value: The effective value of an alternating current is that value which will produce the same heating effect as a specific value of a steady direct current. In other words, an alternating current has an effective value of 1 ampere, if it produces heat at the same rate as the heat produced by 1 ampere of direct current, both flowing in the same value of resistance.

Another name for the effective value of an alternating current or voltage is the root mean square (rms) value. This term was derived from a method used to compute the value. The rms is calculated as follows.

The instantaneous values for one cycle are selected for equal periods of time. Each value is squared, and the average of the squares is calculated (values are squared because the heating effect varies as square of the current or voltage). The square root of this is the rms value. (Fig 11)

Fig 11



By using this method it can be proved that the effective value of a sine wave of current is always equal to 0.707 times its peak value. A simple equation for calculating the effective value of sine wave is:

for voltage, $V = 0.707\ V_m$
for current, $I = 0.707\ I_m$

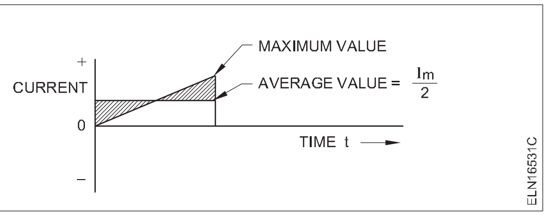
where subscript m refers to the maximum value.

When an alternating current or voltage is specified, it is always the effective value that is meant, unless otherwise stated. Standard AC meters indicate effective values only.

Average value: It is sometimes useful to know the average value for one half cycle. If the current is changed at the same rate over the entire half cycle as in Fig 12, the average value would be one half of the maximum value.

However, because the current does not change at the same rate, another method is used. Find the area covered by the curve over the horizontal axis, then divide that area by the base horizontal length. It has been determined that the average value is equal to 0.637 times the maximum value for sine wave-form i.e.

Fig 12



for voltage, $V_{av} = 0.637 V_m$

for current, $I_{av} = 0.637 I_m$

where subscript av refers to the average value and subscript m refers to the maximum value.

Form factor (k_f): Form factor is defined as the ratio of effective value to average value of half cycle.

For sinusoidal AC

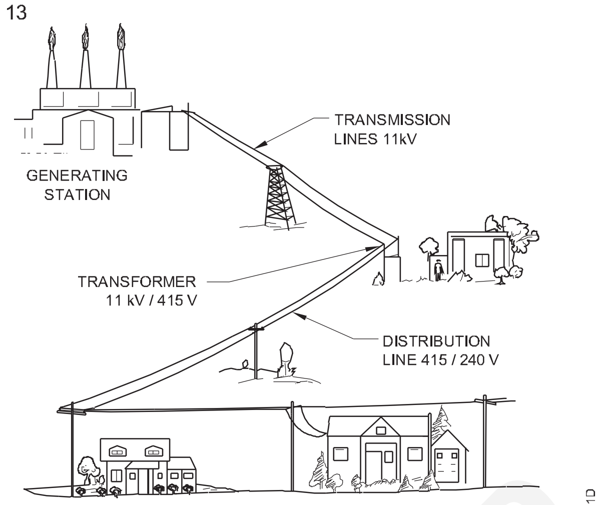
$$\phi = \frac{NI}{S}$$

where the subscript m refers to the maximum value.

Advantages of AC over DC:

1. AC voltages can be raised or lowered with ease. This makes it ideal for transmission purposes.
2. Large amounts of power can be transmitted at high voltage and low currents with minimum loss.
3. Because the current is low, smaller transmission wires can be used to reduce installation and maintenance costs. (Fig 13)

Fig 13



TRANSMISSION AND DISTRIBUTION LINES FROM GENERATING STATION TO RESIDENCES

DC generators limit their output voltage to 6000V or less. The voltage cannot be raised or lowered through the transformers. Long distance transmission requires heavy cables. AC generators are built with a capacity up to 500000 kilowatts. The DC generators capacity is limited to 10000 kw.

AC motors are less expensive to build, install and maintain than the DC motors. DC motors have one distinct advantage over AC motors: they have better speed control.

- AC is easy to generate than DC.
- It is cheaper to generate AC than DC.
- AC generators take higher efficiency than DC.
- The loss of energy during transmission in negligible for AC in long distance.
- The AC can be easily converted to DC.
- It can easily stepup or stepdown using transformer.
- The value or magnitude of AC can be decreased easily without loss of excess of energy using choke.

Neutral and earth conductors

Objectives: At the end of this lesson you shall be able to
- **describe the purpose of earthing**
- **describe the two types of earthing**
- **differentiate between `neutral' and `earth wire'.**

Earthing: The importance of earthing lies in the fact that it deals with safety. One of the most important, but least understood, considerations in the design of electrical systems is that of earthing (grounding). The word `earthing' comes from the fact that the technique itself involves making a low-resistance connection to the earth or to the ground. The earth can be considered to be a large conductor which is at zero potential.

Purpose of earthing: The purpose of earthing is to provide protection to personnel, equipment and circuits by eliminating the possibility of dangerous or excessive voltage.

There are two distinct considerations in the earthing of an electrical system: earthing of one of the conductors of the wiring system, and earthing of all metal enclosures which contain electrical wires or equipment. The two types of earthing are:

- System earthing
- Equipment earthing.

System earthing: This consists of earthing one of the wires of the electrical system, such as the neutral, to limit the maximum voltage to earth under normal operating conditions.

Equipment earthing: This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

What is an earthing electrode?: A metal plate, pipe or other conductors electrically connected to the general mass of the earth is known as an earthing electrode. Earth electrodes shall be provided at generating stations, substations and consumer premises (in accordance with the requirements of IS : 3043-1966).

The neutral used in single phase system is to provide return path for load current to the source. Various method of neutral earthing is provided to serve neutral in single phase distribution at substation according to the requirements.

What is an `earth wire'?: A conductor connected to earth and usually situated in proximity to the associated line conductors which is used for equipment earthing is called an earth wire.

The purpose of equipment earthing: By connecting the metal work not intended to carry current to earth, a path is provided for leakage current which can be detected, and, if necessary, interrupted by the following devices.

- Fuses
- Circuit breakers.

Identification of Cables:

Table 52A of IEE regulations

Colour identification of cores of non-flexible cables and bare conductors for fixed wiring	
Function	**Colour identification**
Protective (including earthing)conductor	Green-and-yellow
Phase of ac. single- or three-phase circuit	Red(or yellow or blue*)
Neutral of ac single- or three-phase circuit	Black
Phase R of 3-phase ac circuit	Red
Phase Y of 3-phase ac circuit	Yellow
Phase B of 3-phase ac circuit	Blue
Positive of dc 2-wire circuit	Red
Negative of dc 2-wire circuit	Black
Outer (positive or negative) of dc 2-wire circuit derived from 3-wire system	Red
Positive of 3-wire dc circuit	Red
Middle wire of 3-wire dc circuit	Black
Negative of 3-wire dc circuit	Blue

Various factors in AC and DC Systems

Objectives: At the end of this lesson you shall be able to
- **Define AC and DC System**
- **Describe the advantages and disadvantages of AC and DC Systems in Transmission line**

A DC System has a less potential stress over AC system for same Voltage level. Therefore, a DC line requires less insulation. In DC System, there is no interference with other communication lines and systems. In DC Line, Corona losses are very low as compared to the AC transmission lines.

In AC transmission system, the power can be transmitted for long distance and in DC transmission system, the losses are low. We use AC transmission in now a days transmission that is higher currents and it have 50hz frequency and low impedance. d.c in power lose is more but ac in power lose is less

Transmitting DC power over a long distance is inefficient. Thus AC supply is a far more efficient to transmit power. According to Siemens it's quite the opposite: Whenever power has to be transmitted over long distances, DC transmission is the most economical solution compared to high-voltage AC.

Alternating current (A.C) is five times more dangerous than Direct current (D.C). The

frequency of the alternating current is the main reason for this severe effect on the human body. ... At this frequency, even a small voltage of 25 volts can kill a person.

Ac is more preferred than dc because it is easy to maintain and change the voltage of ac for transmission and distribution purpose. Plant cost of ac transmission is much lower compared to dc transmission. When fault occurs it is easy to interrupt ac supply.

Advantages of DC Transmission

- There are two conductors are used in DC transmission while three conductors are required in AC transmission.
- There are no inductance and surges (High Voltage waves for very short time) in DC transmission.
- Due to the absence of inductance, there are very low voltage drop in DC transmission lines as compare to the AC (if both Load and Sending end Voltage is same)
- There is no concept of Skin effect in DC transmission lines. Therefore, conductor having small cross sectional area is required in DC transmission line.
- A DC System has a less potential stress over AC system for same Voltage level. Therefore, a DC line requires less insulation.
- In DC System, there is no interference with other communication lines and systems.
- In DC Line, Corona losses are very low as compared to the AC transmission lines.
- In High Voltage DC (HVDC) Transmission lines, there are no dielectric losses.
- In DC Transmission system, there are no difficulties in synchronizing and related stability problems.
- DC system is more efficient than AC, therefore, the rate of price of Towers, Poles, Insulators, and conductor are low so the system is economical.
- In DC System, the speed control range is greater than AC System.
- There is low insulation needed in the DC system (about 70%).
- The price of DC cables is low (due to low insulation).
- In DC Supply System, the Sheath losses in underground cables are low.
- DC system is suitable for High Power Transmission based on High Current transmission.
- In DC System, The Value of charging current is quite low, therefore, the length of the DC Transmission lines is greater than AC lines.

Disadvantages of DC Transmission:

- Due to commutation problem, electric power can't be produced at High (DC) Voltage.
- In High Voltage transmission, we cant step-up the level of DC Voltage (As Transformer won't work on DC).
- There is a limitation of DC switches and circuit breakers (and they are costly too).
- The motor generator set is used to step down the level of DC voltage and the efficiency of Motor-generator set is lower than a transformer.
- DC transmission system is more complex and costly as compared to the AC transmission system..
- The level of DC Voltage can not be changed (step-up or step-down) easily. So we can not get desire voltage for electrical and electronics appliances (such as 5 Volts, 9 Volts 15 Volts, 20 and 22 Volts etc) directly from the transmission and distribution lines.

Advantages of AC Transmission System

- AC Circuit breakers are cheaper than DC Circuit breakers.
- The repairing and maintenance of the AC sub station is easier and inexpensive than DC Substation.
- The Level of AC voltage may be increased or decreased by using step up and Step down transformers.

Disadvantages of AC System

- In AC line, the size of the conductor is grater than the DC Line.
- The cost of AC transmission lines is greater than DC Transmission lines.
- Due to skin effect, the losses in AC system are more.
- Due to the capacitance in AC transmission lines, a continuous power loss occurs when there is no load on the power lines or line is open at all.
- There are some additional line losses due to inductance.
- More insulation are required in AC transmission system.
- The corona losses occur in an AC transmission line system.
- AC transmission lines interfere with other communication lines.
- There are stability and synchronizing problems in AC System.
- AC transmission system is less efficient than the DC transmission System.
- There are difficulties in controlling the reactive power.

DC transmission system is better than the AC transmission system but still, the majority of power transmission is done in AC power lines due to cost and uses of transformers for changing the level of voltages at different levels for different purposes.

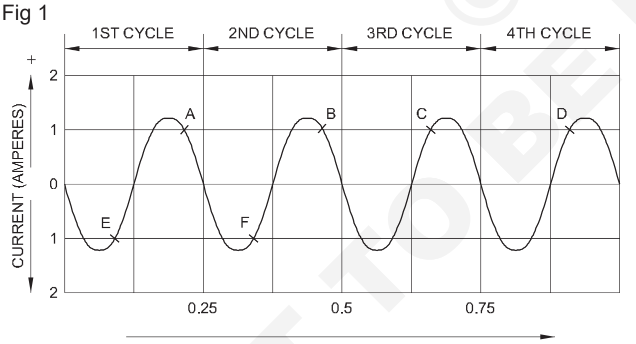
Although, mercury arc rectifier, thyratron, diodes and semiconductors can be used to easily convert AC into DC and DC into AC. Therefore, some countries transmit the electric power through DC power lines. The range of these DC power transmission is up to 100kV to 800kV+.

Related terms frequency, Instantaneous value, R.M.S. value Average value, Peak factor, form factor, power factor and Impedance etc

Objectives: At the end of this lesson you shall be able to

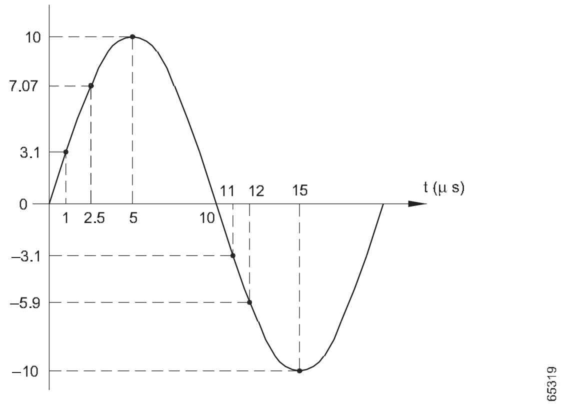
- **explain about various factors in AC supply**
- **compare the Single & Three phase system & Calculation of various factors in AC supply**

Fig 1



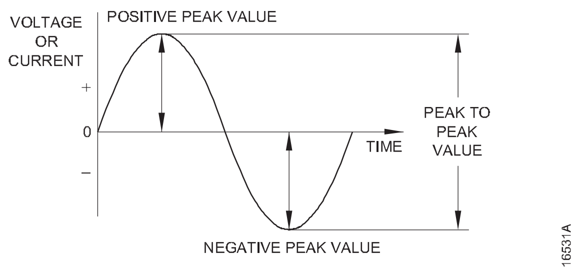
CYCLE, PERIOD, AND FREQUENCY. THE WAVEFORM HAS A PERIOD OF 0.25 SECONDS AND FOUR CYCLES PER SECOND.

Fig 2



EXAMPLE OF INSANTANEOUS VALUES OF A SINE WAVE VOLTAGE

Fig 3



PEAK TO PEAK VALUE OF A SINE WAVE

Instantaneous value: The value of an alternating quantity at any particular instant is called instantaneous value. The instantaneous values of a sine wave voltage is shown in Fig 1. It is 3.1 volts at 1μs, 7.07 V at 2.5μs, 10V at 5μs, 0V at 10μs, 3.1 volt at 11 μs and so on. (Fig 2)

AC voltage and current values: Since the value of a sine wave of voltage or current continuously changes, one must be specific, while referring to and describing the values of the wave-form . There are several ways of expressing the value of a sine wave.

Peak value or maximum value: Each alternation of the sine wave is made up of a number of instantaneous values. These values are plotted at various heights above and below the horizontal line to form a continuous wave-form. (Fig 3)

The peak value of a sine wave refers to the maximum voltage or current value. Note that two equal peak values occur during one cycle.

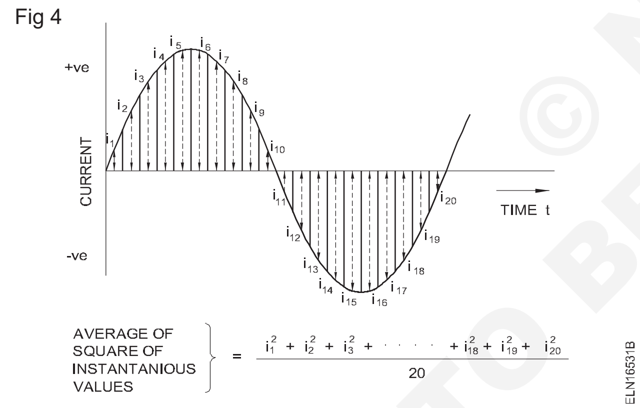
Peak-to-peak value: The peak-to-peak value of a sine wave refers to its total overall value from one peak to the other. (Fig 3) It is equal to two times the peak value.

Effective value: The effective value of an alternating current is that value which will produce the same heating effect as a specific value of a steady direct current. In other words, an alternating current has an effective value of 1 ampere, if it produces heat at the same rate as the heat produced by 1 ampere of direct current, both flowing in the same value of resistance.

Another name for the effective value of an alternating current or voltage is the root mean square (rms) value. This term was derived from a method used to compute the value. The rms is calculated as follows.

The instantaneous values for one cycle are selected for equal periods of time. Each value is squared, and the average of the squares is calculated (values are squared because the heating effect varies as square of the current or voltage). The square root of this is the rms value. (Fig 4)

Fig 4



By using this method it can be proved that the effective value of a sine wave of current is always equal to 0.707 times its peak value. A simple equation for calculating the effective value of sine wave is:

for voltage, $V = 0.707\ V_m$

for current, $I = 0.707\ I_m$

where subscript m refers to the maximum value.

Average value: It is sometimes useful to know the average value for one half cycle. If the current is changed at the same rate over the entire half cycle as in Fig 5, the average value would be one half of the maximum value.

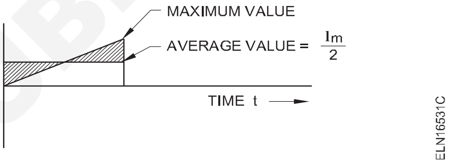
However, because the current does not change at the same rate, another method is used. Find the area covered by the curve over the horizontal axis, then divide that area by the base horizontal length. It has been determined that the average value is equal to 0.637 times the maximum value for sine wave-form i.e.

for voltage, $V_{av} = 0.637\ V_m$

for current, $I_{av} = 0.637 I_m$

where subscript av refers to the average value and subscript m refers to the maximum value.

Fig 5



Form factor (k_f): Form factor is defined as the ratio of effective value to average value of half cycle.

For sinusoidal AC

$$\phi = \frac{NI}{S}$$

where the subscript m refers to the maximum value.

Power and power factor in AC single phase circuit

Objective: At the end of this lesson you shall be able to

- **calculate power and power factor of a single phase AC circuit from the given relevant values.**

Power in pure resistance circuit: Power can be calculated by using the following formulae.

1) $P = V_R x\ I_R$ watts

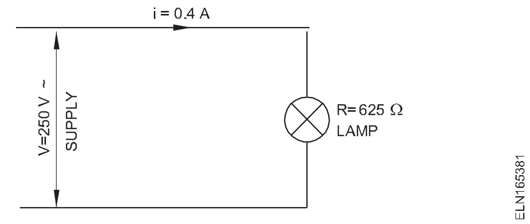
2) $P = I^2_R\ R$ watts

$C = \frac{0.5\ C}{25\ V} = 0.02F$

3) watts

Example 1: Calculate the power taken by an incandescent lamp rated 250V when it carries a current of 0.4A if the resistance is 625 ohms.(Fig 1)

Fig 1



$P = V_R x\ I_R$

$= 250 \times 0.4$

$= 100$ watts.

Alternately

$$P = I^2R$$

$$= 0.4 \times 0.4 \times 625$$

$$= 100 \text{ watts}$$

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots + \frac{1}{C_n}}$$

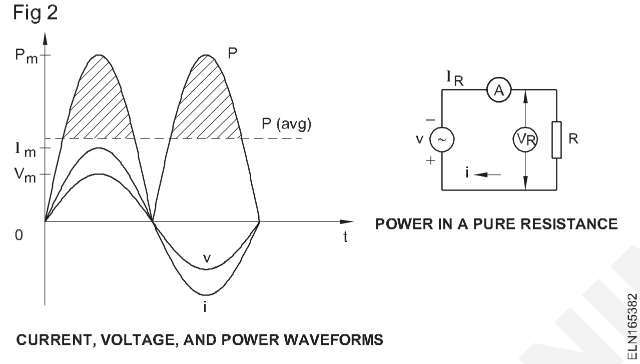
$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots + \frac{1}{C_n}$$

$$= 100 \text{ watts.}$$

Since the current and voltage are in phase, the phase angle is zero and the power factor is unity. Therefore, the power can be calculated with voltage and current itself.

Example 2: A wattmeter connected in an AC circuit indicates 50W. The ammeter connected in series with the load reads 1.5A. Determine the resistance of the load.

Fig 2



Solution

Known: $P = I_R^2R$

The circuit arrangement and wave-forms of I, V and P are shown in Fig 2.

Given: I = 1.5 amperes

P = 50 watts.

Therefore,

$$C_T = \frac{C_1\,C_2}{}$$

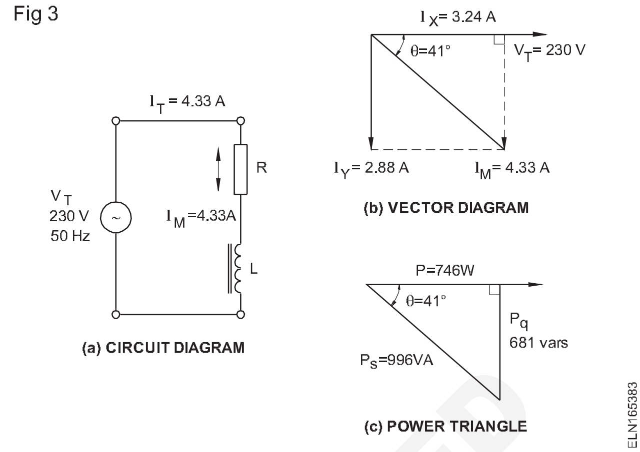
Power in pure inductance: If an AC circuit contains only inductance, the voltage and current are 90° out of phase, and the circuit of the instantaneous values of voltage and current gives with positive and negative power. Net result is the power consumed in a pure inductive circuit is zero.

Power in pure capacitance: If an AC circuit contains only capacitor, the voltage and current are 90°. Out of phase and the product of instantaneous values of voltage and current gives both positive and negative power. Net result is the power consumed in a pure capacitive circuit is zero.

Most industrial installations have a lagging PF because of the large number of AC induction motors that are inherently inductive.

Effect of a low power factor: To show the important effect of the power factor, let us consider a 240V, 50 Hz, 1 hp motor. Let us assume that it is 100% efficient so that it draws a true power of 746 W. Such a motor has a typical power factor of 0.75 lagging. (Fig 3)

Fig 3



To deliver 746 W from 240V at a power factor of 0.75 requires a current of

$$C_T = \frac{C_1\,C_2\,C_3}{(C_1C_2) + (C_2C_3) + (C_3C_1)}$$

C

Now let us assume that we can modify the motor in some way to make the power factor unity (I). The current now required is

$$I = \frac{P}{V \times \text{Cos}\,\theta}$$

$$I = \frac{746\text{W}}{240\text{V} \times 1} = 3.108\text{A}$$

Evidently, it requires a higher current to deliver a given quantity of true power if the power factor of the load is less than unity. This higher current means that more energy is wasted in the feeder wires serving the motor. In fact, if an industrial installation has a power factor less than 85% (0.85) overall, a `power factor penalty' is assessed by the electric utility company. It is for this reason that power factor correction is necessary in large installations.

Power factor correction: In order to make the most efficient use of the current delivered to a load we desire a high PF or a PF that approaches unity.

A low PF is generally due to the large induction loads such as discharge lamps, induction motors, transformers etc. which take a lagging current and produce heat which returns to the generating station without doing any useful work as such it is essential to improve or correct the low PF so as to bring the current as closely in phase with the voltage as possible. That is the phase angle θ is made as small as possible. This is usually done by placing a capacitor load which produces a leading current.

The capacitor is to be connected in parallel with the inductive load.

Power, energy and power factor in AC single phase system - Problems

Objectives: At the end of this lesson you shall be able to
- **state the relationship between power and power factor in single phase circuits**
- **state the connection diagram for measuring power factor using a direct reading meter.**

The power in a DC circuit can be calculated by using the formulae.

- $P = E \times I$ watts
- $P = E^2/R$ watts.

The use of the above formulae in AC circuits will give true power only if the circuit contains pure resistance. Note that the effect of reactance is present in AC circuits.

Power in AC circuit: There are three types of power in AC circuits.

- Active power (True power)
- Reactive power
- Apparent power

Active power (True power)**:** The calculation of active power in an AC circuit differs from that in a direct current circuit. The active power to be measured is the product of V x I x Cos θ where Cos θ is the power factor (cosine of the phase angle between current and voltage). This indicates that with a load which is not purely resistive and where the current and voltage are not in phase, only that part of the current which is in phase with the voltage will produce power. This can be measured with a wattmeter. It is measured in KW (or) MW (or) W

Reactive power (P_r): With the reactive power (wattless power)

$$P_r = V \times I \times \text{Sin}\,\theta$$

only that part of the current which is 90° out of phase (90° phase shift) with the voltage is used in this case. Capacitors and inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt/ampere reactive or vars. Unlike true power, reacitve power can do no useful work. It is measured in VAR (or) KVAR (or) MVAR.

Apparent power: The apparent power, $P_a = V \times I$.

The measurement can be made in the same way as for direct current with a voltmeter and ammeter.

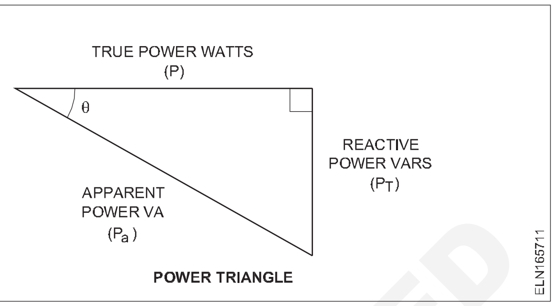
It is simply the product of the total applied voltage and the total circuit current and its unit is volt-ampere (VA).

The power triangle: A power triangle identifies three different types of power in AC circuits.

- True power in watts (P)
- Reactive power in vars (P_r)
- Apparent power VA (P_a)

The relationship among the three types of power can be obtained by referring to the power triangle. (Fig 1)

Fig 1



POWER TRIANGLE

Therefore

$$P_a^2 = P^2 + P_r^2 \text{ volt-amperes (VA)}$$

where `P_a' is the apparent power in volt-ampere (VA)

`P' is the true power in watts (W)

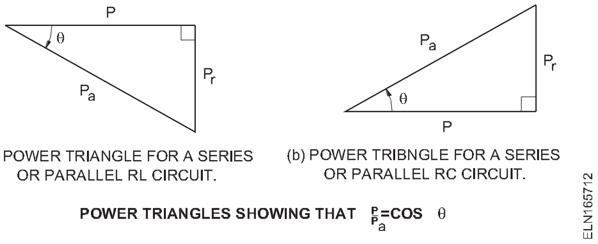
P_q is the reactive power in volt-amperes reactive. (VAR)

Power factor: The ratio of the true power delivered to an AC circuit compared to the apparent power that the source must supply is called the power factor of the load. If we examine any power triangle (Fig 2), you may see the ratio of the true power to the apparent power is the cosine of the angle θ.

$$\text{Power factor} = \frac{P}{P_a} = \text{Cos}\,\theta$$

From the equation, you can observe that the three powers are related and can be represented in a right-angled power triangle, from which the power factor can be obtained as the ratio of true power to apparent power. For inductive loads, the power factor is called lagging to distinguish it from the leading power factor in a capacitive load. (Fig 2)

Fig 2



(a) POWER TRIANGLE FOR A SERIES OR PARALLEL RL CIRCUIT.

(b) POWER TRIBNGLE FOR A SERIES OR PARALLEL RC CIRCUIT.

POWER TRIANGLES SHOWING THAT $\frac{P}{P_a}$=COS θ

A circuit's power factor determines how much current is necessary from the source to deliver a given true power. A circuit with a low power factor requires a higher current than a unity power factor circuit.

Single phase energy

The product of true power and time is known as energy.

(ie) Energy = T.Power x time

= Voltage x current x power factor x time

= VI Cos θ x t (time is in hour)

The unit of energy is watt hour and commercial unit is represented in 'KWH' (or) unit. (Board of trade unit. B.O.T)

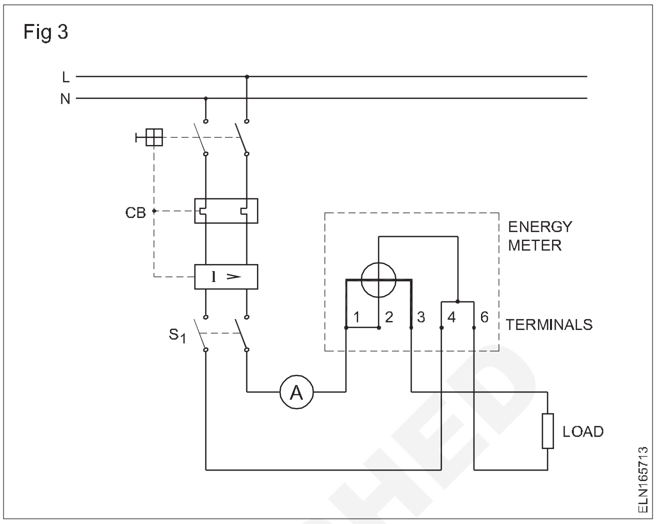
The energy depends upon the following factors:

- Voltage
- Current
- Power factor (load)
- Time

Single phase energy can be measured by energy meter. It contains 4 terminals (Incoming 2 and outgoing 2 common neutral)

The connection is shown in Fig 3.

Fig 3



Single Phase and three-phase system

Objectives: At the end of this lesson you shall be able to

- **differentiate single phase and 3 phase system**
- **define 3-phase star and delta connection.**

In electricity, the phase refers to the distribution of a load. What is the difference between single-phase and three-phase power supplies? Single-phase power is a two-wire alternating current (ac) power circuit. Typically, there is one power wire—the phase wire—and one neutral wire, with current flowing between the power wire (through the load) and the neutral wire. Three-phase power is a three-wire ac power circuit with each phase ac signal 120 electrical degrees apart.

Residential homes are usually served by a single-phase power supply, while commercial and industrial facilities usually use a three-phase supply. One key difference between single-phase vs. three-phase is that a three-phase power supply better accommodates higher loads. Single-phase power supplies are most commonly used when typical loads are lighting or heating, rather than large electric motors.

Single-phase systems can be derived from three-phase systems. In the US, this is done via a transformer to get the proper voltage, while in the EU it is done directly. Voltage levels in the EU are such that a three-phase system can also serve as three single-phase systems.

Single-phase vs. three-phase power

One other important difference between 3-phase power vs. single phase power is the consistency of the delivery of power. Because of the peaks and dips in voltage, a single-phase power supply simply does not offer the same consistency as a three-phase power supply. A three-phase power supply delivers power at a steady, constant rate.

Comparing single-phase vs. three-phase power, three-phase power supplies are more efficient. A three-phase power supply can transmit three times as much power as a single-phase power supply, while only needing one additional wire (that is, three wires instead of two). Thus, three-phase power supplies, whether they have three wires or four, use less conductor material to transmit a set amount of electrical power than do single-phase power supplies.

Difference between 3-phase and single-phase configurations

Some three-phase power supplies do use a fourth wire, which is a neutral wire. The two most common configurations of three-phase systems are known as wye and delta. A delta configuration has only three wires, while a wye configuration may have a fourth, neutral, wire. Single-phase power supplies have a neutral wire as well.

Both single-phase and three-phase power distribution systems have roles for which they are well-suited.

But the two types of systems are quite different from each other.

The comparison between single phase supply system and three phase supply system is summarized in the below table.

Single Phase Supply	Three Phase supply
Power delivered is pulsating	Power delivered is constant
Single Phase induction motors are not self starting as it does not have starting torque.	Three phase induction motors are self starting.
Parallel operation is not easy.	Parallel Operation is easy.
Efficiency of single phase motor is lesser.	High efficiency.
Single phase motors have pulsating torque.	Three phase motors have uniform torque.
Single phase motors have lower power factor.	Three phase motors have higher power factor.

Concept of three-phase Star and Delta connection

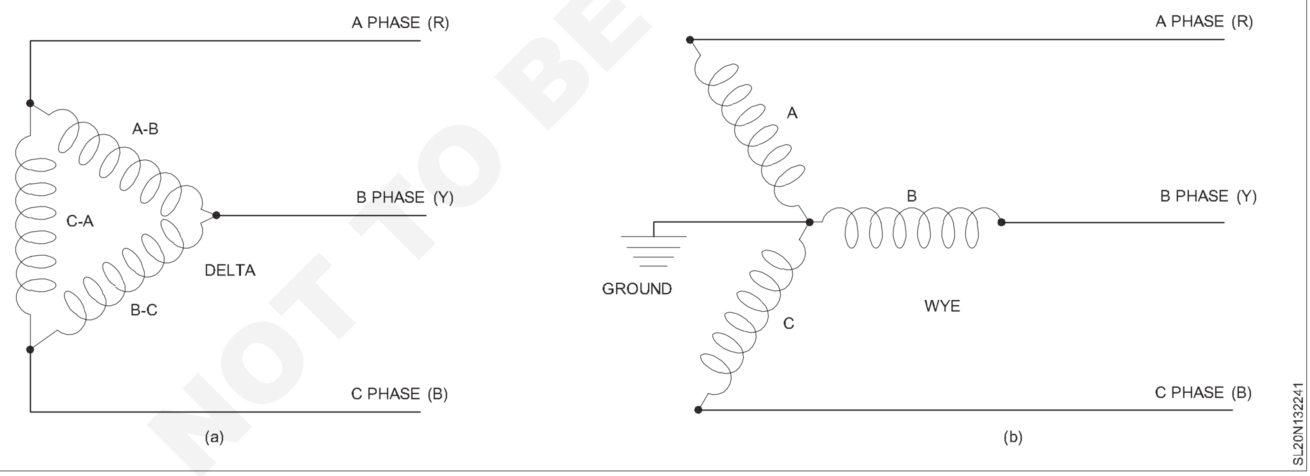
Objectives: At the end of this lesson you shall be able to
- **define single phase system and poly phase system**
- **state advantages of poly phase system**
- **compare single phase and three phase supply.**

In a three phase circuit, there are two types of connections. One is known as Star Connection, and the other one is Delta Connection. A star connection has a common or a star point to which all the three terminals are connected forming a star shape as shown below.

In Delta connection, all the three terminals are connected together forming a closed loop. In this, there is no common or neutral point, and it is used for power transmission for short distances. The connection diagram is shown.

Difference between star and delta connection are explained considering various factors like the basic definition of the connections, the existence of a neutral point, the connection of the terminals, the relation between line current and phase current and also between line voltage and phase voltage, speed, its insulation level, number of turns, type of system and network usage etc.

Fig 1



Basis	Star connection	Delta connection
Basic Definition	The terminals of the three branches are connected to a common point. The network formed is known as Star Connection	The three branches of the network are connected in such a way that it forms a closed loop known as Delta Connection
Connection of terminals	The starting and the finishing point that is the similar ends of the three coils are connected together	The end of each coil is connected to the starting point of the other coil that means the opposite terminals of the coils are connected together.
Neutral point	Neutral or the star point exists in the star connection.	Neutral point does not exist in the delta connection.
Relation between line and phase current	Line current is equal to the Phase current.	Line current is equal to root three times of the Phase Current.
Relation between line and phase voltage	Line voltage is equal to root three times of the Phase Voltage	Line voltage is equal to the Phase voltage.
Speed	The Speed of the star connected motors is slow as they receive 1/√3 of the voltage.	The Speed of the delta connected motors is high because each phase gets the total of the line voltage.
Phase voltage	Phase voltage is low as 1/√3 times of the line voltage.	Phase voltage is equal to the line voltage.
Number of turns	Requires less number of turns	Requires large number of turns.
Insulation level	Insulation required is low.	High insulation is required.
Network Type	Mainly used in the Power Transmission networks.	Used in the Power Distribution networks.
Received voltage	In Star Connection each winding receive 230 volts	In delta connection each winding receives 414 volts.
Type of system	Both Three phase four wire and three phase three wire system can be derived in star connection.	Three phase four wire system can be derived from the Delta connection.

Points to rememeber:

1 The terminals of the three branches are connected to a common point. The network formed is known as Star Connection. The three branches of the network are connected in such a way that it forms a closed loop known as Delta Connection.

2 In a star connection, the starting and the finishing point ends of the three coils are connected together to a common point known as the neutral point. But in Delta connection, there is no neutral point. The end of each coil is connected to the starting point of the other coil that means the opposite terminals of the coils are connected together.

3 In Star connection, the line current is equal to the Phase current, whereas in Delta Connection the line current is equal to root three times of the Phase Current.

4 In Star connection, line voltage is equal to root three times of the Phase Voltage, whereas in Delta Connection line voltage is equal to the Phase voltage.

5 The Speed of the star connected motors is slow as they receive 1/√3 of the voltage but the Speed of the delta connected motors is high because each phase gets the total of the line voltage.

6 In Star Connection, Phase voltage is low as 1/√3 times of the line voltage, whereas in DeltaConnection Phase voltage is equal to the line voltage.

7 Star Connections are mainly required for the Power Transmission Network for longer distances, whereas in Delta connection mainly in Distribution networks and is used for shorter distances.

8 In Star Connection, each winding receives 230 volts and in Delta Connection, each winding receives 415 volts.

9 Both 3 phase 4 wire and 3 phase 3 wire system can be derived in the star connection, whereas in Delta Connection only 3 phase 4 wire system can be derived.

10 The amount of Insulation required in Star Connection is low and in Delta Connection high insulation level is required.

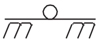
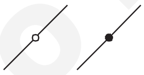
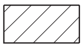
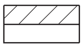
I.E. rules on electrical wiring

Objectives: At the end of this lesson you shall be able to
- **interpret the various BIS symbols used in electrical wiring diagrams**
- **explain the properties of Three phase Balanced System and Unbalanced system**
- **differentiate between Three Phase Balanced System and Unbalanced system.**

In electrotechnical engineering the symbols are used in layouts and wiring circuits to represent the electrical parts or the function of the circuit.

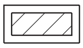
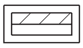
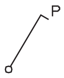
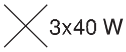
Since the drawing of the actual device is very laborious and would be drawn by each person differently, standardised symbols are used. With the help of the symbols, an electric circuit can be represented easily and can be described precisely as well.

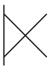
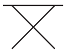
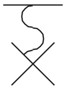
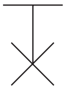
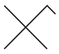
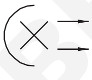
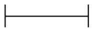
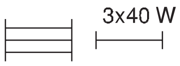
The symbol represents only the function of a part irrespective of the structure and form.

I **Wiring**	
1 General wiring	
2 Wiring on the surface	
3 Wiring under the surface	
4 Wiring in conduit	
a Conduit on the surface	
b Conduit concealed	
The type of conduit may be indi-cated, if necessary.	
5 Wiring going upwards	
6 Wiring going downwards	
7 Wiring passing vertically through a room	
II **Fuse-boards**	
1 Lighting circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
2 Power circuit fuse-boards	

Depending on the purpose of an application, different wiring schemes are used. For example, current flow diagram representation, plans of installation etc. the symbols of various plans of installation (layout) and the current flow diagrams (circuit diagram) differ from one another. A few examples of standard symbols recommended by B.I.S. 2032 (different parts) used for wiring are given here.

The B.I.S. Symbols used in the wiring is given here.

a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
III **Switches and switch outlets**	
1 Single pole pull-switch	
2 Pendent switch	
IV **Socket outlets**	
1 Combined switch and socket outlet, 6A	
2 Combined switch and socket outlet, 16A	
3 Interlocking switch and socket outlet, 6A	
4 Interlocking switch and socket outlet 16A	
V **Lamps**	
1 Group of three 40 W lamps	

2 Lamp,mounted on a wall or light bracket	
3 Lamp, mounted on ceiling	
4 Counterweight lamp fix ture	
5 Chain lamp fixture	
6 Pendent lamp fixture	
7 Lamp fixture with built-in switch	
8 Lamp fed from variable voltage supply	
9 Emergency lamp	
10 Panic lamp	
11 Bulk-head lamp	
12 Watertight light fitting	
13 Batten lamp-holder (Mounted on the wall)	
14 Projector	
15 Spotlight	
16 Floodlight	
17 Fluorescent lamp	
18 Group of three 40W fluorescent lamps	

Indian Electricity Rules - Safety Requirements

The IE rules 1956 was made under sections 37 of Indian Electricity Act 1910. Now it is redefined after the enactment of the Electricity Act 2003. The Central Electricity Authority (measures relating to safety and electric supply) Regulation (CEAR) 2010 which came into effect from 20th September 2010, in place of Indian Electricity Rules 1956.

SAFETY RULES: Among safety rules, the following are important and indeed requires attention. Every rule in the Indian Electricity Rules 1956 is related either directly or indirectly to safety.

Rule 32: Switches shall be on the live conductor. No cutout, link or switch other than gang switch shall be inserted in the neutral conductor. Code of Practice of wiring shall be followed while marking the conductors.

Rule 50: Energy shall not be supplied, transformed, converted or used unless the following provisions are observed. A suitable linked switch or circuit breaker is erected at the secondary side of the transformer. Every circuit is protected by a suitable cut-out. Supply to each motor or group of motors is controlled by a linked switch or circuit breaker. Adequate precautions are taken to ensure that no live parts are exposed.

Special provisions in respect of high and extra high voltage installations

Rule 63: Approval of Inspector is necessary before energizing any high voltage installations.

Rule 65: The installation must be subjected to the prescribed testing before energizing.

Rule 66: Conductors shall be enclosed in a metallic covering and suitable circuit breakers shall be provided to protect the equipment from overloading.

Rule 68: Incase of outdoor type of sub-station a metallic fencing of not less than 1.8 m height shall be erected around the transformer.

Provisions in terms of OH line

Rule 77: Clearance of lowest conductor above ground across street.

- Low and Medium Voltage lines - 5.8 m.
- High voltage Lines - 6.1 m.
- Clearance of lowest conductor above ground along a street. Low and Medium Voltage lines - 5.5 m.
- High voltage lines - 5.8 m.
- Clearance of lowest conductor above ground other than along or across the street. Low, Medium and High Voltage lines upto 11 KV if bare - 4.6m .
- Low, Medium and High upto and including 11KV, if insulated - 4.0m.
- High Voltage above 11 KV - 5.2 m.

Rule 79: Clearance of low and medium voltage lines from building,

- Vertical Clearance - 2.5 m.
- Horizontal clearance - 1.2 m.

Rule 80: Clearance from building of high and extra high voltage. Vertical Clearance High Voltage upto 33KV - 3.7m.

- Extra High Voltage above 33KV - 3.7 m, plus 0.3 m for every 33KV part there of.
- Clearance from building of high and extra high voltage - Pitched Roof . Vertical Clearance upto 11KV - 1.2m.
- Above 11KV upto 33KV - 2.2 m.
- Above 33KV - 2m. plus 0.3m for every 33KV part there of.

Rule 85: Maximum interval between supports. It shall not exceed 65 m except by prior approval of inspector.

Indian electricity rules regarding to internal wiring:

1 The minimum size of conductor used in domestic wiring must not be of size less than 1/1.12mm in copper or 1/1.40mm (1.5mm) in aluminium wire.

2 For flexible wires the minimum size is 14/0.193mm.

3 The height at which meter board, Main switch board are to be fitted 1.5 meters from ground level.

4 The casing will be run at a height of 3.0 meters from the ground level.

5 The light brackets should be fixed at a height of 2 to 2.5 meters from ground level.

6 The maximum number of points in a sub circuit is 10.

7 The maximum load in a sub circuit is 800W.

I.E. Rules regarding - Voltage drop concept:

1 **I.E. Rule 48:** The insulation resistance between the wiring of an installation and earth should be of such a value that the leakage current may not exceed 1/50000 the part or 0.02 percent of the F.L. current.

2 The permissible voltage drop in a lighting circuit is 2% of the supply voltage plus one volt.

3 The maximum permissible voltage drop in a power industrial circuit should not be more than 5% of the declared supply voltage.

4 The insulation resistance of any wiring installation should not be less than 1MÙ .

5 The earth resistance should not exceed the value of one ohm.

I.E. Rules regarding to power wiring:

1 In a power sub circuit the load is normally restricted to 3000 watts and number of outlets to two in each sub circuit.

2 All equipment used in power wiring shall be iron clad construction and wiring shall be of the armoured cable or conduit type.

3 The length of flexible conduit used for connections between the terminal boxes of motors and starters, switches and motors shall not exceed 1.25 meters

4 Every motor, regardless of its size shall be provided with a switch fuse placed near it.

5 The minimum cross-sectional area of conductor, that can be used for power mining of 1.25 mm for copper conductor cables and 1.50 mm for Aluminium conductor cables (refer ISI recommendations). Hence VIR or PVC cables of size lower than 3/0.915 mm copper or 1/1.80 mm Aluminium can not be used for motor wiring.

Types of wiring : Domestic and Industrial - selection of cable size

Objectives: At the end of this lesson you shall be able to
- **state the types wiring used in domestic installations**
- **state the use of cord grip and underwriter's knot.**

Introduction

The type of wiring to be adopted is dependent on various factors viz. location durability, safety, appearance, cost and consumer's budget etc.

Types of wiring

The following are the types of internal wiring used in domestic installations.

- Cleat wiring (for temporary wiring only)
- CTS/TRS (batten) wiring
- Metal/PVC conduit wiring, either on surface or concealed in the wall.
- PVC casing & capping wiring

Types of electrical wiring

Objectives: At the end of this lesson you shall be able to
- **explain the types of electrical wiring and their application**
- **state the advantages and disadvantages of each types.**

Many wiring systems are developed to meet the safety requirements, economy of cost, easy maintenance and trouble shooting. A particular system can be chosen according to technical requirements but the system needs to be approved by the local electricity authorities. The following are the fundamental requirements for any wiring system. They are:

i For safety, switches should control the live phase wire. The second terminal of the switch called as half wire should be connected to the appliance or socket through the wire. The neutral can be connected directly to the appliance, socket or lamp. This enables the workman to rectify the defects of the particular lamp or appliance by switching off the particular circuit only and the main supply need not be switched 'off'.

ii For safety, fuses should be placed in the live/phase wire only. The lamp should not get supply when the fuse is blown.

iii To supply the rated voltage, parallel connections should be given to all lamps and appliances.

Types of wiring system: There are three types of wiring systems used for tapping supply from mains to the different branches. They are as follows.

1 Tree system

2 Ring main system

3 Distribution board system

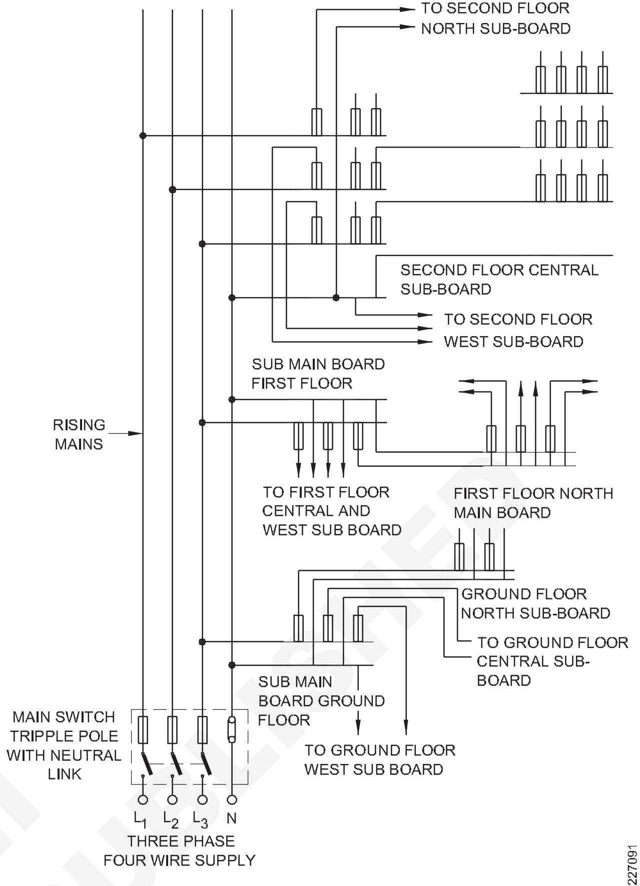
Tree system: In this system, copper or aluminium strips in the form of bus bars are used to connect the main supply to the raising mains (Fig1). This system is suitable for multi-story buildings and the bus bar trunking space is provided in the building at a convenient location and at load centres for the purpose of economy.

At each floor the running main is connected to the sub-main board through proper cable terminations. If there are more than one flat in each floor the individual main switches for the flat get their supply from the sub-main board through a distribution network which may include an energy meter for each flat.

However the system adopted within the flat will be the distribution board system.

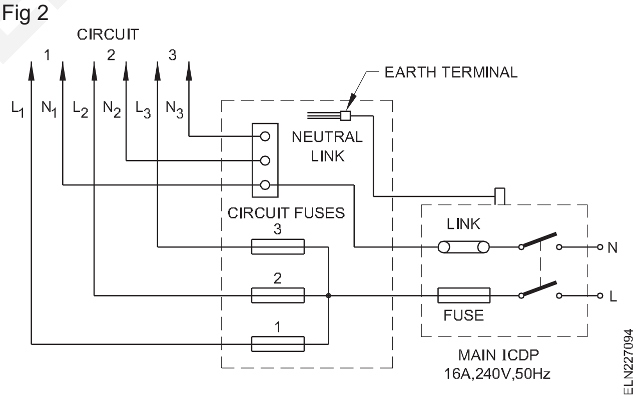
Distribution board system: This is the most commonly used system. This system enables the appliances connected to the system to have the same voltage. The main switch is connected to the distribution board through suitable cables. The distribution board has a number of fuses depending upon the number of circuits required in the installation, and the phase and neutral cable of each phase are taken from the distribution board (Fig 2).

Fig 1



WIRING OF BUILDING BY TREE SYSTEM

Fig 2



Study of wiring accessories e.g. switches, fuses, relays, MCB, ELCB, MCCB, switchgears etc

Objective: At the end of this lesson you shall be able to
- **explain the purpose of switches and their types.**

Types of switches according to their function and place of use

1 Single pole, one-way switch

2 Single pole, two-way switch

3 Intermediate switch

4 Bell-push or push-button switch

5 Pull or ceiling switch

6 Double pole switch (DP switches)

7 Iron clad double pole, (ICDP) switch.

8 Iron clad triple - pole (ICTP) switch.

Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Fuses

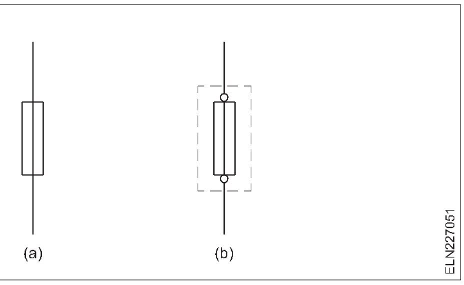
Objectives: At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **classify the different types of fuses and their uses.**

Purpose of fuses: A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols: These are the graphical symbols used to illustrate an electrical fuse in electro-technical diagrams.

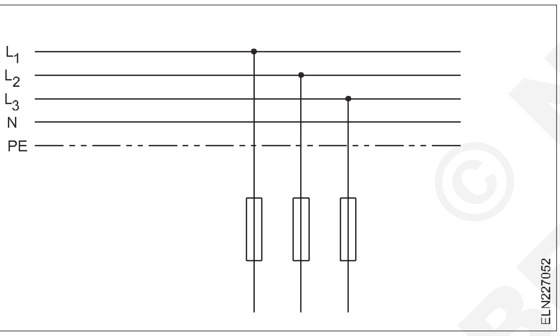
- General symbols of a fuse (Fig 1a)
- Fuse with terminals and protective housing (Fig 1b)

Fig 1



Placement of fuses: In electrical installations, the fuses are always connected into the live wires (Fig 2) and never into the neutral N or the protective earth line PE.

Fig 2



Terminology

Fuse element: The part of the fuse which is designed to melt and open up a circuit.

Fuse-carrier: The removable portion for carrying the fuse element.

Fuse base: The fixed part of the fuse provided with terminals for connection to the circuit which is suitable for the reception of the fuse- carrier.

Current rating: Safe maximum current that can pass continuously without overheating.

Fusing current: The current at which the fuse element melts.

Cut-off factor: Time (period) taken by a fuse to interrupt the circuit in the event of a fault.

Fusing factor: Ratio between minimum fusing current and current rating.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current}}$$

The fusing factor for a re-wirable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

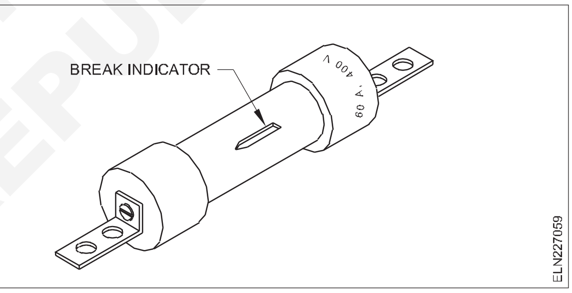
However, a fuse selected for over-current protection should not have a fusing factor of more than 1.4.

Types of fuses used in domestic wiring:

- Re-wirable type (up to 200A)
- Cartridge type (up to 1250A)

High rupturing capacity (HRC) fuses (Fig 3): They are cylindrical in shape and are made of a ceramic body filled in with a chemically treated filling powder or silica to quench the arcing quickly without any fire hazard.

Fig 3



Normally a silver alloy is used as the fusing element and when it melts due to the excessive current, it combines with the surrounded sand/powder, and forms small globules without making an arc, spark or gas. HRC fuses can open a short-circuited circuit within 0.013 second. It has an indicator to show the fuse has blown. The rupturing capacity of the fuse could be calculated from the following formula.

Rupturing capacityin MVA = Fault current x Circuit in
amperes voltage

As HRC fuses are capable of opening circuits having very high faulty currents, these are preferred in high power circuits even though the replacement cost is high.

Relays - types - symbols

Objectives: At the end of this lesson you shall be able to
- **define a relay and classify the relays**
- **classify relays according to the operating force and function**
- **state the common codes used for specifying contacts and poles**
- **specify a relay**
- **explain the function of the shading coil in an AC relay**
- **state the causes of the failure of the relay**
- **identify the symbols used in relay as per I.S.2032 (Part XXVII).**

Relay: A relay is a device which opens or closes an auxiliary circuit under predetermined conditions in the main circuit.

Relays are extensively used in electronics, electrical engineering and many other fields.

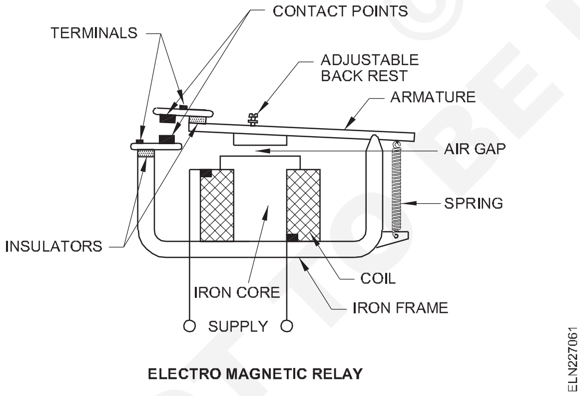
There are relays that are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

Relays are also classified according to their main operating force as stated under.

- Electromagnetic relays
- Thermal relays

Electromagnetic relay: A relay switch assembly is a combination of movable and fixed low-resistance contacts that open or close a circuit. The fixed contacts are mounted on springs or brackets, which have some flexibility. The movable contacts are mounted on a spring or a hinged arm that is moved by the electromagnet in the relay (Fig 1).

Fig 1



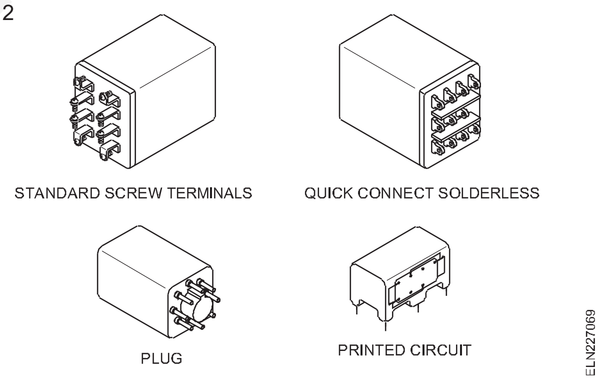
The other types of relays coming under this group are as follows.

Current sensing relay: A current sensing relay functions whenever the current in the coil reaches an upper limit. The difference between the current specified for pick up (must operate) and non-pick up (must not operate) is usually closely controlled. The difference in current may also be closely controlled for drop out (must release) and non-drop out (must not release).

Under-current relay: Under-current relay is an alarm or protective relay. It is specifically designed to operate when the current falls below a predetermined value.

Voltage sensing relay: A voltage sensing relay is used where a condition of under-voltage or over-voltage may cause a damage to the equipment. For example, these types of relays are used in voltage stabilizers. Either a proportional AC voltage derived from a transformer or a proportional DC derived from a transformer and rectifier used for this purpose.

Fig 2



Circuit Breaker (CB) - Miniature Circuit Breaker (MCB)- Moulded Case Circuit Breaker (MCCB)

Objectives: At the end of this lesson you shall be able to
- **explain the types, working principle and parts of a miniature circuit breaker.**
- **state the advantages and disadvantages of MCB**
- **explain the working of combination circuit breaker (ELCB + MCB)**
- **state the categories and applications of MCBs**
- **state the application, advantage and disadvantage of MCCBs.**

Circuit Breaker

A circuit breaker is a mechanical switching device capable of making, carrying and breaking the currents under normal condition and breaking the currents under abnormal conditions like a short circuit.

Miniature circuit breaker (MCB)

A miniature circuit breaker is a compact mechanical device for making and breaking a circuit both in normal condition and in abnormal conditions such as those of over current and short circuit.

Types of MCB's

MCBs are manufactured with three different principles of operation namely

a Thermal Magnetic

b Magnetic hydraulic and

c Assisted bimetallic

Thermal magnetic MCB

The switching mechanism is housed in a moulded housing with phenolic moulded high mechanically strong switching dolly. This type of MCB is also provided with bimetallic overload release.

The electric current gets through two contact tips one each on moving and fixed contact of silver graphite.

An arcing chamber incorporating de-ionising arc chutes for control and quick suppression of the arc is provided in the gap between two contacts. It has a ribbed opening closed by metal grid which allows ventilation and escape of gases.

For protection against over-load and short circuit, MCB's have thermal magnetic release unit. The overload is taken care of by bimetallic strip, short circuit currents and over loads of more than 100% are taken care by solenoid.

Working

The bimetallic strip when flexing due to temperature rise caused by increasing normal rated current beyond 130% rotates a trip lever carrying an armature to which it is to brought into field of a solenoid. The solenoid is designed to attract the armature to full position at about 700% overload or instantaneous short circuit current.

For initial portion of current wise (130% to 400%) tripping of circuit breaker is due to thermal action, between 400 to 700% tripping is due to combined thermal and magnetic action and beyond 700% due to fully magnetic action.

Magnetic hydraulic MCB

Magnetic hydraulic circuit breaker operates on the principle of a solenoid and hydraulically damped plunger.

Construction and working

A movable ferrous plunger is held against a non-ferrous tube containing polysiloxane liquid which have flat temperature viscosity characteristic in temperature range of 20 to 60°C. The solenoid is a series coil in the circuit of MCB. As the plunger moves towards a pole piece, the reluctance of magnetic path.

Containing the armature is cumulatively reduced leading to some magneto motive force producing a progressively increasing flux. The armature is then attracted causing the mechanism to trip and open the controls on overload or short circuit. Instantaneous tripping occurs on very large currents 7 to 8 times the full load current. The construction of magnetic hydraulic tripping mechanism is in Fig 1.

Assisted Bimetal Tripping MCB

In the assisted bimetal form of construction, the time delay characteristic is provided by a thermally operated bimetal element which may be either directly or indirectly heated. Instantaneous tripping in short circuit condition is achieved by arranging a powerful magnetic pull to deflect the bimetal.

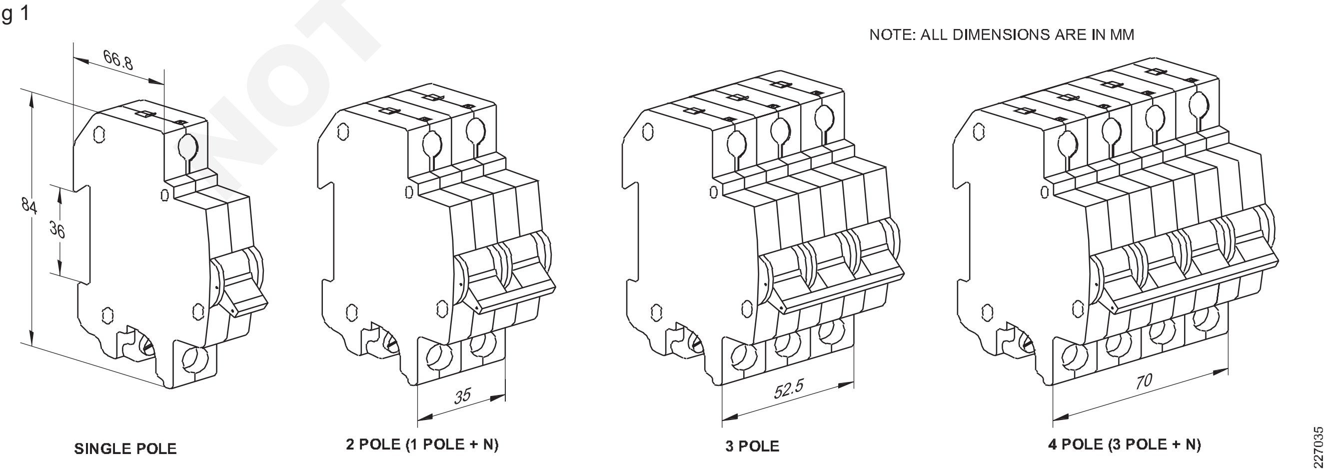
This method utilises the magnetic field which is produced when a current flows through the conductor. By locating the bimetal near to a substantial section of ferrous material, the magnetic field associated with current flowing in the bimetal will cause a sideways pull to be applied to the bimetal element, attracting the bimetal towards the ferrous material.

This sideways pull is arranged to coincide in direction with the normal direction of movement of the bimetal, which is powerful enough to deflect the bimetal (in heavy over load or short circuit condition) sufficiently to trip the breaker.

Design and rating of MCBs

MCBs are normally rated for 25°C ambient temperature and are available in the following various combination of poles and current ratings.

Fig 1



DIFFERENT TYPES OF MCB'S

Sl.No.	No. of poles	Current
1	Single pole MCB	0.5 to 60A
2	Double pole MCB (ie. 2 MCBs with common trip bar)	5 to 60A
3	Triple pole MCB	5 to 60A
4	Four pole MCB	5 to 60A

Isolators

An isolator is a switch. These cannot be used for automatic tripping. Isolators are not meant for either closing or breaking the circuit on load or short circuit. Isolators have the same physical dimensions of MCBs and are available in the following configurations and ratings.

No. of poles	Current rating
Single pole	30, 60, and 100A
Single pole with Neutral	30, 60, and 100A
Triple pole	60, and 100A
Four pole	60 and 100A

ELCB + MCB combination circuit breaker

Now a days some manufacturers have introduced an ELCB + MCB combination circuit breaker which can be used instead of using separate MCB and ELCB (earth leakage circuit breaker). This combination not only allows reduction in costs, but also ensures

- over current
- short circuit
- earth leakage
- earth fault.

Earth leakage circuit breakers are now generally called Residual Current circuit breakers (RCCB).

The rated load currents of the RCCB + MCB combination are 6A, 10A, 16A, 20A, 25A, 32A and 35A. The bimetal trip is so adjusted that no tripping will occur upto 1.3 times the rated current.

Categories of MCBs

Certain manufacturers like Indo Kopp manufacture the MCBs in three different categories namely ‘L’ series, ‘G’ series, and ‘DC’ series.

‘L’ series MCBs

‘L’ series MCBs are designed to protect circuits with resistive loads. They are ideal for protection of equipment like Geysers, ovens and general lighting systems.

‘G’ series MCBs

‘G’ series MCBs are designed to protect circuits with inductive loads. G series MCBs are suitable for protection of motors, air conditioners, hand tools, halogen lamps etc.,

‘DC’ series MCBs

‘DC’ series MCBs are suitable for voltage upto 220V DC and have a breaking capacity up to 6kA.

The tripping characteristics are similar to ‘L’ an ‘G’ series. They find extensive application in DC controls, locomotives, diesel generator sets etc.,

Advantages of MCB

1 Tripping characteristic setting can be done during manufacture and it cannot be altered.

2 They will trip for a sustained overload but not for transient overload.

3 Faulty circuit is easily identified.

4 Supply can be quickly restored.

5 Tamper proof.

6 Multiple units are available.

Disadvantages

1 Expensive.

2 More mechanically moving parts.

3 They require regular testing to ensure satisfactory operation.

4 Their characteristics are affected by the ambient temperature.

Application of (RCCB + MCB) combination circuit breakers

1 All residential premises can have incoming protection after energy meter instead of fixing fuse and main switch.

2 All domestic equipments like water heaters, washing machines, electric iron, pump sets etc.,

3 All construction and outdoor electrical equipments such as lifts, hosts, vibrators, polishing machines etc.,

4 All industrial distribution and equipments

5 All agriculture pump sets.

6 Operation theatres and electrically operated medical equipment such as X-ray machines.

7 All neon sign installations

8 All low and medium voltage electrical distributions.

Technical specification of MCBs

Related voltage	240/ 415V AC 50Hz Up to 220V DC
Current rating	0.5, 1, 1.6, 2, 2.5, 3, 4, 5, 6, 7.5, 10, 16, 20, 25, 32, 35, 40 and 63A.
No. of poles	1,2,3
Types	‘L’ ‘G’ and ‘DC’ series

Breaking capacity	UP to 9kA
Mechanical life	1,00, 000 operations
Electrical life	50,000 operations
Overload capacity	15% over load
Housing	Glass fiber reinforced polyester
Fixing	Snap fixing on 35 mm DIN channel
Types of terminals	25mm² box type terminal at the incoming and outgoing.

Definition of Breaking capacity of MCB

The short circuit breaking capacity of the circuit breaker is the current more than the prospective fault current at the point of installation of circuit breaker. Prospective fault current is the maximum fault current which may have to be interrupted by the circuit breaker.

Moulded Case Circuit Breakers (MCCB)

Moulded case circuit breakers are similar to thermo magnetic type MCBs except that these are available in higher ratings of 100 to 800amp at 500V 3-phase.

In MCCB, thermal and magnetic releases are adjustable. A shunt release is also incorporated for remote tripping and interlocking at MCCB. MCCBs are provided with under voltages release. There are two types of MCCB.

1 Thermal magnetic type.

2 Fully magnetic type.

Advantages of MCCB

1 MCCBs occupy much less space in comparison to fuse switch units.

2 MCCBs provide equal amount of protection against high faults as switch gears having HRC fuses.

Disadvantages

1 MCCBs are much costlier.

2 Leak proof situation required.

3 Sensitivity to insulation resistance low.

Grading of cables and current ratings

Objectives: At the end of this lesson you will be able to
- **state the factors to be considered for selecting the cable for a circuit**
- **apply the factors and select the cable.**

In order to determine the type and size of the cable for a given circuit, the following points should be taken into account.

- Suitability of the type of cable for the location of the circuit and the type of wiring.
- Size of the cable depending upon the current carrying capacity of the cable.
- Size of the cable depending upon the length of the wiring and permissible voltage drop in the cable.
- Minimum size of the cable based on the economy.

Location of the circuit and the type of wiring decide the type of cable.

It is necessary to consider whether the installation is for industry or domestic use and whether the atmosphere is damp or corrosive. Accordingly the type of cable has to be chosen.

Further the type of wiring determines the type of cable suitable for the installations.

The current carrying capacity of the cable decides the size of the cable.

In this, the first step is to find out the current expected to flow in the circuit when the total connected load is fully switched on. This current is the maximum current that would flow through the circuit in case all the loads are working at the same time. But this is not the case in actual situations.

Diversity factor

In the case of lighting installation all the lamps in a domestic installation may not be switched 'on' at the same time. Hence, it is assumed only two thirds of the lights (say 66%) only will be 'on' at a given time. This introduces a factor called 'diversity factor'.

When the connected load is multiplied by the diversity factor you get a load value which can be said as normal working load. Use of this diversity factor enables the technician to use a lesser size cable than the one calculated, based on the connected load. The suggested diversity factor according to IEE rules is given in Table 2.

Based on the working load the current in each circuit is to be calculated and the size of the cable suitable to carry the current has to be chosen from Tables 3, 4 and 5.

Voltage drop in the cable

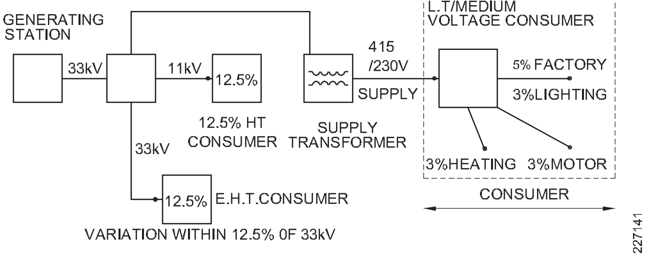
In any current carrying conductor, voltage drop takes place due to its internal resistance. This voltage drop in a premises as per BIS 732 should not be more than 3 percent of the standard supply voltage when measured between the consumer supply point and any point of the installation when the conductors are carrying the maximum current under the normal conditions of service.

If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the load or the cable rating whichever is minimum, to ensure the desired protection (BIS 732).

Declared voltage of supply to consumer

On the other hand according to IE Rule No.54, the voltage at the point of commencement of supply at the consumer should not vary from the declared voltage by more than 5 percent in the case of low or medium voltage or by more than 12 percent in the case of high or extra high voltage (Fig 1).

Fig 1



PERMISSIBLE VOLTAGE DROP-DIAGRAM

Calculation of voltage drop

In DC and single phase AC two-wire circuits

Voltage drop = Current x Total resistance of cables

= 2 IR

where I is the current and

R is the resistance of one conductor only

Wherever voltage drop is given as 1 volt drop per metre run of cable, we have to assume that both (lead and return) cables are taken into account and the cable carries its rated current. In such cases the voltage drop for X metre length of cable for a current of Y amps is calculated as given.

$$\left\{\begin{matrix}\text{Voltage}\\\text{drop}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{Length of}\\\text{the cable}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Actual current}\\\text{of the load}\end{matrix}\right\}}{\left\{\begin{matrix}\text{Metre length of}\\\text{the cable per one}\\\text{volt drop}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Rated current}\\\text{of the cable}\end{matrix}\right\}}$$

$$= \frac{XY}{\left\{\begin{matrix}\text{Metre length of}\\\text{the cable per one}\\\text{volt drop}\end{matrix}\right\} \text{x} \left\{\begin{matrix}\text{Rated current}\\\text{of the cable}\end{matrix}\right\}}$$

3-phase circuits

$$\text{Voltage drop} = 1.73 \text{ x } I \text{ } R = \sqrt{3}\,IR$$

where I is the line current

R is the resistance of one core only.

Principle of laying out of Domestic wiring

Objectives: At the end of this lesson you shall be able to
- **explain the layout, installation plan, circuit -diagram, wiring diagram and state their uses**
- **state the B.I.S. regulation pertaining to wiring installation.**

In electrical wiring work, the electrician is supplied with a layout of wiring installation and an installation plan initially.

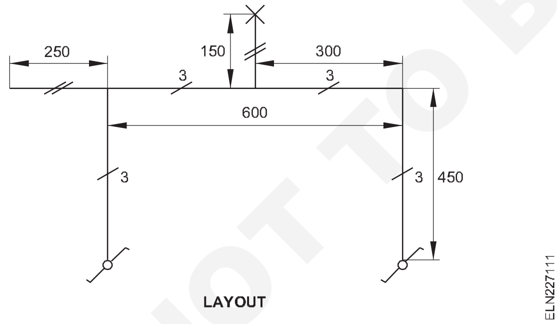
On the basis of the layout and installation plan, the electrician should draw the circuit and wiring diagrams before the commencement of work for systematic execution of the work.

The terms used in wiring installation drawings are explained here.

The layout diagram (Fig 1) is a simplified version of the wiring diagram. Its purpose is to inform the reader quickly and exactly, what the circuit is designed for without giving any information on the circuit itself.

This type of layout diagram is used for preparing architectural diagrams, plans, etc. of a building.

Fig 1



Installation plan (Fig 2): This plan shows the physical position of accessories in an installation, and also gives the final appearance of the installation.

Circuit diagram (Fig 3): The purpose of a circuit diagram is to explain the function of the various accessories in the circuit. Fig 3 is an example of a circuit diagram for controlling a lamp from two different places.

Wiring diagram (Fig 4): This is the diagram in which the position of the components in the diagram bears a resemblance to their actual physical position.

Fig 2

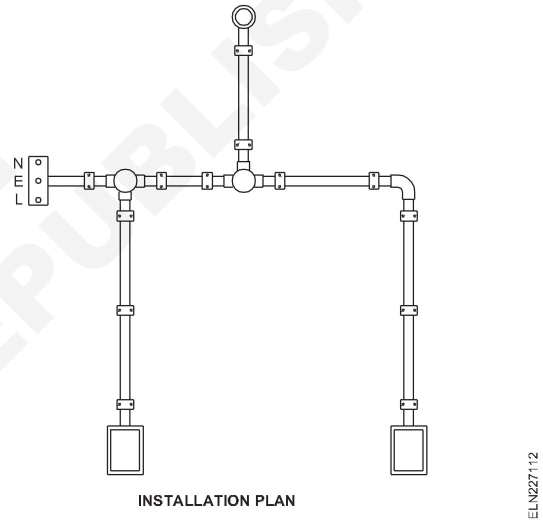
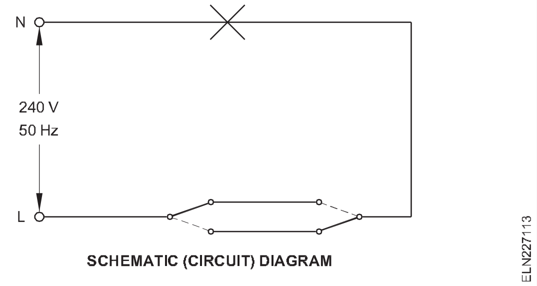
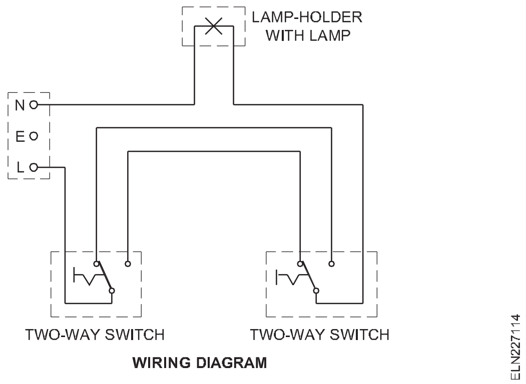


Fig 3



The wiring diagram may not have distance marking. Use of the wiring diagram along with the layout diagram enables the technician in the initial stages of the planning to specify/estimate the required type, size and length of the cables, and also to decide on the vertical, horizontal and ceiling runs of the cable. The wiring diagram is of great use to test and rectify faults in the installation during maintenance work. Fig 4 also shows the wiring plan for controlling a lamp from two different places with their actual locations.

Fig 4



Conduit wiring - types of conduits - non-metallic conduits (PVC)

Objectives: At the end of this lesson you shall be able to
- **distinguish between the different types of conduits used in wiring**
- **compare metal and PVC conduit wiring**
- **state the different types of accessories used in non-metallic conduits wiring.**

In general, conduit is defined as a tube or channel, which is the most commonly used in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

Types of conduits

There are four types of conduits used for wiring.

- Rigid steel conduits
- Rigid non-metallic conduits
- Flexible conduits
- Flexible non-metallic conduits.

Non-metallic conduits

These are made of fibres, asbestos, polyvinyl chloride (PVC), high density polyethylene (HDP) or poly vinyl (PV). Of the above, PVC conduits are popular owing to their high resistance to moisture and chemical atmosphere, high dielectric strength, low weight and low cost. These conduits may be buried in lime, concrete or plaster without harmful effects.

However, light gauge (lower than 1.5 mm wall thickness) PVC pipes are not as strong as metal conduits against mechanical impact. Special PVC pipes which are heavy gauge and high impact resistance are available in the market which can withstand heavy mechanical impact as the thickness of the pipe is more than 2 mm.

There are some PVC heavy gauge conduits having special base material made to withstand temperatures up to 85°C. These PVC conduits are available in 3 m length.

Variation in conduit wiring systems

There are two types of conduit wiring systems as stated below, for either metallic or non-metallic types.

- Surface conduit wiring system done on wall surfaces.
- Concealed (recessed) conduit wiring system done inside the concrete, plaster or wall.

Selection of the type of conduit

Metallic or PVC conduits are equally popular in electrical installations. Selection of the type of conduit depends upon the following criteria.

- Type of location, outdoor or indoor
- Type of atmosphere, dry or damp or explosive or corrosive
- Expected working temperature
- Exposure to physical damage due to mechanical impact
- Allowable weight of conduit runs
- Estimated cost.

A comparison between metal and PVC conduit wirings given in Table 1 will help in choosing the right type of conduit for a specific installation.

Table 1

Comparison between metal and PVC wirings

Metal conduit	PVC conduit
1 Provides good physical protection to cables.	Comparatively poor.
2 Weighs more for a given length.	Lighter.
3 Needs skill and time for installation.	Needs less skill and time.
4 Risk of electric shock due to leakage.	No risk as PVC is an insulator.
5 Good earth continuity available through the pipe itself.	Not possible. Separate earth wire required.
6 Can be used in gas-light and explosive-proof installations.	Not suitable.
7 Not resistant to corrosion, needs protective coating.	Resistant to corrosion.
8 Large ambient temperature range	Suitable for limited temperature range. At temperature above 60^0C, the conduit starts melting. At very low temperature the conduit cracks.
9 Fire resistant.	Non-fire-resistant.
10 More costly.	Less costly.

PVC fittings and accessories

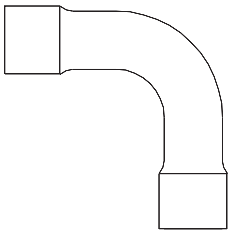
Couplers (Fig 1)

Fig 1

TYPES OF COUPLERS

Elbow (Fig 2)

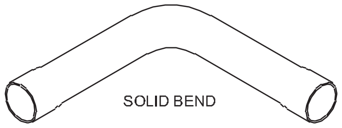
Fig 2



ELBOWS

Bends (Fig 3)

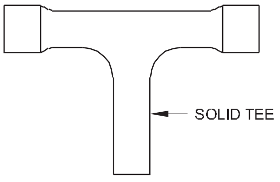
Fig 3



BENDS

Tees (Fig 4)

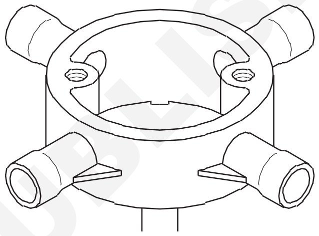
Fig 4



TEE

Circular boxes (Fig 5)

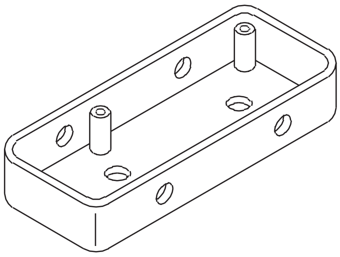
Fig 5



CIRCULAR BOXES

Rectangular boxes (Fig 6)

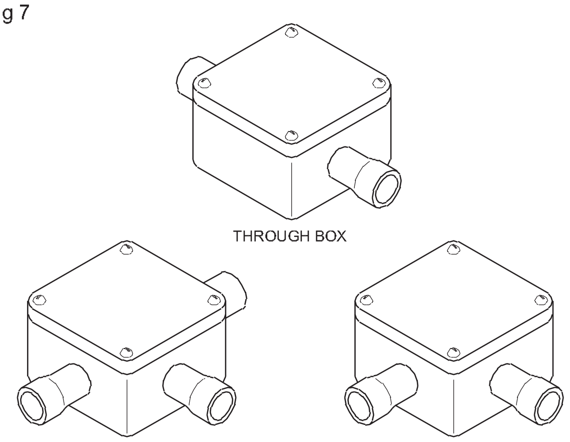
Fig 6



RECTANGULAR BOX

Junction boxes (Fig 7)

Fig 7



TYPES OF BOXES (JUNCTION BOXES)

PVC Channel (casing and capping) wiring

Objectives: At the end of this lesson you shall be able to
- **state the use limitation and rules of channel wiring system**
- **select the channel size according to size and number of cables from the chart**
- **explain the method of fabricating neutral, bend, and junction in PVC channel .**

Introduction : Channel (Casing and Capping) wiring is a system of wiring in which PVC/metallic channels with covers are used for drawing wires. This system of wiring is suitable for indoor surface wiring works. This system is adopted to give a good appearance and for extension of existing wiring installation. PVC insulated cables are generally used for wiring in casing and capping system. This is otherwise called 'wireways'.

The channel and top cover shall be of the same material either PVC or anodised aluminium. The casing is square or rectangular in shape. The capping shall be slide in type with double grooving in the case of PVC wire ways. Plain type capping are used for metallic wireways.

The only disadvantage in a channel wiring is that it is inflammable and risk of fire.

Channel (casing & capping) wireways should not be used.

In residential buildings or such buildings were there is a risk of tampering where ambient temperature exceeds 60°C or less than 5°C in areas exposed to sunlight.

Dimensions : The sizes of channel, the maximum number of wires which can be drawn in each size are given in the table 1 below.

The thickness of channel should be 1.2mm ± 0.1mm.

TABLE 1

Nominal cross sectional area of conductor in sq.mm	10/15mm x 10mm size channel	20mm x 10mm size channel	25mm x 10mm size channel	30mm x 10mm size channel	40mm x 20mm size channel	50mm x 20mm size channel
	No. of wires	No. of wires	No. of wires	No. of wires	No. of wires	No. of wires
1.5	3	5	6	8	12	18
2.5	2	4	5	6	9	15
4	2	3	4	5	8	12
6	-	2	3	4	6	9
10	-	1	2	3	5	8
16	-	-	1	2	4	6
25	-	-	-	1	3	5
35	-	-	-	-	2	4
50	-	-	-	-	1	3
70	-	-	-	-	1	2

Precautions

1 Neutral (Negative) cables should be carried in top channel and phase (Positive) in the bottom channel.

2 Crossing of cables between phase (Positive) and neutral (Negative) should be avoided.

3 Porcelain or PVC pipe should be used for crossing the cables through the walls.

Installation of PVC channel : The channel should be fixed to wall/ceiling with flat headed screws and rawlplugs. These screws shall be fixed at an interval of 60cm. On either side of joints this distance shall not exceed 15cm from the end point. Channel under steel joints shall be fixed with MS clips of not less than 1.2mm (18SWG) thickness and width not less than 19mm.

Floor/Wall crossings : When conductor pass through floors/wall the same should be carried in a steel conduit/ PVC conduits properly bushed at both ends. The conduits shall be carried 20cm above floor level and 2.5cm below ceiling level and properly terminated into the channel.

Joints in PVC/Metal channel : As far as possible wireways in straight runs should be single piece. All joints shall be scarfed or cut diagonally in longitudinal section. The section ends shall be filed smoothly but joined without any gap. Care shall be taken to see that the joints in PVC cover does not overlap those channel.

Joints shall also be done using standard accessories like elbows, tees, 3 ways/4 ways junction box etc of high grade PVC/Aluminium alloy. In PVC channel separate channel cover for joint, elbows, tees, cross etc are available. These can be fixed after fixing the channel to give a good appearance. The radius of curvature of the cables inside a bend should be more than 6 times its over all diameter.

In the case of PVC channel, making joints is comparatively easy. Mark the joints by placing the two pieces in required angle. Identify the position to be cut and remove on each pieces. Cut through the lines and file the edges to get gapless joint.

Power wiring

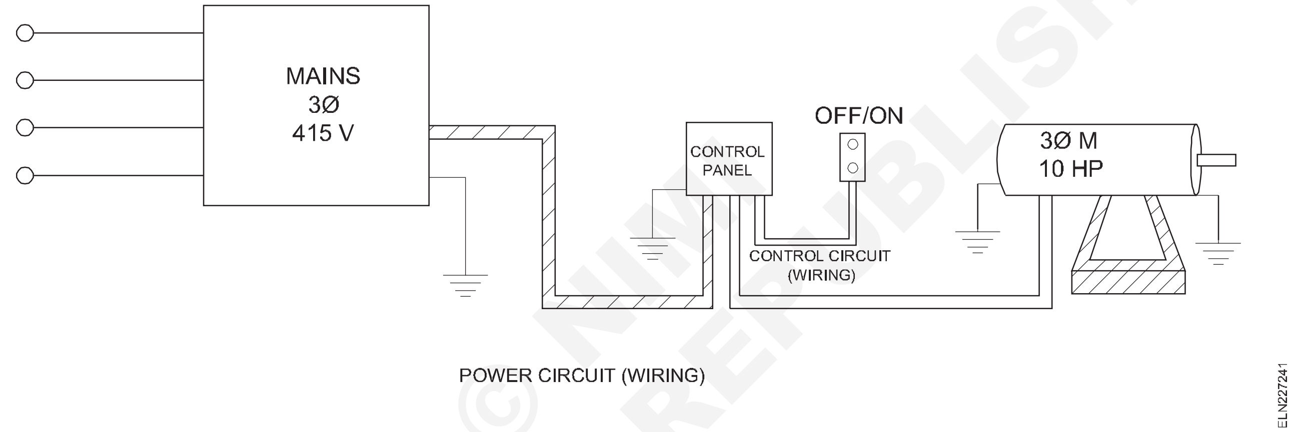
Objectives: At the end of this lesson you shall be able to
- **state the power, control, communication and entertainment wiring**
- **state the necessity of various wiring.**

A panel wiring diagram usually gives information about the relative position and arrangement of devices and terminals of the devices to help in installing or servicing the device.

Generally all the control panel / commercial / industrial wiring invariably consists of two sections viz control wiring and power wiring.

Fig 1 shows the typical layout diagram of a motor wiring. The control panel consisting of all the control and protective devices installed near to the power source and the load like, furnace, compressor etc, are installed away from the power source / panel boards.

Fig 1



Power wiring is a high current carrying circuit which is wired to connect / disconnect the load like motors/ furnace through the protective devices like OLR and fuses etc..

Power wiring has to be done as per the guideline and rules specified in IE rules. The cable size depends on the load current and it varies according to the load.

The power and control cable should not be run into single conduit. As the current radiation influences the control cable, a separate conduit to be provided for control and power cables.

Control wiring

Control wiring is a circuit which is wired to communicate the commands and other information between control devices and lighting.

Control wiring enables the control circuit for various control purpose. In a motor control unit the control circuit is wired and kept near to motor. In other system such as fire alarm, fire detector etc. The control circuit is wired separately with low current carrying conductors and drawn separately for easy maintenance.

Fire alarm

The purpose of fire alarm system is to provide an immediate alarm in case of any fire and to prevent loss of life, also to secure the immediate attention of fire fighting staff.

Fire detectors

The three principal fire detection method involve sensing the heat, presence of flame or smoke. The third method identifies the pre - fire condition that is a flammable gas detector, which is technicaly not a fire detector and its use is limited to places where flammable gases are likely to be present.

I Heat detector

The three basic operating principles for heat detection are:

a Fusion detector (melting of a metal)

b Thermal expansion detector

c Electrical sensing

II Smoke detectors

There are three types of smoke detectors namely

1 Ionisation detector

2 Light - scattering smoke detector

3 Obscuration smoke detector.

III Flammable gas detector

A flammable gas detector is designed to measure the amount of flammable gas in the atmosphere. The gas mixture is drawn over a catalytic surface where oxidation i.e. combustion takes place. The combustion causes a rise in temperature of the surface which is measured by a decrease in its electrical resistance. The instruments are calibrated by considering pentane or heptane as reference gas. The readings are displayed in terms of percentage of lower explosive limit.

Control panel for fire alarm system

The control panel is the heart of the system through which the fire alarm system is monitored and alarm is initiated if any indication/signal is conveyed to the panel.

The working of the fire alarm system should be checked once in a month regularly.

The features of the control panel are the power supply, battery charging unit and control card.

Communication wiring

It is type of wiring which is used to transmit the voice, data, images and video etc to the desired places.

Some of examples are

- Telephone wiring
- Internet / LAN network wiring
- Cable TV and other entertainment wiring
- Data and security services wiring
- Telex/ Fax machines wiring

Faster and more reliable than ordinary phone wiring,low-cost, high-tech copper wiring should serve every room in the modern home. Its is required to carry voice, data and other services from where they enter the house to every room, and from any one room to any other.

Wiring circuits planning, permissible load in sub-circuit and main circuit

Objectives: At the end of this lesson you shall be able to
- **State about components of wiring circuit.**
- **Execution of wiring connection.**

Socket-outlets: All plugs and socket-outlets shall be of 3-pin type, the appropriate pin of the socket being connected permanently to the earthing system.

An adequate number of socket-outlets shall be placed suitably in all rooms so as to avoid the use of long lengths of flexible cords.

Only 3-pin, 6A socket-outlets shall be used in all light and fan sub-circuits. 3 pin, 16A socket-outlets shall be controlled by individual switches which shall be located immediately adjacent to it. For 6A socket-outlets, if installed at a height of 130 cm above the floor level, in situations where a socket-outlet is accessible to children, it is recommended to use shuttered or interlocked socket-outlets.

In case an appliance requiring the use of a socket-outlet of a rating higher than 16A is to be used, it should be connected through a double-pole switch of appropriate rating.

Socket outlets shall not be located centrally behind the appliances with which they are used. Socket-outlets shall be installed either 25 or 130 cm above the floor as desired.

It is recommended that 3-pin, 6A socket-outlets may be provided near the shelves, bookcases, clock positions, probable bed positions etc.

Depending on the size of the kitchen, one or two 3-pin, 16A socket-outlets shall be provided to plug in hot plates and other appliances. Dining rooms, bedrooms, living rooms, and study rooms, if required, shall each be provided with atleast one 3-pin, 16A socket outlet.

No socket-outlet shall be provided in the bathroom at a height less than 130 cm.

A recommended schedule of socket-outlets is given below.

Location	6A Outlets	16A Outlets
Bedroom	2 to 3 Nos.	1 No.
Living room	2 to 3 Nos.	2 Nos.
Kitchen	1 No	2 Nos.
Dining room	2 Nos	1 No.
Garage	1 No	1 No.
Refrigerator	-	1 No.
Air-conditioners	-	1 No.
Verandah	1 No.	1 No.
Bathroom	1 No.	1 No.

Multi-plug adaptors for connecting more than one appliance to one socket outlet should not be used.

Fans: Ceiling fans shall be wired to ceiling roses or to special connector boxes. All ceiling fans shall be provided with a switch besides its regulator.

Fans shall be suspended from hooks or shackles with insulators between the hooks or shackles and also with insulators between the hooks and suspension rods.

Unless otherwise specified, all ceiling fans shall be hung not less than 2.75 m above the floor.

Flexible cords: Flexible cords shall be used only for the following purposes.

- For pendents
- For wiring of fixtures
- For connection of transportable and hand-held appliances

Flexible cords shall not be used in the following cases.

- As a substitute for the fixed wiring.
- Where cables may have to run into holes through the ceiling, walls, floors, windows, etc.
- For concealed wiring.
- If attached permanently to the walls, ceilings, etc.

Mounting levels of the accessories and cables as recommended in B.I.S. and N.E.C.

Height of main and branch distribution boards should be not more than 2m from the floor level. A front clearance of 1 m should also be provided.

All the lighting fittings shall be at a height of not less than 2.25 m from the floor.

A switch shall be installed at any height 1.3 m above the floor level.

Socket-outlets shall be installed either 0.25 or 1.3 m above the floor as desired.

The clearance between the bottom point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades of the fan shall not be less than 300 mm.

The cables shall be run at any desired height from the ground level, and while passing through the floors in the case of wood casing and capping and T.R.S. wiring, it shall be carried in heavy gauge conduit 1.5 m above floor level.

References

I.S. 732-1963

I.S. 4648-1968

N.E. Code

Importance of Earthing

Objectives: At the end of this lesson you shall be able to

- **explain the reasons for system and equipment earthing**
- **define the terminalogy related to earthing**
- **state and explain the methods of preparing pipe earthing and plate earthing, according to B.I.S recommendations**
- **distinguish between Light &Fan circuit and power circuits**
- **calculate the number of sub circuits required for a given wiring**
- **explain the procedure for reducing the resistance of earth electrodes to an acceptable value.**

Earthing:

Connecting the non-condutive metal body/parts of an electrical equipment and system to the earth through a low resistance condutor is called as **earthing**.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and substations.

The purpose of system earthing is to:

- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

Terminology

Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Step potential: The maximum value of the potential difference possible of being shunted by a human body between two accessible points on the ground separated by the distance of one step, which may be assumed to be one metre.

Touch potential: The maximum value of potential difference between a point on the ground and a point touched by a person.

Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond a certain milliampere value. In general, any current flow through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.

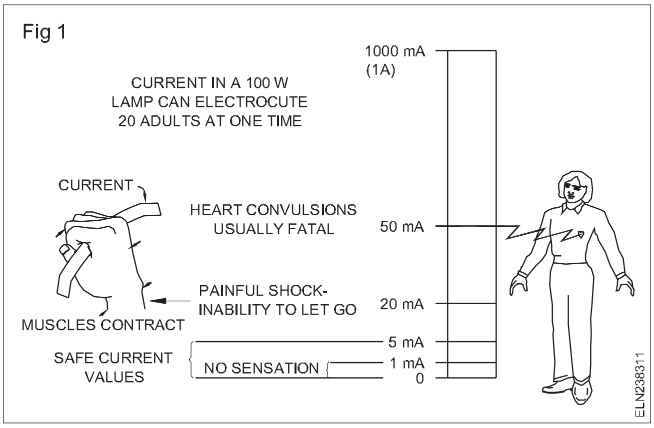


Fig 1

However, the degree of danger is also dependent on the time during which it flows, and resistance of the body. In human beings, the resistance between hand and hand or between hand and foot can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified areas of contact.

Table 1

Skin conditon or area	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1: **Metal body of apparatus when it is not earthed**

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

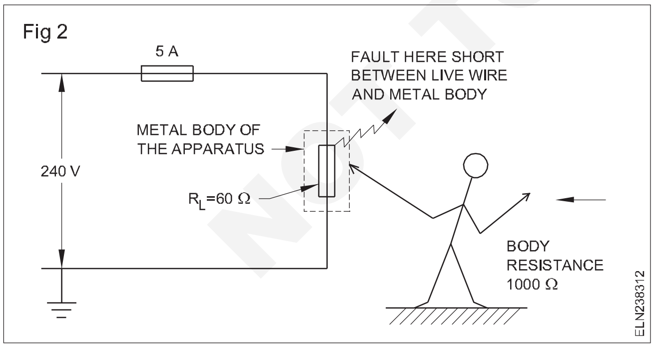


Fig 2

The value of current through the body = $\frac{V}{R_{Body}}$

$$= \frac{240}{1000} = 0.24 \text{ amps or } 240 \text{ milliamps.}$$

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

CASE 2: **Metal body of apparatus when earthed**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

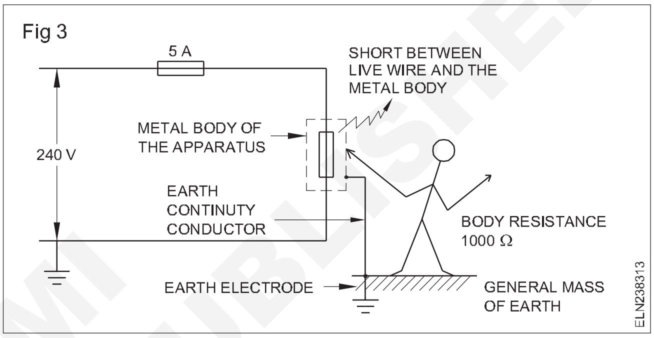


Fig 3

Assuming that the sum of the resistace of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

$$\text{the leakage current} = \frac{V}{R_{Total}} = 240/10 = 24 \text{ amps.}$$

This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

Types of earth electrodes

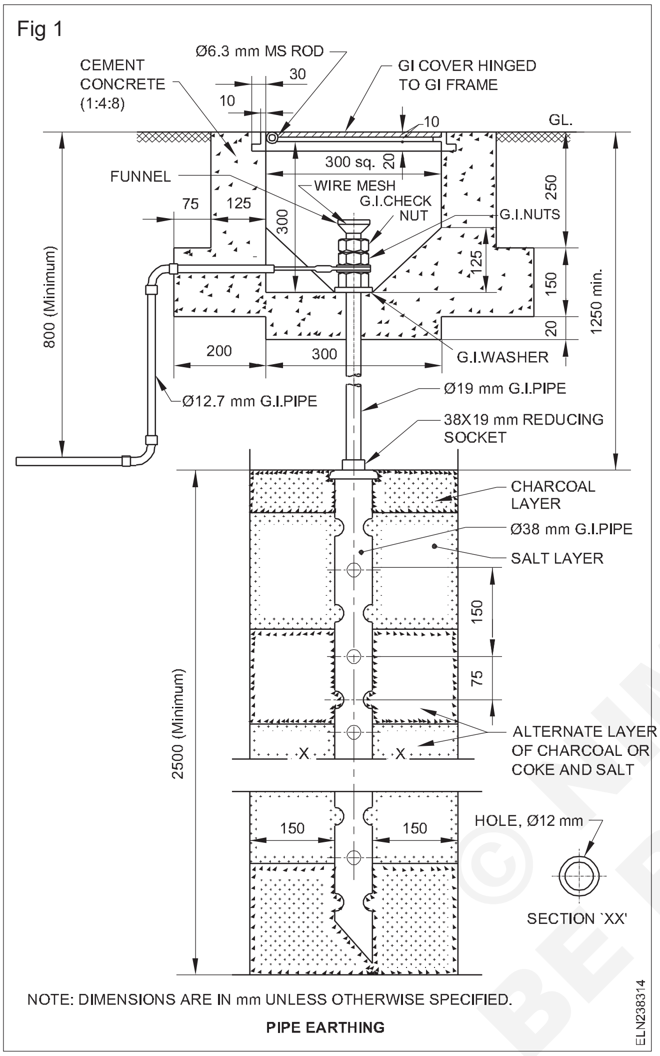
Rod and pipe electrodes: These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.

Plate earthing and pipe earthing methods and IEE regulations

Objectives: At the end of this lesson you shall be able to
- **explain pipe earthing**
- **explain plate earthing**
- **explain the methods of reducing earth resistance.**

Fig 1



NOTE: DIMENSIONS ARE IN mm UNLESS OTHERWISE SPECIFIED.

PIPE EARTHING

Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. Where rock is encountered at a depth of less than 2.5 m, the electrodes may be buried, inclined to the vertical. In this case too, the length of the electrodes shall be atleast 2.5 m, and the inclination not more than 30^0 from the vertical.

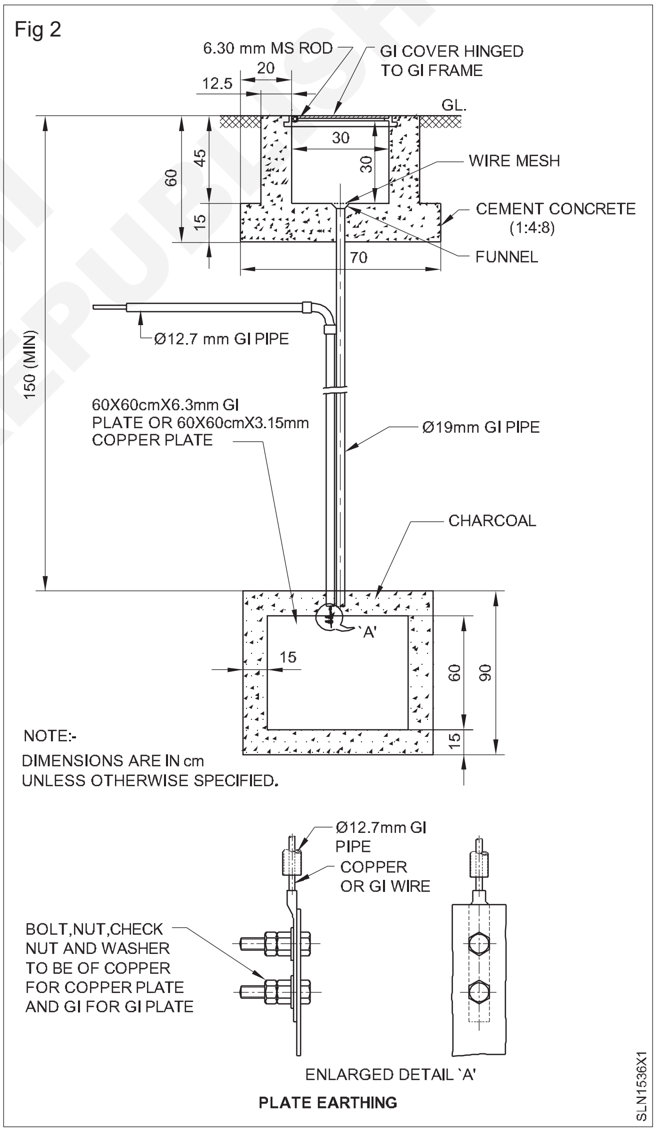
Deeply driven pipes and rods are, however, effective where the soil resistivity decreases with depth or where a sub-stratum of low resistivity occurs at a depth greater than those to which rods and pipes are normally driven.

Pipes or rods, as far as possible, shall be of one piece. For deeply driven rods, joints between sections shall be made by means of a screwed coupling, which should not be of a greater diameter than that of the rods which it connects together.

Plate electrodes (Fig 2): Plate electrodes, when made of galvanised iron or steel, shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Fig 2



NOTE:-
DIMENSIONS ARE IN cm UNLESS OTHERWISE SPECIFIED.

PLATE EARTHING

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Use of plate electrodes is recommended only where the current-carrying capacity is the prime consideration; for example, in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atleast 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be atleast 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

To achieve efficient operation of the protective devices, under fault condition the earth electrode resistance should be lower than an acceptable value which could be calculated from circuit details.

However, the earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance. (Distance between two adjacent electrodes shall be not less than twice the length of the electrodes.)

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

I.E. Rules pertaining to earthing

Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules 1956, as amended from time to time, and the relevant regulations of the electricity supply authority concerned. The following Indian Electricity Rules are particularly applicable to both system and equipment earthing: 32,51,61,62,67,69,88(2) and 90.

Earth resistance and earth leakage circuit breaker

Objectives: At the end of this lesson you shall be able to
- **explain the working principle, different types and construction of an earth leakage circuit breaker (ELCB)**
- **explain the technical specifications of ELCB's.**

Introduction

The sensation of electric shock is caused by the flow of electric current through the human body to earth. When a person comes in contact with electrically live objects like water heaters, washing machines electric iron etc., the extent of damages caused by this current depends on its magnitude and duration.

This kind of current is called the leakage current which comes in milli-amps. These leakage current being very small in magnitude, hence undetected by the fuses/MCBs are the major cause for the fires due to electricity.

The leakage current to earth also results in the wastage of energy and excessive billing for electricity not actually used.

Residual current operated circuit breakers are internationally accepted means of providing maximum protection from electric shocks and fires caused due to earth leakage current and also prevents the waste of electrical energy. These residual current circuit breakers (RCCB) are popularly called as Earth leakage circuit breakers (ELCB). The effect of electric current on human body in various levels represented in graph (Fig 1).

Basically ELCBs are of two types namely voltage operated ELCBs and the current operated ELCBs.

Voltage operated ELCB

This device is used for making and breaking a circuit. It automatically trips or breaks the circuit when the potential difference between the protected metal work of the installation and the general mass of earth exceeds 24V. This voltage signal will cause the relay to operate (Fig 2).

Voltage operated ELCBs are meant to be used where it is not practicable to meet the requirements of IEE wiring regulation by direct earthing or where additional protection is desirable.

Current operated ELCB

This device is used for making and breaking a circuit and for breaking a circuit automatically when the vector sum of current in all conductors differs from zero by a predetermined amount. Current operated ELCBs are much more reliable in operation, easier to install and maintain.

Construction of current operated ELCB

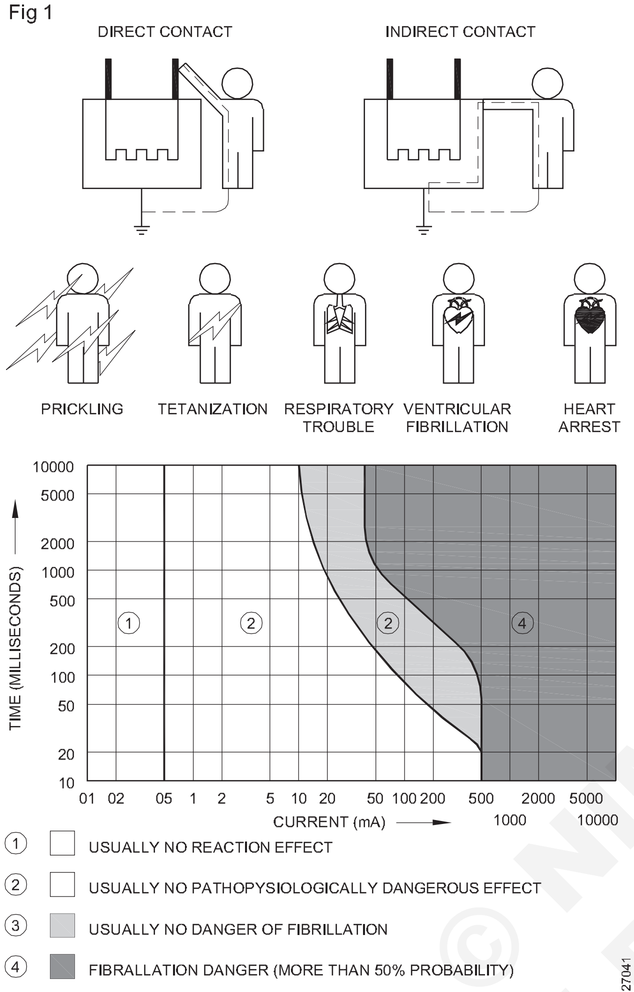
It consists of a Torroid ring made of high permeability magnetic material. It has two primary windings each carrying the current flowing through phase and neutral of the installation. The secondary winding is connected to a highly sensitive electro - magnetic trip relay which operates the trip mechanism.

Working principle

The residual current device (RCD) is a circuit breaker which continuously compares the current in the phase with that in the neutral. The difference between the two is called as the residual current which is flowing to earth.

The purpose of the residual current device is to monitor the residual current and to switch off the circuit if it rises from a preset level (Fig 3).

Fig 1



EFFECT OF ELECTRIC CURRENT ON HUMAN BODY

Fig 2

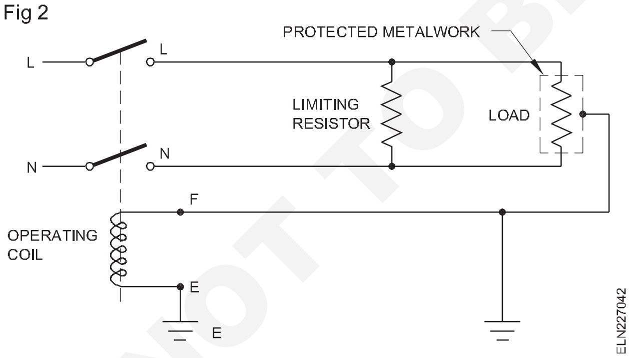
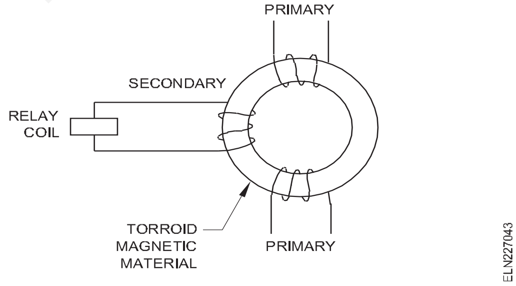


Fig 3



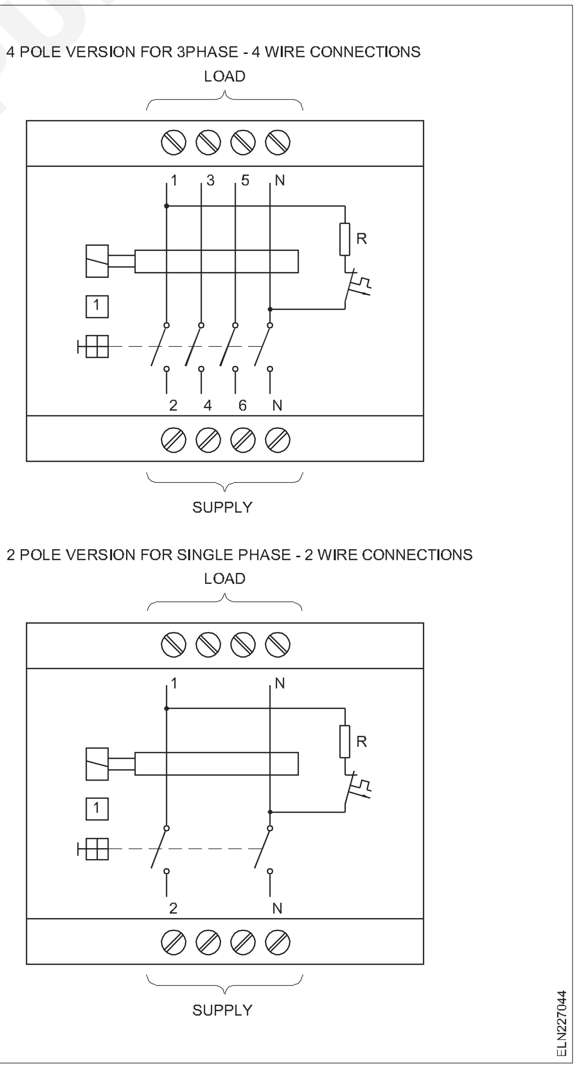
The main contacts are closed against the pressure of a spring which, provides the energy to open them when the device trips. Phase and neutral current pass through identical coils wound in opposing direction on a magnetic circuit, so that each coil will provide equal but opposing numbers of ampere turns when there is no residual current. The opposing ampere turns will cancel and no magnetic flux will be set up in the magnetic circuit.

In a healthy circuit the sum of the current in phases is equal to the current in the neutral and vector sum of all the current is equal to zero. If there is any insulation fault in the circuit then leakage current flows to earth. This residual current passes to the circuit through the phase coil but returns through the earth path and avoids the neutral coil, which will therefore carry less current.

So the phase ampere turns exceeds neutral ampere turns and an alternating magnetic flux results in the core. The flux links with the secondary coil wound on the same magnetic circuit inducing an emf into it. The value of this emf depends on the residual current, so it drives a current to the tripping system which depends on the difference between them and neutral current.

When tripping current reaches a predetermined level the circuit breaker trips and open the main contacts and thus interrupts the circuit. A 3 - phase 4 wire electric system can also be protected by providing a 4 pole RCCB (Fig 4).

Fig 4



Test Switch

A test switch is a requirement as per BS842 (Fig 5). It is used to test the functioning of ELCB. When the test button is pressed it circulates additional current through neutral coil which is determined by the value of current limiting resistor R. As a result there exists a difference in current flowing through phase and neutral coils and hence the ELCB trips OFF.

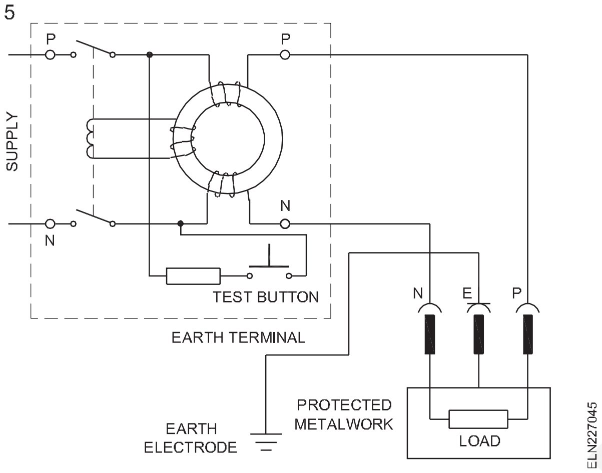
Technical specification

The current ratings of ELCB are 25A, 40A and 63A.

No. of poles - 2 and 4

Nominal voltage - 240/415V 50Hz.

Fig 5



Sensitivities: ELCBs are designed to trip at leakage currents of 30mA, 100mA, and 300mA.

Electrical life: More then 10,000 operations.

Mechanical life:

20000 to 100000 operations.

Tripping time - < 30ms.

Time delayed RCCB

There are cases, where more than one RCCB is used in an installation, for example a complete installation may be protected by an RCCB rated at 100mA, while a socket intended for equipment may be protected by 30mA device.

Discrimination of the two devices then becomes important. For example an earth fault occurs in the equipment giving an earth fault current of 250mA. Since the fault current is higher, than the operating current of both devices, both will trip.

It does not follow, that the device with smaller operating current will trip first. This is a lack of discrimination between the two devices. To ensure proper discrimination, the device with a larger operating current, has a deliberate time delay built into its operation. It is called time-delayed RCCB. Images of 2 pole ELCB and 4 pole RCCB are given below (Fig 6).

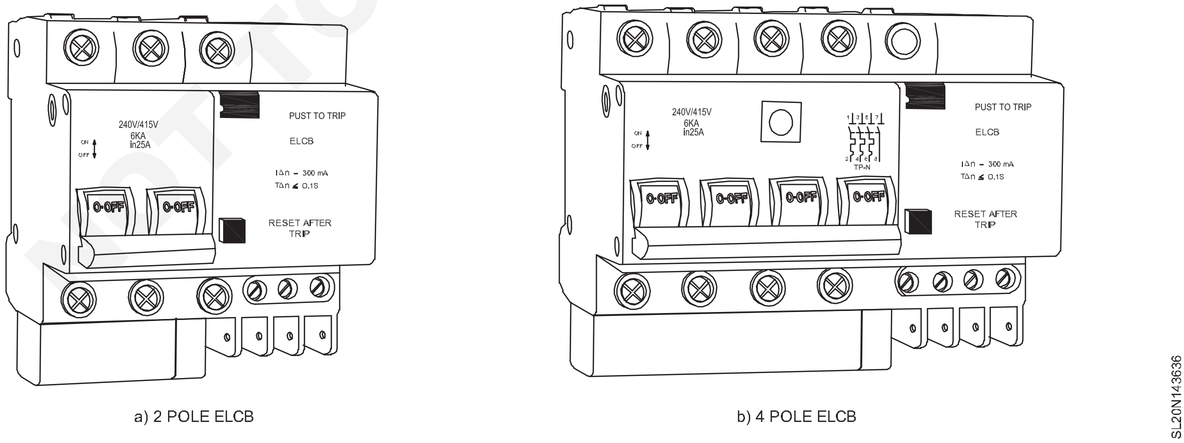
Earth fault loop impedance

Earth wire from an equipment to the earth electrode is called earth loop. Earth fault loop impedance (Z_E) is the impedance of the fault current path. It must be low enough to ensure that the productive devices like ELCB will operate within the specified time.

In any case, the multiplication value of earth fault loop impedance in Ohms and the rated tripping current (I_t)in ampere of ELCB should not exceed 50V .

Z_E x I_t < 50V.

Fig 6



a) 2 POLE ELCB

b) 4 POLE ELCB

Lightening arrestor

Objectives: At the end of this lesson you shall be able to

- **define Lightning arrester**
- **explain the working principle of a lightning arrester**
- **state different types of lightning arrester**
- **state the characteristics of lightning arrester.**

Lightning Arrester:-

Definition: The device which is used for the protection of the equipment at the substations against travelling waves, such type of device is called lightning arrester or surge diverter. In other words, lightning arrester diverts the abnormal high voltage to the ground without affecting the continuity of supply. It is connected between the line and earth, i.e., in parallel with the equipment to be protected at the substation.

The following are the damages that are caused by the travelling wave on the substation equipment.

A The high peak or crest voltage of the surge may cause flash-over in the internal winding thereby spoil the winding insulation.

B The steep wave fronts of the surges may cause external flashover between the terminal of the transformer.

C The highest peak voltage of the surge may cause external flashover, between the terminal of the electrical equipment which may result in damage to the insulator.

Working of Lightning Arrester

When a travelling wave reaches the arrestor, its sparks over at a certain prefixed voltage as shown in the figure below. The arrestor provides a conducting path to the waves of relatively low impedance between the line and the ground. The surge impedance of the line restricts the amplitude of current flowing to ground.

The lightning arrester provides a path of low impedance only when the travelling surge reaches the surge diverter, neither before it nor after it. The insulation of the equipment can be protected if the shape of the voltage and current at the diverter terminal is similar to the shape shown below.

Fig 1

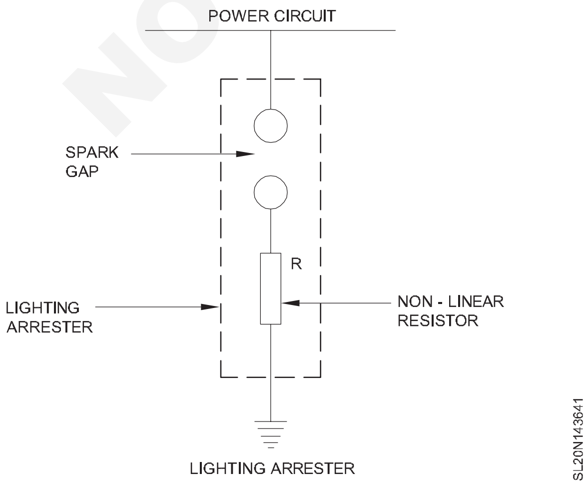
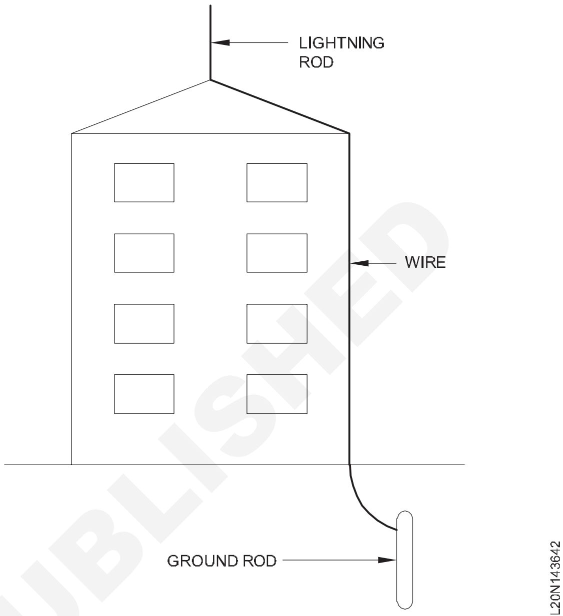


Fig 2



Types of Lightning Arrester

Generally, lightning arresters are classified into different types. The construction of lightning arrestors is different based on its type but the working principle is the same. It provides a low resistance pathway to the surges in the direction of the ground. The types are

Horn Gap Arresters

The gap among the horns can be adjusted so that the usual supply voltage is not sufficient to cause an arc.

Multi-Gap Arresters

Some of the gaps among the next cylinders contain a shunt resistance that grabs a surge when there is a surplus of voltage.

Valve-Type Arresters

These devices include two main parts like a sequence of spark gaps as well as a series of non-linear resistor discs.

Pellet-Type Arresters

The designing of these arresters can be done with glass tubes that are filled with lead pellets.

An ideal lightning arrester should have the following characteristics;

1 It should not draw any current during normal operating condition, i.e., it sparks-over voltage must be above the normal or abnormal power frequency that may occur in the system.

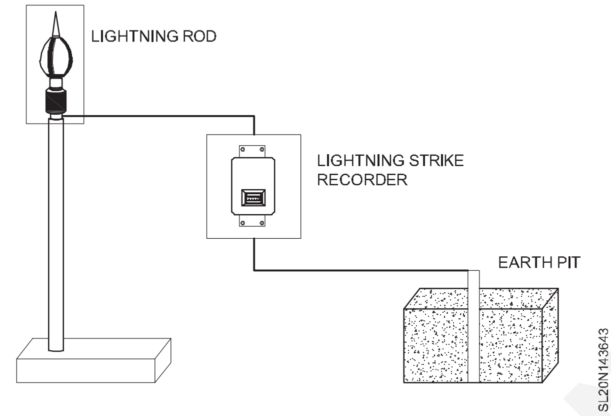
2 Any transient abnormal voltage above the breakdown value must cause it to break down as quickly as possible so that it may provide a conducting path to ground.

3 When the breakdown has taken place, it should be capable of carrying the resulting discharge current without getting damaged itself and without the voltage across it exceeding the breakdown value.

4 The power frequency current following the breakdown must be interrupted as soon as the transient voltage has fallen below the breakdown value.

There are many types of lightning arrester which are used to protect the power system. The choices of the lightning arrester depend on the factor like, voltage and frequency of the line, cost, weather condition and reliability.

Fig 3



Location of Lightning Arrester: -

The lightning arrester is located close to the equipment that is to be protected. They are usually connected between phase and ground in an AC system and pole and ground in case of the DC system. In an AC system, separate arrester is provided for each phase.

In an extra-high voltage AC system, the surge diverter is used to protect the generators, transformers, bus bars, lines, circuit breakers, etc. In HVDC system the arrester is used to protect the buses, valves converter units reactors, filter, etc.

Advantages

- Property damage can be reduced from strokes of lighting.
- Outdoor equipment of the substation can be protected
- Avoid damage in lines
- Outlet surges can be avoided
- Electromagnetic interference
- Simple to use

Disadvantages

- It occupies more space
- The installation cost is high.

Classification of electrical instruments and essential forces required in indicating instruments

Objectives: At the end of this lesson you shall be able to
- **state the instrument, range, position, types, error from the data and symbols**
- **state the terminal markings in instrument**
- **classify the instruments based on measuring accuracy**
- **state the indication error, when measuring**
- **state the instrument scales type.**

Electrical Measuring Instrument

Electrical measuring instruments (meters) is an apparatus, used for measuring the electrical quantities like current, voltage, resistance power and energy etc.

Identification of instrument

Identification of the instrument for any particular measurement is very important. By wrong identification not only the instrument may be damaged but also we may not get the result that we want.

The instrument should be identified for the quantity to be measured, the range, suitability for a particular type of supply etc. by carefully going through the data available on the dial.

Data contained on the measuring instrument dial: The important application data needed for use of the measuring instrument are in the form of symbols on the dial/ scale of the instrument. In addition to the `symbols' the manufacturer's name, the instrument type and the Serial or Production numbers are also indicated on the dial.

Measuring range and measuring units: Instruments are identified by the appropriate letter markings(symbols) on the dial. For example V for voltmeter, mv for millivoltmeter, KV for Kilo Voltmeter etc.

The measuring range is indicated by the series of numbers under the divisions of the scale.

V	Volt	(mV, mV, kV ...)	Voltage
A	Ampere	(mA, mA, kA ...)	Current
W	Watt	(mW, kW, MW ...)	Power
Ω	Ohm	(mΩ, KΩ, MΩ)	Resistance
Hz	Hertz	(kHz, MHz ...)	Frequency

Types of current: The types of supply on which the instrument is suitable for measurement is indicated by symbols as follows.

—	Direct current
∼	Alternating current
≂	Direct and alternating current
∼ ∼ ∼	One phase measured multiphase (alternating) current
≋	Three phase measured multiphase (alternating) current.

Testing potential (voltage): The star mark on the dial indicates the voltage to which the instrument is subjected for test.

☆	Testing potential 500V
☆ 2	Testing potential over 500V eg, 2000V(2KV)
☆ 0	No testing potential

Using position: Instruments must be used as per the specified position mentioned on the dial.

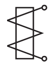
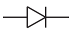
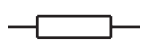
⊥	Vertical using position.
⊓	Horizontal using position.
∠60°	Angle of usage eg. 60^0 tilt angle.
⊥ ±2°	Departure from the permissible position eg. $\pm 2^0$ vertical.
±10° ⊓	Departure from the permissible position eg. $\pm 10^0$ horizontal.

Instruments used in any position other than the one specified may cause error in reading.

Accuracy class: This is specified in two ways. The % of the full scale deflection and the % of the actual reading. This is indicated as follows.

2.5	Class determined by the measuring range end value.
2.5	Class determined by the length of the scale.

Measuring instrument types

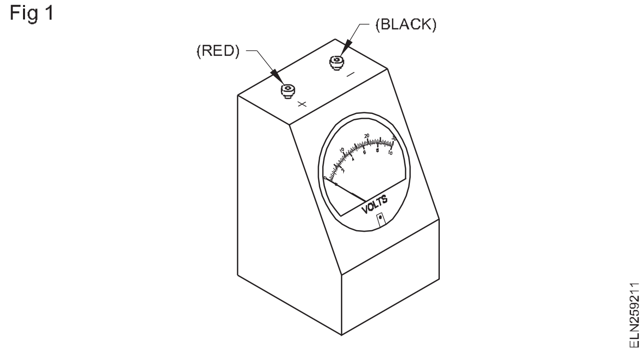
	Moving coil instrument
	Moving iron instrument
	Electrodynamic quotient instrument
	Enclosed electrodynamic quotient instrument
	Moving coil instrument with rectifier
	Device with built-in measuring rectifier
	Separated series and shunt resistance
⚠	Observe instructions for use.

Indication error: Instruments are manufactured to read within certain accuracy. This is indicated on the dial by a number close to the other symbols.

1	Indication error ± 1%
2.5	Indication error ± 2.5%
3.5	Indication error ± 3.5%

Terminal markings: In a moving coil type of instrument, the terminals are marked with _ and . The positive (+) terminal is red in colour and the neg_tive() terminal is black in colour (Fig 1). This type of instrument must be connected in the circuit with correct polarity. i.e. the +ve of supply to the +ve of instrument an_ the ve of supply t _ the ve of the instrument.

Fig 1

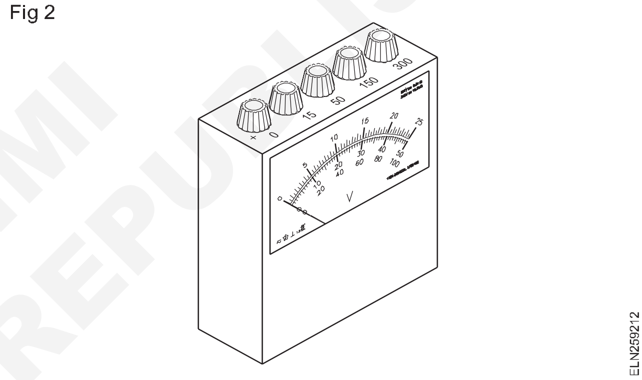


In the moving iron type there is no polarity marking on the terminals. Both the terminals are of the same colour. The instrument can be connected in the circuit without identifying the line and neutral of the supply.

In ohmmeters the terminals are marked in the same way as in the case of the moving coil meters.

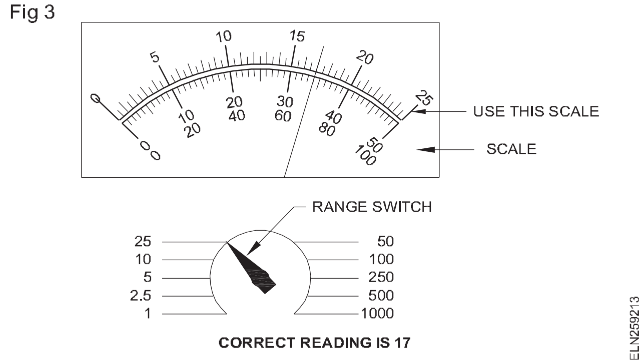
In multi-range meters, one of the terminals is marked as + or zero and the other terminal is marked with the range of measurement value (Fig 2).

Fig 2



A range selector switch is used in some meters (Fig 3). While reading such meters, care should be taken to keep in mind the position of the range selector switch, and read the scale reading corresponding to that selected range.

Fig 3



CORRECT READING IS 17

Permanent magnet moving coil (PMMC) instruments

Objectives: At the end of this lesson you shall be able to
- **state the principle of a permanent magnet moving coil (P.M.M.C) instrument**
- **describe the construction and operation of a P.M.M.C instrument**
- **state the uses, advantages and disadvantages of a P.M.M.C instrument.**

Moving Coil and Moving Iron Instruments :

Instruments are classified based on their moving system They are :

(i) Moving Coil Instruments (MC)
  Permanent Magnet Moving Coil Instrument (PMMC)
  Dynamo meter type instruments
(ii) Moving Iron Instruments (MI)
  Attraction type
  Repulsion type

Permanent magnet moving coil (PMMC) instruments

The most commonly used instrument to measure DC quantities like voltage and current, is the permanent magnet moving coil (PMMC) instrument.

Principle: The working of the PMMC instrument is based on the principle that when a current-carrying conductor is placed in a magnetic field, it is acted upon by a force which tends to move the conductor. The DC motor also works on this principle.

Construction: The PMMC instrument consists of a permanent magnet and a rectangular coil wound with a very fine gauge insulated copper wire on a thin light aluminium former.

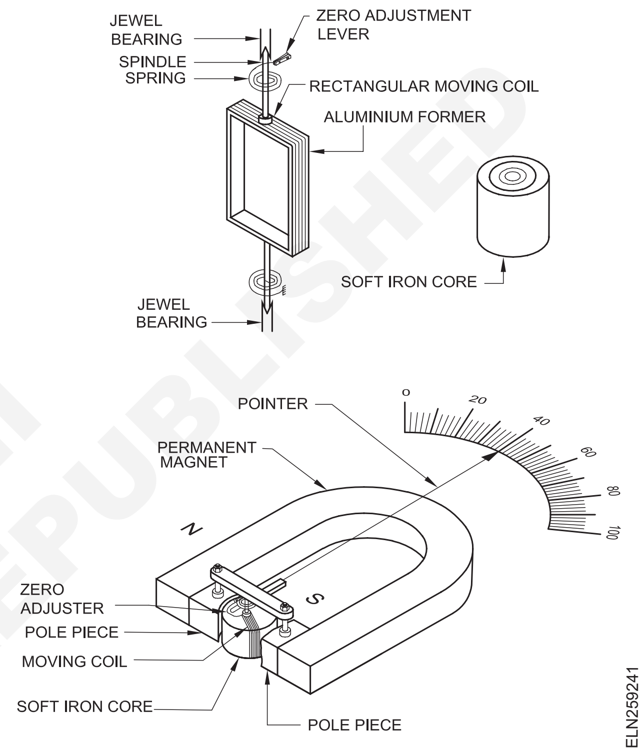
The aluminium former not only supports the coil, but also produces eddy current for damping. The coil and the former are attached with spindles on either side, and supported by jewelled bearings so as to make the assembly move freely in the air gap (Fig 1).

The two ends of the coil are connected to two phosphor-bronze springs, fixed one on each spindle to lead in and lead out the current. The springs are spiralled in the opposite direction in order to neutralize the effect of temperature changes.

The horseshoe shaped permanent magnet is made of an alloy called 'Alnico' and it has soft iron pole pieces which are shaped to distribute uniform flux in the air gap.

A soft iron core is fixed in such a way that the moving coil can move within the gap, between the soft iron core and the pole pieces. The function of the soft iron core is (i) to decrease the reluctance of the magnetic path between the poles and thereby increase the magnetic flux and (ii) to make the flux uniformly distributed in the air gap.

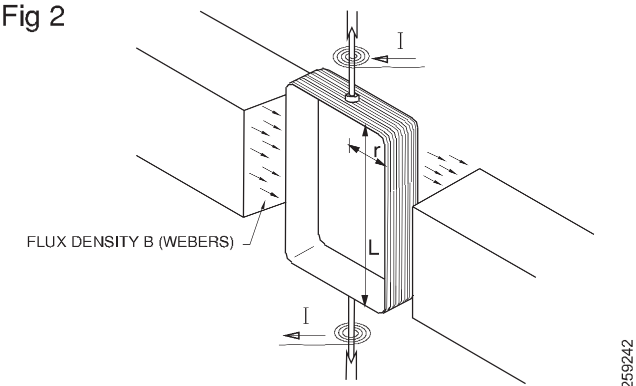
Fig 1



The pointer is attached to one of the spindles, and it moves on a graduated scale when the coil is deflected by the quantity to be measured.

Operation: When the current is passed through the coil, the coil experiences a force due to the interaction of the magnetic fluxes, produced by the permanent magnet and the current in the moving coil.

Fig 2



PRINCIPLE OF THE MOVING COIL INSTRUMENT

The direction of deflection of the moving coil depends upon the direction of the current flowing through the coil. As such, if the instrument is connected with reverse polarity, the deflection of the coil will be reversed, and the pointer will try to move in an anticlockwise direction and read below zero.

Hence, while connecting the instrument in DC the polarity should be correctly observed. Further the instrument will not deflect when connected to an AC supply.

Uses/advantages/disadvantages: As a PMMC instrument is a polarized instrument, it could be used only in DC.

Advantages: The PMMC instrument

- consumes less power
- has uniform scale and can cover an arc up to 270°
- has high torque/weight ratio
- can be modified as voltmeter or ammeter with suitable resistors
- has efficient damping
- is not affected by stray magnetic fields, and
- has no loss due to hysteresis.

Disadvantages: The PMMC instrument

- can be used only in DC
- is very delicate
- is costly when compared to a moving iron instrument
- may show errors due to loss of magnetism of the permanent magnet.

Uses :

It can be used as volt meter and Ammeter

Moving-iron instruments

Objectives: At the end of this lesson you shall be able to
- **state the principle of moving-iron instruments - attraction and repulsion type**
- **describe the construction and working of a moving-iron Instrument**
- **state the use, advantages and disadvantages of moving-iron instruments.**

Moving-iron instruments: This instrument derives its name from the fact that a piece of soft iron which is attached to the spindle and needle moves in a magnetic field, produced by the current or by a current proportional to the quantity of electricity being measured.

There are two types of this instrument which are used either as voltmeter or ammeter.

They are:

- attraction type
- repulsion type.

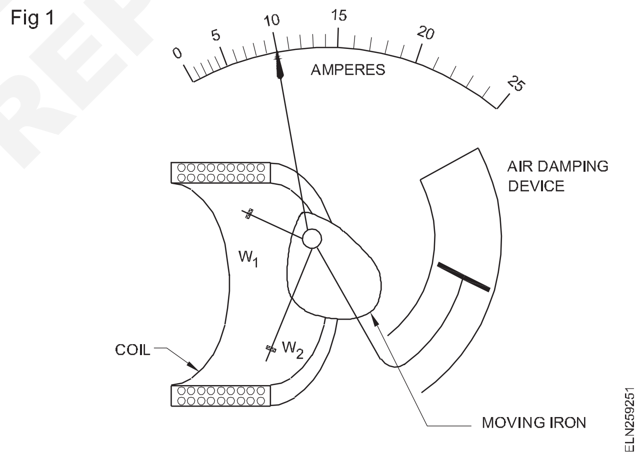
Principle of operation: The attraction type instrument works on the principle of magnetic attraction, and the repulsion type instrument works on the principle of magnetic repulsion between two adjacent pieces of soft iron, magnetised by the same magnetic field.

Construction and working of attraction type moving-iron instrument: This instrument consists of an electromagnetic coil having an air core (Fig 1). Just in front of the air core, an oval shaped soft iron piece is eccentrically pivoted in a spindle (Fig 1).

The spindle is free to move with the help of the jewelled bearings, and the pointer, which is attached to the spindle, could thus move over the graduated scale. When the electromagnetic coil is not connected to the circuit, the soft iron piece hangs vertically down, due to gravitational force and the pointer shows zero reading.

When the electromagnetic coil is connected to the supply, the magnetic field created in the coil attracts the soft iron piece (Fig 1). Due to the eccentricity of pivoting of the iron piece, the enlarged portion of the iron piece is pulled towards the coil. This in turn moves the spindle and makes the pointer to deflect.

Fig 1



The amount of deflection of the pointer will be greater when the current producing the magnetic field is greater. Further the attraction of the soft iron piece is independent on the current direction in the coil. This characteristic enables the instrument to be used both in DC and AC.

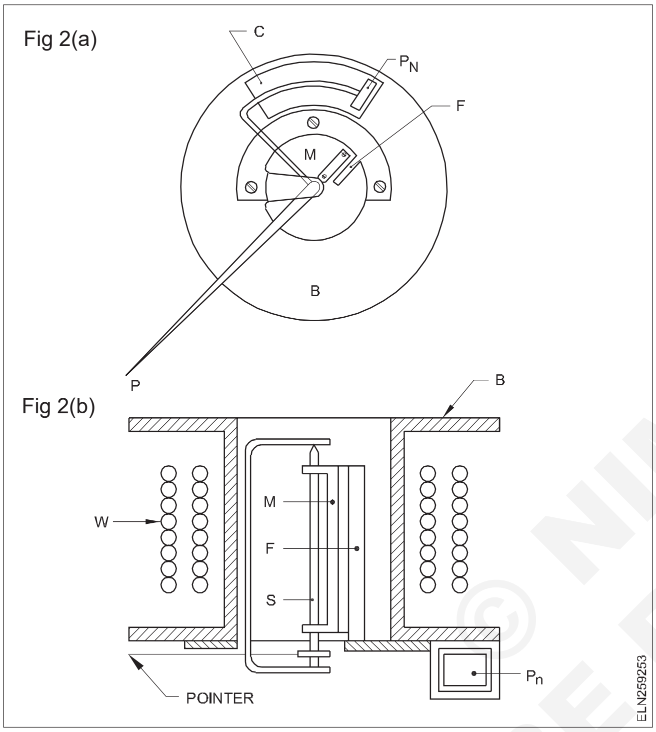
Construction and working of repulsion typemoving-iron instrument: This instrument consists of a coil wound on a brass bobbin B, inside which two strips of soft iron M and F are set axially (Fig 2a). Strip F is fixed whereas the iron strip M is attached to the spindle S, which also carries the pointer P.

Spring control is used, and the instrument is designed such that when no current is flowing through W, the pointer is at zero position and the soft iron strips M and F are almost touching. (Fig 2a & 2b)

When the instrument is connected to the supply, the coil W carries current which in turn produces a magnetic field. This field makes the fixed and moving-iron F and M respectively to produce similar poles in the ends. Therefore, the two strips repel each other.

The torque set up produces a deflection of the moving system end. Therefore it brings into play a controling torque due to torsion of the control springs or weights. The moving system comes to rest in such a position that the deflecting and controlling torques are equal.

In this type of instrument, air damping is used commonly which is provided by the movement of a piston P_N in a cylindrical air chamber C (Fig 2a).



Uses, advantages and disadvantages of Moving-iron instruments

Uses: They are used as voltmeters and ammeters.

The coil W is wound with thick conductor of less number of turns for ammeters and is wound with thin conductors of large number of turns for voltmeter.

Advantages

- They can be used for both AC and DC, and are hence called unpolarized instruments.
- They have a small value of friction errors as the torque/weight ratio is high.
- They are less costly when compared to the moving coil instruments.
- They are robust owing to their simple construction.
- They have satisfactory accuracy levels within the limits of both precision and industrial grades.
- They have scales covering 240°.

Disadvantages

- They have errors due to hysteresis, frequency changes, wave-form and stray magnetic fields.
- They have non-uniform scales commonly. However, special manufacturing designs are utilized to get more or less uniform scales.

Digital Ammeter

Objectives: At the end of this lesson you shall be able to

- **state the features of digital ammeter**
- **state the movements, special operation and standard.**

Digital Ammeter

Digital Ammeters are instruments that measure the current in ampere and display it in digital. These instruments provide information about current drawn and current continuity to help users troubleshoot electric loads.

They have both positive and negative leads and low internal resistance. Digital ammeters are connected in series with a circuit so that current flow passes through the meter.

High current flow may indicate short circuit (or) defective component. Low current flow may indicate high resistance. It can be used to measure the A.C and D.C. Many digital ammeters include a current sensor built in the meter or that is clamped around the wire.

Features:

Different types of digital ammeters can measure different ranges of A.C current and D.C current and also A.C frequency.

Batteries are provided in it to operate without plug-in-power and suitable for cut door use Fig 1 shows a typical digital ammeter.

Special measurements and advanced option:

In some of advanced option, digital ammeters can

- Adjust sampling rates automatically
- Display status information as bar graph
- Measure decibel readings

Standards :

Digital ammeters must have a certain standards and specifications to ensure proper design and functionality refer IEC 600 51 - 2.

Digital Volt Meter (DVM)

Objectives: At the end of this lesson you shall be able to
- **distinguish between analogue and digital voltmeter**
- **list out the advantage of DVM**
- **explain the working principle of DVM.**

Digital Volt Meter (DVM) :

The Digital Volt Meter(DVM) is an electrical measuring instrument which is used to measure line potential difference (P.D) between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are available for the purpose of voltage measurement i.e. analog and digital. Analog voltmeters generally contain a dial with a needle moving over it according to the measure and hence displaying the value of the same.

Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

Advantages of Digital Voltmeters:

- Read out of DVMs is easy as it eliminates observational errors in measurement
- Parallax error is eliminated
- Reading can be taken very fast
- Output can be fed to memory devices for storage and future computations
- More versatile and accurate
- Compact portable and cheap
- Requires low power

Range extension

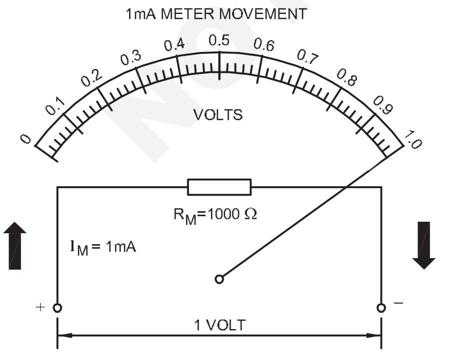
Objectives: At the end of this lesson you shall be able to
- **state the function of the additional series resistance in a voltmeter**
- **calculate the value of the total resistance of the meter with respect to voltage and full scale deflection of current**
- **determine the resistance of a multiplier.**

Meter movement: A basic current meter movement by itself can be used to measure voltage. You know that every meter coil has a fixed resistance, and, therefore, when current flows through the coil, a voltage drop will be developed across this resistance. According to Ohm's Law, the voltage drop (E) will be proportional to the current flowing through the coil of resistance R ($E = IR$).

For example, in Fig 1 you have a 0-1 milliampere meter movement with a coil resistance of 1000 ohms. When 1 milliampere is flowing through the meter coil and is causing f.s.d. the voltage developed across the coil resistance will be:

$$E = I_M R_M = 0.001 \times 1000 = 1 \text{ volt.}$$

Fig 1



SINCE THE VOLTAGE ACROSS THE METER COIL RESISTANCE IS PROPORTIONAL TO THE CURRENT FLOWING THROUGH THE COIL, THE 1MA CURRENT METER MOVEMENT CAN MEASURE VOLTAGE DIRECTLY IN UNITS OF VOLTAGE.

$$E = I_M R_M = 0.001 \times 1000 = 1\text{Volt}$$

If only half that current (0.5 milliampere) was flowing through the coil, then the voltage across the coil would be:

$$E = I_M R_M = 0.0005 \times 1000 = 0.5 \text{ volt.}$$

It can be seen that the voltage developed across the coil is proportional to the current flowing through the coil. Also, the current that flows through the coil is proportional to the voltage applied to the coil. Therefore, by calibrating the meter scale in units of voltage instead of in units of current, the voltage in various parts of a circuit can be measured.

Although a current meter movement inherently can measure voltage, its usefulness is limited because the current that the meter coil can handle, as well as its coil resistance, are very low. For example, the maximum voltage you could measure with the 1 milliampere meter movement in the above example is 1 volt. In actual practice, voltage measurements higher than 1 volt will be required.

Multiplier resistors: Since a basic current meter movement can only measure very small voltages, The voltage range of a meter movement can be extended by adding a resistor, in series. The value of this resistor must be such that, when added to the meter coil resistance, the total resistance limits the current to the full-scale current rating of the meter for any applied voltage.

For example, suppose one wanted to use the 1-milliampere, 1000-ohms meter movement to measure voltages up to 10 volts. From Ohm's Law, it can be seen that, if the movement is connected across a 10-volt source, 10 milliamperes would flow through the movement and would probably ruin the meter ($I = E/R = 10/1000 = 10$ milliamperes).

But the meter current can be limited to 1 milliampere if a multiplier resistor (R_{MULT}) is added in series with the meter resistance (R_M). Since a maximum of only 1 milliampere can flow through the meter, the total resistance of the multiplier resistor and the meter ($R_{TOT} = R_{MULT} + R_M$) must limit the meter current to one milliampere. By Ohm's Law, the total resistance is

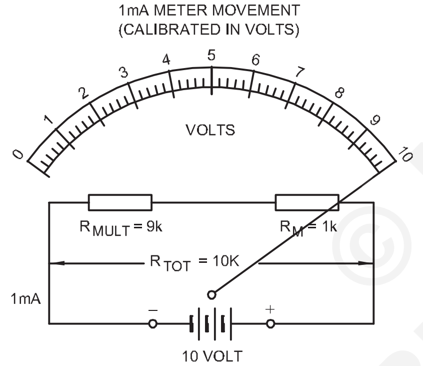
$$R_{TOT} = E_{MAX}/I_M = 10 \text{ volts}/0.001 \text{ ampere}$$
$$= 10{,}000 \text{ ohms.}$$

But this is the total resistance needed. Therefore, the multiplier resistance is

$$R_{MULT} = R_{TOT} - R_M = 10000 - 1000 = 9000 \text{ ohms.}$$

The basic 1-milliampere, 1000-ohms meter movement can now measure 0-10 volts, because 10 volts must be applied to cause a full-scale deflection. However, the meter scale must now be re-calibrated from 0-10 volts, or, if the previous scale is used all the reading should be multiplied by 10 (Fig 2).

Fig 2



BY CONNECTING A MULTIPLIER RESISTOR IN SERIES WITH THE METER RESISTANCE, THE RANGE OF A BASIC METER MOVEMENT CAN BE EXTENDED TO MEASURE VOLTAGES HIGHER THAN THE $I_M R_M$ VOLTAGE DROP ACROSS THE METER COIL.

ELN259712

Multiplying factor (M.F)

$$M.F = \frac{\text{Proposed voltmeter range (V)}}{\text{Voltage drop across } R_M \text{ at FSD}} = \frac{\_\_\_\_V}{\_\_\_\_V}$$

Calculating the multiplier resistance using M F

$$R_{MULT} = (MF - 1)\, R_M$$

where

R_{MULT} = Multiplier resistance

M F = Multiplying factor

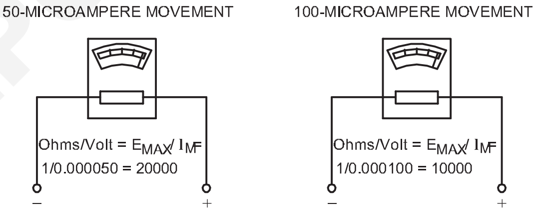
R_M = Meter resistance

$$MF = \frac{V}{v}$$
$$v = I_M \times R_M$$
$$= 1 \times 10^{-3} \times 1000 = 1V$$
$$MF = \frac{V}{v} = \frac{100}{1} = 100$$
$$R_{MULT} = (MF - 1)R_M = (100 - 1)1000$$
$$= 99{,}000 \text{ ohms.}$$

A 1 mA meter has a coil resistance of 1000 ohms. What value of multiplier resistor is needed to measure 100V?

Sensitivity of voltmeter: An important characteristic of any voltmeter is its impedance or ohms per volt (ohms/volt) rating. Ohms/volt rating is the voltmeter sensitivity. The ohms/volt rating is defined as the resistance required ($R_M + R_{MULT}$) for full scale deflection. For example, the 1mA 1000 ohms meter movement indicates 1 volt at full scale deflection. Therefore its `ohm/volt' rating is 1000/1 or 1000 ohms/volt (Fig 3) ohms/volt = E_{MAX}/I_M.

Fig 3



THE VOLTMETER ON THE LEFT IS MORE SENSITIVE THAN THE ONE ON THE RIGHT BECAUSE IT OFFERS MORE RESISTANCE TO OBTAIN A DEFLECTION OF 1 VOLT; OR, TO PUT IT ANOTHER WAY, IT REQUIRES LESS CURRENT FROM THE CIRCUIT IT IS MEASURING FOR FULL-SCALE DEFLECTION.

ELN259713

Multi-range voltmeters: In many types of equipment, one encounters voltages from a few tenths of a volt up to hundreds, and even thousands, of volts. To use single-range meters in these cases will be impractical, and costly. Instead, multi-range voltmeters that can measure several ranges of voltage, can be used.

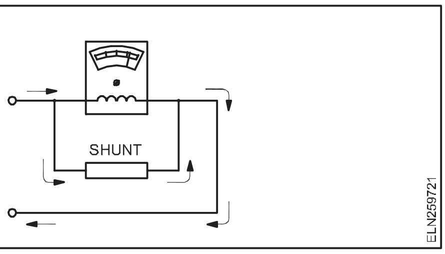
Extension of range of MC ammeters

Objectives: At the end of this lesson you shall be able to
- **define shunt used in ammeter**
- **calculate a shunt resistance to extend the range of an ammeter**
- **name the material used for shunt**
- **apply the use of terminals in standard shunts.**

Shunts: Moving coils of basic meters by themselves cannot carry large currents, since they are made of fine wire. To measure a current greater than that which the moving coil can carry, a low resistance, called a SHUNT, is connected across the instrument terminals (Fig 1).

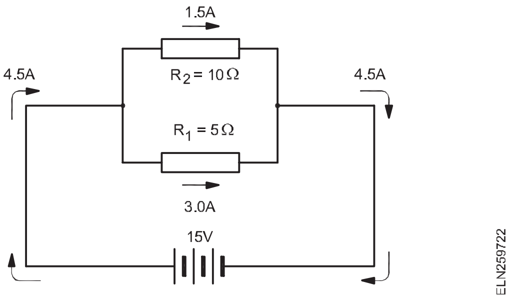
The shunt, therefore, makes it possible to measure currents much greater than that could be measured by the basic meter alone.

Fig 1



The current through each resistor is inversely proportional to its resistance; that is, if one resistor has twice the resistance of another, the current flowing through the larger resistor will be half the current through the smaller one. (Fig 2)

Fig 2



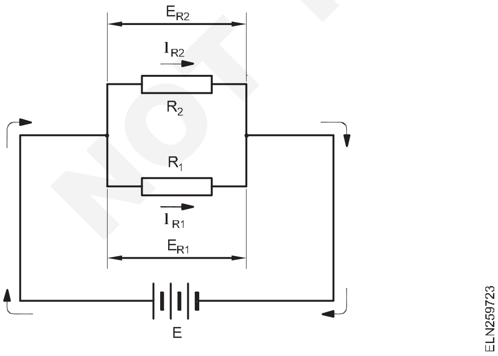
Current flow divides between two resistors parallel in a ratio inversely proportional to their resistance.

Resistor R_2 is twice as large as resistor R_1. Therefore, the current through R_2 will be one-half the current through R_1.

Every meter coil has definite DC resistance. When a shunt is connected in parallel with the coil, the current will divide between the coil and the shunt, just as it does between any two resistors in parallel. By using a shunt of proper resistance, the current through the meter coil will be limited to the value that it can safely handle, and the remainder of the current will flow through the shunt.

Voltage drops in parallel circuits: Examine the parallel circuit shown in Fig 3. It can be seen that the voltage across both resistors is the same. As already explained Ohm's Law states that the voltage across a resistor equals the current through the resistor times the value of the resistor.

Fig 3



Since the same voltage appears across R_1 and R_2 then $E_{R1} = E_{R2}$. From this we derive $I_{R1}R_1 = I_{R2}R_2$. This equation can be used to calculate the shunt needed for a particular current measurement.

Therefore, the voltage across R_1 is $E_{R1} = I_1R_1$ and the voltage across R_2 is

$$E_{R2} = I_2R_2.$$

However, since the same voltage is across both R1 & R2 then

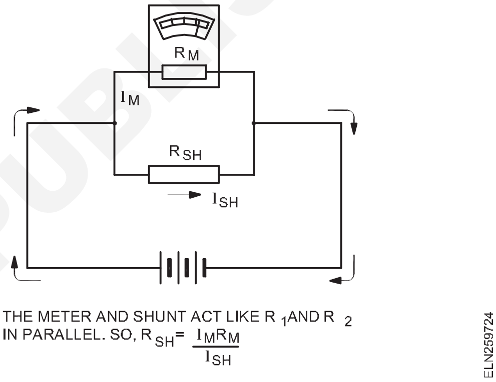
$$E_{R1} = E_{R2}, \text{ therefore,}$$

$$I_{R1}R_1 = I_{R2}R_2.$$

This simple equation, with very slight modifications, can be used to calculate the value of a shunt for a current meter for any application.

The shunt equation: A meter and shunt combination is identical to the parallel circuit shown in Fig 4. Instead of labelling the top resistor R_2, it can be labelled R_M, which represents the resistance of the moving coil. Resistor R_1 can be labelled R_{SH} to represent the resistance of the shunt. I_{R1} and I_{R2} then become I_{SH} and I_M to indicate the current flow through the shunt and through the meter. This means that the equation $I_{R1}R_1 = I_{R2}R_2$ can now be written as $I_{SH}R_{SH} = I_MR_M$.

Fig 4



Therefore, if three of these values are known, the fourth can be calculated. Since the shunt resistance R_{SH} is always the unknown quantity, the basic equation

$I_{SH}R_{SH} = I_MR_M$ becomes $$R_{SH} = \frac{I_MR_M}{I_{SH}}$$

From this equation, shunts can be calculated to extend the range of a current meter to any value,

where R_{SH} = shunt resistance

I_M = meter current

R_M = resistance of moving coil instrument

I_{SH} = current flow through shunt.

The value of current through the shunt(I_{SH}) is simply the difference between the total current you want to measure, and the actual full-scale deflection of the meter.

$I_{SH} = I - I_M$ where I = total current.

The meter and shunt act like R_1 and R_2 in parallel.

So, $$R_{SH} = \frac{I_MR_M}{I_{SH}}$$

Calculating shunt resistance: Assume that the range of a one milliampere meter movement is to be extended to 10 milliamperes, and the moving coil has a resistance of 27 ohms. Extending the range of the meter to 10 milliamperes means that 10 milliamperes will be flowing in the overall circuit when the pointer is deflected full scale. (Fig 5)

I_M = 1 mA (0.001 A)

I = Current to be measured = 10mA

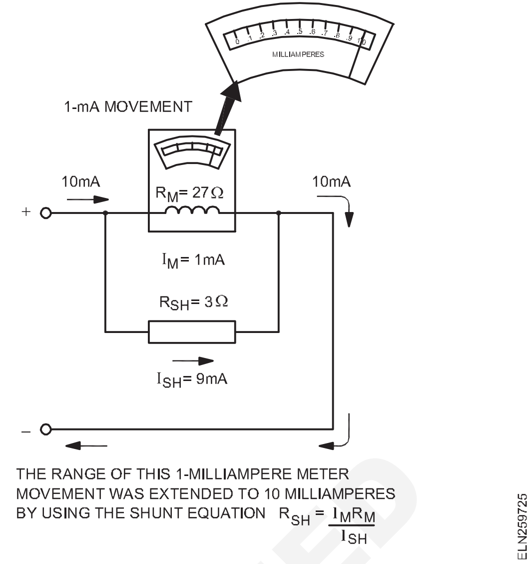
R_M = 27 Ohms

$I_{SH} = I - I_M$ = 10 mA – 1 mA

= 9 mA (0.009 A)

$$R_{SH} = \frac{I_M R_M}{I_{SH}} = \frac{0.001 \times 27}{0.009} = 3 \text{ ohms.}$$

Fig 5



THE RANGE OF THIS 1-MILLIAMPERE METER MOVEMENT WAS EXTENDED TO 10 MILLIAMPERES BY USING THE SHUNT EQUATION $R_{SH} = \frac{I_M R_M}{I_{SH}}$

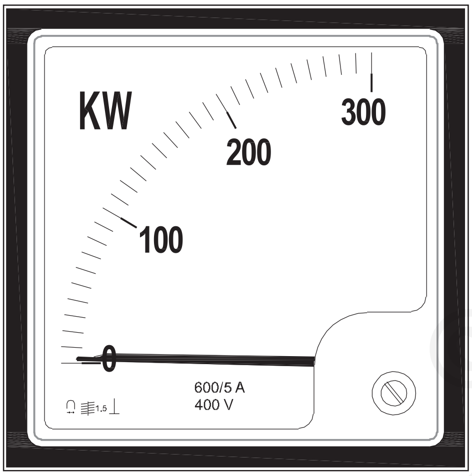
Wattmeter, PF meter, Energy meter, Megger, Earth tester, Frequency meter, Phase sequence meter, Multimeter, Tong tester etc

Objectives: At the end of this lesson you shall be able to
- **explain the working principles of various measuring instruments**
- **state parts of various measuring instruments**
- **differentiate digital and analog meters.**

Wattmeter

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements.

Fig 1



WATTMETER

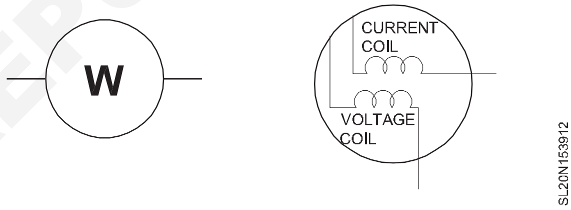
Electrodynamic wattmeters are a design that goes back to the early 20th century. They work by using three coils: two fixed in series with the electrical load, and a moving coil in parallel with it. The series coils measure current flowing through the circuit, the parallel coil measures voltage.

The Electrodynamometer Wattmeter has two types of coils; fixed and the moving coil. The fixed coil connects in series with the circuit whose power consumption use to be measured. The dynamo-meter type wattmeter consists of two coils namely: fixed coil (Current coil) and moving coil (Pressure Coil). The current coil is connected in series with the load hence it carries the circuit current. The potential coil is connected across the load so it carries current proportional to the voltage.

These instruments are used on both AC and DC supplies. These wattmeters provide accurate readings only when frequency and supply voltages are constant. These wattmeters consists of two laminated electro magnets and one of them is excited by the current with exciting winding. This winding is connected in series of the circuit. The other magnet is excited by the current which is proportional to the current. Its exciting coil is connected in parallel with the circuit. The winding of first magnet carries line current and the other coil carries voltage and is highly inductive. This coil is connected to the supply and the flux lags 900 behind the voltage. The torque is produced and is proportional to the power in the load circuit. The torque acts on the disc and force is produced in the disc. The disc starts moving and the pointer is attached on it with a spring and it shows reading on its scale.

These wattmeters are used in various laboratories, industries for specific purposes. These wattmeters plays an important role in measurement of power in distribution and transmission of power.

Fig 2



A modern digital wattmeter samples the voltage and current thousands of times a second. The real power divided by the apparent volt-amperes (VA) is the power factor. A computer circuit uses the sampled values to calculate RMS voltage, RMS current, VA, power (watts), power factor, and kilowatt-hours.

The two-wattmeter method uses two voltage measurements referenced to the same phase (line) and the two currents flowing into that phase. This is true if there is no leakage current from neutral to ground. The three-wattmeter method requires voltage measurements from line-neutral.

An instrument for measuring electric power in watts, the unit of electrical energy, volt times amperes; therefore, combining the functions of a voltmeter and an ammeter.

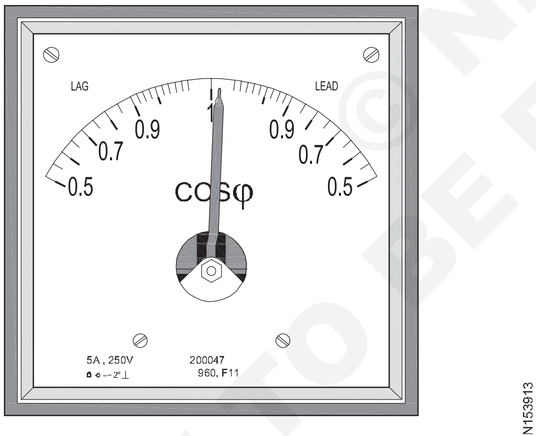
PF meter:

A Power Factor is a unit of measurement of various electric drives like induction motors, Synchronous motors and Generators etc. Power Factor is the ratio between the real power and the apparent power. Now the question rises that what is a real power and apparent power? So, the real power reacts like a resistance in an electric drive. It may be called as power consumed in an electric drive or a term “the total load drawn on the electric drive” can be used for the real power. Real power is denoted by Power (P). It is measured in watts (W). While the apparent power is the product of an electric current and voltage. It is measured in KVAR. It is denoted by S.

A power factor meter is an electric instrument which is used to measure the power factor of various electrical machines like DC Generator, AC Motor, Transformer etc and for measuring the power factor of various transmission and distribution lines of various electric power supplies. These power supplies may be from Grid Stations, Substations or from Power Houses. Power factor must be 0.8 to unity if power factor decreases from 0.8 then the voltage and the current will imbalanced and the power is disturbed. So, in grid stations, Substations the power factor must be between 0.8 to unity (1) leading. The Power Factor is the cosine of angle φ between the voltage and the current of the transmission lines and electrical machines.

Power Factor Meters are mostly used for the observation of electric power to maintain the power factor for the balancing of voltage and current. The power factor of transmission and the distribution lines is unity (1) leading because of the losses occurred in these lines and the reason of the losses is the length of the conductor or wire. If we increase the length of a wire and the power we provide on its first end constant then on the other end of the wire we will get less power as compared to the first end because of the large length of the conductor.

Fig 3



PF METER

The formula to measure the power factor in power factor meters is given below. In simple words, the following formula is used in power factor meters to measure the power factor of the transmission/distribution lines and electrical machines:

For single phase transmission/distribution lines

$$\varphi = IV\cos\theta$$

For three phase transmission/distribution lines

$$\varphi = \sqrt{3}\ \times \cos\theta$$

For single phase electrical machines

$$\varphi = IV\cos\theta$$

For three phase electrical machines

$$\varphi = \sqrt{3}\ \times \cos\theta$$

The power factor meters are divided into many types and these types are discussed in detail below:

Types of Power Factor Meter:

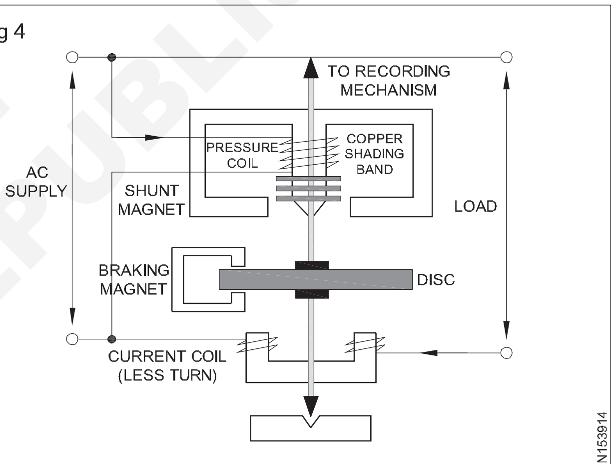
Power Factor Meters consist of the following types:

- Moving-iron Power Factor Meter
- Electrodynamic Power Factor Meter
- Single Phase Power Factor Meter
- Three Phase Power Factor Meter

Energy meter

The meter which is used for measuring the energy utilized by the electric load is known as the energy meter. The energy is the total power consumed and utilized by the load at a particular interval of time. It is used in domestic and industrial AC circuit for measuring the power consumption. The meter is less expensive and accurate.

Fig 4



ENERGY METER

Construction of Energy Meter

The energy meter has four main parts. They are the

1 Driving System

2 Moving System

3 Braking System

4 Registering System

Megger

The Megger test is a method of testing making use of an insulation tester resistance meter that will help to verify the condition of electrical insulation. Insulation resistance quality of an electrical system degrades with time, environment condition i.e. temperature, humidity, moisture and dust particles.

To check whether connections are made perfectly, we use an electrical instrument named megger. In an insulation testing, we send a test voltage down through an electrical system, to check if there is any leakage of current which is gone to be passed through the insulated wiring of all the appliances of the machine.

Anything reading between 2 megohms and 1000 megohms is usually considered a good reading, unless other problems have been noted. Anything less than 2 megohms indicates an insulation problem.

The megger supplies over 500 volts, and that is enough to give a fatal shock. The cable that is to be tested may be used in AC lines and the megger uses DC as the testing voltage.

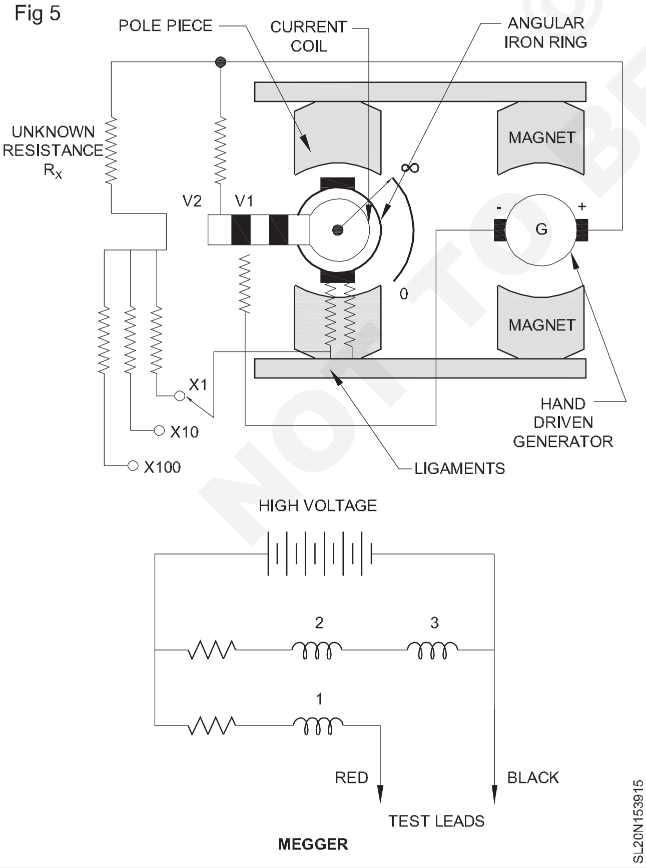
Clamp the alligator clip on one of the megger probes to the wire or cable, touch the other probe to the exposed conductor and press the test button. The megger will generate a current between the probes, and the meter will record the resistance of the jacket to the flow of the current.

If you are testing insulation resistance to ground, place the positive probe on the ground wire or the grounded metal junction box and the negative probe on the conductor or terminal. Energizethe Megger for 1 minute. Read the value of the resistance at the end of the minute test and note it in your table.

The purpose of the IR test is to check for damaged insulation, this can be mechanical damage or damage by heat, (overloaded cables), readings less than 2 Mohm indicate damaged insulation, readings of 2-50 Mohm are indicative of long circuit lengths, moisture and contamination and do not indicate the insulation quality.

Earth tester

Fig 5



MEGGER

The earth tester is one type of equipment, used to measure earth resistance. If the earth resistance value is very low then this tester is also known as ground resistance tester. The Resistance of the earth can be measured with the help of megger earth tester or earth megger.

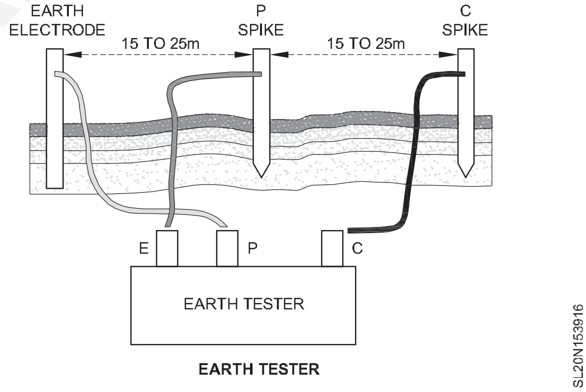
Working Principle

The earth megger is essentially a direct reading ohmmeter and it has a hand driven generator which supplies the testing current. The ohmmeter essentially consists of two coils (current coil and pressure coil) mounted at a fixed angle to each other on a common axis. It has four terminals P1, C1, P2 and C2. Its terminals P1 and C1 are short-circuited. This junction makes a common point. Hence it has got three terminals E (common point), P (P1) and C (C1) outside. To measure the earth resistance with a megger earth tester, the earth electrode under test is connected to its E terminal and P and C terminals are connected to auxiliary electrodes through a connecting lead of negligible resistance.

When the handle of the megger earth tester is rotated at a uniform speed, it directly indicates the earth resistance on the dial or calibrated scale. Set of readings are obtained by burying the electrode P at various positions.

Firstly, it can be buried between earth electrode and current electrode C. Secondly, it should be hurried 15 meters away from the earth electrode on the opposite side of current electrode C. Then it should be buried 15 meters away from the current electrode C. The mean of the three readings gives the resistance between the earth electrode and soil.

Fig 6



EARTH TESTER

The resistance between earth electrode (i.e. plate or pipe etc.) and the soil does not remain constant due to variable moisture conditions. To have good and effective earthing, the earthing system should be tested from time to time and moisture contents in the nearby soil tested from time to time and moisture contents in the nearby soil should be increased by adding water.

The earth resistance should be less than 1 ohm for power stations. And for the sub-stations, it should be less than 5 ohms. It should be noted be that the earth resistance should be as small as possible for two reasons:

In the case of a fault, when the metal frame comes in contact with the live wire or phase wire, a current will flow through the earth connection, which causes a potential difference between the metal frame and earth. This potential difference should be very low because it will act across a person who touches the metal frame in such a faulty condition.

A low resistance to earth will cause high current to flow when the fault occurs. The high current will cause the fuse to melt in a very short time, thus disconnecting to faulty apparatus from the lines thus ensuring safety.

Significance of Earthing and Earth Resistance

The provision of earthing for an electrical installation is very significant due to the following reasons:

All the parts of electrical equipment, like the casing of machines, the casing of circuit breakers, tanks of transformers must be connected to an earth electrode. It is done to protect the various parts of the installation as well as the persons working against damage in case the insulation of a system fails at any point.

By connecting these parts to an earthed electrode a continuous low resistance path is available for leakage currents to flow to earth. This current operates the protective devices and thus the faulty circuit is isolated if a fault occurs.

The earth electrode ensures that in the event of overvoltage on the system due to lightning discharges or other system faults, those parts of equipment which are normally dead, do not attain dangerously high potentials.

In a three-phase circuit the neutral of the system is earthed in order to stabilize the potential of the circuit with respect to earth.

An earth electrode will only be effective so long it has a low resistance to the earth and carry large currents without deteriorating. Since the amount of current which an earth electrode will carry is difficult to measure, the resistance value of earth resistance is taken as sufficiently reliable indication of its effectiveness. The resistance of the earth electrode should be to give good protection and it must be measured.

The main factors on which the resistance of any earthing system depends are:

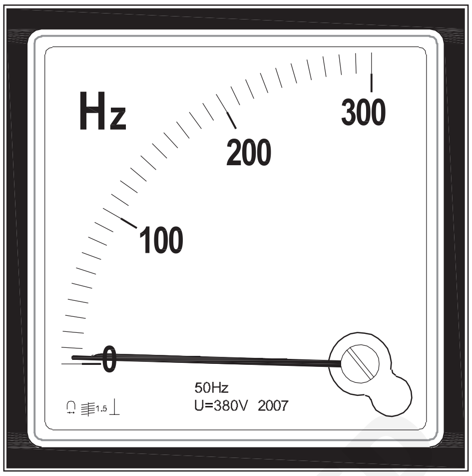
- Shape and material of earth electrode of electrodes used.
- Depth in the soil at which the electrodes are buried.

The specific resistance of soil and in the neighbourhood of electrodes:

The specific resistance of the soil is not constant but varies from one type of soil to another. The amount of moisture present in the soil effects its specific resistance of earth electrode is not a constant factor but suffers seasonal variations. This calls for periodic testing that the earthing system remains reasonably effective.

Frequency meter

Fig 7

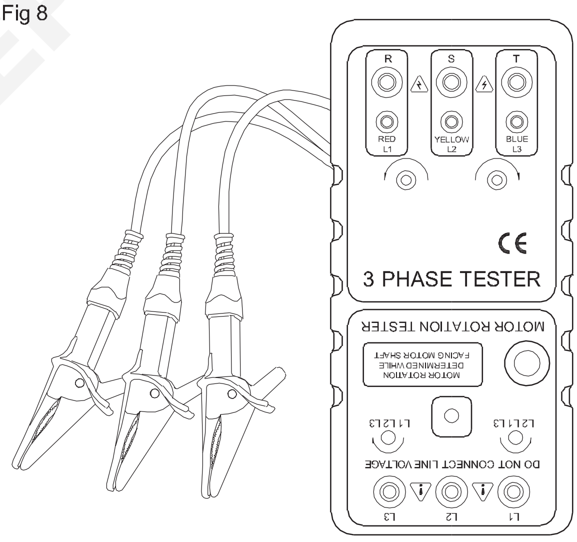


FREQUENCY METER

Frequency meter, device for measuring the repetitions per unit of time (customarily, a second) of a complete electromagnetic waveform. Various types of frequency meters are used. Panel Frequency Meter is used to measure the frequency of 230V AC mains. When you connect it to the 230V AC line, the display shows the line frequency. Generally, the line frequency is 50 Hz, which may vary from 48 Hz to 52 Hz.

Phase sequence meter

Fig 8



PHASE SEQUENCE METER

Phase sequence meter is used for detecting the sequence of the supply in three-phase electric circuits. Since the direction of rotation of three phase electric motors can be changed by changing the phase sequence of supply. And also the correct operation of measuring instruments like 3 phase energy meter and automatic control of devices also depend on the phase sequence. Different types of phase sequence testers are available in today’s market like contact or non contact, static or rotating, etc., in a wide range of voltage or power ratings.

What is Phase Sequence?

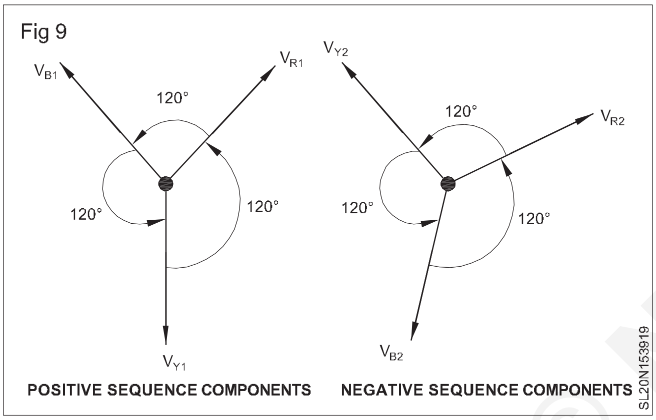
The sequence in which three phase voltages attain their positive maximum values is defined as the phase sequence. It refers to the relation between the voltages or currents in three phase system. Consider the three phases as red-R, yellow-Y and blue-B phases.

The phase sequence can be taken as RYB if R attains its maximum value first with respect to the reference in anti-clockwise direction followed by Y phase 120° later, and B phase 240° later than the R phase.

The phase sequence can be taken as RBY if R followed by B phase is at 120° later and Y phase is at 240° later than the R phase. RYB is considered as a positive sequence, whereas RBY is a negative sequence supply, as shown in the figure.

The phase sequence meter is used for the detection of phase sequence in three phase circuits and there are different types of phase sequence indicators that are **Multimeter** as follows:

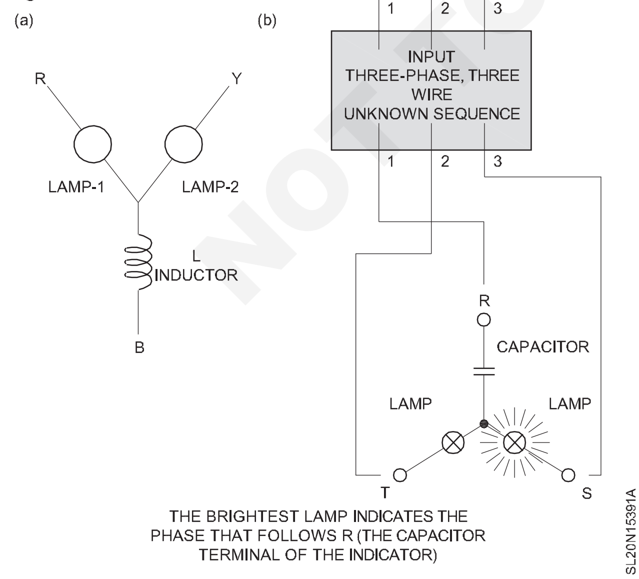
Fig 9



Lamp Testing Method:

If the phase sequence is RYB, then the lamp B will glow brighter than the lamp A, and – if phase sequence is reversed – then the lamp A will glow brighter than the lamp B, as shown below in the lamp arrangement circuit diagram.

Fig 10



It indicates that the voltage at the lamp A is only 27 percent of the lamp B. So, from this, we can observe that the lamp B will glow brighter than the lamp A in case of an RYB phase sequence. While in case of a reversed phase sequence, the lamp A is brighter than the lamp B.

Similarly, from the above circuit by replacing the inductor with a capacitor, as shown in the below figure, the indicator works similar to the above phase indicator.

Here two resistors are connected in series with the two Neon lamps to protect the lamps from over current and breakdown voltages. If the three phase supply is in the sequence of RYB, then the lamp A will be ON, and the lamp B will be off, and if the supply sequence is reversed, then the lamp A will be off while the lamp B will be on.

Multimeter

A Multimeter is an electronic instrument, every electronic technician and engineer's widely used piece of test equipment. A multimeter is mainly used to measure the three basic electrical characteristics of voltage, current, and resistance. It can also be used to test continuity between two points in an electrical circuit.

The multimeter has multi functionalities like, acts like ammeter, voltmeter, and ohmmeter. It is a handheld device with positive and negative indicator needle over a numeric LCD digital display. Multimeters can be used for testing batteries, household wiring, electric motors, and power supplies.

The essential parts of the multimeter mainly include a display, power source, probes, and controls.

The function and operation of a multimeter are similar for both analog and digital types. This instrument includes two leads or probes namely red and black & three ports. The black color lead is used to plug into the common port, whereas the red color leads plugs into other ports based on the requirement.

Once the leads are plugged in, the knob can be switched ON in the center of the instrument so that the appropriate function can be done for the specific component test. For instance, once the knob is situated to 20V DC, then the multi-meter will notice DC voltage up to 20V. To calculate low voltages, then set the knob in the multi-meter to the 2V/200mV range.

To obtain a reading from the meter, touch the end of each probe to the end of the terminals of components. Multimeter is very safe to utilize on devices and circuits to provide the current or voltage that does not go above the highest rating of the meter.

While measuring, we must be very cautious so don't touch the bar ends of the metal in the tester when activated otherwise you will get an electrical shock.

These instruments are capable of different readings based on the model. So basic types of multimeter are mainly used to measure amperage, resistance, voltage, checks continuity and a complete circuit can be tested

Types

- Analog multimeter
- Digital multimeter
- Clamp multimeter

Difference between Analog Multimeter and Digital Multimeter

Analog Multimeter	Digital Multimeter
Analog Multimeter is used to gauge restricted electrical quantities like resistance, voltage &current.	Digital Multimeter is used to compute various electrical quantities like voltage, current, capacitance, resistance, values of diode and impedance, etc.
The size of the analog multimeter is larger	The size of the digital multimeter is smaller
This meter provides the reading on a scale next to the pointer.	This meter provides the reading in the form of numeric on an LCD.
These are calibrated manually.	These are calibrated automatically.
Its construction is simple	Its construction is complicated because of the involvement of components like electronics and logic.
Analog multimeters are less accurate because of the parallax errors & readings of the wrong pointer	Digital multimeters are very accurate
It doesn't need ADC to show reading.	It needs ADC to exhibit the reading.
Input resistance is not stable	Input resistance is stable
The pointer of this multimeter tries to turn aside to the left in reverse polarity.	This multimeter shows a negative quantity once the polarity is reversed.
These are less cost	These are expensive
The o/p of this meter cannot be interfaced through exterior equipment.	The o/p of these meters can be interfaced through exterior equipment.
The frequency range is up to2kHZ.	The frequency range is high as compared to analog
Analog Multimeter measures the current with the help of a Galvanometer.	Digital Multimeter measures voltage with ADC
It has less electric noise	It has more electric noise
It allows simply one i/p signal for each operation.	It allows several input signals & consumers can select the required signal on the variable display.
The maximum AC frequency which can be calculated is lesser	The maximum AC frequency which can be calculated is high than its counter element

Tong tester

Clamp meter is often known as Tong Tester also. It is an easy to use test equipment and is useful in the measurement of a live-conductor without damaging / powering down the circuit.

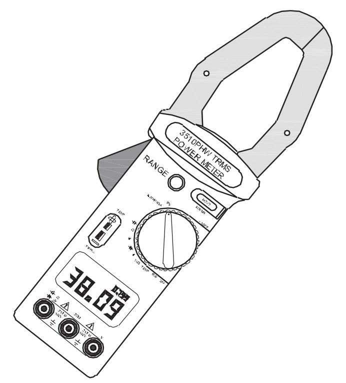
- It can be used in noisy electrical environments.
- It filters out noise and provides accurate and stable measurements such as motor starting current.
- It has ergonomic design which fits in the hand while wearing protective equipment.

Tong tester/Clamp Digital Multimeter

The clamp digital multimeter/Tong test is used to measure the electricity flow. As the name suggests, this multimeter includes the feature namely clamp which measures the amps whenever the probes measure the volts. The adjustment of power utilization otherwise watts can be done through multiplying the reading of voltage with the amps. This multimeter also includes an additional feature that is different kinds of settings. The appropriate feature is used while measuring.

This kind of multimeter includes fixed tools for measuring the current flow. This device extremely changes from the fluke type because, in fluke multimeter, it utilizes a clamp to measure the flow of current. So, this instrument is usually recommended for professionals only.

Fig 11



TONG TESTER/CLAMP DIGITAL MULTIMETER

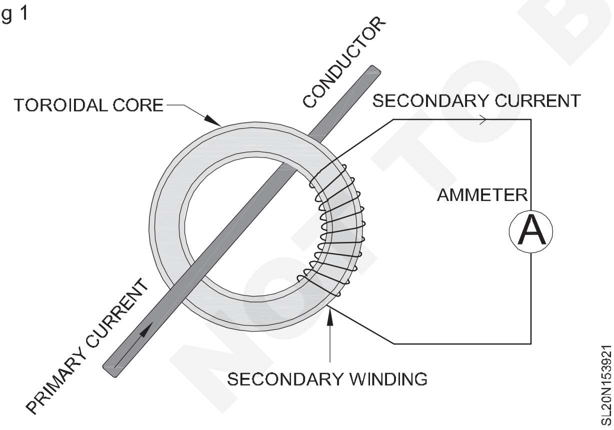
Instrument transformers – CT and PT

Objectives: At the end of this lesson you shall be able to
- **explain the working of current transformer**
- **explain the working of potential transformer**

Instrument Transformers

How will you measure AC currents and voltages of very high magnitude? You will need the measuring instruments having higher range, which literally mean huge instruments. Or there's another way, using the transformation property of AC currents and voltages. You can transform the voltage or current down with a transformer whose turns ratio is accurately known, then measuring the stepped down magnitude with a normal range instrument. The original magnitude can be determined by just multiplying the result with the transformation ratio. Such specially constructed transformers with accurate turns ratio are called as Instrument transformers. These instruments transformers are of two types - (i) Current Transformers (CT) and (ii) Potential Transformers (PT).

Fig 1



Current Transformers (CT)

Current transformers are generally used to measure currents of high magnitude. These transformers step down the current to be measured, so that it can be measured with a normal range ammeter. A Current transformer has only one or very few number of primary turns. The primary winding may be just a conductor or a bus bar placed in a hollow core (as shown in the figure). The secondary winding has large number turns accurately wound for a specific turns ratio. Thus the current transformer steps up (increases) the voltage while stepping down (lowering) the current. Now, the secondary current is measured with the help of an AC ammeter. The turns ratio of a transformer is $N_P / N_S = I_S / I_P$

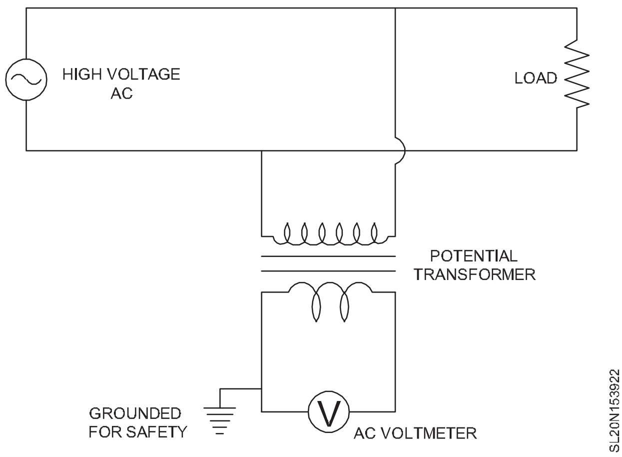
Generally, current transformers are expressed in their primary to secondary current ratio. A 100:5 CT would mean the secondary current of 5 amperes when primary current is 100 amperes. The secondary current rating is generally 5 amperes or 1 ampere, which is compatible with standard measuring instruments.

$$\text{Turns Ratio} = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

Potential Transformer (PT)

Potential transformers are also known as voltage transformers and they are basically step down transformers with extremely accurate turns ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns. A potential transformer is typically expressed in primary to secondary voltage ratio. For example, a 600:120 PT would mean the voltage across secondary is 120 volts when primary voltage is 600 volts.

Fig 2



Calculation of total watt hour of all loads per day and daily average watt hour from twelve months electricity bill

Objectives: At the end of this lesson you shall be able to
- **calculate daily energy consumption from no. of loads and hours of usage**
- **calculate average daily energy consumption from twelve months Electricity bill.**

1 Total watt hour of all loads per day

The loads connected in a residence or industry to the AC mains varies place to place. The loads are manufactured to function on AC mains with voltage rating V= 230 V, I based on internal resistance of the load and Wattage = V*I.

Hence mainly the load is identified by its W rating. All loads in general are connected in parallel in common wiring. There may be similar loads in more numbers. Having all these information the average load per day is calculated as per the following method if hours of usage are known. An example:

Sl no	Name of load	W rating (W)	No of loads (n)	Hours of use (Hrs)	Whr/load (Whr)	Total Whr (n x Whr)
1	Bulb	100	5	6	600	3000
2	Fan	40	4	8	320	1280
3	Fridge	300	1	20	6000	6000
4	Heater	1000	1	2	2000	2000
5	Television	300	2	10	3000	6000
6						
7						
8						
9						
10						
					Total	18280
					No of Electrical units consumed = Total Whr ÷1000 Because 1 unit = 1 KWhr =1000 Whr	18.28 units

2 Daily average watt hour from twelve months electricity bill

Collect latest 12 months Electricity consumption bills received from Electricity board and fill up the following table.

Sl No	Name of month	Units
1	January	138
2	Feb	135
3	Mar	143
4	Apr	150
5	May	165
6	Jun	145
7	Jul	138
8	Aug	142
9	Sep	135
10	Oct	144
11	Nov	154
12	Dec	160
	Total	1749/Annum
	Average daily consumption	1749÷365= 4.79 units/day
	Approximate units per day	5
	Whr/Day = Units*1000	5000 Whr

Transformer - Principle - Classification - EMF Equation

Objectives: At the end of this lesson you shall be able to
- **define a transformer**
- **explain the construction of two winding transformer**
- **state the reasons for laminated silicon steel being used as core material.**

Transformer

Transformer is a static electric device which transfer the electric energy from one circuit to other without changing the frequency and power.

The three-phase synchronous generator is used extensively to generate bulk power. The voltage levels at which this power is generated is typically in the range 11 kV to 22 kV. Electrical power is to be provided at a considerable distance from a generating station. It is possible to transmit the generated power directly but this results in unacceptable power losses and voltage drops.

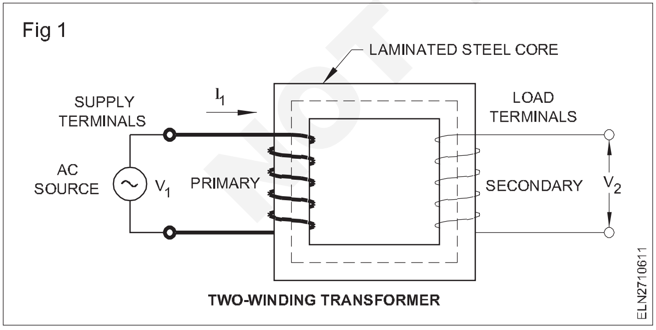
Transmission voltages vary up to the 400 kV level. This is made possible by power transformers. At the receiving end this high voltage must be reduced because ultimately it must supply three phase load at 415V or single phase load at 240V.

The transformer makes it possible for various parts of a power system to operate at different voltage levels.

Standard safety norms: Trainees can be instructed to refer the standard safety norms related with transformer in the International Electrotechnical commission (IEC - 60076-1) for the further details.

Two-winding transformers: A transformer consists of two stationary windings generally called as high voltage and low voltage sides which are electrically isolated but magnetically coupled (Fig 1). The coils are said to be magnetically coupled because they link a common flux.

Fig 1



TWO-WINDING TRANSFORMER

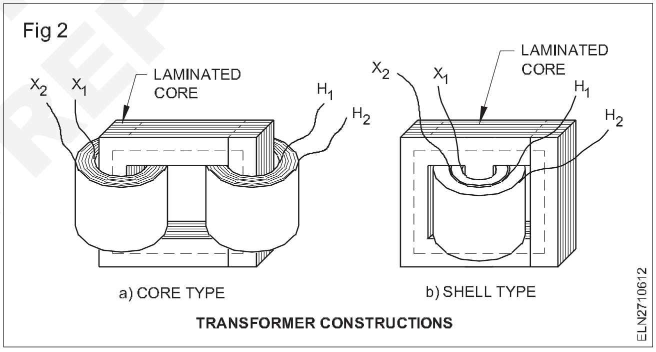
Laminated steel core transformers are used in power applications. Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.

The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Transformers are efficient and reliable devices used mainly to change voltage levels.Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are in the range of 92 to 99%. The higher values apply to the large power transformers. There is no change in frequency of voltage.

Construction: There are basically two types of iron-core construction. Fig 2a shows core type already represented in Fig 1. It consists of two separate coils, one on each of the two opposite legs of a rectangular core.

Fig 2



TRANSFORMER CONSTRUCTIONS

Normally, this is not a desirable design. Its disadvantage is the large leakage fluxes associated with it. The large leakage fluxes cause poor voltage regulation. Therefore, to ensure that most of the flux set by the primary will link the secondary, the construction Fig 2b is employed. This is called shell type construction.

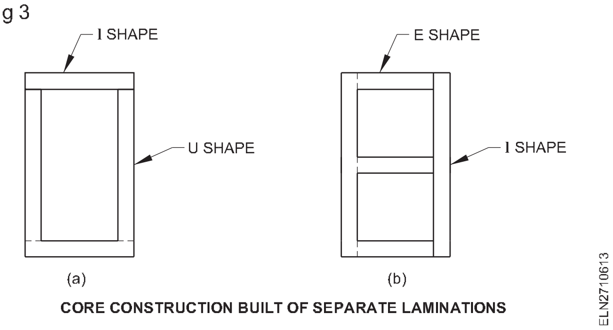
Here the two windings are wound concentrically. The higher voltage winding is wound on top of the lower voltage winding. The low-voltage winding is then located closer to the steel. This arrangement is preferable from an electrical insulating point of view. From the electrical viewpoint there is not much difference between the two constructions.

Cores may be built up of lamination silicon steel sheet. Most laminating materials have an approximate alloy content of 3% silicon and 97% iron. The silicon content reduces the magnetizing losses. Particularly, the loss due to hysteresis is reduced. The silicon makes the material brittle. The brittleness causes problems in stamping operation.

Most laminated materials are cold-rolled and often specially annealed to orient the grain or iron crystals. This provides very high permeability and low hysteresis to the flux in the direction of rolling. Transformer laminations are usually 0.25 to 0.27 mm thick for 50 Hz. operation. The laminations are coated on one side by a thin layer of varnish or paper to insulate them from each other.

Coils are pre-wound, and the core design must be such that it permits placing the coil on the core. Ofcourse, the core must then be made in atleast two sections. The laminations for the core-type transformer of Fig 2a may be made up of (and) shaped laminations, as shown in Fig 3a. The core for the shell type transformer of Fig 2b is normally made up of E and I shaped laminations Fig 3b.

Fig 3

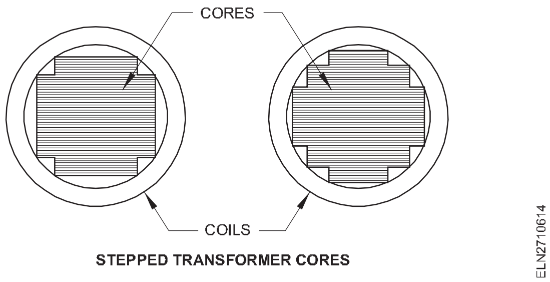


CORE CONSTRUCTION BUILT OF SEPARATE LAMINATIONS

Core construction: As a rule, the number of butt joints is to be limited.The joints are tightly made and laminations interleaved so as to minimize the reluctance of the magnetic circuit. The stacking of laminations to the required core cross-section results in the core legs of square or rectangular cross-section. This permits coils to be fitted on the core legs with either square, rectangular, or circular coil spools or forms.

In larger transformers, a stepped-core arrangement is used to minimise the use of copper and reduce copper loss. (Fig 4) This construction guarantees that each length of copper conductor embraces the maximum cross-sectional area of steel.

Fig 4



STEPPED TRANSFORMER CORES

In practice, the primary and secondary windings of a transformer have two or more coils per leg. They may be arranged in series or parallel. The laminations are pressed together by clamping in such a way as to prevent any fluttering or shifting.

The coils are impregnated. Insufficient clamping of laminations usually results in a humming sound. This generates objectionable and audible noise by the iron core of the transformer.

Transformers are usually air-cooled. Larger transformers are placed in tanks with a special transformer oil. The oil serves a dual purpose as an insulating medium as well as a cooling medium.

The heat generated in the transformer is removed by the transformer oil surrounding the source and is transmitted either to atmospheric air or water. No matter what size of transformer is dealt with, they all operate on the same principle.

Transformer principle

Objectives: At the end of this lesson you shall be able to

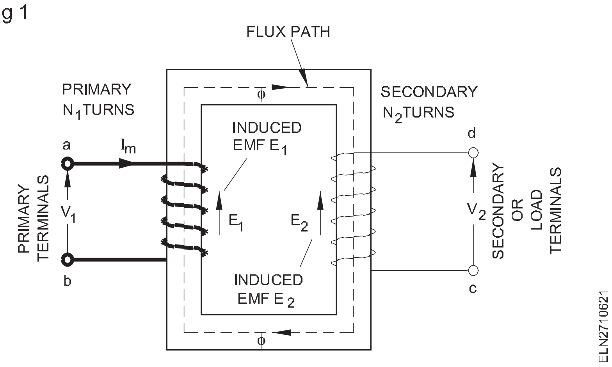
- **describe an ideal transformer and its operation on load and noload**
- **explain the principle of the operation of a transformer**
- **derive the EMFequation of a two-winding transformer**
- **derive the transformation ratio of a transformer.**

An ideal transformer: An ideal transformer is one which has no losses, ie. its windings have no ohmic resistance and there is no magnetic leakage. An ideal transformer consists of two coils which are purely inductive and wound on a loss-free core.

However, it may be noted that it is impossible to realize such a transformer in practice; yet for convenience, we will first analyse such a transformer and then an actual transformer.

Let us consider an ideal transformer (Fig 1) whose secondary is open and whose primary is connected to a sinusoidal voltage V1.

Fig 1



Working principle

The transformers work on the principle of mutual induction of faraday's law of electro - magenetic induction.

The applied voltage causes a small current to flow in the primary winding. This no-load current is meant to build up a counter-electromotive force equal and opposite to the applied voltage.

Since the primary winding is purely inductive and there is no output, the primary draws the magnetizing current Im only. The function of this current is merely to magnetise the core. The Im is small in magnitude and lags V1 by 90°. This alternating current Im produces an alternating flux f which is proportional to the current and hence is in phase with it (Im). This changing flux is linked with both the windings. Therefore, it produces self-induced EMF (E)1 in the primary which lags the flux 'f' by 900. This is shown in vector diagram Fig 2.

The flux 'ø' produced by the primary links with the secondary winding and induces an EMF (E2) by mutual induction which lags behind the flux 'ø' by 90°Fig 2. As the EMF induced in primary or secondary per turn is same the secondary EMFwill depend on the number of turns of the secondary.

When secondary is open circuit, its terminal voltage 'V2' is the same as the induced EMF (E2). On the other hand, the primary current at no load is very small, hence the applied voltage 'V1' is practically equal and opposite to the primary induced EMF (E1). The relationship between primary and secondary voltages Fig 2.

Hence we can say that

$$\frac{Total\ \text{emf indued in seconday}'E_2}{Total\ \text{emf induced in primary}'E_1'}$$

$$=\frac{N_2 \times \text{emf per turn}}{N_1\ x\text{emf per turn}} \qquad \text{OR}$$

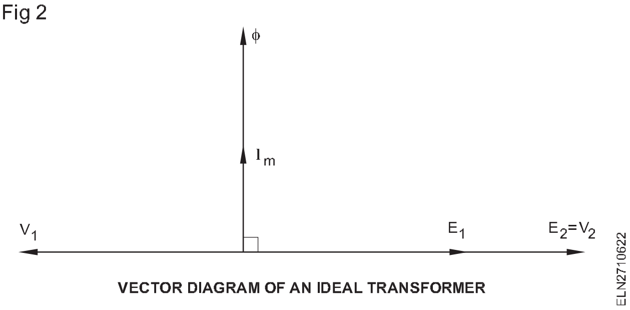
$$\frac{E_2}{E_1}=\frac{N_2}{N_1}$$

$$as\,E_1 = V_1 \text{ and } E_2 = V_2$$

$$\text{We have } \frac{V_2}{V_1}=\frac{N_2}{N_1}$$

Ideal Transformer on Load: When the secondary is connected to a load, secondary current flows this in turn makes the primary current to increase. How this happens is explained below.

Fig 2



VECTOR DIAGRAM OF AN IDEAL TRANSFORMER

The relationship between primary and secondary currents is based upon a comparison of the primary and secondary ampere turns.

When the secondary is open circuit, the primary current is such that the primary ampere turns are just sufficient to produce the flux 'ø' necessary to induce an EMF (E1) that is practically equal and opposite to the applied voltage 'V1'. The magnetising current is usually about 2 to 5 percent of the full load primary current.

When a load is connected across the secondary terminals, the secondary current - by Lenz's law - produces demagnetising effect. Consequently the flux and the EMFinduced in the primary are reduced slightly.

But this small change may increase the difference between applied voltage 'V1' and the induced EMF (E1) by say 1 percent in which case the new primary current would be 20 times the no load current.

The demagnetising ampere turns of the secondary are thus nearly neutralized by the increase in the primary ampere turns and since the primary ampere turns on no load are very small compared with the full load ampere turns.

Therefore Full load primary ampere turns ~ full load secondary ampere turns

i.e I1N1 ~ I2N2

$$\text{so that } \frac{I_1}{I_2} \simeq \frac{N_2}{N_1} \simeq \frac{V_2}{V_1} \qquad \text{Transformation ratio}$$

From the above statement, it is clear that the magnetic flux forms the connecting link between the primary and secondary circuits and that any variation of the secondary current is accompanied by a small variation of the flux and therefore of the EMFinduced in the primary, thereby enabling the primary current to vary approximately, proportional to the secondary current.

Parts and their functions of transformer

Objectives: At the end of this lesson you shall be able to
- **list out the mainparts of transformer**
- **explain the parts of a distribution transformer.**

Distribution transformer: Fig 1 shows the essential parts of a distribution transformer.

The important components of a distribution transformer are briefly described below:-

The important components of transformer are : -

1 Steel tank

2 Conservation tank

3 Temperature gauge

4 Explosion vent

5 Cooling tubes

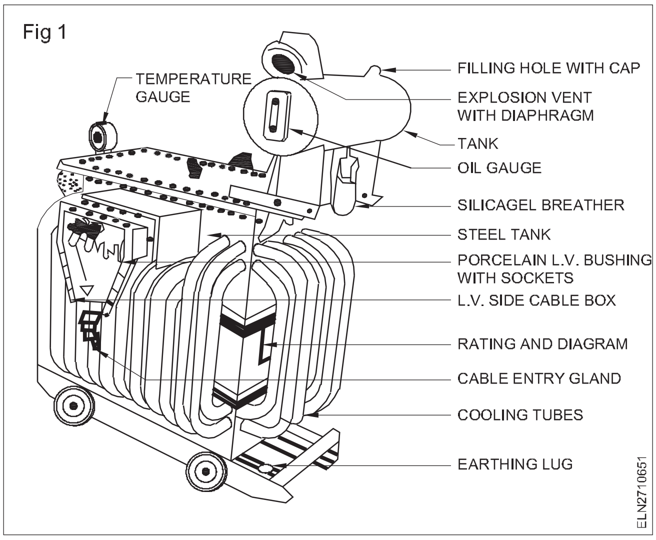
6 Tap changer

7 Bushing termination

8 Silical gel breather

9 Buchholz relay

Fig 1



1 Steel tank

It is a fabricated M.S plate tank used for housing the core, winding and for mounting various accessories required for the operation of a transformer. Core is built from cold rolled grain oriented silicon steel lamination. The L.V winding is normally close to the core and the H.V winding is kept around the L.V winding.

2 Conservator tank

It is in the shape of a drum, mounted on the top of the transformer. An oil level indicator is fitted to the conservator tank. Conservator is connected to the transformer tank through a pipe. The conservator carries the transformer oil to a specified level. When transformer is heated up due to normal load operation, the oil expands and the level of oil in conservator tank is increased or vice versa. A pipe connected to the top of the conservator tank allows the internal air to go out or get in through the breather.

It reduces the oxidation of oil when it get contact with air.

3 Temperature gauge

It is fitted to the transformer which indicates the temperature of the transformer oil.

4 Cooling tubes

In earlier discussions, we found that the transformer is heated up, when the transformer is connected to the supply is due to iron loss and copper loss. To keep down the temperature of the windings, when the transformer is put on load, the heat generated inside the transformer should be radiated to the atmosphere. To dissipate the heat produced inside the winding and core, the transformer tank is filled with an insulating oil. The oil carries the heat to the cooling pipes where the heat is dissipated to atmosphere due to surface contact with air.

5 Protective - devices / parts of transformers:

1) Breather

Transformer oil deterioration takes place due to moisture. Moisture can appear in a transformer from three sources, viz. by leakage through gasket, by absorption from air in contact with the oil surface or by its formation within the transformer as a product of deterioration as insulation ages at high temperature.

The effect of moisture in oil is to reduce the di-electric strength, especially if loose fibres or dust particles are present.

Methods available to reduce oil contamination from moisture are:

- by the use of silica gel breather
- by the use of rubber diaphragm
- by using sealed conservator tank
- by using gas cushion
- by using thermosyphon filter

Silica gel breather

Silica gel breather is a protective device fitted to the conservator through a pipe and allows the moisture free air to and fro into the conservator when the transformer oil get heated and cools down.

As the load and heat on a transformer reduces, air is drawn in to the conservator through a cartridge pakced with **silica gel crystals.**

The silica gel effectively dries the air and thus prevent the moistured dust entering into transformer oil. The fresh silica gel is available in blue colour. The colour of the silica gel changes to pure white or light pink colour as it absorbs moisture from air.

To recondition silica gel either it can be dried in sun or it could be dry roasted on a frying pan kept over a stove.

The oil seal at the bottom of the breather absorbs the dust particles that are present in the air entering the conservator.

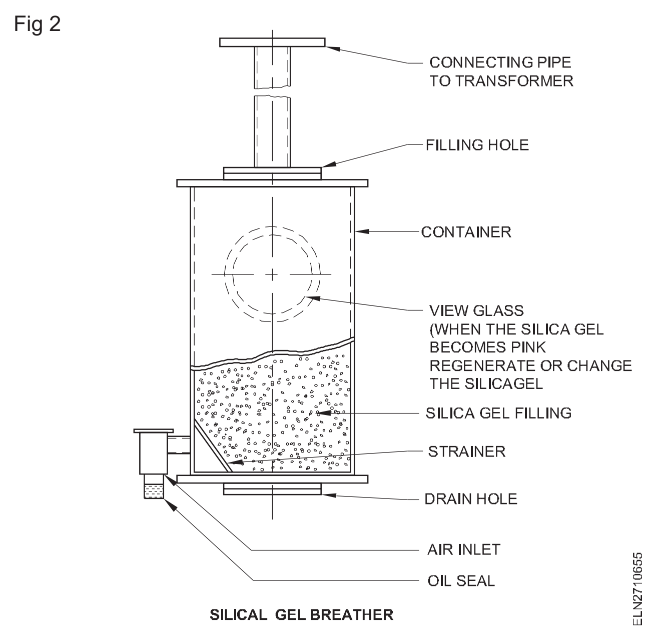
2) Buchholz relay

Buchholz relay is a gas operated - protective device which is connected between the transformer oil tank and the conservator tank.

If a fault is present inside a transformer, it may be indicated by the presence of bubbles (gas) in the transformer oil. Presence of gas could be viewed from class in window of by the Buchholz relay.

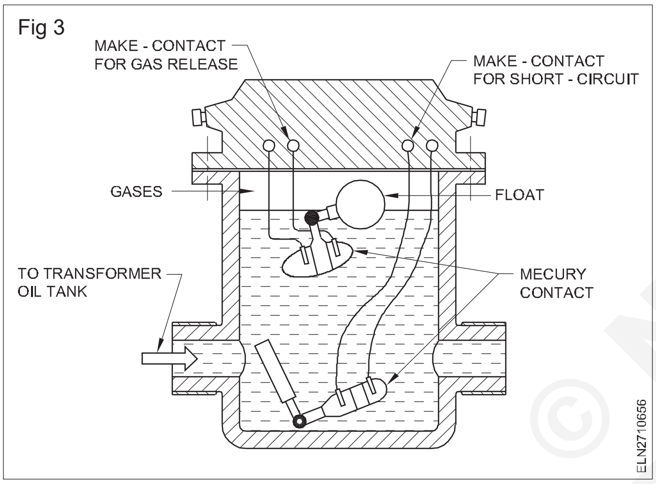
The relay comprises of a cast iron chamber which have two floats Fig 3. Top float assembly operates during initial stages of gas/air bubble formation due to minor fault in the transformer.

Fig 2



SILICAL GEL BREATHER

Fig 3



When sufficient gas bubbles formed around the top float, the float operates in pneumatic pressure principle to close an electric circuit through mercury switch which causes the siren or alarm bell to operate to caution the operator.

On hearing the alarm sound the operator takes necessary preventive steps to safeguard the transformer.

If any major fault like earth, fault etc, occurs in the transformer then the production of gas bubbles are more severe and hence the bottom float activates the mercury switch and closes the relay contacts.

Closing of the bottom relay contacts trips the transformer circuit breaker and opens the transformer from main line to protect the transformer from further damage.

3) Explosion vent

It is a pressure release device fitted to the transformer. The mouth of the explosion pipe is tightly closed using either a thin glass or laminated sheet.

If, by any, chance the transformer is overheated either due to short circuited or sustained overload, the gases produced inside the transformer tank creates tremendous pressure which may damage the tank.

On the other hand the pressure built inside the transformer may break the glass/laminated diaphragm of the explosion pipe and thereby the tank can be saved from total damage.

Voltage Transformation Ratio (K)

From the above equations we get

$E_B/ E_A = V_B/ V_A = N_B/N_A = K$

This constant K is known as voltage transformation ratio.

1 If $N_B>N_A$, that is K>1 , then transformer is called step-up transformer.

2 If NB<1, that is K<1 , then transformer is known as step-down transformer.

Again for an ideal transformer,

Input V_A = output VA

$V_AI_A = V_BI_B$

Or, $I_B/I_A = V_A/V_B = 1/K$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

Applications of a transformer

Transformers are used in most electronic circuits. A transformer has only 3 applications;

1 To step up voltage and current.

2 To Step down voltage and current

3 To prevent DC – transformers can pass only Alternating Currents so they totally prevent DC from passing to the next circuit.

Electric power demand, supply and gap in city, state and national level

Objectives: At the end of this lesson you shall be able to
- **define Electrical power demand, supply and gap**
- **explain India’s power production history.**

India is the world’s third largest producer and third largest consumer of electricity. The national electric grid in India has an installed capacity of 375.32 GW as of 31 December 2020. Renewable power plants, which also include large hydroelectric plants, constitute 36.17% of India’s total installed capacity. During the fiscal year (FY) 2019, the gross electricity generated by utilities in India was 1,383.5 TWh and the total electricity generation (utilities and non - utilities) in the country was 1,598 TWh.

The gross electricity consumption in FY2019 was 1,208 kWh per capita. In FY2015, electric energy consumption in agriculture was recorded as being the highest (17.89%) worldwide. The per capita electricity consumption is low compared to most other countries despite India having a low electricity tariff.

India has a surplus power generation capacity but lacks adequate distribution infrastructure. To address this, the Government of India launched a program called “Power for All” in 2016. The program was accomplished by December 2018 in providing the necessary infrastructure to ensure uninterrupted electricity supply to all households, industries, and commercial establishments. Funding was made through a collaboration between the Government of India and its constituent states.

India’s electricity sector is dominated by fossil fuels, in particular coal, which during the 2018-19 fiscal year produced about three-quarters of the country’s electricity. The government is making efforts to increase investment in renewable energy. The government’s National Electricity Plan of 2018 states that the country does not need more non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plants under construction and addition of 275,000 MW total renewable power capacity after the retirement of nearly 48,000 MW old coal-fired plants. It is expected that non-fossil fuels generation contribution is likely to be around 44.7% of the total gross electricity generation by the year 2029-30.

India began using grid management on a regional basis in the 1960s. Individual State grids were interconnected to form 5 regional grids covering mainland India, the Northern, Eastern, Western, North Eastern and Southern Grids. These regional links were established to enable transmission of surplus electricity between states in each region. In the 1990s, the Indian government began planning for a national grid. Regional grids were initially interconnected by asynchronous high-voltage direct current (HVDC) back-to-back links facilitating the limited exchange of regulated power. The links were subsequently upgraded to high capacity synchronous links.

By the end of the calendar year 2015, despite poor hydroelectricity generation, India had become a power surplus nation with huge power generation capacity idling for want of demand. The calendar year 2016 started with steep falls in the international price of energy commodities such as coal, diesel oil, naphtha, bunker fuel, and liquefied natural gas (LNG), which are used in electricity generation in India. As a result of the global glut in petroleum products, these fuels became cheap enough to compete with pit head coal-based power generators. Coal prices have also fallen. Low demand for coal has led to coal stocks building up at power stations as well as coal mines. New installations of renewable energy in India surpassed installations of fossil fuel for the first time in 2016-17.

On 29 March 2017, the Central Electricity Authority (CEA) stated that for the first time India has become a net exporter of electricity. India exported 5,798 GWh to neighbouring countries, against a total import of 5,585 GWh.

The total installed power generation capacity is the sum of utility capacity, captive power capacity, and other non-utilities. Here we have a comparison of installed capacity of India from 1947 to 2020.

In the year 1947, since independence of India, the total thermal power was 854 MW and Hydro power was 508 MW both together the cumulative was 1362 MW.

As on 31st Mar 2020 the total thermal power was 230600 MW and Hydro power was 132427 MW both together the cumulative was 370106 MW.

Demand trend

During the fiscal year 2019-20, the utility energy availability was 1,284.44 billion KWh, a short fall relative to requirements by 6.5 billion KWh (-0.5%). Peak load met was 182,533 MW, 1,229 MW (-0.6%) below requirements. In the 2020 Load Generation Balance report, India’s Central Electricity Authority anticipated energy surplus and peak surplus to be 2.7% and 9.1%, respectively, for the 2020– 21 fiscal year. Power would be made available to few states expected to face shortages from states with a surplus, through regional transmission links. From calendar year 2015 onwards, power generation in India has been less of a problem than power distribution.

Demand drivers

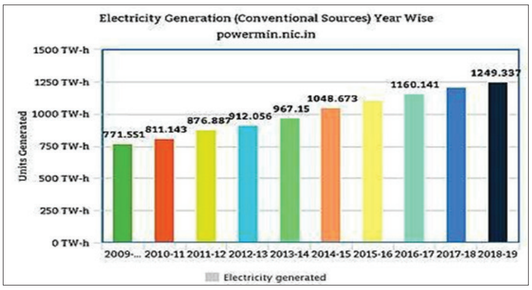
Nearly 0.07% of Indian households (0.2 million) have no access to electricity. The International Energy Agency estimates India will add between 600 GW to 1,200 GW of additional new power generation capacity before 2050. This added new capacity is similar in scale to the 740 GW total power generation capacity of the European Union (EU-27) in 2005. The technologies and fuel sources India adopts as it adds this electricity generation capacity may have a significant impact on global resource usage and environmental issues. The demand for electricity for cooling (HVAC) is projected to grow rapidly.

- Coal: 200,284.5 MW (53.1%)
- Lignite: 6,120 MW (1.6%)
- Large Hydro: 46,059.22 MW (12.2%)
- Small Hydro: 4,758.46 MW (1.3%)
- Solar Power: 38,794.07 MW (10.3%)
- Wind Power: 38,683.65 MW (10.3%)
- Gas: 24,956.51 MW (6.6%)
- Biomass: 10,314.56 MW (2.7%)
- Nuclear: 6,780 MW (1.8%)
- Diesel: 509.71 MW (0.1%)

About 136 million Indians (11%) use traditional fuels – firewood, agricultural waste and dry animal dung fuel – for cooking and general heating needs. These traditional fuels are burnt in cook stoves, sometimes known as chulah or chulha. Traditional fuel is an inefficient source of energy, and its burning releases high levels of smoke, PM10 particulate matter, NOX, SOX, PAHs, polyaromatics, formaldehyde, carbon monoxide and other air pollutants, affecting outdoor air quality, haze and smog, chronic health problems, damage to forests, ecosystems and global climate. The World Health Organization estimates that 300,000 to 400,000 people in India die of indoor air pollution and carbon monoxide poisoning every year because of biomass burning and use of chulahs. Burning traditional fuel in conventional cook stoves is estimated to release 5–15x more pollutants than industrial combustion of coal, and is unlikely to be replaced until electricity or clean-burning fuel and combustion technologies become reliably available and widely adopted in rural and urban India. The growth of the electricity sector in India may help find a sustainable alternative to traditional fuel burning.

In addition to air pollution problems, a 2007 study finds that discharge of untreated sewage is the single most important cause for pollution of surface and groundwater in India. The majority of government-owned sewage treatment plants remain closed most of the time in part because of the lack of a reliable electricity supply to operate the plants. Uncollected waste accumulates in urban areas, causing unhygienic conditions, and release heavy metals and pollutants that leaches to surface and groundwater. A reliable supply of electricity is required to address India's water pollution and associated environmental issues.

Fig 1



Other drivers for India's electricity sector are its rapidly growing economy, rising exports, improving infrastructure and increasing household incomes.

Conventional energy Generation by thermal (coal, gas diesel) and hydel power plant. (small and large)

Objectives: At the end of this lesson you shall be able to

- **explain about the coal energy source**
- **explain about Gas energy source**
- **explain about Diesel energy source**
- **explain about Nuclear energy source**
- **compare various energy sources.**

Introduction of power generation

Energy is the basic necessity for the economic development of a country and it exists in different forms in nature. But the most important form is the electrical energy . The modern society is fully depend on the electrical energy and it has close relationship with standard of living. The per capita consumption of energy is the measure of standard of living of people.

Sources of electrical energy

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. The natural sources of energy which are used to generate the electricity are:

i Sun

ii Wind

iii Water

iv Fuels

v Nuclear energy

vi Tidal

Out of these sources, the energy due to Sun and wind has not been utilized on large scale due to a number of limitations. At present, the other three sources viz, water, fuels and nuclear energy are primarily used for the generation of electrical energy.

i Sun : The Sun is the primary source of energy. .Solar cells are the one of the methods which uses the heat energy of the sun to generate the electrical energy in present days. this method came into large application of solar cells to produce electricity.however, than the limitations as:

a) It requires a large area for the generation of even a small amount of electric power.

b) It cannot be used in cloudy days or at night

c)It is an uneconomical method compared to conventional method

ii Wind: This method can be used where wind flows for a considerable length of time. The wind energy is used to run the wind mill which drives a small generator. In order to obtain the electrical energy from a wind mill continuously, the generator is arranged to charge the batteries which supply the energy even the wind stops. This method has the advantages that maintenance and generation costs are negligible. However, drawbacks of the method are that it is unreliable because of uncertainly about wind pressure and power generated is quite small.

iii Water: When water is stored at a suitable place, it possesses potential energy because of the head created. This water energy can be converted into mechanical energy with the help of water turbines. The water turbine drives the alternator which converts mechanical energy into electrical energy. This method of generation of electrical energy has become very popular because it has low production and maintenance costs.

iv Fuels: The main sources of energy are fuels viz. solid fuel as coal, liquid fuel as oil and gas fuel as natural gas. The heat energy of the fuels is converted into mechanical energy by suitable prime movers such as steam engines, steam turbines, internal combustion engines etc. The prime mover drives the alternator which coverts mechanical energy into electrical energy. Although fuels continue to enjoy the place of chief source for the generation of electrical energy, yet their reserves are diminishing day by day. Therefore, the present trend is to harness water power which is more or less a permanent source of power.

v **Nuclear energy:** Towards the end of Second world War, it was discovered that large amount of heat energy is liberated by the fusion of uranium and other fissionable materials. It is estimated that heat produced by 1 Kg of nuclear fuel is equal to that produced by 27,50,000 kg of coal. The heat produced due to nuclear fission can be utilized to raise steam with suitable arrangements. The steam can run the steam turbine which in turn can drive the alternator to produce the electrical energy.

Comparison of energy sources

The main sources of energy used for the generation of electrical energy are water, fuels and nuclear energy. Below is given their comparison in a tabular form in Table 1.

Table 1

Sl.No	Terms	Water Power	Fuels	Nuclear Energy
1	Initial cost	High	Low	Highest
2	Running cost	Less	High	Least
3	Reserves	Permanent	Exhaustible	Inexhaustible
4	Cleanliness	Cleanest	Dirtiest	Clean
5	Simplicity	Simplest	Complex	Most complex
6	Reliability	Most reliable	Less reliable	More reliable

Types of fuels used for power generations

Fuels are categorized into Three; They are

1 Solid fuels

2 Liquid fuels

3 Gaseous fuels

Solid Fuels

This can further be classified an

a Natural solid fuel

b Artificial soild fuel

The natural solid fuels are wood and different variation of coal, while the artificial solid fuels are charcoal, coke and pulverized fuel.

Liquid Fuels

This can replace coal for the production of steam. The major petroleum products, considered an liquid fuels are the following.

1 Gasoline (Petrol)

2 Kerosene

3 Gas oil

4 Diesel

Gaseous Fuels

This fuel can be divided in the following categories.

1 Natural Gas - It is obtained from soil by mean of dup wells and it is pumped out.

2 Producer Gas - This is a mixture of CO and H2 with a little CO2.

3 By product gases - This gas is obtained from blast furnace and coke ovens.

Advantages and disadvantages of liquid fuel

Advantages

i The design and layout of the plant where liquid fuel is used are quite simple and it occupies less space as the number and size of the auxiliaries are small.

ii Liquid fuel plant can be started quickly and can pick up the load in a short time.

iii There are no stand by losses.

iv The overall cost is much less than that of coal.

v The thermal efficiency is higher than that of a coal.

vi If requires less operating staff.

Disadvantages

i The plant where liquid fuel is used has high running cost as the fuel (i.e. diesel) used is costly.

ii The plant can generate only low power.

Advantage and disadvantage of solid fuel :-

Advantages

i The fuel (i.e coal) used in quite cheap.

ii The coal can be transported to the site of plant by rail or road.

iii Solid fuel plant requires less space as compared to the hydro-electric power station.

iv The cost is lesser than that of diesel.

Disadvantages

i It pollutes the atmosphere due to the production of large amount of smoke and fumes.

ii It's handling cost is high.

Types of electrical power generation

Basically power generation are of two types

a Conventional power generation

Power generations by using non- renewable sources of energy through various methods such as hydro, thermal and nuclear etc is called conventional power generation. It contributes to the major power requirement.

b Non conventional power generation

Power generation by using renewable energy sources such as wind, Tide and sun etc, is called non- conventional power generation. They are small scale power generation used for specific purpose.

Generating stations

Bulk electric power is produced by special plants known as generating station or power plants. A generating station employs a prime mover coupled with an alternator or generator for the production of electric power. The generated power is further transmitted and distributed to the customers.

Depending upon the form of energy converted into electrical energy the generating station are classified into,

1 Steam power stations /Thermal power stations

2 Hydro - electric power stations

3 Diesel power stations

4 Nuclear power stations

5 Gas - turbine power stations

1 Thermal /steam power station

A generating station which converts the heat energy of coal combustion into electrical energy is known as a steam power station.

The scheme of generation can be divided into two phases (i) Formation of steam in the boiler house (ii) Generation of electrical power in the generator room.

In the boiler the fuel is burnt and the water is converted into high pressure steam which is further super heated in a super - heater. The super - heated steam is passed in to the turbine to rotate the turbine blades, thus it converts the heat energy into electrical energy.

The turbine is the generation room acts as a prime mover of the alternator which generates electric energy. The alternator is connected through the circuit breaker to the bus bars.

This type of power station is suitable where coal and water are available in abundance and a large amount of electric power is to be generated.

2 Hydro - electric power station

A generating station which converts the energy posses by the water into the electrical energy is known as hydro-electric power station.

Water is a great source of energy. There are two types of energies which the water can posses. The flowing water in stream may have only kinetic energy. The flowing steam of water may have both kinetic as well as potential energy or simply potential energy at some elevation with respect to a lower datum level. The practical examples of which are water - falls or water stored at the back of a dam. The water stored in the reservoir is allowed to fall on the blades of a water turbine placed at the foot of the dam.

The initial cost of harnessing water and converting the potential energy into electrical energy is quite high but recurring expenses etc. are quite less. So, the overall system will be very economical.

3 Nuclear Power Station

A generating station which converts the nuclear energy into the electric energy is called as nuclear power station.

The nuclear power obtained by nuclear fission is fast entering into arena of energy sources. The heat produced by nuclear fission of atomic material is utilized in special heat exchangers to produce steam to run steam turbines. The atomic materials utilized for nuclear fission are thorium and uranium. Another reason of fast development of nuclear power is that the natural resources of coal and petroleum will exhaust early if the pace of industrial development remained so fast.

4 Non conventional energy

It is evident that all energy resources based on fossil fuels has limitations in availability and will soon exhaust. Hence the long term option for energy supply lies only with non-conventional energy sources. These resources are in-exhaustible/do not deplete for the next hundreds of thousands of years.

For example electrical energy from solar energy, Bio-energy, Wind energy, Geothermal energy, Wave, Tidal and Micro-hydro.

Advantages of high voltage transmission

Objectives: At the end of this lesson you shall be able to
- **define high voltage and state it's range**
- **state the advantages of high voltage transmission**
- **state the disadvantages of high voltage transmission.**

The primary reason that power is transmitted at high voltages is to increase efficiency. As electricity is transmitted over long distances, there are inherent energy losses along the way. High voltage transmission minimizes the amount of power lost as electricity flows from one location to the next.

High-voltage direct current (HVDC) technology offers several advantages compared to alternating current transmission systems. For example, it allows more efficient bulk power transfer over long distances.

With increase in the transmission voltage size of the conductors is reduced (Cross section of the conductors reduce as current required to carry reduces). As the reduction in current carrying requirement losses reduces results in better efficiency.

Disadvantages of using high voltage for transmission

a The increased cost of insulating the conductors.

b The increased cost of transformers, switchgear and the other terminal apparatus.

c Both (a) and (b)

d There is a reduction in the corona loss.

High voltage electricity refers to electrical potential large enough to cause injury or damage. In certain industries, high voltage refers to voltage above a certain threshold. Equipment and conductors that carry high voltage warrant special safety requirements and procedures.

The numerical definition of high voltage depends on context. Two factors considered in classifying a voltage as high voltage are the possibility of causing a spark in air, and the danger of electric shock by contact or proximity.

The International Electro Technical Commission and its national counterparts (IET, IEEE, VDE, etc.) define high voltage as above 1000 V for alternating current, and at least 1500 V for direct current.

EC voltage range	AC RMS voltage (V)	DC voltage (V)	Defining risk
High voltage	> 1 000	> 1 500	Electrical arcing
Low voltage	50 to 1 000	120 to 1 500	Electrical shock
Extra-low voltage	< 50	< 120	Low risk

Advantages of High voltage transmission system: -

1 As Transmission voltage increases, current decreases.

2 As current decreases, cross section of conductor decreases.

3 As cross section of conductor decreases, its weight decreases.

4 As weight of the conductor decreases, design of tower becomes lighter in weight.

5 As current decreases, cross section of bus bar and size of switch gear contact etc. reduces.

6 Due to above advantages, Transmission cost per KM decreases

7 As transmission voltage increases. A current decrease, so copper losses in transmission line reduces.

8 As copper losses reduces, transmission efficiency increases

9 As current reduces, voltage drop in transmission line reduces.

10 As voltage drop in transmission reduces, voltage regulation becomes better (improved).

11 As efficiency and regulation of transmission line gets improved, so performance of transmission line increases

12 As transmission voltage increases power handling capacity of transmission line increases

Transmission network of India

Objectives: At the end of this lesson you shall be able to
- **define overhead distribution system**
- **define underground distribution system**
- **compare OH and UG distribution system**

The National Grid is the high-voltage electricity transmission network in mainland India, connecting power stations and major substations and ensuring that electricity generated anywhere in mainland India can be used to satisfy demand elsewhere. The National Grid is owned, and maintained by state-owned Power Grid Corporation of India and operated by state-owned Power System Operation Corporation. It is one of the largest operational synchronous grids in the world with 371.054 GW of installed power generation capacity as of 30 June 2020.

India's grid is connected as a wide area synchronous grid nominally running at 50 Hz. The permissible range of the frequency band is 49.95-50.05 Hz, effective 17 September 2012. The Union Government regulates grid frequency by requiring States to pay more when they draw power at low frequencies. There are also synchronous interconnections to Bhutan, and asynchronous links with Bangladesh, Myanmar, and Nepal. An undersea interconnection to Sri Lanka (India–Sri Lanka HVDC Interconnection) has also been proposed. A proposed interconnection between Myanmar and Thailand would facilitate the creation of a power pool and enable trading among all BIMSTEC nations.

Substations may be described by their voltage class, their applications within the power system, the method used to insulate most connections, and by the style and materials of the structures used. These categories are not disjointed; for example, to solve a particular problem, a transmission substation may include significant distribution functions.

Fig 1

Transmission substation:

A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems.

Fig 2

Transmission substations can range from simple to complex. A small "switching station" may be little more than a bus plus some circuit breakers. The largest transmission substations can cover a large area (several acres/hectares) with multiple voltage levels, many circuit breakers, and a large amount of protection and control equipment (voltage and current transformers, relays and SCADA systems). Modern substations may be implemented using international standards such as IEC Standard 61850.

Distribution substation.

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution.

The input for a distribution substation is typically at least two transmission or sub-transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltage, between 2.4 kV and 33 kV, depending on the size of the area served and the practices of the local utility. The feeders run along streets overhead (or underground, in some cases) and power the distribution transformers at or near the customer premises.

In addition to transforming voltage, distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometers), voltage regulation equipment may also be installed along the line.

The downtown areas of large cities feature complicated distribution substations, with high-voltage switching, and switching and backup systems on the low-voltage side. More typical distribution substations have a switch, one transformer, and minimal facilities on the low-voltage side.

Collector substation

In distributed generation projects such as a wind farm or photovoltaic power station, a collector substation may be required. It resembles a distribution substation although power flow is in the opposite direction, from many wind turbines or inverters up into the transmission grid. Usually for economy of construction the collector system operates around 35 kV, although some collector systems are 12 KV, and the collector substation steps up voltage to a transmission voltage for the grid. The collector substation can also provide power factor correction if it is needed, metering, and control of the wind farm. In some special cases a collector substation can also contain an HVDC converter station.

Collector substations also exist where multiple thermal or hydroelectric power plants of comparable output power are in proximity. Power is collected from nearby lignite-fired power plants. If no transformers are required for increasing the voltage to transmission level, the substation is a switching station.

Converter substations

Converter substations may be associated with HVDC converter plants, traction current, or interconnected non-synchronous networks. These stations contain power electronic devices to change the frequency of current, or else convert from alternating to direct current or the reverse. Formerly rotary converters changed frequency to interconnect two systems; nowadays such substations are rare.

Switching station

A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. Sometimes they are used for switching the current to back-up lines or for parallelizing circuits in case of failure.

A switching station may also be known as a switchyard, and these are commonly located directly adjacent to or nearby a power station. In this case the generators from the power station supply their power into the yard onto the generator bus on one side of the yard, and the transmission lines take their power from a Feeder Bus on the other side of the yard.

Fig 3

An important function performed by a substation is switching, which is the connecting and disconnecting of transmission lines or other components to and from the system. Switching events may be planned or unplanned. A transmission line or other component may need to be de-energized for maintenance or for new construction, for example, adding or removing a transmission line or a transformer. To maintain reliability of supply, companies aim at keeping the system up and running while performing maintenance. All work to be performed, from routine testing to adding entirely new substations, should be done while keeping the whole system running.

Unplanned switching events are caused by a fault in a transmission line or any other component, for example:

- a line is hit by lightning and develops an arc,
- a tower is blown down by high wind.

The function of the switching station is to isolate the faulty portion of the system in the shortest possible time. De-energizing faulty equipment protects it from further damage, and isolating a fault helps keep the rest of the electrical grid operating with stability.

Study of distribution of power and substation

Objectives: At the end of this lesson you shall be able to
- **enumerate non-renewable energy sources**
- **state the advantages of renewable energy sources**
- **explain the seasonal changes in a year period**
- **define Global Horizontal irradiations (GHI) and Direct Normal Irradiation (DNI)**
- **explain the Sun light spectrum.**

Distribution substation typically operates at 2.4 to 34.5 kV voltage levels. It delivers electric energy directly to industrial and residential consumers. Distribution feeders transport power from the distribution substations to the end consumers' premises.

A distribution substation transfers power from the transmission system to the distribution system of an area. The input for a distribution substation is typically at least two transmission or sub-transmission lines.

A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.

Fig 1

The primary distribution circuit delivers power to various substations, called distribution substations. The substations are situated near the consumers' localities and contain step-down transformers. At each distribution substation, the voltage is stepped down to 400 V and power is delivered by 3-phase, 4-wire system.

Based on findings like these, a minimum safety distance of 1/4 mile (1320 feet) might be considered prudent. And again, individuals with EMF hypersensitivity or other serious health issues may want to consider a much greater safety distance, perhaps a half mile, or even more.

Power plants generate electricity that is delivered to customers through transmission and distribution power lines. High-voltage transmission lines, such as those that hang between tall metal towers, carry electricity over long distances to meet customer needs.

Elements of a substation

1 Primary power lines.

2 Ground wire.

3 Overhead lines.

4 Transformer for measurement of electric voltage.

5 Disconnect switch.

6 Circuit breaker.

7 Current transformer.

8 Lightning arrester.

The most basic power system components are generators, transformers, transmission lines, busses, and loads.

The electrical power system consists of three major components: generation, a high voltage transmission grid, and a distribution system. The high voltage transmission system links the generators to substations, which supply power to the user through the distribution system. Distribution lines on the high voltage side of the distribution transformer are called primary distribution lines or primaries. Those on the low-voltage side of the distribution transformer are called secondary distribution lines or secondaries. Primary lines have voltages ranging from 2,300 to 39,000 volts.

Fig 2

There are three major kinds of power supplies: unregulated, linear regulated, and switching.

The secondary wire carries the lower voltage electricity after it passes through the transformer. Telephone and cable wires are typically the lowest wires. Transformers convert higher voltage electricity carried by primary wires and lowers the voltage for use by customers. Guy wires help stabilize utility poles. Open Wire Secondary – Three conductors with 120/240 volts that run pole to pole below the primary conductors (primary conductors are on top of the pole in an overhead distribution system).

A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer. Generally substations are unattended, relying on SCADA for remote supervision and control.

The word substation comes from the days before the distribution system became a grid. As central generation stations became larger, smaller generating plants were converted to distribution stations, receiving their energy supply from a larger plant instead of using their own generators. The first substations were connected to only one power station, where the generators were housed, and were subsidiaries of that power station.

Overhead v/s underground distribution system

Objectives: At the end of this lesson you shall be able to
- **explain electrical distribution system**
- **describe underground & overhead cables.**

Electrical Distribution System

Underground circuits are more reliable. Overhead circuits typically fault about 90 times/100 mi/year; underground circuits fail less than 10 times/ 100 mi/year. Because overhead circuits have more faults, they cause more voltage sags, more momentary interruptions, and more long-duration interruptions.

The overhead lines are mounted on supports like wooden, steel, RCC, Reinforced plastics. The underground cables require digging trenches and this may be complicated by other utility service lines such as water pipes, oil and gas pipelines, sewer lines

The underground is preferable to overhead, mostly due to the protection feeders get from being buried, but underground service equipment can be much more expensive than similar overhead feeds, and both come with significant safety.

The overhead lines are better suited to carry higher voltages compared to the underground cables, which are limited by the expensive construction and limited heat dissipation. For these reasons, the underground cables are mostly used for transmitting up to 33KV.

Installing underground lines can cost 7-10 times more than overhead lines, a cost that would likely be paid by customers in the form of higher rates. Buried lines must be protected by conduit, otherwise they are susceptible to shortages from groundwater infiltration.

The underground cables have several advantages over the overhead lines; they have smaller voltage drops, low chances of developing faults and have low maintenance costs. However, they are more expensive to manufacture, and their cost may vary depending on the construction as well as the voltage rating.

“Buried power lines are protected from the wind ice, and tree damage that are common causes of outages, and so suffer fewer weather or vegetation-related outages”. “But buried lines are more vulnerable to flooding and can still fail due to equipment issues or lightning.”

The customer/owner is responsible for installing, maintaining and repairing all equipment beyond the service connection point except for the electric meter. If you receive overhead electric service, your electric system con- sists of the following: 1. Electric Lines that run from the utility pole to your residence.

Areas which seem free of overhead lines are generally using underground cable network for the electrical distribution. A distribution system can also have a hybrid setup of overhead and underground lines to efficiently distribute the electricity.

In addition, National Codes dictate the depth, below ground, these lines must be buried. Some low voltage underground circuits could be as shallow as 18 inches, while most higher voltage circuits will be deeper than 24 inches.

The cable technology, both for overhead and underground transmission of electrical power has gained increased attention in recent times due to changed perception of the electrical power system from the point of view of reliability, safety and economic aspects.

The prominence of electrical energy is felt in almost every sector of a common man’s daily activities. The electrical power system is generally segmented into generation, transmission, distribution and utilisation. A distribution network is one of the key parts of an electrical power system which is generally directly connected to the load center. The generated and then transmitted electrical energy is distributed to customers through a utility’s electrical distribution network. The distribution system network consists of electrical distribution substations which step-down the transmission line voltage levels between 69 kV and 765 kV to distribution voltage levels, usually 35 kV or less. As per Indian standards, the level of stepped down voltage is generally 33 kV/11 kV. Distribution networks can consist of overhead electrical lines, as well as underground cable systems. Voltages at utility customer delivery points may require further reduction or stepping down, either by utility transformers or customer owned and operated transformers to a level of 400 V (three phase) or 230 V (single phase).

After the concept of integrating both renewable and distributed energy sources at the distribution level is conceived, the distribution system design and operation is currently of great interest for power system engineers. The demand from the end users of electricity in terms of electrical power quality and the improved reliability of the services has further made the distribution system operation more interesting and challenging.

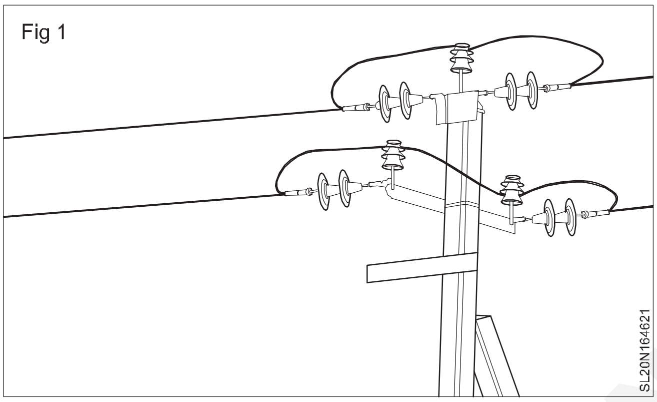
According to the reports of World Bank, India loses 4 per cent of its GDP due to inefficiency in power distribution.

This ranks India 80th among 137 economies in terms of reliability of power supply. India has the dubious distinction of losing 20 per cent of electricity in transmission and distribution, one of the highest in the world which amounts to be somewhere around Rs 8,500 crore per annuum. The changing paradigm in the field of electrical distribution system has resulted in many novel practices being adopted for the overall improvement of the system efficiency and reliability of the power supply. The issue of T&D losses can be addressed by proper transformations and implementation of novel technological innovations.

Electric power can be distributed either by overhead transmission systems or by underground cables. Hence, proper selection of the cables in the distribution network is crucial so as to assure required level of operational reliability with due consideration of the cost aspect.

A typical overhead line

Fig 1



Underground and overhead cables

The general understanding is that the underground cables are laid beneath the ground and the overhead cables are visible overhead. But apart from this, there are many significant features of both the types of these cables from the perspectives of electrical power transmission or distribution. In the changed scenario of the power system design, particularly, the distribution system, the cables and their characteristics have become highly selective and the technological advancements have also made the selection of cable for a particular application more flexible.

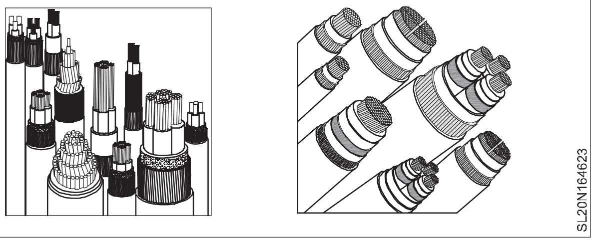
Overhead cables

Traditionally, the overhead cables or the bare conductors have been used for the transmission of electrical power and even for the distribution. These are simple in configuration and are usually commissioned using the towers or poles. The bare wire conductors on the line are generally made of aluminum (either plain or reinforced with steel or composite materials such as carbon and glass fiber), yet, some copper wires are used in medium voltage distribution and low-voltage connections to customer premises.

As the conductors are constantly exposed to the open atmosphere, there are several concerns related to the safety of the system and also reliability. The adverse conditions like heavy rain, wind, snowfall, humid and salty contents in the air could deteriorate the lifespan of these conductors and raise serious electrical safety concerns. Nevertheless, the most unique advantages like less cost of conductors due to less insulation levels required, ease of fault detection due to clear visibility of the conductors, relatively less cost of installation, and ease of expansion are some of the general advantages of the overhead conductors. These advantages are backed up by several other technical advantages as well like being independent of proximity effect, relatively smaller size of conductors, relatively higher life expectancy. However the changed perception of looking at the different premises from the point of view of aesthetic nature and the recent developments in the cable technology have made the deployment underground cables for the power distribution and even transmission more attractive in the recent times. This is also due to some of the critical limitations of the overhead cables apart from their non-aesthetic appearance. The overhead cables often cause the radio interference due to corona discharge. Overhead high voltage lines emit hiss or hum noises.

Different cable types

Fig 2



Underground cables

The underground cables provide the uninterruptable power supply which is not possible with the overhead lines due to the limitations mentioned earlier. However, there are other technical factors which also have made the underground cable to have an edge over the overhead cables which include reduced risks of fault due to external factors like rain, wind and adverse climatic conditions. The underground cables are also free from radio interference. The transmission towers are not required except for the local transformers in the system without considerable height of the tower. However, the underground cables are not free from limitations. Damage to underground cable is difficult to locate, and restoration of the system once the faults are located might take considerably long time. For underground cable system, a large number of cables is required for the same capacity of the overhead counterpart. The construction mechanism of the underground cable involving duct bank, vaults, splices and terminations not only increase the overall cost but also might reduce the overall system reliability. This problem further might increase with the increased line length with the additional necessity of the intermediate equipment. Due to the concealed operating conditions, the heat dissipation from the underground system can

Table 1 Comparison of Underground and overhead cables

Parameters	Overhead	Underground
System cost	Low	High
Safety	Less Safe	High Safe
Possibility of expansion	Easy	Difficult
Size of the conductor for the same capacity	Small	large
Fault detection	Easy	Difficult
Suitability for long distance	Yes	No
Prominent line parameter	Inductance	Capitance
Appearance	Non aesthetic	Aesthetic

also be one of the major bottlenecks for the successful operation of the system. Summarizing all these points, the following table gives a brief comparison between underground and overhead cables.

Recent developments in the cable technology

As the underground cable system is becoming more relevant and popular, there have been some tremendous technological novelties developed to overcome the different shortcomings of the underground cables. The major areas of concentration of these technological novelties are voltage grade and insulation. The developments in the field material science have resulted in the better-quality polymers to achieve desirable electrical and mechanical properties of the cables. Teflon cables can withstand the temperatures up to 250C against conventional PVC cable which can generally withstand up to only 70C. The alternative conductors against the copper which suffers from high cost have already been explored. Concurrently, the operating voltage levels have also increased significantly in the range of 220 kV to 400 kV. These developments can definitely take the cable technology to the new technical dimension and make them more deployed in the transmission and distribution networks. Having mentioned about the recent technological trends in the underground cable manufacturing technology, the similar kinds of advancements have taken place even in the overhead cables. Based on the requirement of conductor types like ACSR (Aluminum Conductor Steel Reinforced), AAAC (All Aluminum Alloy Conductor), ACAR (Aluminum Conductor Alloy Reinforced), AACSR (Aluminum Alloy Conductor Steel Reinforced), AAC (All Aluminum Conductors), operating Temperature Conductors, operating voltage levels, Voltage (132 kV to 220 kV, 221 kV to 660 kV, > 660 kV), Rated Strength (High Strength (10 kN to 75 kN), Extra High Strength (76 kN to 150 kN), Ultra High Strength (> 150 kN), type of the current (HVAC, HVDC) and type of Application (High Tension, Extra High Tension, Ultra High Tension) several cable manufacturers have launched their products in the market as per the requirement of the system.

The cable technology, both for overhead and underground transmission of electrical power has gained increased attention in the recent times due to the changed perception of the electrical power system from the point of view of reliability, safety and economic aspects. Each type has its own advantages and limitations. However, the judicious selection of each type in the power system depends on the specific requirements and also based on the safety of the system.

Non-renewable and Renewable energy concept

Objectives: At the end of this lesson you shall be able to
- **explain the concept of potential & kinetic energy**
- **describe the division of energies**
- **explain renewable & Non-renewable energy sources.**

Non-Renewable Energy (Fig 1)

Energy is the amount of work that can be performed by a particular force. It can be transferred into other areas and objects, but the energy quantity always remains the same. Different forms of energy include thermal, kinetic, potential, sound, and light energy. Although we are surrounded by multiple forms of energy at any given time, learning about energy can be a very intimidating.

Energy helps in powering business, manufacturing and transportation of goods and services. There are many different ways in which the abundance of energy around us can be stored, converted, and amplified for our use. We all use energy for our daily work like when we walk, jump, eat food, drive car, play etc. Energy is stored in different ways and can be transformed from one type to another.

Energy is in everything. We use energy for everything we do, from making a jump shot to baking cookies, to sending astronauts into space.

Fundamentally, there are two types of energy:

1 Potential Energy

2 Kinetic Energy

Potential Energy

Potential Energy is the energy of a body or a system due to the position of the body or the arrangement of the particles of the system in a force field.

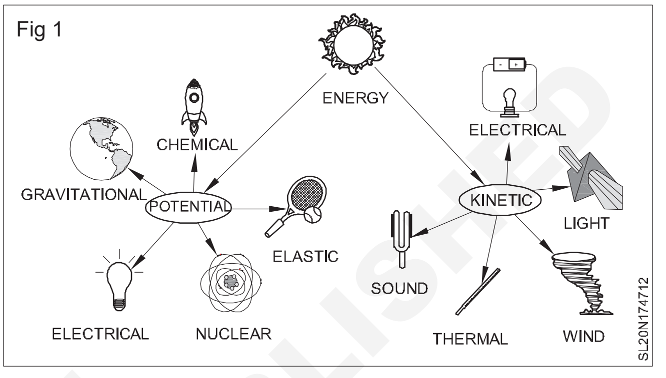
Kinetic energy

Any movement that produces energy is known as kinetic so the kinetic energyof an object is the energy which it possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity. Some examples of this type are swinging a baseball bat or dropping a bowling ball.

In short, the stored energy is called "potential energy" and moving energy is called "kinetic energy".

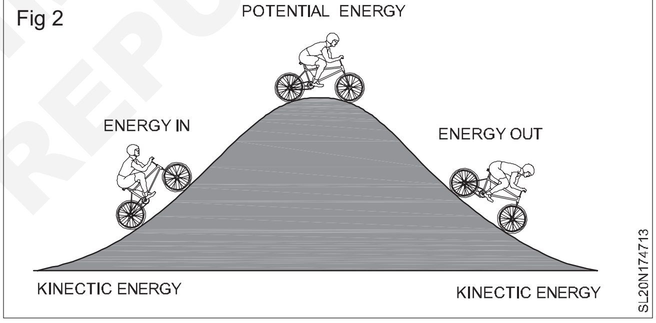
PE and KE - examples (Fig 1)

Fig 1



The concept of potential energy & Kinetic energy (Fig 2)

Fig 2



Other types of energy are commonly thought of as being able to power homes and automobiles.

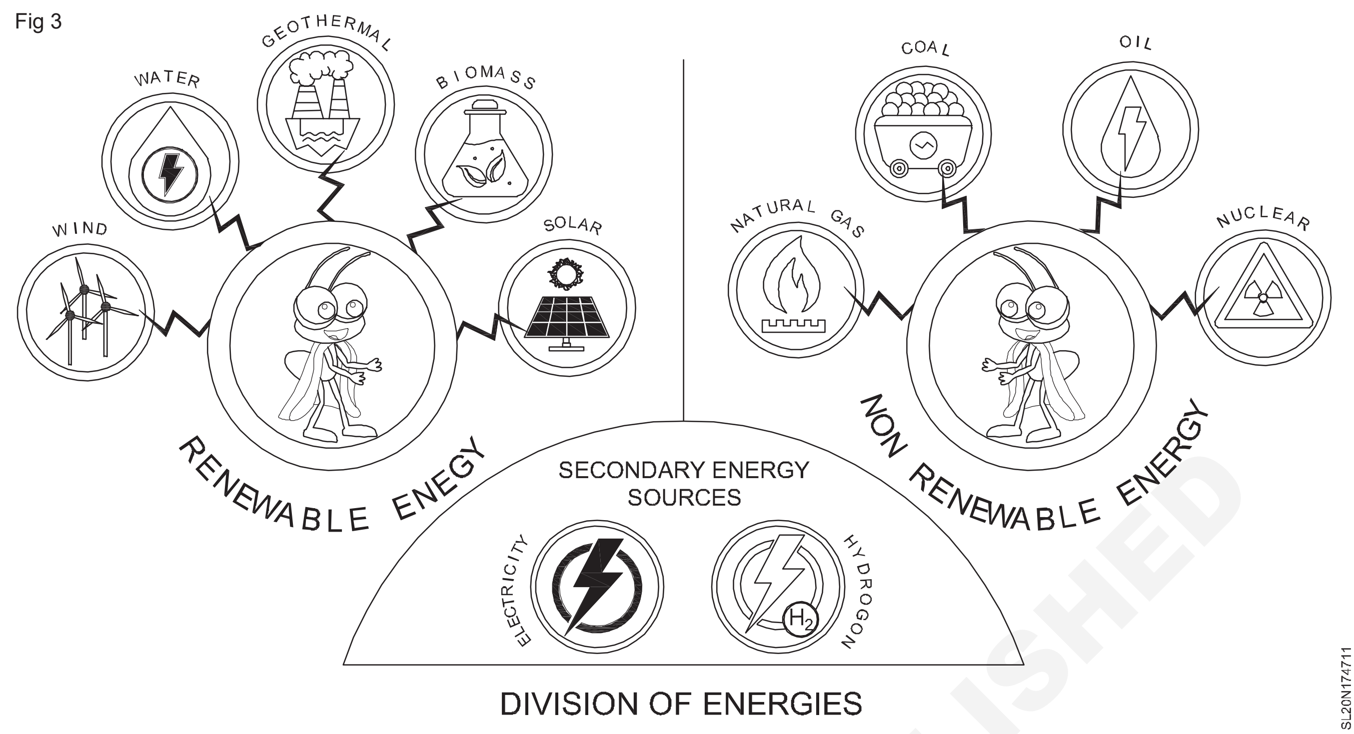
All the forms of energy can be broadly divided into two main subgroups: renewable and non-renewable energy.

Nonrenewable energy will eventually run out and cannot be replaced. The most widely recognized type of nonrenewable energy is fossil fuels such as oil and natural gas.

Renewable energy can be obtained for an unlimited time period. Examples of renewable energy include solar and wind energy.

Division of Energies

Fig 3



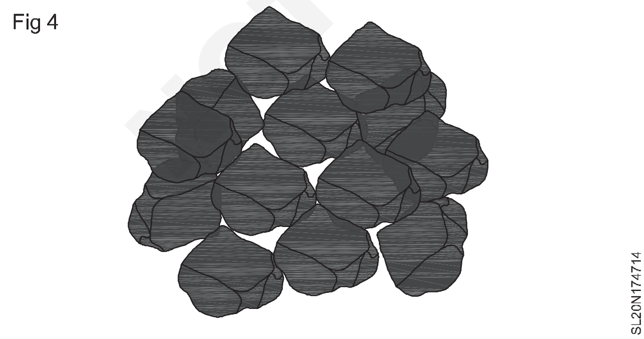
Nonrenewable energy is the one that comes from the ground. It is not replaced in a relatively short amount of time. Fossil fuels are the main category of nonrenewable energy. Fossil fuels include; coal, oil and natural gas. These resources come from animals and plants that have died millions of years ago and then decomposed to create a useable source of energy.

A non-renewable resource is the natural resource which cannot be reproduced, grown, generated, or used on a scale which can sustain its consumption rate. If depleted there is no more available of energy for future needs. It is consumed much faster than nature can create them. Fig 3 Non renewable energies

Fossil fuels (such as coal, petroleum, and natural gas), nuclear power (uranium) and certain aquifers are examples of non-renewable energy resources. Metals are prime examples of non-renewable resources.

Coal (Fig 4)

Fig 4



Oil (Fig 5)

In contrast, resources such as timber (when harvested sustainably) are considered renewable resources.

Coal, the most plentiful fossil fuel, is a black or brownish-black sedimentary rock composed mainly of carbon and hydrocarbons. It is the product of dead plants and animals compressed over millions of years. In a Power plant coal is burnt to produce steam to rotate turbine. When burned, coal releases air pollutants such as sulphur dioxide and nitrogen dioxide, as well as carbon dioxide, a greenhouse gas involved in global warming.

Fig 5

Oil: Oil, also known as petroleum, is used to make gasoline and diesel fuel to power airplanes, automobiles and other vehicles. Formed over millions of years, crude oil is the outcome of the heated and compressed remains of marine plants and animals that predated the dinosaurs.

Most of the renewable sources of energy are fairly non-polluting and considered clean though biomass, a renewable source, is a major polluter indoors.

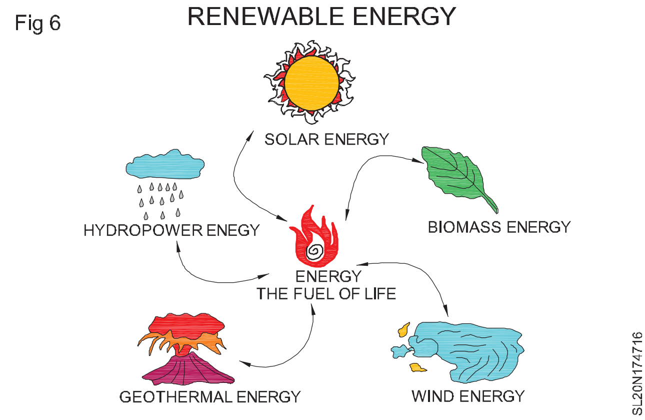
Renewable Energy

Renewable energy is energy which is generated from natural sources i.e. sun, wind, rain, tides and can be generated again and again as required.

They are available in plenty and by far most the cleanest sources of energy available on this planet.

Renewable Energies Fig 6

Fig 6



Advantages of Renewable Energy Sources:

- Obtained for an unlimited time period in plenty
- Generated from natural sources i.e. sun, wind, rain, tides
- Generated naturally again and again, that is, replenished naturally which means they will never run out.
- By far most the cleanest sources of energy available on this planet
- Energy received from the sun, wind, geothermal, biomass (from plants), tides can be used to generate electricity.
- These resources are clean or "green" since these have a much lower environmental impact than conventional energy sources.

Energy that we receive from the sun can be used to generate electricity. Similarly, energy from wind, geothermal, biomass from plants, tides can be used to convert into another form.

Renewable resources are clean or "green" energy sources that have a much lower environmental impact than conventional energy sources. Renewable resources are replenished naturally which means they will never run out.

Renewable energy sources:

- Solar energy
- Wind energy
- Bio fuel
- Bio mass
- Hydroelectricity / small hydro
- Tidal power
- Wave power
- Geo thermal energy

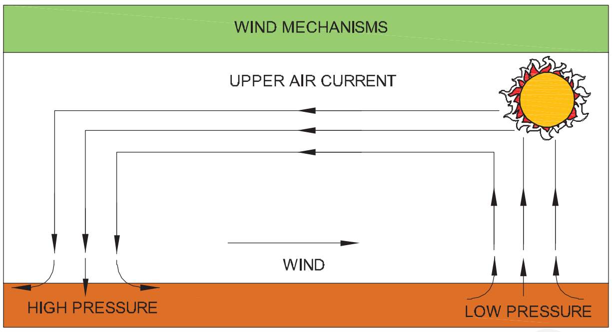
Before learning about the solar energy let us learn a little about the remaining renewable energies.

Wind Energy

Wind is the movement of air, caused by the uneven heating of the Earth by the sun and the Earth's own rotation. Winds range from light breezes to natural hazards such as hurricanes and tornadoes.

Wind Energy (Fig 7)

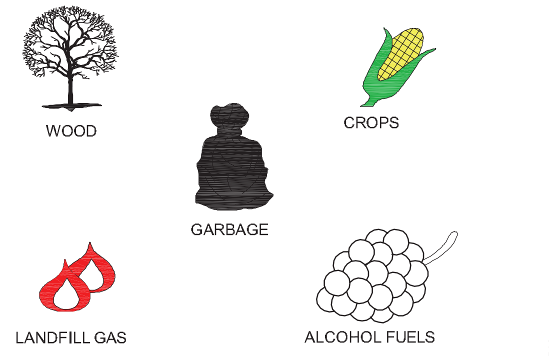
Fig 7



Wind, in climatology, the movement of air relative to the surface of the Earth. Winds play a significant role in determining and controlling climate and weather. Wind is moving air. Wind happens both because of how the Sun heats up the Earth and the tiny air molecules that move around us all the time. Oxygen and nitrogen make up most of Earth's air molecules. As air heats up and cools down, it also exerts air pressure–which is like the weight of air–and a downward force. As the Sun heats up the Earth's surface, differences in air pressure cause air to move. As it moves, it also balances out different air temperatures. As air warms up, it expands and its molecules spread apart. The air tends to weigh less and so it doesn't exert too much air pressure. When air is cold, the molecules are packed tighter. The air weighs more and can exert more pressure. Air usually flows from an area of high pressure to an area of low pressure. The colder air moves in to replace the warm air and we feel the wind.

Biomass Energy

Fig 8



TYPES OF BIOMASS

Biomass energy is a renewable energy resource that derives its energy from plant materials. Wood is the most common and still the largest biomass energy source currently, but breakthroughs in research have increased biofuel to encompass food crops, algae, and industrial waste to make biomass. Biomass materials harness the power inside the plant matter to make this energy. Plants store this energy through the process of photosynthesis which stores the energy of the sun inside the plant; when the plant is combusted or burned it releases this energy which can be used as a substitute for nonrenewable fossil fuels. Essentially biomass utilizes the energy of the sun, stored inside plants, to create a renewable energy source.

Benefits of Biomass

- Environmental protection: Biomass energy has potential to significantly decrease greenhouse gas emissions compared to fossil fuels.
- Energy security: Decentralized biomass energy could help nation to substantially reduce dependence on fossil fuels.
- Rural economic growth: Biomass energy could stimulate growth in farming, forestry and rural industry leading to overall rural development. Biomass energy could also provide a productive avenue for using agricultural and forestry wastes, besides plantations.

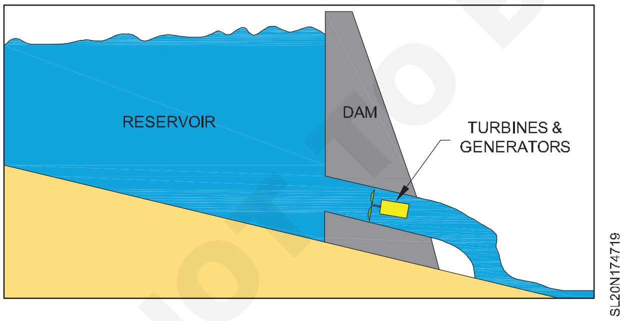
The examples of biomass that are commonly used as fuel includes:

- Wood and agricultural products:
- Solid waste
- Landfill gas
- Alcohol fuels
- Hydro Energy

One of the types of renewable energy, hydroelectricity derives its energy from flowing water. Normally, strong gushes of water. The force will eventually turn the turbines, which will then case the generator to move and create electricity. The latter is then distributed to different homes all over the community.

Hydro energy

Fig 9



Like other types of renewable energy, this doesn‟t create any smoke and hence doesn‟t cause any form of pollution. Moreover today it‟s highly possible for homes to generate their own hydroelectric power using small hydros, without building huge dams.

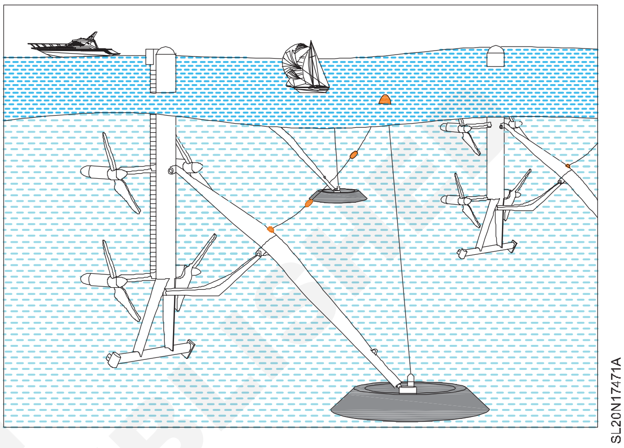
A dam is built to trap water, usually in a valley where there is an existing lake. Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators. Notice that the dam is much thicker at the bottom than at the top, because the pressure of the water increases with depth. Hydro-electric power stations can produce a great deal of power very cheaply.

Tidal energy

This is due to Gravitational attraction of Sun, Earth and Moon.

Tidal power plants use the energy provided by high and low tides. Water is stored during high tide and released during low tide, powering turbines in the process. The technologies associated with tidal power are very similar to those of hydro power, earthmoving, dam building, flooding land, placing turbines in dams. The set up costs are significant.

Fig 10

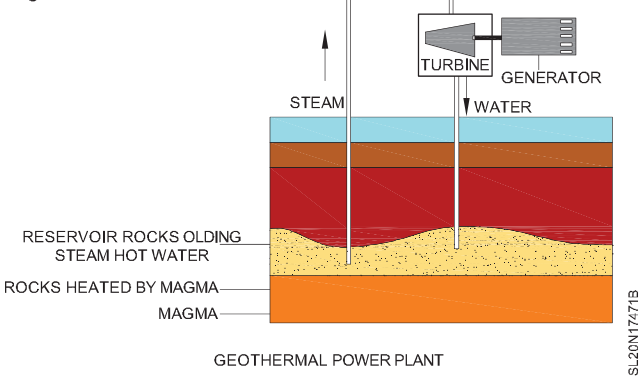


Concerns about the impacts of tidal power technologies have caused recent endeavors to focus on tidal turbines and tidal fences. Tidal turbines can operate with tides and currents some distance from land, like under water wind farms.

Geothermal Energy

This is Radioactivity and primordial heat in Earth's Interior.

Fig 11



Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter.

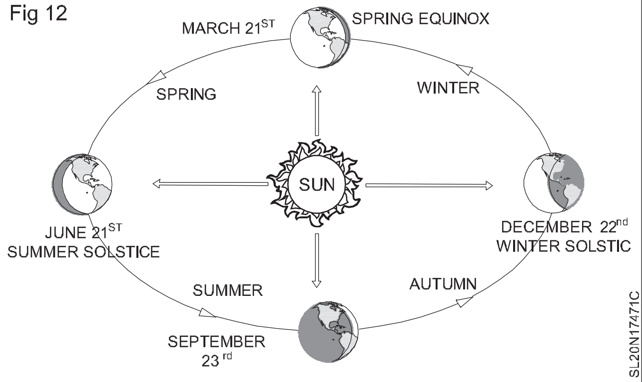
The Geothermal energy of the Earth's crust originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface.

Geothermal power plants use heat released from the interior through Earth‟s crust. The heat can be used directly or converted to electricity.

Renewable energy technologies tap into natural cycles and systems, turning the ever- present energy around us into usable forms. The movement of wind and water, the heat and light of the sun, heat in the ground. The carbohydrates in plants all are natural energy sources that can supply our needs in a sustainable way because they are homegrown, renewable can also increase our energy security.

Seasonal Changes in a year period (Fig 12)

Fig 12



Sun paths at any latitude and any time of the year can be determined from basic geometry. The Earth's axis of rotation tilts about 23.5 degrees, relative to the plane of Earth's orbit around the Sun.

As the Earth orbits the Sun, this creates the 47° declination difference between the solstice sun paths, as well as the hemisphere-specific difference between summer and winter.

In the Northern Hemisphere, the sun path near to the winter solstice (November, December, January), rises in the southeast, transits the celestial meridian at a low angle in the south (more than 43° above the southern horizon in the tropics), and then sets in the southwest.

It is on the south (equator) side of the house all day long.

A vertical window facing south (equator side) is effective for capturing solar thermal energy.

For comparison, the sun path near the winter solstice in the Southern Hemisphere (May, June, July) rises in the northeast, peaks out at a low angle in the north (more than halfway up from the horizon in the tropics), and then sets in the northwest.

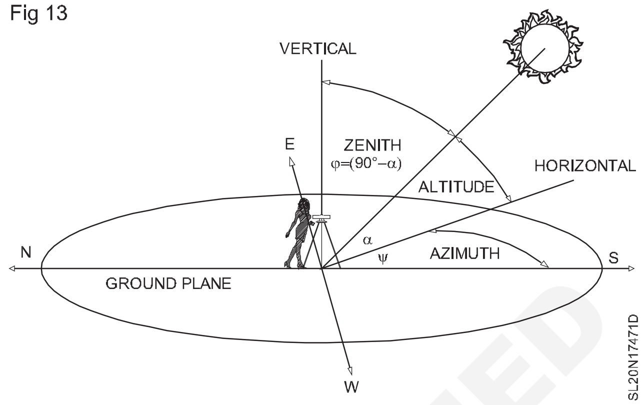
Duration of Daylight

North of the Arctic circle and south of the Antarctic circle, there will be at least one day a year when the sun is not above the horizon for 24 hours during the winter solstice, and at least one day when the sun is above the horizon for 24 hours during the summer solstice.

In the moderate latitudes (between the circles and tropics, where most humans live), the length of the day, solar altitude and azimuth vary from one day to the next, and from season to season. The difference between the length of a long summer day and a short winter day increases as one moves farther away from the equator.

Azimuth and Altitude (Fig 13)

Fig 13



Rise and set directions

On the northern hemisphere the north is to the left, the Sun rises in the east (far arrow), culminates in the south (to the right) while moving to the right and sets in the west (near arrow). Both rise and set positions are displaced towards the north in summer, and towards the south for the winter track.

On the southern hemisphere the south is to the left, the Sun rises in the east (near arrow), culminates in the north (to the right) while moving to the left and sets in the west (far arrow). Both rise and set positions are displaced towards the south in summer, and towards the north for the winter track.

On the imaginary line of the equator the Sun maximum elevation is great during all the year but it doesn't form every day a perfect right angle with the ground at noon. In fact it happens two days of the year, during the equinoxes.

The solstices are the dates that the Sun stays farthest away from the zenith but anyway also in those cases it's high in the sky, reaching an altitude of 66.56° either to the north or the south. All days of the year, solstices included, have the same length of 12 hours.

In the southern hemisphere, the Sun remains in the north during winter, but can reach over the zenith to the south in midsummer. Summer days are longer than winter days, but approximately the difference is no more than only two and a half hours.

Azimuth angle of the sun is defined as the angle from due north in a clockwise direction. (Sometimes from south)

Zenith angle of the sun is defined as the angle measured from vertical downward.

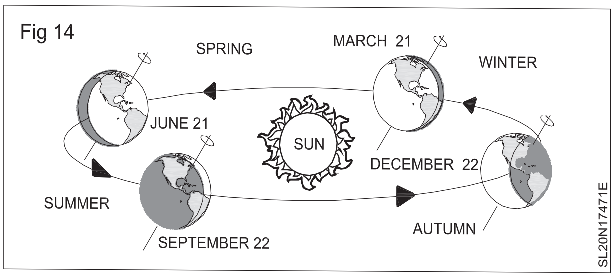
Angle of inclination of radiant light and its relation with latitude and longitude of different locations on Earth.

Depending on a geographical location the closer to the equator the more "potential" solar energy is available. The earth reaches the point nearest to the sun in the beginning of January each year (Perihelion - 147 million kilometers). After 6 months, on the 4th of July, it reaches the farthest distance from the sun (Aphelion - 152 million kilometers). This means that, due to these different distances, the direct solar radiation reaching the earth's atmosphere is 7% more intense in January than it is on the 4th of July. These differing distances between the earth and the sun only have a minor effect on the seasonal temperatures on the earth.

Earth's orbit (Fig 14)

The angle of incidence of the solar radiation is changing continually as the earth is circling around the sun and also spinning around its own axis. The ratio of radiation intensity and angle of incidence may be described as a cosine function, which is also called Lambert‟s law.

Fig 14



The 23.5º inclination of the earth‟s axis also has an influence as can be seen from Illustration above. The all-important factor is the change of the angle of incidence during the different times of the day.

The earth is not a flat disk. It is almost spherical in shape and gravitational force binds the atmosphere like a shell. The intensity of the solar radiation at a point on the surface is therefore influenced by the curvature of the surface and the effective thickness of the atmosphere. The solar radiation reaches its highest intensity when the sun is at its zenith and the angle of incidence is 90° and the thickness of the atmosphere is at its minimum. The lower the sun‟s position is in the sky the more atmospheres the radiation must pass through, and so more radiation is scattered and absorbed by the atmosphere and less radiation reaches the ground surface.

The effective thickness of the atmosphere is called the Atmospheric Depth. Just above the horizon the Atmospheric Depth is approximately 11 times larger than at the shortest path, at 90º (solar zenith), see Illustration. The effects of solar radiation are also influenced by the composition of the ground surface. It is not difficult to understand that a surface covered with snow reflects more radiation than one covered with trees or with black rock. The fraction of the incident solar radiation that is reflected by the surface is called the Albedo.

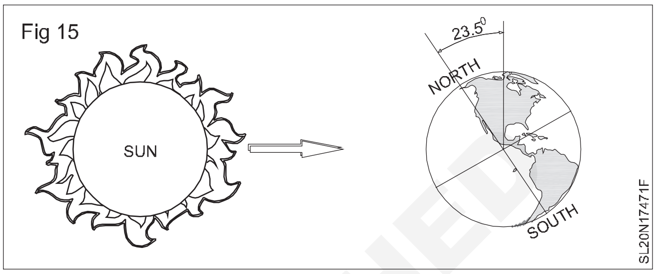
Definition of key earth-sun angles.

Factors Influencing Solar Collector Installation

Solar irradiation is affected by the following factors:

- Angle of Incidence of Solar Radiation
- Inclination of the Earth
- Atmospheric Depth

Fig 15



Inclination of Earth's axis (Fig 15)

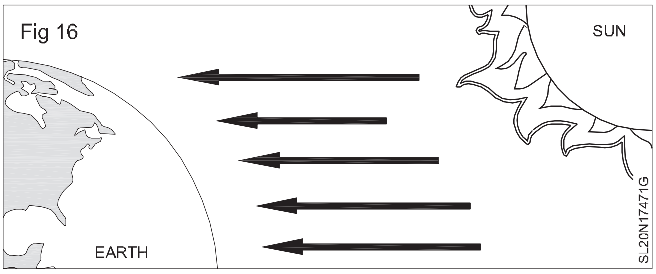
The all-important factor is the change of the angle of incidence during the different times of the day and throughout the year for a given location on earth. Based on these Solar collectors' installation varies place to place.

The closer to the equator the more "potential" solar energy is available. The earth reaches the point nearest to the sun (Perihelion - 147 million kilometers) in the beginning of January each year. After 6 months, on the 4th of July, it reaches the farthest distance from the sun (Aphelion - 152 million kilometers).

Due to these different distances, the direct solar radiation reaching the earth's atmosphere is 7% more intense in January than it is on the 4th of July

Direct radiation (Fig 16)

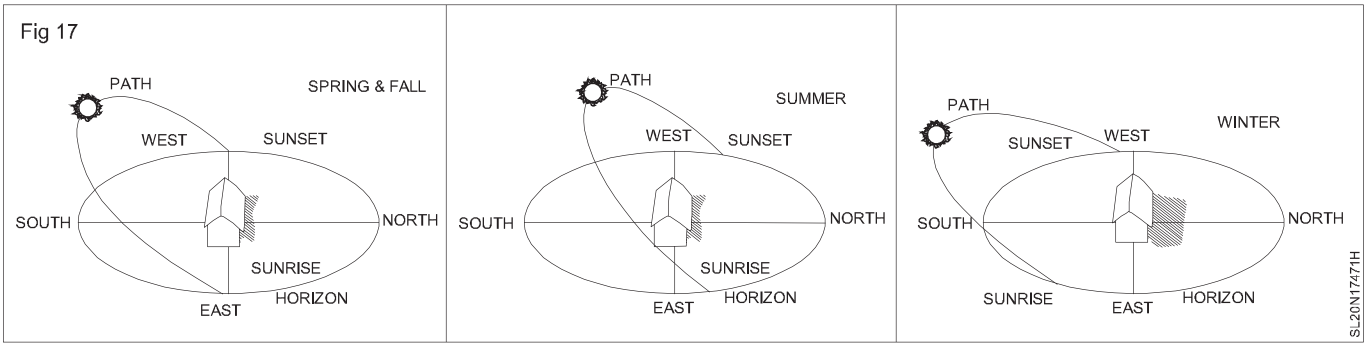
Fig 16



Sun path at Different seasons (Fig 17)

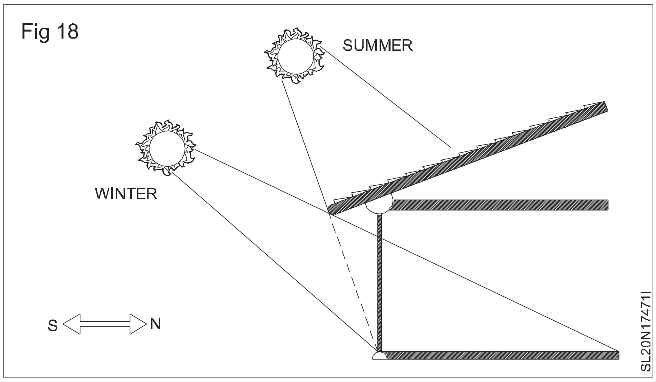
Accordingly, the installation angle varies from season to season, depending on a geographical location.

Fig 17



Installation of Solar Collector and Angle of incidence of Solar irradiation (Fig 18)

Fig 18



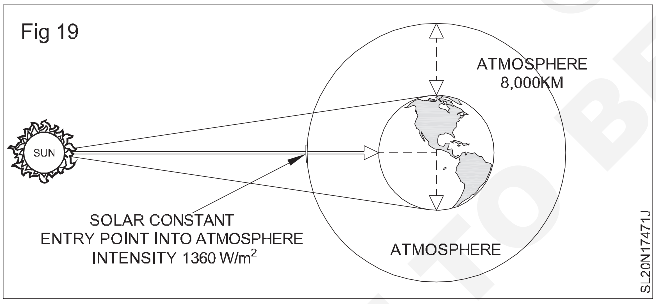
Equation of time, solar constant etc.

The equation of time describes the discrepancy between two kinds of solar time. The word equation is used in the medieval sense of “reconcile a difference”. The two times that differ are the apparent solar time, which directly tracks the diurnal motion of the Sun, and mean solar time, which tracks a theoretical mean Sun with uniform motion. Apparent solar time can be obtained by measurement of the current position (hour angle) of the Sun, as indicated (with limited accuracy) by a sundial. Mean solar time, for the same place, would be the time indicated by a steady clock set so that over the year its differences from apparent solar time would have a mean of zero.

Solar constant is the rate at which energy reaches the earth’s surface from the sun, usually taken to be 1,388 watts per square metre.

Solar Constant (Fig 19)

Fig 19



Solar constant, the total radiation energy received from the Sun per unit of time per unit of area on a theoretical surface perpendicular to the Sun’s rays and at Earth’s mean distance from the Sun. It is most accurately measured from satellites where atmospheric effects are absent. The value of the constant is approximately 1.366 kilowatts per square metre. The “constant” is fairly constant, increasing by only 0.2 percent at the peak of each 11-year solar cycle. Sunspots block out the light and reduce the emission by a few tenths of a percent, but bright spots, called plages, that are associated with solar activity are more extensive and longer lived, so their brightness compensates for the darkness of the sunspots. Moreover, as the Sun burns up its hydrogen, the solar constant increases by about 10 percent every billion years.

Definition of GHI & DNI

Global Horizontal Irradiance (GHI) is the total solar radiation incident on a horizontal surface. It is the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance, and ground-reflected radiation. Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. Typically, you can maximize the amount of irradiance annually received by a surface by keeping it normal to incoming radiation. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.

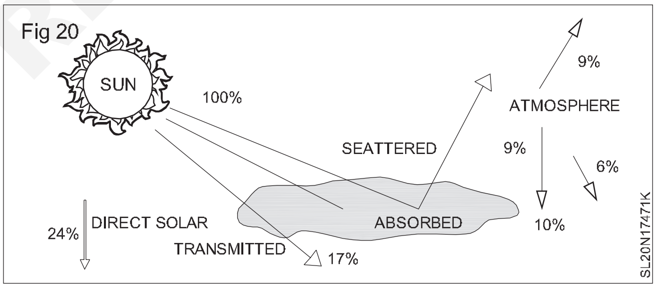
Diffuse Horizontal Irradiance (DHI) is the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI).

Global Horizontal (GHI) = Direct Normal (DNI) X cos(θ) + Diffuse Horizontal (DHI)

Solar radiation through space (Fig 20)

Fig 20



The surface receives about 47% of the total solar energy that reaches the Earth. Only this amount is usable.

Insolation:

- Insolation is the amount of solar irradiation reaching the earth.
- Also called Incident Solar irradiation or incoming solar irradiation
- Insolation reaches the earth, is absorbed and reflected
- Components of Solar Radiation:
  - Direct radiation
  - Diffuse radiation
  - Reflect radiation

Global Solar irradiation = Direct radiation + Diffused radiation

Basically there are two types of solar radiations:

- Global Horizontal irradiations (GHI)
- Direct Normal Irradiation (DNI)

GHI consists of diffuse radiations and direct horizontal radiations (beam).

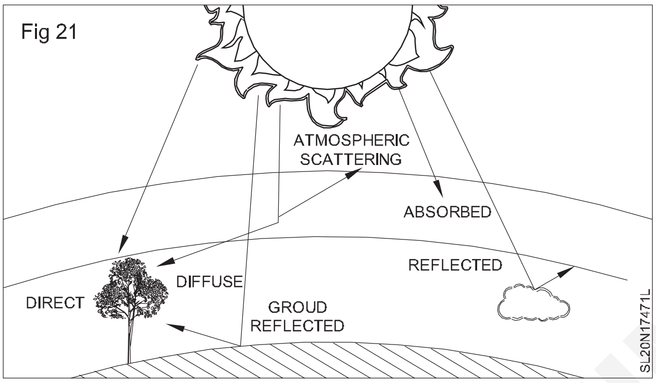
Minimum GHI – 1000 kwh/m^2

DNI is the amount of radiation received by a surface which is permanently aligned perpendicular to the incoming beam.

Minimum DNI – 1900 kwh/m^2

Direct, diffused and reflected radiation (Fig 21)

Fig 21



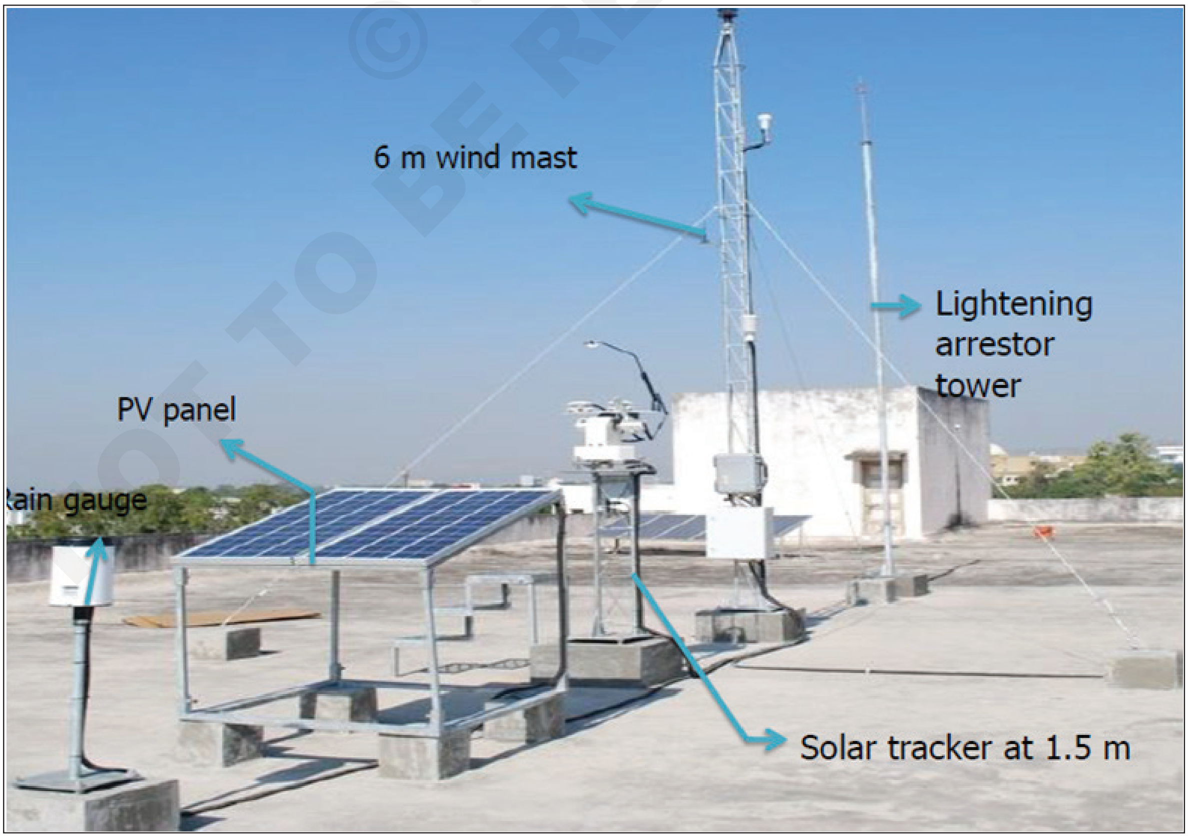
The energy emitted by the sun is 3.72 X 1020 MW, which equates to a irradiative power of 63 MW per m^2 of its surface. At the mean distance between earth and sun, this radiation reaches the outside of the earth's atmosphere with an intensity of 1.367 kW falling onto a 1 m^2 surface oriented normally to the sun's beams.

The Solar panel in fixed orientation needs to face south in Northern hemisphere and face north in southern hemisphere. The panel needs to be tilted at around Latitude angle of the location, in simple manner. At equator the tilt angle is 0˚.

Rooftop Met sensors installation (Fig 22)

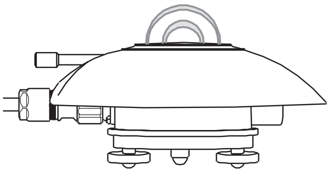
Typical Solar Radiation research station is shown above. It has PV panels mounted on Solar tracker for measuring Seasonal solar intensity, Pyranometer, Wind mast mounted with sensors, rain gauge etc to monitor continuously the weather throughout the year in a location. Data collected from the various sensors and transducers are monitored by suitable software and recorded continuously. We can derive all weather data and plot graphs to find out renewable energy availability over year period. This helps in planning effectively a project. Recorded year wise data would be useful gauge and develop future projects.

Fig 22



Pyranometer (Fig 23)

Fig 23



The Solar radiation data country wise are shown in the maps given below which are generally called Solar PV Maps.

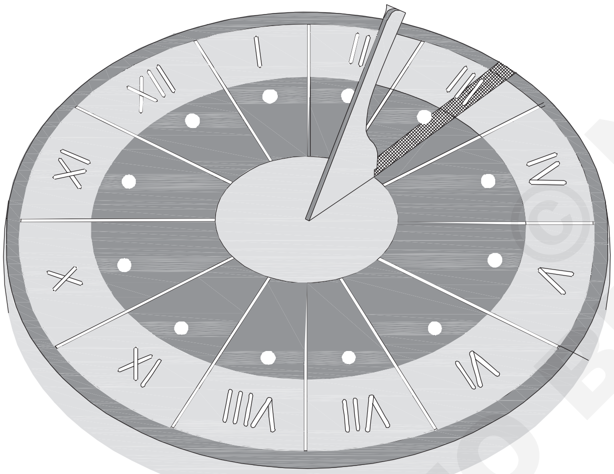
Solar radiation Map

The map indicates Yearly sum of global irradiation incident on optimally – inclined Equator facing Photovoltaic modules. Accordingly, in the map lowest annual Solar radiation regions are marked by Blue colour starting with 800 kWh/m2 and highest radiation received regions are represented by Dark Brown indicating highest as 2800 kWh/m2. In India the received solar radiation levels yearly are between 1600 kWh/m2 and 2500 kWh/m2.

Application of sun chart on shadow identification.

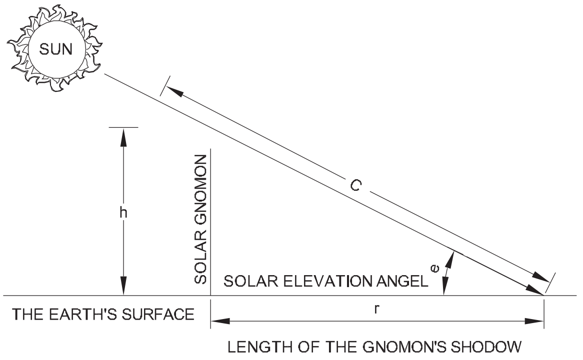
Sundial (Fig 24)

Fig 24



An instrument which uses the shadow cast by the Sun to tell the time. Because the Earth"s axis is tilted in space and because the Earth does not travel at a constant speed around the Sun, the time shown on a sundial can differ from true „clock" time. The correction needed to convert sundial time to clock time is called the Equation of Time.

Fig 25



c = (h2 + r2)½

h/r = tan(Ө)

Ө = tan -1(h/r)

Where

h = height of gonomon

r = length of shadow

Ө = incident angle of light source (sun or artificial light source)

Sunlight spectrum.

The sun's outermost and relatively thin 400 km layer is called the Photosphere and has a temperature of approximately 5,770 Kelvin. This is the layer that emits the spectrum of radiation which is visible to the human eye and is termed 'light'.

Scattering of solar radiation takes place within the whole spectral range. However, there are different ways in which the scattering can occur:

- Scattering by water droplets and/or ice crystals in clouds relatively evenly across
- the whole spectral range;
- Scattering by molecules (Rayleigh-Scattering), predominantly of radiation at shorter wavelengths
- Scattering by aerosol particles (Mie-Scattering) at wavelengths dependent upon the particle size and distribution.

Solar Technician (Electrical) - Characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers and DC appliances of Solar PV

Semiconductor properties and types

Objectives: At the end of this lesson you shall be able to
- **explain the semiconductor properties**
- **define a photo voltaic (PV) cell and state it's application**
- **explain the IV curve of Solar PV cell and factors affecting its performance**
- **state various types of Solar cells and their properties**
- **define a charge controller and explain the types of Charge controller.**

(P-type and N-type semiconductors, PN junction)

Classification of metals based on electrical conductivity:

- Conductors – copper, aluminium etc
- Insulators – wood, paper etc
- Semiconductors – silicon (Si) & Germanium (Ge)

Intrinsic semiconductors:

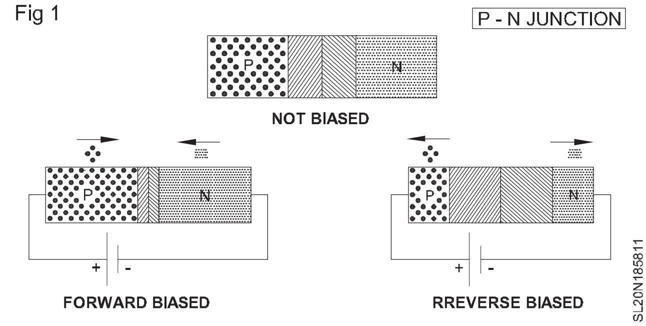
- Pure form of semiconductors
- Tetravalent atoms – each surrounded by four other atoms establishing covalent bonds
- Have two types of current carriers namely electrons and holes
- Electron – hole pairs are thermally liberated carriers

Extrinsic semiconductor:

- Results while impurity (trivalent or pentavalent) atoms are added to the pure tetravalent atoms
- The method of adding impurity to the semiconductor is called DOPING.
- P type semiconductor results by adding trivalent impurity (Al, In, B etc) to the pure silicon.
- P type has holes the majority carriers and electrons the minority carriers.
- N type semiconductor results by adding pentavalent impurity (As, P etc) to the pure silicon.
- N type has electrons the majority carriers and holes the minority carriers.

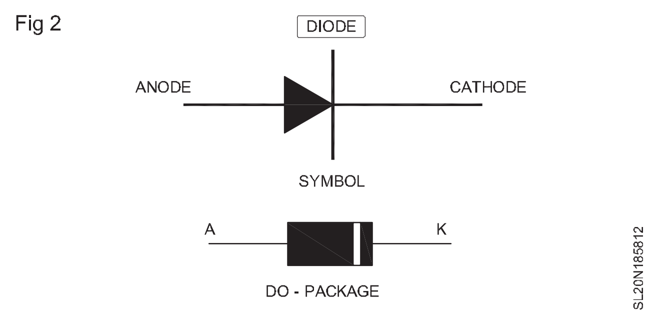
P N junction (Fig 1)

Fig 1



- Formed by fusing/growing together one P-type and one N-type semiconductor.
- All semiconductor devices has one or more P-N junctions
- The combined behaviour of junction(s) will decide the characteristics of the device.
- Hence understanding its characteristics is very important.
- P-N junction has two bias conditions
- Forward bias – when P end is connected to positive terminal of power supply & N end negative
- Reverse bias – when P end is negative & N positive
- Forward bias will reduce the depletion layer and allow the current flow through the junction
- Reverse bias will enhance the depletion layer and block the current flow

Fig 2



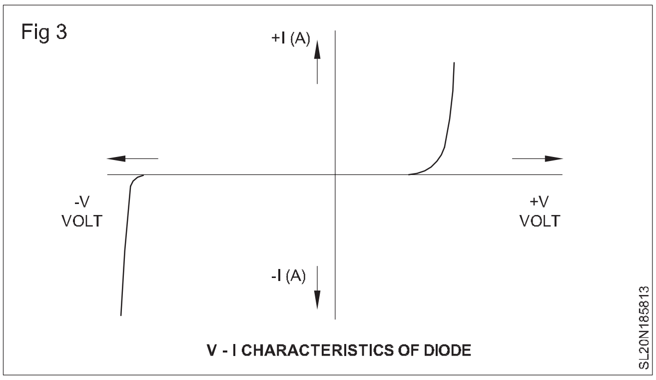
Diode

- A semiconductor diode has one PN junction
- It has two electrodes namely anode and cathode
- A diode behaves similar to the behaviours of a PN Junction in forward & reverse bias conditions

V-I Characterstics:

- Forward bias
- the anode is positive with respect to the cathode
- Reduces the potential barrier
- The junction offers negligible forward resistance to the flow of current (Rf = Zero)
- Diode works like a closed switch

Fig 3



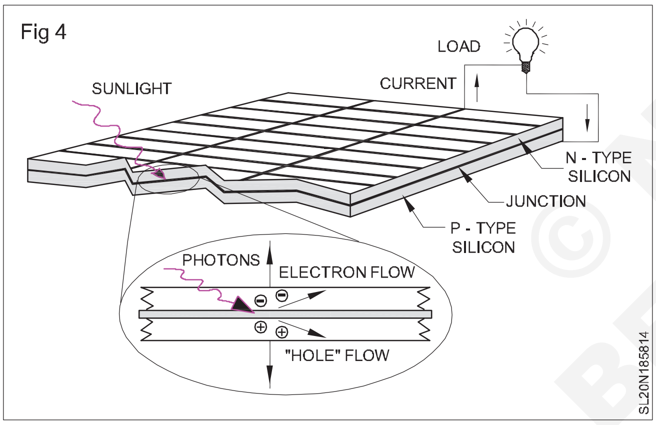
V - I CHARACTERISTICS OF DIODE

- Reverse bias
- the cathode is positive with respect to the anode
- Enhances the depletion layer
- The junction offers very high reverse resistance, (Rr = ∞) blocking the flow of current
- The diode works like an opened switch.
- **Types :** signal diode, Rectifier diode, Regulator diode, Light Emitting Diode and photo sensitive diode

Conversion of solar radiation to electricity.

Photovoltaic Cell / Solar Cell (Fig 4)

Fig 4



A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage, or resistance vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source. This method converts the sun's energy into electricity.

A single solar PV cell will have an output of approximately 0.5 V and current of few mA which depends on various factors such as type & quality of the cell, Solar irradiation, incident angle of solar irradiation, shadow, Spectrum of incident radiation etc. They are grouped to get higher outputs.

Applications of solar cells:

The electricity generated by the photoelectric effect can be either used directly or can be stored in batteries or can directly fed into an electric utility's grid system. The energy stored in the battery (in the form of chemical energy) can be used to operate any electrical device. If the device operates on DC, then it can be directly connected to the output load. If the device operates on AC, then an inverter is required to convert DC into AC.

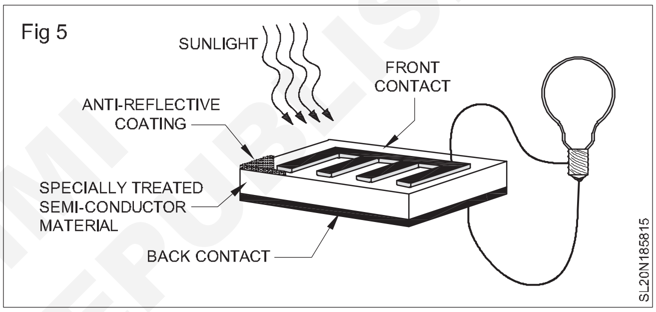
Main materials used to develop solar cells (Silicon, Cadmium tellurides, etc.)

A photovoltaic (PV) cell is an energy harvesting technology that converts solar energy into useful electricity through a process called the photovoltaic effect. There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

A photovoltaic cell is comprised of many layers of materials, each with a specific purpose. The most important layer of a photovoltaic cell is the specially treated semiconductor layer. It is comprised of two distinct layers (p-type and n-type), and is what actually converts the Sun's energy into useful electricity through a process called the photovoltaic effect.

Working

Fig 5



On either side of the semiconductor is a layer of conducting material which "collects" the electricity produced. Note that the backside or shaded side of the cell can afford to be completely covered in the conductor, whereas the front or illuminated side must use the conductors sparingly to avoid blocking too much of the Sun's radiation from reaching the semiconductor. The final layer which is applied only to the illuminated side of the cell is the anti-reflection coating. Since all semiconductors are naturally reflective, reflection loss can be significant. The solution is to use one or several layers of an anti-reflection coating (similar to those used for eyeglasses and cameras) to reduce the amount of solar radiation that is reflected off the surface of the cell.

Photovoltaic cell can be manufactured in a variety of ways and from many different materials. The most common material for commercial solar cell construction is Silicon (Si), but others include Gallium Arsenide (GaAs), Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS). Solar cells can be constructed from brittle crystalline structures (Si, GaAs) or as flexible thin-film cells (Si, CdTe, CIGS). Crystalline solar cells can be further classified into two categories—monocrystalline and polycrystalline.

As the names suggest, monocrystalline PV cells are comprised of a uniform or single crystal lattice, whereas polycrystalline cells contain different or varied crystal structures. Solar cells can also be classified by their number of layers or "p-n junctions". Most commercial PV cells are only single-junction, but multi-junction PV cells have also been developed which provide higher efficiencies at a greater cost.

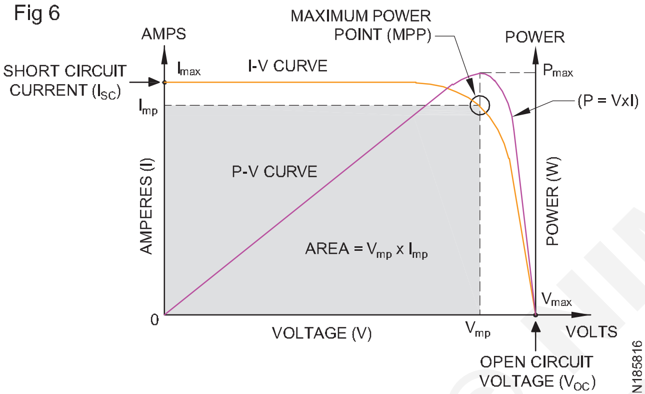
Accordingly, Crystalline Silicon (Si), Amorphous Silicon, Cadmium Telluride (CdTe), Copper Indium Selenide (CIS), Copper Indium Gallium Selenide(CIGS) are the main materials used to develop Solar Cells.

Light sensitive properties of PN junction.

P-N junction diode in the reverse-biased configuration is sensitive to light from a range between 400nm to 1000nm, which includes VISIBLE light. Therefore, it can be used as a photodiode. It can also be used as a solar cell. P-N junction forward bias condition is used in all LED lighting applications. The voltage across the P-N junction biased is used to create Temperature Sensors, and Reference voltages.

I-V curve

Fig 6



SOLAR CELL I-V CHARACTERISTIC CURVE

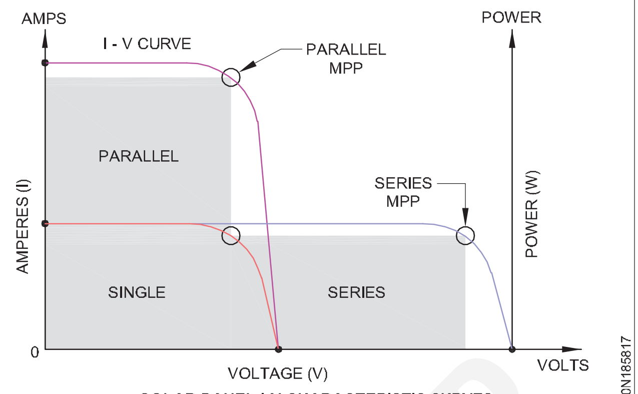
The solar cell I-V characteristics curves shows the current & voltage (I-V) characteristic of a particular photovoltaic (PV) cell, module or array. If gives a detailed description of its solar energy conversion ability and efficiency. Knowing the electrical I-V cjaracteristics (mor importantly Pmax) of a solar cell, or panel is critical in determining the device's output performance and solar efficiency.

Photovoltaic solar cells convert the suns radiant tight directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of enewable energy source increasingly important.

The above graph shows the current voltage (IV) characteristics of a typical silicon PV cell operating under normal conditions. The power delivered by a single solar cell or panel is the product of its output current and voltage (IV) If the multiplication is done, point to point for all voltage from short- circuit to open circuit conditions, the power curve above is obtained for a given radiation level.

With the solar cell open circuited, that is not connected to any load, the current will be at its minimum (o) and the voltage across the cell and its maximum, known as the solar cell open circuit voltage or VOC. At the other extream when the solar cell is short circuited that is the positive and negative leads connected together, the voltage across the cell is at its minimum (Zero) but the current flowing out of the cell reaches its maximum, known as the solar cell short circuit current or Isc.

Fig 7



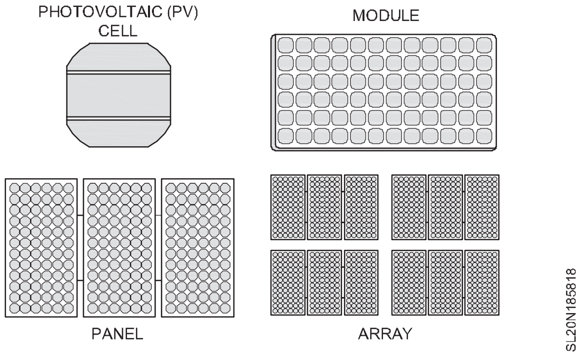
SOLAR PANEL I-V CHARACTERISTIC CURVES

PV panels can be wired or connected together in either series or parallel combination, or both to increase the voltage or current capacity of the solar array. If the array panels are connected together in a series combination. Then the voltage increase increase and if connected together in parallel then the current increases.

The electrical power in walts, generated by these different photovoltaic. Combinations will still be the product of the voltage times the current, (P= V x I). However the solar panels are connected together, the upper right hand. Corner will always be the Maximum Power Point (MPP) of the array.

Comparison of a cell, panel and array (Fig 8)

Fig 8



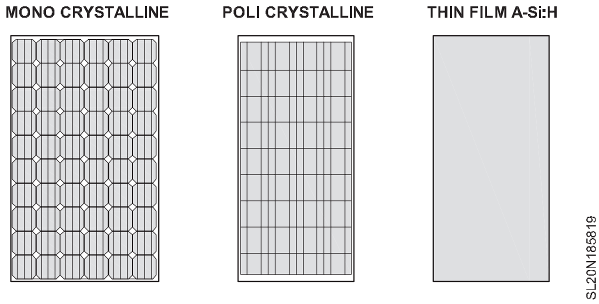
Selection of Solar PV panel

We should understand various features about a solar PV panel to be considered while buying it. Here we have a short look into it.

Types of Solar panel (Fig 23)

Points to remember for selection of a solar PV panel

Fig 9



1 Type

2 Size

3 Specification

4 Test certificate

5 Quality standard

Type

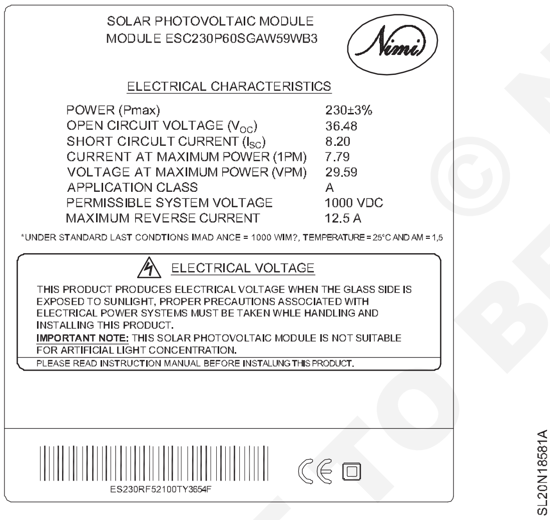
- Monocrystalline
- Poly/Multi crystalline
- Thin film

Size

- Peak power output (WP)
- Specification
- For selected WPlook for
  - V_M: Maximum voltage at W_P
  - I_M: Maximum current at W_P
  - Maximum system voltage
  - Standard Testing Condition (STC)

Typical Specifications of a solar panel (Label on backside of a panel) (Fig 10)

Fig 10



SOLAR PHOTOVOLTAIC MODULE
MODULE ESC230P60SGAW59WB3

ELECTRICAL CHARACTERISTICS

POWER (Pmax)	230±3%
OPEN CIRCUIT VOLTAGE (V_{OC})	36.48
SHORT CIRCULT CURRENT (I_{SC})	8.20
CURRENT AT MAXIMUM POWER (1PM)	7.79
VOLTAGE AT MAXIMUM POWER (VPM)	29.59
APPLICATION CLASS	A
PERMISSIBLE SYSTEM VOLTAGE	1000 VDC
MAXIMUM REVERSE CURRENT	12.5 A

*UNDER STANDARD LAST CONDTIONS IMAD ANCE = 1000 WIM?, TEMPERATURE = 25°C AND AM = 1,5

ELECTRICAL VOLTAGE

THIS PRODUCT PRODUCES ELECTRICAL VOLTAGE WHEN THE GLASS SIDE IS EXPOSED TO SUNLIGHT, PROPER PRECAUTIONS ASSOCIATED WITH ELECTRICAL POWER SYSTEMS MUST BE TAKEN WHLE HANDLING AND INSTALLING THIS PRODUCT.

IMPORTANT NOTE: THIS SOLAR PHOTOVOLTAIC MODULE IS NOT SUITABLE FOR ARTIFICIAL LIGHT CONCENTRATION.

PLEASE READ INSTRUCTION MANUAL BEFORE INSTALUNG THIS PRODUCT.

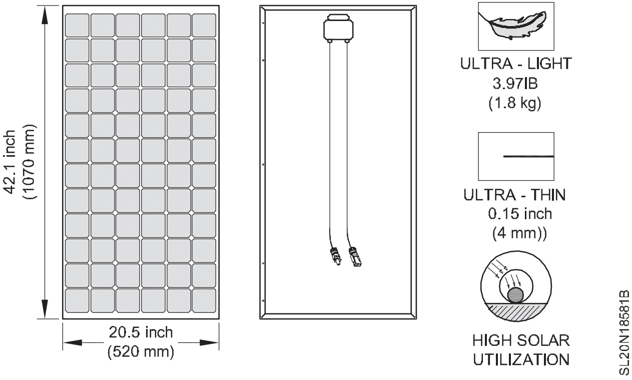
ES230RF52100TY3654F

- Test Certificate
- Manufacturer's test certificate
- Quality Standard

Backside of the Solar Panel (Fig 11)

In a designer approved Single Line Diagram (SLD) the above points are already considered and made available in SLD and part list. The technician can verify as far as possible the panels issued for installation or drawn from store shall have these information correct.

Fig 11



Standard test conditions (STC) of a PV module.

Every manufacturer tests their modules under something called Standard Test Conditions (STC).

STC is a set of rules to follow at manufacturing industry. These rules allow consumers and solar designers to compare panels.

Normal STC includes:

1 Solar Cell Temperature = 25°C

2 Solar Irradiance = 1000 W/m2

3 Air mass: 1 or 1.5

Air mass

The Air Mass is the path length which light takes through the atmosphere normalized to the shortest possible path length (that is, when the sun is directly overhead). The Air Mass quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.

Air Mass is the measure of how far light travels through the Earth's atmosphere.

One air mass, or AM1, is the thickness of the Earth's atmosphere. Air mass zero (AM0) describes solar irradiance in space, where it is unaffected by the atmosphere. The power density of AM1.5 light is about 1,000W/m2; the power density of AM0 light is about 1,360W/m2, which is considered to be the solar constant.

The air mass coefficient defines the direct optical path length through the Earth's atmosphere, expressed as a ratio relative to the path length vertically upwards, i.e. at the zenith. The air mass coefficient can be used to help characterize the solar spectrum after solar radiation has traveled through the atmosphere. The air mass coefficient is commonly used to characterize the performance of solar cells under standardized conditions, and is often referred to using the syntax "AM" followed by a number.

"AM1.5" is almost universal when characterizing terrestrial power-generating panels

Other features to be verified:

ASTM : Standard Spectrum or the type of light that shines on a solar panel

Production Tolerance: Manufacturers often assign an allowable tolerance of plus or minus 5% to the module's rating. Hence a 100 watt solar can be either 95 or 105 watts.

Temperature: Higher cell temperature than the 25°C will decrease efficiency. Roof mounted array's will show temperatures in the 50° to 75° C range, which is two to three times the STC rating.

Dirt and Dust: theseblock sunlight reaching to cells. Eventually panels get dirty until the next rainfall or hose spray. This can account for about a 2% on average loss.

Wiring losses: DC wiring accounts for power losses due to the resistance of the wiring system. We usually design for a 2% wire loss.

Inverter losses: On average, over a day, this is about 90%.

Terminal box and connectors of a Solar PV module.

The PV junction box has a simple, but important role: housing all the electric bits on a solar panel and protecting them from the environment. Wires connect to diodes inside, providing an easy way to link panels together.

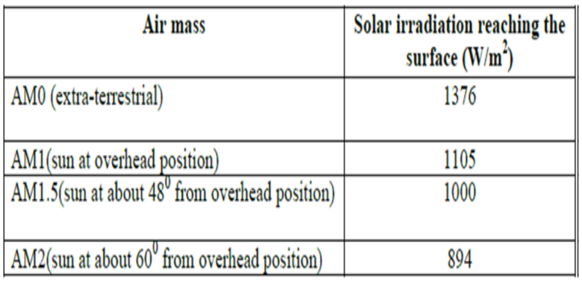
Although solar developers and owners don't get a choice in junction box type—module companies work out those contracts during manufacturing—the role of this enclosure is still important to understand, especially as it houses more "smart" technologies.

A junction box has bypass diodes that keep power flowing in one direction and prevent it from feeding back to the panels. Every string is protected by a diode in the junction box. The diode is the gateway that allows an endless stream of power. If part of a solar panel is shaded, that string will want to consume power, reversing the flow of electricity. Diodes inside the junction box prevent that from happening. There are two different junction box production techniques—soldering/potting and clamping. With the soldering and potting method, foils coming out of the solar panel are soldered to the diodes in the junction box. The junction box then has to be potted or filled with a type of sticky material to allow thermal transfer of heat, keep the solder joint in place and prevent it from failing. Once enough time has passed for sufficient curing of the potting material, the panel is good to go. With clamping production, a simple clamping mechanism attaches the foil to the wires. There are no fumes or major cleanup as with the soldering/potting method. The prices of both methods are fairly equal when comparing material and labor costs as a whole. The clamping box may be more expensive, but the labor needed to solder and pot the other boxes is often higher.

Junction box of Solar panel (Fig 12)

Although there are differing opinions on the best way to produce a junction box, there has been little discussion over the main role of this often-ignored product—until new technologies got involved in the industry.

Fig 12



Air mass	Solar irradiation reaching the surface (W/m^2)
AM0 (extra-terrestrial)	1376
AM1(sun at overhead position)	1105
AM1.5(sun at about 48^0 from overhead position)	1000
AM2(sun at about 60^0 from overhead position)	894

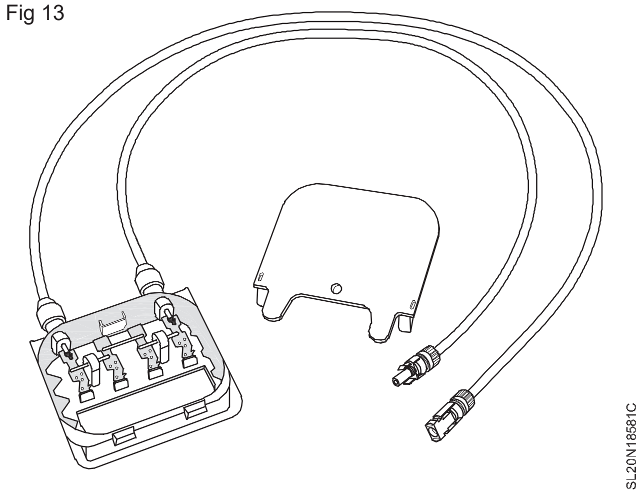
As modules have changed, the junction box has kept the same functionality. But now with increased power outputs and voltages, junction boxes have had to improve their ability to protect that power. In bifacial panels, Energy is still fed through one junction box even though power is being produced on both the front and backside of the module. Junction box manufacturers have had to get creative with their designs.

As the module output gets higher, those bypass diodes have to do more work. The way they absorb that energy is by shedding heat. You have to handle that heat of the diodes.

Cool bypass switches are replacing traditional diodes in some junction boxes to mitigate the excessive heat generated by higher module outputs. When shaded panels want to instinctively consume power, a traditional diode prevents that from happening, but heat is generated in the process. A cool bypass switch works like an on/off switch and opens the circuit when panels are trying to pull energy, preventing heat from building up.

Power optimizer Junction box (Fig 13)

Fig 13



A smart junction box enables customized printed circuit boards (PCBs) to be integrated into solar panel solutions with monitoring, optimizing and rapid shutdown functionality.

Most microinverters and optimizers are added to the back of the module in addition to the junction box. But power optimizer can replace the junction box on factory-assembled smart modules. The embedded power optimizer provides smart capabilities while performing the basic power functions of a junction box.

Junction box manufacturers are also looking into adding inverter technology to their future models. "The next step is going to be that module that has the inverter in the standard junction box with one AC source coming out. It simplifies the installation and makes the module more versatile.

Identification of various test standards of PV module

Success in the solar industry starts with testing and certification. To thrive in the solar energy sector, manufacturers and retailers need to ensure that their products meet established quality and performance standards. This means demonstrating that their PV modules are robust and able to consistently deliver the guaranteed rated power reliably even under more severe climactic conditions. They must also be safe and durable, ensuring the system's high yield over the long term, and still need to be commercially viable.

Industries have developed testing services that address market needs and enable user to meet their goals. At ISO 17025 accredited laboratories around the globe, the manufacturers test and certify PV modules according to national and international standards, including IEC 61215 and IEC 61730. Besides this they offer testing under special as well as more severe conditions, performance characterization and energy yield testing, just to name a few.

International standards such as EN, IEC, ANSI keep abreast of changes and harmonization that affect market access for PV modules.

Few certification services consist of the following process steps:

- Laboratory tests on samples for a module family or type
- Recurring factory inspection
- Certificate and TÜV Rheinland test mark
- Certificate of conformity (CoC) or declarations for individual markets
- Bankability reports

Quality assurance measures for PV modules:

- PID – potential-induced degradation
- Electro-luminescence and IR imaging
- Pre-/Post-shipment inspections
- Ageing of micro-cracks
- LID test (light induced degradation)

Stress tests:

- Fire tests
- Corrosion tests (e.g., salt mist, ammonia and Sulphur dioxide)
- Outdoor long-term tests in different climate zones
- Transport and environmental simulation on PV module shipping units
- Sand abrasion tests
- Snow load testing (non-uniform, heavy snow load)

Added value services:

- PV+ benchmark
- Qualification Plus ("Q+") certification
- Energy yield testing under actual climate conditions in relevant target markets

BIPV – qualification of Building-Integrated PV:

- Risk analysis
- Roof integration
- Facade integrated systems
- Hail testing
- Snow load testing

Measurement of area of the cells and compare with the module area in data sheet

Every solar panel is made up of individual solar photovoltaic (PV) cells. PV cells come in a standard size of 156 mm by 156 mm. (15.6 cm x15.6cm).

Example:

Area of one PV cell = 243.36 cm^2

Area of 60 PV cells = 14601.6 cm^2

Area of a Solar PV panel of 60 cells = 16335 cm^2

The average size of solar panels used in a rooftop solar installation is approximately 165 cm x99cm. The length can go upto 182.88 cm.

Most solar panels for rooftop solar installations are made up of 60 solar cells, while the standard for commercial solar installations is 72 cells (and can go up to 98 cells or more).

The number of solar cells on one panel is directly related to its length. 72-cell commercial solar panels are approximately 33 cm longer than 60-cell residential panels.

If you install a 6 kilowatt (kW) system with 20 average-sized panels, your system will likely measure approximately 8.23 m wide by 3.96 m long = 32.59 m^2.

Identification of faulty PV module.

Understand first how to test solar panels to make sure they're working properly.

Properly testing your solar panels is a very important but often overlooked procedure. Confirmtheir solar power output before installing them.By learning how to test solar panels you can ensure that you don't waste your time installing panels that you'll have to take down and fix.

Procedure for testing Solar Panels:

Testing using multi meter is easier. Test the solar panel for voltage across the output terminals. For this, first, Keep the solar panel in sunlight. Set your multi meter to "DC volts" setting. Touch the positive lead to the panels positive wire and negative lead to the negative wire of the solar panel. If meter reads selected range is low rotate the dial to increase the range. Note the voltage displayed and compare it with V_{OC} rating given on the back of the panel in the label. It should be close to V_{OC}. If it reads so then the given solar panel is good. If it is not then there is a problem with the given panel.

In such a case go back and check the connections of solar cells, strings for any break or any crack in the solar cells. If you find anything like that we can't repair ourselves. It should be sent to manufacturer for repair / replacement as the case may be.

Testing for amps:

If the V_{OC} is close to the printed value then we can go for current checking.

Keep the solar panel in sunlight. Set the multimeter for current reading. Set the range close to I_{SC} of the panel.

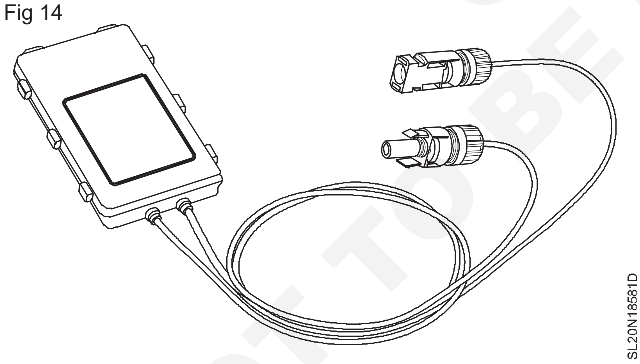
Connect the terminals to the suitable leads of the multimeter. If the meter reads some ampere, then slightly tilt the panel to and fro and check the current varies. Also note that at certain point it reads maximum current equal or closer to printed value of I_{SC}. This is good condition. If not, check for dust, blocks anything and clear. Test again when sky is clear. Results should be ok. Otherwise the solar given is faulty and to be sent to factory for reconditioning.

If the above test results are satisfactory, then Calculate wattage by multiplying the V_{OC} and I_{SC}. The answer should be closer or equal to W_P rating of the solar panel given.

Solar PV array; series and parallel calculation.

Series and parallel connection of solar panels (Fig 14)

Fig 14



Solar PV panels connected in series are called “STRING”. Strings connected in parallel make an array.

Series connection

For a series connection connect positive terminal of one panel to the negative terminal of other panel and so on. Then positive terminal of first panel is the positive terminal of the series path. And negative terminal of last panel is negative terminal of the series path. The voltage of series connected panels is addition of individual panel voltage. Thecurrent path is single and hence series connection's current is equal to current of a single panel. Conditions are all panels in series path must be of same ratings and specifications. No mixing of ratings is allowed.

If

V_m = maximum voltage of each panel

Feature	Residental panels	Commerical panels
No. of Solar Cells	60	72
Average Length	165 cm	198 cm
Average Width	99 cm	99 cm
Average Depth	3.81 cm	3.81 cm

I_m = maximum current of each panel

W_P = Peak Power output of each panel

n = no. of panels in series

Then

$V_{series} = V_{m1} + V_{m2} + \ldots..V_{mn} = nV_m$

$I_{series} = Im$

$P_{series} = nV_mI_m = nW_P$

Parallel connection

For a parallel connection, connect positive terminal of all panels together and connect all negative terminals together. Terminals taken out from any one the panel gives positive and negative terminals of the combination.

If

V_m = maximum voltage of each panel

I_m = maximum current of each panel

W_P = Peak Power output of each panel

m = no. of panels in series

Then

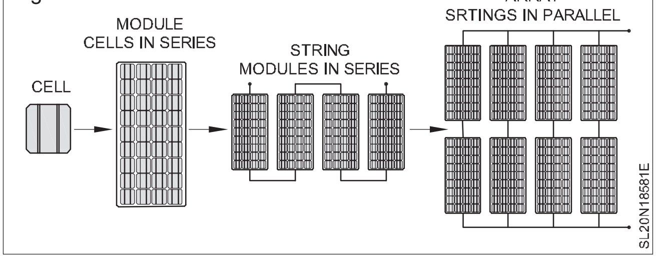
$Vparallel = V_m$

$Iparallel = I_{m1} + I_{m2} + \ldots..I_{mm} = mI_m$

$P_{parallel} = mV_mI_m = mW_P$

Solar Array

Fig 15



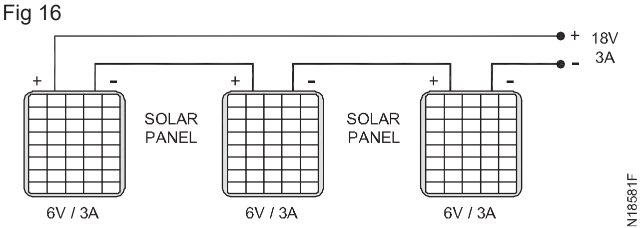
Strings connected in parallel make an array.

In general, if n number of panels in series to form n strings and m such strings are connected in parallel then this combination forms an array.

Solar PV mounting structures

Photovoltaic mounting systems (also called solar module racking) are used to fix solar panels on surfaces like roofs,

Fig 16

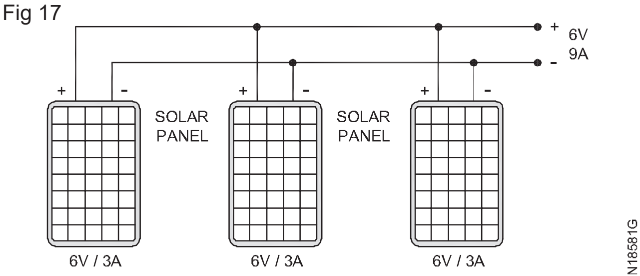


SOLAR PANEL CONNECTED IN SERIES

building facades, or the ground. These mounting systems generally enable retrofitting of solar panels on roofs or as part of the structure of the building (called BIPV)

Mounting structure

Fig 17



SOLAR PANEL CONNECTED IN PARALLEL

The solar array of a PV system can be mounted on rooftops, generally with a few inches gap and parallel to the surface of the roof. If the rooftop is horizontal, the array is mounted with each panel aligned at an angle. If the panels are planned to be mounted before the construction of the roof, the roof can be designed accordingly by installing support brackets for the panels before the materials for the roof are installed. The installation of the solar panels can be undertaken by the crew responsible for installing the roof.

If the roof is already constructed, it is relatively easy to retrofit panels directly on top of existing roofing structures. For small roofs that are designed to bear only the weight of the roof, installing solar panels demands that the roof structure must be strengthened beforehand.

In all cases of retrofits particular consideration to weather sealing is necessary. There are many low-weight designs for PV systems that can be used on either sloped or flat roofs (e.g. plastic wedges or the PV-pod), most however, rely on a type of extruded aluminum rails (e.g. Unirac).

Recently, tension-based PV racking solutions have been tested successfully that reduce weight and cost. In some cases, converting to composition shingles, the weight of the removed roof materials can compensate the additional weight of the panels structure. The general practice for installation of roof-mounted solar panels include having a support bracket per hundred watts of panels.Ground-mounted,

Mounting as a shade structure, Building-integrated photovoltaics are further available options. More details are available in Vol II.

Photovoltaic cell and PV modules: types - mono crystalline, poly crystalline, amorphous silicon and thin film PV cells and their comparison.

Types of Solar Cells: There are three basic types of solar cells which are as follows:

1 Crystalline Solar Cells

2 Concentrating Photovoltaic

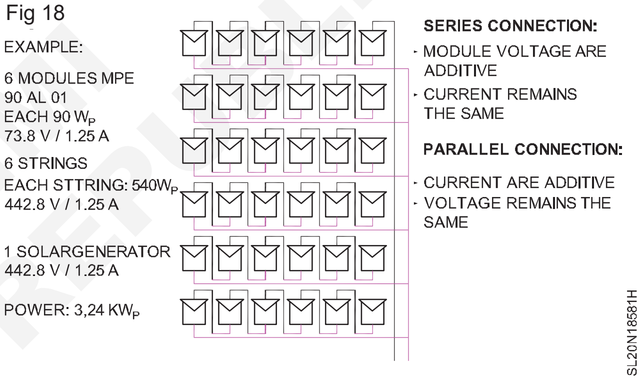
3 Thin film Technology

Crystalline solar cells are wired in series to produce solar panels. As each cell produces a voltage of between 0.5 and 0.6 Volts, 36 cells are needed to produce an open-circuit voltage of about 20 Volts. This is sufficient to charge a 12 Volt battery under most conditions. The majority of PV cells produced today use crystalline silicon (c-Si) as it is a light absorbing semiconductor. The c-Si technology was originally developed for the semiconductor industry to produce PV cells for integrated circuits and microchips.

These PV cells have energy conversion efficiencies between 11 percent and 16 percent. The energy conversion efficiency of a solar cell is the percentage of incident sunlight converted into electricity. While the efficiency of c-Si is high, it absorbs light poorly and requires many layers to perform efficiently in solar applications.

Mono Crystal Line PV cells (Fig 18)

Fig 18

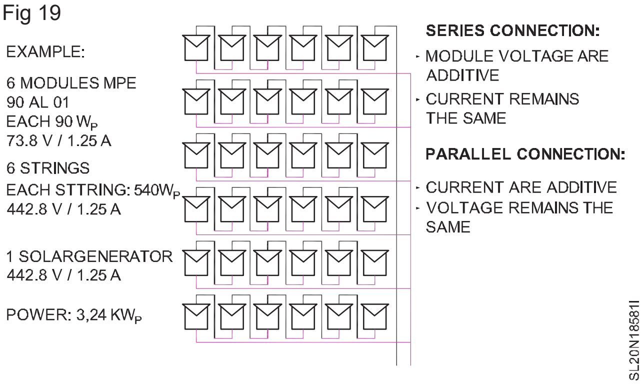


Crystalline type can be further divided into Mono crystalline and polycrystalline PV cells

Monocrystalline cells are cut from a single crystal of silicon. They are effectively a slice from a crystal. In appearance, it will have a smooth texture and you will be able to see the thickness of the slice. These are the most efficient and the most expensive to produce. They are also rigid and must be mounted in a rigid frame to protect them.

Poly-crystalline Solar Cell & Module (Fig 19)

Fig 19



Features:

- Good power-to-size ratio: efficiency typically within the range of 135-170 Watts per m2 (13-17%, with notable exceptions).
- Outstanding performance in cooler conditions.
- Some leading units now have over 18% conversion efficiency.
- Previously the most commonly used technology in the world, with over 50 years of technological development.
- Excellent life span / longevity. Usually come with 25yr warranty.

Polycrystalline (or Multicrystalline) cells are effectively a slice cut from a block of silicon, consisting of a large number of crystals. They have a speckled reflective appearance and again you can you see the thickness of the slice. These cells are slightly less efficient and slightly less expensive than monocrystalline cells and again need to be mounted in a rigid frame.

Module Mounting Features (Fig 20)

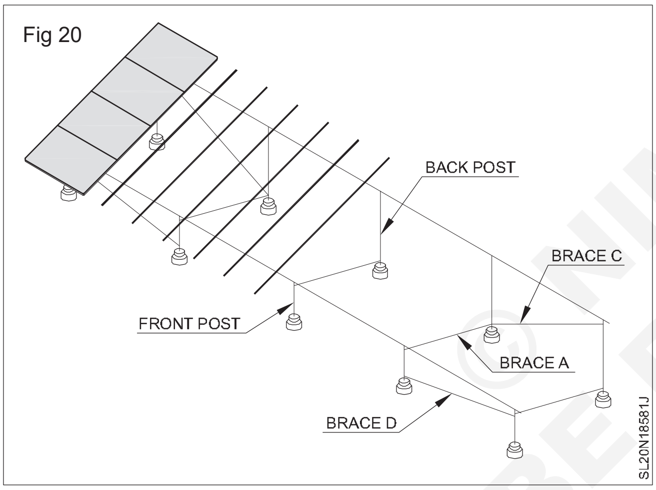


Fig 20

- Good efficiency: typically 120-150 Watts per m2 (12-15%, with notable exceptions).
- Generally speaking, marginally less expensive to produce than monocrystalline.
- Slightly better performance in hotter conditions.
- Excellent life span / longevity. Usually come with 25yr warranty.

Concentrating Photovoltaic Solar Panel Technology:

Based on the principle that a solar cell receiving more light energy will produce more electricity, concentrating photovoltaic solar panels simply involve a method (usually using a lens or mirrors) to concentrate more sunlight onto a photovoltaic cell. As fewer cells are then requiredfor the same area of panel (or light capturing area) it may then become economical to use a highly efficient multi junction cell.

Thin film Technology

Recent thin film technologies include CdTe, GIGS, CISetc

Thin film PV cell (Fig 21)

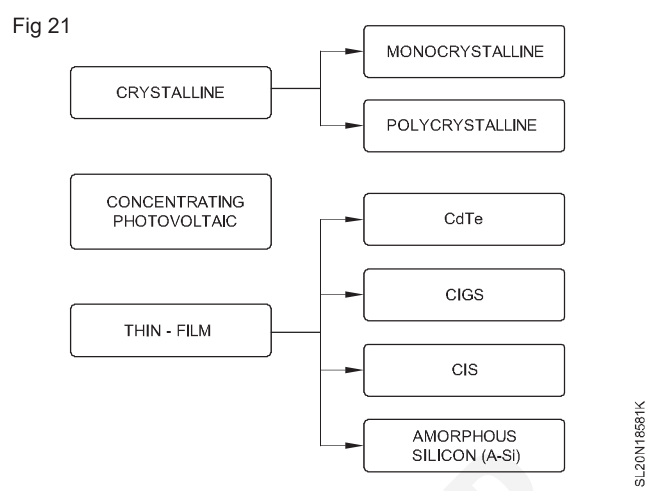


Fig 21

In this approach thin layers of semiconductor material are deposited onto a supporting substrate, such as a large sheet of glass. Typically, less than a micron thickness of semiconductor material is required, 100-1000 times less than the thickness of Silicon wafer. They are known as thin-film because they are deposited in very thin layers on stainless steel, glass or a flexible substrate. The thickness of the film is less than 1 micron. Like c-Si, thin-film PV cells are combined into modules and laminated to protect them from the elements. They are less expensive than c-Si cells, but their demonstrated energy conversion efficiency is only around 8%. The advantage of thin-film technology is that it can be applied over large areas, providing more opportunity to generate electricity in cloudy conditions.

Features:

- Lowest efficiency: typically 60-80 Watts/m2 (60-80%, with notable exceptions).
- Expected lifespan is less than crystalline panels.
- Optimal efficiency in hot weather, less effective in cooler conditions.
- 3-6 month „breaking in" period where long term output is exceeded.
- Requires 2-3 times more panels and surface area for same output as crystalline.

Thin film solar cell & Module (Fig 22)

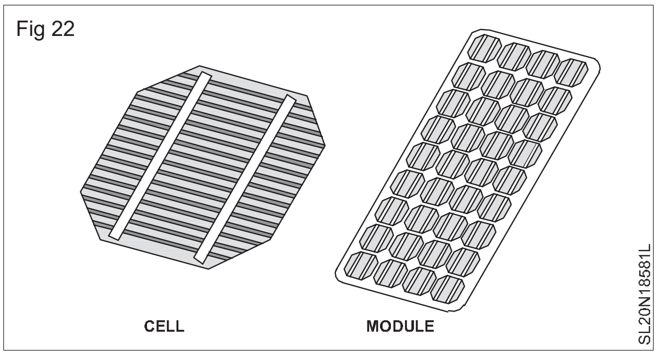


Fig 22

Some of the thin film solar cells in use are as follows:

- Amorphous silicon (a – Si)
- Cd Te (Cadmium Telluride)

- CIS (Copper Indium Selenium)
- CIGS (copper indium gallium di-selenide)

Charge controllers

The need for a charge controller

Though abundant, solar insolation is an unreliable source of energy, in the sense,it fluctuates as a function oftime and is not available during the nights or in cloudy sky. Therefore when the PV systems are usedfor stand –alone applications, a backup source of energy is necessary to compensate for the balancepower demand of the load.

Batteries are used as generally backup source in such applications. Toreduce the cost of system, the ratings of batteries are designed optimally. Battery feeds the loadwhen the PV output power is less than load demand and is charged when PV output power is morethan load demand. In applications where batteries are used, it is critical to prevent overcharging ordeep discharging of the batteries to preserve their life and to ensure good performance. This isachieved using Charge controllers.

The block diagram of a stand –alone PV system with batterybackup and a charge controller is shown in fig. 38. This shows the solar energy is received from the solar panel by the charge controller. The energy received is either used for charging the battery or delivered to the load based on energy level in the battery and the requirement by the load. Battery delivers out or receives in the energy.

A charge controller (an electronic circuit) is basically a voltage and/or current regulator to keep batteries gets charged and prevent from overcharging. It regulates the voltage and current coming from the solar panels and going to the battery.

Standalone solar PV electrical system

The Solar charge controller performs the following major functions:

- Charges the battery.
- Gives an indication when battery is fully charged.
- Connect/disconnect the load
- Monitors the battery voltage and when it is minimum disconnects the load
- Connects or disconnects solar panel to circuit
- Protects the battery from over charging
- Prevents battery from deep discharge
- Monitors the reverse current flow and block
- Indications for charging ON, Battery connect, Solar ON etc
- Commercial charge controllers have 10amp to 40amp of charging current

As a common application, the Solar Street lights use photovoltaic modules to convert sunlight into DC electric charge and use a solar charge controller to store DC in the batteries and automatically switch ON street light in the evening after sunset.

Home systems use PV module for house-hold applications in which charge controller plays important role.

Charge Controller

Basically there are three types of charge controller

1 On/Off (bang-bang) type controller

- Disconnects module when high battery voltage is reached
- Reconnects module when battery voltage lowers
- Control may be relay or solid state

2 PulseWidth Modulation (PWM)

- When desired battery voltage is reached (≈14V) output turns on/off quite rapidly (100Hz -50KHz)
- Battery voltage held constant, producing a more fully charged battery

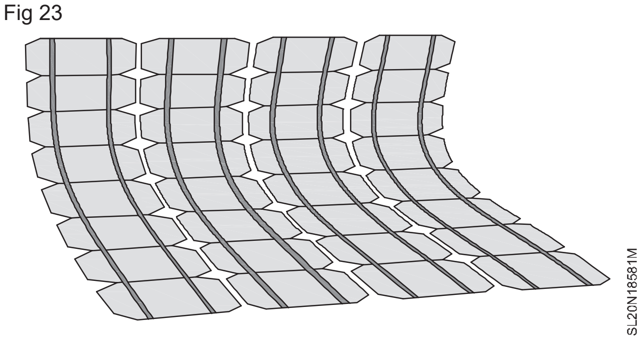
3 Maximum Power Point Tracking (MPPT)

- Provides PWM type battery voltage control
- Extracts all available power from the PV module
- MPPT technology can increases charge current up to 30% or more compared to traditionalcharge controllers

The solar charge controllers are necessary for most solar power system that uses batteries. The solar charge controller functions to control the power as it moves from the solar panels to batteries. Ifovercharged, the life of battery is reduced. The simple type of charge controller functions to monitor the battery voltage and opens the circuit to stop the charging process once the voltage reaches acertain level. Older charge controllers accomplished this through the use of a mechanical relay.

Charge controller and its connections with other components in Solar PV electrical system (Fig 23)

Fig 23



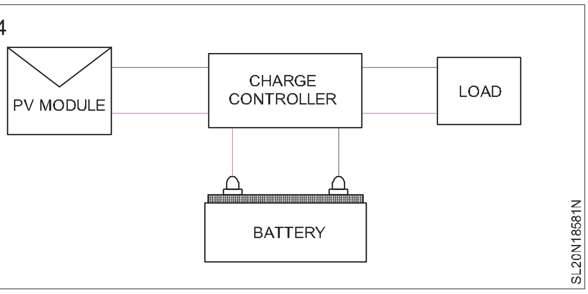
PWM solar charge controller

More charge controllers make use of pulse width modulation. This is a process in which, asthe battery starts to reach a fully charged state, the amount of power being transferred to it graduallydecreases.

Block diagram of a PWM type charge controller (Fig 24)

PWM extends the battery life even more, as it decreases stress on battery. It can also keepbatteries in a completely charged state, or floating, indefinitely. PWM chargers are more complex,but they tend to be more durable as they do not use any breakable mechanical connection.

Fig 24



Graphical representation of functions of a charge controller (Fig 25)

Control by duty cycle in a PWM controller (Fig 26)

Fig 25

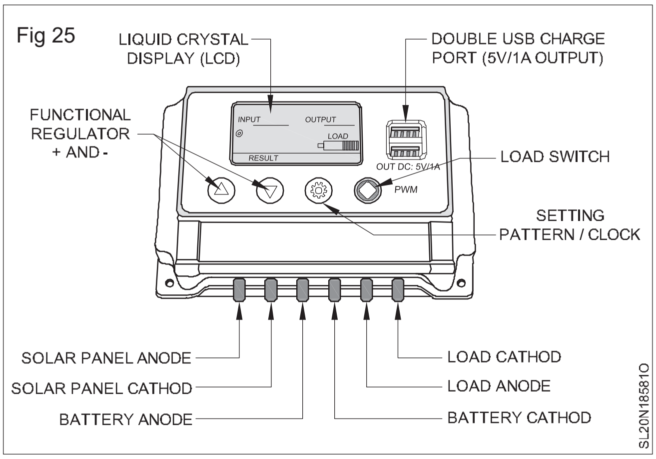
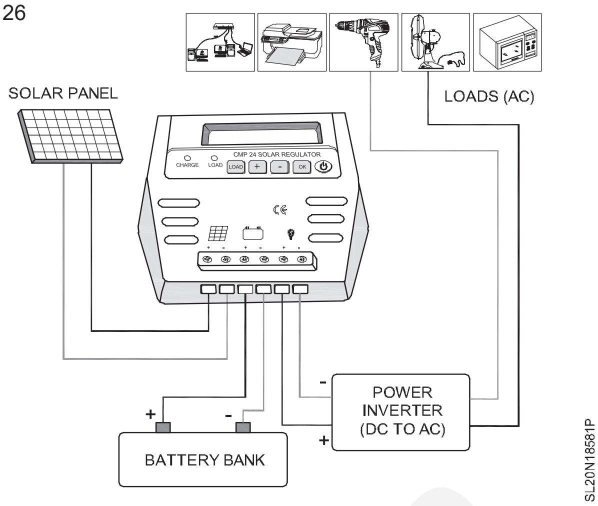


Fig 26

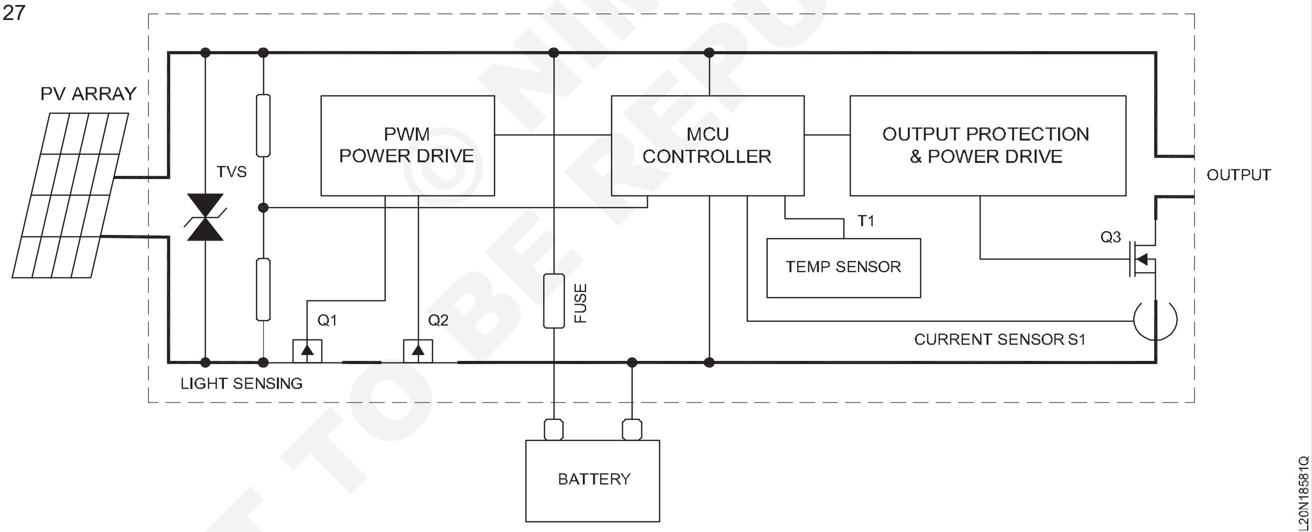


MPPT solar charge controller

The most recent type of solar charge controllers use maximum power point tracking, or MPPT. Thisis an electronic tracking system that continuously compares the battery charge level with the outputof solar panel. It will then adjust the voltage and current to be applied to the battery, conserving thesame power from the solar panel, but charging the battery more efficiently.

Block diagram of a MPPT type charge controller (Fig 27)

Fig 27

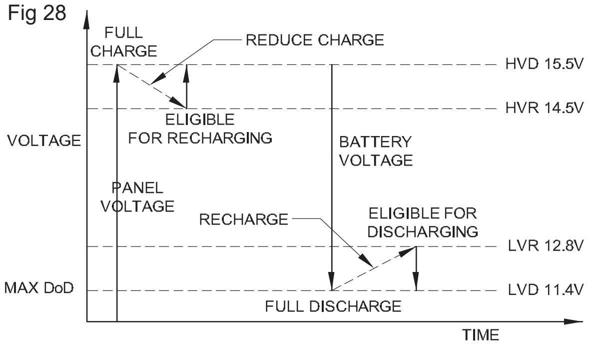


MPPT Solar Charge Controller is a battery charger and load controller for standalone PVsystems. This controller features a smart tracking algorithm that maximizes energyharvest from solar panels.

Maximum power point in a solar panel characteristic (Fig 28)

The controller also prevents over charge or deep discharge. It providesautomatic load control for the external load connected to the controller board. This optimized batterycharging process increases battery life, minimizes battery maintenance, and improves system performance.

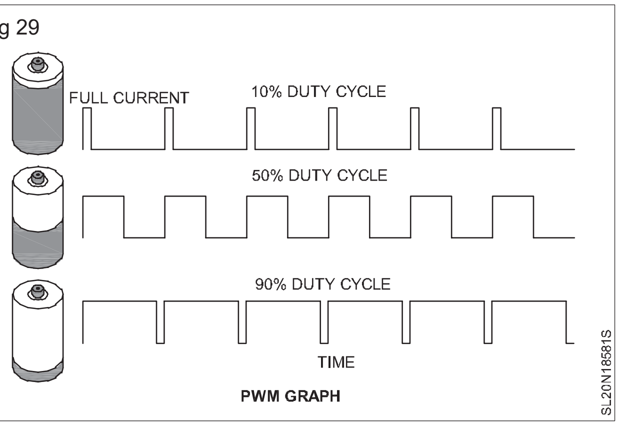
Fig 28



HVD- HIGH VOLTAGE DISCONNECT. PV PANEL IS DISCONNECTED
HVR- HIGH VOLTAGE RECONNECT. PV PANEL IS RECONNECTED FOR CHARGING
LVD- LOW VOLTAGE DISCONNECT. LOAD IS DISCONNECTED
LVR- LOW VOLTAGE RECONNECT. LOAD CAN BE RECONNECTED FOR DISCHARGING

The advantage of MPPT (Fig 29)

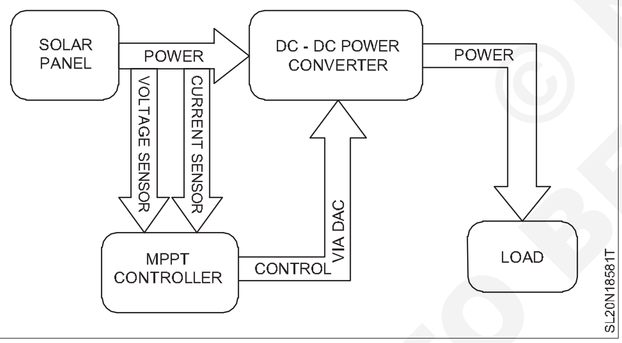
Fig 29



Maximum power point tracking, referred to as MPPT, is an electronic system thatoperates the photovoltaic modules to produce maximum power. MPPT varies the electrical operatingpoint of the modules and enables them to deliver maximum available power. The additional powerharvested increases the current available for battery charging. MPPT can be used in conjunction witha mechanical tracking system, but the two systems are completely different. In comparison to PWM controllers, MPPT charge controllers are more expensive, but theirperformance is significantly enhanced.

PWM charge controller and MPPT charge controller (Fig 30)

Fig 30



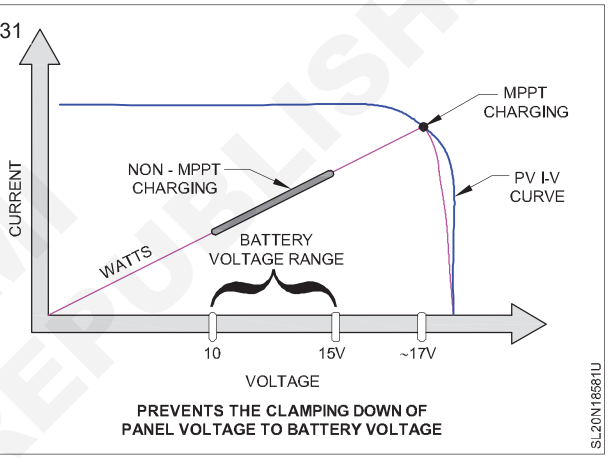
Besides the type, charge controllers are characterized by thecurrent they can control (5, 10, 15, …….. 50 A….) and the voltage under which they can control it,generally 12, 24 or 48 V which is the voltage of the solar module or array. They can be dual voltagewith automatic switch, as 12/24 V.

They also feature the operating temperature and efficiency, almost always above 95%. Most power controllers for 12V applications will control a maximumunder 50A. Generally high power photovoltaic systems are based on higher voltages (24, 48V…..).

Further in modern inverters used in Solar PV electrical system, three levels of charging required by the solar batteries are accomplished by MPPT charge controllers. They are Bulk charging, absorption charging and float charging.

Three stages of charging required for battery by charge controller (Fig 31)

Fig 31



Another way of classification is by the way application i.e., Day lighting with manual control and dusk to dawn with automatic control. Day lighting control is preferred in Solar PV DC electrical system which can be totally independent of AC mains supply.

The dusk to dawn is used by the street light that requires automatic turn ON at subset.

Power **Related Theory For Exercise 1.6.68-82**

Solar Technician (Electrical) - Characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers and DC appliances of Solar PV

Solar batteries

Objectives: At the end of this lesson you shall be able to

- **Explain the specification details of the various component of PV system**
- **State the connection and operation of the solar PV system.**

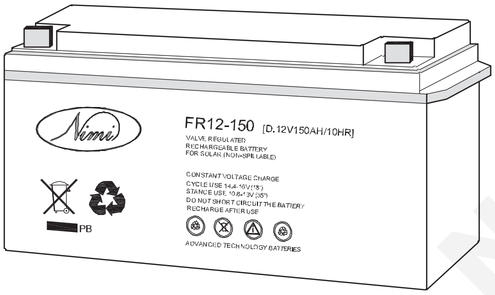
Solar batteries

Various types of Batteries- Lead acid battery, nickel cadmium battery, lithium ion battery are discussed here. Their construction, working, handling, selection, installation and maintenance are also elaborately discussed here. The tools and equipment required for use with solar batteries are dealt in the end.

Solar Batteries (Fig 1)

1 **Maintenance free Solar Battery (High Efficient Deep Discharge)**

Fig 1



2 **Maintenance battery (With and Without Level indicator)**

Fig 2

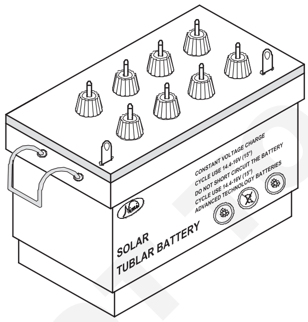
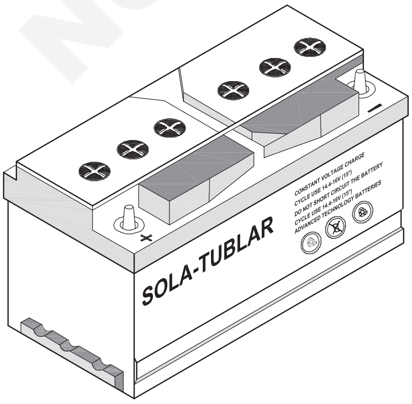


Fig 3



A battery is an electrochemical cell which stores energy in chemical bonds. Chemical energy is converted to electrical energy when a battery is connected to a load.

Battery Functions in PV systems are to Store energy produced by the PV array and supply it to electrical loads as needed, to power electrical loads at stable voltages, suppressing transients, to supply surge currents to electrical loads or appliances.

Battery Classifications and Types

Primary Battery: Can store and deliver energy, but cannot be recharged. Primary batteries are not used in PV systems.

Batteries (Fig 4)

Fig 4

Secondary Battery: Can store and deliver electrical energy, and can also be recharged.

Another way of classifying batteries is Starting, Lighting and Ignition (SLI) Batteries. They are:

- Designed for shallow cycle service, damaged by deep discharges.
- Designed for automobile starting.
- Large number of thin plates per cell, provide high discharge currents for short periods, but lack the mechanical strength to sustain deep discharges.
- **NOT SUITABLE FOR PV SYSTEMS**

Finally Motive Power or Traction Batteries are:

- Designed for deep discharge cycle service, typically used in electric vehicles and equipment
- Fewer number of thicker plates than SLI batteries
- Thick lead-antimony grids provide good deep cycle high temperature performance, but are not well suited for high discharge rates.

Battery Operation includes:

Discharge: The process when a battery delivers current, quantified by the discharge current or rate.

Charge: The process when a battery receives or accepts current, quantified by the charge current or rate.

Specification of a solar battery: mainly Voltage rating and AHr.

Ampere-Hour (Ah)

- Common measure of a battery's electrical storage capacity.
- An Ampere-hour is equal to the transfer of one amp over one hour
- A battery which discharges 5 amps for 20 hours delivers 100 ampere-hours
- A measure of a battery's ability to store and deliver electrical energy.
- Commonly expressed in ampere-hours at a specified temperature,discharge rate and cut-off voltage.

Battery Load Testing

- Battery load testing applies very high discharge rates for a few seconds, while measuring the decrease in battery voltage.
- Weak or failed cells are indicated by significantly greater voltage drop.
- Battery capacity testing involves discharging the battery at nominal discharge rates to a prescribed depth-of-discharge.
- Evaluates available energy storage capacity for the system.

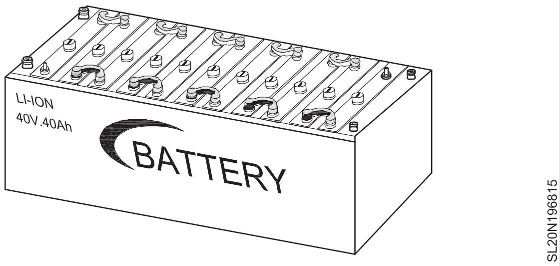
Battery Test Equipment

- DC voltmeters are used to measure battery and cell voltages.
- DC ammeters (clamp-on type) are used to measure battery currents.
- Hydrometers are used to measure electrolyte specific gravity.
- Load testers discharge the battery at high rates for short periods while the voltage drop is recorded.
- Impedance and conductance testers may be used on some VRLA batteries
- Periodic battery maintenance should include checks of all terminals for corrosion and proper torque

Lithium Battery (Fig 5)

Li-ion batteries are almost everywhere. They are used in applications from mobile phones and laptops to hybrid and electric vehicles. Lithium-ion batteries are also increasingly popular in large-scale applications like Uninterruptible Power Supplies (UPSs) and stationary Battery Energy Storage Systems (BESSs).

Fig 5



Lithium-ion batteries conform to this generic battery definition. Other examples include lead-acid and nickel cadmium (Ni-Cad).

Working of a lithium-ion battery:

Most Li-ion batteries share a similar design consisting of a metal oxide positive electrode (cathode) coated onto an aluminum current collector, a negative electrode (anode) made from carbon/graphite coated on a copper current collector, a separator and electrolyte made of lithium salt in an organic solvent.

While the battery is discharging and providing an electric current, the electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator. The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector. The electrical current then flows from the current collector through a device being powered (cell phone, computer, etc.) to the negative current collector. The separator blocks the flow of electrons inside the battery.

During charging, an external electrical power source (the charging circuit) applies an over-voltage (a higher voltage than the battery produces, of the same polarity), forcing a charging current to flow within the battery from the positive to the negative electrode, i.e. in the reverse direction of a discharge current under normal conditions. The lithium ions then migrate from the positive to the negative electrode, where they become embedded in the porous electrode material in a process known as intercalation.

Primary batteries, or cells, are not rechargeable, and must be discarded once their charge is exhausted. By contrast, secondary types can be recharged using an external electric charger.

Today, most attention is given to secondary types, particularly Li-ion batteries, because of their widespread application in cell phones and electric vehicles. However, primaries still play an important role, especially when charging is impractical or impossible, such as in military combat, rescue missions and forest-fire services.

Regulated under IEC 60086, primary batteries are also used for pacemakers in heart patients, tire pressure gauges in vehicles, smart meters, intelligent drill bits in mining, animal-tracking, remote light beacons, as well as wristwatches, remote controls, electric keys and children's toys.

Alkaline is the most popular primary battery chemistry, while lithium-metal is used for heavier loads.The three most common form factors are prismatic (rectangular), pouch, and cylindrical.

However, one battery cell is not always enough to power a practical load. Instead, battery cells are connected in series and parallel, into a so-called battery pack, to achieve the desired voltage and energy capacity. An electric car for example requires 400-800 V while one single battery cell typically supplies 3-4 V.

A battery pack is a complete enclosure that delivers power to a final product, such as an electric car. The pack contains battery cells, software (battery management system) and often a cooling and heating system, depending on where and how the battery pack is to be used. In large battery packs, the battery cells are arranged in modules to achieve serviceable units.

Lithium-ion battery applications

Lithium-ion batteries are popular because of their high energy density and other properties – and as the technology improves and prices reduce, they are proliferating in many applications. Here are some examples for Li-ion battery applications:

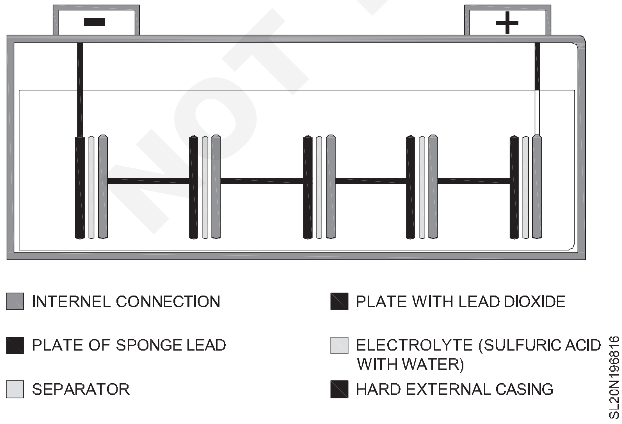
- Portable power packs
- Uninterruptible Power Supplies (UPSs)
- Electric vehicles
- Marine vehicles
- Personal mobility
- Renewable energy storage

Construction of Lead Acid Battery

Lead is a chemical element (symbol is Pb and the atomic number is 82). It is a soft and malleable element. We know what Acid is; it can donate a proton or accept an electron pair when it is reacting. So, a battery, which consists of Lead and anhydrous plumbic acid (sometimes wrongly called as lead peroxide), is called as Lead Acid Battery.

Lead acid battery - construction (Fig 6)

Fig 6



A Lead Acid Battery consists of Plates, Separator, and Electrolyte, Hard Plastic with a hard rubber case.

In the batteries, the plates are of two types, positive and negative. The positive one consists of Lead dioxide and negative one consists of Sponge Lead. These two plates are separated using a separator which is an insulating material.This total construction is kept in a hard plastic case with an electrolyte. The electrolyte is water and sulfuric acid.

The hard plastic case is one cell. A single cell store typically 2.1V. Due to this reason, A 12V lead acid battery consists of 6 cells and provide 6 x 2.1V/Cell = 12.6V typically.

Charge storage capacity

It is highly dependable on the active material (Electrolyte quantity) and the plate's size. You may have seen that lithium battery storage capacity is described in mAh or milliamp-hour rating, but in the case of Lead Acid battery, it is Amp hour. We will describe this in later section.

Working of the Lead Acid battery

This is all about chemistry and it is very interesting to know about it. There are huge chemical process is involved in Lead Acid battery's charging and discharging condition.

The diluted sulfuric acid H2SO4 molecules break into two parts when the acid dissolves. It will create positive ions 2H+ and negative ions SO4-. The two electrodes are connected as plates, Anode and Cathode. Anode catches the negative ions and cathode attracts the positive ions. This bonding in Anode and SO4- and Cathode with 2H+ interchange electrons and which is further react with the H2O or with the water (Diluted sulfuric acid, Sulfuric Acid + Water).

The battery has two states of chemical reaction, Charging and Discharging.

Lead Acid Battery Charging

To charge a battery, we need to provide a voltage greater than the terminal voltage. So to charge a 12.6V battery, 13V can be applied.

When we charge a Lead Acid Battery, the same chemical reactions happens which were described before. Specifically, when the battery is connected with the charger, the sulfuric acid molecules break into two ions, positive ions 2H+ and negative ions SO4-. The hydrogen exchange electrons with the cathode and become hydrogen, this hydrogen reacts with the PbSO4 in cathode and form Sulfuric Acid (H2SO4) and Lead (Pb). On the other hand, SO4- exchange electrons with anode and become radical SO4. This SO4 reacts with PbSO4 of anode and create the lead peroxide PbO2 and sulfuric acid (H2SO4). The energy gets stored by increasing the gravity of sulfuric acid and increasing the cell potential voltage.

As explained above, following chemical reactions takes place at Anode and Cathode during the charging process.

At cathode

$PbSO_4 + 2e^- => Pb + SO_4^{2-}$

At anode

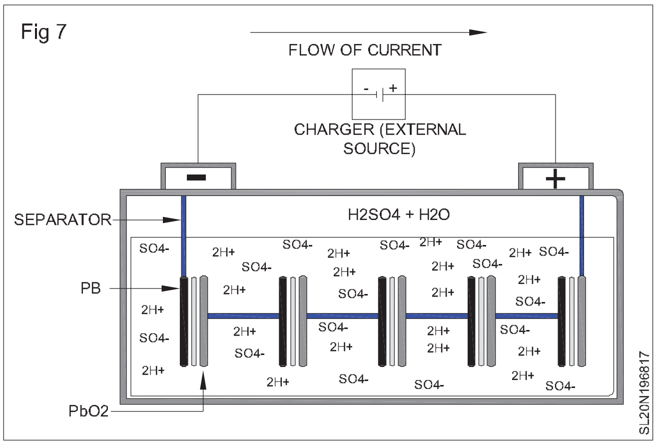
$PbSO_4 + 2H_2O => PbO_2 + SO_4^{2-} + 4H^- + 2e^-$

Combining above two equations, the overall chemical reaction will be

$2PbSO_4 + 2H2O \Rightarrow PbO_2 + Pb + 2H_2SO_4$

Charging of Lead acid battery (Fig 7)

Fig 7



There are various methods applicable for charging the lead-acid battery. Each method can be used for specific lead-acid battery for specific applications. Some application uses constant voltage charging method, some application uses a constant current method, whereas tickle charging also useful in some cases. Normally battery manufacturer provides the proper method of charging the specific lead-acid batteries. Constant current charging is not typically used in Lead Acid Battery charging.

Most common charging method used in lead acid battery is constant voltage charging method which is an effective process in terms of charging time. In full charge cycle the charge voltage remains constant and the current gradually decreased with the increase of battery charge level.

Lead Acid Battery Discharging: (Also, Procedure for capacity testing)

Discharging of a lead acid battery is again involved with chemical reactions. The sulfuric acid is in the diluted form with typically 3:1 ratio with water and sulfuric acid. When the loads are connected across the plates, the sulfuric acid again breaks into positive ions 2H+ and negative ions SO4. The hydrogen ions react with the PbO2 and make PbO and water H2O. PbO start reacting with the H2SO4 and creates PbSO4 and H2O.

On the other side SO4- ions exchange electrons from Pb, creating radical SO4 which further creates PbSO4 reacting with the Pb.

As explained above, following chemical reactions takes place at Anode and Cathode during the discharging process. These reaction are exactly opposite of charging reactions:

At cathode

$Pb + SO_4^{2-} \Rightarrow PbSO_4 + 2e^-$

At anode

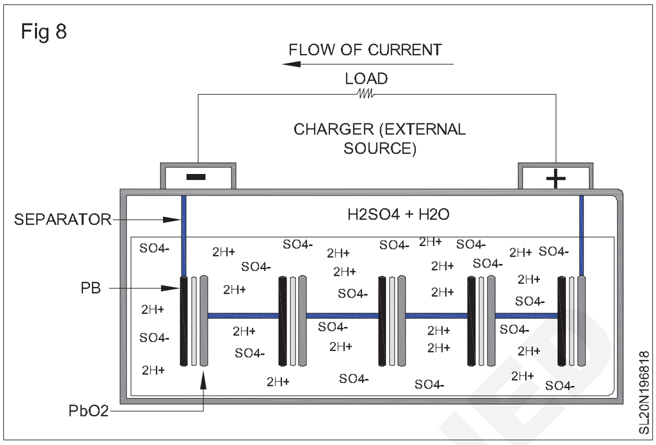
$PbO_2 + SO_4^{2-} + 4H^- + 2e^- \Rightarrow PbSO_4 + 2H_2O$

Combining above two equation, the overall chemical reaction will be

$PbO_2 + Pb + 2H_2SO_4 \Rightarrow 2PbSO_4 + 2H_2O$

Discharge action ina Lead Acid battery (Fig 8)

Fig 8



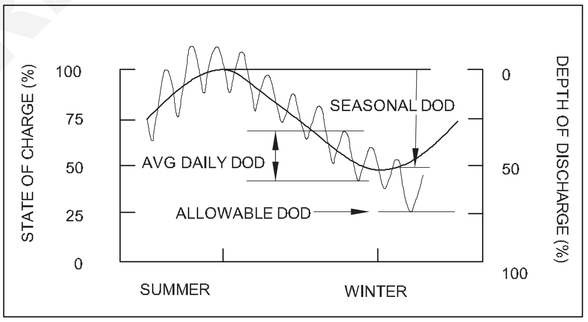
Due to the electron exchange across anode and cathode, electron balance across the plates is affected. The electrons then flow through the load and the battery gets discharged.

During this discharge, the diluted sulfuric acid gravity decrease. Also, at the same time, the potential difference of the cell decrease.

State of Charge Versus Depth of Discharge:

SOC, DOC during summer and winter (Fig 9)

Fig 9



Factors Affecting Battery LifetimeareBattery design, construction and materials, Temperature, Frequency and depth of discharges and average state of charge.

Battery lifetime is expressed in terms of cycles to a specific depth of discharge (cutoff voltage and discharge rate). Battery life can be extended if the battery is kept at high state-of-charge, not over discharged, or operated at excessive temperatures (over 35 C). Properly maintaining battery state-of-charge is key to maximizing battery life.

Ventilation requirements and Effects of Temperature

For vented batteries, a 10 C increase in average operating temperature above 25 C reduces battery life by 50 %. This is worse for VRLA batteries.Higher temperatures accelerate corrosion of the grids and result in greater gassing and electrolyte loss. This cannot be tolerated for VRLA batteries.Lower temperatures reduce battery capacity and increase cycle life.

Battery System Design Considerations are PV system design and autonomy requirements, Ambient and environmental conditions, Capacity and series-parallel arrangement, Installation, maintenance and structural requirements, Overcurrent protection, disconnects and wiring, Safety and auxiliary systems and Cost and warranty.

Days of Autonomy are the number of days a fully charged battery can supply energy to the system loads when there is not energy input from the PV array.

Energy and Cost

Remember: Power = Voltage x Current or P = V x I

Energy = Power x Time = V x I x Time

Therefore,

Energy in a battery = Voltage x Current x Time

= Voltage x Amp-hours = V x Ah

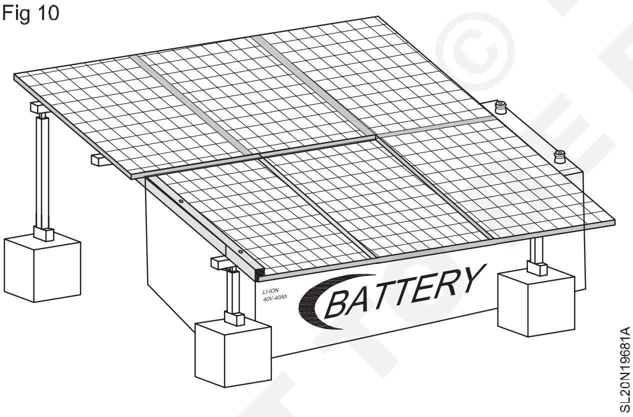
Example: 12 volt battery, 100 Ah

Energy = 12V x 100Ah = 1,200 W-hr

Battery EnclosuresMust be in a vented place and vented box

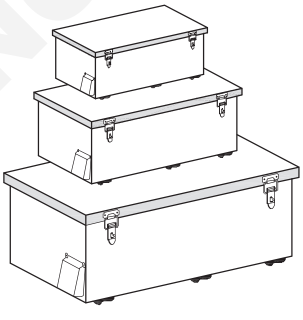
Battery housing under panels (Fig 10)

Fig 10



Battery Enclosures (Fig 11)

Fig 11



Battery enclosures (Fig 12)

Battery rack (Fig 13)

Fig 12

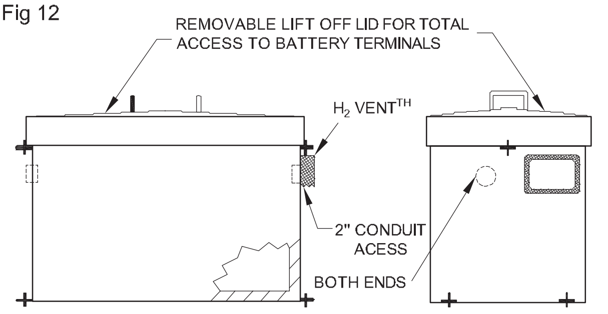
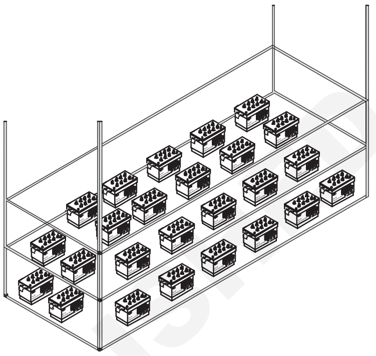


Fig 13



Deep discharge and shallow cycle

A battery's cycle is known as a discharge and a recharge cycle. A shallow cycle battery is meant to give relatively quick bursts of energy and not be used for a very long time before it's returned to a fully charged state. A deep cycle battery is meant to provide extended usage of the battery going well below 50% discharge before it is recharged.

This depends on different uses of a battery, which is very important to think about before selecting the type of battery to buy for specific system.

Shallow cycle battery

This is a car battery. This is a battery that doesn't run all day long, it's a short burst of electricity that is requires the turn the ignition and to give the car a big boost to start. Once your car is running, the usage of your car battery goes down to nearly zero.

Shallow Cycle batteries do not like to be discharged over long periods of time. To extend the life of it, it requirestohave a discharge control circuit that will cut off usage of the battery after it has been depleted by about 50%, and recharged as soon as possible.

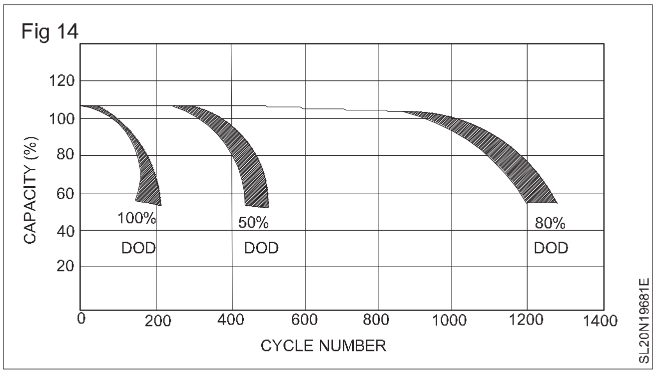
The less the discharge of shallow cycle battery (Depth of Discharge – DOD – is less), the more cycles it can be used.

Depth of Discharge lifetime for a shallow cycle battery graph (Fig 14)

Deep cycle battery

This is a battery that runs all day long, every day, similar to the one used in inverter. There is no big burst of energy required to start an engine or fire a rocket off, it's just a continual drain, depending on how many loads are connected.

Fig 14



Contrary to the shallow cycle battery, the deep cycle batteries can go beyond 50% discharge all the way up to 80% discharge before its usage should be cut off by the control circuit and recharged.

If shallow cycle battery is discharged to 50% and recharged from there, it is most likely to get around 500 cycles from that battery.

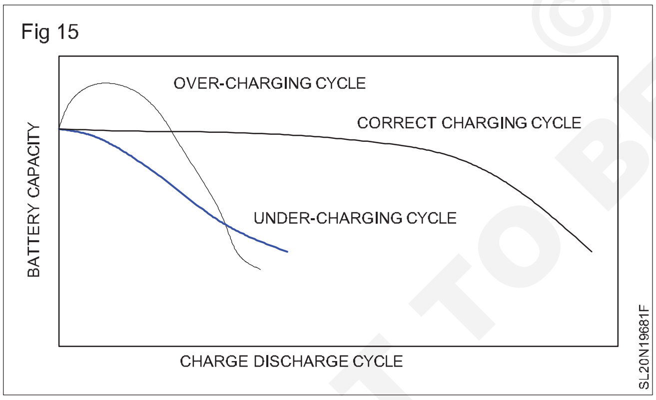
However, a deep-cycle lead acid battery should be able to maintain a cycle life of more than 1,000 even at DOD over 50%.

Charging also effects the cycle of a battery

Hence, to maintain the health of the deep cycle or the shallow cycle battery, it's very important to have a smart charge/discharge monitor. Not having one will result in either overcharging or undercharging with most definitely results in drastic loss of capacity of the battery, as shown by the graph below.

Battery Capacity defined by Charging cycle (Fig 15)

Fig 15



Temperature is another very big factor effects the life cycle of a battery. The colder the battery is, the less capacity it has to deliver to. As the battery gets colder it will be as if it can no longer maintain full capacity in spite of charging it for very long periods of time, and maintaining the same usage it will be depleted much quicker.

The higher the temperature of the battery, the quicker it ages, so the number of cycles you get out of your battery will rapidly diminish.

Safety aspects in handling batteries: Battery Safety

- Battery acid requires protection of eyes, skin and clothing
- Size and weight of batteries often dictate using special lifting devices
- High short-circuit current potential requires using insulated tools.
- No steel case batteries over 48 volts.

Maintenance of battery

Battery maintenance involves various tasks depending on the type of battery and manufacturer requirements, including:

- Inspecting and cleaning battery racks, cases trays and terminations
- Inspecting battery disconnects, overcurrent devices and wiring systems
- Checking termination torques
- Measuring voltage and specific gravity
- Adding water
- Inspecting auxiliary systems
- Load and capacity testing

Lead-acid battery maintenance rules

1 Watering is the most neglected maintenance feature of flooded lead-acid batteries. As overcharging decreases water, we need to check it frequently. Less water creates oxidation in plates and decreases the lifespan of the battery. Add distilled or ionized water when needed.

2 Check for the vents, they need to be perfected with rubber caps, often the rubber caps sticks with the holes too tightly.

3 Recharge lead-acid batteries after each use. A long period without recharging provides sulfating in the plates.

4 Do not freeze the battery or charge it more than 49-degree centigrade. In cold ambient batteries need to be fully charged as fully charge batteries safer than the empty batteries in respect of freezing.

5 Do not deep discharge the battery less than 1.7V per cell.

6 To store a lead acid battery, it needs to be completely charged then the electrolyte needs to be drained. Then the battery will become dry and can be stored for a long time period.

Requirement of connecting only similar batteries

Batteries achieve the desired operating voltage by connecting several cells in series; each cell adds its voltage potential to derive at the total terminal voltage. Parallel connection attains higher capacity by adding up the total ampere-hour (Ah).

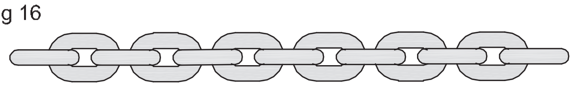
Most battery chemistries lend themselves to series and parallel connection. It is important to use the same battery type with equal voltage and capacity (Ah) and never to mix different makes and sizes.

A weaker cell would cause an imbalance. This is especially critical in a series configuration because a battery is only as strong as the weakest link in the chain.

An analogy is a chain in which the links represent the cells of a battery connected in series (Figure 57).

Figure 16 : Comparing a battery with a chain.

Fig 16



Chain links represent cells in series to increase voltage, doubling a link denotes parallel connection to boost current loading.

A weak cell may not fail immediately but will get exhausted more quickly than the strong ones when on a load. On charge, the low cell fills up before the strong ones because there is less to fill and it remains in over-charge longer than the others. On discharge, the weak cell empties first and gets hammered by the stronger brothers. Cells in multi-packs must be matched, especially when used under heavy loads.

High-voltage batteries require careful cell matching, especially when drawing heavy loads or when operating at cold temperatures. With multiple cells connected in a string, the possibility of one cell failing is real and this would cause a failure. To prevent this from happening, a solid state switch in some large packs bypasses the failing cell to allow continued current flow, albeit at a lower string voltage.

Cell matching is a challenge when replacing a faulty cell in an aging pack. A new cell has a higher capacity than the others, causing an imbalance. Welded construction adds to the complexity of the repair, and this is why battery packs are commonly replaced as a unit.

High-voltage batteries in electric vehicles, in which a full replacement would be prohibitive, divide the pack into modules, each consisting of a specific number of cells. If one cell fails, only the affected module is replaced. A slight imbalance might occur if the new module is fitted with new cells.

1 Faulty cell in a group of 4 in series lowers the voltage and cuts the equipment off prematurely.

Disposal procedure of batteries and Recycling

- Hazardous items that require proper disposal and recycling
- All battery components are recyclable; but for solar PV electrical system perform better with First hand Batteries. Recycled batteries not suitable for heavy loads and long backup.

Lithium-ion battery recycling:

- As electric vehicles become more popular, the demand for Li-ion battery recycling will grow significantly over the coming decades.
- There is some lag to this, as EV batteries have to work through their life of, say, eight years before they become fit for recycling. Additionally, many of these batteries will find further years' work in a 'second life'; although no longer suitable for their vehicle application, they can successfully be used in stationary energy storage systems for grid balancing etc.

Common defects in batteries

Non-manufacturing Defects:

- Physical Damage

If the battery is stored, handled or fitted incorrectly, if the connectors leads are hammered onto terminals, leads are not correctly fastened, the battery will have damage to casing and/or terminals.

- Sulphation

If a battery is allowed to stand in a discharged state either on or off a vehicle for a period of time, a chemical reaction takes place which will permanently impair the performance and life of the battery, this process is called "sulphation".

Sulphation can be seen as a fine white/grey coating on the positive plate and a non metallic luster on the negative plate. In most cases this signifies the battery as not serviceable. Attempts to recharge batteries left in a discharged state, even at very low charge rates will lead to damage to the grid and active material interfaces and also sulphate deposits can be formed within the separators which produce dendritic shorts.

The damage can occur in storage or if the battery is installed on the vehicle (or equipment) that is not used for a period of time, for example tractor, motorcycle, boat, airport vehicle even a car or truck that is stored with the battery connected can still damage the battery. This is because there is a permanent drain on the battery from items such as the alarm, clock, lights, etc left on which drag the battery down to its lowest possible state of charge. The longer the period left, the greater the sulphation builds up on the plates.

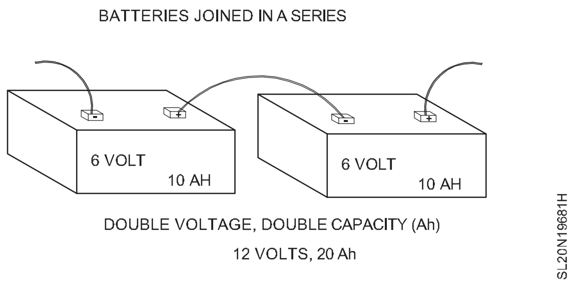
Battery bank: Series and parallel connections.

A battery bank is the result of joining two or more batteries together for a single application. By connecting batteries, we can increase the voltage, amperage, or both.There are two primary ways to successfully connect two or more batteries. The first is via a series and the second is called parallel.

Connecting batteries in series adds the voltage of the two batteries, but it keeps the same amperage rating (also known as Amp Hours). For example, two 6-volt batteries joined in series produce 12 volts, but they still have a total capacity of 10 amps.

Batteries in series (Fig 17)

Fig 17



Batteries in parallel (Fig 18)

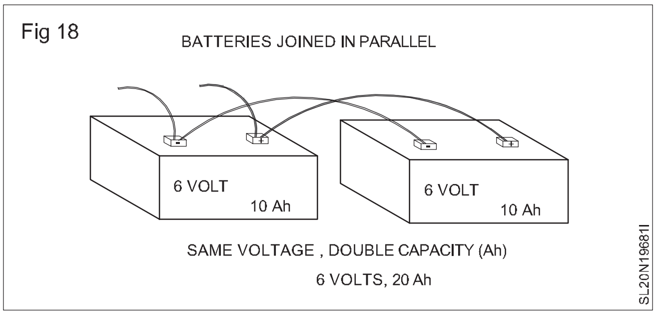


Fig 18

To connect batteries in a series, use jumper wire to connect the negative terminal of the first battery to the positive terminal of the second battery. Use another set of cables to connect the open positive and negative terminals to your application.

> **Important: When connecting batteries: Never cross the remaining open positive and open negative terminals with each other, as this will short circuit the batteries and cause damage or injury. (Most people try to do this even if they are not anyway related in this work!)**

Be sure the batteries you're connecting have the same voltage and capacity rating. Otherwise, you may end up with charging problems, and shortened battery life.

In a series connection, batteries of like voltage and amp-hour capacity are connected to increase the voltage of the overall assembly. The positive terminal of the first battery is connected to the negative terminal of the second battery and so on, until the desired voltage is reached. The final voltage is the sum of all battery voltages added together while the final amp-hours remain unchanged.

Parallel connections will increase your current rating, but the voltage will stay the same. In the "Parallel" diagram, with the above batteries, we're back to 6 volts, but the amps increase to 20AH. It's important to note that because the amperage of the batteries increased, you may need a heavier-duty cable to keep the cables from burning out.

To join batteries in parallel, use a jumper wire to connect both the positive terminals, and another jumper wire to connect both the negative terminals of both batteries to each other. Negative to negative and positive to positive; You CAN connect your load to ONE of the batteries, and it will drain both equally. However, the preferred method for keeping the batteries equalized is to connect to the positive at one end of the battery pack, and the negative at the other end of the pack.

In a parallel connection, batteries of like voltages and capacities are connected to increase the capacity of the overall assembly. The positive terminals of all batteries are connected together, or to a common conductor, and all negative terminals are connected in the same manner. The final voltage remains unchanged while the capacity of the assembly is the sum of the capacities of the individual batteries of this connection.

It is also possible to connect batteries in series and parallel configuration. This may sound confusing, but we will explain below. This is the way you can increase your voltage output and Amp/Hour rating. To do this successfully, you need at least 4 batteries. In the figure six batteries of same specifications are in series – parallel connection. Each series path have two batteries and total three parallel paths are shown. The output will be 2 X V, 3 X AHr, if each battery is rated V, AHr.

Batteries in series – parallel connection (Fig 19)

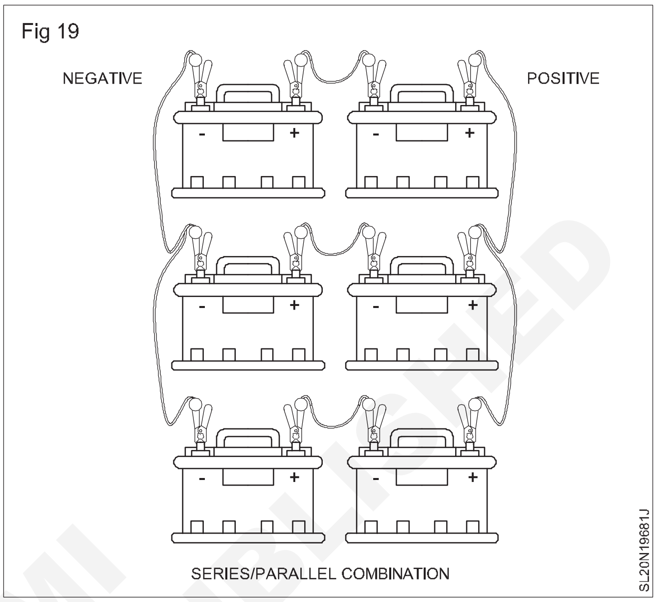


Fig 19

Use of Hydrometer

Hydrometer is an instrument used for determining the density of a liquid. It usually consists of a glass float with a long thin stem which is graduated. The glass float is a large hollow bulb which increases the buoyancy so that the hydrometer floats.

The narrow stem increases the sensitivity of the hydrometer.The bottom of the hydrometer is made heavier by loading it with lead shots so that it floats vertically.

Hydrometer (Fig 20)

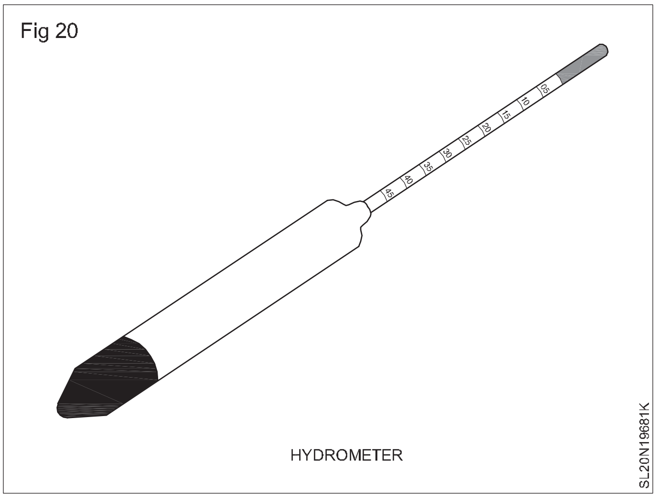


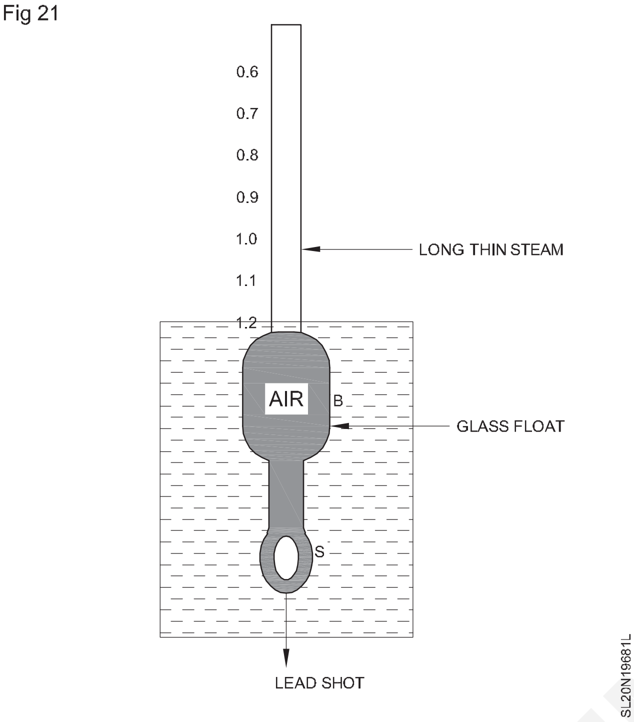
Fig 20

A hydrometer is used to measure the concentration of sulphuric acid (Specific Gravity) of battery electrolyte ("battery acid").We can easily and accurately determine a non-sealed battery's State-of-Charge.It sinks less in a denser liquid and more in a lighter liquid.

The lowest density is marked on the top of the stem of a hydrometer and the maximum density is marked at the bottom of the graduated stem.

Hydrometer showing graduations and contents (Fig 21)

Fig 21



A battery hydrometer is shown in figure 74. It is used for measuring the relative density of accumulator acid. It is kept inside a glass tube fitted with a rubber bulb at the upper end. The lower end of the glass tube is connected with a narrow tube which is made of acid resistant material. When in use, this end is submerged in the acid in the accumulator.

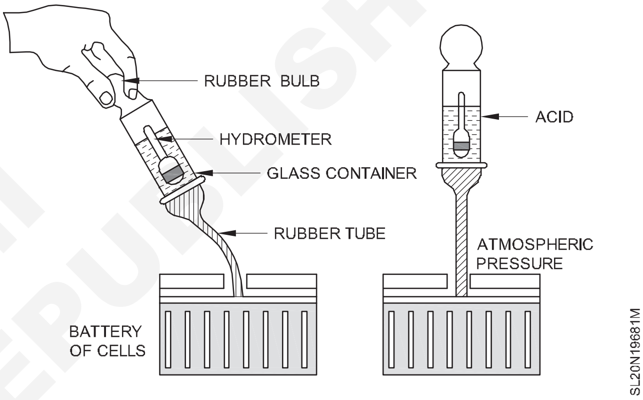
When the rubber bulb is squeezed, the air escapes from the narrow tube at the other end of the glass tube. When the pressure is removed there is a partial vacuum in the glass tube. Since, the atmospheric pressure outside is greater, it pushes acid up into the glass tube. Now the hydrometer floats in the acid.

The density of the acid can then be read on the floating hydrometer. The acid in a fully charged cell should have a relative density of 1.25 to 1.30. A reading of less than 1.18 indicates that recharging is necessary.

The following is a list of instructions on how to correctly use a battery hydrometer:

Battery Hydrometer

Fig 22



Power Related Theory For Exercise 1.6.83
Solar Technician (Electrical) - Characteristics of Photovoltaic cells, Modules, Batteries and Charge controllers and DC appliances of Solar PV

Solar DC appliances

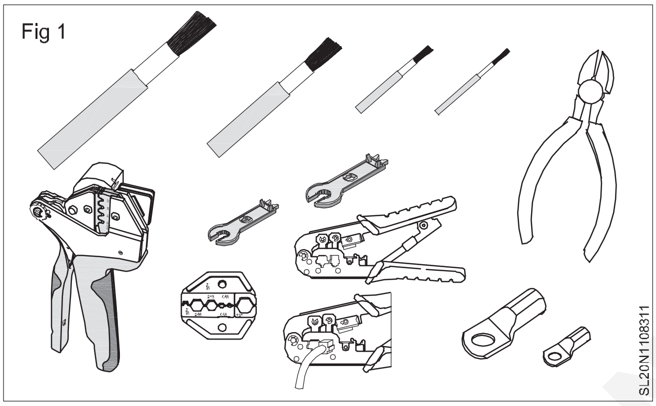
Objectives: At the end of this lesson you shall be able to
- **identify the various tools and instruments used in Sola Power plants**
- **explain the operation of various Solar DC appliances.**

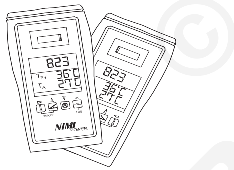
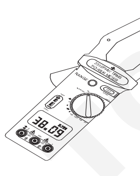
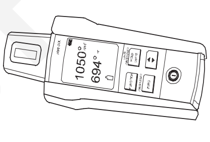
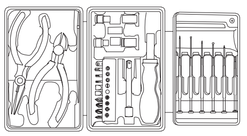
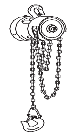
Selection and usage of Tool kit

The solar technician shall be able toidentify the tools and components required in solar power plant, select tools for various activities in plantand practice the usage of tools for various activities in plant

Set of tools and accessories (Fig 1)

Fig 1



Solar Survey 100 Irradiance Meter	
Solar Power Analyzer Clamp	
Solar Installation Tester	
Crimp Set	
1 Ton Chain Hoist Accessory	

Tools and types

The technician shall be able to identify the different type tools required in solar PV plants, identify various categories of tools based nature of work and select a tool for a given work.

Commonly used tools and few special tools are required for solar PV installation. The helper should be able identify first and then practice thoroughly before put in use in field. Engaging Solar PV helper directly in field thinking on job training would pose lot of difficulties for him as well as brings more loss of materials and tool damage. Even helper getting injured to any extent or sometimes proving fatal are the worst possibilities if the Integrator team desires to engage the helper directly on job. Based on site assessment, installation and maintenance the tools requirement differs.

Site Assessment Tools are mostly the special tools such as 50-100 ft. Tape measure, Solar Pathfinder (evaluates the solar energy potential at a site), Compass (not needed if you're using a Solar Pathfinder), Maps (reference for location latitude and magnetic declination), clinometers, spirit level and Digital camera.

At present if you have an android mobile of even lower specification it will be useful since the apps for Compass, Map, camera, Clinometers (angle meter) and spirit level can be installed and used effectively. Some apps even make it possible for measuring distances or length in the field. Except Map other apps are offline functional.

List of Installation tools: (Essential)

1 Angle finder
2 Torpedo level
3 Fish tape
4 Chalk line
5 Cordless drill (14.4V or greater), multiple batteries
6 Unibit and multiple drill bits (wood, metal, masonry)
7 Hole saw
8 Hole punch
9 Torque wrench with deep sockets
10 Nut drivers (most common PV sizes are 7/16", ½", 9/16")
11 Wire strippers

12 Crimpers

13 Needle-nose pliers

14 Lineman’s pliers

15 Slip-joint pliers

16 Small cable cutters

17 Large cable cutters

18 AC/DC multimeter

19 Hacksaw

20 Tape measure

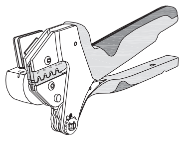
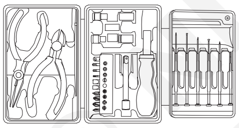
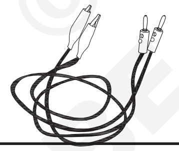
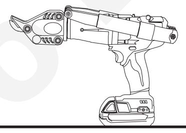
21 Blanket, cardboard or black plastic to keep modules from going “live” during installation

22 Heavy duty extension cords

23 Caulking gun

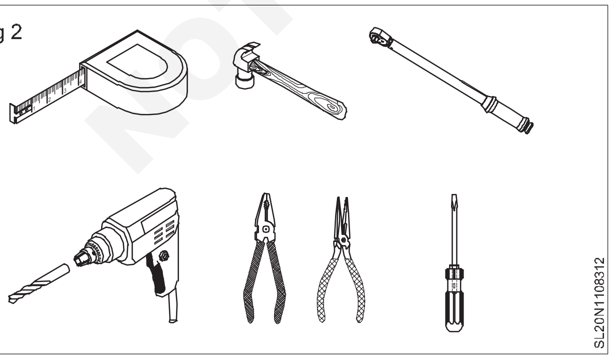
24 Fuse Pullers

Installation tools

Multi functional tool /Crimping pliers	
Tool kit	
Accessories	
Turbo Shear Drill Accessory	

Tool kit (Fig 2)

Fig 2



List of Installation tools: (optional)

1 DC clamp-on ammeter

2 Reciprocating saw / Jig saw

3 Right angle drill

4 Conduit bender

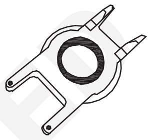
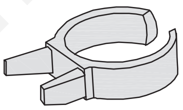
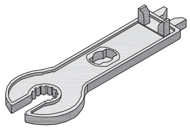
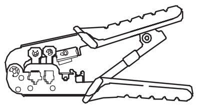
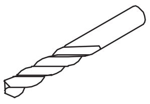
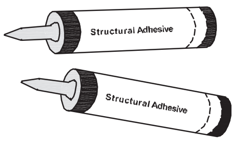
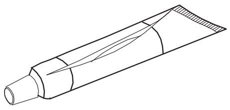
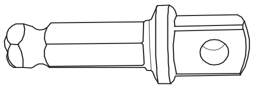
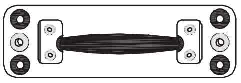
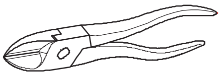
5 Large crimpers

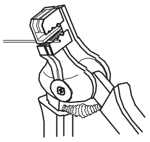
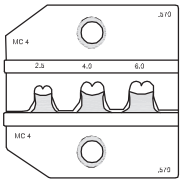
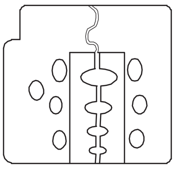
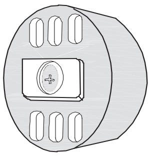
6 Magnetic wristband for holding bits and parts

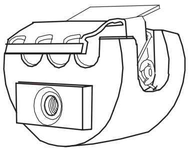
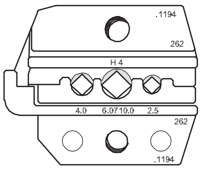
7 C-clamps

8 Stud finder

Different tools essential for Solar PV project helper

Universal unlocking tool	
Unlocking Ring Tool	
wrench assembly tool	
Crimping tool	
Speed Drill Bit	
Structural Adhesive	
Translucent Sealant	
Socket Adapter	
Drill Guide Base	
14/12/10 AWG Wire Cutter	

14/12/10 AWG Wire Stripper	
MC4 Crimp Die Set	
Stripper Replacement Blade	
Locator	

MC4 Die Locator	
Crimp Die Set	

Solar PV Electrical system

Based on our requirement we may plan the solar electrical systems for

- different load conditions
- different applications
- AC /DC voltage types
- on grid or off grid types
- hybrid types

The following table shows the various types of systems,

Sl no	Type of system	Load condition	Major components of system
1	Off-Grid/ Stand-alone	DC loads only	Solar array, DC disconnects, alarm circuit, protective circuits
2	Off-Grid	DC loads only + batteries	Solar array, DC disconnects, charge controller, battery bank, alarm circuit, protective circuits. (no inverter)
3	Off-Grid	DC & AC loads	Solar array, DC disconnects, charge controller, battery bank, alarm circuit, protective circuits, inverter, ac disconnects
4	Off-Grid Hybrid	DC & AC loads	supplemental power system (wind turbine, generator), Solar array, DC disconnects, charge controller, battery bank, , alarm circuit, protective circuits, inverter, ac disconnects
5	On-Grid	AC loads only	Solar array, DC disconnects, charge controller, alarm circuit, protective circuits, inverter, ac disconnects (no battery bank)
6	Grid-Connected	AC loads only	Solar array, DC disconnects, charge controller, battery bank, alarm circuit, protective circuits, inverter, ac disconnects + separate distribution panel for critical loads
7	Grid-Connected	DC & AC loads	Solar array, DC disconnects, charge controller, battery bank, alarm circuit, protective circuits, inverter, ac disconnects + separate distribution panel for DC/AC and critical loads

their utilities and possible components of systems:

Solar Photovoltaic System designed exclusively for DC loads include mostly domestic products such as Lantern, Home lighting, day lighting, garden lighting, mobile hand set charger etc. They are mainly for self-organized assembly and use.

The other commercial applications in DC sector are Solar DC pumps, Solar Street lights, Solar Water treatment plants, Solar Electric vehicle battery charging stations etc.

The Component List for Battery Backup DC solar Systemincludes PV Modules, Charge Controller,Solar Batteries, Monitoring/Metering circuits,mounting structures, Hardware Wiring, Fuses/Breakers/Disconnect Switch etc.

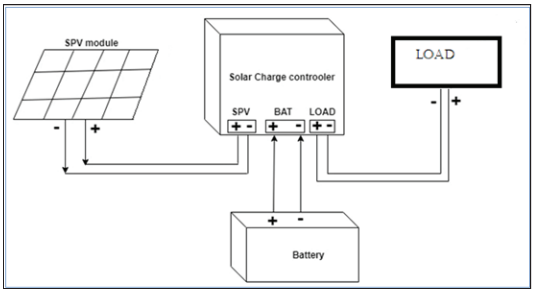
Solar DC domestic application: Making of solar lantern. Solar Day lighting, Solar Garden Lights

All DC products can be thought of made with Solar tag. We need solar panel, charge controller, batteries, control switches (Manual or automatic), wiring, Dc loads (in case of present topic LED lights), lamp housing, cabinets, posts and fittings.

All follow the same block diagram as below:

Block diagram for DC solar product (Fig 3)

Fig 3



Solar Lanterns not only serves general purpose use like study lamp, room light etc, but also in other variants like the solar lamp post lights and hanging solar lights/ lanterns they enhance the solar landscape design of a house or any living space.

Solar lantern and multi utility (Fig 4)

Fig 4

These solar power lights will add a mission theme to the solar garden or enhance the nautical style of the walkways and yards. Most of the solar lamp posts are finished with durable yet stylish materials in a variety of styles and shapes.

All of the post-mounted and hanging solar powered lanterns add a unique, personal touch to any space. Varieties of solar lamp posts and solar hanging lanterns of many brands with single, double and even triple styles are available for the garden, patio or walkway. This has become a way of lifestyle.

Solar powered lights add a lot of features to interior lighting or outdoor landscaping. To get the most out of the solar indoor/outdoor lights, we still need to maintain and use them properly. Outdoor solar landscape light scan last for many years of continuous operation if well cared for. Of course, choosing a high quality brand is also important.

These solar garden lights or solar lanterns work simply by using power from solar panels and one or more rechargeable batteries. Through the PV effect, the solar panels generate electricity from sunlight and thus charge the batteries during the day. When it gets dark, the energy stored in the batteries powers an LED light.

Single Solar Garden lamp (Fig 5)

Fig 5

Safety in DC system.

Two particular characteristics of PV generators are their DC voltage levels and the fact they cannot be shut off as long as PV modules are exposed to the sun. The short-circuit current produced by the PV module is too low to trigger the power supply's automatic disconnect. The most frequently used protective measures do not therefore apply to PV systems. However, as PV modules are installed outdoors they are exposed to the elements. And since they can be installed on roofs, critical attention should be paid to the risk of fire and the protection of fire fighters and emergency services staff.

1) Over current protection

2) Insulation fault detection

3) Grounding

Fig 6

Fig 7

Solar street light

A solar street light is the raised light source from the ground mounted on the pole of metal pipe. The light sources uses Solar Photovoltaic (SPV) module as the primary source of energy. Street light stores electric energy during the day time and powers a fluorescent or LED lamp (called as luminary) during the night. It has necessary devices to store electricity such as rechargeable battery and charge controller.

The solar street light does not need to set up the transmission line or route the cable, and no any special management and control are required. It can be installed in the entire public place such as the square, the parking lot, the campus, the street or the highway etc.The street lighting is closely related to people's daily life.

A good LED Street lighting system is characterized with High efficiency, Energy-saving, Long-life, High color rendering index and Environmental protection. So it is a noticeable issue how to design a reasonable LED street light system.

Following are the basic requirements of a qualified solar LED Street Light System during design process:

- Learn general information of the meteorological conditions in the area.
- Select the cost-effective solar panel, controller, battery and a series of components.
- Adopt effective measures to protect the system.

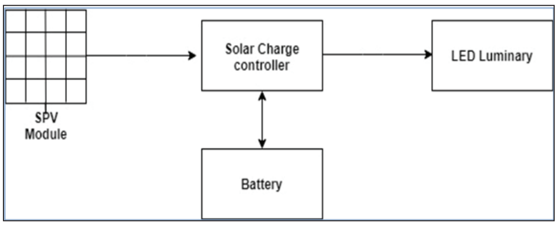
These conditions ensure to design a reasonable solution and realize the significance and value of the existence of solar LED Street Light Street.

The system consists of:

- Solar PV module
- LED lamps
- Light pole
- Control box (charger, controller, battery)

Block diagram of solar street light system (Fig 8)

Fig 8



Operation principle

The SPV Module receives solar energy and converts it into electrical energy.Converted electrical energy is stored in the battery through solar charge controller or simply, charge controller. When the light intensity reduced to about 10 lx during sun set, charge controller will turns ON the LED Light. Battery provides the energy to luminary and discharges as time passes. When sun rises the charge controller will turns off the LED Light. During night if battery voltage reduces below its critical value the charge controller will turn off the LED light to protect battery from deep discharge.

Current situation and Development

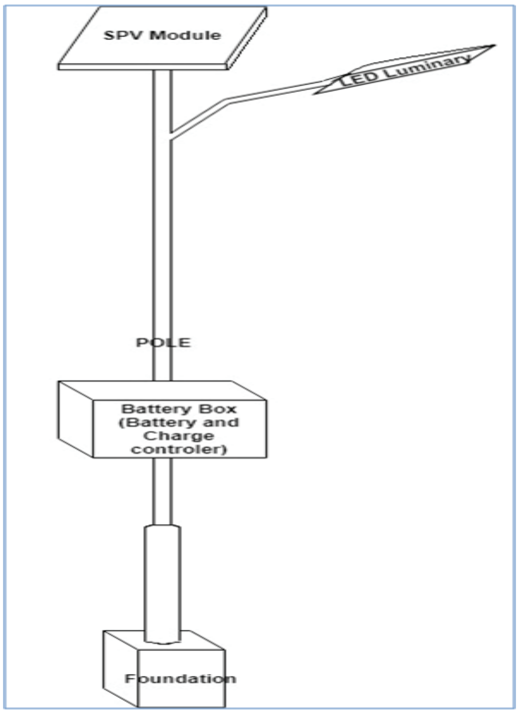
From the current situation of the LED, there are still many problems which shall be further improved. For example,

- The quality of the LED chip
- Heating problem
- Package problem
- cost and life time of the battery
- The lifetime of the electronic components.

The different parts of the solar street lighting system are shown in the Figure below. It consists of Solar panel, the Battery, the Controller and the Led lights.

Parts of Typical Solar Street Light (Fig 9)

Fig 9



Solar Photovoltaic module

The solar panel converts solar energy into electricity. The solar panels used for the solar street light system is dependent on the wattage rating of the LED Luminary used. Typically, 12W LED luminary for its 12 Hours of working requires 40Wp of SPV Module.

Battery

Battery will store the electricity from solar panel during the day and provide energy to the fixture during night. The life cycle of the battery is very important to the lifetime of the light and the capacity of the battery will affect the backup days of the lights.

Automatic switch and brightness control of lamp

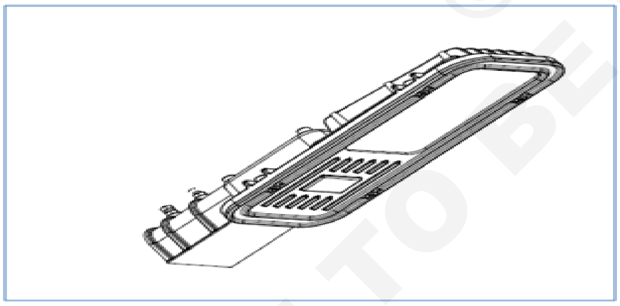
The Solar charge controller for the operation of the street light needs dusk to dawn feature i.e., turns on the luminary during sunset(dusk) and turn off during sun rise(dawn) .

Now days the adaptive brightness controlling street lights are available to optimize the battery and system size. For example first four hours of turn on time with 100% brightness and till morning 30% brightness and during the operation if any human activity is detected in the range of 5 meters from street light it increases the brightness to 100% for 10 min and revert back to the 30% brightness.

This type of street light requires smaller battery and uses higher wattage of luminary than that of the normal one, for the same rated SPV power. And requires specially designed charge controller.

Luminary (Fig 10)

Fig 10



Integrated solar LED Street light (Fig 11)

In some cases charge controller is in-built in luminary. Only battery is kept in the box.

Note: Charge controller must present about 90cm form battery, because charge controller has temperature compensation feature to charge the battery at different battery temperature.

Fig 11

Installation of Solar street light system

The technician shall be able toselect proper place to install Solar street light system, identify different tools used in the installation process, describe the process of civil work involved in the installation of Solar street light systemand describe the electrical connections involved in the installation of Solar street light system

Place of Installation

Solar street light are installed either sides of the road to light-up the road or the place where light is necessary from the top especially in the open area. Since street light uses the sun light as the source of energy, the place of installation must be

- Free from shadows caused by the trees
- Free from shadows caused by the buildings or any erected structures
- Plane area, because street light requires regular maintenance
- Well connected to road for transportation.

Civil work

Preparation of the Place of installation

The condition discussed above may not present in all the places. Sobefore installation of the street light it is necessary to prepare the proper site to meet these requirements.

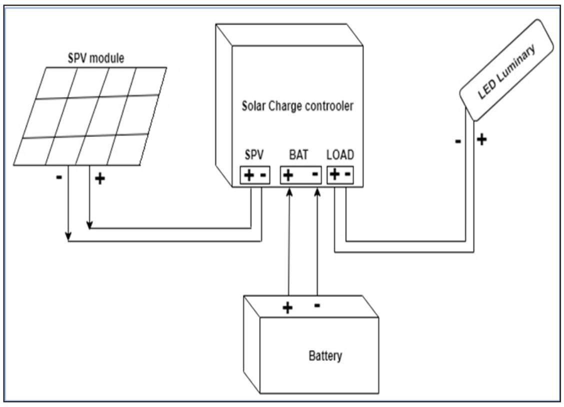
- Find the place where shadow of tree is not present or the branches of the tree must be chopped-off.
- Make place plane with the help of Hoe, trowel etc.
- Dig the hole for the street light pole
- Erection of the pole using proper tools

Electrical connection

Electrical connection of the solar street light system is connecting the different components together. The electrical connection of a solar street light system is as shown in the figure

Electric connection of the solar street light system (Fig 12)

Fig 12



Maintenances of Solar Street light system

Battery is charged only by SPV module and therefore during rainy season this product will not work beyond 1 day of Autonomy and the light must be manually switched OFF during rainy season. If not the battery will be dead immediately

A solar electric system that is properly maintained requires very little maintenance. The routine maintenance includes Battery, SPV modules, Controller, Luminary and all electrical contacts.

Batteries require regular and careful maintenance. For a longer life batteries should:

- Be cleaned for every 6 months
- Have their electrolyte level checked
- Be kept in a high state of charge
- Cleaning (once a month)
- Carry the battery outside when cleaning to avoid spilling of acid. Keep water nearby to rinse spills.
- Checking and Topping up Electrolyte level (monthly)

Remove caps of each of the cells one at a time and check the level of electrolyte. Acid Level should be within two centimeters of the top battery. If you can look inside the battery, check the plates to see their condition

If the electrolyte level is down, add ionized distilled water till it is about two centimeters below the top of the battery.

Solar home lighting system

The other names used for this are small solar system, solar DC Home lighting and Solar DC Day lighting.

A small solar systemis the off grid solar lighting system for the house. The light sources uses Solar Photovoltaic (SPV) module as the primary source of energy. System stores electric energy during the day time and powers a fluorescent or LED lamp and Fans during the night. It has necessary devices to store electricity such as rechargeable battery and charge controller.

Components of Small solar system (Fig 13)

Fig 13

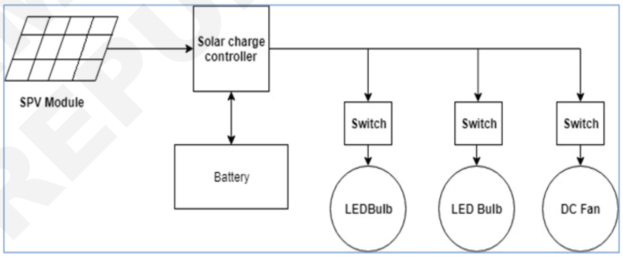
Requirements on small solar system

The small solar homesystem does not need to set up the transmission line or route the cable, and no any special management and control are required. It can be installed in any indoor such as house temple, farm house etc. Following are the basic requirements of a qualified small solar system during design process:

Operation principle

Block diagram of solar street light system (Fig 14)

Fig 14



LED Bulbs and Fans

DC LED bulbs are the lighting element in the small solar system. They are efficient and low cost. the manufacturer like Syska has many ranges of bulbs with different wattage ratings. The wattage ratings are 3W, 5W, 7W, 9W

LED bulb (Fig 15)

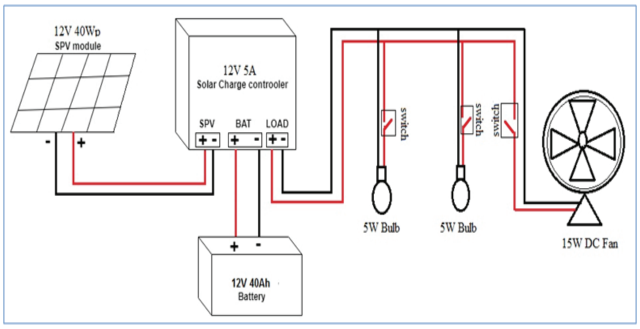
Fig 15

The user can opt for the bulb based on the lighting requirement and the wattage capacity of the system.

DC fans are usually aTable fans with wattage rating from 15W and ceiling fans with wattage ratings from 25W to 40W.

Circuit diagram of typical Small home lighting system (Fig 16)

Fig 16



Maintenance of Small Solar System

Importance

Battery is charged only by SPV module and therefore during rainy season this product will not work beyond 1 day of Autonomy and the light must be manually switched OFF during rainy season. If not the battery will be dead immediately

Routine Maintenance

A solar electric system that is properly maintained requires very little maintenance. The routine maintenance includes Battery, SPV modules, Controller, Luminary and all electrical contacts.

Battery maintenance

Batteries require regular and careful maintenance. For a longer life batteries should:

- Be cleaned for every 6 months
- Have their electrolyte level checked
- Be kept in a high state of charge

Solar water pump (AC or DC)

A solar-powered pump is a pump running on electricity generated by photovoltaicpanels.The operation of solarpowered pumps is more economical mainly due to the lower operation andmaintenance costs and has less environmental impact than pumps powered byan internal combustion engine (ICE).

Typical Solar pump system (Fig 17)

Devices involved are a water pump (AC or DC), solar PV array, Pump controller etc.

Solar pumps are useful where grid electricityis unavailable and alternative sources (in particular wind) do not provide sufficientenergy.

Fig 17

A pump will require a certain amount of electric power to produce a certain amount of pressure and flow. By using suitable size PV array, the water pump can be operated at economical cost. Most solar pumps actually require about 20% more wattage than specified when wiring the panel directly to the pump (If this is thecase, the pump manufacturer usually will state this clearly in the productspecification literature). Also, having a larger panel will allow the pump to turn onearlier and later in the day and also in relatively lower light conditions.For example, a 1Hp pump requires 1KWp SPV modules.

The solar panels make up most (up to 80%) of the systems cost. The size of thePV-system is directly dependent on the size of the pump, the amount of water thatis required (m^3/d) and the solar irradiance available.

Pump Controlleris a small device that is installed between the panels and the pump that allows the pump to switch on during low light conditions.

The purpose of the controller is twofold:

- It matches the output power that the pump receives with the input power available from the solar panels
- provides a low voltage protection, whereby the system is switched off, if the voltage is too low or too high for the operating voltage range of the pump.

Solar AC Pump controller is as shown in fig 27. It has the connection terminals for

1 SPV Input connection

2 Three Phase Output connection with Red Yellow and Blue color indication

3 LCD Display to display Information

4 Control buttons to Turn ON and OFF

5 Earthing point

Solar Pump controller (Fig 18)

Pump is the heart, forgiven power input; the pump produces a unique combination of flow andpressure. These pumps when maintained well last for more than 15 years on the field.

Fig 18

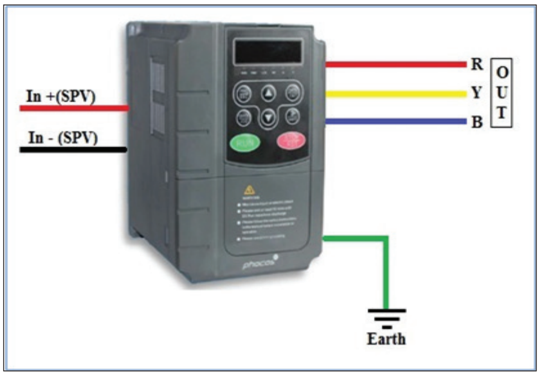
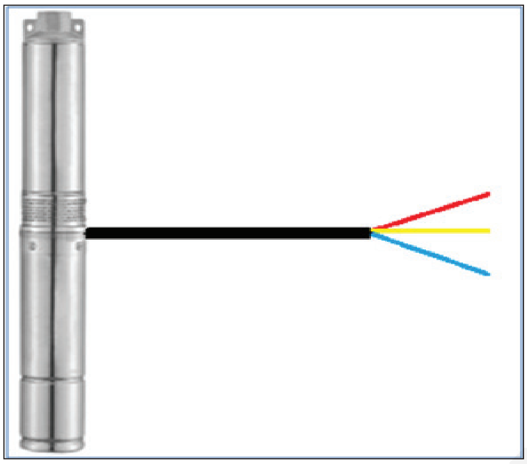
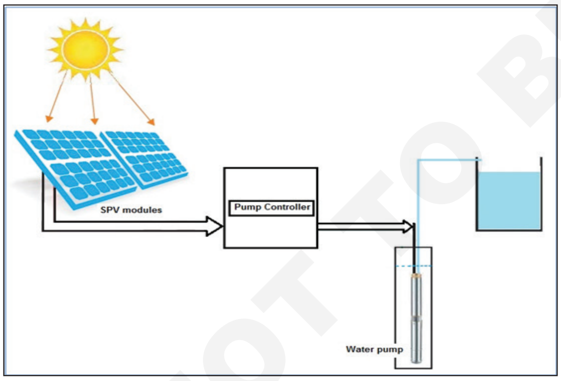


Fig 19



3 Phase AC Solar Submersible Pump (Fig 20)

Fig 20



An illustrative diagram and an operational pumpset are shown below:

Each solar array has a number of solar modules connected in parallel orseries. Every solar PV panel generates current by converting solar radiationto electrical energy.

The electrical energy from the entire array is controlled by the inbuilt controller in DC pumps or through the Variable Frequency Driver (VFD) for AC pumps and enables the connected pump (may be submersible orsurface) to draw water and feed the delivery pipelines.

The water thus drawn from ponds, rivers, bore wells or other sources by asolar water pump is pumped to supply water as required.

Performance Specifications and Requirements

Solar PV Water Pumps with PV module capacity in the range of 900 Watt to 5KWp may be installed on a suitable bore-well / open well / Water Reservoir /Water stream etc.

Under the Average Daily Solar Radiation condition of 7.15KWh / sq.m. On the surface of PV array (i.e. coplanar with the PV Modules), theminimum water output from a Solar PV Water Pumping System at different “TotalDynamic Heads” should be as specified below :

D.C. Motor Pump Set with Brushes or Brush Less D.C. (B.L.D.C.):

- 100 liters of water per watt peak of PV array, from a Total Dynamic Head of 10 metres (Suction head, if applicable, minimum of 7 metres) and with the shut off head being at least 12 metres.
- 50 liters of water per watt peak of PV array, from a Total Dynamic Head of 20 metres (Suction head, if applicable, up to a maximum of 7 metres) and with the shut off head being at least 25 metres.
- 35 liters of water per watt peak of PV array, from a Total Dynamic Head of 30
- metres and the shut off head being at least 45 metres.
- 21 liters of water per watt peak of PV array, from a Total Dynamic Head of 50 metres and the shut off head being at least 70 metres.
- 14 liters of water per watt peak of PV array, from a Total Dynamic Head of 70metres and the shut off head being at least 100 metres.
- 9.5 liters of water per watt peak of PV array, from a Total Dynamic Head of 100metres and the shut off head being at least 150 metres.

For A.C. Induction Motor Pump Set with a suitable Inverter

- 90 liters of water per watt peak of PV array, from a Total Dynamic Head of 10 metres (Suction head, if applicable, minimum of 7 metres) and with the shut off head being at least 12 metres.
- 45 liters of water per watt peak of PV array, from a Total Dynamic Head of 20 metres (Suction head, if applicable, up to a maximum of 7 metres) and with the shut off head being at least 25 metres.
- 32 liters of water per watt peak of PV array, from a Total Dynamic Head of 30 metres and the shut off head being at least 45 metres.
- 19 liters of water per watt peak of PV array, from a Total Dynamic Head of 50 metres and the shut off head being at least 70 metres.
- 13 liters of water per watt peak of PV array, from a Total Dynamic Head of 70 metres and the shut off head being at least 100 metres.

- liters of water per watt peak of PV array, from a Total Dynamic Head of 100 metres and the shut off head being at least 150 metres.

Installation of Solar Water Pump system

Place of Installation

The Solar Pump system uses the sun light as the source of energy. So the place of installation of the solar pump system shall be

- Free from shadows caused by the trees for Solar array
- Free from shadows caused by the buildings or any erected structures for array
- Free from natural water channels
- Plane area
- Near to the Bore well or the Pump

If the place does not satisfy the above requirements, then it is necessary to prepare the suitable place.

Civil work

Civil work includes the preparation of proper foundation for mounting structure. the number of SPV modules are more and all must be mounted on the same structure. So, the foundation must be strong enough to hold the weight of the SPV module and withstand wind. The civil work includes

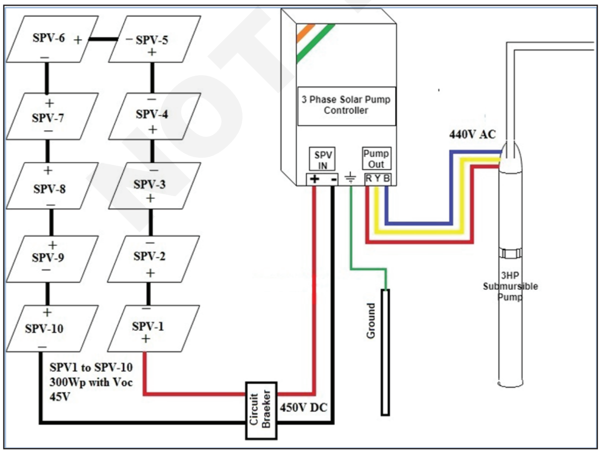
- Preparation of the Pit for mounting structure and electrical ground point
- Preparation of the cement concrete
- Erection of the Structure

Electrical connection

The electrical connection is the process of connecting all the devices electrically together. The typical electrical circuit diagram of Solar pump system is as shown in figure below:

Circuit diagram of solar pump system (Fig 21)

Fig 21



Maintenance of Solar Water Pump system

Routine Maintenance

A solar electric system that is properly maintained requires very little maintenance. The routine maintenance includes SPV modules, Controller and all electrical contacts.

Module Maintenance

Cleaning of the SPV module needs careful attention as it is mounted on a single pole at a height of 6/8 feet and must be done every month as it is mounted in the field and dust accumulations can be fast.

Keeping the glass surface clean is the most important task. Dust and shade will reduce the electric output. Clean the module with water and if necessary a mild soap. Do not allow a plant or a tree to shade the panel.

Checking Connections

Inspect the junction box on the back of each panel to make sure that the wiring is tight. Make sure those wires have not been chewed by rats and that there are no insects etc, living in the junction boxes

Wiring and control

If the wiring is installed properly, there should be no wiring problems for the life of the system. However, it is useful to check the wiring of the system at least once a year, especially in places where it might be damaged by animals, tampered with or accidently.

Power packs for decentralized energy supply

Here is an interesting discussion about Decentralized Energy supply. Rather than technical it is approached here as national and international feature in job market particularly self-employment. This is a concept growing globally in recent years after the Solar Technology in particular and Renewable energy as a whole playing an important role in Industries and hence in job market also.

Extraordinary growth potential exists for decentralized applications of renewable energy, especially in the least-developed/developing countries, where only 52% or more of the overall population had access to electricity in 2018. Income countries, rural access rates are well below 10%. At the same time, even before the COVID-19 crisisun employment rates in these rural communities were high and rising, with women and youth the most affected.

Decentralized renewable energy (DRE) solutions – solar for home and business, green mini-grids and standalone machinery for productive use (such as solar power edirrigation pumps) – are generating significant economic opportunity, including employment.

Emerging economies, by mainstreaming DRE, can not only meet the goal of universal electrification by 2030,but this can also provide more decent works.

DRE companies operating locally are already a large contributor to direct and indirect employment. Companies directly employed 95 000 workers in India, in 2018, as many as the traditional utility-scale power sector, and that number was expected to double by 2022-23. Informal employment was almost double the size of the direct.

Additional research is required to understand the full scope of employment in non-electricity DRE, such asclean cooking solutions. Initial data on employment in some developing countries from clean cooking showed that direct, formal jobs are currently dominated by liquefied petroleum gas suppliers, representing 17000 jobs, while electric cooking, bio ethanol and biogas account for just1700 jobs.

DRE solutions have the potential to create up to five times more jobs in local communities than direct, formal DRE employment, through their application in so-calledproductive uses in agro-processing, communications, commerce, education and other fields. Early and rough analysis of the productive use of new or improved electricity access in 2017-18 indicates that 470000 jobs were created in India.

In economies still dominated by agriculture, this is an important linkage, especially as food insecurity is increasing with the disruption of supply chains caused by global events.

In addition to their growing volume, DRE jobs also offer quality. Companies delivering access to electricity create skilled jobs that largely fall within the middle-income range. Another opportunity to generate both social and economic impact is by further engaging women in theDRE industry.

Despite its vital role in achieving universal electrification and generating employment, the DRE sector is experiencing significant skill gaps. There is a growing shortage of job-ready talent to finance, develop, install,operate and market energy solutions in the sector.

Thus for a solar technician – electrical to note here is that most of the solar DC products explained in this chapter are falling in the context of DRE and the trainee should view it as a great opportunity for self-employment and entrepreneurship development in India.

Test solar panel, Charge controller, Battery bank and Inverter

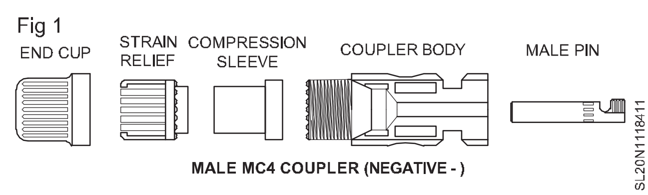
Objectives: At the end of this lesson you shall be able to
- **Describe about component details of PV and Distribution System**
- **Operation details of ON and OFF Grid PV System**

Solar panel terminal wires and MC-4 connectors

The MC4 system consists of a plug and socket design. The plugs and sockets are inside plastic shells that appear to be the opposite gender - the plug is inside a cylindrical shell that looks like a female connector but is referred to as male, and the socket is inside a square probe that looks male but is electrically female. (Important to note)

MC 4 Male connector (Fig 1)

Fig 1

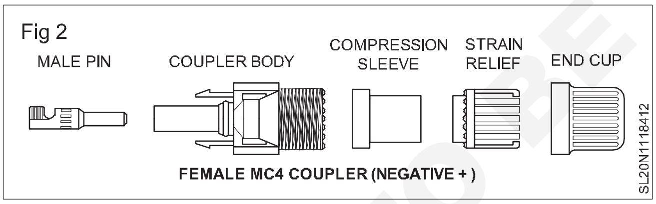


MALE MC4 COUPLER (NEGATIVE -)

The female connector has two plastic fingers that have to be pressed toward the central probe, slightly to insert into holes in the front of the male connector. When the two are pushed together, the fingers slide down the holes until they reach a notch in the side of the male connector, where they pop outward to lock the two together.

MC 4 Female connector (Fig 2)

Fig 2



FEMALE MC4 COUPLER (NEGATIVE +)

For a proper seal, MC4s must be used with cable of the correct diameter. The cable is normally double-insulated (insulation plus black sheath) and UV resistant (most cables deteriorate if used outdoors without protection from sunlight). Connectors are typically attached by crimping, though soldering is also possible.

The MC4 connector is rated at 20 A and 600 V maximum, depending on the conductor size used. Standards allow 1000 V versions.

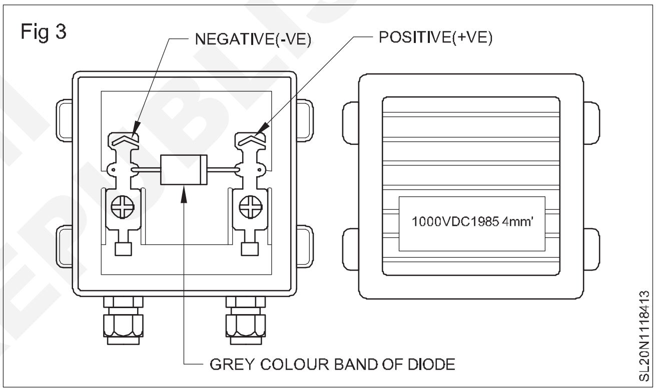
A general MC4 Connector Specification includes Manufacturer name, Rated for say, 30 amps max (the connector itself, not the wire), Rated for say, 1,000 volts max and Rated temperature range, say, -40 degrees C to +90 degrees C (-40 F to 194 F).

It is noted that, not to cut the MC4 connectors off of the solar modules, that voids the warranty of most manufacturers.

Constantspring pressure provides reliable low contact resistance.However, it is very important to never connect or disconnect them under load, even on low-voltage (12–48 V) systems. An electric arc may form which can melt and seriously damage contact materials, resulting in high resistance and subsequent overheating. This is partly because direct current (DC) continues to arc, whereas commonly used alternating current (AC) more readily self-extinguishes at the zero-crossing voltage point. Large arrays of panels are commonly interconnected in series, made of strings of panels generating 17 to 34 V each, with overall voltages up to 600 V per string.

Junction box on Backside of Solar panel (Fig 3)

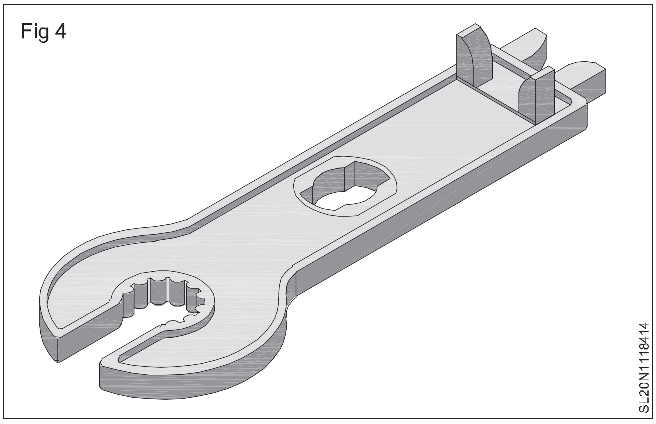
Fig 3



Due to the locking mechanism of the MC4 connectors, they will not come unplugged and are well suited for outdoor environments. The connectors can be separated but it requires a special MC4 unlocking tool.

Unlocking tool for MC4

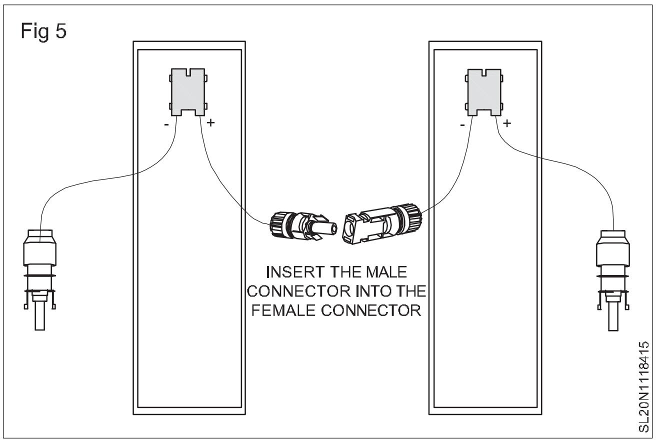
Fig 4



Series connection using MC 4

In a series connection the modules are wired together by connecting the positive lead on one module to the negative lead on another module. The male connector will snap directly into the female connector. This increases the voltage of the circuit.

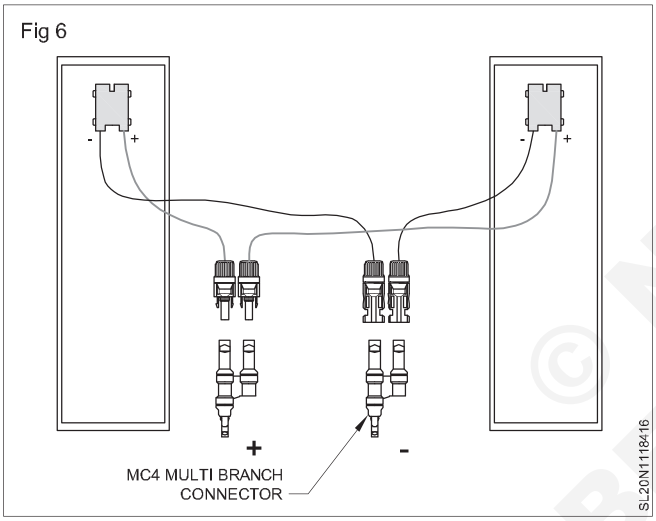
Fig 5



If the modules are rated for 18 volts at maximum power (Vmp), then two of them connected in series will measure 36 Vmp. If three modules are in series, the total Vmp would be 54 volts. The current at max power (Imp) will be constant when wiring a series circuit.

Parallel connection using MC4 multi branch connectors (Fig 6)

Fig 6



A device called a PV combiner box is used for paralleling more than two modules or paralleling strings of modules. Thecombiner box will be performing the same function of the multi-branch connectors but for more than two panels.

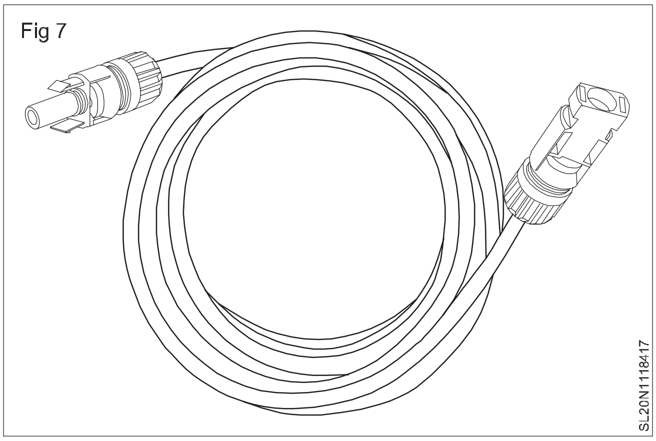
The total number of modules that can be combined will depend upon the electrical rating and physical size of the combiner box and also on the PV design. Further the technician should know how to select and use MC4 extension cables.

PV array wiring cables (Fig 7)

Solarcables are of 4mm or 6mm cables in general. Thedifferences between cables/wires, sizing methods, and 4mm solar cable installation are discussed here.

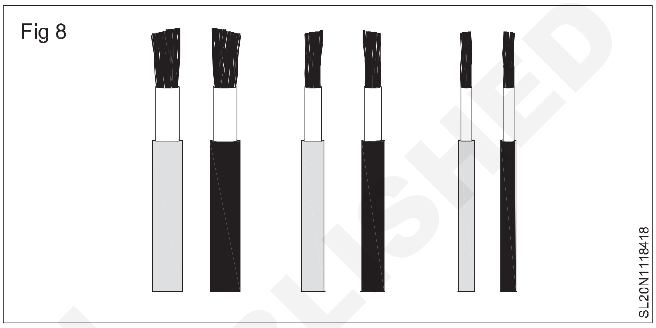
The terms "wire" and "cable" are assumed to be the same by the public, but there is actually a major difference between the two. A solar cable is a group of multiple conductors while a wire is only a single conductor. Hence wires are essentially the small components that make up the larger cable. A 4mm solar cable has multiple small wires inside the cable which are used to transfer electricity between different endpoints in the solar setup.

Fig 7



Different Solar DC cables (Fig 8)

Fig 8



Each wire located inside a 4mm cable works as a conductor and the cable is comprised of multiple such conductors. Solar wires are made from a study material such as copper or aluminum. These materials provide reliable connectivity and the ability to transfer electricity from the solar panels to the home.

Steps to connect MC4 connector to the DC cable

Requirements are male and female MC4 connectors, 4mm solar cable, wire strippers and wire crimps (Crimping tool)

1 **Set Up The Connectors**

Mark the distance and decide on the length of cable so as to join all MC4 connectors together.

2 **Crimp Male Connector**

Start by passing the screw nut over your metal crimp and then make sure the plastic housing has a non-return clip inside it. If you didn't put the nut on the cable first, you won't be able to get the plastic housing off.

3 **Insert 4mm Cable**

After crimping the 4mm solar cable right, push in the connector till a "click" sound is heard, which indicates it is secured safely. Then lock the cable in the plastic housing.

4 **Secure Rubber Washer**

The seal washer, made of rubber, is flush at the end of the cable requires the nut to be tightened closely. This gives a solid grip for a 4mm solar cable. Otherwise the connector may spin around the cable and damage the connection. This completes the connectivity for the male connector.

5 Crimp Female Connector

Take the cable and put a small bend on it to ensure better surface contact within the crimp. Strip the cable insulation by a small amount in order to expose the wire for crimping. Crimp the female connector the same way as it was done for the male connector.

6 Connect the Cable

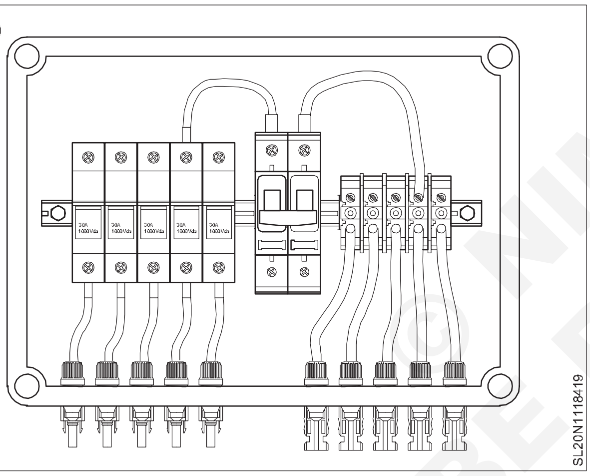
At this stage, you only have to insert the cable. Pass the screw nut over the cable and check the rubber washer again. Then you need to push the crimped cable into the female housing. You should hear a "Click" sound here as well to know it is locked it in place.

7 Test Connectivity

The final state of the connecting process is to test the connectivity. Test the MC4 connectors exclusively before connecting them to the main solar panels or the charge controller in order to verify everything is working properly.

Array Junction Box or Combiner Box (Fig 9)

Fig 9



An Array Junction Box, AJB, is used to connect the photovoltaic strings in parallel. The combined DC power is fed to the photovoltaic inverter. It includes photovoltaic string protection, overvoltage protection and a DC output switch isolator.

The AJB can be customized for different configurations, based on the number of strings of solar panel modules used in the layout.

AJB have the following components

1 Enclosure

2 PV fuses

3 Surge Protection Device

4 DC Disconnect/Isolator and

5 Cable Glands/Connectors

These are the Protection devices in an AJB.

1 Enclosure

The combiner box enclosures are usually made of thermoset (eg. GRP or polyester), or thermoplastic (polycarbonate) material, and come with IP65 protection. Enclosures come in various sizes, based on the number of input strings. The protection features required also contribute to the changes in the enclosure needed. Enclosure should be fire-resistant with self-extinguishing property. It should be UV-resistant and halogen-free and should also have a good mechanical impact resistance.

2 PV fuse

PV fuse or photovoltaic fuse of the range from 1A to 32A is easily available in market. The PV fuses are used for overcurrent protection.

PV fuse selection:-

N_s= No. of PV modules in series per PV string

N_p = No. of PV strings in parallel per PV sub-array

I_{sc} = Short-circuit current of one module at Standard Test Conditions (STC)

V_{oc}= Open circuit voltage of one PV module at STC

Calculations to verify volts and amps:

Fuse voltage rating = 1.20 x V x Ns

Fuse amp rating = 1.56 x I_{sc}

For Example:-

Let's assume that

N_s = 20, N_p = 16, I_{sc} = 8.6 A and Voc=37.2 V

Then Fuse amp rating = 1.56x8.6 A = 13.41 A

As per the standard fuse available in market, a 15A fuse should be used here.

And Voltage rating of Fuse = 1.2x37.2x20 = 892.8 V

As per the standard fuse available in market, a 1000 V DC fuse should be used to meet this requirement.

3 Surge Protection Device:

SPD or Surge Protection Device is used in the AJB/ SCB. It protects electrical and electronic equipment from the power surges and voltage spikes. SPD diverts the excess voltage and current from transient or surge into ground through earthing system.

Selection Of SPDs according to the voltage protection level Vp : Every SPD has a maximum voltage protection level specified for operation & diverts the excess energy in ground. The protection voltage level of SPD is usually kept at 20% less than dielectric strength & greater than operating voltage of PV system.

4 DC Disconnect /Isolator:

DC Disconnect/Isolator is a switch used to disconnect the power supply between PV string & inverter. It is recommended to be placed before the inverter, to disconnect the DC side of the system when required.

Selection criteria for PV isolator:

Initial conditions for specifying PV disconnect:

N_s = No. of PV module in series per PV string

N_p= No. of PV string in parallel per PV sub-array

I_{sc} = Short-circuit current of one PV module at Standard Test Conditions

Voc = Open circuit voltage of one PV module at STC

Circuit breaker voltage rating = 1.20 x Voc x N_s Volt

PV Output current rating = 1.56 x I_{sc} x N_p Amp

For example:-

Let's we assume that Ns = 20, Np= 16, Isc = 8.6 A and Voc=37.2 V

Circuit breaker voltage = 1.20 x 37.2 x 20 = 892.8 Volt

As per standard available circuit breakers in market, it should be 1000 V DC Disconnect.

Current rating of isolator = 1.56 x Isc x Np A = 1.56 x 8.6 x 16 = 214.65 A

As per standard available circuit breakers in market, it should be 225 A isolator.

5 Cable Glands/Connectors

Every solar system is outdoor type, so AJB component should be IP65 protected & UV protected. There are two options with cable entry in AJB.

1 Cable Gland

2 MC4 connector.

Cable glands require the sealing arrangement after the connection inside AJB to outside systems is done. MC4 Connectors have the male-female socket for connection, and hence do not require sealing to maintain the IP protection. MC4 connectors have the limitation of current capacity. In low rating, 30 A for string level MC4 is the best option. In case of AJB, output rating of more than 30A cable gland is suitable.

By pass diode

We should know about shading in PV Cells to understand the role of bypass diode. According to Kirchhoff's current law all the cells connected in series in a string will have the same current.When one cell is shaded the individual current in this cell drops. The cell tries to increase its current output to equal the current in the network, and goes into reverse bias in the process. The cell operating in reverse bias requires more energy. This produces a negative voltage and increased heat dissipation.

Due to imperfections in the cell the temperature increases in some parts of the cell.This leads to a hotspot in the cell, thus damaging the cell.

Diodes used to minimize the effect of shading. Diodes are used in parallel with the with a string of cells. Current flows through the forward biased diodes, when the cells are switched to reverse bias due to shading. This reduces the effect of shading.

Effect of Shadow on one cell in a string (Fig 10)

Bypass diodes across each Solar panel in an array (Fig 11)

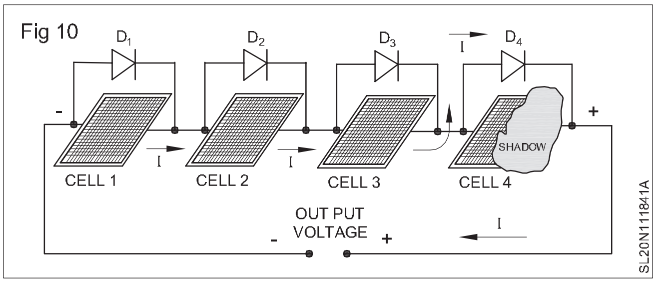


Fig 10

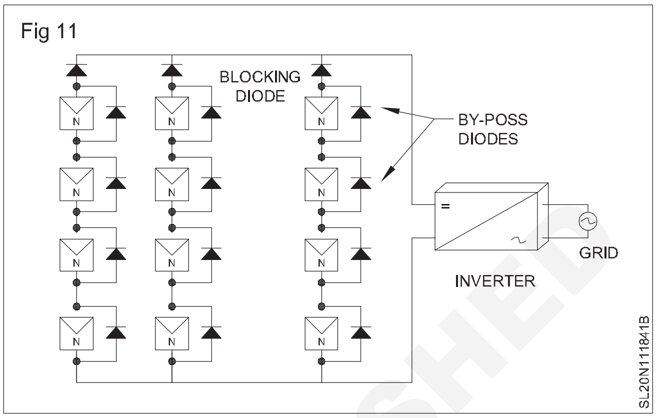


Fig 11

Diodes per cell string within a panel (Fig 12)

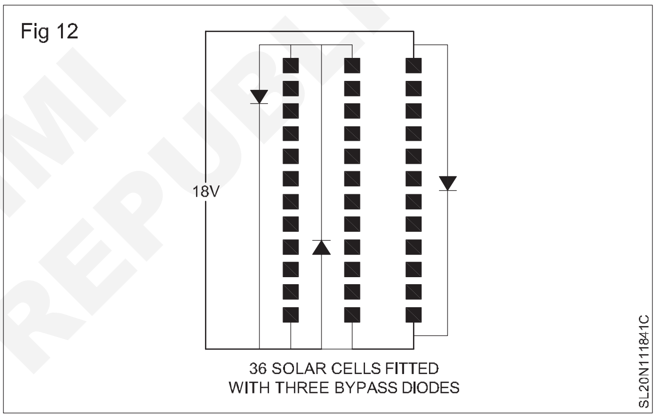


Fig 12

Shading stages over a cell (Fig 13)

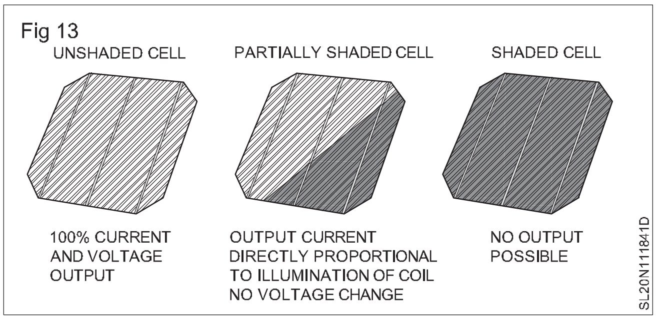


Fig 13

Power reduction from a solar panel due to shading (Fig 14)

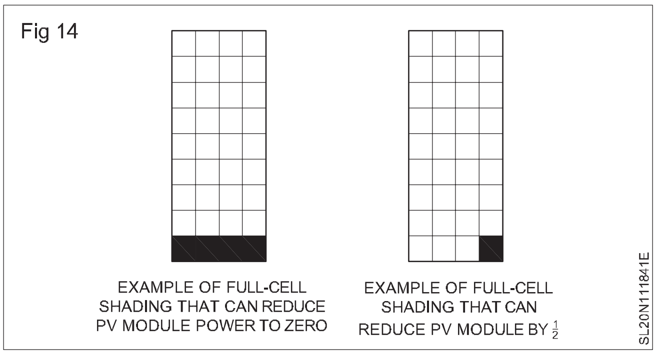


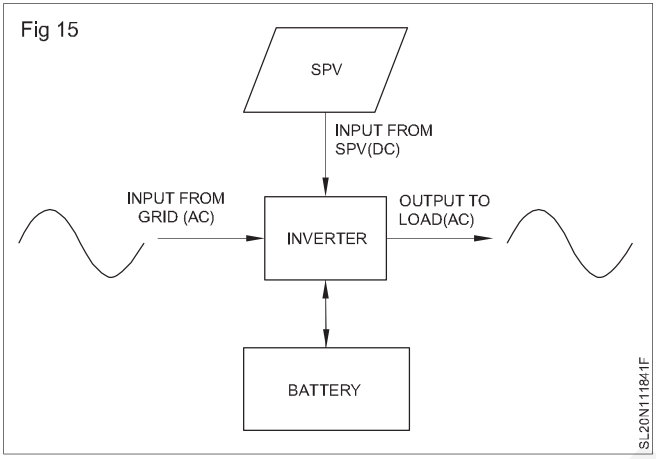
Fig 14

Normal and solar inverter

A solar inverter, or PV inverter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection.

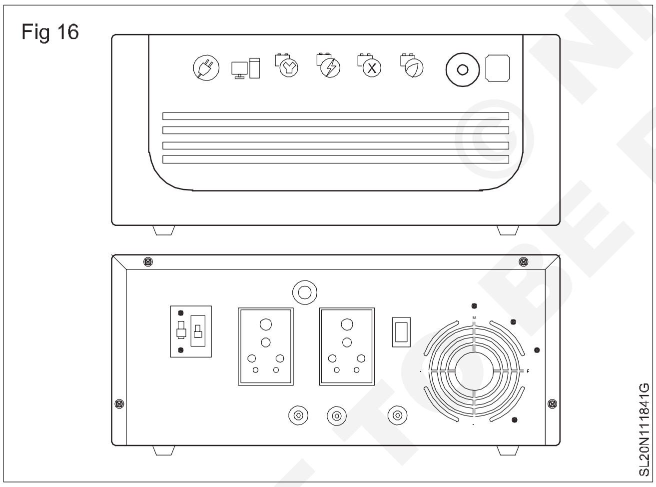
Solar Inverter (Fig 15)

Fig 15



Commercial inverter (Fig 16)

Fig 16



The front panel has Power ON/OFF switch, LED indicators for AC mains, Solar ON, on Battery, Normal load, Over load Low battery etc. The back panel has AC adaptor jack, Solar DC input terminals, Battery input terminals, AC out socket, overload MCB, Fuse, exhaust fan etc.

Classification of Inverter

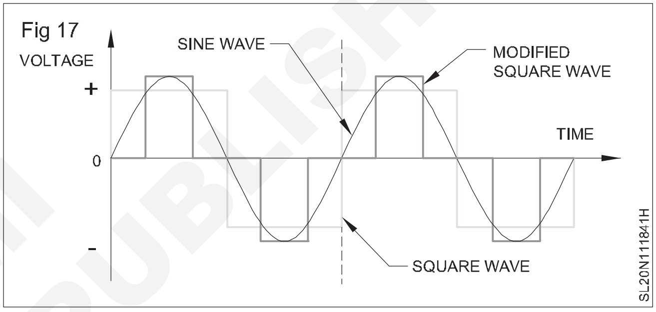
Inverter can be classified on the basis of nature of source, nature of output waveform, type of commutation circuit used, configuration and type of power semiconductor devices used. A square wave inverter switches the DC input into a multistepped square wave AC output. This kind of inverter offers little voltage control and limited surge capability, and creates harmonic distortion. Square wave inverters are used only for small heating loads, some appliances, and incandescent lights.

A Quasi-Square or modified square wave Inverter switches DC input to AC output, it uses field effect transistor or silicon controlled rectifiers in order to do this, and the output is greater multiple of steps. This type of inverter has complex circuitry and thus can handle large surges and produces less harmonic disruption. This inverter is used for variety of loads like motors, lights, and televisions.

A sine wave inverter is used to operate electronic hardware that has a high quality waveform built usually on thousands of steps that make it look like a pure sine wave or smooth flowing curve. This is the most common type of inverter in residential and commercial PV applications. For this reason, the sine wave inverter has an advantage over other kinds of inverters. This inverter is designed to produce output that has little harmonic distortion andwith high surge capabilities. For these reasons the sine wave inverter can operate sensitive electronic equipment and many kinds of motors.

Output waveforms of different inverters (Fig 17)

Fig 17



Study of different parameters of Inverter

i Efficiency measurement

ii PWM switching technique

iii Charging of batteries

iv Protection like over load and low battery

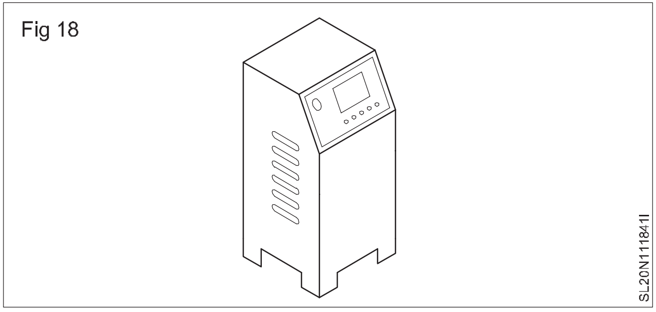
An inverter's efficiency indicates how much of the input DC power it converts into AC power. This will never be 100% because the inverter uses some of the input DC power itself, generally around10-25 W.

The efficiency of an inverter depends on the power output level it is operating at. At different powerlevels, it will be operating at different efficiencies.

Inverters operate at maximum efficiency at a power level know as its peak efficiency point. This isgenerally at around 20-30 percent of its maximum power rating. So if you have a 4000 W inverter,its peak efficiency point will be between 800 and 1200 W

Solar Power Conditioning Unit (Fig 18)

Fig 18



Terms related to Inverter

Watt (W)is the measure of how much power a device uses when turned on or can supply. If a deviceuses 100 watts, it is simply the voltage times the ampere (rate of current).If the device takes 10Amps at 12 Volt DC, it uses 120 watts power. That is 10A x 12 V = 120 W. (W = V X I Where V is the 230 volt AC and I is the current consumption.) Watt rating is usually printed on the back side of the appliance near the power cord.

Watt Hour (WH)(or Kilo Watt hour – kWh) is simply how many watt times, how many hours the deviceis used. If the device uses 100 watts for 10 hours, it is 1000 watt hour or 1 kWh. The electricity tariffis based on kWh.

Ampere (A)is the measure of electrical current at the moment. Amps are important to determine the wire sizefor connecting the inverter to the battery. Low gauge wire will heat up and burn if heavy currentflows through it from the battery.Current consumption depends on the wattage of the appliances used and it can be calculated using the formula I =W / V Where I is the current in amps, W is the wattage of the appliance and V the 12volt (battery voltage).

Power in Inverter can be Peak power and Typical or Average power. An inverter needs Peak or Surge power and Typical or Average (Usual) power. Peak power is themaximum power that an inverter can supply usually for short time .Some heavy current applianceslike motor and refrigerator requires a startup peak power than they require when running. Typicalpower is the power that the inverter gives on a steady basis. This is usually much lower than the peakpower. Typical power is useful in estimating the battery capacity. Therefore inverters must be' sized'for the maximum peak load and typical continuous power.

Power Rating of Inverter is expressed in Volt Ampere (VA). It represents the maximum load capacity of the inverter. Commonly available inverters are 500VA, 800 VA, 1000 VA, 1500 VA etc. Inverters are available in different 'Size ratings' from 50 VA up to 50000 VA.Inverters larger than11000 VA are seldom used in household applications. The first thing you have to consider about theinverter system is its maximum peak power or surge power and steady current supply. The surgerating is usually specified at so many watts for so many seconds. This means that the inverter willhandle an over load of that many watts for a short time. This 'surge capacity' will vary considerablybetween inverters and even with in the same brand. Generally 3-15 seconds surge rating is enough tocover 99% of appliances. Inverters with lowest surge rating are the high speed electronic switchingtypes.VA indicates the 'Size' (capacity) of the inverter. To select the inverter size, the given formula VA = Wx Inverter loss. Inverter loss is typical around 1.15. If the total load connected to the inverter is 400 watts then the minimum inverter size should be 400x1.15. That is 460 VA. A 500 VA is suitable for the load.

Ampere Hour (Ah) or Amp-Hour usually abbreviated as Ah is the Amps x Time. Ah is the measure of battery capacity which determines the backup time of the inverter. The capacity of the battery is represented in Ah. It is the amount of current a battery can give duringone hour of charge / discharge cycle. High capacity batteries (100 Ah, 150 Ah) are used to powerinverters to get sufficient backup time. The formula to select the battery power (Ah) is Load inwatts / Voltage of battery x Backup hour.

For example if you wants to run 400 watts load on 12 volt battery for 3 hours, then the capacity ofthe battery should be minimum 100 Ah.

Ah = 400 / 12 x 3 = 100 Ah. If the load increases (within the capacity of the inverter), backup timereduces.

Connections for Solar inverter (Fig 19)

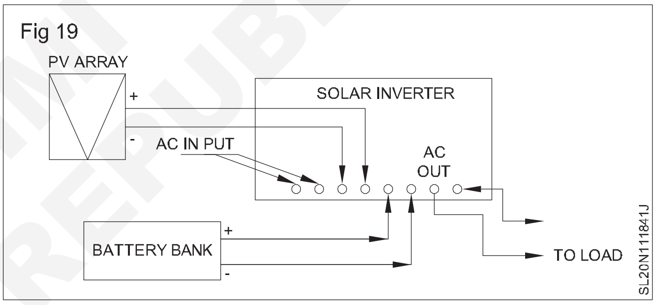


Fig 19

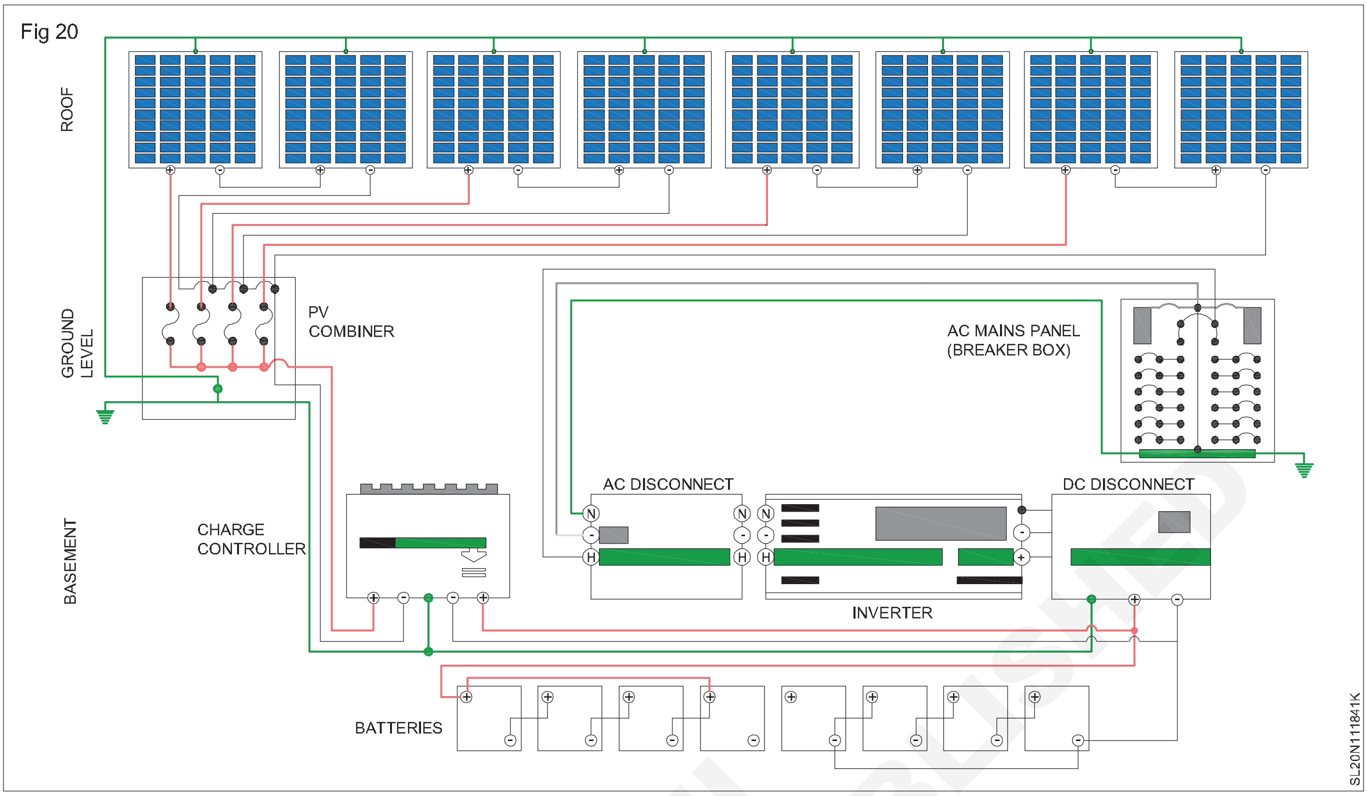
Inverter wiring/Sequence of connection (step wise) in an off grid system:

- Wire the charge controller
- Connect charge controller to battery
- Connect battery to inverter
- Connect panel to charge controller
- Connect loads

In all the above steps wire or connect means only physical connection. But not energizing. Keep all MCB in OFF position and fuses removed for safety.

Solar PV plant layout (Fig 20)

Fig 20



Power Related Theory For Exercise 1.7.89-91

Solar Technician (Electrical) - Connection, Test, under take Maintenance and Disposal of Solar Batteries

Series, Parallel or Series and Parallel Battery Banks

Objectives: At the end of this lesson you shall be able to
- **Explain the type of Battery Connection.**
- **State the Current and Voltage Rating of Battery Bank**

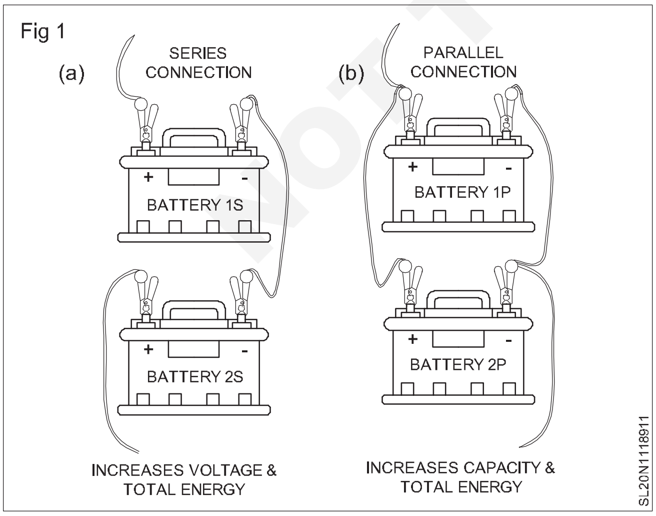
Series, Parallel or Series and Parallel Battery Banks

Introduction Battery banks are created by connecting two or more batteries together to support a single application. By connecting batteries into connected strings of individual batteries we create a battery bank with the potential to operate at an increased voltage; or with the potential to operate with increased capacity and runtime, or with the potential to operate both at an increased voltage and with higher capacity and increased runtime. If you intend to utilise Series, Parallel or Series and Parallel battery banks you must make the connections amongst the batteries and in conjunction with the load and charging circuits in a manner that will prevent them becoming out of balance. Batteries improperly connected will experience uneven resistance to charge and discharge activity and will experience premature failure.

Series Connection

Batteries are connected in series as shown in Fig 1. When the goal is to increase the nominal voltage rating of one individual battery - by connecting it in series strings with at least one other individual battery of the same type and specification - to meet the operating voltage of the system the batteries are being installed to support. Connecting batteries in series incrementally adds the voltage and stored energy potential of each battery connected in the series string without changing the total amp-hour capacity of the completed battery bank.

Fig 1



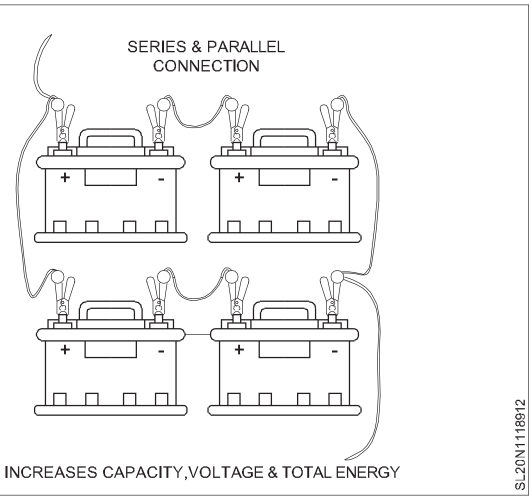
Parallel Connection

Batteries are connected in parallel as shown in Fig 1. when the need is to increase the amp-hour capacity of a battery bank without increasing its voltage. This is very prevalent in the RV and Marine house battery world. Batteries are connected in parallel strings with other individual batteries to meet the required capacity or run-time of the loads the battery bank will need to support. Connecting batteries in parallel incrementally adds the capacity and stored energy potential of each battery connected in the parallel string without changing the voltage of an individual battery within the string.

Series and Parallel Connection

Batteries are connected in series to increase the nominal voltage rating – without increasing the capacity - of one individual battery to the operating voltage requirements of the application. Batteries are connected in parallel to increase the amp-hour capacity – without increasing the voltage - of an individual battery to the capacity or run-time needs of the application. Batteries can be combined in both series and parallel to build a battery bank that combines both an increase in voltage and an increase in amp-hour capacity. Fig 2

Fig 2



Power — Related Theory For Exercise 1.7.92

Solar Technician (Electrical) - Connection, Test, under take Maintenance and Disposal of Solar Batteries

Specific Gravity & Hydrometer

Objectives: At the end of this lesson you shall be able to
- **Identify the Instrument to measure Electrolyte of Battery.**

Care of Battery

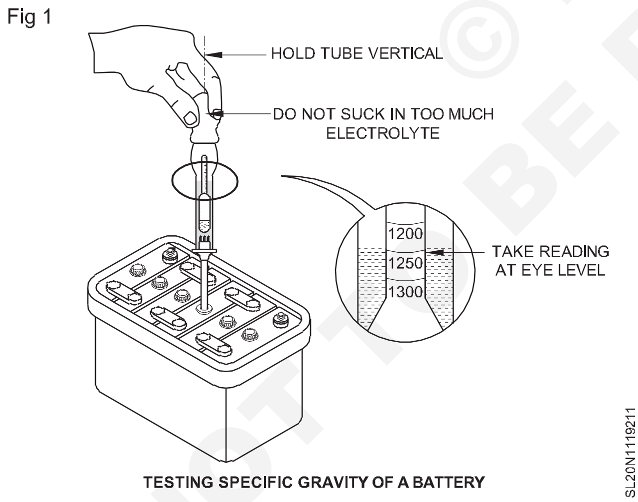
1 Visual inspection: Check electrolyte level at least once a month. If the batteries are fully charged and still charging, water loss may increase. It is advisable that a suitable charging regulator be installed to prevent overcharging of the battery.

Overcharging is indicated if the battery is bubbling vigorously.

2 Hydrometer Test: Check the electrolyte level, to ensure that it is above the plates in all cells. If it is below the plates, the test cannot be carried out until water is added and the battery charged to mix the water and residual acid in the battery. It is important to ensure that the plates do not remain exposed to air and allowed to dry and oxidise.

The state of charge of each cell can be measured with a hydrometer to determine the specific gravity of the electrolyte (specific gravity is its weight compared to water) as shown in Fig 1.

Fig 1



TESTING SPECIFIC GRAVITY OF A BATTERY

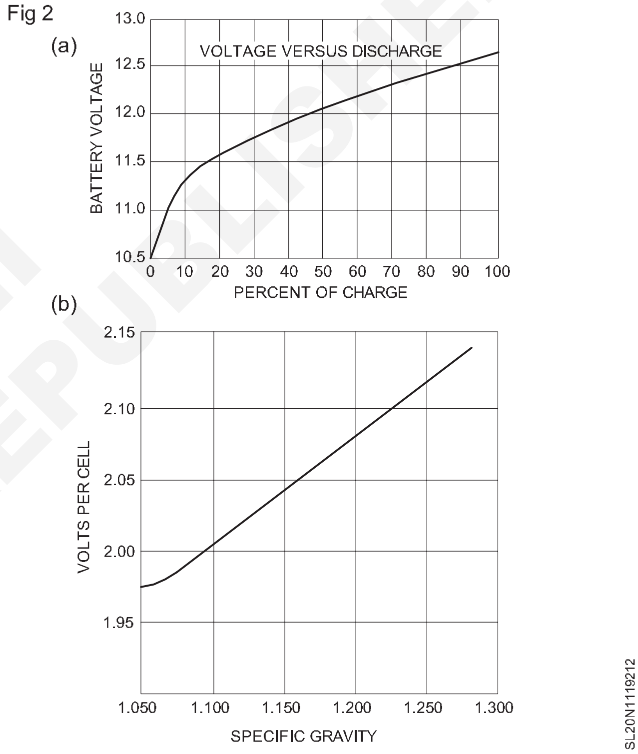
Using Hydrometer

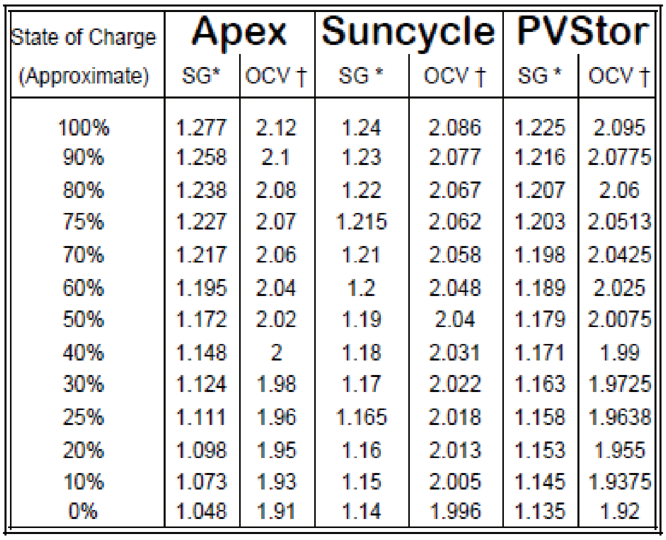
Draw the acid into the hydrometer, so that the float is lifted free and not touching the top or the bottom. The barrel must be held vertically and the eye level with the surface of the liquid. Disregard the curvature of the liquid against the glass.

Cell temperature corrections should be applied if accurate readings are required. 0.004 points should be added or subtracted for each 5°C +/- variation from 25°C.

3 Voltage Test: Voltage readings should be taken whilst the batteries are neither charging nor discharging (nothing connected and turned on). Immediately after either charging or discharging the battery voltage may not have stabilised as shown in Fig 2(a) & 2(b). The voltage will settle down in about 30 minutes after charge or discharge are discontinued.

Fig 2





State of Charge (Approximate)	Apex		Suncycle		PVStor	
	SG*	OCV †	SG *	OCV †	SG *	OCV †
100%	1.277	2.12	1.24	2.086	1.225	2.095
90%	1.258	2.1	1.23	2.077	1.216	2.0775
80%	1.238	2.08	1.22	2.067	1.207	2.06
75%	1.227	2.07	1.215	2.062	1.203	2.0513
70%	1.217	2.06	1.21	2.058	1.198	2.0425
60%	1.195	2.04	1.2	2.048	1.189	2.025
50%	1.172	2.02	1.19	2.04	1.179	2.0075
40%	1.148	2	1.18	2.031	1.171	1.99
30%	1.124	1.98	1.17	2.022	1.163	1.9725
25%	1.111	1.96	1.165	2.018	1.158	1.9638
20%	1.098	1.95	1.16	2.013	1.153	1.955
10%	1.073	1.93	1.15	2.005	1.145	1.9375
0%	1.048	1.91	1.14	1.996	1.135	1.92

SG * — Specific Gravity @ 25°C

OCV † — Open Circuit Voltage per 2 Volt Cell

Specific Gravity

The hydrometer measures the Specific Gravity (SG) of a battery. You will find that the electrolyte in the hydrometer tends to curve up at the edges against the glass. This curvature is referred to as a meniscus. The SG reading should be taken from the bottom of the meniscus.

The SG is a measure of the concentration of the acid in a battery. Due to chemical action caused by charging and discharging, the proportion of sulphuric acid (SG = 1.8) to water (SG = 1) in the electrolyte and therefore, the SG of the electrolyte, gradually increases during charge and decreases during discharge.

The complete working range of SG lies between the limits of 1.1 and 1.3. If below 1.1, damage may be caused by the plates becoming hydrated, while if above 1.3 the plates and grids are liable to be corroded.

The SG of the electrolyte of a fully charged battery is between 1.215 and 1.28, depending on the battery type. When the SG falls to about 1.175 the battery is considered to be discharged and needs charging.

The SG is often multiplied by 1000 and the hydrometer scale marked accordingly. SG readings should be referred to a temperature of 25°C. A temperature that is significantly at variance with this temperature will cause a change of density of the electrolyte and needs to be taken into account when the SG is measured. Refer to the SG versus temperature graph (page 35). A significantly lower temperature will also cause a sluggishness of the battery.

Owing to the time required for the diffusion of the electrolyte, the change in SG lags behind the charge or discharge by an amount which depends on the characteristics and dimensions of individual cells and the rate of charge or discharge. Consequently, the SG will continue to rise for a short period after the charge has been terminated and similarly may continue to fall after a discharge has been terminated, although, if the end of the discharge is at a low rate the lag may not be noticeable.

Only add distilled water to the electrolyte. Do not add acid, unless under the instruction and supervision of a Rainbow Power Company Battery Technician. Do not add water with impurities as these impurities will be accumulative over time and will cause problems. Do not take a SG reading just after topping up with water.

Power **Related Theory For Exercise 1.7.93-94**

Solar Technician (Electrical) - Connection, Test, under take Maintenance and Disposal of Solar Batteries

Safety aspects, maintenance, capacity, defects of batteries

Objectives: At the end of this lesson you shall be able to
- **Describe the Safety and Maintenance of Battery**
- **Explain the Battery Capacity.**

SAFETY PRECAUTIONS FOR HANDLING BATTERIES

Batteries are large, contain corrosive acids and produce an electrical charge. All of these post a threat to your safety and necessitate a number of precautions be taken when handling batteries.

1. Avoid bringing metal into contact with batteries. This includes metal tools and hoist chain as well as personal items such as jewelry, watches and belts. As metal conducts electricity, anyone touching a metal object as it comes into contact with the battery runs the risk of electrocution.
2. Never allow both terminals to make contact with an item (particularly yourself) simultaneously. When both terminals are engaged, an electrical current will pass through anything touching them.
3. Do not hand-guide batteries during lifting/moving process. This puts you in danger if the battery were to drop or shift. Also, touching the battery proves a danger as it may lead to electrical shock or bring the worker into contact with corrosive battery acid.
4. Practice safe and appropriate lifting procedures. Do not bring unprotected hands into contact with the battery throughout the moving process. Additionally, use only specified lifting equipment designed for this purpose and approved for the battery's weight. Otherwise, one runs the risk of damaging the battery or lifting equipment.
5. Wear protective equipment when handling batteries including gloves, eyewear and hardhat. Gloves and protective eye gear are to guard against battery acid while a hard hat is important during the lifting process in case a battery swings or falls.
6. Batteries can be dangerous when mishandled. Not only are these batteries large and heavy objects that can cause severe injury and damage if dropped, battery acid is extremely corrosive and can cause severe burns to the skin or corrode equipment that it comes into contact with. Likewise, touching batteries without proper equipment and preparation can result in high-voltage electric shocks.

All personnel working with batteries should first be trained in the proper lifting and handling procedures. Also, it is a good practice to regularly remind workers of appropriate battery handling procedures in order to maintain a safe working environment.

Industrial Battery & Charger Inc. scheduled maintenance programs offer the ability to pro-actively manage your fleet maintenance on a schedule rather than a purely corrective basis. A preventive maintenance program is at the core of any efficient and well run facility, and will save you time and money in the long run, as well as increase the lifespan of your batteries.

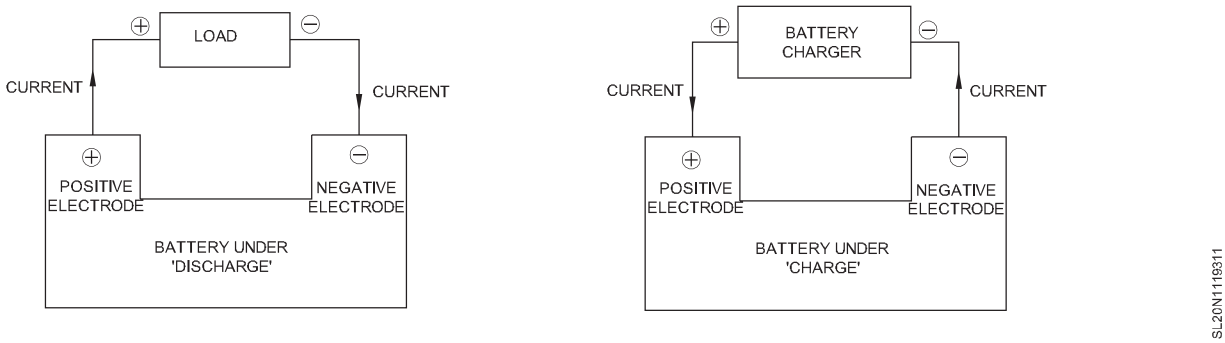
Charging and Discharging of Battery

Charging

To charge a battery, a current must be forced back through it. So a positive voltage must be applied to the positive terminal, and negative to the negative terminal. Also the voltage must be high enough to overcome the battery voltage and drive sufficient current into the battery. About 14 Volts is adequate, for a 12V battery. • Oxygen in the electrolyte combines with the lead sulphate of the positive plate to become lead peroxide; • Sulphate is released from both plates, which is converted to sulfuric acid and the concentration of the electrolyte is restored; and • The negative plate becomes spongy lead. Charging is thus the reverse of discharging, and the plate materials return to their original forming of lead peroxide for the positive plates and spongy lead for the negative plates. The sulfuric acid (H2SO4) concentration becomes highest when the cell is fully charged.

Discharging In a fully-charged battery the positive plates are made of lead peroxide and the negative plates are spongy lead. During discharge or use: • Sulphur in the acid combines with the plates to form lead sulphate; and • The oxygen and hydrogen released combine to form water, which dilutes the electrolyte. As the battery is discharged, or used, the acid concentration decreases and becomes weaker (dilute) until the battery cannot produce an electrical current. This makes it possible to tell the state of charge by seeing how weak the electrolyte is. A hydrometer is used to measure the strength of the electrolyte. Both negative and positive plates become lead sulphate as the battery is discharged by use. The resulting lead sulphate is bulkier than spongy lead or lead peroxide, so if the battery is discharged too quickly the plates will buckle and some paste will fall out. This shortens the life of the battery. Note, the strength is generally expressed in terms of specific gravity, which is weight of the electrolyte compared to the weight of an equal volume of pure water. The charging and discharging time period current direction as shown in Fig 1.

Fig 1



BATTERY MAINTENANCE

attery maintenance is well recognized as an important part of running an efficient and safe warehouse. However, the appropriate procedure for battery maintenance is often overlooked. Performing maintenance in the correct order is just as essential as the maintenance steps themselves when it comes to saving time, extending the lifespan of your battery and protecting your equipment.

Follow the correct maintenance order for your batteries:

1 **Charge battery once it is down to 20% capacity.**

Do not allow battery to drop below 20% power before charging. Discharging the battery's banks too far will harm the battery, permanently impacting the performance and endurance of the battery. It may also overheat, damaging electric circuits to the forklift.

Allow battery to charge to full power uninterrupted. A battery's lifespan is often proportional to the number of charges it receives. Undercharging, charging for short periods of time multiple times a day (this includes quick charging during a lunch break) or charging before battery has discharged more than 50% of its power can all lead to decreased performance rate and a shortened battery life.

2 **Deliver equalizer charge when necessary.**

This is a deliberate overcharge that many batteries require to function properly and efficiently. Chargers for batteries that need this will have button that must be manually pressed to turn on the equalizer charge. If you are uncertain about whether an equalizer charge is necessary, how often to deliver it or how to deliver an equalizer charge, consult your battery/ charger manual for further instructions.

During the process of receiving an equalizer charge, batteries will charge for a longer period of time. This extended charge time may lead to overheating, and batteries should be monitored during this process.

3 **Turn power off and allow battery to cool before removing.**

Do not turn power off until after battery has reached 100% power. The battery will run more efficiently throughout the day if it has reached full power. This practice will also decrease the number of times the battery needs to be charged, thus increasing the battery's lifespan.

Battery must cool before being placed back into service or it may overheat, potentially damaging both the battery and electrical circuits

4 **When water/electrolytes are needed, be sure to water battery after charging and disconnecting.**

It is not safe to water battery at any other point in time. Charge before watering as heat of charging can cause changes in water levels (both as evaporation and overflow). If water levels are quite low before charging, you may add a small amount of water to prevent battery overheating during the charging process.

5. **If battery is overfilled, clean battery immediately following overflow.**

Overflow during this process will leak battery acid across the surface of the battery and will cause corrosion if not immediately cleaned. Corrosion and residual acid can deteriorate battery life and cause battery to overheat during charging and use.

6 **Clean battery with a neutralizing detergent solution on a regular basis.**

Surface cleaning will prevent grime build-up, corrosion and resulting problems.

Clean battery after watering. This will save you from repeating a step in the event of an overflow, water drips, etc. Always clean batteries in the designated washing area with the appropriate equipment and specialized neutralizing detergent. The neutralizing agent may be a specified cleaner or a simple sprinkling of baking soda. Whatever is used, this is a vital step that will neutralize any battery acid that has accumulated on the surface and prevent corrosion of the battery and surrounding electrical circuits.

Establishing the appropriate procedure for battery maintenance is a vital part of maintaining a productive and safe work environment. Charts and maintenance schedules are a good way to ensure that batteries receive the appropriate maintenance.

Your satisfaction and safety are very important to us. For battery maintenance needs contact your IBCI representative for options on scheduled maintenance programs to keep your fleet running efficiently and extend your battery life.

Battery Capacity

The ampere-hour (AH) capacity is the unit used in specifying the storage capacity of a battery. While a battery that can deliver 10 A for 10 hours can be said to have a capacity of 100 AH, that is not how the rating is determined by the manufacturers. A 100 AH rated battery most likely will not deliver 10 A for 10 hours. Battery manufacturers use a standard method to determine how to rate their batteries. Their rating is based on tests performed over 20 hours with a discharge rate of 1/20 (5%) of the expected capacity of the battery per hour. So a 100 ampere-hour battery is rated to provide 5 A for 20 hours. The efficiency of a battery is different at different discharge rates. When discharging at 5% an hour, the battery's energy is delivered more efficiently than at higher discharge rates. To calculate the 5% discharge rate of a battery, take the manufacturer's ampere-hour rating and divide it by 20. C-rate C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. 1C rate means that the discharge current will discharge the entire battery in 1 hour; 0.1C means 10% transfer in one hour, or full transfer in 10 hours; 5C means full transfer in 12 minutes, and so on.

Common Defects in Batteries

1. Short-circuited cell due to failure of the separator between the positive and negative plates.
2. Short-circuited cell or cells due to a build-up of shed plate material below the plates.
3. Sulfation after a long period of disuse in a low- or no-charge state.
4. Corrosion or damage to the positive and negative terminals.
5. Broken internal connections as a result of corrosion.
6. Broken plates due to corrosion and vibration.
7. Damage to the battery case.
8. Low electrolyte (fluid) level.

Power Related Theory For Exercise 1.7.95-96

Solar Technician (Electrical) - Connection, Test, under take Maintenance and Disposal of Solar Batteries

Disposal procedure of batteries

Objectives: At the end of this lesson you shall be able to
- **Explain the variety type of Batteries Dispoasal.**

Many labs have equipment that runs directly from battery power or uses batteries as a backup source of energy in the event of a power failure. Many of these batteries contain toxic, heavy metals and therefore must be managed in a safe and environmentally sustainable manner.

The following is a quick guide listing some common batteries and the proper methods of disposal.

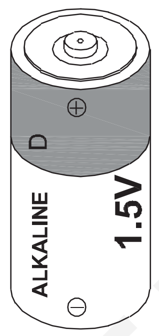
Batteries For General Waste (Trash)

Alkaline Batteries

Alkaline batteries are not rechargeable and do not contain any regulated hazardous materials. From a life cycle and energy management standpoint, recycling an alkaline battery is more environmentally detrimental than disposing of it directly in the trash; i.e., landfilling.

Princeton University follows this guideline and does not recycle alkaline batteries. Please help our Building Services staff and refrain from placing alkaline batteries in the universal waste/recycling pails.

Fig 1



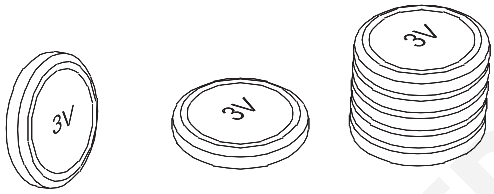
Batteries For Recycling

The following batteries are collected for recycling and are prohibited from disposal in the general trash. Building Services provides containers in research buildings on campus for collecting batteries approved for recycling.

Lithium Batteries

Lithium batteries are typically non-rechargeable and contain lithium, a water reactive alkali metal. They are commonly known as "button cell" batteries due to their small size. They are commonly found in watches, laser pointers, computer motherboards, and other electronic devices that require a power source of small size.

Fig 2



Nickel/Metal Hydride (Ni-MH) Batteries

Ni-MH Batteries contain a NiOOH positive electrode and a water reactive, metal alloy forming the negative electrode. Batteries of this type are rechargeable and available in sizes similar to alkaline batteries (size AAA, AA, C, and D).

Nickel/Metal Hydride (Ni-MH) batteries can be identified by the markings "RECHARGEABLE" OR "Ni-MH".

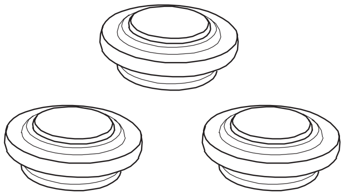
Fig 3

Mercury and Silver Oxide Batteries

Non-rechargeable batteries similar in appearance to the lithium button cell batteries mentioned above. Mercury and silver are toxic

Although this type of battery is becoming increasing rare, it may still be found in older equipment.

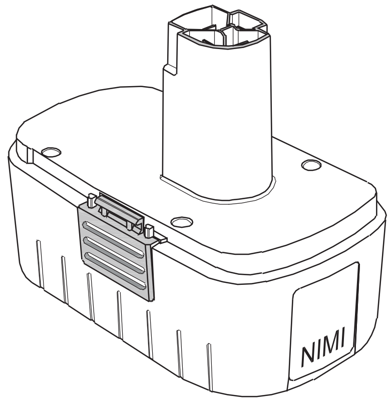
Fig 4



Nickel-Cadmium (Ni-Cad) Batteries

Ni-Cad batteries are a very common rechargeable battery found in many devices, most commonly in cordless power tools. The presence of cadmium, a

Fig 5

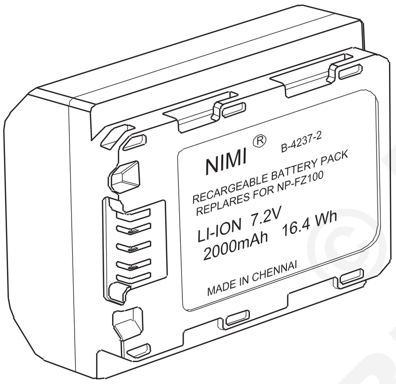


toxic metal, requires this battery to be recycled. Ni-Cad batteries are available in a host of sizes from large rectangular devices to smaller sizes akin to alkaline batteries.

Lithium-Ion Batteries

Lithium-ion batteries are most commonly found in devices that drain a significant amount of power quickly such as cameras, cordless power tools and, most commonly, laptop computers. They come in sizes similar to that of Ni-Cad batteries. A number of these batteries manufactured by Sony in Dell, Sony, Apple, Lenovo, Panasonic, Toshiba and Sharp laptop computers have been recalled in the past due to possibility of a dangerous short circuit causing the units to become unstable, posing a risk of explosion. These batteries must be recycled as universal waste.

Fig 6



FUN FACT

Recyclable batteries are categorized by the EPA as universal waste, i.e. hazardous but common (other examples include pesticides and mercurylamps). While storage and shipping requirements are less stringent, proper disposal is mandatory.

Lead-Sulfuric Acid Batteries

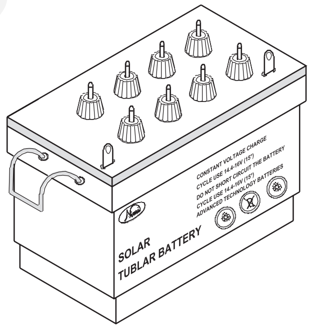
Lead-acid batteries are commonly known as car batteries. They contain both a toxic heavy metal (lead) and corrosive liquid (sulfuric acid), both of which are hazardous materials.

Smaller versions of this battery are often found in uninterruptable power supplies (UPS) and emergency lighting systems. They are rechargeable but have a lifespan of 3-5 years.

Due to their size, these batteries are not collected in normal lab recycling containers, but rather large blue plastic drums. Collection drums are located in the following areas: Engineering Quadrangle loading dock, Lewis Thomas Lab loading dock, Carl Icahn Lab loading dock, and Frick Chemistry stockroom.

Contact EHS for more information about recycling batteries.

Fig 7



FUN FACT

To prevent short-circuits and potential fire hazard during storage and transport, battery terminals must be taped over prior to placing the battery into the receptacle.

Power — Related Theory For Exercise 1.8.97

Solar Technician (Electrical) - Basic circuits of solar panel, Charge controller, Battery bank and inverter

Solar Photovoltaic Electrical system

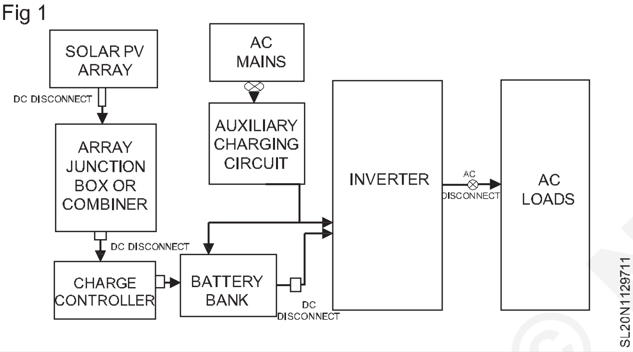
Objectives: At the end of this lesson you shall be able to

- **appraise different components of the Solar PV electrical system.**

A photovoltaic (PV) system is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. Although PV systems can operate by themselves as off-grid PV systems, let us focus on systems connected to the utility grid, or grid-tied PV systems.

Fig 1 Block diagram showing components of Solar PV system

Fig 1



The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount of energy, but can be linked together with other panels to produce higher amounts of energy as a solar array. The solar array could be a series, parallel or series-parallel combination of solar PV panels.

The electricity produced from a solar panel (or array) is in the form of direct current (DC). Although many electronic devices use DC electricity, including your phone or laptop, they are designed to operate using the electrical utility grid which provides (and requires) alternating current (AC). Therefore, in order for the solar electricity to be useful it must first be converted from DC to AC using an inverter. This AC electricity from the inverter can then be used to power electronics locally, or be sent on to the electrical grid for use elsewhere.

System Components

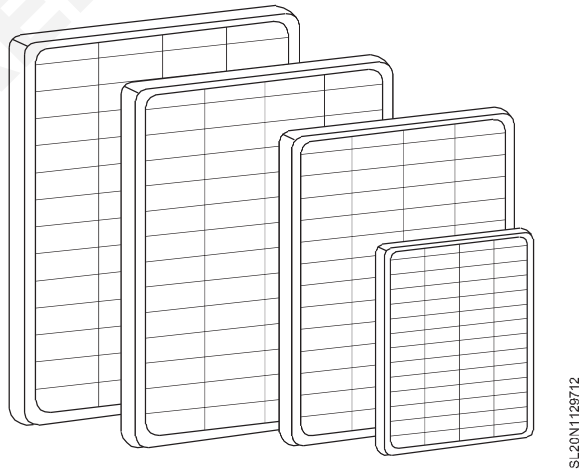
In addition to the solar panels, there are other important components of a PV system include charge controllers, inverters, racking, wiring, combiners, disconnects, circuit breakers and electric meters.

Solar Panel

A solar panel consists of many solar cells with semiconductor properties encapsulated within a material to protect it from the environment. These properties enable the cell to capture light, or more specifically, the photons from the sun and convert their energy into useful electricity through a process called the photovoltaic effect. On either side of the semiconductor is a layer of conducting material which “collects” the electricity produced. The illuminated side of the panel also contains an anti-reflection coating to minimize the losses due to reflection. The majority of solar panels produced worldwide are made from crystalline silicon, which has a theoretical efficiency limit of 33% for converting the Sun’s energy into electricity. Many other semiconductor materials and solar cell technologies have been developed that operate at higher efficiencies, but these come with a higher cost to manufacture.

Fig 2 Solar panel

Fig 2



Inverters

An inverter is an electrical device which accepts electrical current in the form of direct current (DC) and converts it to alternating current (AC). For solar energy systems, this means the DC current from the solar array is fed through an inverter which converts it to AC. This conversion is necessary to operate most electric devices or interface with the electrical grid. Inverters are important for almost all solar energy systems and are typically the most expensive component after the solar panels themselves.

Power Related Theory For Exercise 1.8.98-104

Solar Technician (Electrical) - Basic circuits of solar panel, Charge controller, Battery bank and inverter

Classification of inverters

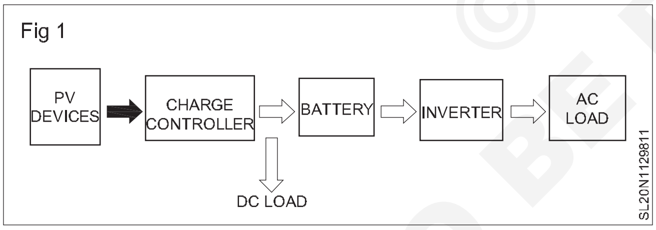
Objectives: At the end of this lesson you shall be able to
- **Differentiate between types of SPV systems.**

Based on the necessity in a solar PV electrical system different types of inverters are in use. Quite often the type of Inverter used helps in naming the type of solar PV electrical system itself. Accordingly we have Standalone SPV system, Hybrid system, Grid tied SPV system and Grid interactive SPV system in use.

Stand alone or off-grid inverter

Standalone SPV system is normally preferred in places where electricity is not available. Hence it is suitable for remote areas, land or water bodies where Grid supply is not available. Examples: Border Military service camps, naval services, farm houses, mountains, forests, resorts etc. the main components include Battery backup and inverter. An AC main from Grid is not used. Solar energy, the only source is used to charge the battery bank and day lighting. During night Battery provides the energy input to inverter. Loads are normal AC loads and can be any. DC loads also can be used after charge controller. No AC output when battery bank voltage goes below its designed value.

Fig 1 Standalone SPV system

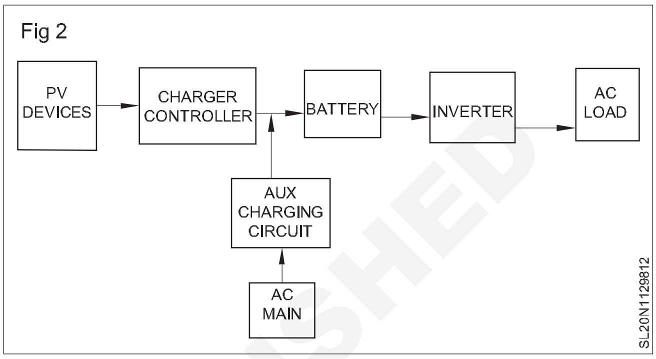


Hybrid inverter

When we add an option of additional source of charging to the standalone solar PV system, we get the Hybrid Inverter based SPV system. Solar energy is the main source for charging the battery. Additional energy requirement is supplemented by AC mains. An auxiliary charging circuit helps charge the battery in the absence of solar energy. In the absence of sunlight either partially or totally and while the system is not able to supply AC power to load, then the additional energy is drawn from AC mains.

AC mains power is converted to DC power by rectifiers to supply additional energy input to the battery. Diesel generator is also one of the choices, in the absence of AC mains power. Both AC mains and Diesel generator are Non-renewable.

Fig 2 Hybrid Solar PV electrical system

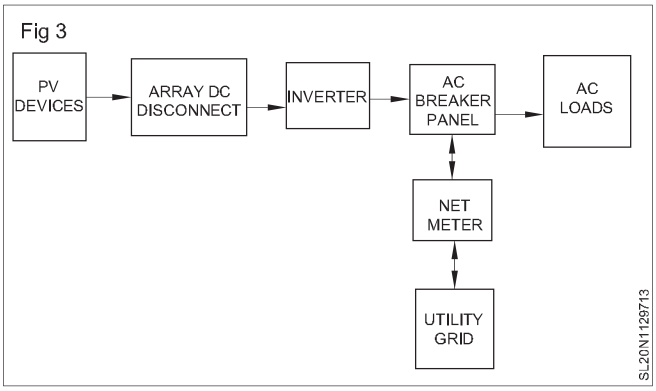


Other renewable energy sources such as wind or hydro may also be used to expand the scope of hybrid SPV systems. Priority of charging starting from 1 to solar energy, followed by other sources can be set by including electronic circuits in the input of battery bank.

Grid-tied inverter

No battery is used hence no back-up of solar energy is available. Generation is possible only when sun light is there.

Fig 3 Grid tied Solar PV system



Solar energy is directly converted to AC by a Grid-tied Inverter and supplied to the grid. When Grid is shut down solar input is disconnected and no output from the Grid tie inverter. Load shares the inverter output so that remaining is supplied to the grid. When load draws more than generated power the excess only is drawn from Grid. The normal AC energy meter in the Grid input point is replaced by a utility meter (also known as Bi-directional energy meter) to get the net usage of electricity by the customer.

This type allows the consumer as an electricity producer and government pays for it. Hence proper approval by government is to be taken before installation.

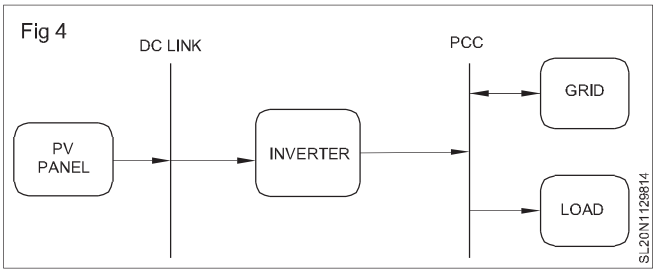
Grid interactive SPV system

This is a combination of Off grid battery backup SPV system and On grid/grid tied SPV system. Hence it has advantages of both. When grid power is available this functions similar to the On grid system. When grid shuts down this will work like off grid system by changeover of Solar array connections. An off grid system at the load end of an ON grid system also provide similar results.

A grid-interactive solar system generates clean power from the unlimited energy of sunlight. Grid-interactive inverters can also use other renewable sources such as wind or hydro power. When the sun shines, the PV system charges its deep cycle solar batteries and feeds all excess clean power into the electricity grid via the inverter.

When there is no solar power because it's night, the system can draw power from the electricity grid. When there is a power failure, the inverter draws clean power from the solar panels and batteries to meet the electricity needs of your home or business. Then it is a stand-alone system.

Fig 4 Grid interactive SPV system



A grid-interactive photovoltaic (PV) system uses solar energy to generate renewable power that charges batteries for use during power failures and feeds power into the electricity grid.

Grid-tied systems feed green energy into the electricity grid but must disconnect if the grid goes down. Tied systems receive credits and incentives for feeding green power into the grid but they can't generate energy for their own use when grid electricity is unavailable.

Grid-interactive systems also feed power into the grid but they can keep generating green energy from their PV modules and battery backup systems and use this electricity to meet their own needs.

Selection of solar inverter or Power Conditioning Unit (PCU)

Objectives: At the end of this lesson you shall be able to
- **select a suitable solar inverter or PCU for a given application.**

Solar Power Conditioning unit (PCU) is an integrated system consisting of a solar charge controller, inverter and a Grid charger. It provides the facility to charge the battery bank through either a Solar or Grid/DG set. The PCU continuously monitors the state of battery voltage, solar power output and the load. Due to constant usage of power, if the battery voltage goes below a set level, the PCU will automatically transfer the load to the Grid/DG power and also charge simultaneously. The PCU always gives preference to the solar power and will use Grid/DG power only when the solar power / battery charger is unable to meet the load requirement.

Solar Power conditioning Unit (PCU) should be a powerful hybrid solar inverter with advanced MPPT technology based solar charge controller, Digital display, and purely safe form short-circuits. Heavy load handling solar PCU shall be an Industrial design, heavy built for running power load such as 2 Air-conditioners and lighting load such as fans, lights, computers, printers, Xerox machine used in home, office and commercial space. It should have conversion efficiency up to 97% through MPPT technology and Connect solar panels up to rated kW. It should give pure sine wave output and have multiple MCBs' Protection for safety to connected load.

We can select the Solar PCU based on descriptions in the product manual such as Capacity (kW), Technology (Sine wave, MPPT etc), allowed power Load, Batteries required, Solar panel voltage (voc), Solar panel current, Full Battery Recharge Time, Inverter monitoring Displays namely LED display and LCD display for customer friendly monitoring system etc.

Specification of a PCU

The LED display may have

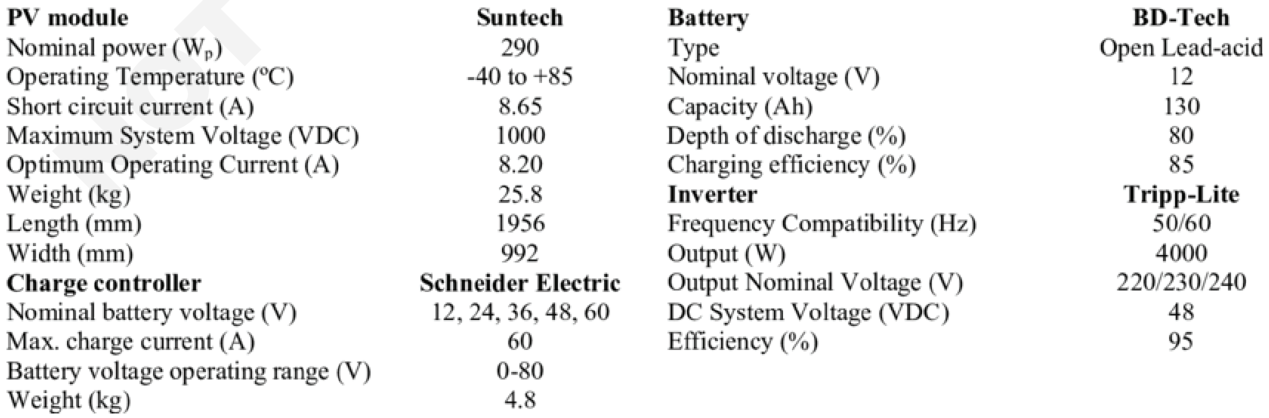
- grid led (green) – grid power is available
- pv led (green) – solar is available
- inverter led (green) – inverter is switched on
- battery led - battery charging (blinking) / battery discharging (led steady),
- fault led (red) – inverter is faulty

The LCD display may have

- battery voltage – charge level of battery
- load % - power consumption as a % of total inverter power
- output voltage
- pv voltage – solar panel generating voltage
- pv current – solar panel generating power in amps
- grid voltage – utility grid voltage level
- grid charging current – amp with which battery is being charged
- electricity saved - kwh

Collect product profiles from different manufacturers and compare the specifications. A sample one is given at Fig 1.

Fig 1



PV module	**Suntech**	**Battery**	**BD-Tech**
Nominal power (W_p)	290	Type	Open Lead-acid
Operating Temperature (ºC)	-40 to +85	Nominal voltage (V)	12
Short circuit current (A)	8.65	Capacity (Ah)	130
Maximum System Voltage (VDC)	1000	Depth of discharge (%)	80
Optimum Operating Current (A)	8.20	Charging efficiency (%)	85
Weight (kg)	25.8	**Inverter**	**Tripp-Lite**
Length (mm)	1956	Frequency Compatibility (Hz)	50/60
Width (mm)	992	Output (W)	4000
Charge controller	**Schneider Electric**	Output Nominal Voltage (V)	220/230/240
Nominal battery voltage (V)	12, 24, 36, 48, 60	DC System Voltage (VDC)	48
Max. charge current (A)	60	Efficiency (%)	95
Battery voltage operating range (V)	0-80		
Weight (kg)	4.8		

Wall mount or array-mount inverter

The ideal place to house string inverters on commercial rooftop solar projects is indoors in a climate-controlled, locked room — but that's not always feasible. When ground-level mounting options are scarce, installers often put these fragile power electronics on the rooftop alongside the array.

Inverters mounted in rooftop

String inverters

Central inverters

Micro inverter

Switching ON and shut down procedure of a solar inverter

Objectives: At the end of this lesson you shall be able to
- **switch ON or Shut down based on procedure**

Normally switching ON the Solar inverter (hence a solar PV system) is to be done in a sequence. Switch ON DC isolator first, followed by AC isolator, followed by solar supply main switch.

While shutting down, switch OFF solar supply main switch first, followed by solar AC isolator (Disconnect), then by PV Array and DC Isolator (Disconnect) and then Inverter Isolator (Disconnect). The solar PV system should now be completely switched off. All lights and screen displays will be dead. Keep the system off for a minimum of five minutes before you restart.

Shutdown system:

1 Turn off the main DC battery isolator

2 Turn off the Solar Array AC Main Switch located in the switchboard or next to the inverter

3 In case you have 2 AC Switches, both have to be shutdown

4 Turn off the Solar Array DC Main Switch located next to the inverter

5 Please also check the shutdown procedure on the main switchboard

To restart the system

1 Turn on the Solar Array DC Main Switch located next to the inverter

2 Turn on Solar Array AC Main Switch located in the switchboard and/or next to the inverter

3 Turn on the main DC battery isolator

To confirm the operation of the system, check inverter display while full sun is shining on the panels.

IEC Standard followed for Inverter in solar projects

Objectives: At the end of this lesson you shall be able to
- **appraise governing quality standards.**

The International Certification Bodies – an Introduction

Leading national and international organizations, involved in the development of solar power generating systems, create certification standards that dictate the safety requirements and often durability requirements of fuses used in solar systems. While some standards are mandatory (violators may be prosecuted as per law), others are just for elevating the product standard and to include industry best practices and benchmarks. Leading organizations involved in developing standards, in the field of solar power are:

- IEC: International Electro-technical Commission
- UL: Underwriter Laboratories Inc.
- IEEE: Institute of Electrical and Electronics Engineers
- CEN: European Committee for Standardization

Leading standards focusing on inverters for solar power systems

The quality of a solar inverter is important as it's usually the first component in a solar power system that might need replacement. Besides durability, the solar inverter's efficiency while converting the electricity produced by the solar panel (DC) to electricity consumed by the loads (AC) is important, as it directly influences the solar system's performance.

The following standards list requirements for solar inverters such as the desired nameplate information, requirements for safe operation of inverters, procedures for measuring efficiency, general standard for inverters connected in independent power system, and many other requirements.

- EN 50524 (Data Sheet and Name Plate for Photovoltaic Inverters)
- EN 50530 (Overall Efficiency of Photovoltaic Inverters)
- UL 1741 (Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources)
- IEC 61683 (Power conditioners – Procedure for measuring efficiency)
- IEC 62109-1 (Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements)
- IEC 62109-2 (Safety of Power Converters for Use in Photovoltaic Power Systems – Part 2: Particular Requirements for Inverters)

Inverter room planning for mega projects

Objectives: At the end of this lesson you shall be able to
- **plan for a inverter room**

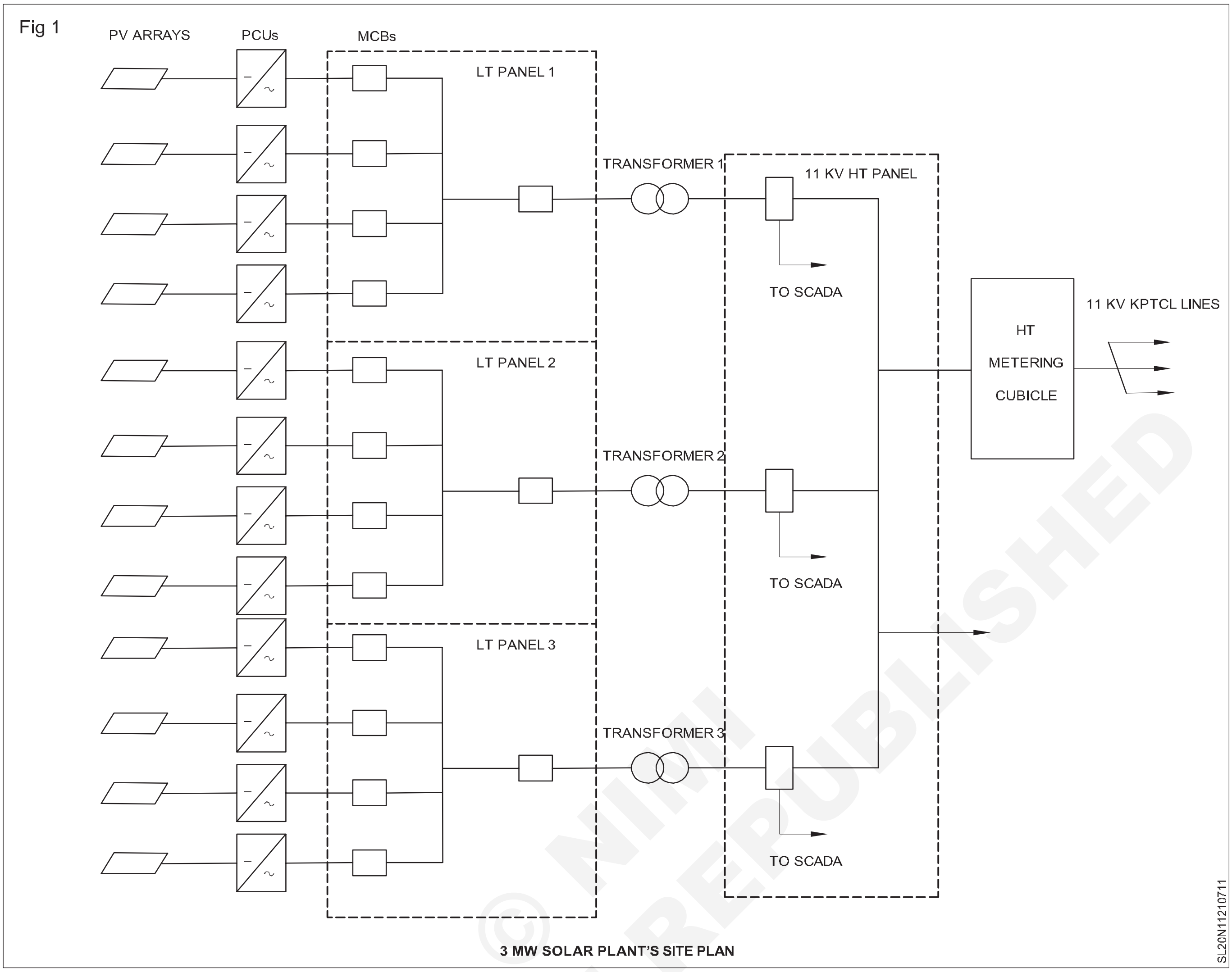
Central inverters, suitable for mega projects, are highly efficient while being compatible with distinct features of the grid-like -- fluctuation management, balancing, etc. These types of solar inverters are generally very huge and have their own storage room, exhaust system, etc. They are generally available with a capacity of 400 KW or more.

Central inverters are generally used for large commercial installations, industrial facilities or industrial facilities or utility-scale solar farms as central inverters support uniform and consistent production throughout. They are generally not preferable for residential requirements as their much smaller counterpart -- string inverters -- are sufficient for fulfilling household energy requirements. These have Advantages such as Centralized control leading to ease of management, Optimized per watt cost, Highly efficient and Easy installation.

Normally, if 1 MW is the size of the plant, say, 4 inverters (PCUs) with a capacity of 250 kW each can be used. These 4 inverters are fed from huge solar array. For example if 250 W modules used, then there are approximately 13,400 modules in multiple strings with say 24 modules per string feed the DC power input to the 4 central inverters. The solar photovoltaic modules are connected such that a voltage of 415 volts at 250 kW is generated at the output of each inverter. The AC combiner combines the outputs from 4 inverters to get 1 MW generation. This is stepped up to 11 kV by a step-up transformer and connected to the existing 11 kV grid. Naturally this requires approximately 1 acre size of landscape together for all these components. The inverter room comprises 4 inverters(PCUs), AC combiners and SCADA monitoring cabin. This room is surrounded by solar array, 11 KVA transformer, grid network etc. Additionally lightning arrestor, maintenance room are also there in this location.

A layout for typical 3 MW solar plant in Karnataka is shown below for illustration.

Fig 1 A 3 MW Solar plant's site plan



Integration of inverters in large PV projects

Objectives: At the end of this lesson you shall be able to

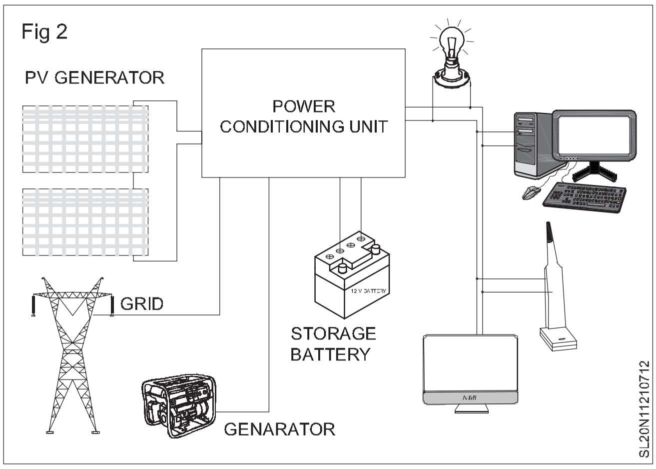
- **obtain an idea on large scale integration**

With reference to the above mentioned solar plant let us discuss the integration.

The 3 MW Plant is divided into three independent segments of one MW each. Each segment is equipped with four Inverters of 250 kW each and grouped together to form one LT panel. Depending on the mix of 225 & 240 Wp modules, 45 to 46 PV strings are connected in parallel to each single Inverter. Each string consists of 24 modules connected in series. The power generated from 3 MW PV Plant at 0.415 kV is stepped up to 11 kV with the help of three step-up transformers and connected to the existing 11 kV lines.

Solar PV integration involves all the works related to such huge plants. It begins with bidding the tender called by the organization who is calling for. After winning the tender, right from site inspection, preparing the site, planning and arranging the components and other store required as per the blueprint approved, procurement and storing, making foundations and mounting the structures, installing solar panels, construction of inverter rooms, installing inverters and associate equipment, wiring and connections, conducting quality tests, installation and commissioning of all solar arrays, inverter and combiners, after due verifications and approval connecting to grid are all included in the Solar PV integration works of a large PV projects.

Fig 1 Solar PV integration



Overview of PV System Software

Objectives: At the end of this lesson you shall be able to
- **get an initiative to use a PV system design software**

The success of the solar PV integration lies with proper planning and execution of the project. It needs accurate design of the complete plant. Adequate knowledge of available technology, components variations, market provisions, manufacturers around, import essentials, logistics, manpower requirement etc. supports the design team.

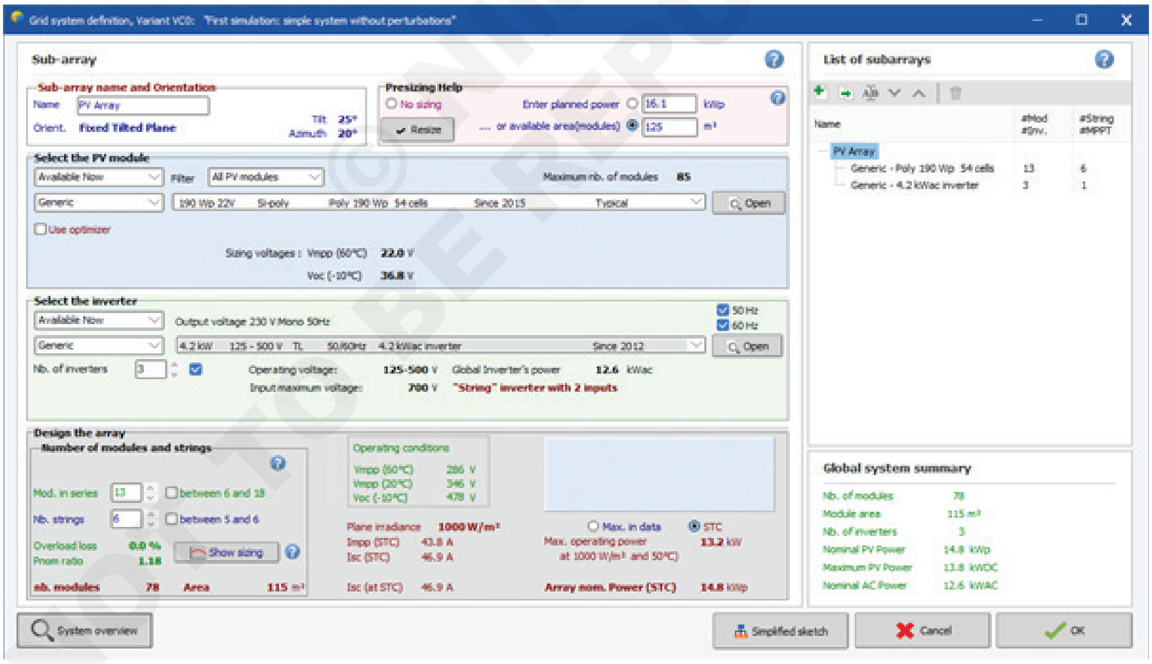
PV system software is one such tool which simplifies the work of the design team to great extent. It even starts from analyzing solar irradiation location wise and guides best approach for designing.

PVsyst is a PC software package used generally for the study, sizing, simulation and data analysis of complete PV systems. While practically using this software we may encounter some limitations which could alter the predictions and thus may affect the design of our system at an early stage & project viability / bankability.

A lot of financial decisions are taken based on the simulation report which is given as an output by the software. PVsyst software is designed to be used by architects, engineers, and researchers. It is also a very useful educative tool. It includes a detailed contextual Help menu that explains the procedures and models that are used, and offers a user-friendly approach with a guide to develop a project. PVsyst is able to import meteo data, as well as personal data from many different sources. PVsyst presents results in the form of a full report, specific graphs and tables, and data can be exported for use in other software.

Fig 1 – A window of PV syst software

Fig 1



Grid system definition, Variant VC0: "First simulation: simple system without perturbations"

Sub-array

Sub-array name and Orientation
Name: PV Array
Orient. Fixed Tilted Plane
Tilt 25°
Azimuth 20°

Presizing Help
○ No sizing
Enter planned power ○ 16.1 kWp
... or available area(modules) ● 125 m²

Select the PV module
Available Now
Filter: All PV modules
Maximum nb. of modules 85
Generic
190 Wp 22V Si-poly Poly 190 Wp 54 cells Since 2015 Typical
☐ Use optimizer
Sizing voltages : Vmpp (60°C) 22.0 V
Voc (-10°C) 36.8 V

Select the inverter
Available Now
Output voltage 230 V Mono 50Hz
☑ 50 Hz
☑ 60 Hz
Generic
4.2 kW 125 - 500 V TL 50/60Hz 4.2 kWac inverter Since 2012
Nb. of inverters 3 ☑
Operating voltage: 125-500 V
Global Inverter's power 12.6 kWac
Input maximum voltage: 700 V
"String" inverter with 2 inputs

Design the array
Number of modules and strings
Mod. in series 13 ☐ between 6 and 18
Nb. strings 6 ☐ between 5 and 6
Overload loss 0.0 %
Pnom ratio 1.18
nb. modules 78 Area 115 m²

Operating conditions
Vmpp (60°C) 286 V
Vmpp (20°C) 346 V
Voc (-10°C) 478 V

Plane irradiance 1000 W/m²
Impp (STC) 43.8 A
Isc (STC) 46.9 A
Isc (at STC) 46.9 A

○ Max. in data ● STC
Max. operating power at 1000 W/m² and 50°C) 13.2 kW
Array nom. Power (STC) 14.8 kWp

List of subarrays

Name	#Mod #Inv.	#String #MPPT
PV Array		
Generic - Poly 190 Wp 54 cells	13	6
Generic - 4.2 kWac inverter	3	1

Global system summary
Nb. of modules 78
Module area 115 m²
Nb. of inverters 3
Nominal PV Power 14.8 kWp
Maximum PV Power 13.8 kWDC
Nominal AC Power 12.6 kWAC

System Design Board

The system design is based on a quick and simple procedure:

- Specify the desired power or available area
- Choose the PV module from the internal database
- Choose the inverter from the internal database and PVsyst will propose an array/system configuration, that allows you to conduct a preliminary simulation.

The software embeds a color-coded warning / errors messaging system. If there's a mismatch, issue, warning with your design, you will be warned within the proper frame.

There are other software available over the internet similar to the above. We can select, purchase and use for designing the solar PV plant.

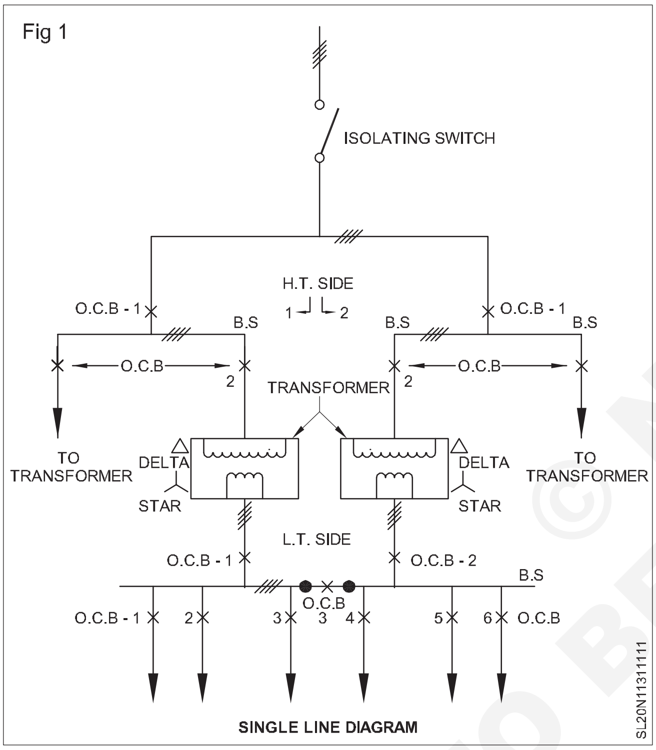
Single Line Diagram (SLD)

Objectives: At the end of this lesson you shall be able to
- **draw a single line diagram**

The electrical distribution system is depicted by a graphic or pictorial representation known as a single line diagram (SLD). A single line is used to show the complete system or a portion of it. It is very much adaptable and all-inclusive because it can show even simple DC circuits or a complex three-phase system as well.

Fig 1 A sample SLD

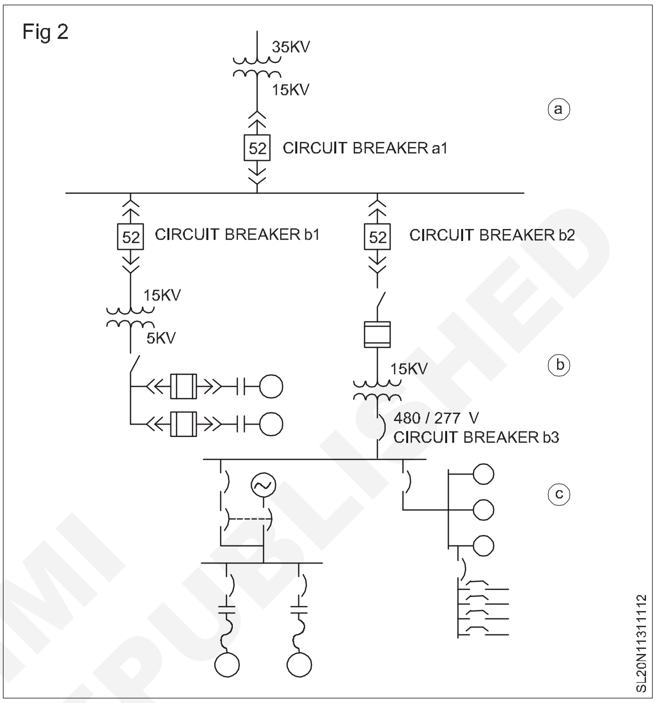
Fig 1



When understanding a single line diagram, we should always start at the top where the highest voltage is and go down to the lowest voltage. This helps to keep the voltages and their paths straight. It is easily explained in three steps here.

Fig 2 Industrial SLD

Fig 2



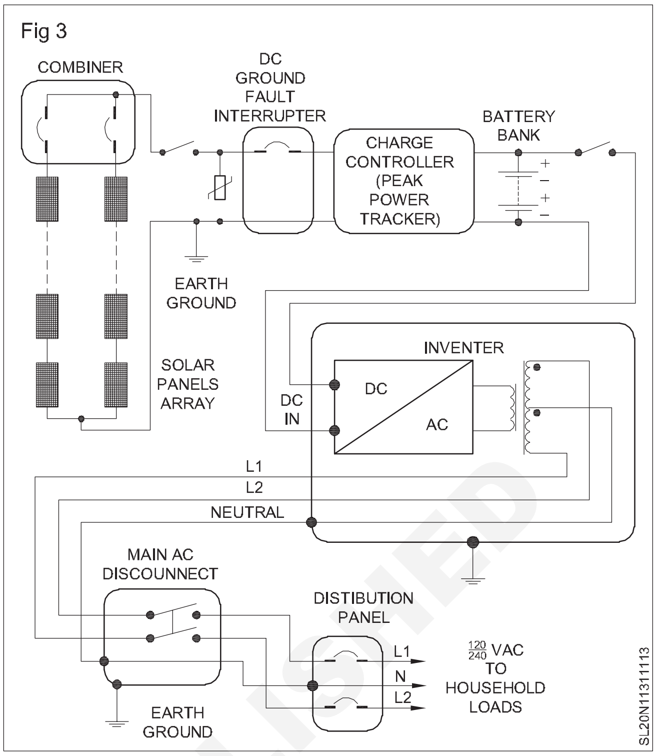
A Starting at the top, see a transformer feeds power to the whole system. The transformer steps the voltage down from 35kV to 15kV. It is indicated by the numbers next to the transformer symbol. Once the voltage has been stepped down, a draw-out circuit breaker (a1) is encountered. We can assume this circuit breaker can handle 15kV, since it is attached to the 15kV side of the transformer and nothing else is indicated on the SLD. Following the draw-out circuit breaker (a1) from the transformer, it is attached to a heavier, horizontal line. This horizontal line represents an electrical bus, which is a means used to get electricity to other areas or circuits.

B Look at two more draw-out circuit breakers (b1 and b2) attached to the bus and feed other circuits. They are at 15kV, since there has been no indication of voltage change in the system. Attached to the draw-out circuit breaker (b1), a step-down transformer is used to take the voltage in that area of the system from 15kV down to 5kV. On the 5kV side of this transformer, a disconnect switch is shown, which is used to connect or isolate the equipment below it from the transformer. The equipment below the disconnect is at 5kV, since nothing indicates the contrary. The equipment attached to the lower side of the disconnect switch are two medium-voltage motor starters. A number of starters could be connected depending upon the particular system requirements. Now locate the second draw out circuit breaker (b2) that is attached to a fused disconnect switch and then connected to a step-down transformer. Notice that all the equipment below the transformer is now considered low voltage equipment, because the voltage has been stepped down to a level of 600 volts or lower. The last piece of electrical equipment in the middle portion of the diagram is another circuit breaker (b3). This time, however, the circuit breaker is a fixed low voltage circuit breaker, as indicated by the symbol. Moving to the bottom area of the SLD, notice that the circuit breaker (b3) in the middle is connected to the bus in the bottom portion.

C To the bottom left and connected to the bus is another fixed circuit breaker. Look carefully at the next grouping of symbols. There is an automatic transfer switch symbol. Also, notice that a circle symbol which represents an emergency generator is attached to the automatic transfer switch. This area of the single line diagram tells us that it is important for the equipment connected below the automatic transfer switch to keep running, even if power from the bus is lost. You can tell from the single line diagram that the automatic transfer switch would connect the emergency generator into the circuit to keep equipment running, if power from the bus were lost. A low-voltage motor control circuit is attached to the automatic transfer switch through a low-voltage bus. Make sure you recognize these symbols. Although we do not know the exact function of the low voltage motor control in this circuit, it is obvious that it is important to keep the equipment up and running. A written specification would normally provide the details of the application. On the right side of the third area there is another fixed circuit breaker connected to the bus. It is attached to a meter center, as indicated by the symbol formed by three circles. This indicates that the electric company is using these meters to keep track of power consumed by the equipment below the meter center. Below the meter center is a load center or panel board that is feeding a number of smaller circuits. This could represent a load center in a building that feeds power to the lights, air conditioning, heat and any other electrical equipment connected to the building.

Such diagrams tell about electrical system connections and equipment. Although some single line diagrams may appear overwhelming by virtue of their size and the wide variety of equipment represented, they can all be analyzed using the same step-by-step method.

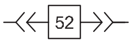
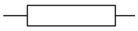
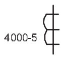
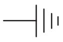
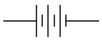
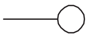
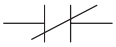
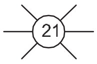
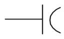
FIG 3 SLD of Off-grid SPV

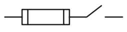
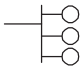
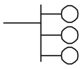
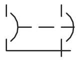
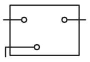
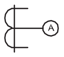
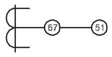


Identifying different component symbols in SLD

The table below shows often universally accepted electrical symbols to represent the different electrical components and their meaning within a circuit or system. These help in interpreting SLDs and understand the electrical symbols.

Individual electrical symbols

Symbol	Identification	Explanation
	Transformer	Represents a variety of transformers from liquid filled to dry types. Additional information is normally printed next to symbol indicating winding connections, primary /secondary voltages and KVA or MVA ratings.
	Removable or drawout circuit breaker	Normally represents a MV drawout circuit breaker 5kV and above.
	Future removable or drawout circuit breaker position	Represents a structure equipped to accept circuit breaker in the future, commonly known as provisions.
	Non-drawout circuit breaker	Represents a fixed mounted low voltage circuit breaker.
	Removable or drawout circuit breaker	Represents a drawout low voltage circuit breaker.
	Disconnect switch	Represents a switch in low or medium/high voltage applications (open position shown)
	Fuse	Represents low voltage and power fuses.
	Bus duct	Represents low and medium/high voltage bus duct.
	Current transformer	Represents current transformers mounted in assembled equipment. A ratio of 4000A to 5A shown.
	Potential or voltage transformer	Represents potential transformers usually mounted in assembled equipment. A ratio of 480V to 120V shown.
	Ground (earth)	Represents a grounding (earthing) point
	Battery	Represents a battery in an equipment package
	Motor	Represents a motor and is also shown with an “M” inside the circle. Additional motor information is commonly printed next to symbol, such as horsepower, RPM and voltage.
	Normally open (NO) contact	Can represent a single contact or single pole switch in the open position for motor control
	Normally closed (NC) contact	Can represent a single contact or single pole switch in the closed position for motor control
	Indicating light	The letter inside circle indicates the color. The color red is indicated.
	Overload relay	Protects a motor should an overload condition develop.
	Capacitor	Represents a variety of capacitors.
	Ammeter	A letter is usually shown to designate the meter type (A = ammeter, V = voltmeter, etc.)
	Instantaneous overcurrent protective relay	The device number designates the relay type (50 = instantaneous overcurrent, 59 = overvoltage, 86 = lockout, etc.)
	Emergency generator	The symbol is frequently shown in conjuction with a transfer switch.

	Fused disconnect switch	The symbol is a combination of a fuse and disconnect switch with the switch in the open position.
	Low voltage motor control	The symbol is a combination of a normally open contact (switch), overload relay, motor and disconnect device.
	Medium voltage motor starter	The symbol is a combination of a drawout fuse, normally open contact (switch) and motor.
	Meter center	A series of circle symbols representing meters usually mounted in a common enclosure.
	Load center or panelboard	One circuit breaker representing a main device and other circuit breakers representing feeder circuits usually in a common enclosure.
 (or) 	Transfer switch	• Circuit breaker type transfer switch • Non-circuit breaker type transfer switch
	Current transformer with connected ammeter	The instrument connected could be a different instrument or several different instruments identified by the letter.
	Protective relays connected to current transformer	Device numbers indicate types of relays connected, such as: • 67 – Directional overcurrent • 51 – Time overcurrent

System sizing: Selection of components of the Solar Photovoltaic Electrical system and their rating

Objectives: At the end of this lesson you shall be able to
- **size a load**
- **size an inverter**
- **size a battery bank**
- **solar PV array**
- **select other components of a SPV electrical system.**

Sizing means exact matching. Just like we have a size in number or letter(s) for our apparels such as 34, 36, M, XL etc. Same way, we have to identify the components and their specification as suitable for desired SPV system. Though many times discussed, it is good to list here the components of SPV system. Simultaneously let us have look at possible parameters for specification also.

Components	Specifications/Types/Features that influence sizing/selection
Load	AC load DC load Capacity: Watt Hours of usage V, I Rating Days of autonomy Type of load: Resistive (Lamp, TV, Oven, Heater, PC) and Inductive (Pump, Fridge, Air conditioner, Fan) Critical and non-critical load
Inverter	DC input range AC output Watt or kilowatt VA or KVA Power factor For p.f. = 0.8, 1000W = 1250 VA Waveform: Sinusoidal, square wave, Quasi sine wave
Battery Bank	V Voltage Ahr Ampere hour η efficiency DOD Depth of discharge C rating Hours of charging Maintenance or maintenance free
Charge controller	V System voltage I CC rating of Battery bank I > ISC of Solar array (ISC per panel X no of strings) DC input: Vmin to Vmax
Solar array	Panel specification Wp Vm Im ISC VOC All identical panel
Solar structure	Length and breadth based on panel size and number of panels per string as well as per frame Types of mount: Raft, Rack, Pillar, Ballast, Building Integrated, Fixed or Tracker, Manual, semi – automatic, or automatic, single or dual track Foundations based on RCC, roof, slope of tilted roof, soil of ground, rocks, Green bldg

Tools	Survey tools and equipment Foundation tools Installation tools Testing tools Maintenance tools Safety tools

Other components:

- Accessories
- AJB
- Disconnects
- Wire

Load calculation

We have to calculate per day average utilization of electrical energy in 'watt-hours'. We have three methods.

Method 1: Total watt hour of all loads per day

Find out various loads in an installation (House, or school or office or industry). Find their ratings and fill up the following table. If it is not a residence then days/ week also may vary and to be taken into consideration.

Example:

Sl no	Name of load	W rating (W)	No of loads (n)	Hours of use (Hrs)	Whr/load (Whr)	Total Whr (n x Whr)
1	Bulb	100	5	6	600	3000
2	Fan	40	4	8	320	1280
3	Fridge	300	1	20	6000	6000
4	Heater	1000	1	2	2000	2000
5	Television	300	2	10	3000	6000

Total	18280
No of Electrical units consumed = Total Whr ÷1000	18.28
Because 1 unit = 1 KWhr =1000 Whr	units

Hence if we are planning a SPV system it should generate average 18.28 KW per hour. That means 20 KW SPV system. For this we have to size remaining components.

Method 2. Daily average watt hour from twelve months electricity bill

Collect latest 12 months Electricity consumption bills received from Electricity board and fill up the following table. 'latest' means we may calculate from any of the 12 months in between not necessarily from Jan to Dec.

In the bills total units consumed per month would be given so that Amount to be paid is calculated based on this and rate per unit. If bills are generated once in two months then accordingly modify the table. Finally average out for 365 days/year to get daily consumption.

Sl No	Name of month	Units
1	January	138
2	Feb	135
3	Mar	143
4	Apr	150
5	May	165
6	Jun	145
7	Jul	138
8	Aug	142
9	Sep	135
10	Oct	144
11	Nov	154
12	Dec	160
	Total	1749/Annum
	Average daily consumption	1749÷365 = 4.79 units/day
	Approximate units per day	5
	Whr/Day = Units*1000	5000 Whr

Hence if we are planning a SPV system it should generate maximum 5000 W per hour. That means 5 KW SPV system. For this we have to size remaining components.

Method 3: Calculate Whr/Day from sanctioned load

Example:

If the sanctioned load of a residence is 5 KW then the total load shall not exceed 5000 W at any time. If the residence uses full load for one hour then power consumption at this time is 5000Whr or 5 units. Hence if we are planning a SPV system it should generate maximum 5000 W per hour. That means 5 KW SPV system. For this we have to size remaining components.

Check yourself: If in a group of flats the sanctioned load for every 2 BHK flat is 3 KW and for every 3 BHK flat is 5 KW, then calculate the size of the SPV required for this group of flats having 25 no. 2 BHK and 35 no. 3 BHK with a common utility of 10 KW.

System Voltage of a SPV system

For deciding on battery size or charge controller etc. we have to decide on system voltage first. System voltage is the operating DC voltage. Since we have the strings in array, Charge controller, battery bank and input of Solar inverter/PCU all are having operating DC voltage, there needs to be common value to be decided first before we size the ratings of the components individually.

Hence, System Voltage (Vsys) is a DC value in volts selected as working voltage common to all DC Components in a SPV system so that mismatch of level of voltages is avoided. It also depends on Total capacity of the SPV plant aimed at. Because the net power input is to be drawn from solar array and pass on to remaining stages and should also supply energy through inverter to meet the load capacity finally. That is why in the beginning we found the daily need of load in watt-hour.

Based on this the current rating of wires and cables in the system, disconnects etc will be determined for their specifications. Naturally other accessories like connectors, washers, and even tools required all dependable on this selection of system voltage. Hence its importance should understood by the technician and design engineer at this stage to avoid mismatches in components and due to that losses of components or even accidents that may happen.

Recommended values are given in the table:

Capacity of power plant	System Voltage
Less than 1 kW	12 V
1 – 3 kW	24 V
3 – 8 kW	48 – 96 V
10 – 20 kW	120 – 240 V

We can notice here the values of system voltage are multiples of 12 V since we have the unit size of battery is 12 V. Then according to the value preferred based on capacity of the system we can group the batteries in series, parallel or series – parallel combinations.

This is holding good for SPV systems with battery bank i.e. particularly for off-grid SPV systems.

Whereas for On-grid SPV systems like Grid –tied units, we find Solar array only external and the charge controller is in built in the Grid tie inverter. On the output side AC loads are there. Hence in this case we refer to the Solar DC input specifications of the Grid tie inverter and select a center value suitable as system voltage which will be string voltage also later on for the solar array. The technician will get more clarity on this in due course.

Hence in case of grid tied SPV systems the typical values of System voltage would be 50 V, 100V, 200V, 300V, …450 V…750 V. (Not a multiple of 12 V).

Battery bank sizing

From first step, i.e. ‘Load Calculation’ carry forward the daily average consumption by connected loads in watt-hours. This is the AC energy required to be generated by our Off grid SPV system.

Ampere hour per day = (AC energy required)/(System Voltage) Ah

AC energy required is in watthour and system voltage is in Volts

Hence we get ampere hour per day while dividing watthour by system voltage.

Learn here a new word “Autonomy” which is nothing but additional ‘backup time’ required in ‘Days’.

If

Ah = Ampere hour per day which PV system can provide

n = number of days battery backup is required

ᵑb = Battery efficiency

DOD = Depth of Discharge

Then Battery capacity = (n x Ah)/(ᵑb x DOD)

Normally for lowest case it is desired to have ᵑb = 0.9 and DOD = 0.8

Solar panel sizing

The actual energy required to be generated by Solar Array is calculated by considering the losses due to inverter.

Ah required to be generated by Solar PV array =

$$\frac{\text{(Proposed Ah required for the load at System voltage)}}{\text{(Inverter efficiency)}}$$

Average current drawn =

$$\frac{\text{(Ah required to be generated by solar PV array)}}{\text{(Estimated Solar hours per day)}}$$

Total number of panels required in parallel =

$$\frac{\text{(Average current drawn)}}{\text{(current of one panel)}}$$

Total number of panels in series =

$$\frac{\text{(System Voltage)}}{\text{(Voltage of one panel)}}$$

SLDs for small and medium solar PV projects

Objectives: At the end of this lesson you shall be able to
- **draw a SLD for small, medium and mega SPV projects.**

1 Rooftop 1 kW off-grid Solar PV system

If you want to install on the terrace of your house or any building for a minimum 1 kilo watt capacity the the following list of components are required.

Solar PV panels 250 WP x 4 nos, (Sample specifications: Vm = 30 V, Im = 7.5 A, VOC = 34 V , ISC = 8 A, VSYS = 800 V, STC: 1000 W/m2, 25˚C, AM1)

Solar inverter (sample specifications)

Output : AC 230 V, 50 Hz

Power : 1.5 kVA

Solar DC input: 20 V to 60 V, 40 A (Max.)

Battery input: 24 V DC

Solar battery bank: 12 V, 100 AHr x 4 No

Back up time minimum 4 hours

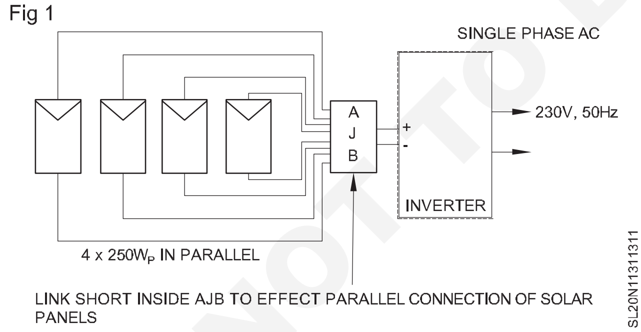
Charge controller type: MPPT, 24 V, 20 A

You have to connect for these specifications, the four numbers solar panels in parallel through AJB and the output would be 30 V @ 30 A which is then fed to DC input of Solar inverter.

Batteries are connected such that a set of two batteries are series and both sets in parallel. Output of this combination will be 24 V, 200 AHr.

The SLD for this given below:

Fig 1 A 1 kW Solar plant SLD with parallel connected panels



Note: Battery bank is not shown

2 Rooftop 1 kW off-grid Solar PV system (Alternative)

Here main difference is specifications of inverter vary.

List of components are required.

Solar PV panels 250 WP x 4 nos, (Sample specifications: Vm = 30 V, Im = 7.5 A, VOC = 34 V , ISC = 8 A, VSYS = 800 V, STC: 1000 W/m2, 25˚C, AM1)

Solar inverter (sample specifications)

Output : AC 230 V, 50 Hz

Power : 1.5 kVA

Solar DC input: 75 V to 150 V, 10 A (Max.)

Battery input: 24 V DC

Solar battery bank: 12 V, 100 AHr x 4 No

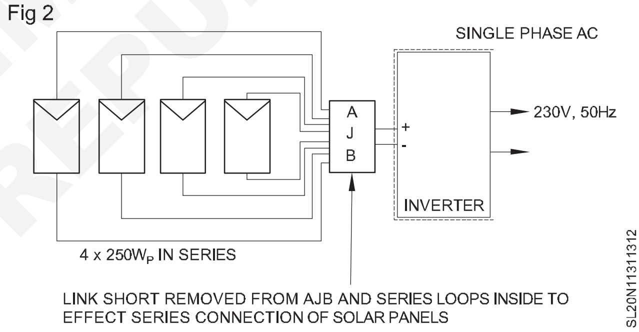
Back up time minimum 4 hours

Charge controller type: MPPT, 24 V, 20 A

You have to connect for these specifications, the four numbers solar panels in series through AJB and the output would be 120 V @ 7.5 A which is then fed to DC input of Solar inverter. Batteries are connected such that a set of two batteries are series and both sets in parallel. Output of this combination will be 24 V, 200 AHr.

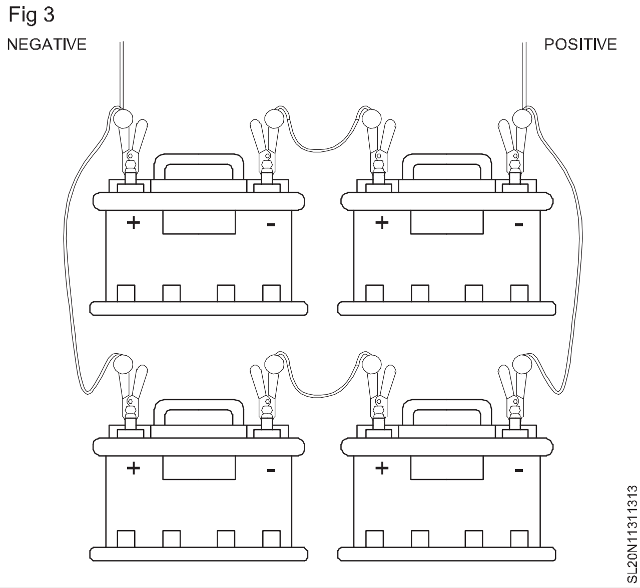
The SLD for this given below:

Fig 2 A 1 kW Solar plant SLD with series connected panels



Battery bank for these two SLDs:

Fig 3 Battery bank 24 V, 200 AHr



3 A 5 kW SPV system

To increase the plant capacity if we go on increase series connected solar panels it will result in Vm multiplies with ‘n’ number of panels used. We should keep at least two points in mind here: (very important)

nVm < 0.8 VSYS

Resulting string voltage should be within mid-point of solar input DC range of the inverter or PCU

In other words, the specifications of inverter or PCU should be decided based on the Solar array combination.

For a 5kW SPV plant say minimum 5000 W to be generated by solar array, then it can be achieved by grouping 20 number of Solar panels of WP = 250 W in multiple ways. That is:

20 X 250 = 5000. Series connection of all 20 panels. This results in string voltage of 600 V for a VM of 30 V per panel, which will necessitate PCU should have a range of 450 V to 800 V Solar DC input at 10 A.

If this is altered to have two series paths of 10 panels each and both connected in parallel then also we get 5000 W array output with string voltage 300 V but AJB output 300 V, 15.0 A. (if we have VM = 30 V, Im = 7.5 A). Then Solar DC input range for PCU/inverter should be 150 V to 450 V DC at 20 A.

If this is further altered to have four series paths of 5 panels each and all connected in parallel then also we get 5000 W array output with string voltage 150 V but AJB output 150 V, 30.0 A. (if we have VM = 30 V, Im = 7.5 A). Then Solar DC input range for PCU/inverter should be 75 V to 300 V DC at 40 A.

Therefore, observe the variations of above groupings and thereby resulting specification requirements. Accordingly, part list of SLD will vary.

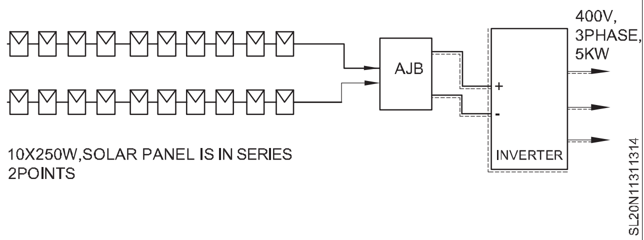
SLD for case 2 is given below:

Fig 4: SLD for 5 kW SPV plant

4 SLD for 20kW SPV plant

We can build 4 number of 5 kW SPV plant and combine the AC outputs of all to get 20 kW AC output with the help of AC combiner.

Fig 4



Otherwise a single 20 kW PCU can be fed with solar array DC input. Let us assume a typical 20kW PCU or inverter have the following specifications:

- Output: AC 400 V, 50 Hz, 3 phase
- Maximum Power output: 25 kVA
- Solar DC input: 450 V to 850 V, 30 A (Max.) X 2 inputs
- Total IM in maximum: 60 A
- Charge controller type: MPPT

We can still use same 250 WP solar panels but we require 80 numbers in this case. We can use 20 panels in one string and have total 4 such strings. Each string output will be 600 V, 7.5 A if specification is same. Two AJBs are required. Each AJB is combining two string outputs in parallel to give 600 V, 15.0 A. You can observe that, the 600 V is mid-point of MPPT input of inverter.

Both the AJBs’ outputs are fed into 2 x MPPT inputs of the inverter. The output will be 3 phase, 400 V, 20 kW at 50Hz. SLD for this is given below:

Fig 5 SLD for 20 kW SPV plant

5 SLD for 100 kW SPV plant

We can combine five such 20 kW segments to generate 100 kW solar power. A box of 20 kW segment represents complete SLD of 20 kW SPV plant. AC combiner is used in the outputs of 5 such segments to deliver 100 kW, 3 phase, 400 V. This if fed to the 11 kVA transformer then the final output is 11kVA, 400 V 3 phase which is directly connected to the H.T. grid.

Fig 5

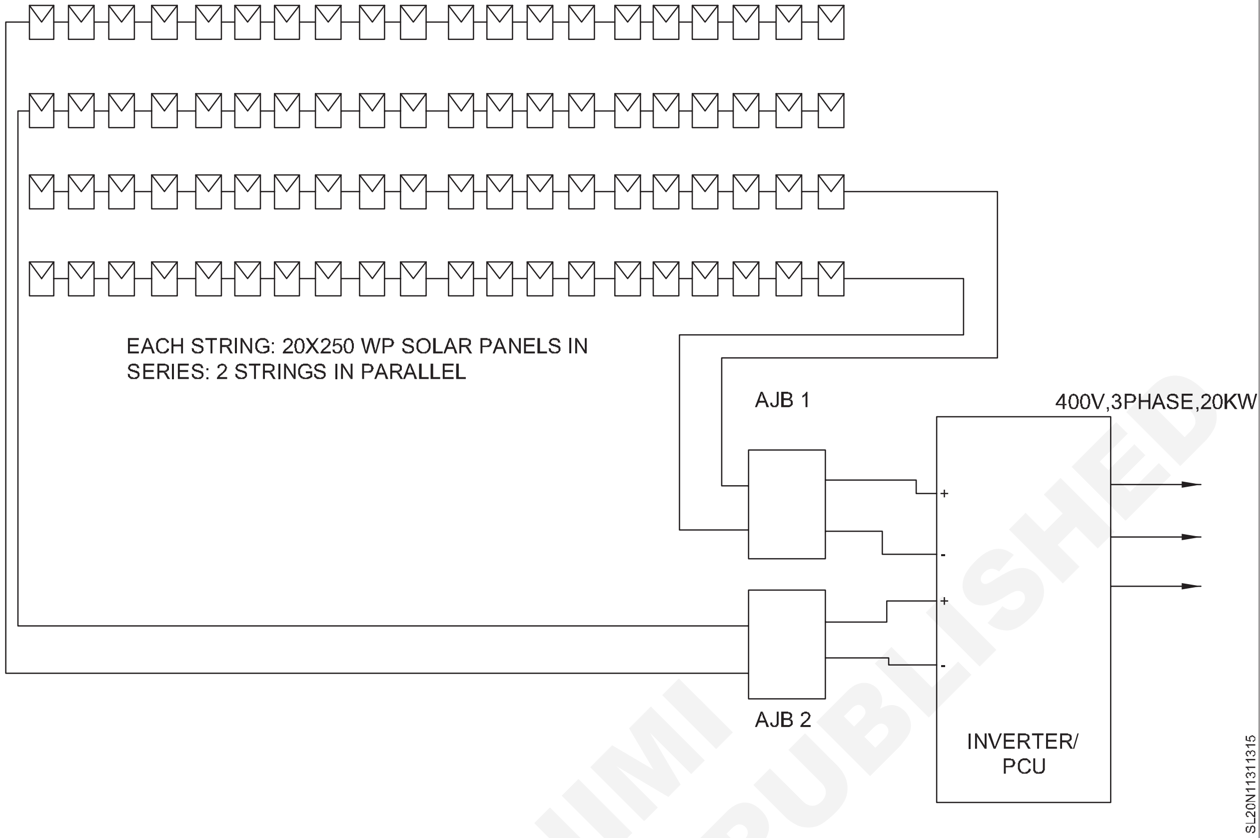
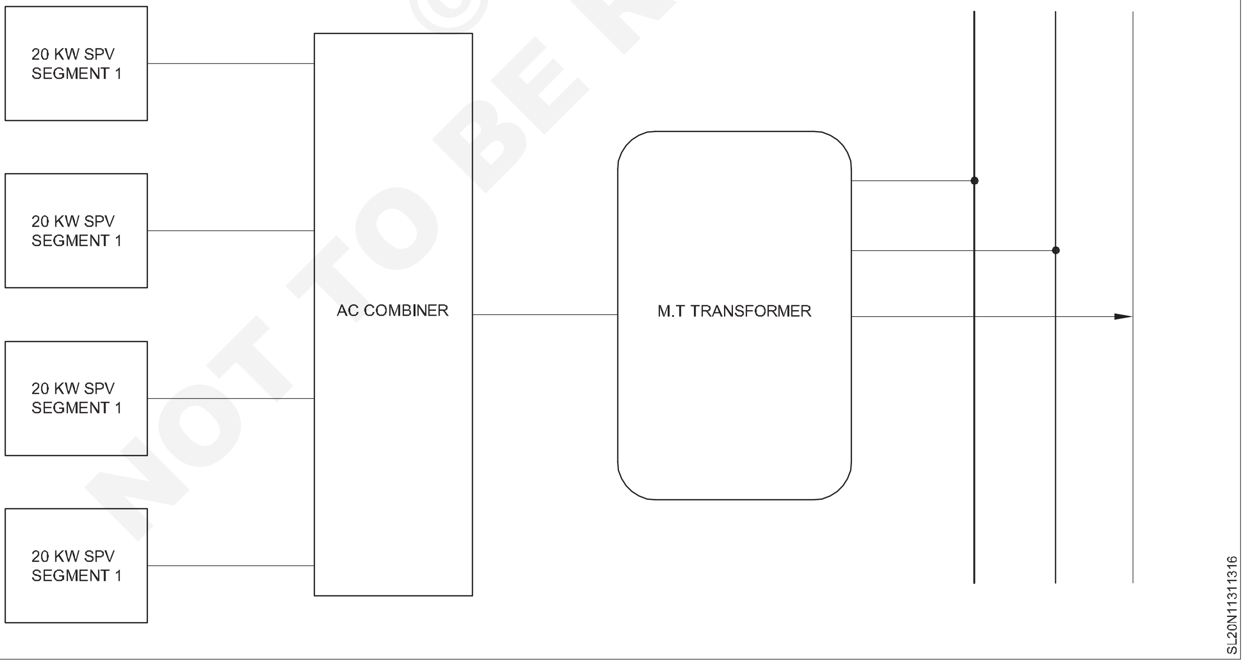


Fig 6 HT SPV plant: 100 kW On-grid

Fig 6



System types based on: Backup requirements, Grid availability, Budget and space

Objectives: At the end of this lesson you shall be able to
- **assess space requirement of a SPV plant.**

Selection of SPV plant for your requirement has to be approached with many guidelines. If the grid is available in your place and generally there is no power cut problem then it is better to go for an ON-grid plant because it earns money. While there is no much power cut keeping an OFF-grid plant but not used much, would be a waste investment.

While more power cut problems are there or in places where nearby grind is not available then the off-grid plant is a boon to the investor provided great utility of generated power is there. Back-up time in hours or days is decided on the need basis. Optimum utilization must be kept in mind to avoid unnecessarily parking the money on backup facility. It will prove loss if regular use is not there.

If proper utility or returns are not feasible then going for higher budget also not advisable. Balancing on financial feasibility and technical viability to be considered. Better market survey helps to earn or save huge money.

Space constraints or excess availability also to be kept in mind so that difficulties of planning a higher capacity in small space or low utilization of available space could be avoided.

Roughly 110 square ft or 10 square meter area is required for a 1 KW installation. Accordingly assess the site and recommend for more capacity. This will benefit the business as well as customer.

Various skill requirements during solar PV plant installation

Objectives: At the end of this lesson you shall be able to
- **acquire information on various skills required in SPV installation.**

While assessing the site the technician need to

- identify the actual work spot and assess the feasibilities
- identify the places to position the different components and draw a plan
- foresee the difficulties that may arise after landing in the work place
- identifying the shadow causing areas that may vary the power output later on
- calculating the space requirement as per the work order
- identifying requirement of additional special tools or services specific to the work place

Accordingly, we can understand the site survey skills

While preparing foundation of solar plant the typical activities would be:

- mark for foundation
- prepare and lay foundation for Solar PV structures on roof top
- prepare and lay foundation for Solar PV structures on ground
- erect the pillar mount

As such, the foundation skills identified are, On rooftop – Marking, Drilling, Fixing anchor bolt, Mounting pole, Mounting solar PV panels, Filling concrete on base etc and On ground – Marking, Digging, Bar bending, Filling concrete mix and Curing concrete are the identified skills.

Skill sets recommended for mounting panels Fabrication of super structure if not available readily (involves structural planning, drawing, dimensions of solar panel, sheet metal works, welding etc), Fitting poles, arms and lever, Mounting or clamping the panels.

When the technician comes to the electrical works he/she has to identify the connectors, crimple the terminals end, interconnect the panels, conduit pipe laying, lay underground cable and connect end terminals to inverter. Assembly of batteries, erecting battery rack and housing batteries, connect battery bank to inverter etc are skills relevant to off-grid plants.

All the above skills are commonly known as installation skills. This is followed by commissioning skills which include check for errors and removing, procedural switch ON of plant, testing and report making, load testing, customer orientation etc.

On-site observation and remote monitoring are post commissioning skills. Status monitoring and recording, reports making, alerting, preventive maintenance, corrective maintenance are other activities that draw importance.

Guidance for Solar Installation by MNRE

Objectives: At the end of this lesson you shall be able to
- **obtain information on MNRE.**

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy to supplement the energy requirements of the country.

- Commission for Additional Sources of Energy (CASE) in 1981.
- Department of Non-Conventional Energy Sources (DNES) in 1982.
- Ministry of Non-Conventional Energy Sources (MNES) in 1992.
- Ministry of Non-Conventional Energy Sources (MNES) renamed as Ministry of New and Renewable Energy (MNRE) in 2006.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. Energy self-sufficiency was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s. The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy in the Department of Science & Technology in March 1981. The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying R&D in the sector. In 1982, a new department, i.e., Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources. In October 2006, the Ministry was re-christened as the Ministry of New and Renewable Energy.

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions. National Solar Mission (NSM) was launched on 11th January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is line with India's Intended Nationally Determined Contributions(INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

Various policy measures undertaken included declaration of trajectory for Renewable Purchase Obligation (RPO) including Solar, Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to March 2022, Must run status, Guidelines for procurement of solar power though tariff based competitive bidding process, Standards for deployment of Solar Photovoltaic systems and devices, Provision of roof top solar and Guidelines for development of smart cities, Amendments in building bye-laws for mandatory provision of roof top solar for new construction or higher Floor Area Ratio, Infrastructure status for solar projects, Raising tax free solar bonds, Providing long tenor loans from multi-lateral agencies, etc.

Recently, India achieved 5th global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

Quality certification, Standards and testing for Grid-connected Rooftop Solar PV Systems/Power Plants

Objectives: At the end of this lesson you shall be able to
- **become informative on Quality standards.**

Quality certification and standards for grid-connected rooftop solar PV systems are essential for the successful mass-scale implementation (in-order to achieve 40 GW of rooftop solar target under 'National Solar Mission' programme) of this technology.

It is also imperative to put in place an efficient and rigorous monitoring mechanism, adherence to these standards. In-addition, a few standards which are still under development/draft need to be introduced in the ongoing rooftop solar PV programmes at the earliest. The relevant standards and certifications for a grid-connected rooftop solar PV system/plant (component-wise, upto LV-side) are given below: [currently, all applicable standards (International and Indian) are listed, and bifurcation of mandatory and advisory is done]

Solar PV Modules/Panels	
IEC 61215/ IS 14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61646/ IS 16077	Design Qualification and Type Approval for Thin-Film Terrestrial Photovoltaic (PV) Modules
IEC 62108	Design Qualification and Type Approval for Concentrator Photovoltaic (CPV) Modules and Assemblies
IEC 61701- As applicable	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1/ IS 16170 : Part 1	Photovoltaic (PV) module performance testing and energy rating –: Irradiance and temperature performance measurements, and power rating
IEC 62716	Photovoltaic (PV) Modules – Ammonia (NH3) Corrosion Testing (Advisory - As per the site condition like dairies, toilets)
IEC 61730-1,2	Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804 (Draft Specifications)	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation (PID). IEC TS 62804-1: Part 1: Crystalline silicon (Mandatory for system voltage is more than 600 VDC and advisory for system voltage is less than 600 VDC)
IEC 62759-1	Photovoltaic (PV) modules – Transportation testing, Part 1: Transportation and shipping of module package units

Solar PV Inverters	
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
(For stand Alone System) BS EN 50530 (Will become IEC 62891) (For Grid Interactive system)	Overall efficiency of grid-connected photovoltaic inverters: This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems. In that case the inverter energizes a low voltage grid of stable AC voltage and constant frequency. Both the static and dynamic MPPT efficiency is considered.
IEC 62116/ UL 1741/ IEEE 1547	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System – Power Conditioners and Inverters
IEC 61000- 2,3,5	Electromagnetic Interference (EMI), and Electromagnetic Compatibility (EMC) testing of PV Inverters (as applicable)
Fuses	
IS/IEC 60947 (Part 1, 2 & 3), EN 50521 IEC 60269-6	General safety requirements for connectors, switches, circuit breakers (AC/DC) Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems
Surge Arrestors	
IEC 61643-11:2011 / IS 15086-5 (SPD)	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods
Cables	
IEC 60227/IS 694, IEC 60502/IS 1554 (Part 1 & 2) BS EN 50618	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation) Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC cables
Earthing /Lightning	
IEC 62561 Series(Part 1,2 & &) (Chemical earthing)	IEC 62561-1 Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561-7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds

Junction Boxes	
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo plastic type with IP 65 protection for outdoor use, and IP 54 protection for indoor use
Energy Meter	
IS 16444 or as specified by the DISCOMs	a.c. Static direct connected watt-hour Smart Meter Class 1 and 2 — Specification (with Import & Export/ Net energy measurements)
Solar PV Roof Mounting Structure	
IS 2062/IS 4759	Material for the structure mounting

Solar Technician (Electrical) - Tests and Measurement of PV Modules and Installation

Guidelines - Best Practices

Objectives: At the end of this lesson you shall be able to

- **obtain information on best practices in Solar PV installation.**

Solar PV Roof Mounting Structure

- Aluminum frames will be avoided for installations in coastal areas.

Solar Panels

- Plants installed in high dust geographies like Rajasthan and Gujrat must have the solar panels tested with relevant dust standards (Applicable standard would be IEC 60068-2-68).

Fuse:

- The fuse shall have DIN rail mountable fuse holders and shall be housed in thermoplastic IP 65 enclosures with transparent covers.

Cables:

- For the DC cabling, XLPE or, XLPO insulated and sheathed, UV-stabilized single core flexible copper cables shall be used; Multi-core cables shall not be used.
- For the AC cabling, PVC or, XLPE insulated and PVC sheathed single or, multi-core flexible copper cables shall be used; Outdoor AC cables shall have a UV-stabilized outer sheath.
- The total voltage drop on the cable segments from the solar PV modules to the solar grid inverter shall not exceed 2.0%
- The total voltage drop on the cable segments from the solar grid inverter to the building distribution board shall not exceed 2.0%
- The DC cables from the SPV module array shall run through a UV-stabilized PVC conduit pipe of adequate diameter with a minimum wall thickness of 1.5mm.
- Cables and wires used for the interconnection of solar PV modules shall be provided with solar PV connectors (MC4) and couplers.
- All cables and conduit pipes shall be clamped to the rooftop, walls and ceilings with thermo-plastic clamps at intervals not exceeding 50 cm; the minimum DC cable size shall be 4.0 mm2 copper; the minimum AC cable size shall be 4.0 mm2 copper. In three phase systems, the size of the neutral wire size shall be equal to the size of the phase wires.

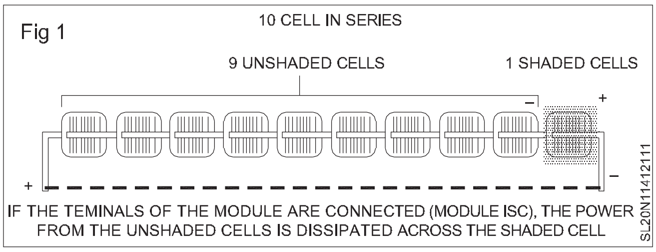
Hot spot on modules and method to detect them at site

Objectives: At the end of this lesson you shall be able to
- **acquire specific information on installation in fixed or variable angle of inclination of solar panels.**

Hot spot heating occurs in a PV module when its operating current exceeds the reduced short-circuit current (Isc) of a shadowed or faulty cell or group of cells. When such a condition occurs, the affected cell or group of cells is forced into reverse bias and dissipates power, which can cause local overheating.

Fig 1 Hot spot in a group of cells

Fig 1



One shaded cell in a string reduces the current through the good cells, causing the good cells to produce higher voltages that can often reverse bias the bad cell.It is a typical degradation mode in PV modules.

Causes of shading might include Bird or Leaf, Dirt or Snow, Building Shadow etc

Common Causes of Hotspots due to manufacturing process:

Cell Manufacture

- Incomplete edge isolation
- Crystalline defects intersecting junction
- Metal-decorated cracks
- Overfiring: pn junction "punchthrough"
- Scribeline shunts- incomplete removal or redeposition
- Metal particles & bridges on backside
- Print alignment errors

Module Manufacture

- High resistance or "cold" solder points
- Current mismatch between cells

Hotspot defects are known to cause reliability problems in both thin-film and conventional c-Si modules. Detection of hotspots in completed modules can identify potential failures before the module is installed in the field.

Module Measurement Method

Quick detection is possible with infrared camera, performing thermography imaging. A hot spot can also lead to browning in the glass plane of the PV module, if it is present for long time. Thus, the hot spot can become visible for the human eye.

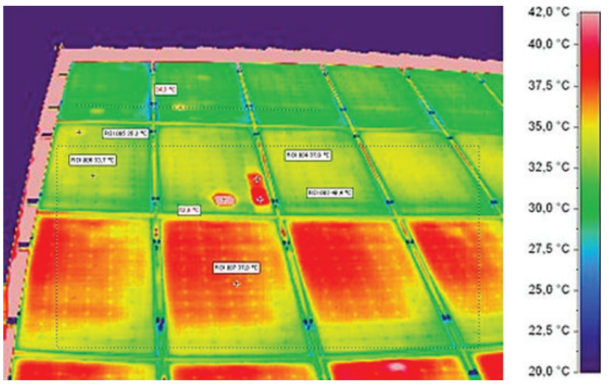
To prevent emergence of hot spots, the different causes have to be considered. Cell mismatches are prevented by measuring the maximum power point of produced cells and then combining similar cells into one module. To ensure a homogeneous irradiation on the module, shadow-casting structures are considered and avoided during PV plant construction. And to avoid severe damage from dirt, periodic cleaning is necessary. Finally, bypass diodes are integrated in PV modules to shortcut a cell string, if the voltage drop becomes too high.

Thermography is the method used to measure hotspots based on Lock-in & Time-resolved techniques. This uses a Camera like LWIR (8-12 micron) which has speed of ~20 seconds / module or above. R&D is going on for 30ms- 5 min.

Using this technique, hotspots may beconclusively identified before or during fieldinstallation with IRIS inspection machinescapable of >25 modules per hour. The techniqueworks in ambient light and directly measures thelocal heating due to defects.

Fig 2 Thermography image of a PV module with visible hot spot in centered cell

Fig 2



Identifying challenges' in the placement of modules/PCU in the site. (Portrait/ landscape placement, number of tables etc.)

Objectives: At the end of this lesson you shall be able to

- **acquire specific information on installation in fixed or variable angle of inclination of solar panels.**

When we plan to get the solar panels installed on rooftop and power the home or office, there are many things to be considered. Apart from how much power each panel can produce how many panels are needed, what size, and how well they'll work with your rooftop, and also we have to consider the best direction for solar panels to face.

The direction the solar panels face can be a major factor in how much energy the rooftop solar system produces. Solar panel positioning based on the rate structures at different utility companies is to be discussed.

The traditional advice is to position solar panels to be north – facing or south-facing, depending on the location in southern or northern hemisphere respectively. This is because, for those living in the Northern Hemisphere, the sun is always along the southern part of the sky as we complete our yearly orbit around it.

Similarly, for those living in the Southern Hemisphere, the sun is always along the northern part of the sky as we complete our yearly orbit around it.

This being the case, the general best practice to date has always been to position solar panels facing south for places in northern hemisphere in order to capture the maximum amount of sunlight overall.

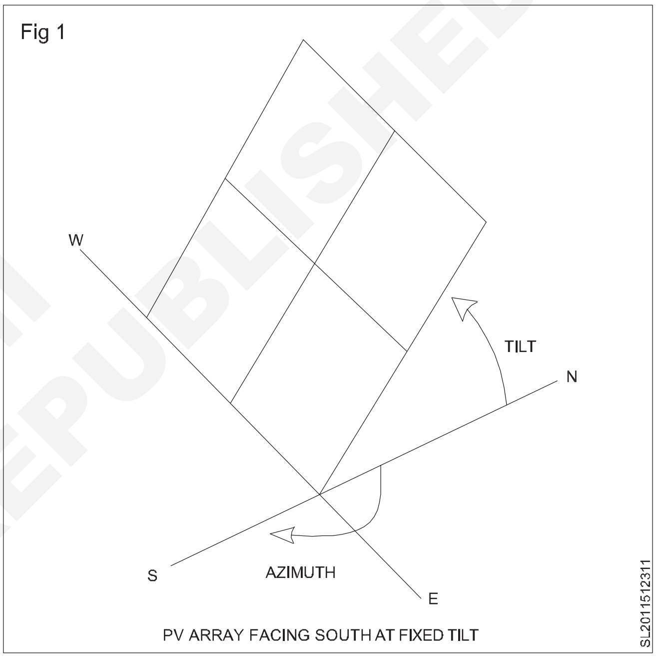
While the pitch or angle is important to your solar panel's efficiency, what truly matters most is the direction your home faces. Pointing your solar panels in the direction with the most direct sunlight is imperative to producing the most energy.

For homes in the northern hemisphere, panels should face true south. For southern hemisphere homes, your solar panels should face true north. If your southern facing roof has too much shade due to surrounding trees or buildings, you still have options. The eastern sun in the morning and western sun in the afternoon will still provide a good amount of energy for your solar panels to use. If that's the case, keep in mind that the solar panels you install may not produce the full wattage they say they will.

However, you will still notice a significant decrease in the amount of energy you need from your city's power grid—and therefore a lower electricity bill each month.

Generally, it's common knowledge in the solar industry that these south-facing panels should be tilted between a 30- and 40-degree angle. But, this angle varies and is just about equal to the latitude of your home (how far north you are in relation to the equator).

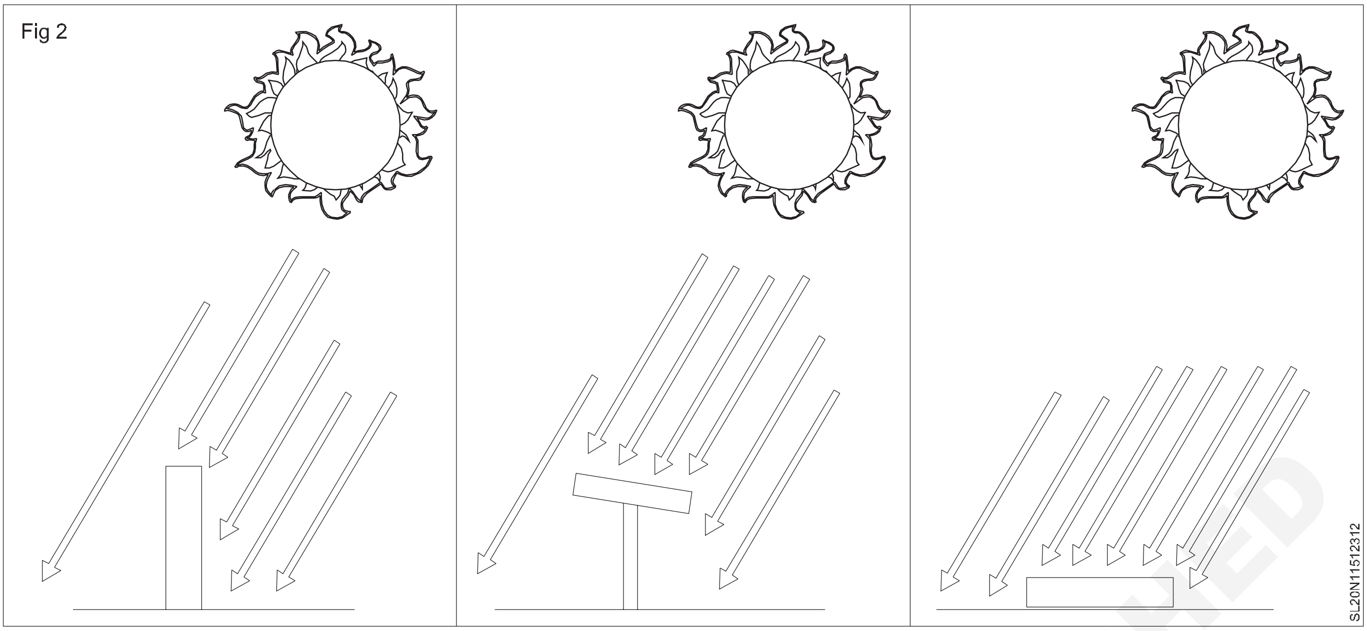
Fig 1 PV array tilt and azimuth



The reasoning behind this angle specificity is to ensure sunlight hits panels at a perpendicular angle, which produces the most energy.

Some rooftops slope just about perfectly in a way that lets installers secure the panels flush against them and still be at a great angle for capturing the sun's energy. Other rooftops might be steeper, or some others are flat. Depending on the type of roof you have, there are different mounting systems to help position your solar modules so that they can produce at their best. The angle of slope of the roof to be considered and compared with the tilt requirement and accordingly the mounting system's dimensions are calculated.

Fig 2 Effect of Tilt angle while mounting Solar panel



Different Solar Panel Sizes and Dimensions

The average dimensions for solar panels are 65 inches (1651 mm) long by 39 inches (991 mm) wide. This is more common standard.

Some manufacturer's solar panels may be smaller, making them a great choice if we have a smaller home or don't need to convert as much solar energy into power for the customer. First Solar's panels are a good option if we have more space to hold solar panels— like a large roof— or plan on installing solar panels on the land instead of the roof.

The depth dimensions vary a little more widely than the length and width because they are impacted by the base of the solar panels and any mounting equipment installed underneath the solar panels.

The reasoning behind having most solar panels be about the same size is that it creates an industry standard. That means that you'll know what to expect, in terms of potential power, from a solar panel of a certain size. This also makes it easier to know how many solar panels you will need, or how many solar panels fit on your roof.

Horizontal vs. Vertical Solar Panel Installation

Solar panels are mounted to the roof using the rafters in the roof as anchors for the solar panel mounts— generally utilizing steel bolts to attach mounts to the home. Solar installation companies mount their solar panels on rails attached to the steel bolts, specifically for added security and stability. There are a few reasons why most solar panels are installed vertically:

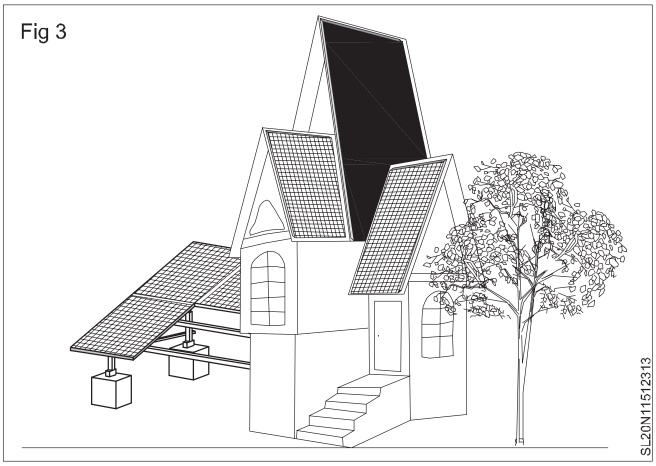
- Fewer rails are required to mount a solar panel vertically instead of horizontally.
- It is easier to have a continuous row of solar panels if they are installed vertically.
- The size of solar panels makes them well suited to be installed vertically on most roofs.

Of course, not every home—or roof—is designed the same. Depending on the climate, the roof's construction, and the solar energy needs, horizontal solar panel installation may be the right choice for the home or office.

The amount of direct sunlight could impact the direction in which your solar panels are installed. Depending on how your home is situated, your solar panels may actually receive more sunlight if they are installed vertically.

It's important to note that horizontal solar panels require about twice as many railings and mountings to be installed. However, the benefits of having more efficient solar panels outweigh the cost of using twice as many railings to install the solar panels. The Solar technician as an installer must discuss the options before planning the mounting systems.

Fig 3 Horizontal mounting of Solar panels



If horizontal solar panel installation is considered the best option, then we need not worry about taking any extra steps for their maintenance, because it requires the same care as vertically installed solar panels. In fact, depending on your home's location and the amount of sunlight it receives, the pitch (angle) and direction of your horizontal solar panels will be nearly identical to what they would be if oriented vertically.

It is also important to note that you don't have to install all of your solar panels in one direction/orientation. Panel orientation also has no effect on the number of panels that can be installed. Homeowners have the option to install them using differing orientations, depending on the shape of your roof. However, it is more efficient to have a consecutive block of solar panels installed using the same orientation— either vertical or horizontal. If there is a break in your roof, or you have room for one more solar panel, then the solar technician can install the solar panel to fit the space.

There are several factors in your control when it comes to finding the ideal pitch/angle for your solar panels. Solar technician shall recommend using the latitude of the site's location as the degree of tilt. For example, the latitude of Delhi, India is 28.7 degrees North, so the tilt of the solar panels would be 28 degrees. Whereas, if you live in Bangalore, Karnataka, India your latitude is 12.9716 degrees North, meaning your solar panels would be at an angle 13 degrees. As most roofs are not flat, the solar technician will factor the pitch/angle of the roof into the equation.

Fixed or Tracking Solar Panels

There are two types of solar panel mounting options: fixed or tracking solar panels. Fixed panels are stationary and remain at the same pitch throughout the day and year. Tracking panels live up to their name— they track the sun as it moves through the sky each day. Depending on the pitch of the roof, tracking panels may not be an option for certain home. In that case, the solar technician must work to find the optimal pitch/angle for the solar panels. (More details later)

Roof area, shadow free area, structure, type & age of the building, usable area, O&M challenges, and integration issues

Objectives: At the end of this lesson you shall be able to
- **analyze the issues based on type of roof and its age etc.**

A well-conducted assessment of the roof requires developers to answer the following questions:

- Is the roof suitable for installation of solar PV?
- Is the solar resource high enough?
- How much installed capacity could fit on the roof?
- How much energy could that system deliver?

A rooftop solar PV installation comprises of PV panels assembled in arrays, mounting frames to support the panels and secure them to the roof, wiring, inverters, and other components depending on the type of installation. The roof site must be able to accommodate all of these components, which requires examining the following aspects:

Accessibility: The roof must be accessible to carry out installation and maintenance. It must be possible to lift the solar system components onto the roof and for personnel to physically access the site to install and maintain the system.

Roof configuration: A roof plan can help quantify the roof area available for the PV power plant. The plan should indicate the location (including longitude and latitude), height, and slope of the roof itself, as well as any additional structures present on the roof. Identify any possible conflicts in usage of the roof, (just a possibility!) such as a helipad or communication antennae, and contact relevant bodies to ascertain if any special permission is required to use and/or alter usage of the roof space.

Roof materials and structure: For existing buildings, first find out when the roof would need replacement. If a roof is nearing the end of its life span, it is more cost-effective to install the rooftop PV system once the new roof is in place. It is also easier to integrate a system into the design of a new roof.

.**Aesthetics:** Check that the solar PV modules would not negatively affect the aesthetics of the building. From street level, solar modules will be more visible on a sloped roof than on a flat roof. If they will be seen, find out if there are any local building restrictions preventing a visible rooftop solar PV installation. With growing support for the use of renewable energy, guidelines are being modified, where necessary, to allow rooftop solar installations.

Roof leasing: If planning to lease the roof space to the owner of the rooftop PV system, consult a legal advisor who would be able to confirm whether that type of arrangement is permissible.

Electrical load: Obtain the current and expected electrical load of the building or facility. Should the load be comparable to or less than the electricity generated through solar PV, plan a smaller system or plan to use the excess energy—either store the energy in batteries, send it to another building within the facility, or feed it into the grid.

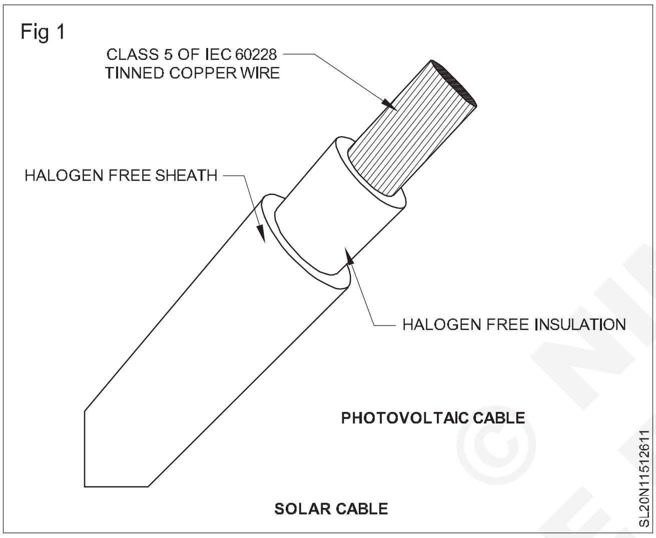
Wire (cable) requirement/ estimation

Objectives: At the end of this lesson you shall be able to

- **elaborate on selection of solar cables.**

Most solar panel systems include basic cables, but sometimes we have to purchase the cables independently. The solar cable, sometimes known as a 'PV Wire' or 'PV Cable' is the most important cable of any PV solar system. The solar panels generate electricity which has to be transferred elsewhere - this is where solar cables come in. The biggest distinction in terms of size is between solar cable 4mm and solar cable 6mm.

Fig 1 Solar cable



To understand how solar cables function, we must get to the core functionality of the cable: The wire. Even though people assume cables and wires are the same things, these terms are completely different. Solar wires are single components, known as 'conductors'. Solar cables are groups of wires/conductors that are assembled together.

The following is an introduction to correct sizing and terminology.

To start with, the most common size for solar wires is "AWG" or 'American Wire Gauge'. If you have a low AWG, this means it covers a large cross-sectional area and hence has lower voltage drops. The solar panel manufacturer supplies the charts that showcase connecting basic DC/AC circuits. They should give information on the maximum current allowed for the cross-sectional area of the solar system, the voltage drop, and DVI.

The chart below shows the capacity of various wire gauge sizes and their average amp rating:

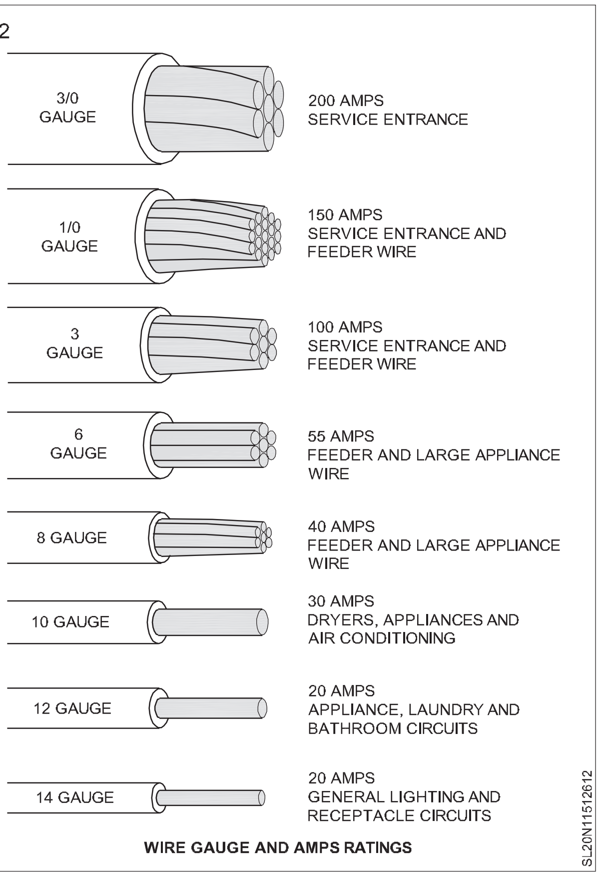
Fig 2 Wire Gauge and Amps ratings

The size of solar panel cable used is important. The size of the cable can affect the performance of the entire solar system. If a smaller cable than recommended by the solar manufacturer is used, we can experience severe drops in voltage across the wires which eventually results in power loss. If we undersize the wires this can lead to a surge in energy that leads to a fire. If a fire erupts in areas such as the rooftop, it could quickly spread to the rest of the house.

To illustrate the importance of PV cable size, imagine the cable like hose carrying water. If you have a large diameter on the hose, the water will flow easily and won't put up any resistance. However, if you have a small hose then you will experience resistance as the water can't flow properly. The length also has an impact - if you have a short hose, the water flow will faster. If you have a large hose, you need the right pressure or the water flow will slow down.

All electric wires function in the same manner. If you have a PV cable that is not large enough to support the solar panel, the resistance can result in fewer watts being transferred and blocking the circuit. PV cables are sized using American Wire Gauges in order to estimate the gauge scale. (The Standard Wire Gauge (SWG) series commonly used in Great Britain were given in BS 3737: 1964. The standard is now withdrawn. The basis of the system is the mil, or 0.001 inches.) The lesser gauge number (AWG) of a wire, the lesser the resistance and the current flowing from the solar panels will arrive safely. Different PV cables have different gauge sizes. Each gauge size has its own AMP rating which is the maximum amount of AMPs that can travel through the cable safely.

Fig 2

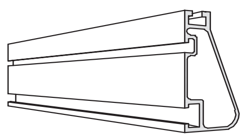


WIRE GAUGE AND AMPS RATINGS

Solar panel mounting structures

Objectives: At the end of this lesson you shall be able to
- **Select from varieties of fittings for mounting solar panels.**

Racking and Mounting products are market ready, for all roof-top, ground mount and solar tracker PV arrays. Market available large assortment of solar racking and mounting components can be uniquely fitted for any type of solar energy system.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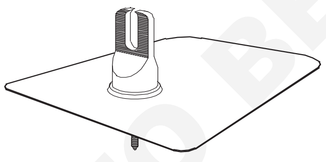
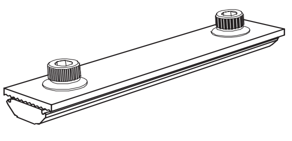
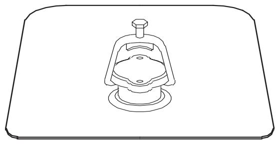
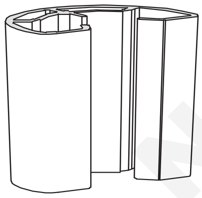

FLASHINGS


SPLICE KITS


CIRCUIT MOUNT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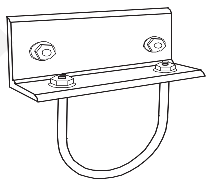
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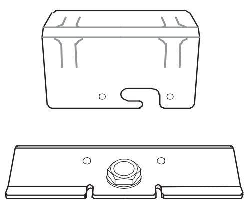
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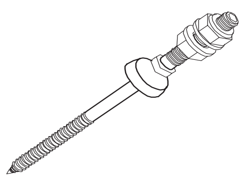
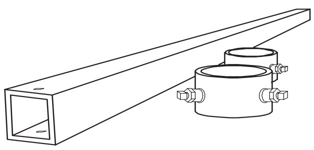
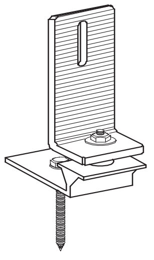
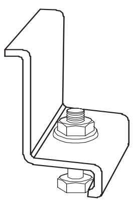

BOLTS


BRACE ASSEMBLY


BASE MOUNT


CLAMPS

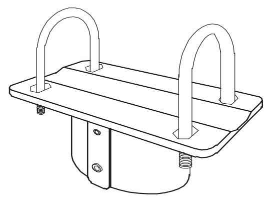

CAPS

Fig 1 Racking and mounting components

Solar technician should get familiar with different mounting systems and their accessories available in the market locally or online to make perfect installations of Solar arrays on roof or rooftop or on ground. This occupies major activity of solar technician as installer.

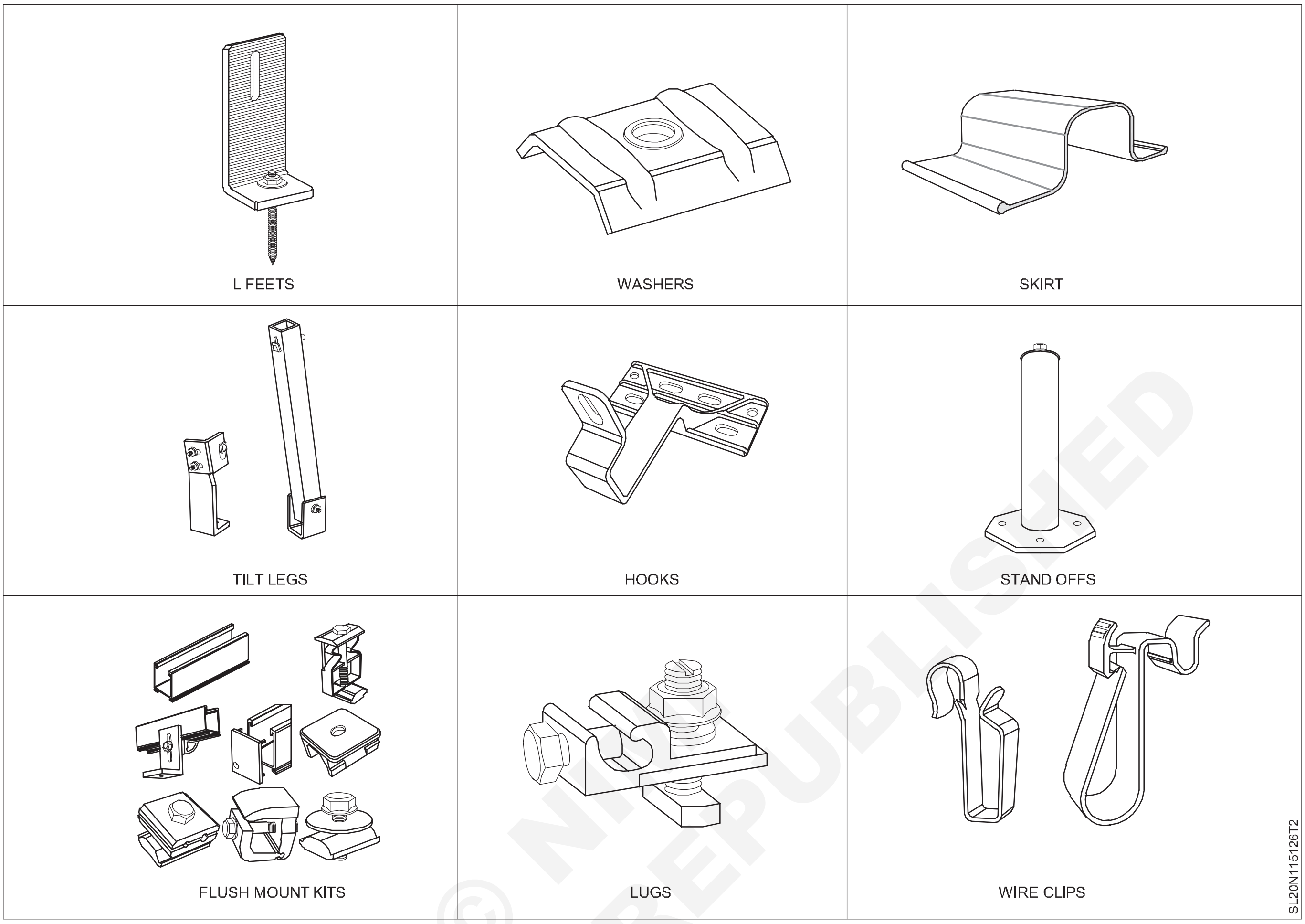
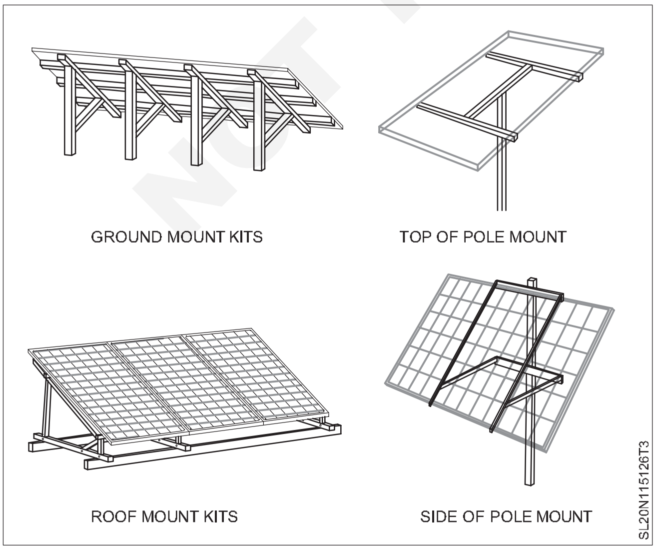
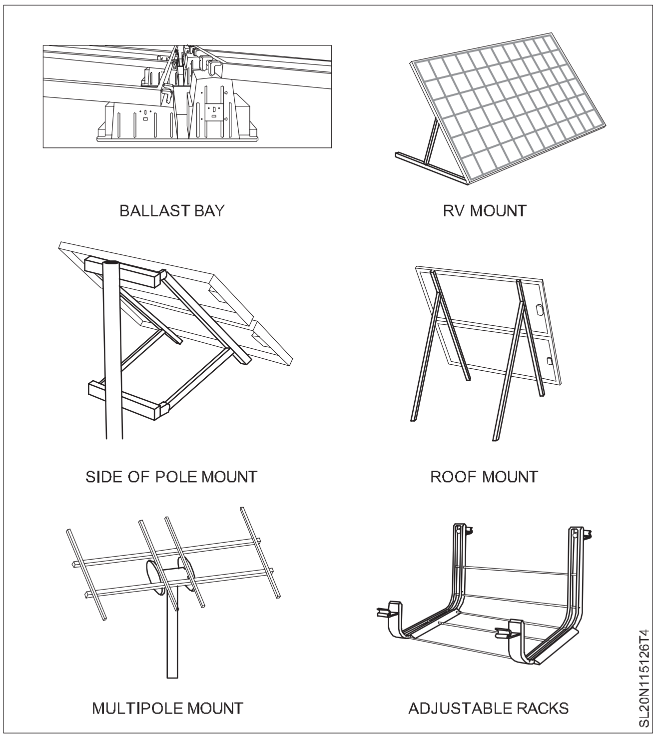


Fig 2 Additional mounting kits

Varieties of mounting systems are also in use, so that, based on type of roof the type of system is selected. Rack mount, flush mount, roof mount, wall mount, pole mount, ground mount and ballast mount are common. Building integrated mounting are designed for Green buildings.





Solar plant foundation planning

Objectives: At the end of this lesson you shall be able to
- **plan a foundation for a solar PV installation.**

Construction of foundation and Erection of pillar or pole mount can be on roof top or ground. Mostly requires civil work related skills, can be outsourced for a larger plant but when a solar technician functions as a self-employed person he/she possessing these skills to some extent can make the small project attempts more profitable.

While the technician understands the steps involved in civil work and fitting the solar structure, he/she may appraise the combination of works at the erection of solar structure, collect the tools required in work place (roof top or ground mount), collect the materials required, plan and make foundations, make right facing of solar panels and make right inclination for a given location.

Tools required for making of foundation include Civil construction work related tools: crowbar, spade etc, Drilling machine for rooftop, Marking pen and nail, Thread , Measuring tape, Ruler, Tool kit and Safety gadgets.

Material handling equipment or machineries include earthmovers, diggers, tractors, concrete mixers, water tanks etc. their capacity varies based on size of the project.

Materials required include Gravels, sand, cement as per requirement, Pole or pillar as per design, Anchor bolts for RCC roof, Other bolt and nuts etc.

Civil works in work area involve Skills required in making foundation, On rooftop - Marking, Drilling, Fixing anchor bolt, Mounting pole, Mounting solar PV panels, Filling concrete on base etc. Skills required on ground include Marking, Digging, Bar bending, Filling concrete mix and Curing concrete.

Steps for making foundation on rooftop

- Use compass and mark true north and south poles
- Draw line connecting north and south poles points
- Place the pillar mount aligned to the connecting lines
- Mark the holes of base on ceiling
- Remove the pillar mount
- Drill holes on the markings
- Hammer the anchor bolts on the holes
- Keep the pillar mount aligned to the anchor bolts and fix nuts
- Mark parallel to the first pillar mount and repeat the above steps

Repeating these steps for as many numbers of pillars or poles to be mounted as per drawing is there to be noted.

Fig 1 Marking foundation on rooftop

Steps in Making foundation on ground

- Use compass and mark true north and south poles
- Draw line connecting north and south poles points

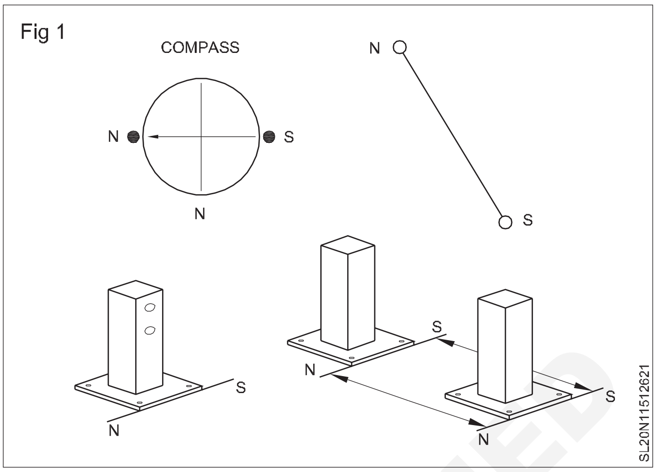


Fig 1

- Place the pillar mount aligned to the connecting lines
- Mark the base
- Remove the pillar mount
- Dig pit (Crater) as per drawing (Eample: if Base is 1ft x 1 ft then the crater should be 1ft x 1 ft x 1.5ft as shown)
- Use the wooden stencil of base of the pillar mount
- Fix the bar bended TMT rods with thread on top end on to the stencil
- Keep the assembly in the carter with the stencil on ground level
- Fill in concrete mortar in the pit and allow to harden doing proper curing
- Remove the stencil and place pillar mount & fasten the bolts

Repeating the steps for as many numbers of pillars or poles to be mounted as per drawing is there to be noted.

Fig 2 Wooden stencil

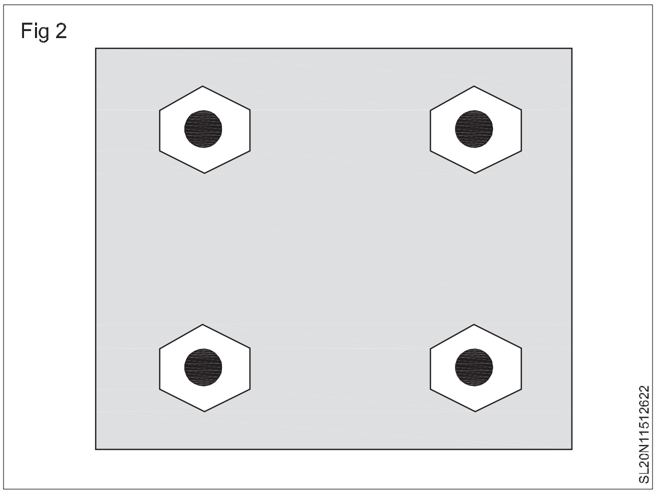


Fig 2

Fig 3 Finished foundation

Fig 4 Steps involved - Ground mount foundation

Fig 5 Installed Pillar mount

Fig 3

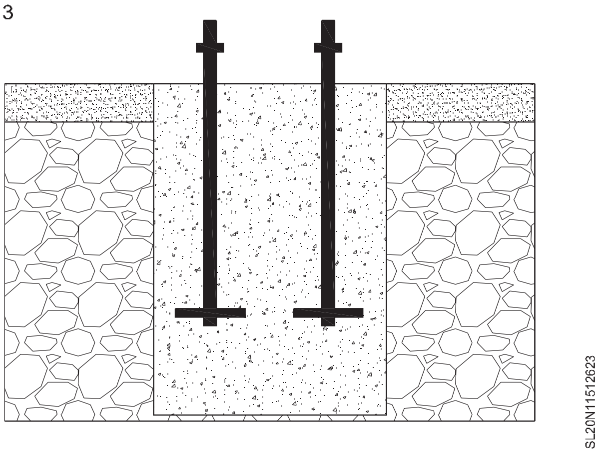


Fig 4

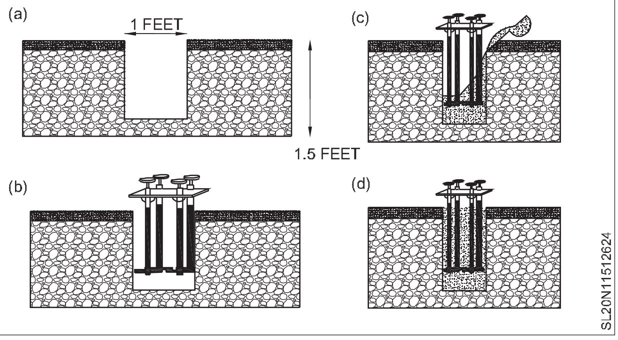
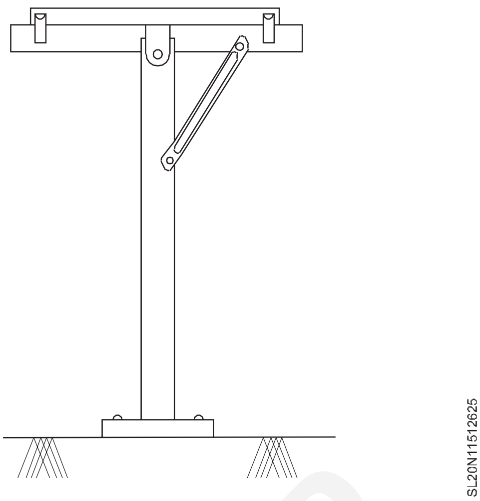


Fig 5



Similar activities the technician can come across while doing foundation for solar street light also.

While doing multiple poles/pillars for a mega project, care is taken for maintaining parallelisms between them as well as accessibility for installation and maintenance activities.

Installation of solar panels

Objective: At the end of this lesson you shall be able to

- **install a solar PV mounting.**

Here we have mechanical fitting nature of works such as lifting, shifting, storing, mounting, setting gaps between panels and adjusting angle of tilt.

While mounting of Solar PV panels, the solar technicians have to

- mount the connecting arms over the pillar mounts
- fit the angle adjusting rod between the arms and pillar mount
- mount the solar PV panels on the arms
- set the angle of inclination (Tilt angle) for the solar array towards south for given location
- adjust the angle for different locations
- set manually the Tilt angle for different seasons.

Steps involved in mounting Solar PV panels over Pillar structure are

1 assemble the complete structure of pillar mount (rooftop/Ground mount)

2 mount the solar panels (example 4 X 250WP panels for 1 kW plant)

3 face the solar panels towards south

4 adjust the inclination towards proper facing

Tools required include mainly Spanners set.

Skill set involve mainly

- Fabrication of super structure if not available readily (involves structural planning, drawing, dimensions of solar panel, sheet metal works, welding etc)
- Fitting poles, arms and lever
- Mounting or clamping the panels

Procedure for mounting connecting arms over Pillar mounts:

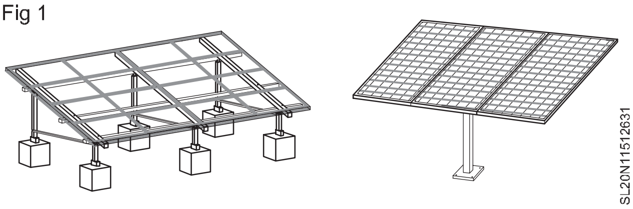
- Mount the swinging arm on the pillar mount by keeping the hole for angle adjustment rod/lever towards south
- Mount the angle adjustment rod/lever connecting the pillar and swinging arm
- Repeat the steps for second or more pillar mounts
- Mount the long connecting arm over the swinging arms
- Adjust the levers and fit evenly.

Procedure for mounting the Solar PV panels:

- Place the panels on the connecting arms matching the holes if available
- If not mark the holes over the arms; repeat for remaining panels and mark leaving air gap of minimum 10 mm between the panels
- In marked case drill holes on the arms
- Place the panels and fit with bolt and nuts

Fig 1 Solar panels mounted over structures

Fig 1



Adjusting inclination angle

Objective: At the end of this lesson you shall be able to
- **select a direction for the solar panel to face.**

Tools required:

- maps
- clinometers
- spirit level
- solar tilt app
- Calculation of Tilt angle

The solar panel is mounted on a Tilt angle towards south or north (Facing) based on location on Earth. The usage of above tools explained next.

Solar panel facing direction

Facing of the panel is towards

- South for locations in Northern Hemisphere (Above equator)
- North for locations in southern hemisphere (Below equator)
- Flat on equator

Changing the angle of inclination as per location and seasonal setting

Objective: At the end of this lesson you shall be able to
- **select suitable angle of inclination for the solar PV panel mount.**

Tilt angle is

- 0 º at equator
- θº towards south or north depending on the location of site
- θ depends on latitude of a place on the Earth
- Angle of incidence of Sun irradiation varies daily throughout the day from east to west
- Also varies over six months period from North to south and South to north (Hence seasonal tilt)

Finding tilt angle

- Using mobile with GPS or location ON you can get local latitude
- In Google browser search latitude of ………….. (Name of a place) you will get latitude of other locations
- In solar tilt app by feeding latitude angle you will get four seasons tilt angles

Optimum Tilt of Solar Panels*

- If your latitude is below 25°, use the latitude times 0.87.
- If your latitude is between 25° and 50°, use the latitude, times 0.76, plus 3.1 degrees

*Only results were shown here collected from reliable sources. Derivations are not given here.

Simple tool to find the angle of inclination:

Sl. No.	Latitude	Angle of Inclination
1	0 – 15°	15°
2	15° – 25°	Same as latitude
3	25° – 30°	Latitude + 5°
4	30° – 35°	Latitude + 10°
5	35° – 40°	Latitude + 15°
6	Above 40°	Latitude + 20°

Adjusting the Tilt angles/seasonal tilt angles

- Loosen the bolt and nuts on connecting lever on either side
- Vary the entire tilt of entire solar array
- Simultaneously measure the desired angle using the clinometers
- After setting desired angles fasten the nuts on connecting levers

Recall, that, the sun's path changes throughout the year. The days are longer during the summer, which means we get the most sunlight because of the sun's summer path. The solar panels are able to produce the most energy during the summer because of this. During the winter, the sun's rays are less direct because its path has changed.

This is important because it may affect the slope of the solar panels. If we are able to adjust the tilt of the solar panels, even manually, they will be significantly more efficient. If this applies in a site, consider increasing the tilt of the solar panels by 15 degrees during the winter. During summer months, decrease the original tilt by 15 degrees.

This results in 'Summer angle' and 'Winter angle' increasing the output power.

Follow the same procedure discussed above adjusting the inclination angle for changing or setting the seasonal angles also.

Calculation results show that, for solar panels with seasonal adjustment of tilt-angles, the optimum date of tilt-angle adjustment is 22 days from the equinoxes, and the optimum value of tilt-angle adjustment from the site latitude is in between 23-25° for maximizing the annual energy collection. (*Only results were shown here collected from reliable sources. Derivations are not given here.)

If you are going to adjust the tilt of your solar panels twice a year, and you want to get the most energy over the whole year, then this section is for you.

The following table gives the best dates on which to adjust:

	Northern hemisphere	Southern hemisphere
Adjust to summer angle on	March 30	September 29
Adjust to winter angle on	September 10	March 12

If your latitude is between 25° and 50°, then the best tilt angle for summer is the latitude, times 0.93, minus 21 degrees. The best tilt angle for winter is the latitude, times 0.875, plus 19.2 degrees.

The seasons are:

Winter: December, January, and February

Spring: March, April, and May

Summer: June, July, and August

Autumn: September, October, and November.

MMS systems or using trackers

Objectives: At the end of this lesson you shall be able to

- **select suitable mounting structure for a site.**

Fig 1 MMS

Fig 1

MMS means Module Mounting Structure.

Owing to the structure of the modules themselves, they are required to be mounted on another structure. This allows the modules to be held firmly to the surface of installation, capable of battling strong winds that could, without careful design of the mounting structures, damage the entire installation. Additionally, in order to raise the overall efficiency and generation capabilities of the installation, a tilt is afforded to the modules of the system-based on the geographical location and the positioning of the area of the installation. Now, to achieve higher levels of generation, the optimum tilt of the modules is achieved by raising the modules on a mounting structure. Based on the cost and customer requirements, a tracker may be used in ground mount installations as well, in order to allow for the tracking of the sun's movement across the sky, and thereby, adapt the optimum tilt of the modules.

Mounting structures at times are built independent of a roof or ground installation. Pole mounts and car-ports are examples of mounting structures created such that the entire installation is raised several feet into the air, thereby keeping the installation independent of the conventional ground or roof mount solar systems.

In case of roof or ground mount installations, the specific type of module mounting structure (MMS) used, changes based on the surface of installation. Further, in solar rooftop solutions, a tilted roof and a flat roof have different routes of approach to designing the system. A closer examination of tilted roofs, based on the surface of the roof itself (tiled, corrugated fibre cement, trapezoidal metal sheet, round seam, etc.) dictate if clamps, adhesives or raised structures are required for a particular installation (with specific latitude-longitude coordinates, installation position with respect to the sun's movement across the sky, etc.).

In order to design a suitable MMS and its foundation, it is of primary importance to first examine the type of roof under consideration. Some standard roof types are discussed here:

Flat concrete roof: For a flat concrete roof, an MMS is of immense importance, as it is the MMS that allows the modules to be tilted at an angle optimal to the particular installation. A non-penetrative (ballast) foundation is used to resist wind uplift acting on the modules. The mounting structure is raised on this foundation.

Sheet roof-Trapezoidal: For a trapezoidal roof, running aluminium rails, that may be affixed using an industrial-grade adhesive or long-tapping screws, are used. The modules are then fixed with suitable end and middle clamps.

Sheet Roof-Standing Seam: Aluminium rails, to which the modules are affixed, are held to the roof using specific types of standing seam clips, based on the roof itself. The modules are affixed to these rails using suitable end and middle clamps.

Tiled Roof: In case of a tiled roof, where the entire area of the roof is lined with tiles, the MMS is fixed to the roof by using screws that hold the MMS to the purlin, below the roof. Suitable end and middle clamps are then used to hold the modules to the structures themselves.

The types of installation for solar array mounts based roof types are:

Fixed Mount:

- Raft/rack mounts
- Pillar or Pole mount
- Building integrated mount
- Ballast roof mounts
- RCC rooftop mount

Tracking mounts:

- Manual track
- Automatic track
- Single axis and dual axis

Fig 2 Ballast mount

Fig 2

Fig 3 Pillar/Pole mount

Fig 3

Fig 4 Rack mount

Fig 4

Fig 5 Building integrated mount

Fig 5

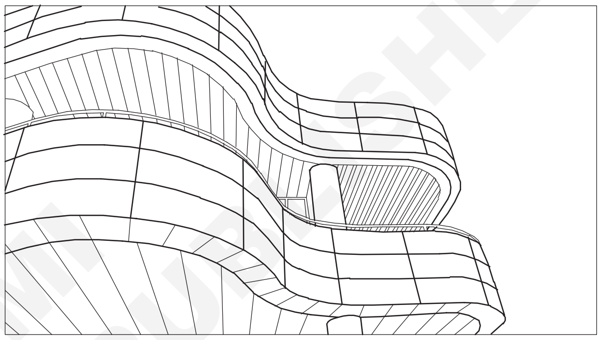


Fig 6 Single axis tracking mount

Fig 6

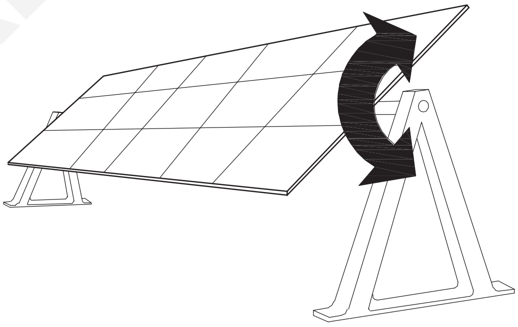
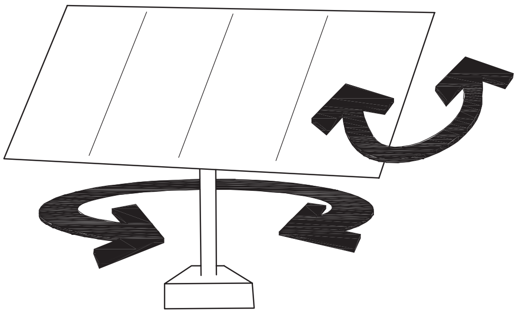


Fig 7 Double axis tracking mount

Fig 7



Solar panel wiring and cable Laying

Objectives: At the end of this lesson you shall be able to
- **wire the solar PV panels mounted on the structure.**

After completing fixing of mounting structures and fitting solar panels on mounts then we have the activity of solar panel wiring. This involves:

- connect the solar PV panels with the array junction box
- extend the wire/cable up to inverter input

In the process, the solar technicians have to perform assembly of connectors, wiring and extension till inverter input. The steps involved are:

- identify the connectors
- crimple the terminals end
- interconnect the panels
- conduit pipe laying
- lay underground cable
- connect end terminals to inverter

These skills have been discussed in detail in volume I and briefly recalled here.

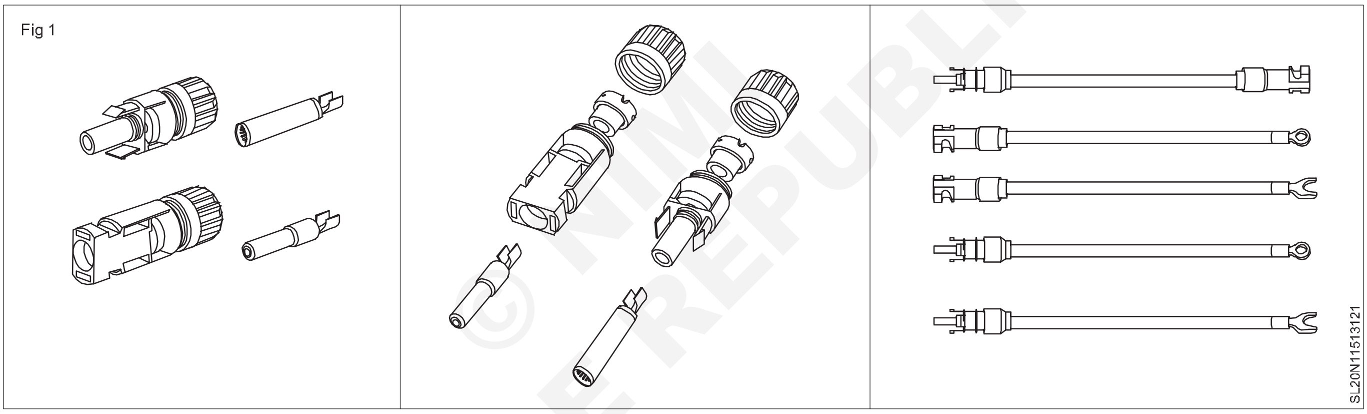
Connecting MC 4 connectors require materials such as MC 4 connectors, DC cables and Wires as well as Tools kit with crimping tool.

Caution: Keep all the circuit breakers, switches in OFF position and all fuses removed &stored separately till commissioning starts. DC volt more than 70 volts prove very dangerous. Once solar panels are exposed to sunlight they start generating DC volt. Construction work continues for long period based on capacity of the plant.

Follow the pictures and practice connecting the MC4 connectors for extension of Solar panel output wires.

Fig 1 MC4 connectors

Fig 1



Then inter connect solar PV panels and wire the Array Junction Box.

Fig 2 Connecting Solar panels using MC4

People connect as shown for series connection of solar PV panels.

Fig 2

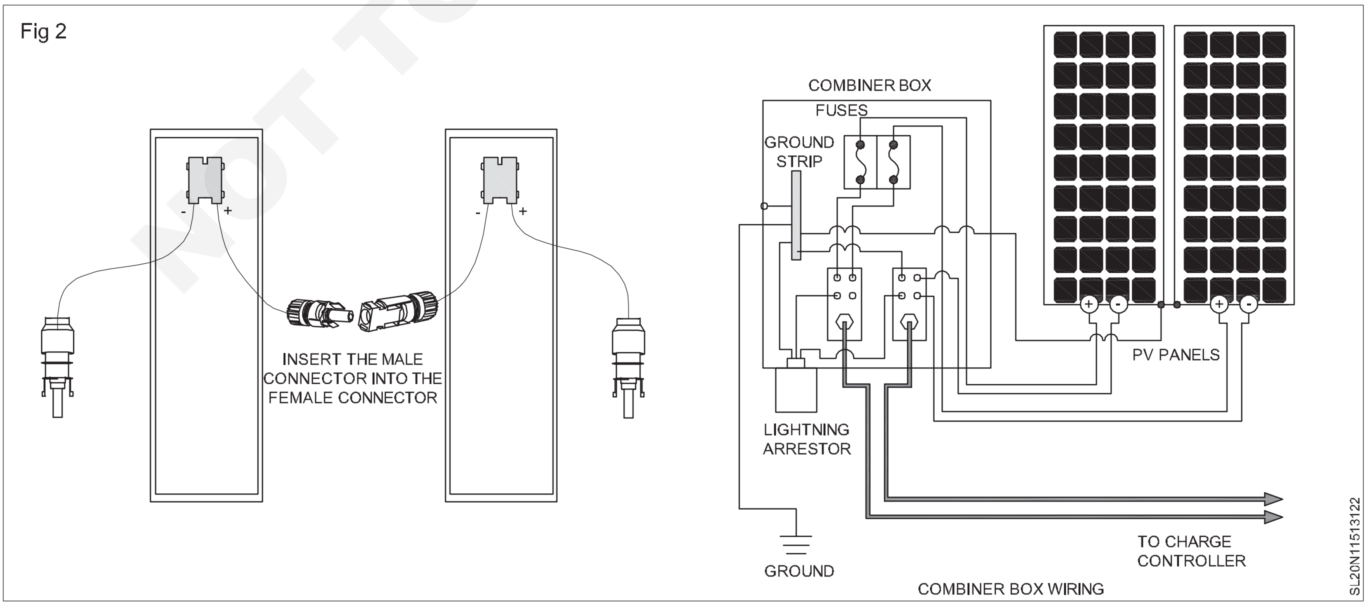


Fig 3 Cable laying and extension

Fig 3

After this if the system is Off grid then perform Battery Bank wiring. The remaining activities are load wiring and distribution panel common for any type of system.

Further Inverter wiring and Interface with the existing electrical system are to be carried out to complete the installation process of SPV system.

Commissioning skills

Objectives: At the end of this lesson you shall be able to
- **commission the installed SPV plant.**

Installation is only physical fitting and connecting the various components of the SPV system. It does not have energizing part. That means there is no flow of current from one to other component. Still mounted solar panels continue to generate electricity once exposed to sunlight. Hence enough care is to be taken in handling the risk. Do not imagine all panels could be kept covered with blanket! Prepare a detailed list of Do's and Don'ts in the installation.

Due to the above risk involved DC disconnects and AC disconnects are connected at every points between blocks. All these disconnects are kept in OFF position. Even fuses are removed and stored carefully.

Remember that depending on size of the project enough time even in months elapse before we go for commissioning. Many think that installation is commissioning but it is wrong. Commissioning is different.

Procedure of commissioning involves

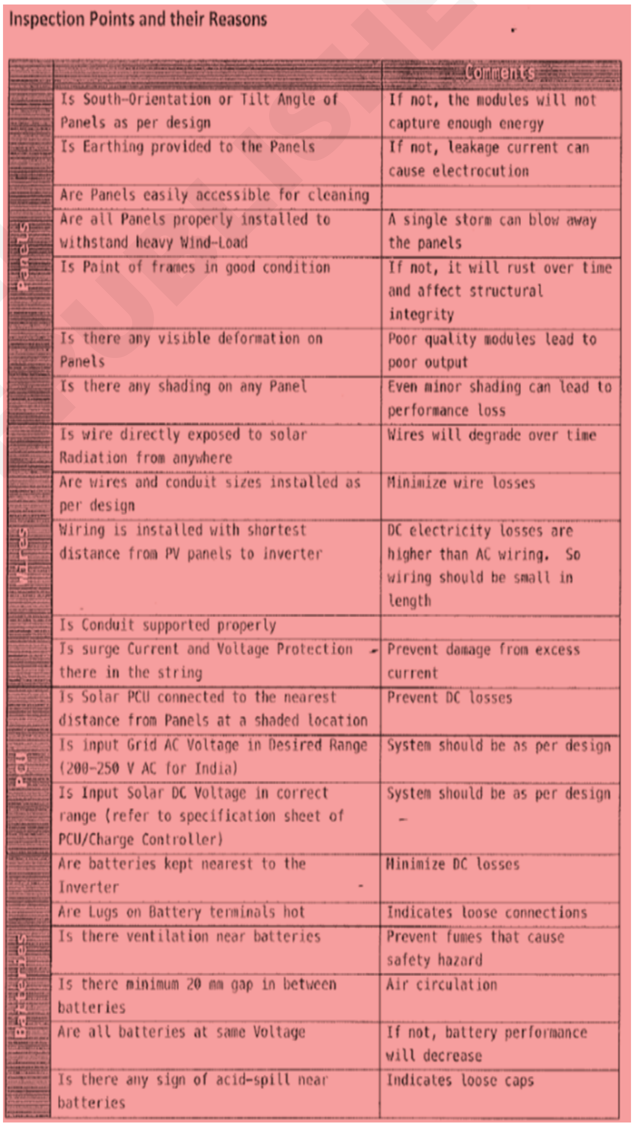
- check for errors during installation - Preparation of check off list
- locate and remove errors during installation process
- procedural switching ON of the solar plant
- observe and record readings during initial operation of the solar PV plant
- prepare documentation and records
- fill up the history sheets at the time of handing over to customer

Check before first switch ON - Safety precautions before initial starting

- Check all connections as per drawing; make a separate check list for possible errors during installation and check all points. Team leader should sign the checked list and is an important DOCUMENT.
- A sample check points developed by a firm 'Anthropower Training Pvt ltd' is provided here for reference with due regards. For every plant the Installation team shall prepare individually a check list so that time and again changes could be incorporated. Over period certain points will become very normal status and new points get in.
- A list of check points in the format of Questionnaire (to be separately by the team based on project) also is provided so that all the observations can be recorded and signed by the team to proceed further.
- Rectify any loose or wrong connections

Fig 1 Inspection points

Fig 1

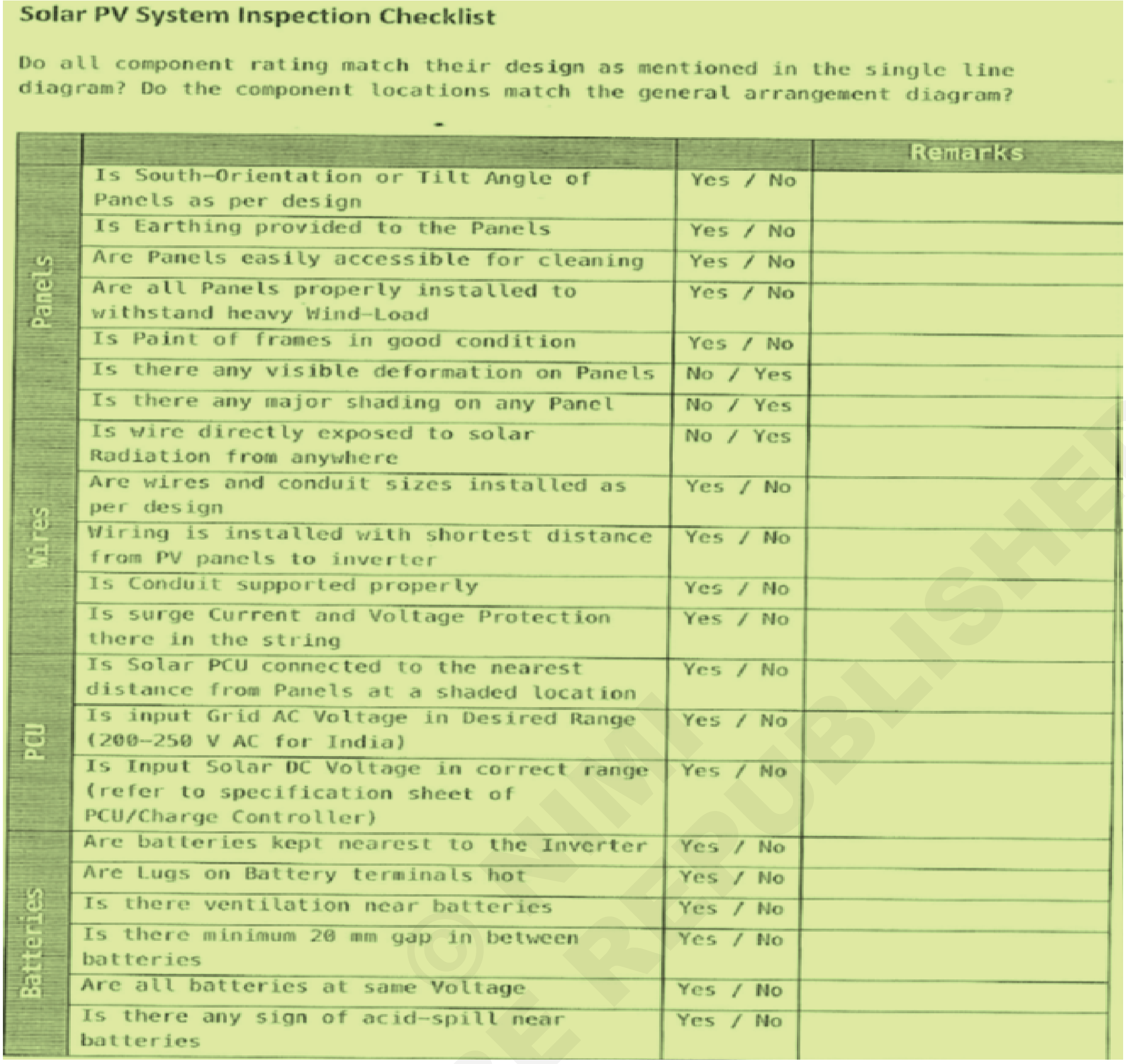


Inspection Points and their Reasons

		Comments
Panels	Is South-Orientation or Tilt Angle of Panels as per design	If not, the modules will not capture enough energy
	Is Earthing provided to the Panels	If not, leakage current can cause electrocution
	Are Panels easily accessible for cleaning	
	Are all Panels properly installed to withstand heavy Wind-Load	A single storm can blow away the panels
	Is Paint of frames in good condition	If not, it will rust over time and affect structural integrity
	Is there any visible deformation on Panels	Poor quality modules lead to poor output
	Is there any shading on any Panel	Even minor shading can lead to performance loss
Wires	Is wire directly exposed to solar Radiation from anywhere	Wires will degrade over time
	Are wires and conduit sizes installed as per design	Minimize wire losses
	Wiring is installed with shortest distance from PV panels to inverter	DC electricity losses are higher than AC wiring. So wiring should be small in length
	Is Conduit supported properly	
	Is surge Current and Voltage Protection there in the string	Prevent damage from excess current
PCU	Is Solar PCU connected to the nearest distance from Panels at a shaded location	Prevent DC losses
	Is input Grid AC Voltage in Desired Range (200-250 V AC for India)	System should be as per design
	Is Input Solar DC Voltage in correct range (refer to specification sheet of PCU/Charge Controller)	System should be as per design
Batteries	Are batteries kept nearest to the Inverter	Minimize DC losses
	Are Lugs on Battery terminals hot	Indicates loose connections
	Is there ventilation near batteries	Prevent fumes that cause safety hazard
	Is there minimum 20 mm gap in between batteries	Air circulation
	Are all batteries at same Voltage	If not, battery performance will decrease
	Is there any sign of acid-spill near batteries	Indicates loose caps

Check list before First switch ON Fig 2

Fig 2



Solar PV System Inspection Checklist

Do all component rating match their design as mentioned in the single line diagram? Do the component locations match the general arrangement diagram?

			Remarks
Panels	Is South-Orientation or Tilt Angle of Panels as per design	Yes / No	
	Is Earthing provided to the Panels	Yes / No	
	Are Panels easily accessible for cleaning	Yes / No	
	Are all Panels properly installed to withstand heavy Wind-Load	Yes / No	
	Is Paint of frames in good condition	Yes / No	
	Is there any visible deformation on Panels	No / Yes	
	Is there any major shading on any Panel	No / Yes	
Wires	Is wire directly exposed to solar Radiation from anywhere	No / Yes	
	Are wires and conduit sizes installed as per design	Yes / No	
	Wiring is installed with shortest distance from PV panels to inverter	Yes / No	
	Is Conduit supported properly	Yes / No	
	Is surge Current and Voltage Protection there in the string	Yes / No	
PCU	Is Solar PCU connected to the nearest distance from Panels at a shaded location	Yes / No	
	Is input Grid AC Voltage in Desired Range (200-250 V AC for India)	Yes / No	
	Is Input Solar DC Voltage in correct range (refer to specification sheet of PCU/Charge Controller)	Yes / No	
Batteries	Are batteries kept nearest to the Inverter	Yes / No	
	Are Lugs on Battery terminals hot	Yes / No	
	Is there ventilation near batteries	Yes / No	
	Is there minimum 20 mm gap in between batteries	Yes / No	
	Are all batteries at same Voltage	Yes / No	
	Is there any sign of acid-spill near batteries	Yes / No	

Check during first switch ON - Observation of parameters pre operation and Operational test before connecting to Load

- Switch on disconnect of charge controller to battery
- Switch on the disconnect of battery to inverter
- Switch on disconnect of solar pv panel to charge controller
- Switch on the inverter
- Observe correct working condition of above before connecting load
- Test and measure voltage and current on
- Battery voltage
- Charge controller
- Solar panel
- Inverter output

Checks after first switch ON - Observation of parameters post operation

- After assuring the above step is free of any defect connect the load step by step
- Check for
- Normal load operation - Progressive load connecting and on load testing
- Over load indication (Connect little excess load and observe) - Overload testing
- Short circuit indication (Use ELCB)
- Visual and audio alarms
- Tripping of circuit and breakers
- Protection circuits operation
- Record all the above in printed forms. This is an important document for the customer as well as for solar company to claim against any warranty and guaranty - First inspection report generation.
- Customer orientation.

Activities at the time of completion of installation and commissioning

Objective: At the end of this lesson you shall be able to
- **complete the installation and commissioning works.**

- Up keeping the Toolkit and work place - keep the tools and testing equipment in order and handover the plant properly to the customer
- assure all the tools and equipment brought for field work are in order
- prepare a report of missing or damaged tools and equipment
- assure cleanliness of work area while handing over to customer
- Collect the tools
- When the work at customer's site is over the helper should check for tools and testing equipments whatever brought for the field work as per the list of material pass from industry
- Handle safely the tools and replace them in their place in toolkit box.
- Where tools are brought in separate boxes or envelopes the helper should keep in mind the cases and accordingly replace the items
- A check list can be kept in each case so that the availability of items is ensured for later reference. This will avoid delay in next field work.
- Any malfunctioning or damages incurred should be properly recorded and reported in prescribed forms. This will enable the management to provide replacement.
- Clean the work area
- Collect unused consumables and segregate usable and unusable
- Collect all used raw material wastages such as broken lugs, cut wires, strands of wires etc and properly dispose
- Clean the solar PV panels
- Check the levels of distilled water and their specific gravity in solar batteries
- Close the control panels properly
- Clean the work area before handing over to the customer

Documentation and job completion

Objective: At the end of this lesson you shall be able to
- **prepare documentation.**

Solar Technicians should keep the documents for installation and commissioning in order and advice the customer for better utilization of the solar plant at this point of work.

The final work at customer‘s place includes prepare completion of work record, appraise the customer about do’s and don’ts at the plant and ensure the customer satisfaction and collect a feedback.

Documentation and record is the more important work the technician has to carry out. This will assure:

- Perform the first switch ON activity after the satisfactory visual inspection of installation
- Verify AC mains input Voltage and current, solar array Voltage and current, battery charging Voltage and current, Inverter output AC Voltage and current in the prescribed form brought from company.
- The above step is to be done with no load, step by step increase in load, full load and little overload condition
- All actual observations should noted in front of customer to show him the proper functioning of the Solar PV plant what he ordered.
- Any abnormality noticed record and try to rectify if possible
- Otherwise inform maintenance team
- Take the acceptance from customer by getting his/her signature in the test report

Customer orientation

Objective: At the end of this lesson you shall be able to
- **prepare customer orientation.**

- Advice for regular checkup of panels, inverter and battery
- Not to make any alteration to any component
- Not to use acid mixed distilled water for batteries
- Not to clean the terminals of the battery
- Not to pour water in nearby area to inverter
- Not to open the inverter at any cause
- In case of risky observation let them shut down the unit and inform maintenance team

Switching loads, economical planning of load distribution can be taught to the customers for efficient and optimum utilization of the plant. This can bring enough Return on Investment.

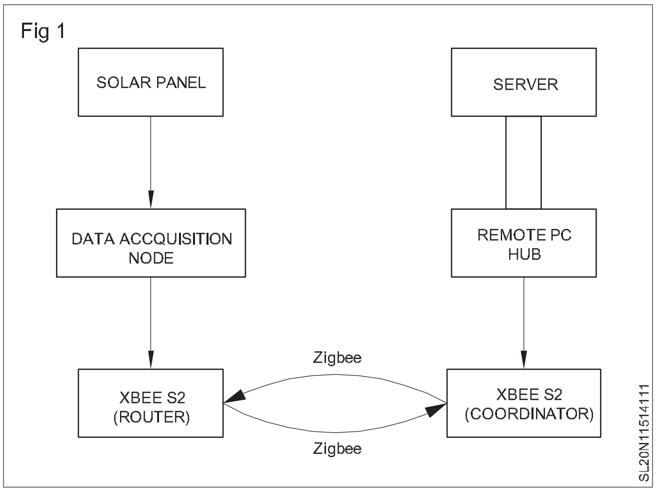
Condition monitoring and report generation

Objectives: At the end of this lesson you shall be able to
- **monitor performance of a solar PV plant**
- **prepare reports on the performance of SPV plant.**

The pace of installation of photovoltaic (PV) systems is growing over the last two decades worldwide. The PV systems have been installed in extreme climatic and environmental conditions which often degrade their performance. In order to improve the performance of PV systems, duly maintenance and detection of faults are required which prompt for the need for condition monitoring.

Fig 1 Typical Architecture of Condition monitoring

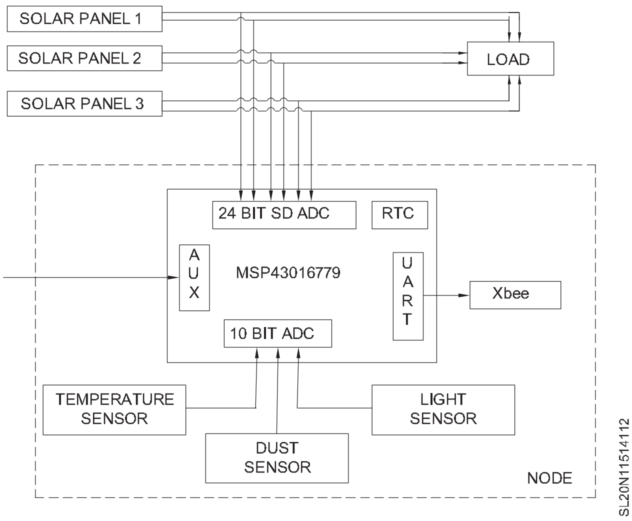
Fig 1



The purpose of condition monitoring of PV systems is to acquire information about power outages, to maintain good power quality, protection from islanding, evaluation of performance, identification of faulty modules, calculation of efficiency of modules, and compliance to grid standards for connecting PV to the grid.

Fig 2 Node design

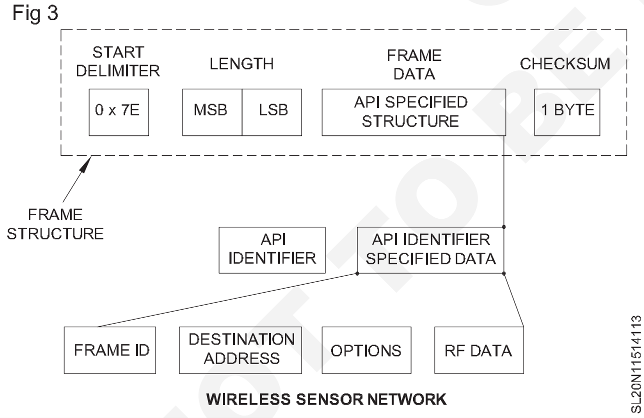
Fig 2



The condition monitoring of a PV system requires a substantial amount of measured data and software tools. Currently, the operation and maintenance of most of the PV plants are performed by manual and dispersive means.

Fig 3 Wireless sensor network

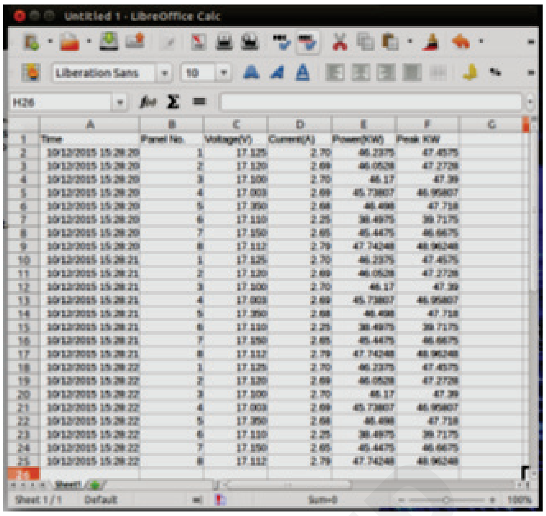
Fig 3



According to studies, condition monitoring using these means is not only quite difficult to be performed but also not able to improve the efficiency up to desired level. Hence, it is desirable to implement novel inspection methods and analysis tools for efficient condition monitoring and accurate module defect detection in PV systems.

Fig 4 Typical data logged in Excel sheet

Fig 4



Untitled 1 - LibreOffice Calc

H26

	A	B	C	D	E	F	G
1	Time	Panel No.	Voltage(V)	Current(A)	Power(KW)	Peak KW	
2	10/12/2015 15:28:20	1	17.125	2.70	46.2375	47.4575	
3	10/12/2015 15:28:20	2	17.120	2.69	46.0528	47.2728	
4	10/12/2015 15:28:20	3	17.100	2.70	46.17	47.39	
5	10/12/2015 15:28:20	4	17.003	2.69	45.73807	46.95807	
6	10/12/2015 15:28:20	5	17.350	2.68	46.498	47.718	
7	10/12/2015 15:28:20	6	17.110	2.25	38.4975	39.7175	
8	10/12/2015 15:28:20	7	17.150	2.65	45.4475	46.6675	
9	10/12/2015 15:28:20	8	17.112	2.79	47.74248	48.96248	
10	10/12/2015 15:28:21	1	17.125	2.70	46.2375	47.4575	
11	10/12/2015 15:28:21	2	17.120	2.69	46.0528	47.2728	
12	10/12/2015 15:28:21	3	17.100	2.70	46.17	47.39	
13	10/12/2015 15:28:21	4	17.003	2.69	45.73807	46.95807	
14	10/12/2015 15:28:21	5	17.350	2.68	46.498	47.718	
15	10/12/2015 15:28:21	6	17.110	2.25	38.4975	39.7175	
16	10/12/2015 15:28:21	7	17.150	2.65	45.4475	46.6675	
17	10/12/2015 15:28:21	8	17.112	2.79	47.74248	48.96248	
18	10/12/2015 15:28:22	1	17.125	2.70	46.2375	47.4575	
19	10/12/2015 15:28:22	2	17.120	2.69	46.0528	47.2728	
20	10/12/2015 15:28:22	3	17.100	2.70	46.17	47.39	
21	10/12/2015 15:28:22	4	17.003	2.69	45.73807	46.95807	
22	10/12/2015 15:28:22	5	17.350	2.68	46.498	47.718	
23	10/12/2015 15:28:22	6	17.110	2.25	38.4975	39.7175	
24	10/12/2015 15:28:22	7	17.150	2.65	45.4475	46.6675	
25	10/12/2015 15:28:22	8	17.112	2.79	47.74248	48.96248	
26							

Sheet1

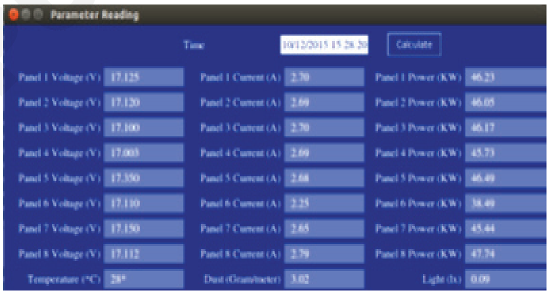
Sheet 1 / 1 Default Sum=0 100%

At present, there is a considerable interest given to the storage, dispatchability, and management of photovoltaic (PV) power in real time. So, there is need to manage. Researchers suggest that automation of the monitoring techniques, real-time processing of information and Unmanned Aerial System (UAS) technology can play an important role in the future.

Apart from the commercial applications, photovoltaic (PV) systems in residential premises are growing day by day and represent a predominant component around the globe.

Fig 5 GUI of HUB

Fig 5



Parameter Reading

Time: 10/12/2015 15:28:20

Calculate

Panel 1 Voltage (V): 17.125
Panel 1 Current (A): 2.70
Panel 1 Power (KW): 46.23
Panel 2 Voltage (V): 17.120
Panel 2 Current (A): 2.69
Panel 2 Power (KW): 46.05
Panel 3 Voltage (V): 17.100
Panel 3 Current (A): 2.70
Panel 3 Power (KW): 46.17
Panel 4 Voltage (V): 17.003
Panel 4 Current (A): 2.69
Panel 4 Power (KW): 45.73
Panel 5 Voltage (V): 17.350
Panel 5 Current (A): 2.68
Panel 5 Power (KW): 46.49
Panel 6 Voltage (V): 17.110
Panel 6 Current (A): 2.25
Panel 6 Power (KW): 38.49
Panel 7 Voltage (V): 17.150
Panel 7 Current (A): 2.65
Panel 7 Power (KW): 45.44
Panel 8 Voltage (V): 17.112
Panel 8 Current (A): 2.79
Panel 8 Power (KW): 47.74
Temperature (°C): 28°
Dust (Gram/meter): 3.02
Light (lx): 0.09

Fig 6 Hardware design of node

Fig 6

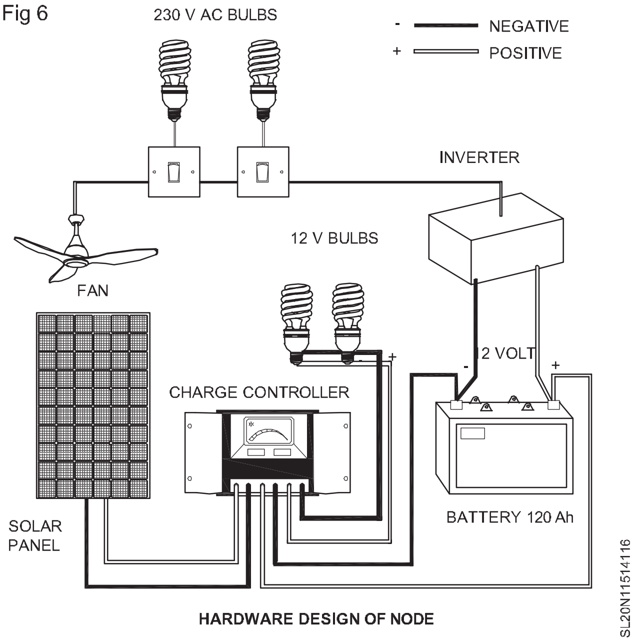
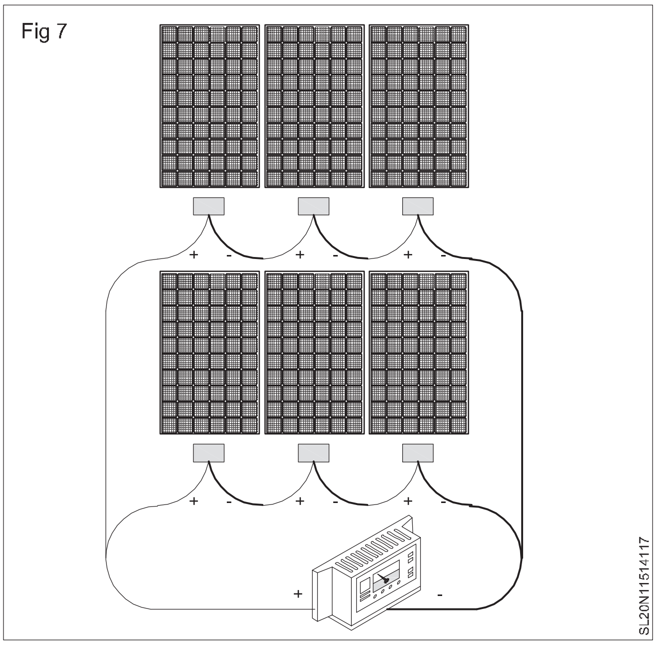
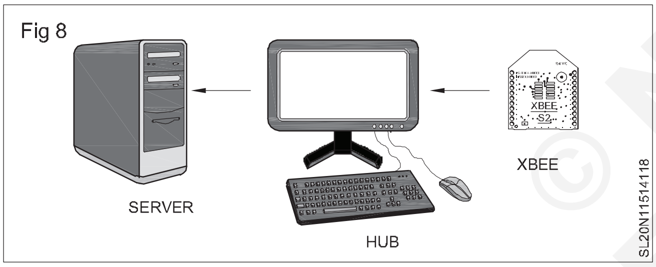


Fig 7 System Architecture



As the PV systems are major sources in micro grids and distributed generation (DGs), reliable islanding detection algorithm is required to determine the electrical grid status and operation in the grid-connected inverter.

Fig 8 Typical design of the Hub



The issues related to performance of PV systems have the strong dependency on many factors such as insolation intensity, ambient temperature, cell temperature, air velocity, humidity, cloudiness, and pollution.

As an example, in the above pictures it is described about the hardware and software implementation for fault detection and continuous monitoring system for solar panel in remote area. The wireless sensor node is provided with Voltage sensor, Current sensor, Light sensor, Temperature sensor and Dust sensor and XBeeS2 to implement WSN. Data are being continuously stored and monitored at central station called HUB and through that data are being sent to server via Ethernet. A friendly GUI using for example Python is implemented to visualize monitoring process and save data on Excel file.

Typical reports generated in similar condition monitoring systems are provided for academic interest of the solar technicians

Fig 9 Average Capacity Utilization Factor

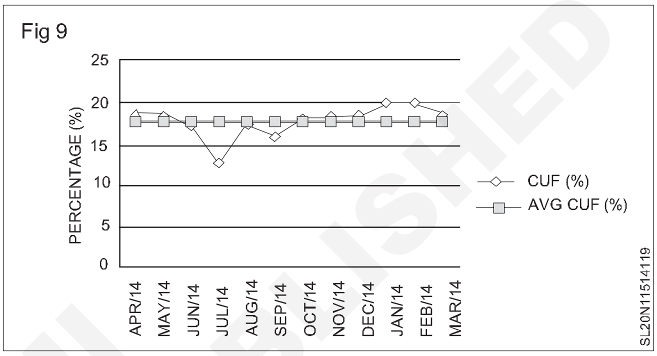


Fig 10 Average performance over months

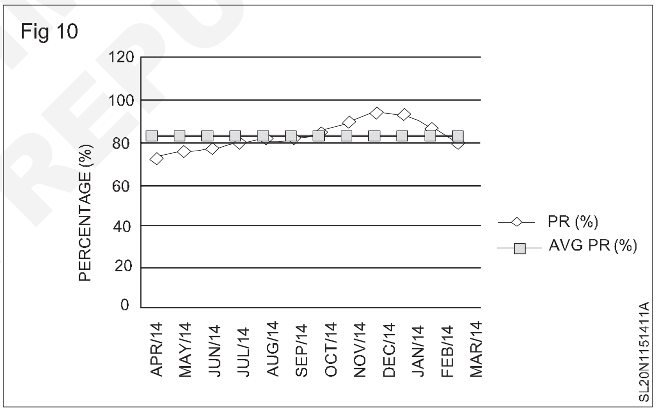


Fig 11 Daily sum of Global irradiation in horizontal and in-plane directions

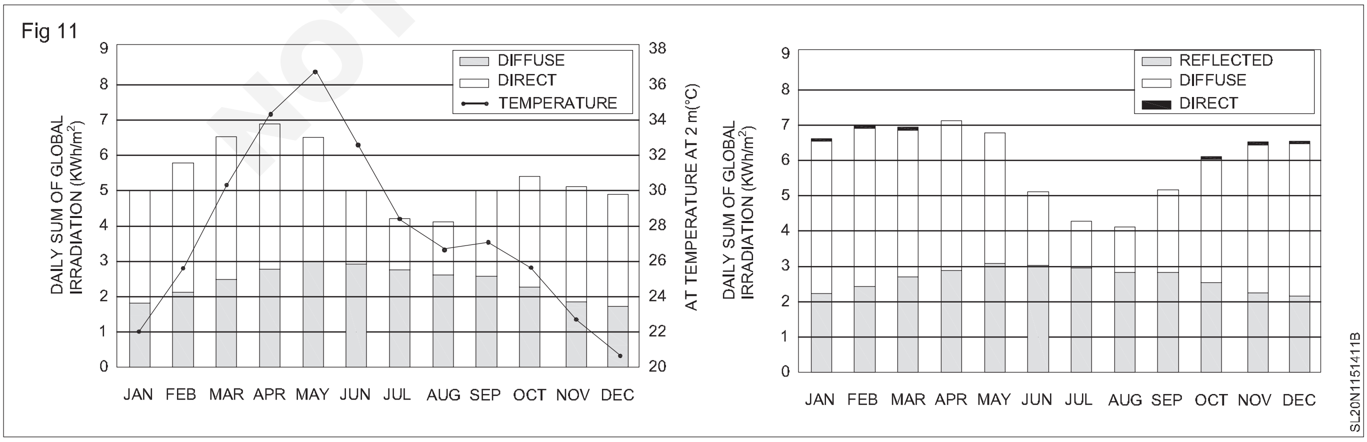
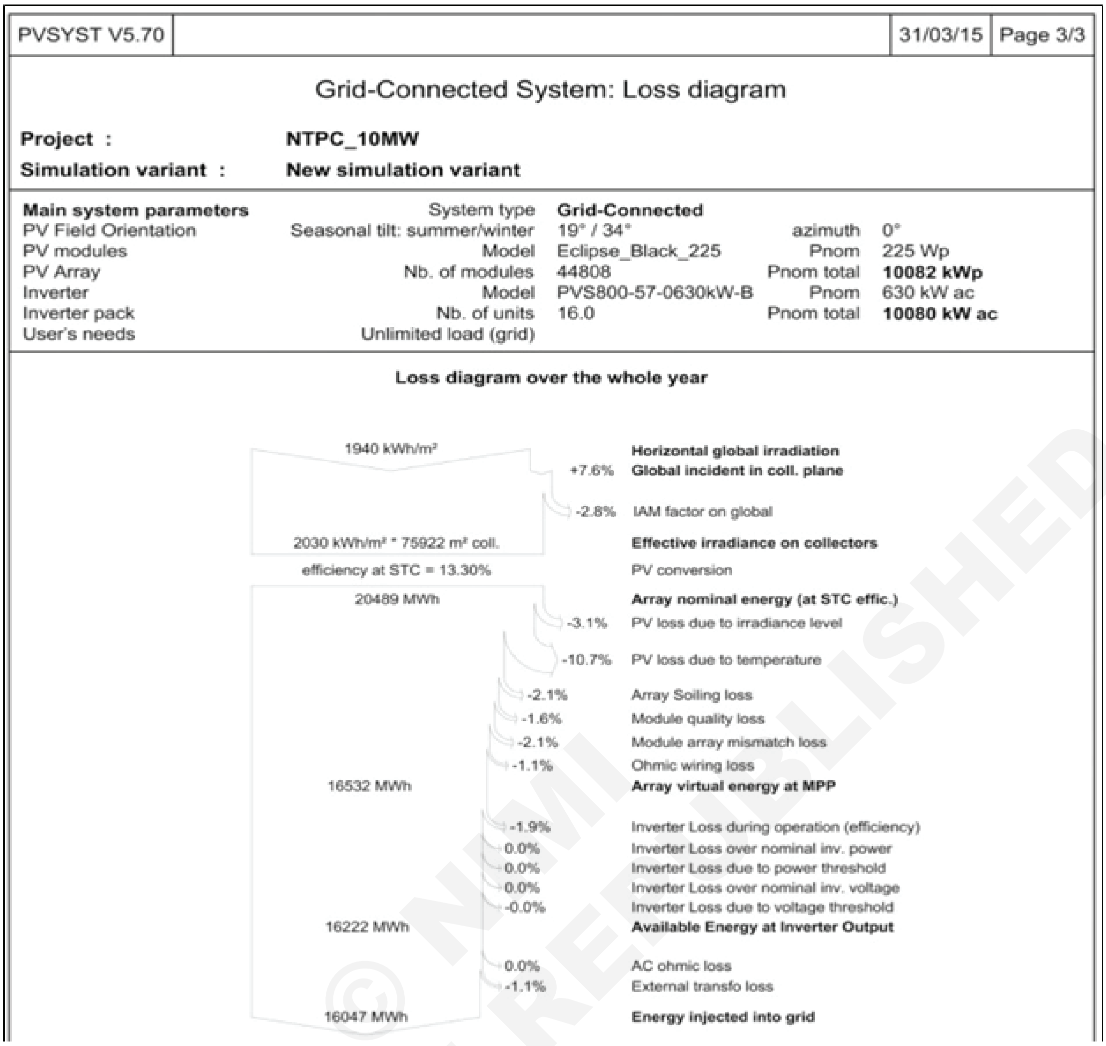


Fig 12 Loss diagram for entire year

Fig 12



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Grid-Connected System: Loss diagram

Project : **NTPC_10MW**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	Seasonal tilt: summer/winter	19° / 34°	azimuth	0°
PV modules	Model	Eclipse_Black_225	Pnom	225 Wp
PV Array	Nb. of modules	44808	Pnom total	**10082 kWp**
Inverter	Model	PVS800-57-0630kW-B	Pnom	630 kW ac
Inverter pack	Nb. of units	16.0	Pnom total	**10080 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year

1940 kWh/m²		**Horizontal global irradiation**
	+7.6%	**Global incident in coll. plane**
	-2.8%	IAM factor on global
2030 kWh/m² * 75922 m² coll.		**Effective irradiance on collectors**
efficiency at STC = 13.30%		PV conversion
20489 MWh		**Array nominal energy (at STC effic.)**
	-3.1%	PV loss due to irradiance level
	-10.7%	PV loss due to temperature
	-2.1%	Array Soiling loss
	-1.6%	Module quality loss
	-2.1%	Module array mismatch loss
	-1.1%	Ohmic wiring loss
16532 MWh		**Array virtual energy at MPP**
	-1.9%	Inverter Loss during operation (efficiency)
	0.0%	Inverter Loss over nominal inv. power
	0.0%	Inverter Loss due to power threshold
	0.0%	Inverter Loss over nominal inv. voltage
	-0.0%	Inverter Loss due to voltage threshold
16222 MWh		**Available Energy at Inverter Output**
	0.0%	AC ohmic loss
	-1.1%	External transfo loss
16047 MWh		**Energy injected into grid**

Data logger and SCADA room

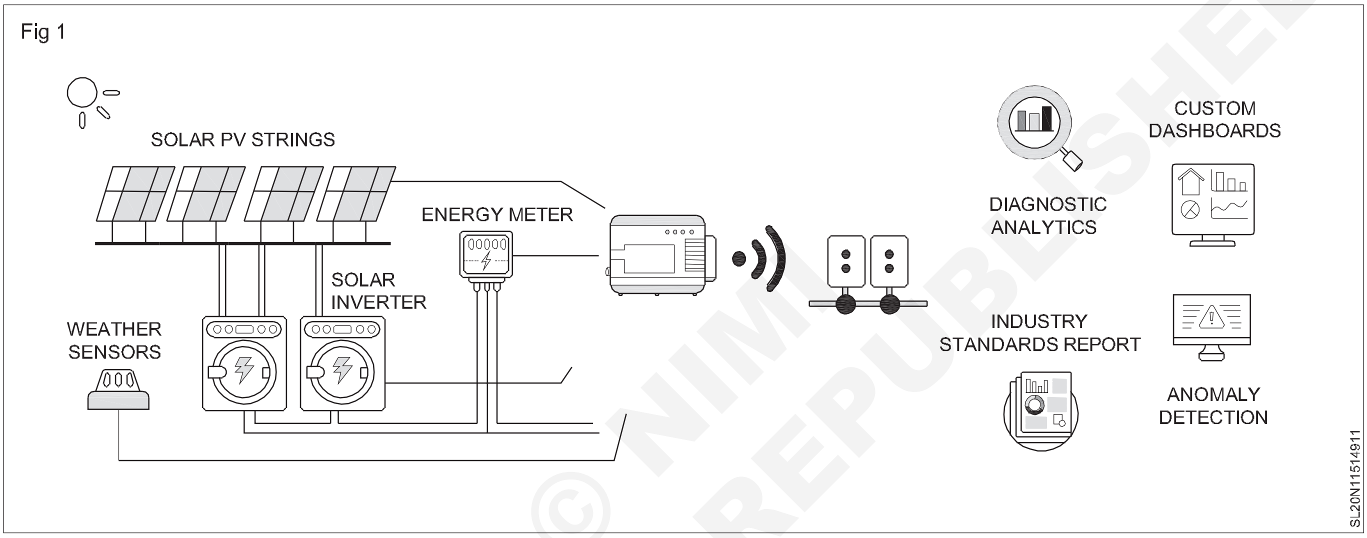
Objectives: At the end of this lesson you shall be able to
- **utilize benefits of datalogger and SCADA.**

In continuation to the condition monitoring let us study about Data logger and SCADA room. This is only extension of this topic that has become mandatory component in a sizeable solar plant. Normally more useful for maintenance purposes but most desired for evaluation and improvement of the plant since a lot investment is being made expecting a handsome return.

Supervisory Control and Data Acquisition is popularly known as SCADA.

Fig 1 Data logger and SCADA – IoT solutions

Using this we can collect data from the following components, at a remote place:

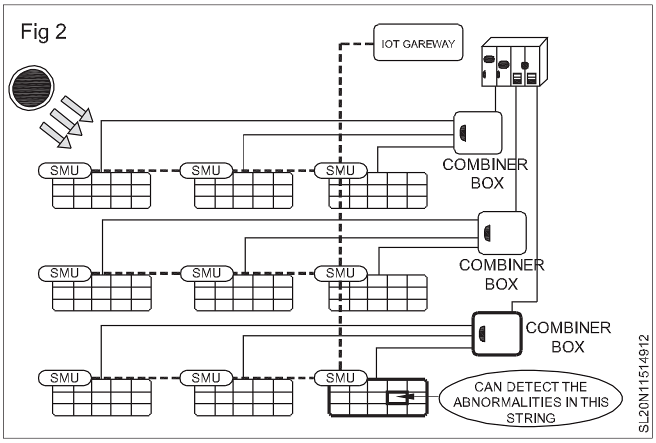


- Solar PV Strings
- Solar Inverter
- Energy Meter
- Water Pump
- DG Sync
- Weather Station
- MODBUS Slaves
- Zero export (Recent development)

From collected data, we can

- Get detailed insights in solar PV system by monitoring each string & identify anomaly instantly at the right place
- Collect data from solar inverters & MPPT strings to give accurate insights into the plant's performance
- Monitor energy meters to make sure energy transfer happens with minimum losses, else, identify anomalies instantly
- Know the pump's runtime & be aware about overuse & misuse. Keep track of performance & get timely alerts
- Synchronize the solar PV systems with existing DG sets locally to derive the maximum benefit
- Keep track of weather conditions at the plant location to understand or predict generation loss & get instant alerts
- Connect & configure any MODBUS slave along with other components.
- Enable the SPV system with Zero export capability and ensure avoid all net metering procedures

Fig 2 String Monitoring using Data logger & SCADA



String Monitoring Unit (SMU)

One of the critical ways to keep a track of the solar PV panels and identify the faulty component in the shortest time possible is string monitoring.

String monitoring is a concept where all the strings of solar PV panels [individual solar PV panels in some cases] are monitored to track the output and performance of each unit along with the overall output and performance of the system. String monitoring can be done in 2 ways:

- Using solar inverter based string monitoring
- Using a 3rd party string monitoring system

Solar Inverter based String Monitoring

In this case, the solar inverter allows the user to provide string level inputs and then monitor it along with other parameters. These inverters generally have a few MPPT inputs and each MPPT input consist of multiple strings. Hence, with 1 MPPT, the user can monitor multiple strings individually as well as the combined production. Such a system is mostly available with inverters with a capacity greater than 50 kWp. A few brands provide string monitoring in the many of inverter models. Having a string monitoring feature in the inverter itself has two advantages:

- It saves some cost in installing additional string monitoring system
- It reduces the complexity of the overall design as all the strings are directly connected to the inverter

3rd Party Based String Monitoring

In case the inverter is less than 50 kWp capacity or the overall design of the plant is such that the string monitoring could not be available in the inverter itself, the user can install a 3rd party string monitoring system. The function of the string monitoring box is exactly the same as the one inside the inverter. But only the design is different. All the solar PV strings come to this string monitoring box and then they are combined to provide an output to the MPPT input of the inverter. This string monitoring box acts as an independent unit and can send data to the monitoring portal using MODBUS protocol just as the solar inverters.

Alarms & security

Objective: At the end of this lesson you shall be able to
- **analyze the alarms and security features in a SPV plant.**

Alarms, beeps and some noise are indications of normal healthy as well as unhealthy conditions of components such as inverters or PCUs. Some common symptoms and solutions are given below as example. The actual cases vary among different service providers or manufacturers. Usually the alarms are visual, audio or audio-visual alerts in inverters.

Alarm /Fault description	Possible cause	Solution
Alarm buzzer beeps continuously	Over load error	Disconnect extra load
Chattering noise in cooling fan	Cooling fan is stuck	Call or take the inverter to the service center
Inverter making a humming noise.	Wind noise	This is normal. No need of any action
‘Hizz’ing sound in inverter	Humming noise produced by non-pure sine wave Inverter	This is normal. No need of any action
Heavy noise in Cooling fan	Too much of fan noise	Clean the fan Vacuum clean the inverter Check for faulty fan If problem persists, replace it or get it done by trained personnel

Wired in different ways

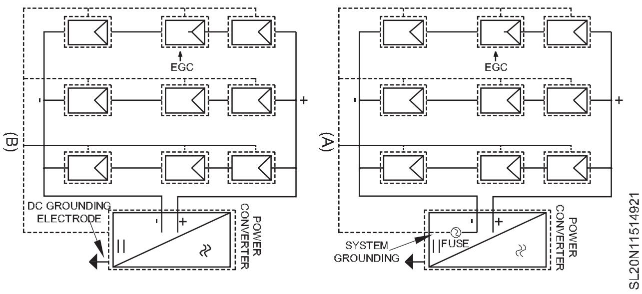
PV systems are wired in different ways to handle system grounding. The DC side of the system may be directly grounded (e.g., one pole connected to earth) or ungrounded, or the array may be grounded through a connection to the AC side ground.

Systems also may or may not have galvanic isolation between the DC and AC sides. These design factors influence a system’s fault tolerance and response to ground faults, and add complexity to properly implementing ground fault protection.

A ground-fault detector interrupter (GFDI) such as the new high performance circuit breaker (HPCB) is a safety device that is specially designed for PV solar arrays. A ground fault at the PV generator will trigger the GFDI, interrupting the leakage and preventing damage to the system.

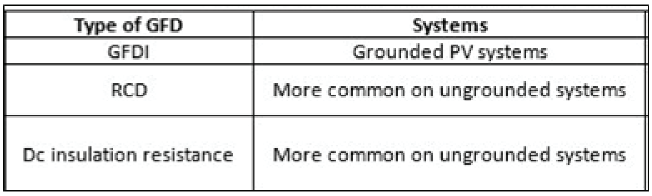
Fig 1 Schematic diagram of grounded and ungrounded PV systems

Fig 1



Different types of ground fault detection methods:

A GFDI is used in grounded PV systems, which means the manufacturers of PV modules recommend or require positive or negative grounding of the PV generator when using thin-film and back-contact PV modules. the GFDI is also referred to as a GFCI – ground-fault current interrupter.



Type of GFD	Systems
GFDI	Grounded PV systems
RCD	More common on ungrounded systems
Dc insulation resistance	More common on ungrounded systems

Fault Errors displayed in Inverter Screen

Read the respective inverter user manual for various LED indications on the panel and the inverter error codes. Some of which are listed below:

- Grid under voltage
- Grid over voltage
- Faulty phase sequence
- Over load
- Short circuit
- Battery under voltage
- Battery over voltage
- Earthing fault

Ground Fault Error, Load Problem Error, AC under voltage or over voltage fault and Software fault are some error messages displayed on inverter screen the meanings as well as remedies are guided in the relevant maintenance manuals of the systems supplied by their manufacturers.

In general these points can be discussed but particular to the components actually used in SPV systems have customized design and user guide books.

Introduction to wind power

Objective: At the end of this lesson you shall be able to
- **learn features of wind plant.**

Winds are influenced by the ground surface at altitudes up to 100 meters. Wind is slowed by the surface roughness and obstacles. When dealing with wind energy, we are concerned with surface winds.

A wind turbine obtains its power input by converting the force of the wind into torque (turning force) acting on the rotor blades. The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.

The kinetic energy of a moving body is proportional to its mass (or weight). The kinetic energy in the wind thus depends on the density of the air, i.e. its mass per unit of volume. In other words, the "heavier" the air, the more energy is received by the turbine.

Fig 1 Types of Winds and their speed

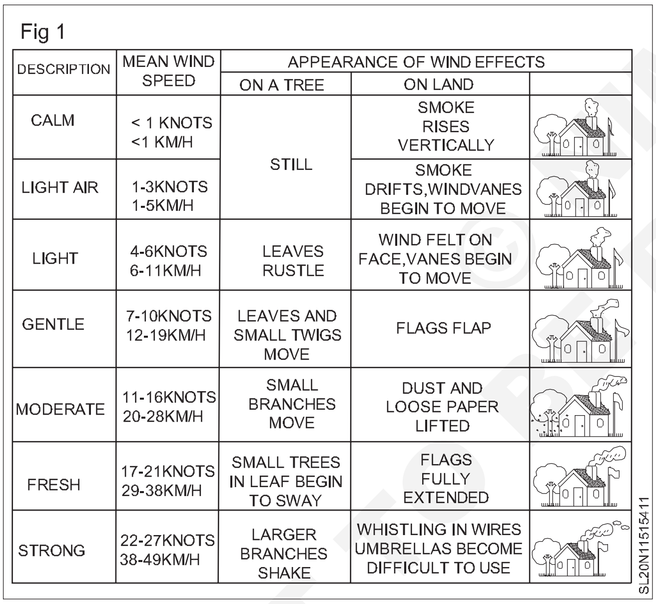


Fig 1

DESCRIPTION	MEAN WIND SPEED	APPEARANCE OF WIND EFFECTS		
		ON A TREE	ON LAND	
CALM	< 1 KNOTS <1 KM/H	STILL	SMOKE RISES VERTICALLY	
LIGHT AIR	1-3KNOTS 1-5KM/H		SMOKE DRIFTS,WINDVANES BEGIN TO MOVE	
LIGHT	4-6KNOTS 6-11KM/H	LEAVES RUSTLE	WIND FELT ON FACE,VANES BEGIN TO MOVE	
GENTLE	7-10KNOTS 12-19KM/H	LEAVES AND SMALL TWIGS MOVE	FLAGS FLAP	
MODERATE	11-16KNOTS 20-28KM/H	SMALL BRANCHES MOVE	DUST AND LOOSE PAPER LIFTED	
FRESH	17-21KNOTS 29-38KM/H	SMALL TREES IN LEAF BEGIN TO SWAY	FLAGS FULLY EXTENDED	
STRONG	22-27KNOTS 38-49KM/H	LARGER BRANCHES SHAKE	WHISTLING IN WIRES UMBRELLAS BECOME DIFFICULT TO USE	

Windmill: principle of operation and types

A wind turbine extracts energy from moving air by slowing the wind down, and transferring this energy into a spinning shaft, which usually turns a generator to produce electricity. The power in the wind that's available for harvest depends on both the wind speed and the area that's swept by the turbine blades.

Two types of turbine design are possible – Horizontal axis and Vertical axis. In horizontal axis turbine, it is possible to catch more wind and so the power output can be higher than that of vertical axis. But in horizontal axis design, the tower is higher and more blade design parameters have to be defined. In vertical axis turbine, no yaw system is required and there is no cyclic load on the blade, thus it is easier to design. Maintenance is easier in vertical axis turbine whereas horizontal axis turbine offers better performance.

The two types are based on the resolved forces of the directed wind. In other words the wind blows in the resultant direction of the two forces namely, Lift and Drag.

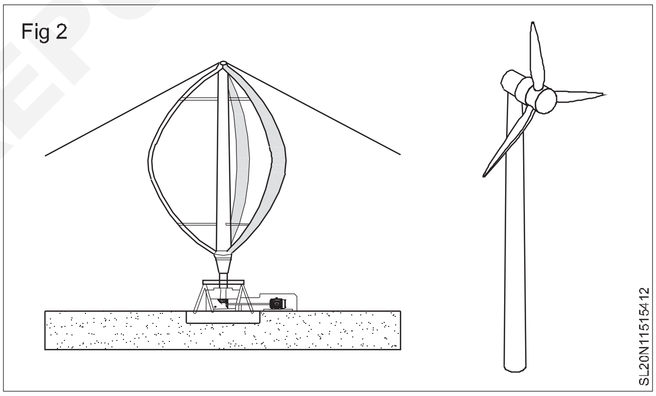
Types of turbines

VAWT

- Drag is the main force
- Nacelle is placed at the bottom
- Yaw mechanism is not required
- Lower starting torque
- Difficulty in mounting the turbine
- Unwanted fluctuations in the power output

Fig 2 Types of Wind power Plants

Fig 2



HAWT

Lift is the main force

- Much lower cyclic stresses
- 95% of the existing turbines are HAWTs
- Nacelle is placed at the top of the tower
- Yaw mechanism is required

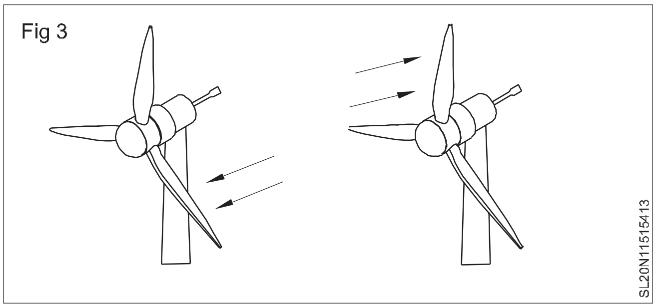
Fig 3 Types of HAWT

Two types of HAWT

- Downwind turbine
- Upwind turbine

Counter Rotating HAWT

- Increase the rotation speed
- Rear one is smaller and stalls at high wind speeds

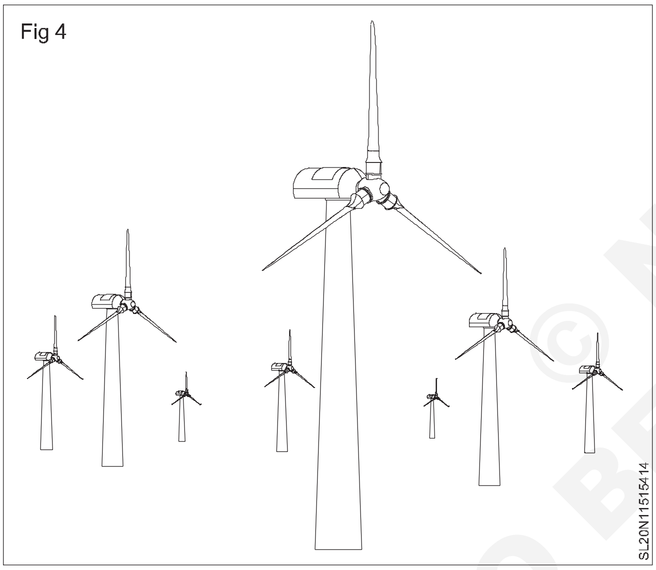


- Operates for wider range of wind speeds

Offshore turbines

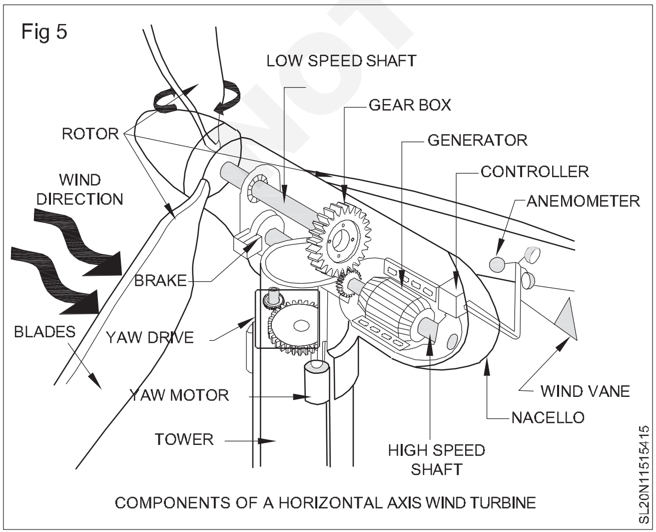
- More wind speeds
- Less noise pollution
- Less visual impact
- Difficult to install and maintain
- Energy losses due long distance
- Transport

Fig 4 Off shore Wind turbines



Elements / Components of wind turbine generator (WTG)

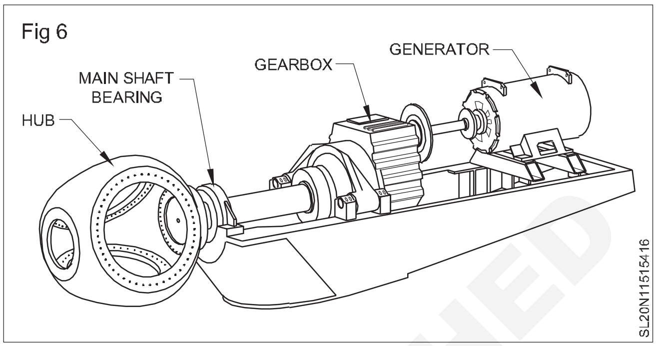
Fig 5 Cut-away view



Main components considered are:

- Blades
- Material used
- Typical length
- Tower height
- Heights twice the blade length are found economical

Fig 6 Main components



Rotor

The portion of the wind turbine that collects energy from the wind is called the rotor. The rotor usually consists of two or more wooden, fiberglass or metal blades which rotate about an axis (horizontal or vertical) at a rate determined by the wind speed and the shape of the blades. The blades are attached to the hub, which in turn is attached to the main shaft.

Technical challenges

- Rotational control
- Maintenance
- Noise reduction
- Centripetal force reduction
- Mechanisms
- Stalling
- Furling
- Yaw Mechanism
- To turn the turbine against the wind
- Yaw error and fatigue loads
- Uses electric motors and gear boxes
- Wind turbine safety
- Sensors – controlling vibrations
- Over speed protection
- Mechanical Braking
- Aero dynamic braking

What should be the blade profile?

- Blade Length
- Blade Number
- Blade Pitch
- Blade Shape
- Blade Materials
- Blade Weight
- Rotor Blade Variables

Small (mini) hydro electricity generation and charge controller

Objective: At the end of this lesson you shall be able to
- **learn features of a small hydro plant.**

A Turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and water wheels.

Gas, steam, and water turbines usually have a casing around the blades that contains and controls the working fluid. The word "turbine" was coined in 1822 by the French mining engineer Claude Bur din.

Water Turbine

A water turbine is a rotary engine that takes energy from moving water. Water turbines were developed in the 19th century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation. They harness a clean and renewable energy source.

Flowing water is directed on to the blades of a turbine runner, creating a force on the blades. Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work). In this way, energy is transferred from the water flow to the turbine.

Water turbines are divided into two groups; reaction turbines and impulse turbines. The precise shape of water turbine blades is a function of the supply pressure of water, and the type of impeller selected.

The reaction turbine, as the name implies, is turned by reactive force rather than by a direct push or impulse.

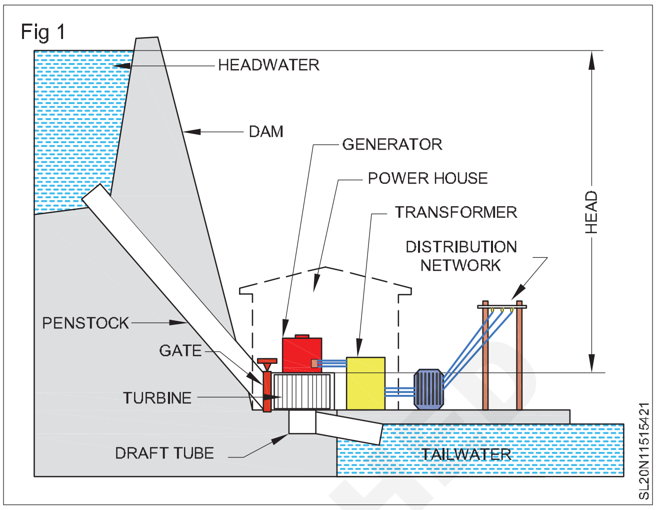
Reaction turbines are those turbines which operate under hydraulic pressure energy and part of kinetic energy. In this case, the water reacts with the vanes as it moves through the vanes and transfers its pressure energy to the vanes so that the vanes move in turn rotating the runner on which they are mounted.

Newton's third law describes the transfer of energy for reaction turbines. Most water turbines in use are reaction turbines and are used in low (<30m/98 ft) and medium (30-300m/98–984 ft) head applications. In reaction turbine pressure drop occurs in both fixed and moving blades.

Impulse turbines

Impulse turbines change the velocity of a water jet. The jet pushes on the turbine's curved blades which changes the direction of the flow. The resulting change in momentum (impulse) causes a force on the turbine blades. Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy.

Fig 1



Prior to hitting the turbine blades, the water's pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine. No pressure change occurs at the turbine blades, and the turbine doesn't require housing for operation.

Newton's second law describes the transfer of energy for impulse turbines. Impulse turbines are most often used in very high (>300m/984 ft) head applications.

Turbine selection is based mostly on the available water head, and less so on the available flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites.

Kaplan turbines with adjustable blade pitch are well-adapted to wide ranges of flow or head conditions, since their peak efficiency can be achieved over a wide range of flow conditions

The Pelton wheel is an impulse turbine which is among the most efficient types of water turbines. The Pelton wheel extracts energy from the impulse (momentum) of moving water, as opposed to its weight like traditional overshot water wheel. Although many variations of impulse turbines existed prior to Pelton's design, they were less efficient than Pelton's design; the water leaving these wheels typically still had high speed, and carried away much of the energy. Pelton's paddle geometry was designed so that when the rim runs at ½ the speed of the water jet, the water leaves the wheel with very little speed, extracting almost all of its energy, and allowing for a very efficient turbine.

Penstock

A penstock is a sluice or gate or intake structure that controls water flow, or an enclosed pipe that delivers water to hydraulic turbines and sewerage systems. It is a term that has been inherited from the technology of wooden watermills.

Turbine Runner

The runner is the heart of the turbine. This is where water power is transformed into the rotational force that drives the generator. All the buckets are mounted on runner.

Nozzle

A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe via an orifice. A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.

Basics of other renewable energy resources for power generation, such as bio gas plant and Fuel Cell

Objective: At the end of this lesson you shall be able to
- **learn basics of fuel cell and biogas plant.**

A fuel cell is an electrochemical energy conversion device. A fuel cell converts the chemicals hydrogen and oxygen into water, and in the process it produces electricity.

PEM Electrolyzers:

Hydrogen and oxygen can be produced by the electrolysis of water. Electrolysis is an electrochemical process through which a substance (the electrolyte) is decomposed when an external DC voltage is applied to two electrodes (cathode and anode) that are in contact with the electrolyte. For electrolysis to happen the DC voltage must be equal to or exceed a certain material-dependent threshold voltage known as the decomposition voltage.

Different types of electrolyzers are usually distinguished by their type of electrolyte and/or electrodes. PEM electrolyzers have a particularly simple and compact design. The central component is a proton-conducting polymer membrane which is coated with a layer of catalyst material on either side. These two layers are the electrodes of the cell.

When a DC voltage greater than the decomposition voltage of water is applied to its electrodes, the PEM electrolyzer splits pure water into hydrogen and oxygen. The theoretical decomposition voltage of water is 1.23 V, however, because of transition resistances, somewhat higher voltages are necessary in practice.

Higher power electrolyzers are built as stacks in which individual electrolyzers are connected in series and voltages are added.

PEM electrolyzers have efficiencies of up to ~ 85 %.

How PEM electrolyzers work:

Suppose a DC voltage is applied to the PEM electrolyzer electrodes (solar panel on the transparency). At the anode (electrode on the right) water is oxidized, leaving oxygen, protons (H+-ions) and free electrons. While the oxygen gas can be collected directly at the anode, the protons (yellow +) migrate through the proton-conducting membrane to the cathode where they are reduced to hydrogen (the electrons for this are provided by the external circuit).

Anode reaction: 2H2O –> 4H

+ + 4e- + O2

Cathode reaction: 4H

+ + 4e- –> 2H2

Total reaction: 2H2O –> 2H2 + O2

PEM electrolyzers are named after their electrolyte material, a proton-conducting polymer membrane. The acronym PEM stands for proton exchange-membrane or polymer electrolyte-membrane. A PEM consists of a teflon-like polymer structure to which sulfonic acid groups (SO3H) are attached. When the membrane becomes wet the sulfonic acid dissociates, the membrane becomes acidic and thereby proton-conducting. While this allows for an easy transport of protons (H+-ions), anions (negatively charged ions) cannot pass the membrane.

Hydrogen Storage:

Hydrogen can be stored in various ways, e.g. as a pressurized gas, as a cryogenic liquid as a metal hydride or in a carbon nanofiber structure.

Pressure storage:

The easiest and most economical method of storing hydrogen is to simply compress the gas and store it in containers that can withstand the resulting high pressure. Unless space or weight is issues this is the storage method of choice. Conventional pressure tanks are designed to withstand pressures of up to 200 bar and can therefore hold 200 times the volume of a given gas (as compared to the gas volume at ambient pressures). They are mainly used for indoor and stationary applications. Among the more recent developments in this area are tanks made of carbon composites. Not only are these more lightweight than their conventional counterparts but they can also withstand pressures of up to 350 bar (700 bar in the future).

Windmill integration with solar PV plant and with grid

Objective: At the end of this lesson you shall be able to
- **integrate a SPV plant and wind plant.**

Fig 1 Solar – Wind Hybrid plant

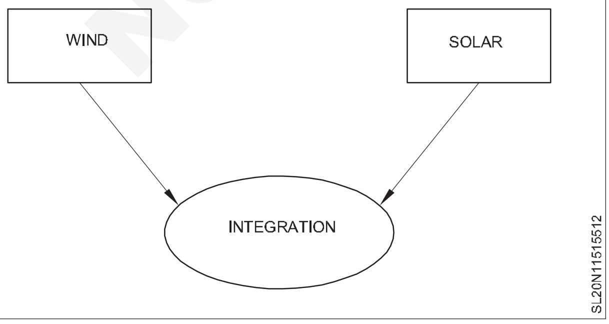
Fig 1

Wind energy has the following unique characteristics, and consequently, consequences when connected to the grid:

- Wind energy is not constant and unreliable. The consequence is that other generators on the grid must react not only to load variability, but also to wind energy variability. This requires conventional generators to support higher ramp rates in both directions. In addition for cost-efficient operations, accurate wind energy forecasts and responsive systems operations are necessary.
- Wind generator is asynchronous in contrast to synchronous conventional generators. The consequence is that wind energy provides no inertial response, so when wind energy saturation is high, grid inertia can be low. Hence the grid may become unstable and unable to provide a stable timely frequency response in reaction to fault on the grid.

Fig 2 Wind –solar integration model

Fig 2



Best practices on Wind – Solar PV integration:

- Transmission from high potential areas to load centers: planning in advance and perfect designing is essential. Policy guidelines must be clear.
- Responsive systems operations: Flexible production based on availability of wind energy based on forecasts and timely interleaving in export to the grid.
- Flexible generation and demand: Grid fluctuations are common in Indian environment. Generation or shutdown, even a slowdown influences major user variations or blackouts. Wind energy variations pose breaks in addition. Higher ramp rates and shallow cycles should manage the losses. Intermittent operations and shutdowns should be monitored in steps with load shifts.
- Comprehensive planning process: one solution for all issues is never a possibility. Nationwide network integration in a broader view a possible way out.
- Grid code for wind integration: Keeping in mind safe and reliability, minimum technical standards must be defined to accommodate all wind energy producer.

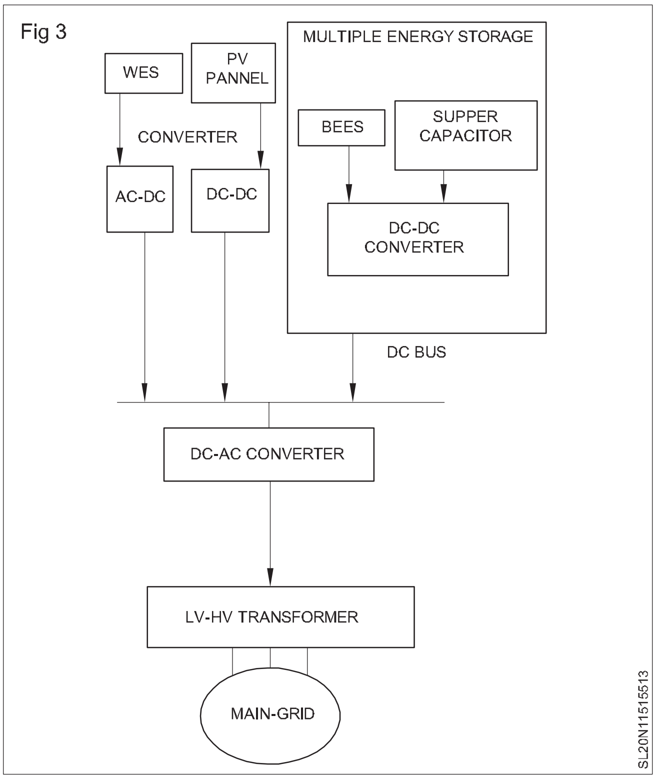
Fig 3 Wind – Solar integration with grid

Under high load conditions, line losses escalate exponentially. If lines are congested and operating at or near their thermal limits, they would also be exhibiting significant line losses during high load conditions.

There have been cases when wind farms are forced to shut down even when the wind is blowing because there is no capacity available in the lines for the electricity they create. Without adequate transmission to transport power from “renewable” rich areas to densely populated areas, it is only cost effective to use renewable sources in certain areas of the country.

While building new infrastructure would certainly help, smart grid technologies can also help utilities alleviate grid congestion and maximize the potential of our current infrastructure. Smart grid technologies can help provide real-time readings of the power line, enabling utilities to maximize flow through those lines and help alleviate congestion. As smart grid technologies become more widespread, the electrical grid will be made more efficient, helping reduce issues of congestion.

Fig 3



Sensors and controls will help intelligently reroute power to other lines when necessary, accommodating energy from renewable sources, so that power can be transported greater distances, exactly where it's needed.

SOP (Standard Operation Procedures) of PV system

Objectives: At the end of this lesson you shall be able to
- **execute SOP in a SPV plant.**

Safety Preparation at Work Area

Solar technician must understand essential safety norms to be followed at field and be able to prepare documentation of safety procedures. The main purpose of the Health and Safety policies and procedures is to instruct and follow all workers to prevent injury, to themselves and others. Every worker has to participate in developing, implementing, and enforcing Health and Safety policies and procedures.

The separate instruction manual is prepared for health and safety at work area at solar PV project. The structure and usage of the manual is supported by the following two document sets.

1 Standard Operating Procedures (SOP) applicable for different tasks, business processes or risk areas.

2 Documentation Formats for preparation and maintenance of important records.

The manual should be read in conjunction with the most updated versions of the standard operating procedures (SOPs) and documentation formats (DF) for different sub-tasks at all times, as applicable.

The manual is intended to provide guidance on the basic framework for health & safety management and its continual improvement across all our operations. These standards are to be followed along with SOPs as good practise and mitigate Health & Safety risks in operations.

The list of SOPs and documentation formats is prepared and recorded.

For Example: SOPs with versions

1 Risk Management
2 Waste Management
3 Fire and emergency procedures
4 Electrical safety
5 Work at height and fall prevention
6 Tools and equipment
7 Traffic safety
8 Personal protective equipment
9 Work permit system
10 Safe lifting operations
11 Health & Safety audit procedure

For example Documentation formats

1 Health & Safety checklist
2 Accident/Incident Reporting
3 Risk mitigation plan

Personal Protective Equipment (PPE)

Objectives: At the end of this lesson you shall be able to
- **handle PPE for use in SPV plant.**

Solar technician shall be able to

- Place personal safety equipment properly at work area.
- Identify and segregate good personal safety equipment.
- Inspect visually wear and tear of safety equipment.
- Verify expiry date of personal protection equipment.
- Arrange protective equipment as per instruction from supervisor.
- Arrange required test devices as per required site work.

We should first understand the importance of PPE and select suitable equipment to protect different part of the body.

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

Making the workplace safe includes providing instructions, procedures, training and supervision to encourage people to work safely and responsibly. Even where engineering controls and safe systems of work have been applied, some hazards might remain.

These include injuries to:

- the lungs, example from breathing in contaminated air
- the head and feet, example from falling materials
- the eyes, example from flying particles or splashes of corrosive liquids

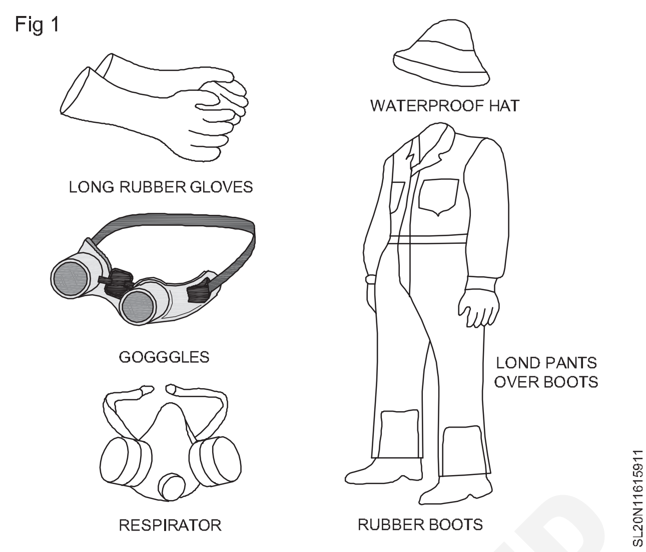
- the skin, example from contact with corrosive materials
- the body, example from extremes of heat or cold

PPE is needed in these cases to reduce the risk.

Fig 1 Types of PPE

You must choose the equipment carefully and ensure employees are trained to use it properly, and know how to detect and report any faults. When selecting and using PPE:

Fig 1



Types of PPE

Personal safety for	Hazards	Options	Remarks
Eyes	Chemical or metal splash, dust, projectiles, gas and vapour, radiation	Safety spectacles Goggles face screens face shields visors.	Make sure the eye protection chosen has the right combination of impact/dust/splash/molten metal eye protection for the task and fits the user properly.
Head and neck	Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery.	Industrial safety helmets bump caps, hairnets fire fighters' helmets.	Helmet protects the head from injury. The neck protection is also very important. Replace head protection if it is damaged.
Ears	Noise - very high-level sounds are a hazard even with short duration	Earplugs earmuffs semi-insert/ canal caps	Provide the right hearing protectors for the type of work, and make sure workers know how to fit them.
Hands and arms	Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, vibration, biological agents and prolonged immersion in water.	Gloves gloves with a cuff gauntlets sleeving that covers part or all of the arm.	Wearing gloves for long periods can make the skin hot and sweaty, leading to skin problems. Using separate cotton inner gloves can help prevent this.
Feet and legs	Wet, hot and cold conditions, electrostatic build-up, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, vehicles.	Safety boots shoes with protective toecaps mid-sole wellington boots	Footwear can have a variety of sole patterns and materials to help prevent slips in different conditions, including oil - or chemical-resistant soles. It can also be anti-static, electrically conductive or thermally insulating.
Lungs	Oxygen-deficient atmospheres, dusts, gases and vapours	Respiratory protective equipment (RPE)	Only use breathing apparatus - never use a filtering cartridge.

Whole body	Heat, chemical or metal splash, spray from pressure leaks or spray guns, contaminated dust, impact or penetration.	boiler suits aprons Chemical suits.	The choice of materials includes flame-retardant, anti-static, chain mail, chemically impermeable, and high-visibility.

Safety at heights

Objective: At the end of this lesson you shall be able to
- **work safely at heights.**

Follow Instructions for Work at Height, such as:

1 Arrange fall protection materials and devices as per supervisor instructions

2 Arrange perimeter protection material and devices to work area.

3 Assist in plan fall protection and perimeter protection.

4 Verify tools and materials as per list.

5 Remove the tools and materials from work area.

6 Verify protection equipment as per list.

7 Remove the protection equipment from work area.

8 Dispose the scrap material from work area.

Fall protection at workplace

Objectives:

1 identify tools essential for working at height

2 handle various safety gadgets

The solar PV panels are often installed at heights, the following safety precautions should be kept in mind.

Solar technician should:

- Use proper ladder safety techniques when accessing all elevated areas.
- Hoist materials instead of trying to take them up ladders manually.
- Evaluate the height and the roof pitch to determine if fall protection or safety barriers are required.
- Stay away from elevated edges.

Fig 1 Fall Protection Equipment

Fig 1

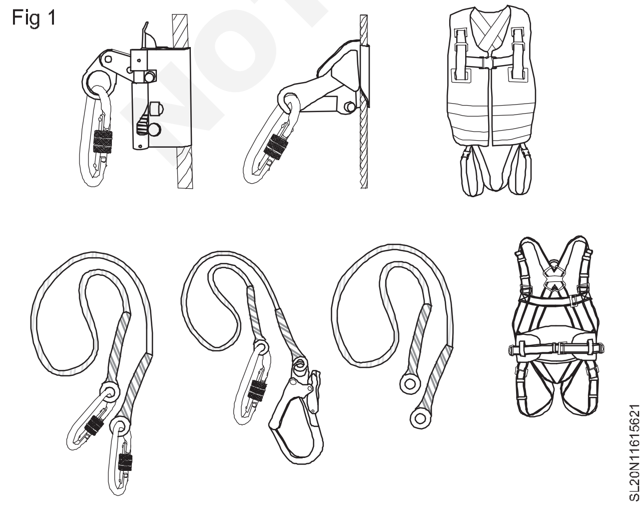


Fig 2 Fall protection hazards

Fig 2

Ladder Safety

Solar construction often involves working on roofs and from ladders. Choosing the right ladder and using it properly are essential.

Safety measures for solar technicians:

1 Select the ladder that best suits the need for access – whether a stepladder, straight ladder or extension ladder. Straight or extension ladders should extend a minimum of three feet above the rung that the worker will stand upon.

2 Select the right ladder material. Aluminium and metal ladders are the most commonly used today and may have their place on the job, but they're a serious hazard near power lines or electrical work. Use a fibreglass ladder with non-conductive side rails near power sources.

3 Place the ladder on dry, level ground removed from walkways and doorways, and at least 10 feet from power lines and secure it to the ground or rooftop.

Trips and Falls Hazard

Trips and falls are a common hazard of all construction jobs, including solar. They can happen anywhere on the jobsite, especially off roofs or ladders. The solar installations on pole type structures are especially hazardous because the work space diminishes as more panels are installed, increasing the risk of falls.

Safety measures for solar PV technicians:

1 Keep all work areas dry and clear of obstructions.

2 For fall distances of six feet or more, take one of three protective measures: install guardrails around ledges, sunroofs or skylights; use safety nets; or provide each employee with a body harness that is anchored to the rooftop to arrest a potential fall.

3 Cover holes on rooftops, including skylights, and on ground-level work surfaces.

Fall hazard assessment checklist		
1 Can an employee enter the area without restriction and perform work?	Yes	No
2 Are fall prevention systems such as cages, guardrails, toeboards, and manlifts in place?	Yes	No
3 Have slipping and tripping hazards been removed or controlled?	Yes	No
4 Have visual warnings of fall hazards been installed?	Yes	No
5 Can the distance a worker could fall be reduced by installing platforms, nets, etc.?	Yes	No
6 Are any permanently installed floor coverings, gratings, hatches, or doors missing?	Yes	No
7 Does the location contain any other recognized safety and or health hazards?	Yes	No
8 Is the space designated as a Permit Required Confined Space?	Yes	No
9 Working near telecommunication or electric equipment?	Yes	No
10 Working near fume hood stacks?	Yes	No
11 Have anchor points been designated, tested, and inspected?	Yes	No
12 Is work being performed (above or below) power lines?	Yes	No
13 Are the weather conditions acceptable to work in: i.e. wind, wet footing, lightning, rain1:	Yes	No

Fall Assessment Tool/Checklist: Conditions to be checked

- Work Areas Associated with:
- Loading docks
- Balconies
- Galleries
- Landings
- Platforms
- Stairs
- Walkways
- Mezzanines
- Parking areas
- Sidewalks
- Working Surface Conditions: Oil, grease, wax Fluids Ice Irregular surfaces
- Working at heights with: Portable ladders, Fixed ladders, Elevated Platforms, Scaffolds, Cherry pickers, Catwalks and Other elevating devices

Factors for increased potential for electrical shock, tripping, slipping, and falling are highlighted below:

- The surface of PV modules is normally slippery. When installed on a peaked structure or when the modules are wet, they become extremely slippery. DO NOT walk on modules.
- Accidental contact with high-voltage PV components could cause involuntary muscle reaction and could result in a fall from the structure.
- Fire fighters should never attempt to place a ladder on PV modules.
- Do not attempt to break the glass covering PV modules, as this could expose high-voltage internal components within the module and increase the risk of electrical shock.
- The mounting racks, electrical conduit, and wires are sometimes partially concealed and are not always visible during the day. They become even more difficult to identify in the dark or in the presence of smoke.

Types of Maintenance (Preventive/Corrective/Condition Based)

Objective: At the end of this lesson you shall be able to
- **practice maintenance activities in Solar PV plant.**

Solar Technician has to practice various maintenance activities at the solar power plant.

Maintenance basics are to understand importance of maintenance and to plan and perform various activities in maintenance of the plant

Maintenance is a combination of activities done in the Solar PV power plant to retain the healthy working condition accepted at the time of commissioning, for all the times.

Also the repair and rectification works carried out at any point of time whenever failure is noticed during inspection and reported by customer.

Further training and information on in fault diagnosis and testing, the overall design, the location relative to service facilities, availability of spare parts, availability of diagnostic instruments & test gear and the maintenance policy are required for effective functioning of maintenance team.

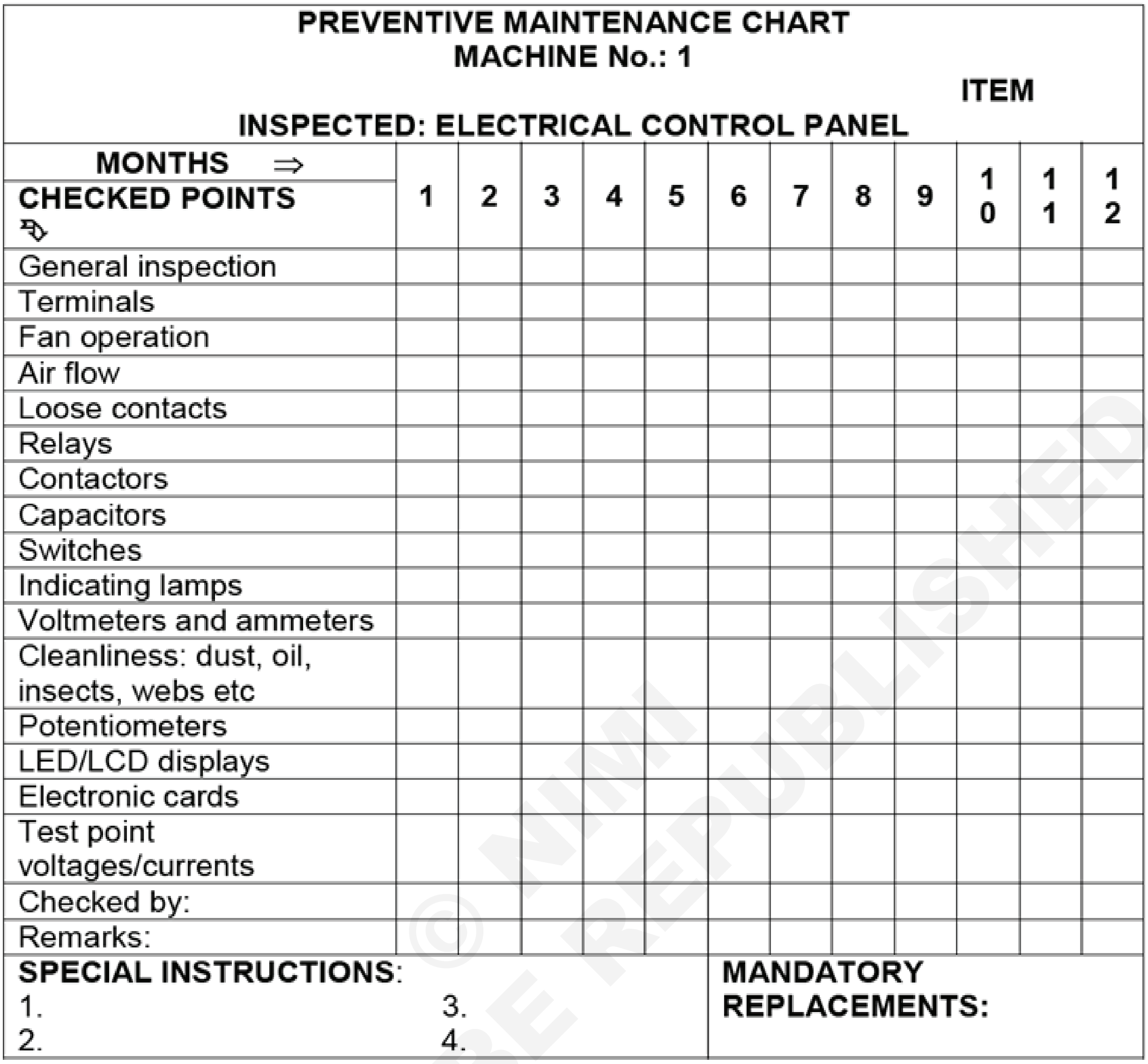
Preventive maintenance

- It is a policy of replacing components or parts of a system that are nearing the end of their life and therefore wearing out and is carried out before the components actually fail.
- Failure of components entering the wear – out period or subjected to continuous wear can be easily predicted to make the replacement possible improving the reliability of the system to a great extent
- Preventive maintenance may not be possible while it becomes difficult to accurately predict the point at which components enter the wear out period or it is uneconomic to carry out P.M.
- Disadvantage: the disturbance created during P.M. activity may itself cause failure(s)
- Components covered under the P.M. category are those with moving parts which are continuously in use. Example:
- Contacts on relays
- Switches
- Switches subjected to arcing when switching inductive or capacitive loads
- Filament lamps

Factors influencing the failures and against which PM activity is carried out are:

- Vibration and noise
- Shock
- Dust
- Damage of cover
- Stains and smudges
- Temperature
- Humidity
- Corrosion
- Continuous monitoring, cleaning and inspection helps in getting alert about the problems leading to failure. A minor failure ignored or not noticed at the beginning leads to permanent breakdown later; hence, perfect monitoring of failure chances and preventive measures taken in time avoids all breakdowns

A typical preventive maintenance chart



PREVENTIVE MAINTENANCE CHART
MACHINE No.: 1
ITEM INSPECTED: ELECTRICAL CONTROL PANEL

MONTHS ⇒ CHECKED POINTS ⇩	1	2	3	4	5	6	7	8	9	10	11	12
General inspection												
Terminals												
Fan operation												
Air flow												
Loose contacts												
Relays												
Contactors												
Capacitors												
Switches												
Indicating lamps												
Voltmeters and ammeters												
Cleanliness: dust, oil, insects, webs etc												
Potentiometers												
LED/LCD displays												
Electronic cards												
Test point voltages/currents												
Checked by:												
Remarks:												

SPECIAL INSTRUCTIONS:
1.
2.
3.
4.

MANDATORY REPLACEMENTS:

The main activities under PM of SPV systems include:

- Mounting structure integrity
- Module cleaning
- Hotspots detection
- Junction box servicing
- Inverter servicing
- Cabling connections
- Balance of plant
- Inverter Servicing
- Earthing protection
- Vegetation control

Solar PV Panel Analysisis done to identify the defects and find remedies. They should be detected visually for

- Defective frames
- Yellowing (The panel becomes yellow)
- Defective connection boxes
- Broken glass
- De-lamination
- Any others........(to specify observation)

A periodic schedule for maintenance activities should be ready with the maintenance team.

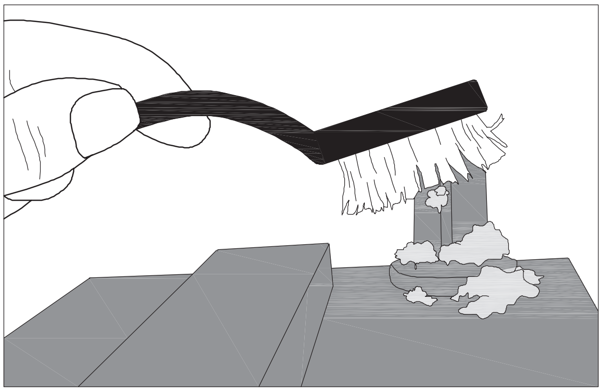
- As a daily schedule it can be to Ensure security of the power plant and Monitor power generation and export. Find out similar duties for daily performance.
- To Inspect and clean the PV modules from dust and other dirt like bird's dropping etc. as and when required can be a weekly monitored activity.
- Check quarterly keeping the inverters clean to minimize the possibility of dust ingress.
- Ensure half yearly all electrical connections are kept clean and tight.
- In annual check category include points like Check mechanical integrity of the array structure, Check all cabling for mechanical damage, Check output

voltage and current of each string of the array and compare to the expected output under the existing conditions, Check the operation of the PV array DC isolator etc.

Fig 1 Cleaning of Battery terminal

Corrective maintenance

Fig 1



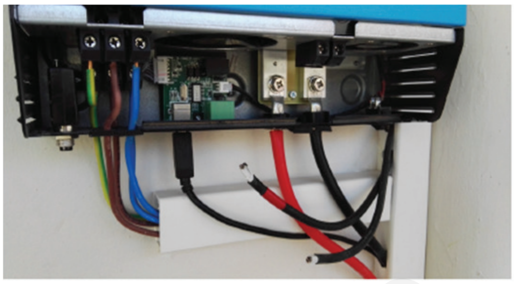
- Replace as and when failed
- Most preferred for Electronic control systems because failures of components are random
- and cannot be predicted
- Carrying out preventive maintenance action itself may be real cause of the fault
- Corrective Maintenance is concerned with the detection, location and repair of the faults as they occur
- Developing skill in this area requires good understanding of overall system, its circuit operation and its fault location methods

Some of the corrective maintenance activities pertaining to Solar PV systems are:

- Tightening loose connections
- Replacing damaged modules
- Replacing blown fuses
- Repairing blown fuses
- Rectifying inverter faults
- Repairing equipment damaged by intruders
- Replacing blown connectors
- Rectifying SCADA faults
- Rectifying mounting structure faults

Fig 2 Loose and disconnected wires

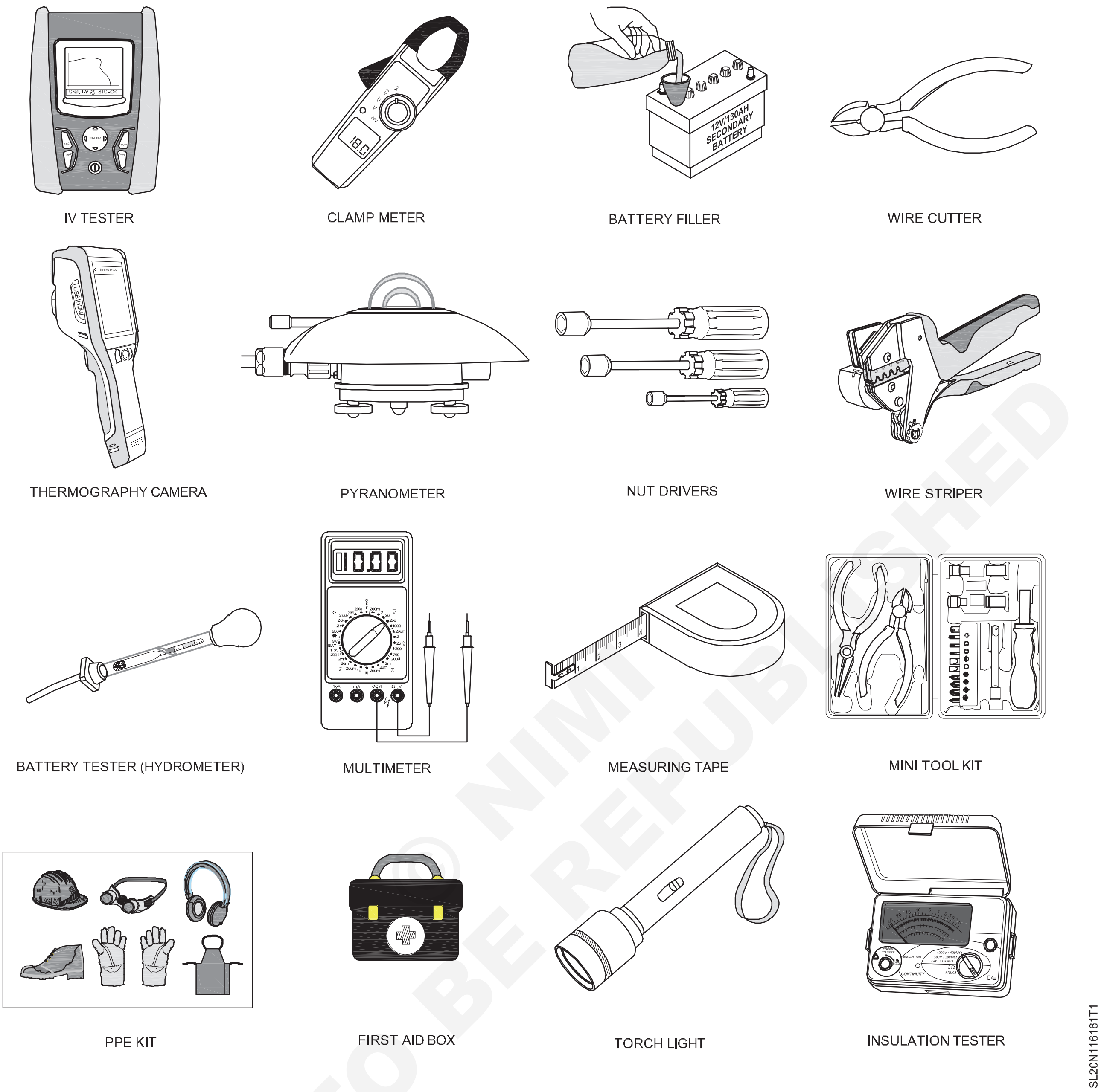
Fig 2



Tools & Equipment for maintenance team:

- Documentation such as O&M Manual and Datasheets are essentials for beginning the activity. Safety first is to be strictly followed for technician as well as the equipment. First aid kit and PPE are understood thoroughly and their availability to be ensured. Their usable condition is to be checked.
- System Service logbook and writing utensils are a must.
- Equipment such as Digital Multimeter, Clamp Meter, Hydrometer, Sun pathfinder, Thermography Camera, IV- Tester, Pyranometeretc are carried for the maintenance work.
- Other essentials include Battery maintenance kit, Battery water filler, Tool kit having Screw drivers, Nut drivers 1/4in & 5/16in, Crimping tool set, Angle Finder, Measuring Tape, Compass, Flashlight and Cleaning Brush Hammer, Wire Cutter Wire Stripper Cutting Pliers
- The using methods of various tools and equipment have been discussed at different sections of this course content and to be recalled as and when required.
- The safety and PPE kits are discussed later in a elaborate way since more attention exclusively to be given.
- Standard Operating Procedures (SOP) are also dealt in detail to educate the solar technician completely.

Fig 1



General Maintenance Kit

Maintenance Checklist may initially include for every component about their manufacturer's details such as, Basic Information of Company that includes Company Name, Name of the Contact Person Designation of Contact Person, Mobile number of Contact Person, Landline number of Contact Person, E-mail Address of the contact Person, Company Website, Company Local Address etc.

Basic Information of Plant may include Date of Inspection &Maintenance, Plant Capacity etc.

Carry out the following inspections:

- Module & Array Inspection shall give details on Module Condition, Module Cleaning, Damage of Module, Dirt Accumulation etc.
- Check Shading observed on Modules.
- Inspect a subset of array top glass inspection - look for Blemishes, spots, bonding of frame to glass and discoloration.
- Back sheet inspection - look for spots, Blisters burn through, Discoloration. Check for Insulation on module wiring.
- Proper wire condition and sizing.
- Check for connectors on array wiring extensions.
- Inspect module Junction boxes - look for sealants, proper wire management.
- Check for proper grounding of array and array mount.
- Inspect module clamping methodology - check for loose fasteners, secured and sealed properly.

- Perform thermal scan of modules and note any discrepancies
- Check for Proper Labelling
- Visually check array - if broken, damaged or loose module, loose racking hardware, wiring and MC4 connectors. Visually inspect all supporting parts-corrosion/evidence of rust, when encountered apply the cold galvanization spray.
- Verify proper operation of dc disconnections. Measure output circuit conductor to see if any combiner box is reading low.
- Measure output current of each combiner box on single string, if low check for all strings
- Visually check all D.C disconnections and combiners - corrosion, blown fuses, moisture entry, heat distortion, insect or rodent issues.
- Check all duct seals, gaskets and other sealing methodologies are fully intact and functional. Repair or replace if necessary.
- Inspect wire, conduits, piping, tighten all electrical connections and correct if any issue is identified.
- Check for ground continuity between the frames and racking structure.
- Check for continuity of cable to electrical earth.
- Check for corrosion - copper wires, PV frames and galvanized steel racking structure
- For Ballasted system, verify ballasted material is not degraded.
- For folded rack sites, verify wind deflectors are firmly attached to racking structure.
- Inspect array for build-up of debris underneath, clean whenever necessary. Check for labelling.

For combiner box (AJB) perform the following:

- Measure the current in each string, if found zero then check the fuse (replace if necessary)
- Check for any damages of cabinet or enclosures.
- Check for deposition of any dirt or dust.
- Check out for wear out screws or handle of enclosure and support structure. Check for any loose connections or tightness of the terminations.
- Check for heating, hardening of cables and change in colour of the components of the combiner box.
- Proper wire condition, sizing and insulation.
- Check for proper labelling.
- Check for proper functioning of the MCB, MCCB, Disconnector switch and diodes.

In case of OFF grid battery backup systems carry out the following inspections:

For charge controllers:

- Check for any damages of cabinet or enclosures.
- Check for proper wire condition, sizing and insulation.
- Check for deposition of any dirt or dust.
- Check for proper labelling.
- Input and output disconnects labelled.
- Check for proper grounding.

For Battery banks:

- Proper ventilation for cooling.
- Check the terminals protected from shorting.
- Check for proper wire condition, sizing and insulation and burnt marks if any. Check for deposition of any dirt or dust.
- Check for electrolyte leaks and cracks in cells.
- Check for corrosion at terminals, connectors, racks and cabinets.
- Check for ambient temperature (all cells must be at same ambient temperature). Flooded vented to outside.
- Check for proper labelling.
- Check for proper wire condition, sizing and insulation

For inverters perform the following inspections:

- Visually inspect inverter for external damage
- Check the functionality of inverter
- Check that the installation is neat and permanent
- Check inverter display and record all input and output voltages
- Clean area around inverter and verify base is sealed
- Shut down A.C/D.C breakers to inverter, power down the inverter
- Wait for inverter to discharge (approx. 5 min)
- Install safety lock outs
- Check for conduits and wire sizes installed properly. Check area around
- inverter is cleaned and verify base is sealed
- Vacuum all debris from inverter
- Visually inspect for moisture intrusions
- Clean or replace air filters and clean air returns
- Check the tightness of cable termination
- Check for proper wire condition, sizing and insulation
- Check for proper labelling of cables
- Inspect Air filters
- Visually inspect inverter for external damage
- Check the functionality of inverter
- Check that the installation is neat and permanent
- Check inverter display and record all input and output voltages
- Clean area around inverter and verify base is sealed
- Shut down A.C/D.C breakers to inverter, power down

the inverter

- Wait for inverter to discharge (approx. 5 min)
- Install safety lock outs
- Check for conduits and wire sizes installed properly Check area around
- inverter is cleaned and verify base is sealed
- Vacuum all debris from inverter
- Visually inspect for moisture intrusions
- Clean or replace air filters and clean air returns
- Check the tightness of cable termination
- Check for proper wire condition, sizing and insulation
- Check for proper labelling of cables
- Inspect Air filters
- Check for abnormal operating temperature
- Check for faulty fuses
- Power up the inverter
- Check the system is properly operational
- Check for ventilation condition (exhaust fan is working properly or not)
- Record Inverter and Meter power reading
- Check if Inverter inlet and outlet fan is working properly or not
- Check for Noise levels of inverter
- Torquing of terminals and fasteners
- Check for proper grounding levels
- The inverter mounted on ground or wall should be at a height convenient for reading its display
- Check for Inverter ground fault interruptions

Perform the following inspections for Trackers:

- Inspect flexible conduit and wires between moving modules for wear and cyclic motion
- Examine gear box for leakage of oil or grease
- Check for ground braids between movable torque tube and wear due to cyclic motion, replace if necessary
- For multiple tracker motors, examine array controlled by each tracker, and confirm they are in same positional orientation for all groupings
- Check there is no cracking at tube ends
- Inspect the wind sensor is positioned properly and functional
- Wherever available confirm date and time in tracker PLC's
- Check U-joint is greased properly
- Check for proper wire condition, sizing and insulation
- Check seal tight on trackers
- Check torque tubes and drive shafts to ensure that they haven't got loose by themselves
- Check array for backtrack shading
- Check for deposition of any dirt or dust
- Check for proper labelling
- Check sensors or mini controllers for its proper functioning
- Check for all fuses in the main controller

In case of SCADA systems the following inspections need to be carried out:

- Check for proper wire condition, sizing and insulation
- Wire management must be proper and secured to weather station instrumentation (module temp sensor, ambient air temperature sensor, pyranometers etc.)
- Check that there is no moisture ingress in enclosures, seal as necessary
- Check for enclosures open and close hasps are functioning properly
- Check that wires are landed and secured properly within SCADA
- Cleaning inside of enclosures (dust, debris, insects etc.) vacuum with static-free vacuum
- Check for proper ventilation (fans must turn freely and functional) Check for deposition of any dirt or dust
- Verify all pyranometers are properly secured and mounted properly

The above inspection points are indicative and in actual case depending on plant design and modern features etc the reality would be exhaustive. At any point of time training and retraining of the solar technician by self or by the management of employed place will be essential to meet the market demands.

Documents & Records for maintenance activity:

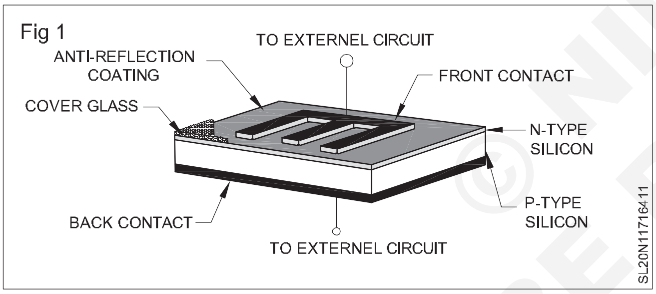
- Detailed inspection sheet with all remarks incorporated in prescribed formats must be sighed at every stage by the inspecting team and the customer who may be an individual public or representative of firm or plant manager as the case may be.
- Defects investigation reports: indicate defects reported, date & time, testing method adopted, used tools &equipments, fault located block, relation with reported fault, action taken, replacement done, spare used, spare drawn from, suppliers of spare, number of occurrence etc
- Expert systems: Tabulation of symptom of defects, probable causes, probable problem area or block, suggested remedial measures
- Cause and effect diagrams: pictorial representation of each fault linked with associated blocks, possible defective components
- Periodical reports to management, design department etc to take action to prevent the failures in future

Solar Cell manufacturing

Objectives: At the end of this lesson you shall be able to
- **evaluate the process of Solar PV cell manufacturing.**

Solar cells are structured in layers with different functions. The working principle is the same as in semiconductors. The main part of a silicon (Si) solar cell generating solar power is formed by two differently doped (n- and p-) silicon layers. A physical barrier is created between them along the p-/n- junction, with electrons and holes diffusing into regions of lower concentration. This depleted region or space charge region can only be overcome with the help of photons i.e. sunlight. To be able to channel electrons and holes and generate electric power, metal contacts need to be printed onto the front and rear side. Generally, a full aluminum or silver layer is screen printed onto the rear. A thin grid forms the front contact keeping the impact on light entering the silicon cells as low as possible. To reduce light reflection, a thin film of silicon nitride or titanium dioxide is coated onto the surface.

Fig 1 PV cell structure



A typical solar cell is a multi-layered material, comprising:

- A cover layer of clear glass that provides outer protection from the elements.
- Transparent adhesive that holds the glass to the solar cell.
- An anti-reflective coating that is designed to maximize energy absorption by preventing the light that strikes the cell from bouncing off.
- Front contact that transmits the electric current.
- A thin N-type semiconductor layer made of silicon, doped with phosphorous.
- A second thin P-type semiconductor layer of silicon, doped with boron.
- A back contact that transmits the electric current

PV Manufacturing

Some of the manufacturing processes and resources for photovoltaics are shared with other applications, especially electronic chips for computers, mobile phones and any other electronic device. This competition has caused a shortage in supply of crystalline cells.

The raw material of most solar cells today is crystalline silicon. Luckily, silicon is one of the most widely available elements in the form of sand. Before silicon can be cut into thin wafers, however, it has to be purified, as otherwise the photo effect will not be very efficient. Purity levels for solar cells do not have to be as high as in chip applications. Solar-grade purity is 99.999% (5N) as opposed to electronic-grade silicon purity of up to 99.9999999% (9N).

Solar panel manufacturing

Objectives: At the end of this lesson you shall be able to
- **Manufacture a solar PV panel.**

In the process of making Solar PV panel from PV cell, there are a total of 20-25 machines which involves about 18 steps to finally make a complete solar panel. These steps,from the Incoming Quality Check (IQC) to Final Quality Assurance (FQA), are discussed below:

1 Incoming Quality Check (IQC)

The PV cells mostly imported will have size of say 156 mm x 156mm. The peak power vary from 3.5 W to 4.2 W per cell with VOC = 0.5 V and ISC 7 A to 8 A. These specifications may vary from one to other cell from same manufacturer and even from same package received. For making solar panel we need cells having uniform specifications so that performance of the panel will be better with long life.

Hence all cells are to be verified at the incoming stage only and group according to their capacity such as 3. 5 W and above, 3.25 to 3.5 W, 3.00 W to 3.25 W and below 3.00 W. Actually using software accompanied by electronic circuits their I-V characteristics are studied for accepting best ones.

Incoming QC check of PV cells

Normally below 3.00 W are considered rejected and returned to the supplier for replacement. Then group wise separated PV cells sent to Cell cutting stage.

Incoming QC passed and grouped PV cells

2 Cell Cutting

Using a laser cutting machine, the accepted PV cells are cut out into equal sizes depending upon the wattage of the panels those are to be manufactured. For higher wattage panels full sized are as it is used and this process is skipped.

3 Stringing Process

For larger size panels, it is a fully automated process, using any cell of size greater than 39 mm. These cells are then assembled or soldered together. The upper Sun facing Side (Blue / Black side) is the negative part while the bottom white side is positive. For smaller sized panels this process can be done manually also, but more skilled technicians required.

Connecting wires on negative sides of cut PV cells

Connecting cell strings

Cell strings are connected as required for module

Automated Cell string assembly

4 Solar Glass

Once the cells are stringed together, the machine transfers it to tempered glass, which already having ethylene vinyl acetate (EVA) encapsulation layer over it. Some manufacturers do this manually.

Spreading EVA layer

Automated Solar Glass stage

5 Visual Inspection

The cells are examined by a technician for any fault or error in any string.

6 Taping

In taping, a technician tapes the cells into a matrix alignment.

7 Connection

Connections are then soldered together. Any excess material is cut out.

8 Insulate Module Connection

The next step consists of insulating the connections by using a back sheet and EVA encapsulation. This process protects the module from any dust and moisture.

9 Mirror Observation

The module is visually checked once again for any dust particle, colour mismatch, etc.

10 EI Testing

EI Testing or Electroluminescence test is the real testing of the module made so far. It is a testing process, where the module is kind of scanned in an EI machine. We can easily spot any dead or low power cell, short circuit cells, cracks, etc. If any such error is spotted, the module is sent back for fixing the error.

11 Lamination Process

The module is laminated at 140-degree Celsius. This process takes approximately 20 minutes. After lamination, the modules are left for 10-15 minutes to cool down till it reaches room temperature.

12 Trimming Back-sheet

This step involves cutting off the excess material of the back sheet to make perfectly shaped modules.

13 Frame Cutting

In this step, frames of different sizes are cut out for bordering the panels.

14 Frame Punching

Then holes are punched in the frames for the purpose of mounting and grounding the panels.

15 Sealant Filling / Framing

A sealant protects the panels from air, dust, and moisture and helps the module to firmly attach on the frame. After the frame is attached to the module it is again sent to the framing machine, where it is punched to make sure it is permanently attached to the frame. Automatic machines for perfect sealing of frames are also used.

16 Fixing Junction box

A junction box is attached to the module using the sealant to firmly attach it to the structure. Connections are then soldered and left for 10-12 hours for curing, so that the structures are perfectly dry and attached properly.

17 Clean Module

The module is then wiped outside to remove any traces of dust, foreign particles or extra sealant.

18 Module Testing

The module is connected to check its output current, voltage, power, etc. A report is generated for each module's output data. A back label (with all details) is pasted behind the module for the benefit of the users. Finally, the module is sent to the QC lab where it is tested for insulation resistance. A 3000 V DC is passed through it for a minute. If the panel can endure the current, it is passed else failed. Then it is sent to Mechanical Load Test. Temperature test also is performed on the panel during environmental test.

19 Packing

After Final Quality Assurance (FQA), this is the last step in the module manufacturing process, where the modules are safely packed into large boxes for transportation and storage.

Modules ready for packing

Fig 2

Growing Solar Technologies

Objectives: At the end of this lesson you shall be able to
- **explore latest trends in Solar applications**
- **appreciate Solar thermal applications**
- **manufacture Solar DC commercial products**
- **practice innovative ideas**.

Solar water treatment plant

At present in India Waste water treatment plant are well known. The water so treated is recycled for cleaning purpose or just for watering plants in the garden. But, with the growing population, deforestation, climate changes and losing land occupied area water scarcity increases day by day and it may be global issue to get drinkable water in future. Is it not scaring? Or are you getting laugh at this thought? But, in reality the earth will face this one day. So suggestion is call this as 'Used water treatment' instead of waste water treatment because we will depend on this.

Even now corporations do the water treatment on good water also such as river water, before distributing to the towns. Large quantum of electricity is being used. This can be substituted by solar electricity.

Solar-Powered Used Water Treatment Plant – sounds nice?

Why not the points above to be repeated? It's so important!

Water we consider for our use becomes used water after our work. Then we consider it as waste water. Most of us do not think of a fact that where do the water again come to our use. Those who thought of it treated the so called waste water and brought recycled water for use in garden at present. There would be soon in future the same treated water only be available for drinking for future generation. In that case calling waste water henceforth is not doing justice for future generation. Hence calling right now as used water is more practical.

Stop calling Waste water treatment plant

The existing power plants that are powering the water treatment plants that provide us with drinkable and usable water are in most cases the same ones that help to pollute it by releasing smog, which causes acid rain of varying pollution levels.

Solar air conditioning

The technology described here is for academic interest only because the actual basics of the many components we may come across are not covered in this syllabus of Solar Technician. None of the components of a Solar PV system you will find in this topic. That means even a solar panel also is not used here. Instead a solar thermal collector is used.

The solar assisted air condition system uses the heat from the solar radiation to drive a thermally driven chiller such as absorption chiller. Due to this less amount of electricity is used as compare to conventional cooling system. The solar air condition is powered by solar energy collector in the evacuated tube solar thermal panels. The thermal energy collected is then delivered to the solar powers chiller using a propylene Glycol heat transfer solution and simple but carefully designed pumping system.

The main components in the solar Assist air conditioning system are:

1 Solar collector

2 Hot water & chilled water storage

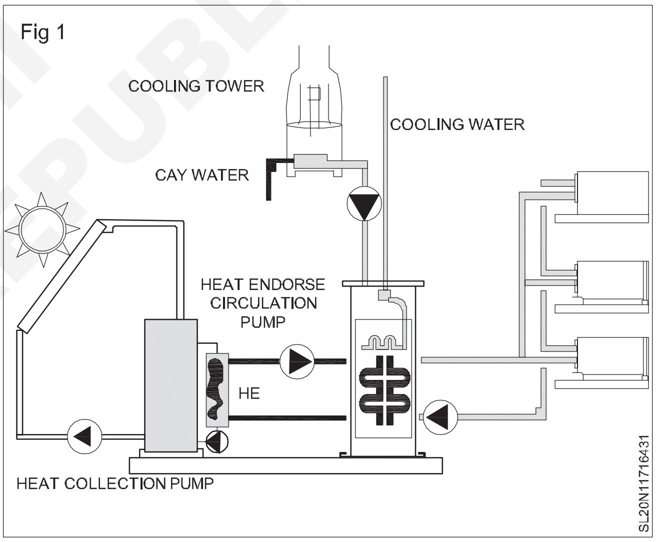
3 Chiller (cold production)

4 Cooling towers

5 Fan coils.

Solar Air conditioning

Fig 1



The basic principle behind thermal driving cooling is thermochemical process of absorption: A liquid or gaseous substance is either attached to a solid, porous material or is taken in by a liquid or solid material. The sorbent is provided with heat and is dehumidified. After "drying ", or desorption, the process can be repeated in the opposite direction. When providing water vapor or steam, it is stored in the porous storage medium (adsorption) and simultaneously heat is released.

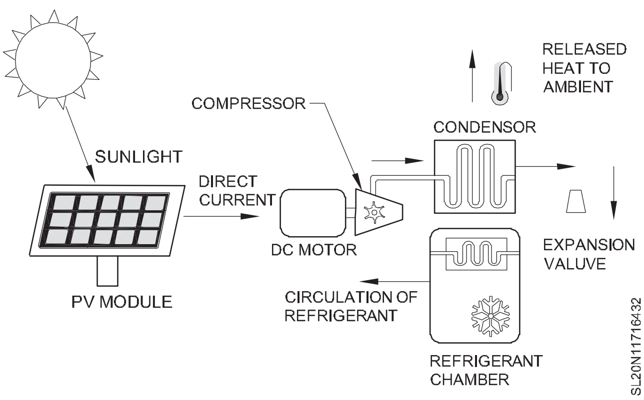
Solar refrigeration

schematic diagram

Solar - powered refrigeration system that eliminates reliance on an electric grid, requires no batteries, and stores thermal energy for efficient use when sunlight is absent.

Solar - powered refrigeration system employs a PV panel, vapor compressor, thermal storage and

Fig 2



reservoir, and electronic controls. The variable speed, direct current (DC) vapor compression cooling system is connected to the solar photovoltaic (PV) panel via novel electronic controls. The process that makes the refrigeration possible is the conversion of sunlight into DC electrical power, achieved by the PV panel. The DC electrical power drives the compressor to circulate refrigerant through a vapor compression refrigeration loop that extracts heat from an insulated enclosure. This enclosure includes the thermal reservoir and a phase change material. This material freezes as heat is extracted from the enclosure. This process effectively creates an “ice pack,” enabling temperature maintenance inside the enclosure in the absence of sunlight.

Proper sizing of the highly insulated cabinet, phase change thermal storage, variable speed compressor, and solar PV panel allow the refrigerator to stay cold all year long. To optimize the conversion of solar power into stored thermal energy, a compressor control method fully exploits the available energy.

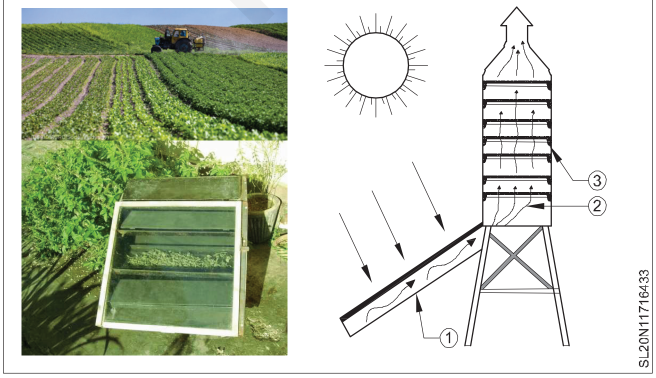
Passive Solar energy trapping is used in:

- Daylight
- Drying Agricultural Products
- Space Heating
- Water Heating

You may appreciate here a natural way of using solar energy, light and heat.

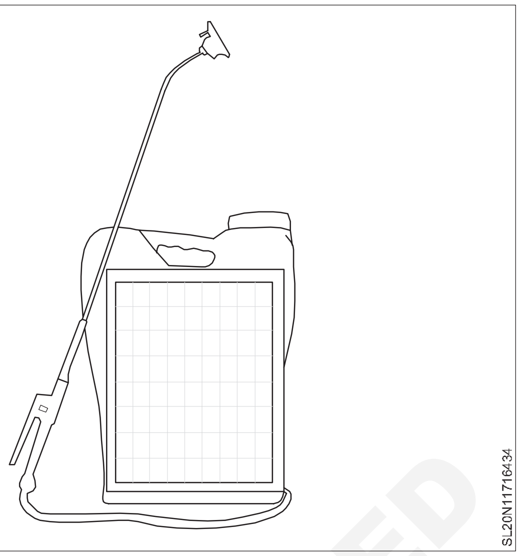
Agricultural application

Fig 3 DRYING AGRICULTURAL PRODUCTS



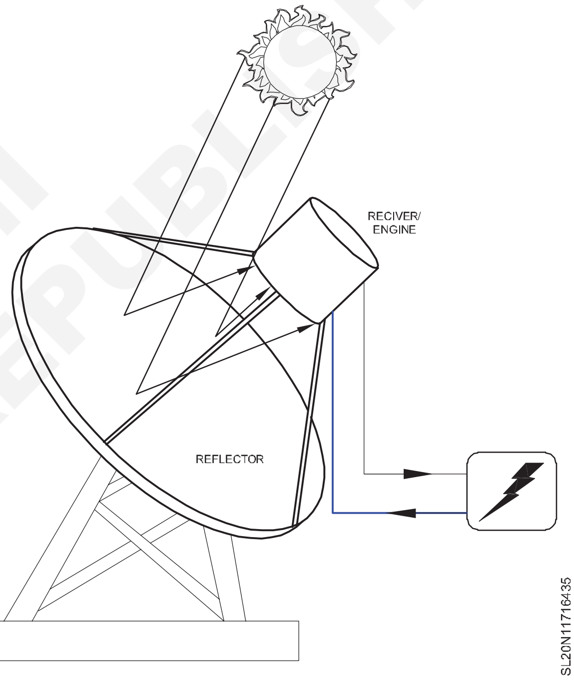
Solar Sprayer (for fertilize or pesticide)

Fig 4



Parabolic Dish system

Fig 5



Concentrating Solar Power (CSP)

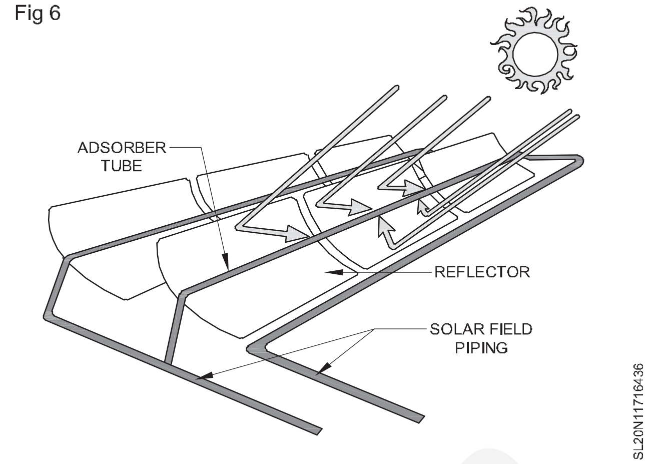
Concentratingsolar power (CSP) is used in special power plants that use mirrors to convert the sun’s energy into high-temperature heat. The heat energy is then used to generate electricity in a steam generator. Highlights of this category are:

- Require Direct Sunlight
- Concentrating solar power systems cannot reflect diffuse sunlight, making them ineffective in cloudy conditions
- Because they work best under direct sunlight, parabolic dishes and troughs must be steered throughout the day in the direction of the sun
- Two Approaches
- Power Tower

- Parabolic Trough
- Focus sunlight on a smaller receiver for each device; the heated liquid drives a steam engine to generate electricity.
- The more recent facilities converted a remarkable 22% of sunlight into electricity
- Two methods of energy transfer
- Steam Heat Transfer
- Molten Salt Heat Transfer

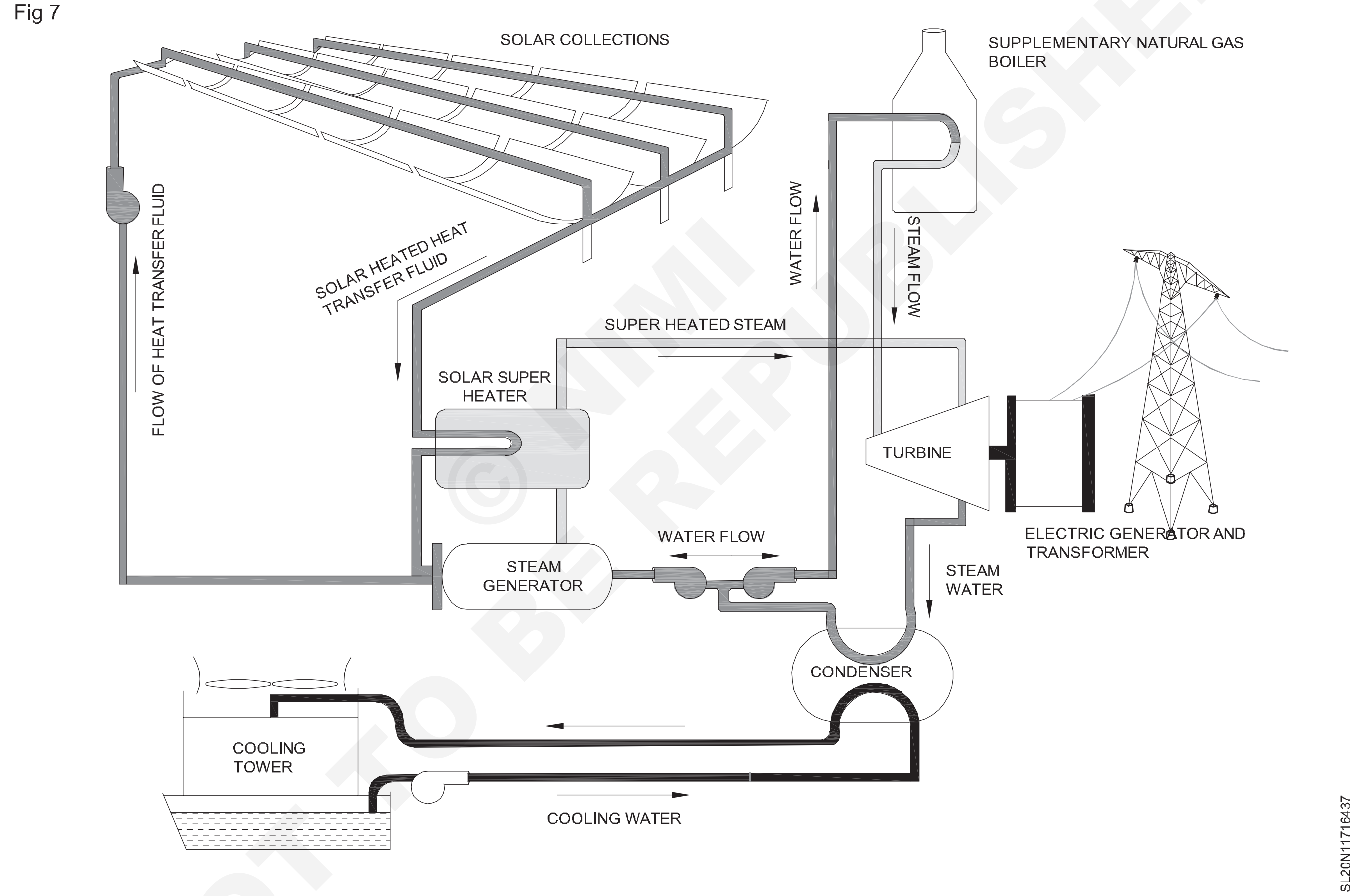
Parabolic trough functioning

Fig 6



CSP thermal power station – trough based

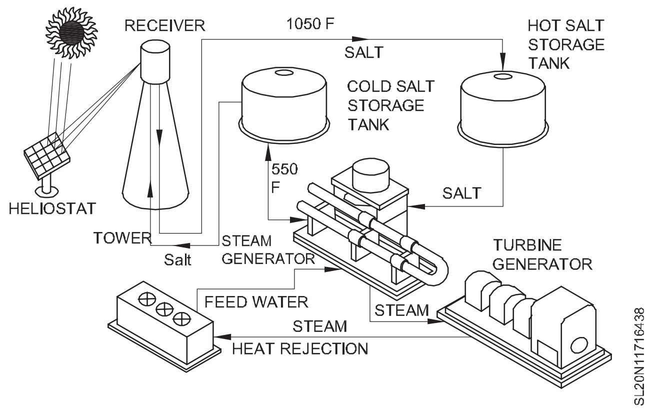
Fig 7



CSP – Solar power tower – Functional block diagram

The power tower is used to heat molten salt which is used to heat water to produce steam to turn a turbine which produces electricity.

Fig 8



Solar cookers for domestic and community cooking

Solar thermal applications are aplenty.

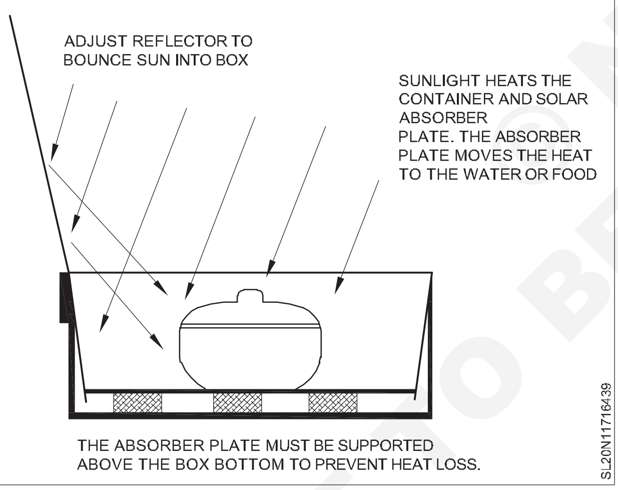
A solar oven or solar cooker is a device which uses sunlight as its energy source. Since they use no fuel and they cost nothing to run. Humanitarian organizations are promoting their use worldwide to help slow deforestation and desertification, caused by using wood as fuel for cooking. Solar cookers are also sometimes used in outdoor cooking, especially in situations where minimum fuel consumption or fire risks are considered highly important.

There are different types of solar cookers. Flat box type or concentrator type are common.Concentrating sunlight and trapping the heat are basic principles. Some device, usually a mirror or some type of reflective material, is used to concentrate light and heat from the sun into a small cooking area, making the energy more concentrated and therefore more potent.

Any black on the inside of a solar cooker, as well as certain materials for pots, will improve the effectiveness of turning light energy into heat. A black pan will absorb almost all of the sun's light and turn it into heat, substantially improving the effectiveness of the cooker. Also, the better a pan conducts heat, the faster the oven will work.

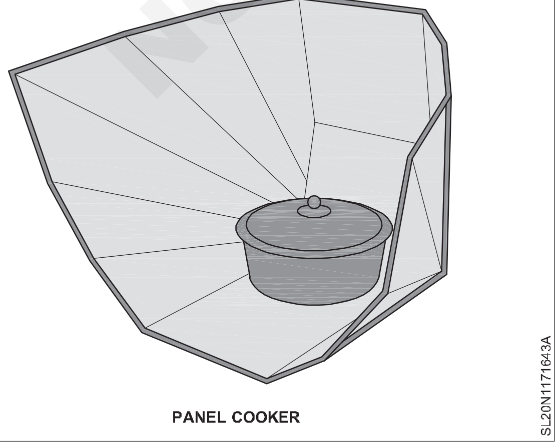
Box type Solar cooker

Fig 9



Panel cooker

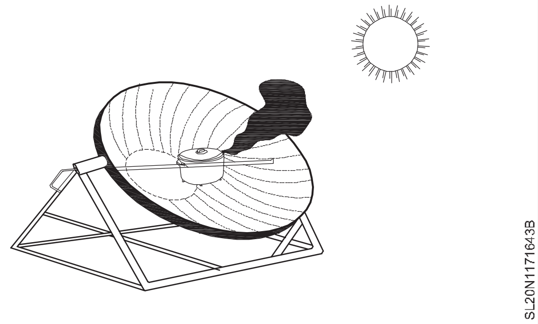
Fig 10



PANEL COOKER

Solar concentrator type cooker

Fig 11



Solar water heating systems

Water Heating Systems are used for Domestic Hot Water, Laundry, Restaurant, Pool/Spa Heating, Hospitals/ Clinics, Photo processing, Space Conditioning (Heat or Cool) etc.

Solar water heating system are of two types: Active (Uses a pump, fan, or other powered device) and Passive (Does not use a pump or fan - relies on natural forces "Gravity & density").

Major System Components are:

- Active System - Collector(s), Storage tank, Controller and Pump or Circulator
- Passive System - Collector(s) and Storage tank

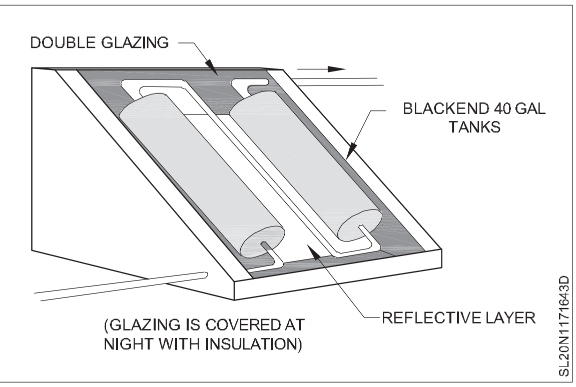
Solar water heater

Fig 12

SOLAR WATER HEATER

Batch water heater

Fig 13



Heat collection and transfer is done by Collectors, Pumps and Heat Exchangers. Heat storage is in vertical or horizontal Tanks. Heat delivery is by pump or circulator. Freeze protection is included wherever required, especially in cold areas. Controls for active systems, Valves and other hardware are additional requirements. Batch heaters are used for industrial purpose or large volume of water heating.

Similarly Solar dryer, Solar air Heateretc are thermal applications of Solar energy, using the same principles of trapping the heat and storing to increase the chamber temperature. Necessary safety precautions are to be included in the design to care of accidents possibility due to relations between pressure, volume and temperature.

Other applications

Solar water pumping and Solar Sprinklers for drip irrigation are applications of Solar PV electrical system which discussed already in depth. Based on the load capacity the design features would vary. Hence care to be taken in selecting the components to match with each other.

Solar Traffic Light could be an extended topic of solar street lights. The difference will be in components. Coloured lamp modules replace the luminaire. Battery bank can be accompanied by stand by electricity or extended days of autonomy. Additional electronic circuits required for controlling the sequence of lighting lamps and timing. Market available electronic projects can be clubbed for betterment.

Solar distillation is an industrial application may use PV technology or thermal technology or both. Solar pond is entirely different application used either to convert sea water into drinkable water or to make salt. Existing salt fields over sea shore are best examples. Solar pond is an extended topic of this.

The following pictures show several such innovative ideas and applications. Many of them are commercially successful and speaking about our future.

Fig 14 Building with Photovoltaic Façade

Fig 14

Fig 15 Solar Bicycle

Fig 15

Fig 16 Solar powered buses

Fig 16

Fig 17 Solar car parking

Fig 17

Fig 18 Solar CCTV

Fig 18

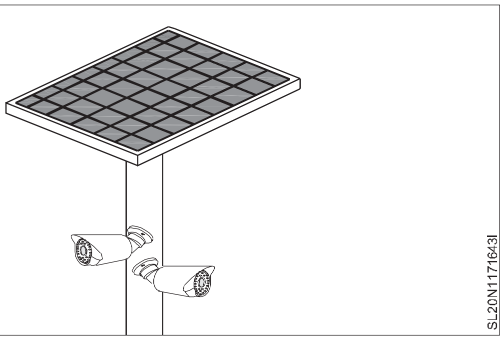


Fig 19 Solar fancy light

Fig 19

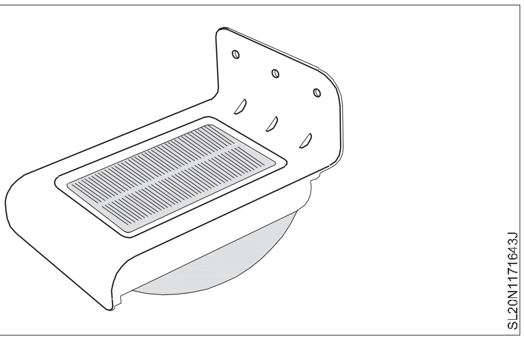


Fig 20 Solar wall lights

Fig 20

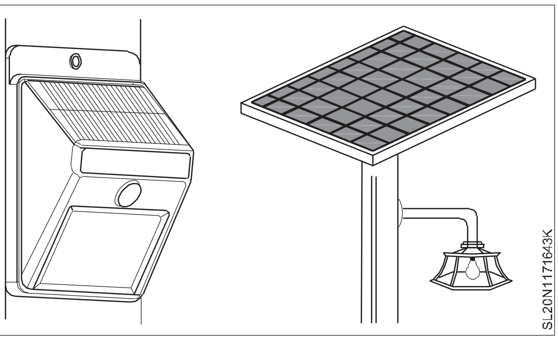


Fig 21 Solar DC home lighting

Fig 21

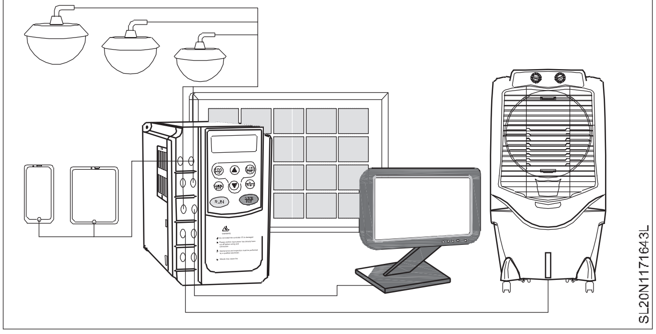


Fig 22 Solar tent for camp

Fig 22

Fig 23 Solar powered ship

Fig 23

Fig 24 Solar powered mobile communication tower

Fig 24

Fig 25 Solar brief case

Fig 25

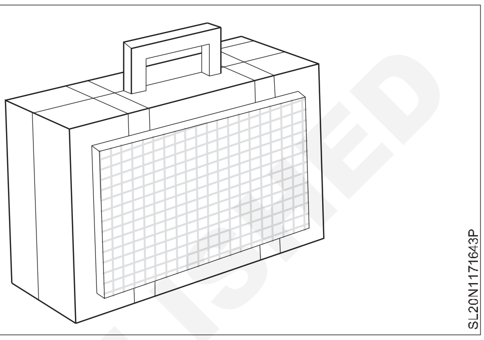


Fig 26 Solar mobile charger

Fig 26

Fig 27 Solar table lamp

Fig 27

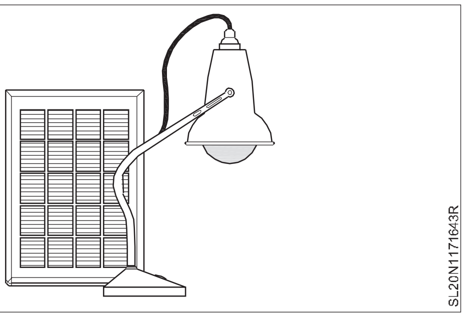


Fig 28 Solar shoulder bag

Fig 29 Solar powered car

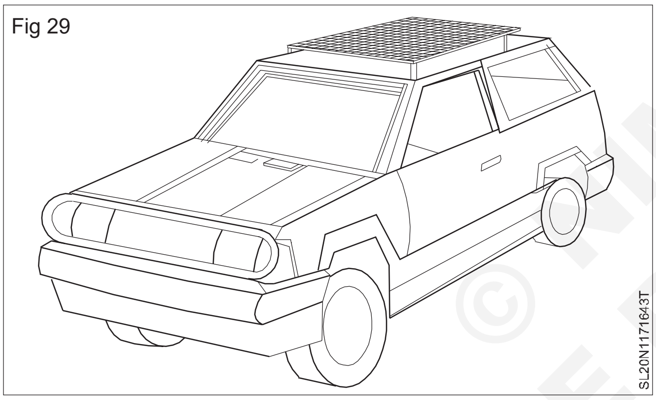


Fig 30 Solar cap

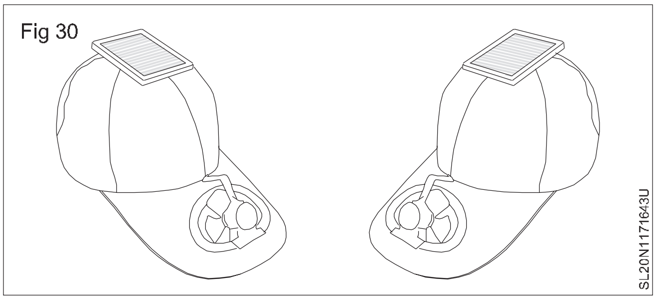
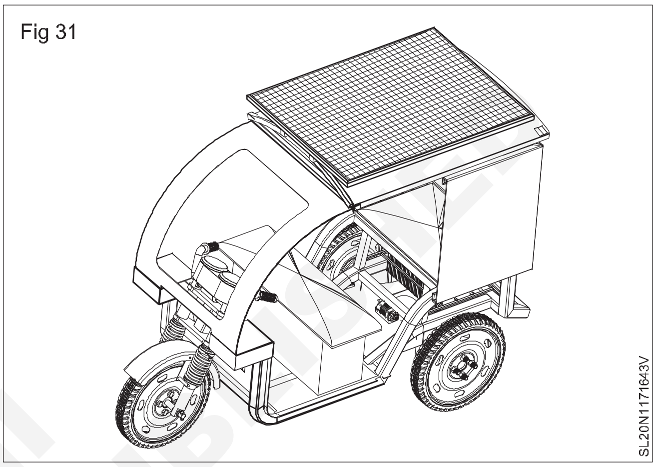


Fig 31 Solar power passenger auto



National and international energy policies

Objectives: At the end of this lesson you shall be able to
- **appreciate national and international solar energy policies.**

Anything tangible or intangible, that costs money is evaluated very carefully and used equally carefully in India. This means expenses are controlled and kept as low as possible. The scenario in energy consumption in India is no different. It is not surprising that the per capita energy consumption figures are very low in spite of high rate of development now taking place. The per capita consumption in India is in the range of 400 KWH or even more per annum.

India is blessed with an abundance of sunlight, water and biomass. Vigorous efforts during the past two decades are now bearing fruit as people in all walks of life are more aware of the benefits of renewable energy, especially decentralized energy where required in villages and in urban or semi-urban centers. India has the world's largest programme for renewable energy.

Government created the Department of Non-conventional Energy Sources (DNES) in 1982.

In the ninth five year plan (1997-2002) energy strategy is divided into short term strategy, medium strategy and long term strategy.

Short term strategy

- Administered pricing mechanism
- Institutional reforms to be consolidated for deregulation
- Optimum utilization of existing assets
- Production systems to be made efficient, transmission and distribution losses to be reduced
- R&D transfer of technologies to be promoted
- Energy efficiency improvement in accordance with national and socio-economic and environmental priorities
- Energy efficiency and emission standards to be promoted
- Labelling programmes for products
- Adoption of energy efficient technologies in giant industries

Medium and long term strategies

- Demand management through greater conservation of energy, optimum fuel mix, increasing reliance on rail for movement of goods and passengers and shift to emphasis on utilizing mass movement and transport systems for public rather than private transports
- Better urban planning to reduce need for energy in transport sector
- Shift and emphasis to solar, wind, biomass energy sources
- Emphasis on research and development, transfer and use of energy efficient technologies and practices in the supply and end-use sectors.

In 1992 a full-fledged Ministry of Non-conventional Energy Sources was established under the overall charge of the Prime Minister.

The range of its activities cover

- promotion of renewable energy technologies,
- create an environment conducive to promote renewable energy technologies,
- create an environment conducive for their commercialization,
- renewable energy resource assessment,
- research and development,
- demonstration,
- extension,
- Production of biogas units, solar thermal devices, solar photovoltaic, cook stoves, wind energy and small hydropower units.

Important steps in Government action in this regard are:

- Commission for Additional Sources of Energy (CASE) in 1981.
- Department of Non-Conventional Energy Sources (DNES) in 1982.
- Ministry of Non-Conventional Energy Sources (MNES) in 1992.
- Ministry of Non-Conventional Energy Sources (MNES) renamed as Ministry of New and Renewable Energy (MNRE) in 2006.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. Energy self-sufficiency was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s.

The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy in the Department of Science & Technology in March 1981.

The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying R&D in the sector.

In 1982, a new department, i.e., Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources. In October 2006, the Ministry was re-christened as the Ministry of New and Renewable Energy.

At present, The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy.

The broad aim of the Ministry is to develop and deploy new and renewable energy for supplementing the energy requirements of the country.

The various renewable energy resources which, the Government of India targets includes:

- Solar Energy
- SPV Systems
- Solar Cookers
- Solar Water Heaters
- Wind Power

Latest trends in Solar power generation in India

India is densely populated and has high solar insolation, an ideal combination for using solar power in India. In the solar energy sector, some large projects have been done, and a 35,000 km2 (14,000 sq mi) area of theThar Desert has been set aside for solar power projects, sufficient to generate 700 to 2,100 GW.

In July 2009, India unveiled a US$19 billion plan to produce 20 GW of solar power by 2020. Under the plan, the use of solar-powered equipment and applications would be made compulsory in all government buildings, as well as hospitals and hotels.

In January 2015, the Indian government significantly expanded its solar plans, targetingUS$100 billion of investment and 100 GW of solar capacity by 2022.

According to a 2011 report by BRIDGE TO INDIA and GTM Research, India is facing a perfect storm of factors that will drive solar photovoltaic (PV) adoption at a "furious pace over the next five years and beyond". The falling prices of PV panels, mostly from China but also from the U.S., have coincided with the growing cost of grid power in India. Government support and ample solar resources have also helped to increase solar adoption, but perhaps the biggest factor has been need. India, "as a growing economy with a surging middle class, is now facing a severe electricity deficit that often runs between 10% and 13% of daily need".

India is planning to install the World's largest Solar Power Plant with 4,000 MW Capacity near Sambhar Lake in Rajasthan.

There are various factors that we need to consider before investing into a solar power plant. A lot of enthusiasm has been seen among people about the use of Solar Energy as a substitute of conventional sources of energy. However, currently, with the power subsidies in India, solar works economical only in those areas that are using diesel generators as a primary source of electricity. The entire payback is made in 2–3 years. Solar system for petrol pumps is a leading example of such an application. IOCL is leading the race for solarization of petrol pumps with aggressive targets. Solar applications for petrol pumps by RelyOn Solar has been installed in more than 150 IOCL petrol pumps across India and now other oil companies are also looking to solarize their ROs. Solar installations for commercial buildings, where the electricity rates are higher, are also proving to be a game changer for the owners of IT companies.

Installed solar PV on 31 March 2018

Year	Cumulative Capacity (in MW)
2010	161
2011	461
2012	1,205
2013	2,319
2014	2,632
2015	3,744
2016	6,763
2017	12,289
2018	21,651
2019	28,180.71
2020	34,627.82
2021	40,085.37

On 16 May 2011, India's first 5 MW of installed capacity solar power project was registered under the Clean Development Mechanism. The project is in Sivagangai Village, Sivaganga district, Tamil Nadu.

Rural electrification

Lack of electricity infrastructure is one of the main hurdles in the development of rural India. India's grid system is considerably under-developed, with major sections of its populace still surviving off-grid. As of 2004 there are about 80,000 un-electrified villages in the country. Of these villages, 18,000 could not be electrified through extension of the conventional grid. A target for electrifying 5,000 such villages was set for the Tenth National Five Year Plan (2002–2007). As of

2004, more than 2,700 villages and hamlets had been electrified, mainly using solar photovoltaic systems.

Developments in cheap solar technology are considered as a potential alternative that allows an electricity infrastructure consisting of a network of local-grid clusters with distributed electricity generation.

It could allow bypassing (or at least relieving) the need to install expensive, lossy, long-distance, centralized power delivery systems and yet bring cheap electricity to the masses.

India currently has around 1.2 million solar home lighting systems and 3.2 million solar lanterns sold/distributed.

Also, India has been ranked the number one market in Asia for solar off-grid products.

Projects currently planned include 3,000 villages of Orissa, which will be lighted with solar power by 2014.

Solar lamps and lighting

By 2012, a total of 4,600,000 solar lanterns and 861,654 solar powered home lights had been installed. These typically replace kerosene lamps and can be purchased for the cost of a few months worth of kerosene through a small loan. The Ministry of New and Renewable Energy is offering a 30% to 40% subsidy for the cost of lanterns, home lights and small systems up to 210 Wp. 20 million solar lamps are expected by 2022.

Agricultural support

Solar PV water pumping systems are used for irrigation and drinking water. The majority of the pumps are fitted with a 200–3,000 watt motor that are powered with 1,800 Wp PV array which can deliver about 140,000 litres of water per day from a total head of 10 metres. By 30 September 2006, a total of 7,068 solar PV water pumping systems had been installed, and by March 2012, 7,771 had been installed. Solar driers are used to dry harvests before storage.

Solar water heaters

Bangalore has the largest deployment of roof top solar water heaters in India. These heaters generate an energy equivalent of 200 MW.

Bangalore is also the first city in the country to put in place an incentive mechanism by providing a rebate of 50 (79¢ US) on monthly electricity bills for residents using roof-top thermal systems.

These systems are now mandatory for all new structures.

Pune has also recently made installation of solar water heaters in new buildings mandatory.

Challenges and opportunities

Land is a scarce resource in India and per capita land availability is low. Dedication of land area for exclusive installation of solar arrays might have to compete with other necessities that require land. The amount of land required for utility-scale solar power plants — currently approximately 1 km2 (250 acres) for every 20–60 MW generated — could pose a strain on India's available land resource. The architecture more suitable for most of India would be a highly distributed set of individual rooftop power generation systems, all connected via a local grid.

However, erecting such an infrastructure, which does not enjoy the economies of scale possible in mass, utility-scale, solar panel deployment, needs the market price of solar technology deployment to substantially decline, so that it attracts the individual and average family size household consumer. That might be possible in the future, because PV is projected to continue its current cost reductions for the next decades and be able to compete with fossil fuel.

Government can provide subsidies for the production of PV panels, in which there will be reduction in the market price and this can lead to more usage of solar power in India. In the past three years, solar-generation costs here have dropped from around 18 (28¢ US) a kWh to about 7 (11¢ US) a kWh, whereas power from imported coal and domestically-produced natural gas currently costs around 4.5 (7.1¢ US) a kWh and it is increasing with time.

Experts believe that ultra mega solar power plants like the upcoming world's largest 4,000 MW UMPP in Rajasthan, would be able to produce power for around 5 (7.9¢ US) a kWh.

Some noted think-tanks recommend that India should adopt a policy of developing solar power as a dominant component of the renewable energy mix, since being a densely populated region in the sunny tropical belt, the subcontinent has the ideal combination of both high solar insolation and therefore a big potential consumer base density.[

In one of the analysed scenarios, India can make renewable resources such as solar the backbone of its economy by 2050, reining in its long-term carbon emissions without compromising its economic growth potential.

51 Solar Radiation Resource Assessment stations have been installed across India by the Ministry of New and Renewable Energy (MNRE) to monitor the availability of solar energy. Data is collected and reported to the Centre for Wind Energy Technology (C-WET), in order to create a Solar Atlas.

The government of India is promoting the use of solar energy through various strategies. In the latest budget for 2010/11, the government has announced an allocation of 1000 crore towards the Jawaharlal Nehru National Solar Mission and the establishment of a clean energy fund. It is an increase of 380 crores from the previous budget. This new budget has also encouraged private solar companies by reducing customs duty on solar panels by 5% and exempting excise duty on solar photovoltaic panels. This is expected to reduce the cost of a roof-top solar panel installation by 15–20%. The budget also proposed a coal tax of US$1 per metric ton on domestic and imported coal used for power generation.

Additionally, the government has initiated a Renewable Energy Certificate (REC) scheme, which is designed to drive investment in low-carbon energy projects.

The Ministry of New and Renewable Energy provides 70 percent subsidy on the installation cost of a solar photovoltaic power plant in North-East states and 30 percentage subsidy on other regions. The detailed outlay of the National Solar Mission highlights various targets set by the government to increase solar energy in the country's energy portfolio.

The Mysore City Corporation has decided to set up a mega Solar power plant in Mysore with 50% concession from the Government of India.

The Maharashtra State Power Generation Company (Mahagenco) has made plans for setting up more power plants in the state to take up total generation up to 200 MW.

Delhi Metro Rail Corporation plans to install rooftop solar power plants at AnandVihar and PragatiMaidan Metro stations and its residential complex at PushpVihar.

Reeling under an acute power crises, the Government of Tamil Nadu has recently unveiled its new Solar Energy Policy which aims at increasing the installed solar capacity from the current approximate of 20 MW to over 3000 MW by 2015.

The policy aims at fixing a 6% solar energy requirement on industries and residential buildings for which incentives in the form of tax rebates and current tariff rebates of up to Rs.1 / unit will be applicable to those who comply with the Solar Energy Policy. The policy also gives an option to those industries/buildings who do not want to install rooftop solar photo-voltaic systems to invest in the government's policy and be given the same incentives as explained above.

National Solar Mission

Objectives: At the end of this lesson you shall be able to
- **gain information on National Solar Mission**

The National Solar Mission is an initiative of the Government of India and State Governments to promote solar power. The mission is one of the several policies of the National Action Plan on Climate Change. The program was inaugurated as the Jawaharlal Nehru National Solar Mission by former Prime Minister Manmohan Singh on 11 January 2010 with a target of 20 GW by 2022. This was later increased to 100 GW by the NarendraModi government in the 2015 Union budget of India. India increased its solar power generation capacity by nearly 5 times from 2,650 MW on 26 May 2014 to 12,288.83 MW on 31 March 2017. The country added 9,362.65 MW in 2017–18, the highest of any year. The original target of 20 GW was surpassed in 2018, four years ahead of the 2022 deadline.

The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. Under the original plan, the Government aimed to achieve a total installed solar capacity of 20 GW by 2022. This was proposed to be achieved in three phase. The first phase comprised the period from 2010 to 2013, the first year of the 12th five-year plan. The second phase extended up to 2017, while the third phase would have been the 13th five-year plan (2017–22). Targets were set as 1.4 GW in the first phase, 11–15 GW by the end of the second phase and 22 GW by the end of the third phase in 2022.

The Government revised the target from 20 GW to 100 GW on 1 July 2015. To reach 100 GW by 2022, the yearly targets from 2015 to 2016 onwards were also revised upwards. India had an installed solar capacity of 161 MW on 31 March 2010, about 2 and half months after the mission was launched on 11 January. By 31 March 2015, three months before the targets were revised, India had achieved an installed solar capacity of 3,744 MW.

Year-wise targets

To meet the scaled up target of 100,000 MW, MNRE has proposed to achieve it through 60 GW of large and medium scale solar projects, and 40 GW through rooftop solar projects.

Year-wise Targets (in MW)

Category	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	Total
Rooftop Solar	200	4,800	5,000	6,000	7,000	8,000	9,000	40,000
Ground Mounted Solar projects	1,800	7,200	10,000	10,000	10,000	9,500	8,500	57,000
Total	2,000	12,000	15,000	16,000	17,000	17,500	17,500	97,000

Growth of utilities installed solar capacity

The following table records the growth of the utilities installed solar capacity in India for every year of the National Solar Mission. All capacities are as on 31 March of the listed year

Year	Installed capacity	Annual growth (MW)	Annual growth (%)
2010	161 MW	N/A	N/A
2011	461 MW	300 MW	186.34%
2012	1,205 MW	744 MW	161.39%
2013	2,319 MW	1,114 MW	92.45%
2014	2,632 MW	313 MW	13.50%
2015	3,744 MW	1,112 MW	42.25%
2016	6,762.85 MW	3,018.85 MW	80.63%
2017	12,288.83 MW	5,525.98 MW	81.71%
2018	21,651.48 MW	9,362.65 MW	76.19%
2019	28,180.71 MW	6,529.23 MW	30.16%
2020	34,627.82 MW	6,224.96 MW	22.09%
2021	40,085.37 MW	5,457.55 MW	15.76%

Phase 1 (2010–13)

The first phase of this mission aims to commission 1000 MW of grid-connected solar power projects by 2013. The implementation of this phase is in hands of a subsidiary of National Thermal Power Corporation, the largest power producer in India. The subsidiary, NTPC VidyutVyapar Nigam Ltd (NVVN), laid out guidelines for selection of developers for commissioning grid connected solar power projects in India. See JNNSM Phase 1 Guidelines. While NVVN is the public face of this phase, several other departments and ministries will play a significant role in formulating guidelines. NVVN will sign power purchase agreements with the developers. Since NVVN is not a utility, it will sell purchased power to different state utilities via separate agreements.

Technologies

For Phase 1 projects, NVVN started with a proposal for 50:50 allocation towards solar PV and solar thermal. The latter is quite ambitious given India has no operational solar thermal projects and less than 10MW of solar PV projects. While growing at a rapid pace lately, solar thermal technologies are still evolving globally. The first batch of projects allotted for Phase 1 included 150MW of Solar PV and 500MW of Solar Thermal. NVVN issued Request for Selection document outlining criteria for selection of projects under the Phase 1.

A growing solar PV industry in India is hoping to take off by supplying equipment to power project developers. Well known equipment manufacturers started increasing their presence in India and may give competition to local Indian manufacturers. Due to generally high temperatures in India, crystalline silicon-based products are not the most ideal ones. Thin film technologies like amorphous silicon, CIGS and CdTe could be more suitable for higher temperature situations.

Solar thermal technology providers barely have a foothold in India. A few technology providers like Abengoa have some Indian presence in anticipation of demand from this mission.

NVVN Solar PV allotment process for Phase 1

NVVN issued Request for Selection notice for allotment of capacity to Independent Power Producers (IPPs). See NVVN Solar PV RfS. 150MWs of Solar PV and 470MW of Solar Thermal were up for allotment under the first batch of Phase 1 projects. Project size per IPP was fixed at 5MW for Solar PV and 100MW for Solar Thermal projects. To avoid allocating entire capacity to a select few corporate, guidelines required no two projects to have the same parent company or common shareholders. In case of over subscription, a reverse bidding process was to be used to select the final IPPs based on lowest tariff they offer. Several hundred IPPs responded to this RfS.

The approach for reverse bidding and methodology to calculate the discount to be offered was presented by Shri Shakti Alternative Energy Ltd through a webinar on 19 October 2010 on the eve of the reverse bidding by NVVN.

The quantum of discount would depend on project site location (i.e. solar radiation), technology used, simulated energy generation, capital cost and interest cost. Multivariate analysis was carried out using key variables like capital cost, interest and the capacity utilization factor (i.e. CUF which is actual generation of the plant and depends on the location (radiation) and technology used) to calculate the levelized tariff for a target equity IRR based on which the discount to be offered can be determined.

The final 30 solar PV projectsselected had bids between INR 10.95 to INR 12.75. The Solar Thermal projects selected had bids between INR 10.24 to INR 12.24. PPAs were signed with IPPs in early January.

2014–present

In December 2014, the Government of India introduced a scheme to establish at least 25 solar parks and Ultra Mega Solar Power Projects to add over 20 GW of installed solar power capacity. The Central Government provides financial support for the construction of these solar projects.As of December 2016, the Central Government has provided in-principle approval to set up 34 solar parks across 21 states. Each power project has a minimum capacity of 500 MW.

Domestic content complaint

Guidelines for the solar mission mandated cells and modules for solar PV projects based on crystalline silicon to be manufactured in India. That accounts to over 60% of total system costs. For solar thermal, guidelines mandated 30% project to have domestic content. A vigorous controversy emerged between power project developers and solar PV equipment manufacturers. The former camp prefers to source modules by accessing highly competitive global market to attain flexible pricing, better quality, predictable delivery and use of latest technologies. The latter camp prefers a controlled/planned environment to force developers to purchase modules from a small, albeit growing, group of module manufacturers in India. Manufacturers want to avoid competition with global players and are lobbying the government to incentivise growth of local industry.

Market responded to domestic content requirement by choosing to procure thin film modules from well-established international players. A significant number of announced project completions are using modules from outside India.

US Trade Representative has filed a complaint at World Trade Organization challenging India's domestic content requirements in Phase II of this Mission, citing discrimination against US exports and that industry in US which has invested hugely will be at loss. US insists that such restrictions are prohibited by WTO. India however claims that it is only an attempt to grow local potential and to ensure self-sustenance and reduce dependence.

Renewable Purchase Obligation

Objectives: At the end of this lesson you shall be able to
- **analyze on Renewable Energy purchase obligations.**

Renewable Purchase Obligation (RPO) mandates that all electricity distribution licensees should purchase or produce a minimum specified quantity of their requirements from Renewable Energy Sources. This is as per the Indian Electricity Act, 2003.

Enforcement of RPO targets, despite availability of RECs, is poor. The government has launched RPO Compliance Cell, which will coordinate with states, CERC and SERCs on matters relating to RPO compliance.To provide a fillip to the ambitious renewable energy targets, obligations have been imposed on certain entitles to purchase energy from renewable sources by various state electricity regulatory commissions (SERCs) based on each state's varying renewable energy potentials. Known as renewable purchase obligations (RPOs), power distribution companies, captive power plants and other large electricity consumers are bound to meet them by purchasing a certain percentage of their requirements from renewable energy sources. Applicable regulations also provide for purchase of renewable energy certificates (RECs) in lieu of purchasing renewable power by obligated entities from the National Load Dispatch Centre. However, enforcing compliance of RPO targets is a challenge, with 16 states and UTs achieving less than 60% of respective RPOs in 2016-17. Regrettably, most states have shown poor proclivity in enforcing their RPO targets. The success of the RPO regime depends on strict adherence, which, in turn, depends on enforcement. The lack of uniformity in the enforcement of RPOs—as can be seen from recent decisions of the Maharashtra Electricity Regulatory Commission (MERC)—further compounds the problem.

Enforcement of RPOs is made difficult due to restrictions on trading of RECs. Renewable energy producers sell electricity to distribution licensees at the rate of conventional energy and recover the balance cost by selling RECs to other obligated entities, enabling them to meet their RPOs. RECs serve as a substitute to physical procurement of renewable energy and help obligated entities to plan and tap on favourable market conditions.

In 2017, trading in RECs was suspended on account of a Supreme Court order arising due to a dispute regarding change in the price regime by the Central Electricity Regulatory Commission (CERC). Whilst trading in non-solar RECs was subsequently allowed, trading in solar RECs was prohibited until earlier this year. Several obligated entities attributed their shortfall in meeting RPO targets to the halt in trading of solar RECs. Consequently, entities have been requesting SERCs for permission to carry forward their solar obligations shortfall. In May 2018, CERC clarified that pursuant to an order from the Supreme Court, trading in solar and non-solar RECs may be carried out in accordance with the floor price and forbearance price as determined by CERC (floor price is the minimum price at which an REC can be traded on a power exchange; forbearance price is the ceiling price).

SERCs have, in many instances, considered the mitigating factors put forward by obligated entities and permitted them to carry forward their shortfall or relaxed RPO targets, although this has resulted in a lack of consistency. In particular, MERC passed several orders on July 31, 2018. In one order, it directed the Maharashtra State Electricity Distribution Company Ltd (MSEDCL) to purchase solar power and/or RECs so as to meet its shortfall by the end of March 2019 as opposed to March 2020 as requested by MSEDCL. In this order, MERC noted the justifications provided by MSEDCL with regards to its failure to meet RPO targets. However, taking a tough stance, MERC observed that regardless of circumstances, MERC's RPO shortfall has increased and thus mandated MSEDCL to fulfil its RPO targets in any case.

The Haryana Electricity Regulatory Commission (HERC), in an order passed on June 30, 2018, observed that RPO targets were fixed and thus there was no reason to change the same. HERC opined there was no convincing reason to carry forward excess renewable energy for the purpose of offsetting for more than 12 months.

In contrast, in another order on the same date, MERC granted Brihanmumbai Electric Supply & Transport Undertaking (BEST) another chance to comply with its non-solar RPO targets by procuring renewable energy or purchasing RECs. BEST was rendered this opportunity, in light of the efforts made by it, in meeting the targets. Reliance Infrastructure Ltd (Distribution) was also accorded a chance to meet its solar and non-solar RPO shortfall vide an order on the same date. Such permissiveness could result in a supply-demand mismatch that adversely affects renewable power generators.

It is clear that enforcement of RPO targets, despite availability of RECs, is poor. Considering this, the government recently launched the RPO Compliance Cell. As per the notification, the Cell is to coordinate with states, CERC and SERCs on matters relating to RPO compliance, including for monthly reports on compliance, and to take up non-compliance related issues with appropriate authorities. Given that enforcement of RPO has historically been a task, it would be interesting to see if the Cell will have the desired impact. Further, it appears that the Cell has no powers of enforcement and its advice or directions would be non-binding. Failure to meet RPO targets could result in direction from relevant SERCs to deposit RPO regulatory charges and forbearance price as determined by the relevant SERC into a separate fund. Whilst regulations of most states do link regulatory charges to forbearance price, SERCs usually have the discretion to specify what charges are to be deposited in the fund and the manner in which such charges are to be utilised. Most regulations empower SERCs to authorise an officer to procure requisite RECs from the power exchange out of the amount deposited in the fund in order to meet RPO shortfall.

Given this, and further compounded with divergence amongst state SERCs, it would be interesting to see how the RPO Compliance Cell encourages compliance of, and aids in enforcement of, RPO targets. In light of the recent positive results of trading of RECs, it is hoped that obligated entities will cover their RPO shortfalls to avoid hefty costs in the future. Effective enforcement of RPO would, in the long run, benefit consumers of electricity and also help the government achieve long-term targets. To ultimately ensure this goal, a proactive initiative from the government, a consistent approach across all SERCs, smooth trading of RECs, clarity on the role of the RPO Compliance Cell, and stringent and uniform enforcement of RPO are needed.

Loan and promotional schemes

Objectives: At the end of this lesson you shall be able to

- **analyze the business opportunities in Solar energy field.**

India has set an ambitious target of reaching 175 GW of installed capacity from renewable energy sources by the year 2022, which includes 100 GW of solar and 60 GW of wind power capacity.

Various policy initiatives have been taken to achieve this target. At the end of 2017-18 the total renewable power installed capacity in the country was almost 70 GW.

Updated details of Renewable energy generation, utilization and demand in different states of India will be available in MNRE website periodically. Cost of projects, cost of electricity etc also can be obtained similarly to have an effective plan.

The knowledge on our Government of policies will help us to understand the need of manpower in Solar PV plant installation, operation and maintenance.

A solar loan is a loan taken out for the purchase and installation of solar panels. They offer a way for homeowners to invest in a solar panel system without paying lots of money upfront.

Many solar loan providers offer zero-down solar loans and options to pay down a loan early without penalty.

Solar loans are generally considered a subcategory of home improvement loans. As such, they are available with many different payment structures, terms, and rates.

Homeowners are attracted to solar loans because the purchase of solar panels results in immediate utility bill savings. The bill savings can then be used towards the monthly loan repayment.

However, while solar loans are convenient, overall they offer a lower financial return than solar panel systems purchased with cash.

Solar energy business contains huge opportunities with larger profits that can be earned with sheer patience and persistence. Solar being one of the largest renewable sources of energy, a lot of experienced businessmen and start-ups have already ventured into solar energy business. To start a solar energy business, entrepreneurs or businessmen should have sound backup of financial support, as well as political acquaintance, if required.

There are two major divisions of the solar industry that are flourishing and expanding, such as Solar PV and Solar Thermal. To get assistance regarding solar energy projects, there are several government institutions and commercial organizations. Further, let's discuss the process of starting a Solar Energy Business with its types and segments.

Process to Start a Solar Energy Business

1 Creating a Business Plan

Writing a detailed business plan is the most important task before starting any business. Business plan should contain all the necessary details like business background and detailed information related to budget, working capital investment, workers, strategies, techniques, location, equipment, raw materials, etc. Business plan further helps in getting funding support from lending institutions like private and public sector banks, NBFCs,Regional Rural Banks, Small Finance Banks and Micro Financial Institutions, whenever required during the business tenure.

2 Market Research

Another essential task before starting a solar energy business is performing thorough research of almost every component involved in the business. More the research, less are the chances of business failure. Research could be related to solar projects, equipment, parts, infrastructure, marketing, hiring, and finding customer base, suppliers, contractors, etc.

3 Legalising Business

The next important step is to legalize the business entity by forming a company by undertaking company registration. Under the Company's Act 2013, a business can be registered as a company under various forms, such as sole private or public limited, proprietorship, partnership firm, Limited Liability Partnership, etc.

Following documents, registration certificates and licenses are required to be obtained by business to get registered as a company:

- Company/LLP registration certificate
- Company's bank account number and PAN
- GST registration with Identity Proofs of Directors/ Owners/Partners
- Sales Tax and TIN numbers
- Article of Association (AoA) & Memorandum of Association (MoA)
- Shop and Establishment Act License
- Certificate of Commencement
- Other licenses, if required

4 Acquainted with Government's Electricity Department

It's vital to maintain good connections with the electricity department that comes under the respective State Government, wherein the solar plant is about to be set up. It helps business owners in getting over with various complex or lengthy documentation processes in less time and also making it easier to get approvals.

5 Finalizing Location

Location decides the fate of the business whether it will be a success or failure. Moreover, considering the nature of this business, it is highly important. Solar energy plants need to be set up considering the density of sunlight. Locations need to be chosen wherein there is high density of sunlight to capture maximum sunlight for more storage and future usage.

6 Financial Actions

Business owner also needs to prepare a rough budget of his/her spending that shall include various business divisions as follows:

- Infrastructure
- Land/Space
- Logistics
- Machinery/Equipment
- Maintenance
- Manpower/Workers
- Marketing/Advertising
- Office premises
- Raw materials' purchase
- Tax payments

7 Hiring Workers

One of the key steps in making business a success is hiring efficient and skillful workers or employees. For Start-ups, even more hardworking and competitive employees are required. Efficient workers may start delivering results in the initial stages of the business and shall lead ahead in making solar energy companies into a profitable venture in much lesser time.

Types of Solar Energy Companies

Solar energy sector is divided into 3 types of companies that include:

1. **Solar EPC Company:** Solar Engineering, Procurement and Construction Company is a type of company that manufactures solar panels that are used in capturing sunlight.
2. **Solar Inverter Manufacturers:** Companies that manufacture solar inverters that help in the

conversion of Direct Current (DC) into Alternate Current (AC).

3 **Energy Storage System (ESS) Manufacturers:** Companies that develop batteries and energy backup solutions that can be attached with solar energy systems.

Types of Engineering Segments

Solar energy sector is further divided into 3 major engineering segments:

Civil: Cement blocks for supporting the module mounting structure

Electrical: Cabling, inverter, protection and switchgear and Solar Panels

Mechanical: Module Mounting Structure

Solar Energy business can be started considering various types of business divisions like manufacturing, distribution, consulting, installation, sales, parts & accessories, contractor, financer, R&D, maintenance, trading, execution and training. All these divisions contain a lot of scope with multiple opportunities for business to grow, expand and earn profit.

If in case, any financial assistance or funding support is required during the business tenure or before starting a business, business owners can simply visit financial consultants to check and compare from various business loan deals offered from leading financial institutions at competitive interest rates with flexible repayment options.

Incentives, subsidies & concessions

Objective: At the end of this lesson you shall be able to
- **appreciate the incentives, subsidies and concessions in Government of India schemes related to solar energy industries.**

By installing solar rooftop systems, people can generate their own energy and use it for different purposes. These panels are eco-friendly and they can help in curbing the user's carbon footprint. The generated energy can be used to power residential, commercial or industrial buildings. In fact, people can even supply excess electricity to the grid and make some money out of it. Thus, a rooftop solar system is a worthy investment.

However, the problem is the huge upfront installation cost of a rooftop solar system. As per MNRE, the average cost of a rooftop solar system connected with the grid is Rs 75 per watt. Most of the population of India cannot afford this installation cost. Thus, in order to pose a solution to this problem and to encourage people to exploit renewable energy, the Government of India has launched a subsidy scheme as well as various other incentives.

Government subsidy scheme for rooftop solar systems

Both the Central Government as well as State Nodal Agencies (SNAs) offer subsidy schemes to the people for installing rooftop PV systems. This encourages people to exploit renewable energy and to cut their electricity bill. Though the upfront cost of installation of a rooftop PV system is high, it is inexpensive in the long run when compared to electric generators. Once rooftop PV systems are installed, they don't need any other expenses as they use solar energy instead of fossil fuels.

According to the Ministry of New and Renewable Energy, the Central Government pays 30% of the benchmarked installation cost for rooftop PV systems. This subsidy is applicable in states that are in the general category. However, a subsidy of up to 70% of the benchmarked installation cost is offered in some states that lie in the special category -- North MNRE PV Rooftop Cell. These include states such as Uttarakhand, Sikkim, Himachal Pradesh, Jammu & Kashmir and Lakshadweep. In addition to this, State Nodal Agencies also offer subsidies in various states.

This subsidy scheme is applicable for institutional, residential and social sectors. However, it is not applicable to the commercial sector, industrial sector and public sector undertakings. PSUs are eligible to avail incentives on the basis of energy generation.

Other perks offered by the government for installing a rooftop PV system

In addition to the subsidy, people can avail various other benefits by installing a rooftop solar system:

- Those planning to install rooftop PV systems can avail priority sector loans of up to 10 lakhs from nationalized banks. This loan shall fall under the category of home loan or home improvement loan.
- Consumers will be eligible for generation-based incentives and will receive Rs 2 per unit of electricity generated.
- Furthermore, people can sell the excess of electricity. For this, they'd receive a regulated cost per unit as per tariffs set by the government.

Specifications of rooftop PV system for the subsidy scheme

- Approximately 100 square feet of space is required for the installation of the rooftop PV system.
- The average cost of installation of rooftop PV system without subsidy is around Rs 60,000 - 70,000.
- After leveraging 30% subsidy, people just have to pay Rs 42,000 - 49,000 for installing a rooftop PV system.
- In order to avail generation-based incentive, the

customer should generate 1100 kWh - 1500 kWh per year.

- Under the scheme, a customer can earn up to Rs 2000 to 3000 per annum as generation-based incentive.

Application process for the scheme

Interested people should contact their electricity provider to express their interest. Next, concerned officials will visit the installation site, assess it and give approval. They will also explain the necessary details for installation along with fee structure.

Users can also seek approval for the installation of monitoring systems from the inspection officers during their visit.

The customer needs to call the electricity provider for inspection after completion of the installation process as well. Next, the officer will inspect the installation and give their approval for availing the subsidy.

Subsidy is provided to customers via MNRE and state renewable departments.

As per the current guidelines set by MNRE , CFA (Central Finance Assistance) subsidy for Grid-Tie Solar system is as following :

MNRE Subsidy	Applicable for
30% max of benchmark cost	General Category States:All other States/UTs not covered under special states
70% max of benchmark cost	Special Category States/Islands:North Eastern States including Sikkim, Uttarakhand,Himachal Pradesh, Jammu & Kashmir and Lakshadweep, Andaman & Nicobar Islands

Present benchmarking cost by MNRE is as follows :

Rooftop capacity	Benchmark cost (INR/W)
up to 10kW	70
>10-100kWp	65
>100-500kWp	60

The subsidy is available only to these categories:

Type	Details
Residential	All types of residential buildings, including group housing.
Institutional	Schools, health institutes including medical colleges & hospitals, universities, educational institutes, etc
Social Sector	Community centers, welfare homes, old age homes,orphanages, common service centers, common workshop for artisans or craftsman,facilities used for the community. Trusts/NGO/Voluntary organizations/ training institutes,any other establishments for common public use, etc.

Procedure to get MNRE Subsidy

Step-1 Submit a project report with technical and financial details, operations and maintenance plan along with system monitoring and reporting details to MNRE via district head of your state nodal agency

Step-2 MNRE evaluates your project on technical and financial points

Step- 3 After your project is approved by MNRE, Open tenders are invited by your state nodal agency and a channel partner will be selected from open bidding process

Step-4 Channel Partner completes the installation process

Step-5 SNA inspects your installation to ensure that only MNRE approved components are installed

Step-6 Subsidy amount is released to channel partner directly from MNRE

Step-7 You will be responsible for payment of 70% of the system cost, if you chose to finance your solar plant, you may work with you bank to procure financing 70% of the system cost.

Solar rooftop business models

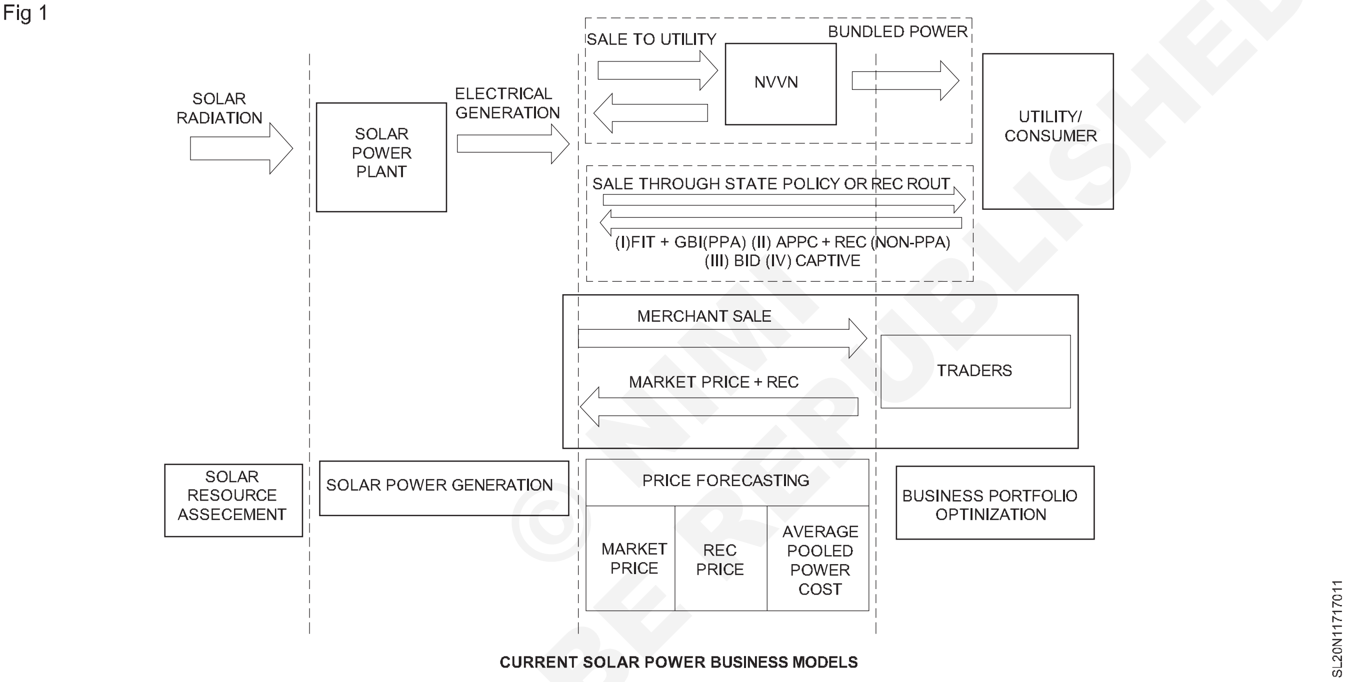
Objectives: At the end of this lesson you shall be able to
- **Differentiate among various business models in Renewable energy.**

Solar Energy is one of the most reliable sources of renewable energy available to us today. The world is currently racing to make this technology widespread, especially with the ever-looming threat of global warming. Renewable energy, which has minimal to none carbon footprint, is essential to make our world and our environment a better and healthier place to be in.

The government of India is encouraging every Indian to opt for clean and green solar energy. To promote convenient adoption and use of solar energy, public and private sectors have been informed by the Ministry of Finance to offer a loan at the minimal interest rate for encouraging Solar Ideology to every home, business, office, and other places. It is vital for the customer and investor that they choose the right business model to minimize the risk and maximize the Return on Investment.

Fig 1 Solar power business models

Fig 1

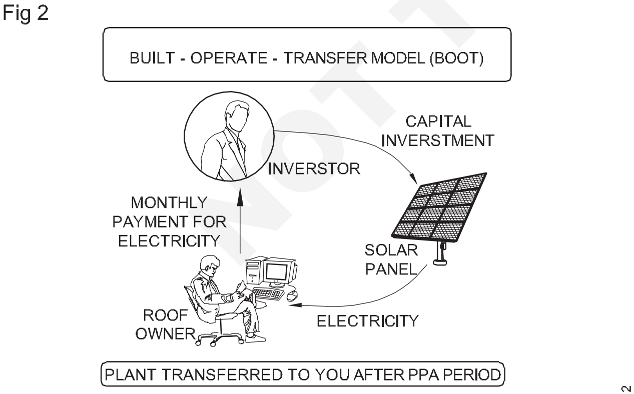


CURRENT SOLAR POWER BUSINESS MODELS

BOOT model:

Fig 2 BOOT model

Fig 2

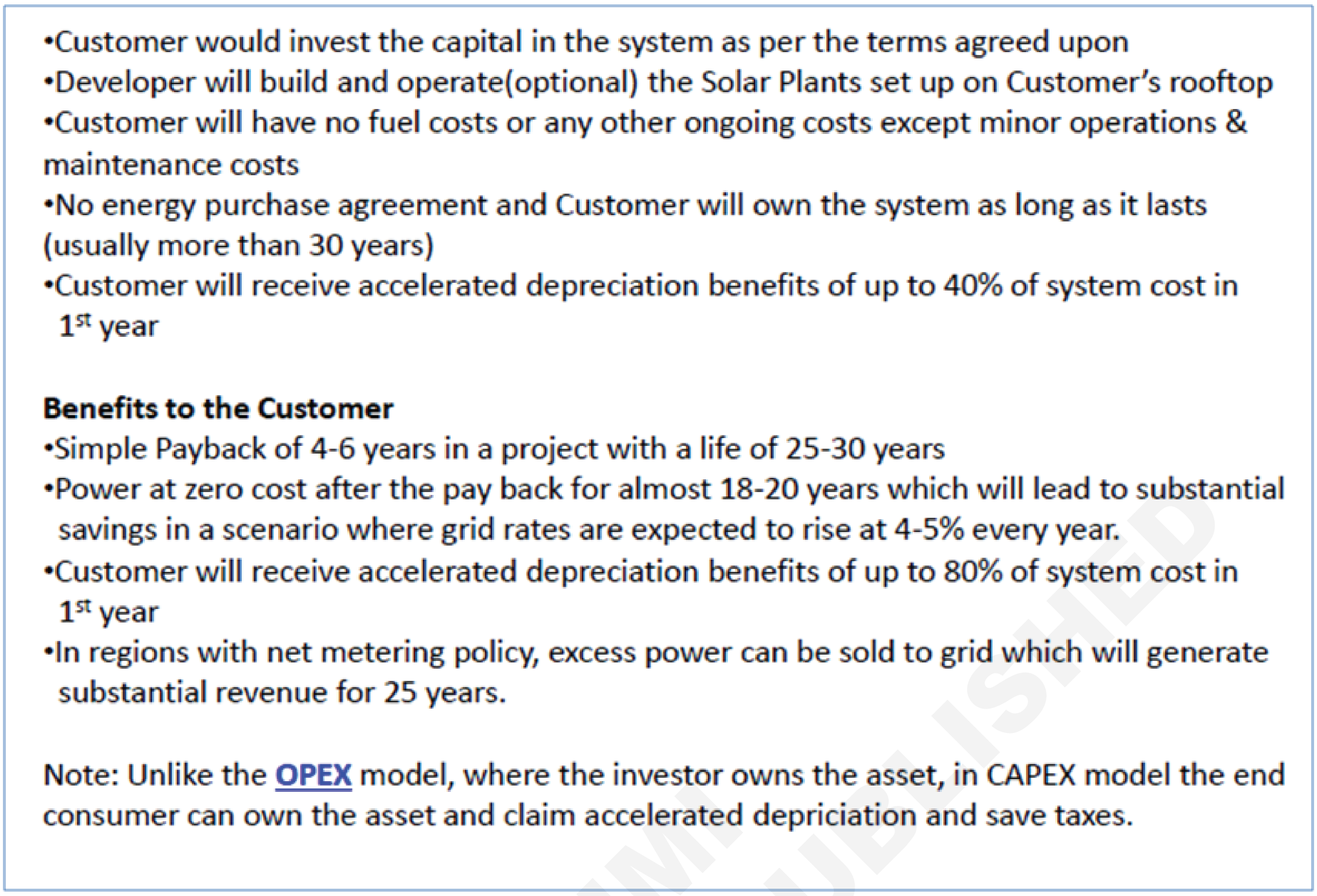


IN INDIAN SOLAR INDUSTRY, BROADLY SPEAKING BOOT/ LEASE/ OPEX/ SOLAR PPA MODEL- ALL MEAN THE SAME. ESSENTIALLY A COMPANY WITH INTERST IN INVERSTING IN SOLAR POWER PROJECTS AND SELLING POWER TO AN ENERGY USER TO MAKE RETURNS OFFERS SUCH A MODEL.

The two Solar Business Models popular in India are CAPEX and RESCO models.Both models have their pros and cons. It all depends on your objectives. An in-depth analysis is very important to find out which solar business model is suitable for your business. As per the project size, investment amount, and different financial needs, two solar business models are followed in India.

CAPEX Model. (Capital Expenditure)

It is the most common model form of the solar power plant business model in India. In this model, the customer generally hires a solar EPC (Engineering, Procurement, and Construction) company that provides the installation of the entire solar power system and hand over access to the consumer. One of the major advantages of this model is that the customer is eligible to claim the accelerated depreciation to gain tax savings from the government.



- •Customer would invest the capital in the system as per the terms agreed upon
- •Developer will build and operate(optional) the Solar Plants set up on Customer's rooftop
- •Customer will have no fuel costs or any other ongoing costs except minor operations & maintenance costs
- •No energy purchase agreement and Customer will own the system as long as it lasts (usually more than 30 years)
- •Customer will receive accelerated depreciation benefits of up to 40% of system cost in 1st year

Benefits to the Customer

- •Simple Payback of 4-6 years in a project with a life of 25-30 years
- •Power at zero cost after the pay back for almost 18-20 years which will lead to substantial savings in a scenario where grid rates are expected to rise at 4-5% every year.
- •Customer will receive accelerated depreciation benefits of up to 80% of system cost in 1st year
- •In regions with net metering policy, excess power can be sold to grid which will generate substantial revenue for 25 years.

Note: Unlike the OPEX model, where the investor owns the asset, in CAPEX model the end consumer can own the asset and claim accelerated depriciation and save taxes.

Highlights:

- Allows Residential, Industrial, and Commercial to own the system.
- The customer sets up the rooftop solar project with the intent to reduce his power costs.
- The customer bears the entire capital expenditure of the project.
- The customer gets benefit by selling the surplus power generated to the DISCOM.
- The gains from tariff savings accrue to the roof and solar power plant owner.
- Commercial & Institutional clients can also claim the accelerated depreciation.
- EPC also performs the annual operation and maintained (O&M) of the plant on mutually agreed cost per annum.

RESCO Model (Fig 3)

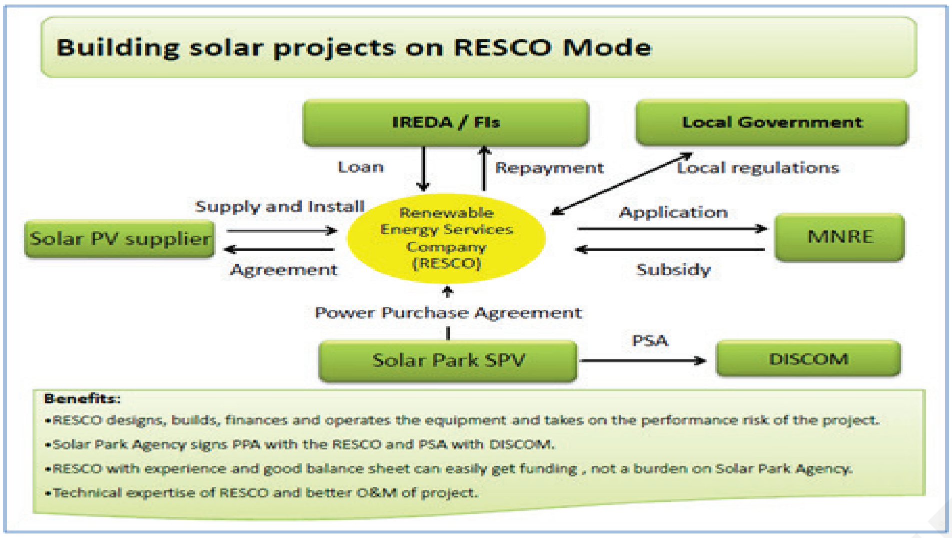
Renewable Energy Service Company is an energy service company which provides energy to the customer from renewable energy sources usually from Solar Photovoltaic, Wind Power or Hydropower. RESCO about pays as you consume electricity. Since it is operated and maintained by the RESCO, it carries a longer production run than the CAPEX model.

Highlights:

- Solar Power Plant is owned by the RESCO and ENERCO (Energy Company).
- The customer service does not own any rights on the solar energy system.
- Customers have to sign the Power Purchase Agreement (PPA) with an actual investor at a mutually agreed tariff and tenure.
- The customer only pays for electricity consumed as per units for power basis.
- RESCO developer is responsible for its annual operation and maintenance.
- RESCO gets the benefit by selling surplus power generated to the DISCOM.

Fig 3 RESCO model

Fig 3

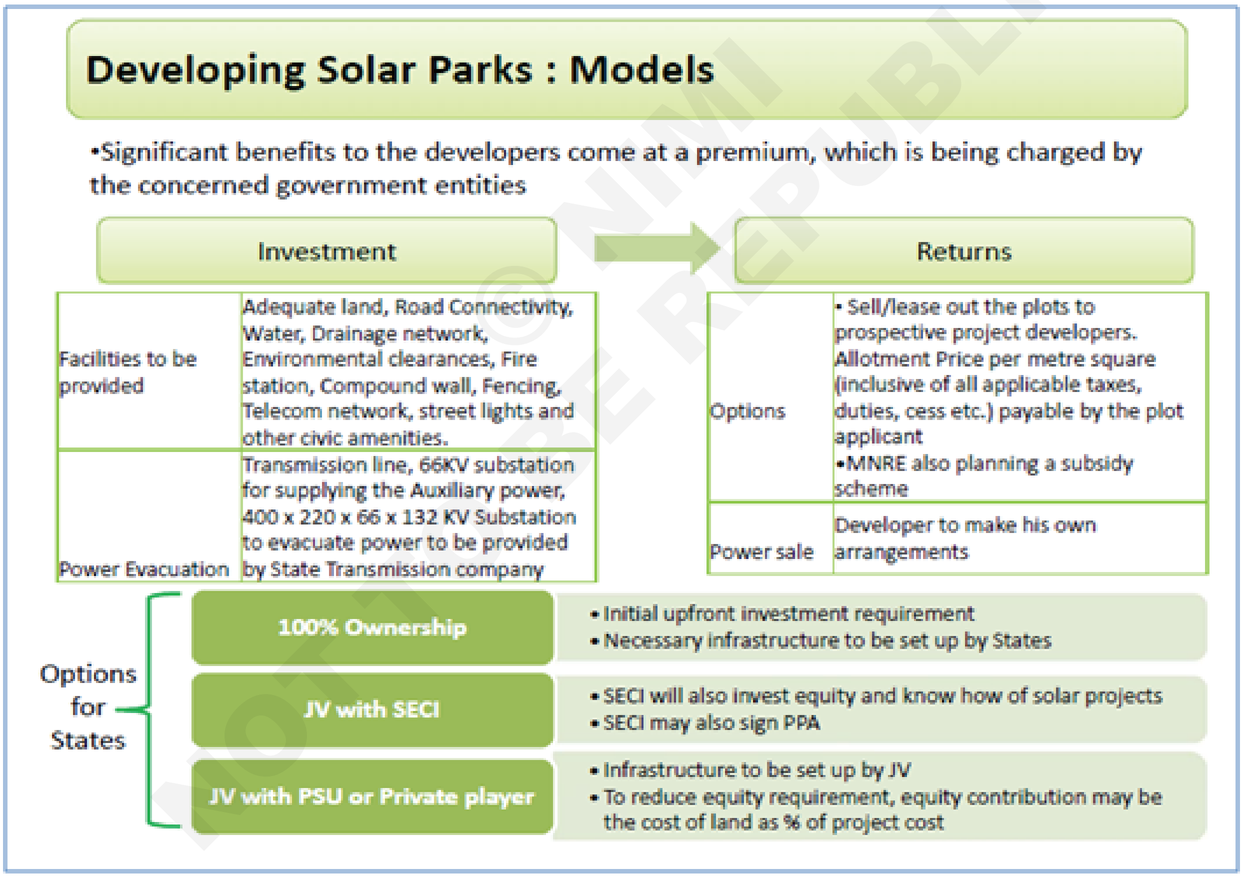


Benefits:

- RESCO designs, builds, finances and operates the equipment and takes on the performance risk of the project.
- Solar Park Agency signs PPA with the RESCO and PSA with DISCOM.
- RESCO with experience and good balance sheet can easily get funding , not a burden on Solar Park Agency.
- Technical expertise of RESCO and better O&M of project.

Administrative processes

Fig 4



Developing Solar Parks : Models

- Significant benefits to the developers come at a premium, which is being charged by the concerned government entities

Investment

Facilities to be provided	Adequate land, Road Connectivity, Water, Drainage network, Environmental clearances, Fire station, Compound wall, Fencing, Telecom network, street lights and other civic amenities.
Power Evacuation	Transmission line, 66KV substation for supplying the Auxiliary power, 400 x 220 x 66 x 132 KV Substation to evacuate power to be provided by State Transmission company

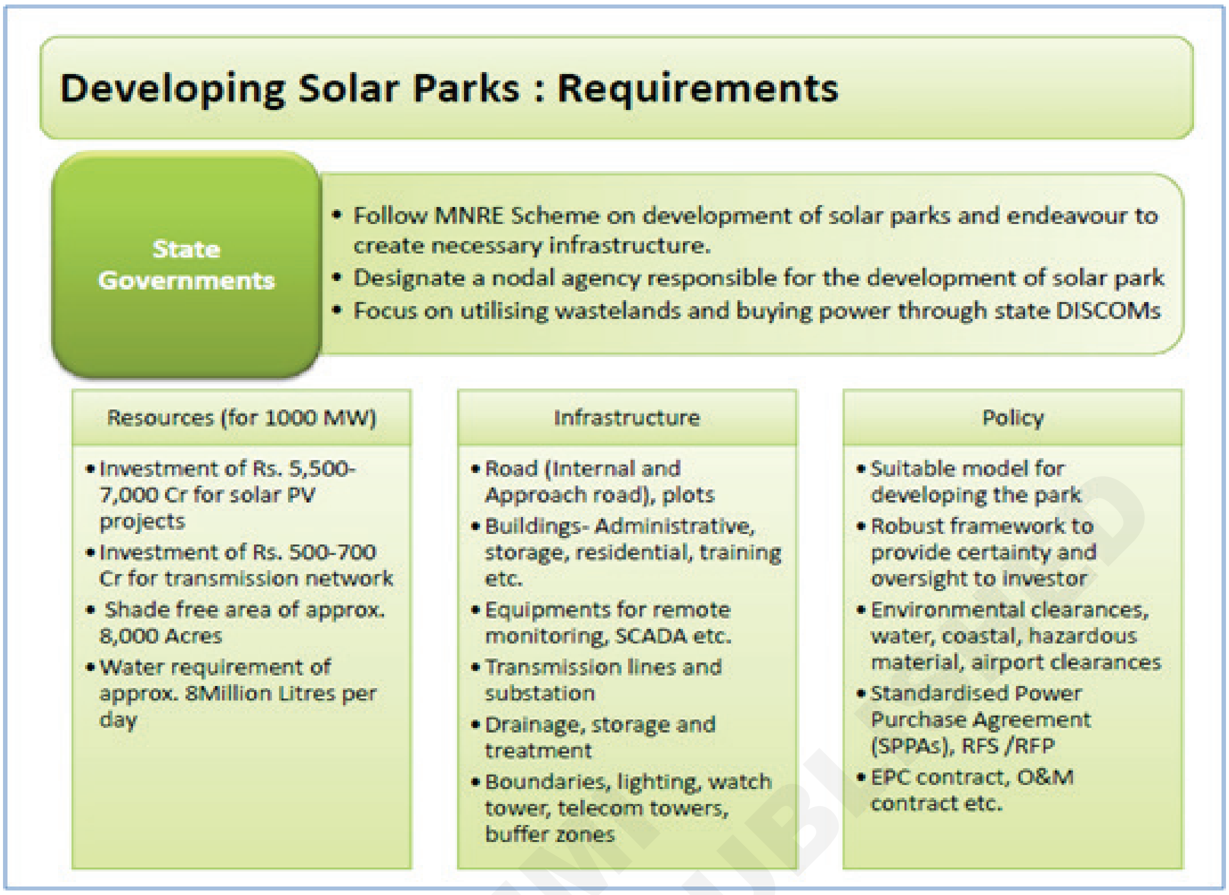
Returns

Options	• Sell/lease out the plots to prospective project developers. Allotment Price per metre square (inclusive of all applicable taxes, duties, cess etc.) payable by the plot applicant •MNRE also planning a subsidy scheme
Power sale	Developer to make his own arrangements

Options for States

100% Ownership	• Initial upfront investment requirement • Necessary infrastructure to be set up by States
JV with SECI	• SECI will also invest equity and know how of solar projects • SECI may also sign PPA
JV with PSU or Private player	• Infrastructure to be set up by JV • To reduce equity requirement, equity contribution may be the cost of land as % of project cost

Fig 5



Developing Solar Parks : Requirements

State Governments

- Follow MNRE Scheme on development of solar parks and endeavour to create necessary infrastructure.
- Designate a nodal agency responsible for the development of solar park
- Focus on utilising wastelands and buying power through state DISCOMs

Resources (for 1000 MW)

- Investment of Rs. 5,500-7,000 Cr for solar PV projects
- Investment of Rs. 500-700 Cr for transmission network
- Shade free area of approx. 8,000 Acres
- Water requirement of approx. 8Million Litres per day

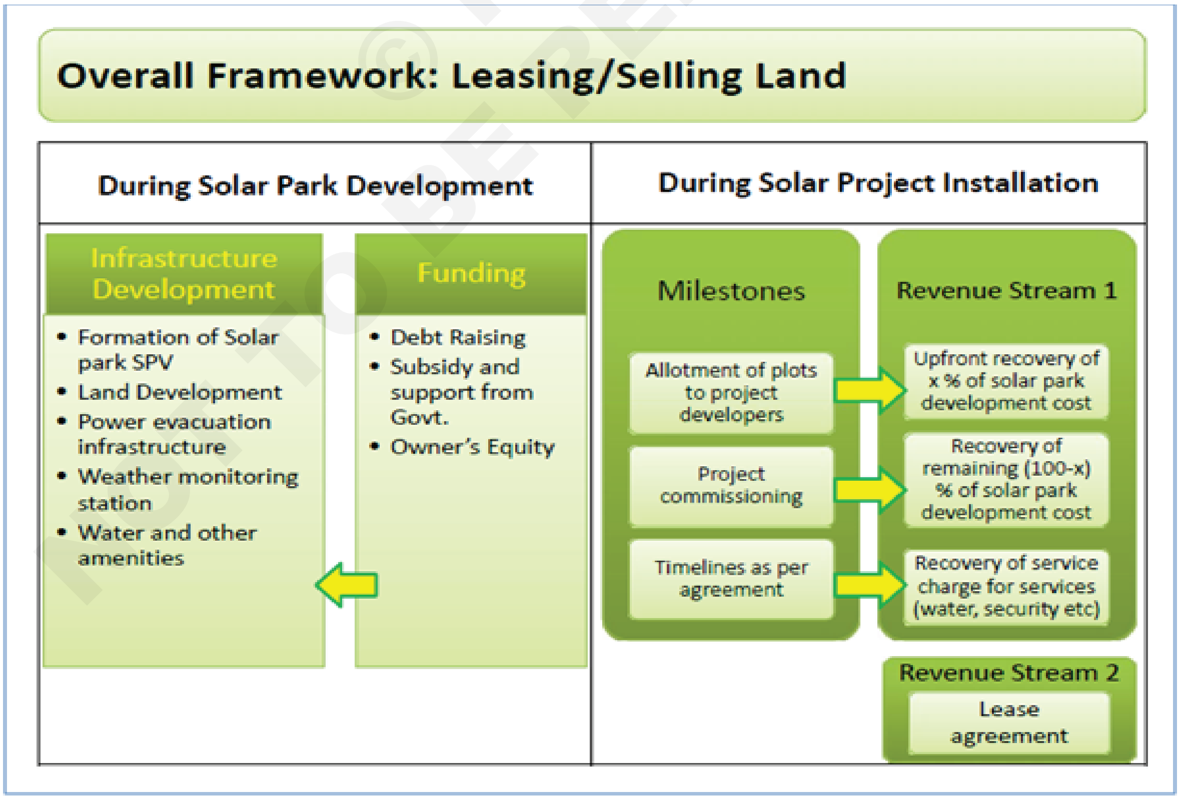
Infrastructure

- Road (Internal and Approach road), plots
- Buildings- Administrative, storage, residential, training etc.
- Equipments for remote monitoring, SCADA etc.
- Transmission lines and substation
- Drainage, storage and treatment
- Boundaries, lighting, watch tower, telecom towers, buffer zones

Policy

- Suitable model for developing the park
- Robust framework to provide certainty and oversight to investor
- Environmental clearances, water, coastal, hazardous material, airport clearances
- Standardised Power Purchase Agreement (SPPAs), RFS /RFP
- EPC contract, O&M contract etc.

Fig 6



Overall Framework: Leasing/Selling Land

During Solar Park Development

Infrastructure Development

- Formation of Solar park SPV
- Land Development
- Power evacuation infrastructure
- Weather monitoring station
- Water and other amenities

Funding

- Debt Raising
- Subsidy and support from Govt.
- Owner's Equity

During Solar Project Installation

Milestones

Allotment of plots to project developers

Project commissioning

Timelines as per agreement

Revenue Stream 1

Upfront recovery of x % of solar park development cost

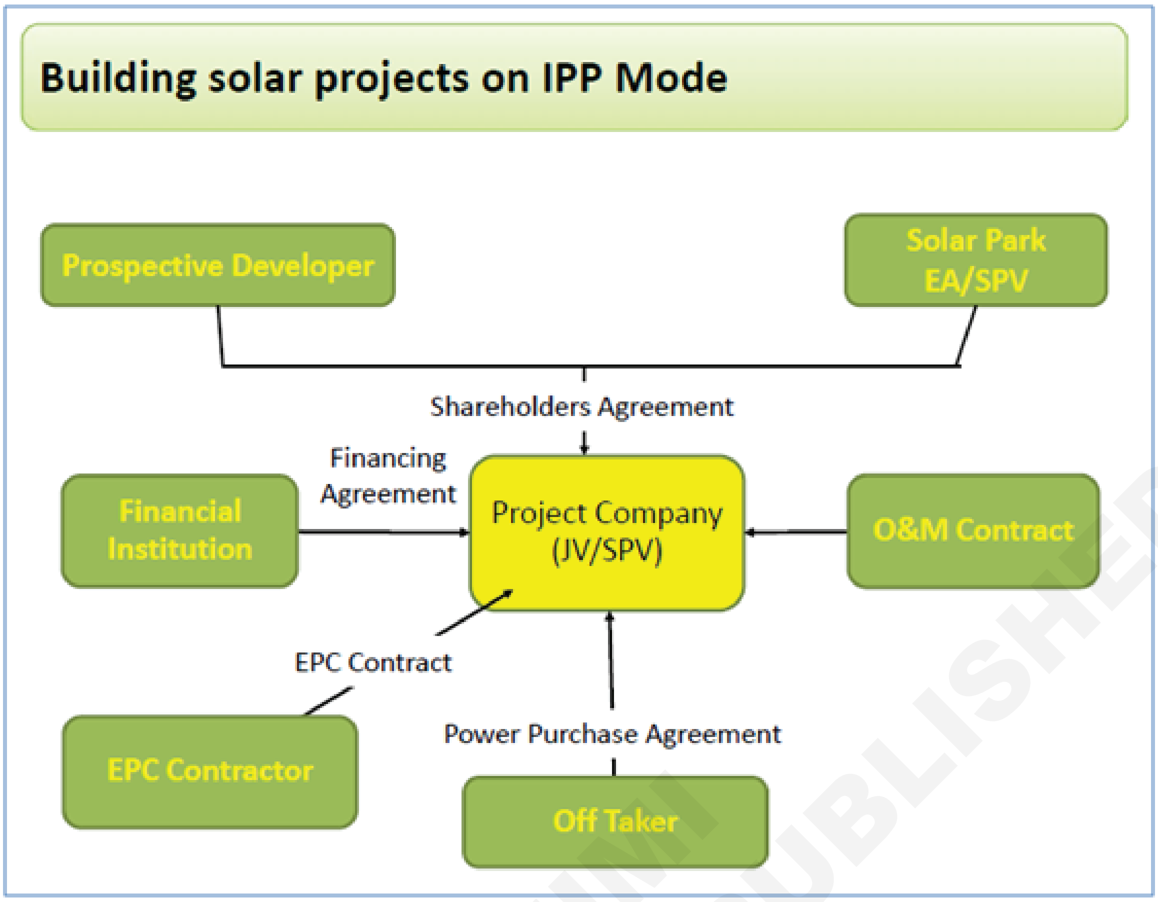
Recovery of remaining (100-x) % of solar park development cost

Recovery of service charge for services (water, security etc)

Revenue Stream 2

Lease agreement

Fig 7



Building solar projects on IPP Mode

Prospective Developer

Solar Park EA/SPV

Shareholders Agreement

Financing Agreement

Financial Institution

Project Company (JV/SPV)

O&M Contract

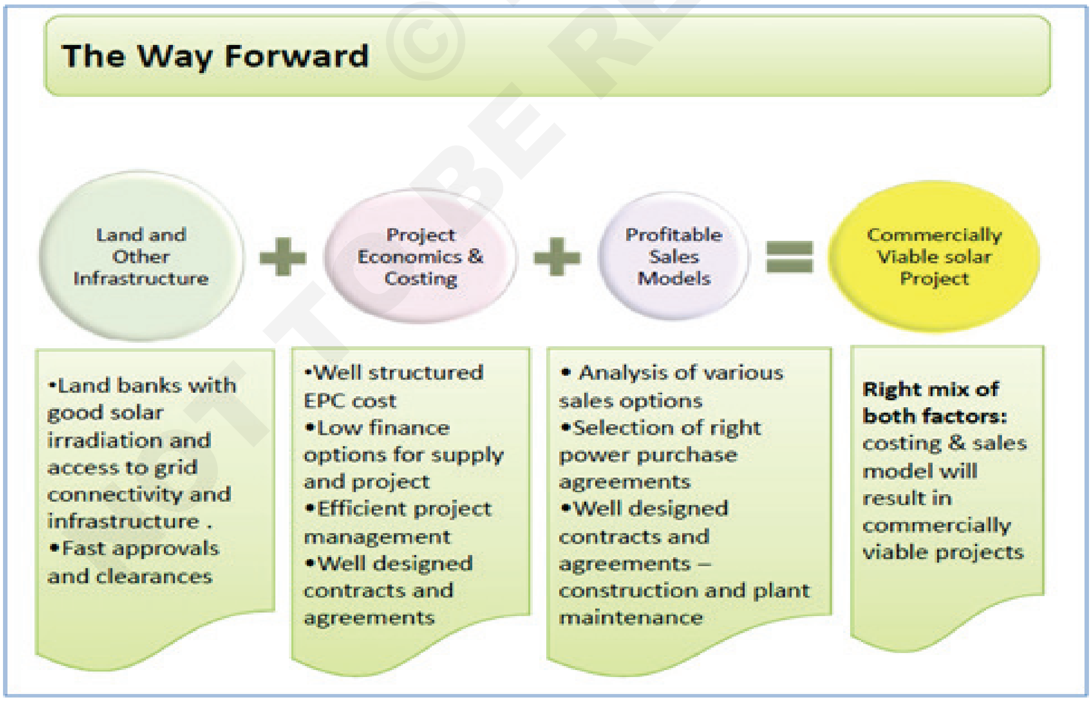
EPC Contract

EPC Contractor

Power Purchase Agreement

Off Taker

Fig 8



The Way Forward

Land and Other Infrastructure + Project Economics & Costing + Profitable Sales Models = Commercially Viable solar Project

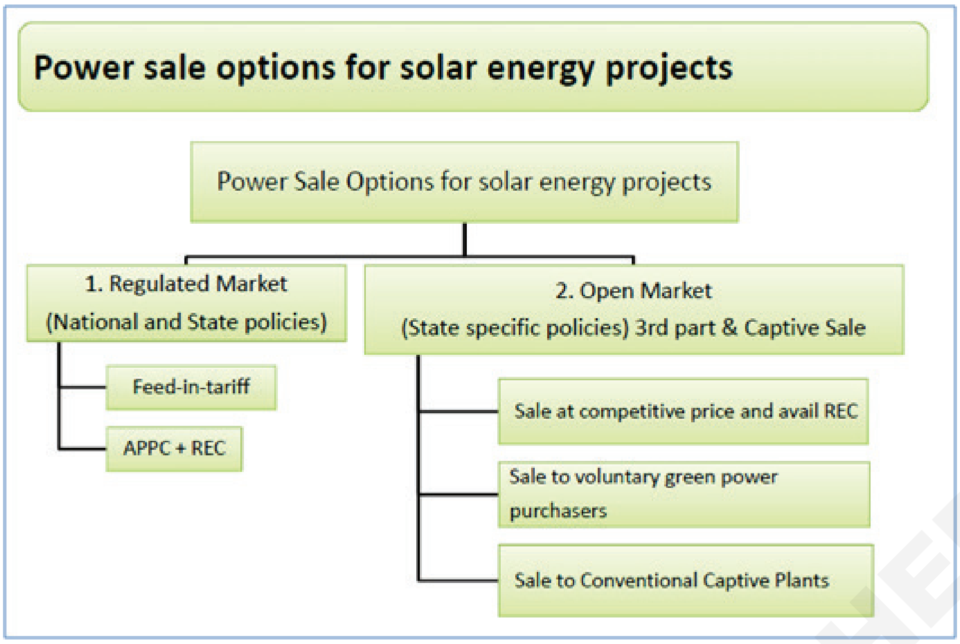
- Land banks with good solar irradiation and access to grid connectivity and infrastructure .
- Fast approvals and clearances

- Well structured EPC cost
- Low finance options for supply and project
- Efficient project management
- Well designed contracts and agreements

- Analysis of various sales options
- Selection of right power purchase agreements
- Well designed contracts and agreements – construction and plant maintenance

Right mix of both factors: costing & sales model will result in commercially viable projects

Fig 9



Power sale options for solar energy projects

Power Sale Options for solar energy projects

1. Regulated Market (National and State policies)
   - Feed-in-tariff
   - APPC + REC

2. Open Market (State specific policies) 3rd part & Captive Sale
   - Sale at competitive price and avail REC
   - Sale to voluntary green power purchasers
   - Sale to Conventional Captive Plants

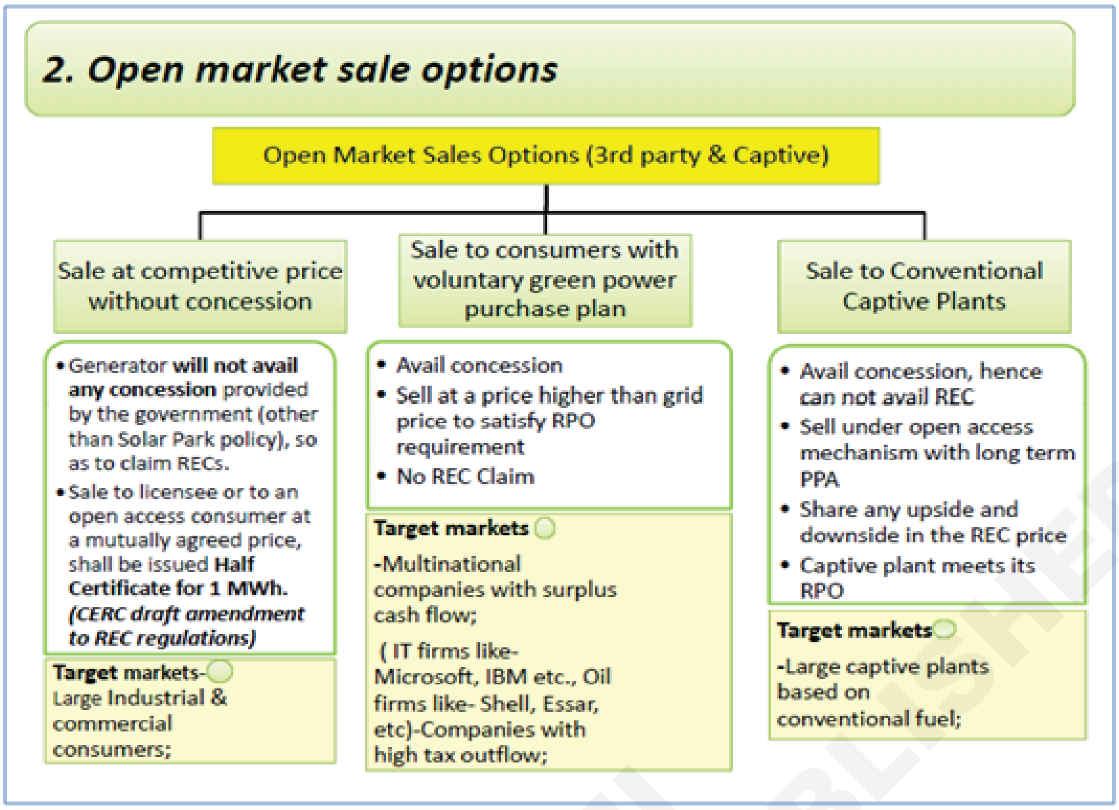
Fig 10

1. Regulated market sale options

Two options exist under regulated market:

Feed in tariff / Preferential tariff	Average Power Purchase Cost + REC
• Most preferred sale option in the market as seen from National and State policies. • Sale through a long term PPA (25 years) to state DISCOM at preferential tariff /Feed-in-tariff. • Weighted average price of INR 6.45 per kWh – 8 per kWh realized in the recent bids largely possible due to drop in EPC prices • Tariff largely discovered through a competitive bid process estimated to provide 10% - 15% returns and largely driven by financing options. • REC cannot be claimed under this mode.	• Sale under a long term PPA with state DISCOM on Average Power Purchase Cost notified by State Electricity Regulatory Commission. • REC can be claimed under this mode. • In this sales mode, energy produced is sold to State Utilities at APPC (INR. 2.0/kWh – INR 3.0/kWh) of the state as realization. • Tariff largely discovered through a long term PPA (10years) and largely driven by REC price. However, low APPC, uncertainty in REC market and low bankability is a hindrance • Non-visibility of REC price beyond 2017 and firm APPC for the PPA period are seen as market hurdles.

Fig 11



2. Open market sale options

Open Market Sales Options (3rd party & Captive)

Sale at competitive price without concession

- Generator **will not avail any concession** provided by the government (other than Solar Park policy), so as to claim RECs.
- Sale to licensee or to an open access consumer at a mutually agreed price, shall be issued **Half Certificate for 1 MWh.** ***(CERC draft amendment to REC regulations)***

Target markets- Large Industrial & commercial consumers;

Sale to consumers with voluntary green power purchase plan

- Avail concession
- Sell at a price higher than grid price to satisfy RPO requirement
- No REC Claim

Target markets

-Multinational companies with surplus cash flow;

(IT firms like- Microsoft, IBM etc., Oil firms like- Shell, Essar, etc)-Companies with high tax outflow;

Sale to Conventional Captive Plants

- Avail concession, hence can not avail REC
- Sell under open access mechanism with long term PPA
- Share any upside and downside in the REC price
- Captive plant meets its RPO

Target markets

-Large captive plants based on conventional fuel;

Fig 12

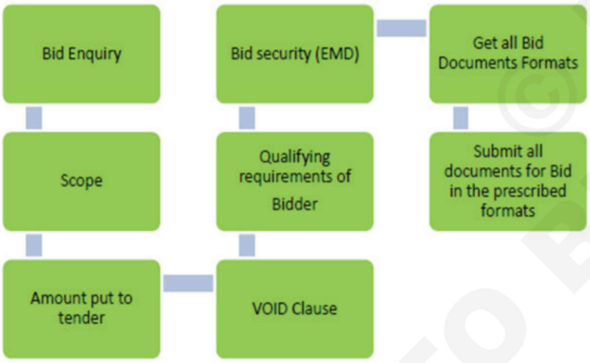
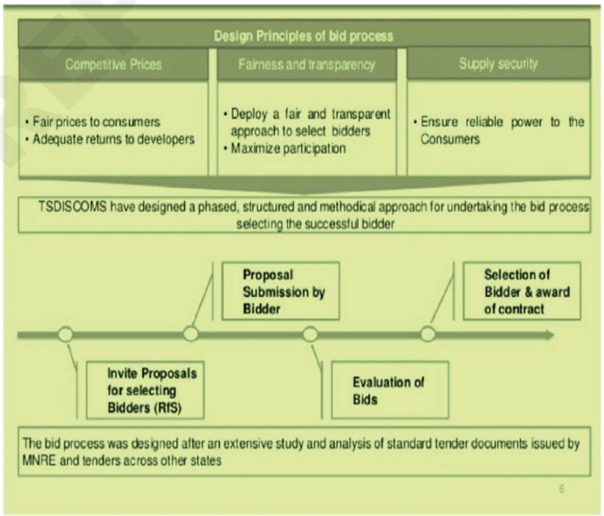


Fig 13



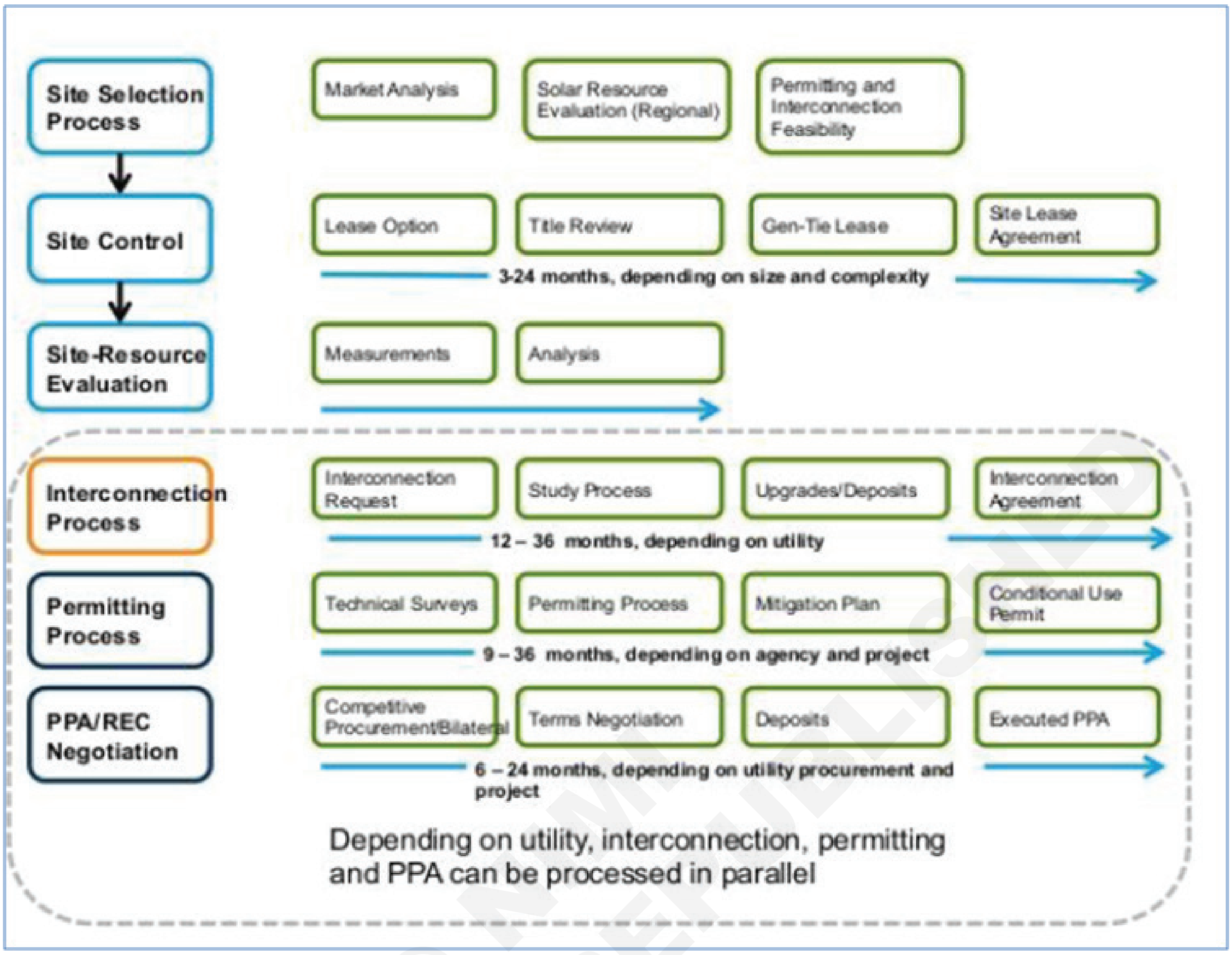
Design Principles of bid process

Competitive Prices	Fairness and transparency	Supply security
• Fair prices to consumers • Adequate returns to developers	• Deploy a fair and transparent approach to select bidders • Maximize participation	• Ensure reliable power to the Consumers

TSDISCOMS have designed a phased, structured and methodical approach for undertaking the bid process selecting the successful bidder

The bid process was designed after an extensive study and analysis of standard tender documents issued by MNRE and tenders across other states

Fig 14



Solar Industry opportunities

Objectives: At the end of this lesson you shall be able to
- **select from various solar industry opportunities.**

- Solar PV equipmentsmanufacturing
- Set up SPV power generation plants
- SPV project developer
- SPV consultancy services
- SPV plant: O & M services
- SPV monitoring systems
- Software based services
- SPV measuring & verification services in conjunction with certifying bodies

Choices for beginners as entrepreneurs:

1 Solar EPC contractor

Requirement: Strong technical team, Marketing team, Experience in solar installation (upto 200kW)

Software required: PVsyst & AUTOCAD

This model required a good technical team of two peoples with experience in solar designing, project execution and procurement. These experts should have knowledge of solar PVsyst (for shadow mapping) and AutoCAD (for detail drawings of projects) Also you will need 3 to 4 technicians for different project site. You can also use this team along with yourself for marketing. In the beginning you have to satisfy yourself with small projects and investment of 10 lakh to 15 lakh (depend upon the salary packages of engineers). But as the market start knowing your name and your work, you will get more projects with high profit.

2 O&M (Operation & Maintenance)

Requirement: Strong technical team, Experience in solar installation (upto 200kW)

Software required: NONE

This model required 1-2 engineers with knowledge of the solar sting inverter. To maintain the solar issues of solar inverters also you will need 3-4 labor for cleaning of solar panels. This model required a very marketing strategy. With lower investment of 2 to 5 lakh in this model. The profit is also not so high but if you can take O&M contract of 5MW or above you can easily make profits. But here is an advice never O&M of plant capacity lower than 500kW.

3 Distributorship

Requirement: Marketing team

Software required: NONE

Since the solar market is increasing day by day the distributorship of solar panels, inveters, DC cables, solar light, solar heater, solar laltenetc can be a big opportunity for those who are masters in selling. The minimum investment is 10 lakh for distributorship only. You should have space of storage too.

4 Structure supplier

Requirement: Structure engineer, Marketing team

Software required: STAAD PRO & AutoCAD.

This business model is basically a structure based model. You will required good structure design engineers with knowledge of STAAD PRO and AutoCAD. Also you will need a storage place with some tools like electric hacksaw, drill machine, measuring tape etc. Now rest of things are depend upon your marketing strategies. Since there hundreds of solar EPC contractors you can easily get work order. The initial investment is about 10 lakh for structure only. Where as price of storage place and tools need to be added in it.

5 BOM/BOS (Bill of material/Bill of spare) supplier

Requirement: Procurement team, Marketing team

Software required: NONE

Since there are hundreds of solar EPC contractors in market, procurement become main headache to them. BOS or BOM of a solar project contains each and everything beside solar panels, inveter and structure. You can also quote with solar structure.

Following are the items include in solar BOS

1 Earthing kit.

2 Lightning arrestor.

3 G.I strip.

4 DC cable.

5 Cable connector (MC4 connectors)

6 Cable ties.

7 Junction Box.

8 AC distribution box/panel

9 Structure (optional)

6 Solar promoter

Requirement: Marketing team (you can do it yourself)

Software required: NONE

This model required only basic knowledge of solar, i.e. type of solar power plant and how they work. And your investment is only your time and contacts.