CEW 02

KRISHNA KANTA HANDIQUI STATE OPEN UNIVERSITY

Housefed Complex, Dispur, Guwahati - 781 006

Six Month Certificate Programme in

Electrical House Wiring

BLOCK-2

ELEMENTS OF WIRING

CONTENTS

UNIT 1 : Wires and Accessories

UNIT 2 : Electrical Measurement Instruments

UNIT 3 : Earthing

UNIT 4 : Power Conditioning Appliances

UNIT 5 : Electrical Estimation and Costing

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COURSE INTRODUCTION

The second Block of the programme is titles as ‘Elements of Wiring’. It contains five units. Unit 1 deals with the types of wire and wiring accessories. It also mentions about some safety considerations and regulations. Unit 2 is all about different electrical measurement instruments. Unit 3 describes the importance and need of Earthing, then it describes about the basic considerations for earthing and types of earthing. Unit 4 covers about the Power conditioning Appliances. It describes about different types of Power Conditioning Appliances and their needs and importance. Finally, the Unit 5 contains about the Electrical wiring estimation and costing.

While going through the units of the course, you will find that each unit is further divided into certain sections and sub-sections, wherever necessary, for your better understanding. Again, each unit carries certain *activities* after every section. These ‘‘ACTIVITIES’’ will provide you the opportunity to practically apply your own thoughts based on the knowledge gained from reading the text in a particular section. Besides, in order to give you additional information on certain relevant topics, you will find a category called ‘‘LET US KNOW’’ after the sections in each unit. Another category that has been included at the end of each section of a particular unit is ‘‘CHECK YOUR PROGRESS’’. The purpose of this category is to help you to asses for yourself as to how thoroughly you have understood a particular section. It will be better if you answer the questions put in these boxes immediately after you go through the sections of the units and then match your answers with ‘‘ANSWERS TO CHECK YOUR PROGRESS’’ given at the end of each unit. Further more, the category called ‘‘MODEL QUESTIONS’’ is intended to give you a hint of the kind of questions you are likely to get in the examination.

ELEMENTS OF WIRING

BLOCK-2

CONTENTS

UNIT 1: Wires and Accessories (Marks: 20) Pages: 5-24

Wires, cables and their characteristics; Terminations and joints; Wiring accessories; Safety Considerations and Regulations

UNIT 2: Electrical Measurement Instruments (Marks: 20) Pages: 25-46

Multimeter: Analog Multi-meter, Digital Multi-meter; Tester: Tong Tester, Energy-meter, Megger, Earth resistance meter, Power Factor meter; Extension of range of measurement instruments: Voltmeter, Ammeter, Loading effect of voltmeter, Voltage drop effect of an ammeter; High Voltage Testing and Measurements; Calibration

UNIT 3 : Earthing (Marks: 20) Pages: 47-61

Earthing and its importance: Basic considerations of earthing, Measurement of soil resistivity; Types of ground connections, Pipe Earthing, Plate Earthing; Ground Testing

UNIT 4 : Power Conditioning Appliances (Marks: 20) Pages: 62-81

Power Conditioning and its Importance; Different Power Conditioning Appliances: Battery, Inverter, Diesel Generator set, Stabilizer, UPS; Change over switch, Connection of water-pump and geyser

UNIT 5 : Electrical Estimation and Costing (Marks: 20) Pages: 82-100

Estimating and Costing Fundamentals; Estimation of Single and Three Phase Wiring: Steps for Estimation and Costing of Electrical Installations, Costing calculations and Schedule of Rates; Estimation and Costing of House Wiring and Electrical Installations

UNIT 1 : WIRES AND ACCESSORIES

UNIT STRUCTURE

1.1 Learning Objectives

1.2 Introduction

1.3 Wires, Cables and their Characteristics

1.4 Terminations and joints

1.5 Wiring Accessories

1.6 Safety Considerations and Regulations

1.7 Let Us Sum Up

1.8 Further Readings

1.9 Answers to Check Your Progress

1.10 Model Questions

1.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- know about wire and cable characteristics.
- understand the importance of joints and terminations.
- describe what are the wiring accessories.
- go through the electrical safety regulations and recommendations.

1.2 INTRODUCTION

In this unit, you will learn the basic the principles behind wiring and its types. You will also lean about wiring diagrams, wire and cable characteristics. The unit shall also inform you regarding the importance of joints and terminations. You will also lean about wiring accessories, safety rules and regulations.

1.3 WIRES, CABLES AND THEIR CHARACTERISTICS

Any metallic conductor with a symmetrical cylindrical shape that facilitates conduction of electric charges and is shielded be a non-

conducting cover is an electrical wire. Electrical wires have markings stamped or printed on the outside sheath of the cable which indicate the type and size of wire available for applications. The colour of the wires inside of the sheath, indicates that different colour wires are intended for different purposes.

Black Wires : Black wires are always used for hot wires. These wires may feed a switch or outlet and are often used as switch legs. Black wire is not used for a neutral or ground connection.

Red Wires : Red wires are also used for hot wires, switch legs etc. Another useful application is the interconnect wire between two appliances.

Blue and Yellow Wires : Blue and yellow wires are used as main conductors and are pulled through conduits and casings. The blue wires are used as switch legs to things like lights and fans. Yellow wires are generally used for switch legs and control things like light, fans, and switched outlets.

Green and Bare Copper Wires : Green wires and bare copper wires are used only for grounding. These wires will ground devices and shall be bonded to junction boxes and appliance connections for safety.

Wire Color Exceptions : In certain instances, wire colors may be used for connections that don't follow these general rules. For instance, a white wire in a two-conductor cable may be used for the second hot wire on a 240-volt appliance or outlet connection.

A cable is formed by two or more wires running side by side and bonded, twisted or braided together to form a single assembly. Cables are used to carry special purpose electric signals. Cables have a protective jacket that works as insulation also. When a conductor carries current it radiates an electromagnetic field. It is true with a cable also. Similarly a conductor or cables can also pick-up energy from any existing electro-magnetic field around. These effects are undesirable as it leads to unwanted transmission of energy which is loss making and unwanted pickup of noise which may degrade the desired signal being carried by the cable. It can also corrupt electric voltages being carried by a cable to such an extent as to cause equipment malfunction.

There are particular cable designs that minimize electromagnetic pickup and transmission. These are *shielding, coaxial* and *twisted-pair* geometry used in cables.

Shielding encases the cable for its entire length in foil or wire mesh. All wires running inside this shielding layer is isolated from external electric fields, particularly if the shield is connected to a point of constant voltage, such as earth.

Coaxial design helps to further reduce magnetic transmission and pickup. In this design the foil or mesh shield is perfectly tubular - i.e. with a circular cross section - and the inner conductor is situated exactly at its center. This causes the voltages induced by a magnetic field between the shield and the core conductor to consist of two nearly equal magnitudes which cancel each other.

The *twisted pair* is a result of two wires twisted around each other, forming a pair of intertwined helices. This can be achieved by putting one end of the pair in a hand drill and turning while maintaining moderate tension on the line. Field cancellation between successive twists of the pair considerably reduces electromagnetic pickup and transmission.

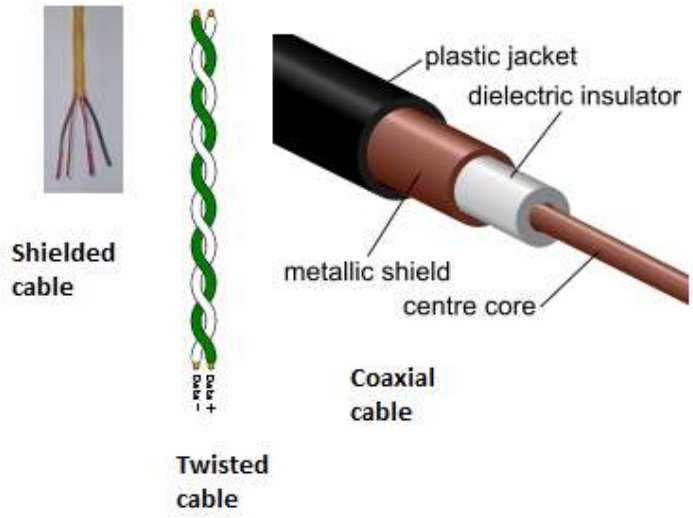


Fig. 1.1 : Shielded, twisted and coaxial cable

1.3.1 Wires Gauge and Application

Electric wires shielded with one medium of conduction are called a **single strand** wire. Single strand wires are generally used

as hook-up wires. These are mostly used with jumper circuits, laboratory experiments and certain low-voltage applications.

In contrast to single strand, **multi-strand** wires have several layers of conductors or more than one wires are packed so that they acquire greater current conducting capability. Multi-strand wires have several advantages compared to single strand wires. A few of them are:

- Greater flexibility
- Easy of bending in any direction
- Rugged
- Higher current carrying capacity, hence suitable for higher power applications Better compatibility with high frequency applications due to low frequency-induced losses
- Cancellation of nearby magnetic effects.

Certain considerations are taken into account while constituting stranded wires. Stranded wires will always have certain voltage ratings which must not be crossed for hazard free application. The wire has certain diameter specifications including the thickness of the jacket and a operation temperature limit which must not be exceeded to make it suitable for intended applications. The jacket around the wire is formed by an insulation layer which has strong resistance to prevent current flowing through it. Some common insulation materials that are used as jackets across single and multi-strand wires are:

- Ethylene propylene diene elastomer (EPDM)– a chemically cross-linked elastomer with excellent flexibility at both high and low temperatures (- 55° C to 150° C).
- Polyethylene (PE)– a thermoplastic material with excellent electrical properties and a stable dielectric constant over all frequencies. It is stiff to very hard and provides excellent moisture resistance.
- Polyvinyl chloride (PVC)– a general-purpose thermoplastic used for wire and cable insulation. PVC offers high flexibility

and is often used in nonplenum wire insulation and cable jackets. Modified PVC may be found in the jacketing of some plenum-rated cables.

- Teflon is used widely in wire and cable jacketing. It is inert to most chemicals and extremely slippery.

The material used as conductor of the wires also paly an important role in determining its ability to conduct electricity. Some of the common choices are

- Aluminum– a metal characterized by high resistance to corrosion, proper electrical and thermal conductivity, and can be used as a power conductor, or for wire and cable shielding. Some wires have a steel core to which an outer shell of aluminum is fused.
- Copper and copper alloys offer high corrosion resistance, thermal conductivity, and ease of fabricating, joining and forming. Copper is the most widely used electrical conductor in wires and cables.

Conducting properties of wires are also dependent on the dimension of the conductor. American wire gauge (AWG) is a standard for wires made of non-ferrous conductor like copper and aluminum. The term “gauge” refers to the wire’s diameter. The higher the gauge number, the smaller the diameter and the thinner the wire. Typical household wiring is AWG 12 or 14. Telephone wire is usually AWG 22, 24, or 26. International practices may also indicate wire thickness in terms of square millimeters (mm^2).

Selecting the appropriate wire gauge is critical while ensuring safe functioning of appliances. The table below summaries the wire size in terms of gauge and the intended application.

Table 1.1 : Wire conductor thickness and application

Sl. No.	Application	Ampere rating	Wire Gauge
1	Low-voltage Lighting and Lamp Cords	10 Amps	18 Gauge
2	Extension Cords	13 Amps	16 Gauge
3	Light Fixtures, Lamps, Lighting Runs	15 Amps	14 Gauge
4	Receptacles, 110-volt Air Conditioners, Sump Pumps, Kitchen Appliances	20 Amps	12 Gauge
5	Electric Clothes Dryers, 220-volt Window Air Conditioners, Built-in Ovens, Electric Water Heaters	30 Amps	10 Gauge
6	Cook Tops	45 Amps	8 Gauge
7	Electric Furnaces, Large Electric Heaters	60 Amps	6 Gauge
8	Electric Furnaces, Large Electric Water Heaters, Sub Panels	80 Amps	4 Gauge
9	Service Panels, Sub Panels	100 Amps	2 Gauge
10	Service Entrance	150 Amps	1/0 Gauge
11	Service Entrance	200 Amps	2/0 Gauge



CHECK YOUR PROGRESS

Q.1. Find True or False :

a) Black wires are always used for hot wires.

b) Green wires and bare copper wires are used only for supplying power.

c) Coaxial cables help to further reduce magnetic transmission and pickup.

1.4 TERMINATIONS AND JOINTS

In electrical installation and wiring appropriate termination is important to ensure safe operations of the appliances. Terminations ensure

that the electric supply reaches the intended end and carries out the required work. An electric termination can be an appliance or a point from which another connection can be made. Without appropriate termination, an electrical connection may not only be dangerous but also prove to be loss making. An electrical termination is a connecting wire or cable or a special terminal or a terminal connector. Terminations are required to establish appropriate electrical connections. All terminations therefore should fulfill the following conditions:

- Physical firmness,
- Appropriate electrical conductivity and zero resistance and
- Prevention of contact with other metallic part, conductors etc near to it.

If terminations are loose following may occur:

a) Electrical arching leading to heating of wires and terminals with probability of burn out and fire;
b) Increase in electrical resistance leading to unwanted voltage drop;
c) Slipping of live wires from connections leading to electrical shock, short circuits, accidental fire and similar hazardous situations.

Therefore, extra-care must be taken while installing termination. Regular inspection is required to ensure that the terminations are firm and strong enough to withstand physical strain. It can be tested by pulling a terminated wire either by hand or by using a tool. Also close scrutiny is required to prevent any terminating wire from touching some metallic contact that may exist in the vicinity even when the set-up is moved or shaken as part of some application.

There are three types of terminations:

1. Screw type termination
2. Crimp type termination and
3. Solder type termination.

1. *Screw type termination*– In this type of termination, a wire is skinned a bit at its end and wounded round a screw to which a nut is bolted and fixed. Over-tightening of the screw should be avoided as it can lead to cutting of the terminating wire. Special purpose nuts-

bolts are available with appropriate teeth like arrangement to hold terminating wires firm. This type of connection is suitable for domestic low voltage (< 230 V) applications.



Fig. 1.2 : Screw type termination

2. *Crimp type termination*– This is stronger and a bit better then the screw type due to the fact that it establishes appropriate physical contact between a wire and a termination point. In this type of connection, conductors of a wire is inserted or placed in a crimping fitting or tied around crimp eyelets and reshaped into an arrangement using a crimping tool such that the joint with the termination point becomes securely fastened. It is a one-stroke process. A loosely crimped connection cannot be re-worked but shall require a fresh crimping. To ensure appropriate crimping the exact tool and arrangement is essential.



Fig. 1.3 : Crimp type termination

3. *Soldering type termination*– It is the best way to do a termination. A soldering instrument, material and flux is used to permanently fix a wire with a terminating point. The soldering iron when heated up using electric power burns the soldering material and fixes the joint.



Fig. 1.4 : Soldering type termination

Joints are required during wiring. Since there are corners and bend in the structures of houses, rooms and similar places where wiring is to be done, a host of joints are available to meet the requirements. A few of them are as below:

1. Straight joint.
2. Tee joint.
3. Right- angled joint.
4. Corner joint.
5. Tee-bridge joint.
6. Cross-bridge joint.

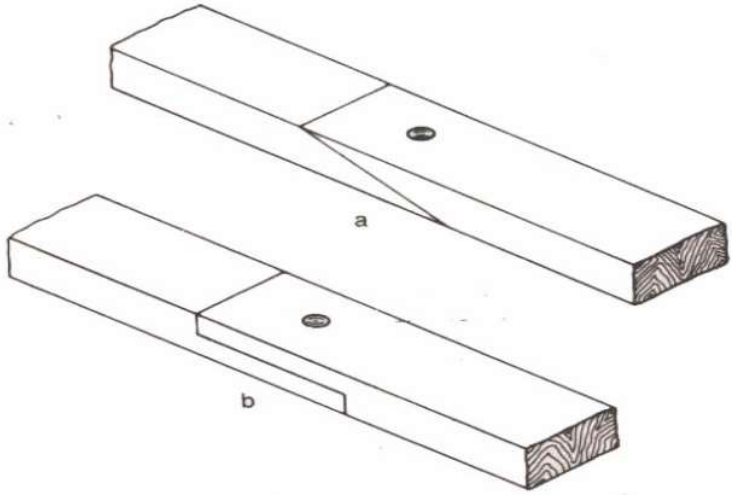


Fig. 1.5 : Straight joint

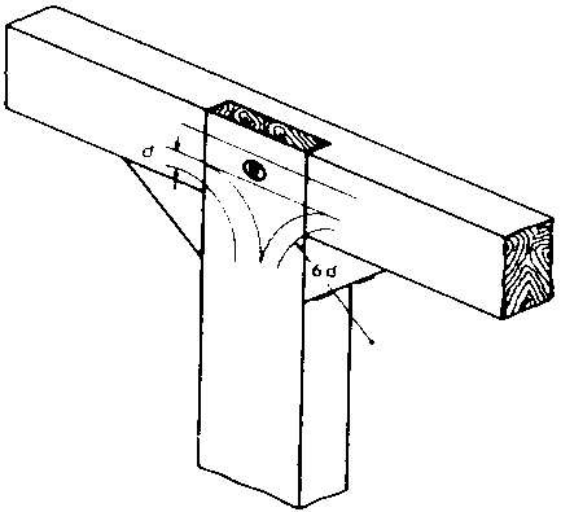


Fig. 1.6 : Tee-joint

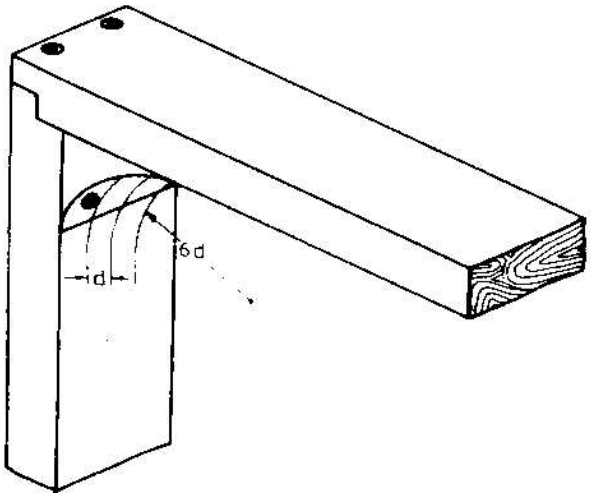


Fig. 1.7 : Right angled-joint

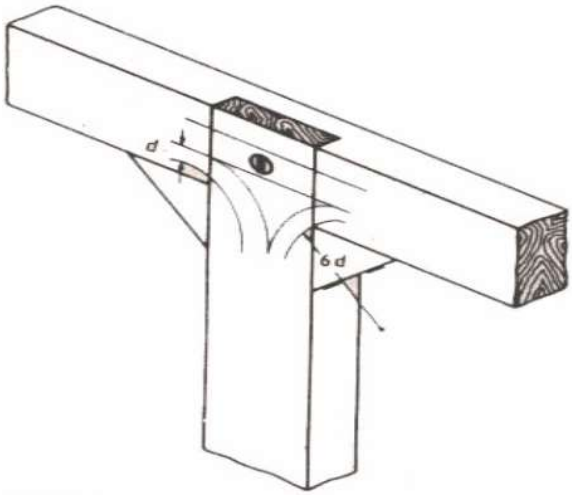


Fig. 1.8 : Tee-bridge joint

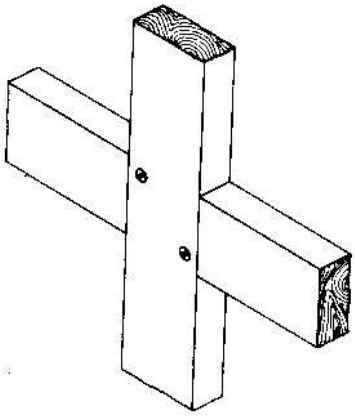


Fig. 1.9 : Cross bridge-joint



CHECK YOUR PROGRESS

Q.2. Find True or False :

a) An electrical termination is a connecting wire or cable or a special terminal or a terminal connector.

b) A termination should have appropriate electrical conductivity and zero resistance.

c) Regular inspection is required to ensure that the terminations are firm and strong enough to withstand physical strain.

d) In screw type of termination, a wire is skinned a bit at its end and wounded round a screw to which a nut is bolted and fixed.

e) Joints are required during inspection.

f) A loosely crimped connection can be re-worked.

1.4 WIRING ACCESSORIES

Electric accessories are essential components of the wiring process. Without them, the wiring remains incomplete. Junction box is an important wiring accessory. It is made of either metal, wood or PVC. It has certain dimension and is regularly used to hold wires joined for diversion and

extension of connection. Sometimes junction boxes play the roles of termination points or electrical taps.

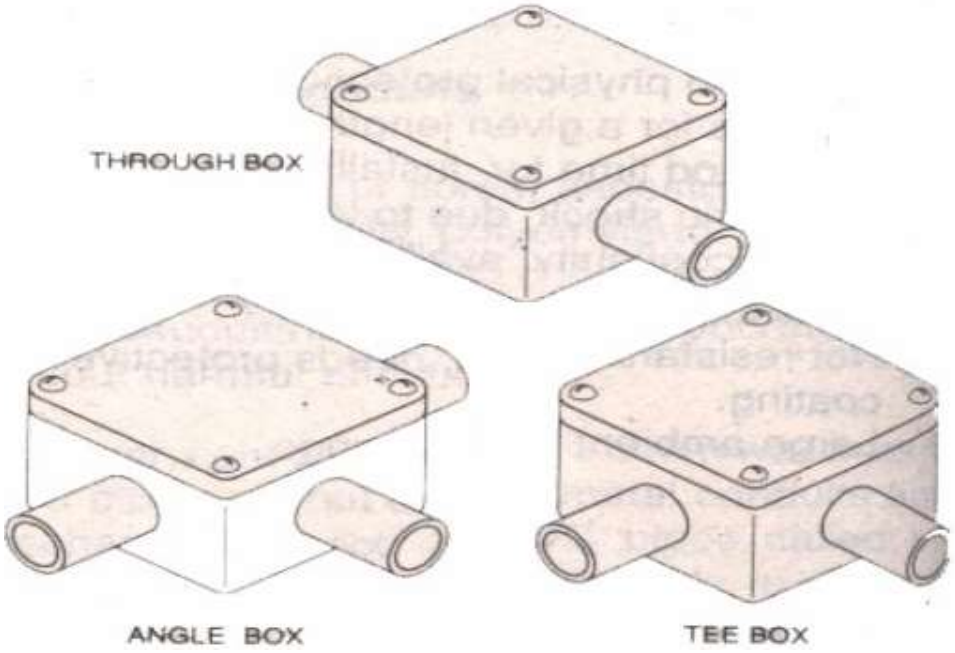


Fig. 1.10 : Junction box

Some other wiring accessories include the following:

1. Couplers
2. Elbow
3. Bends
4. Circular boxes
5. Rectangular boxes.

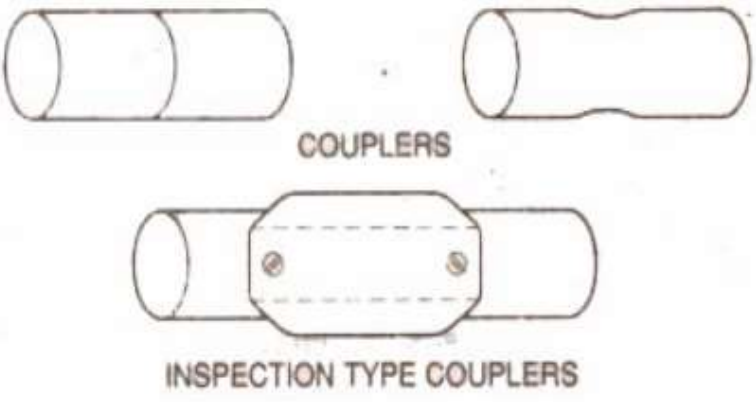


Fig. 1.11 : Couplers

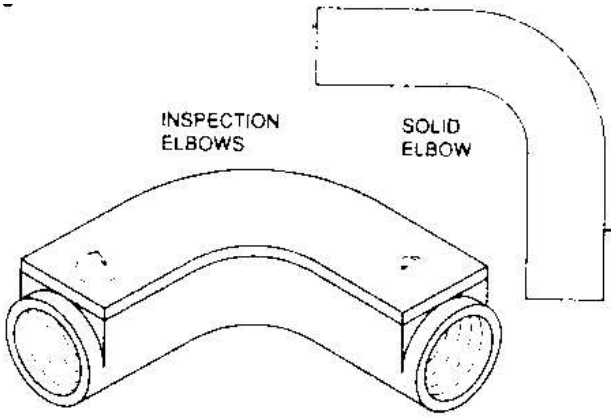


Fig. 1.12 : Elbows

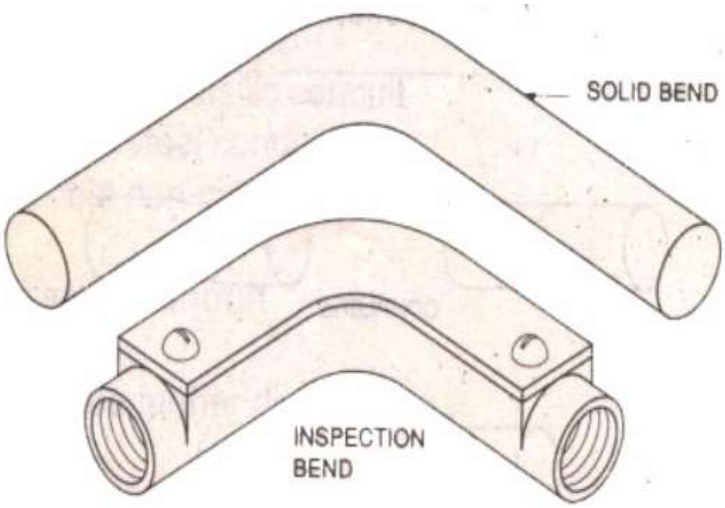


Fig. 1.13 : Bends

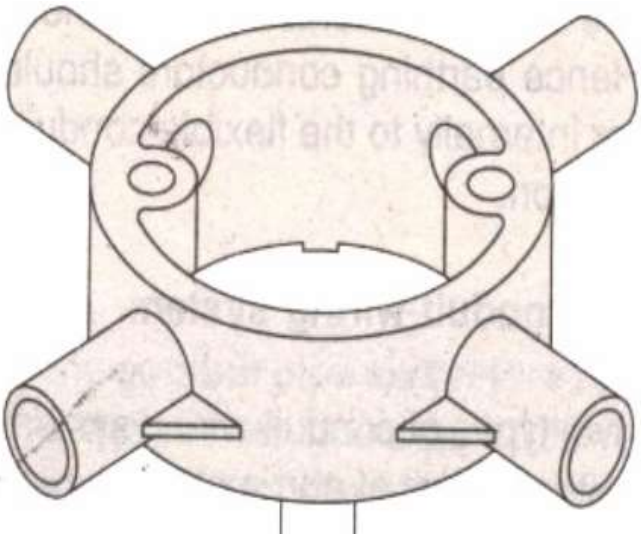


Fig. 1.14 : Circular box

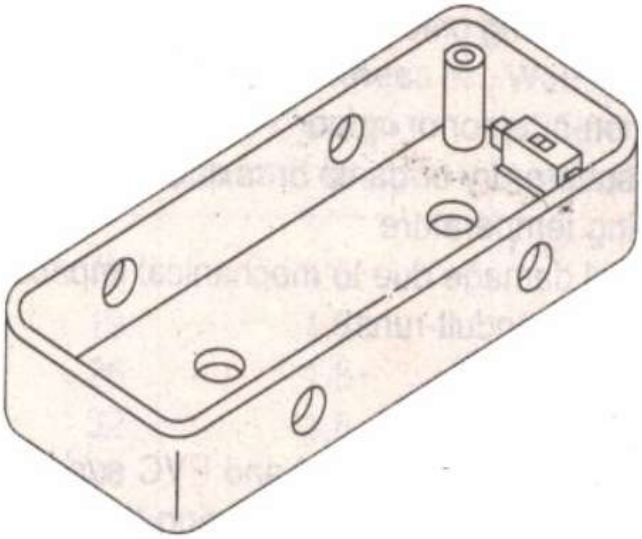


Fig. 1.15 : Rectangular box

Connectors : These are required to connect a switching arrangement for supply of electricity to common domestic appliances. Sometimes the connection can be with the phase line, at times to the neural and in certain cases to the earth connector. These are metallic and in most cases made up of brass. These connectors require screws to fix the links which come in appropriate sizes. Screws are available in brass as well as steel material.



Fig. 1.16 : Different types of connectors

Switch : Single pole double through switches are common in domestic connections. These are used to connect the phase line to the appliances. Polycarbonate used in the switch to make them user friendly

is nearly safe. These prevent sudden spark and when in proper state they prevent fire, spark etc. Sizes of switches vary as per applications with 5A rates ones being the most common. Along with switches, sockets are also available. Like switches, sockets also vary as per applications. They can have a three or two wire connection.

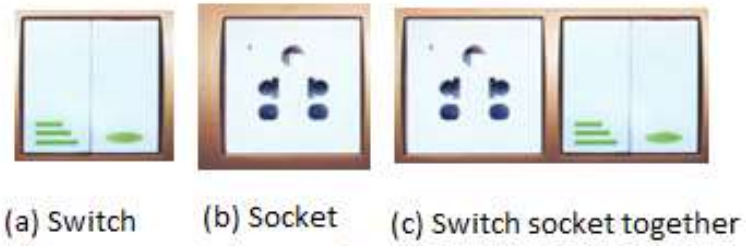


Fig. 1.17 : Switch and socket

DB Box : A distribution board (or panelboard) is part of an electricity supply system used to subdivide the incoming electrical power into subsidiary segments. The distribution board holds protective fuse which acts as a circuit breaker, a main switch and a few isolators in a common enclosure. Fuse Boxes usually use cartridge or rewirable fuses with no other protective device In certain cases these may even have Residual Current Breakers with Overcurrent protection (RCBO) for greater safety and higher voltage appliances.

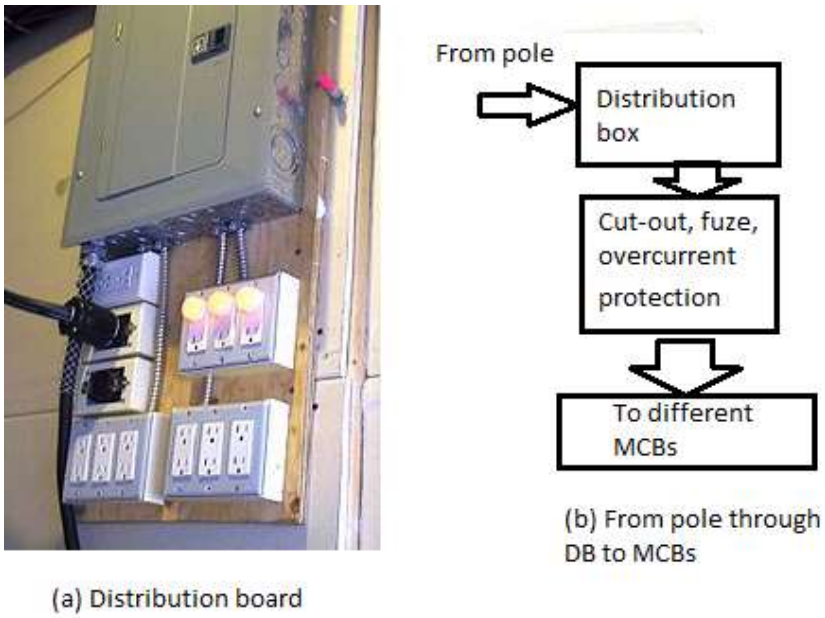


Fig. 1.18 : Distribution board

MCB Box : MCB stands for miniature circuit breaker. It is an arrangement through which a number of switch boards can be connected to the distribution box. The switch boards are used by the consumer to run an electrical appliance.

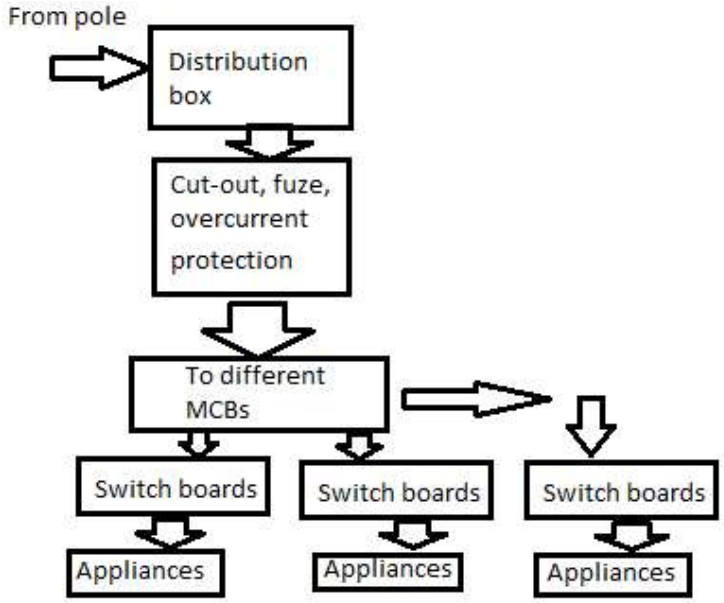


Fig. 1.19 : From pole to the appliance through the MCB

The MCB is formed by a number of isolators, two way single pole switches etc which ensure safe connection and supply of electric power. The MCB has slots for input, output and earth connection. Special metallic enclosures are available for holding the MCB arrangement. The MCB shown in Figure 2.20 is a single pole with neutral, busbar, incoming contact, channel and has a transparent acrylic window.



Fig. 1.20 : MCB with enclosure



CHECK YOUR PROGRESS

Q.3. Find True or False :

a) Junction box is made of either metal, wood or PVC.

b) Junction box is used to hold wires joined for diversion and extension of connection.

1.5 SAFETY CONSIDERATIONS AND REGUALTIONS

Some electrical safety considerations should always be followed for safe operation of appliances and installation. A few of the safety considerations can be as below:

- Don't put a lot of connections into one electrical or extension cord. It could damage the electrical system in the premises or even cause a fire.
- Always ask the technician to put safety caps on all unused electrical outlets. It will provide safety
- Don't pull an electrical cord from the wall. It can damage an appliance, the plug or the outlet.
- Always ensure that all electric cords are installed with casing or concealment neat and tidy. Else pets might chew on electrical cords, and people might trip and fall.
- Always have a line tester to test a supply line before doing any maintenance work. Don't touch a live wire, it can be dangerous.
- While working with electrical appliances using a ladder always ensure that there is no open connection or live conductor around which is carrying current. It can give electric shock on touching.
- Always keep electrical items away from water and fire.
- Do not touch or tamper with any electrical gear or conductor unless it is not conducting electricity and earthed.
- Do not open or close switch or fuse slowly or hesitatingly. Do it quickly and positively.

- Do not use wires with poor insulation. Do not touch any electrical circuit when your hands are wet or bleeding from a cut or an abrasion.

In India, electricity considerations are governed by the provisions of the Indian Electricity Rules, 1956. It contains details of nearly all provisions of electricity generation, distribution, use, safety etc. Also the Electricity Act, 2003 provides a set of laws governing generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff etc.



CHECK YOUR PROGRESS

Q.4. Find True or False :

a) Some electrical safety considerations should always be followed for safe operation of appliances and installation.

b) Also the Electricity Act, 2003 provides a set of laws governing generation, transmission, distribution etc.



1.6 LET US SUM UP

- Electrical wiring is a system through which electricity is distributed from a source to appliances.
- Cleat wiring is a cheap wiring method and is most suitable for temporary wiring.
- Batten wiring is suitable on wooden battens.
- Casing capping wiring is suitable for low voltage installation.
- A conduit is a type of a tube or channel. Tubular conduit is the most commonly used material 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.

- An electrical wiring diagram is an installation plan required to set-up an electrical system which can be used for domestic, commercial and industrial purposes as per requirements.
- Electrical wires have markings stamped or printed on the outside sheath of the cable which indicate the type and size of wire available for applications.
- An electrical termination is a connecting wire or cable or a special terminal or a terminal connector. Terminations are required to establish appropriate electrical connections.
- Electric accessories are essential components of the wiring process. Without them wiring remains incomplete.
- Some electrical safety considerations should always be followed for safe operation of appliances and installation.
- In India, electricity considerations are governed by the provisions of the Indian Electricity Rules, 1956. It contains details of nearly all provisions of electricity generation, distribution, use, safety etc. Also the Electricity Act, 2003 provides a set of laws governing generation, transmission, distribution etc.



1.7 FURTHER READING

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1.8 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1 : a) True, b) False, c) True

Ans. to Q. No. 2 : a) True, b) True, c) True, d) True, e) False, f) False

Ans. to Q. No. 3 : a) True, b) True



1.9 MODEL QUESTIONS

Q.1. What is electrical wiring? Why is it necessary? What are its different types?

Q.2. What is conduit wiring? Describe briefly.

Q.3. Write a brief note regarding the importance of wiring diagram.

Q.4. Write short notes on the following:

a) Electrical accessories

b) Electrical terminations

c) Electrical Safety Norms

* * * * * * * * * * *

UNIT 2 : ELECTRICAL MEASUREMENT INSTRUMENTS

UNIT STRUCTURE

2.1 Learning Objectives

2.2 Introduction

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2.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- describe the working of an electrical measurement instrument
- explain the different types of electrical measurement instruments
- know the working of the multi-meter.

- understand the principles behind the working of different testers.
- describe the various electrical tools
- classify the different processes of extension of range of electrical instruments.
- explain high voltage testing and measurements
- know about calibration of measurement equipments.

2.2 INTRODUCTION

In this unit, you will learn the basic concepts of electrical measurement instruments. These are essential to monitor conditions of different electrical quantities. These instruments are vital in testing and servicing of appliances. Moreover, domestic electricity supply is also regulated and monitored using these instruments. The most commonly used electrical instrument is the multi-meter which can be useful for measurements of dc and ac voltages as well as currents. There are certain techniques through which the range of measurements of electrical instruments can be extended.



Multi-meter is a versatile instrument that combines several functions into one unit.

2.3 MULTI-METER

As the name suggests, a multi-meter is a versatile instrument that combines several functions into one unit. It can be used to measure current, voltage, resistance, capacitance etc. Multi-meters are hand-held devices useful for a range of fault finding applications. These are also useful for servicing and trouble-shooting of electrical problems in a wide array of industrial and household devices. These can provide measurements with a high degree of accuracy. The volt-ohm-milli-ammeter (VOM) is the most commonly used multi-meter. The typical VOM has a meter movement with a full scale current of 50 μA, or a sensitivity of 20 KW/V, when used as a DC voltmeter. A single meter movement is used to measure current, AC and DC voltage, and resistance. Range switches are usually provided for scale selection (e.g., 0-1V, 0-10V, etc). There are two broad categories of multi-meters: analog and digital.

2.3.1 Analog Multi-Meter



Analog multi-meters are commonly used electrical instruments implemented using a galvanometer.

Analog multi-meters are commonly used electrical instruments implemented using a galvanometer. Analog multi-meters have limited accuracy. These are however suitable for determining the rate of change of a reading. This is due to the fact that a needle moves over a scale and with better sensitivity detects small variation in the electrical quantity.

In a basic analog multi-meter the current to deflect the coil and pointer is drawn from the circuit being measured; it is usually an advantage to minimize the current drawn from the circuit.

The sensitivity of an analog multi-meter is given in units of ohms per volt. For example, an inexpensive multi-meter would have a sensitivity of 1000 ohms per volt and would draw 1 milli-ampere from a circuit at the full scale measured voltage. To avoid the loading of the measured circuit by the current drawn by the meter movement, some analog multi-meters use an amplifier inserted between the measured circuit and the meter movement. Multi-meters can be used as voltmeters, ammeters and ohmmeters. While measuring voltage, a multi-meter is connected in parallel while during current measurement it is placed in series.

Resolution of analog multi-meters is limited by a number of factors. These are the scale pointer width, vibration of the pointer, the accuracy of scale-printing, calibration, number of ranges, errors in observation, eyesight and errors due mechanical display.



Fig. 2.1 : Analog multi-meter

2.3.2 Digital Multi-Meter

The digital multi-meter or DMM is a versatile device that can be used to measure both ac and dc voltage and current from say micro to a few tens or hundred ranges. The DMM is essential equipment in the laboratory. Without it, making measurements of current and voltage values will be very tedious and time consuming. The DMM can also be sued to find component values and determine terminals of semiconductor devices like diodes and transistors. A basic DMM used frequently in the laboratory is as in Figure 2.2.

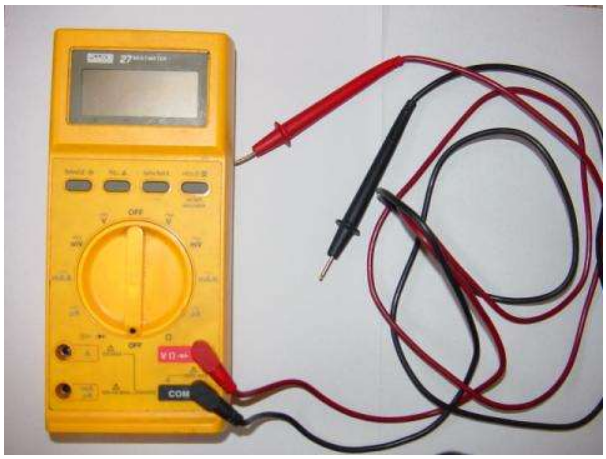


Fig. 2.2 : DMM used frequently in laboratory

The DMM is an instrument which can be used to do the following:

a) Measurement of d.c and a.c voltages and currents,
b) Measurement of resistance values,
c) Measurement of capacitance values,
d) Obtain forward current gains of transistors, thereby providing a terminal identification of transistors.
e) Provide diode check to identify terminals of a diode.

Signals are input to the DMM through two leads (red for positive, and black for negative), and then the value measured is displayed.

While measuring voltage using a DMM it must be connected in parallel to a resistance (Figure 2.3).

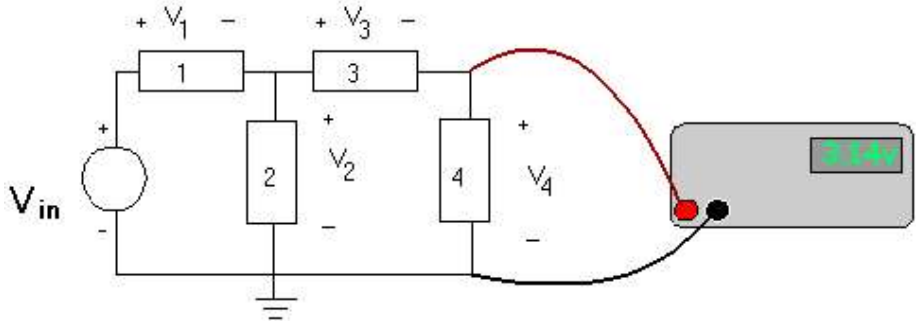


Fig. 2.3 : Measuring voltage across a resistance

But while measuring current the DMM must be connected in series (Figure 2.4).

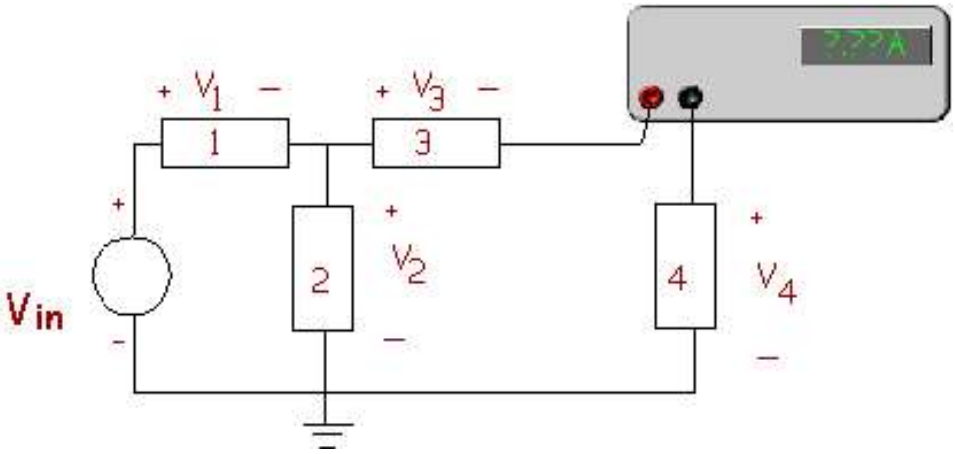


Fig. 2.4 : Measuring current using a DMM

While measuring resistance the DMM works as an ohmmeter. An ohmmeter sends out a current and measures the voltage produced across the DUT. Because the ohmmeter is ultimately measuring a voltage, it should be connected in parallel with the DUT. When measuring a resistance, one end of the resistor should be disconnected from the circuit so that all of the current from the DMM's current source is passing through the resistor to be measured. The precision of the DMM is an important criterion while making measurements. The precision of a DMM is dependent on the number of bits used by the internal ADC (Analog to Digital Converter) while converting an analog readout to digital form.



CHECK YOUR PROGRESS

Q.1. Find True or False :

a) A multi-meter is a versatile instrument that combines several functions into one unit.

b) Multi-meters are useful for servicing and trouble-shooting of electrical problems.

c) Analog multi-meters are implemented using a galvanometer.

d) Resolution of analog multi-meters is limited by a factor.

e) The precision of a DMM is dependent on the number of bits used by the internal ADC.

2.4 TESTER

Testing is part of installation of any electrical instrument. It also is essential before making any electrical appliance operational. Even after servicing, testing is required to determine if the device can be used or not. Troubleshooting of defects requires a series of testing as well. Some of the commonly used electrical testing equipments are tong-tester, energy-meter, megger, earth resistance meter, power factor meter etc.



Tong tester is a special purpose current probe which allows measurement of current without having to disconnect the conductor from the circuit.

2.4.1 Tong Tester

Tong tester is a special purpose current probe which allows measurement of current without having to disconnect the conductor from the circuit. When an ammeter or a voltmeter cannot be connected to a conductor to measure the current or voltage, the tong tester is used. In short, current or voltage of cable or insulated conductor is measured by Tong Tester. It has two jaws which open to allow clamping around an electrical conductor and find the value without any break in the existing arrangement of the conductor or

device. A few types of tong testers even induce current in an electrical appliance to find out the amount of current flowing. Tong testers find out root mean square (RMS) values of current flowing through electrical appliances without any consideration to waveforms. These are applicable even for high voltage applications as well. Tong testers can also be used to measure temperature, resistance, frequency, check transistors, diodes etc.



Fig. 2.5 : Tong tester

2.4.2 Energy-Meter

Energy meters can be used to amount of electrical energy consumed by consumers, industries etc while using electrical appliances. The read-outs provided by energy meters is in billing units, the most common one being the kilowatt hour. The read-outs of electric meters provides billing cycles and energy consumed during a cycle. Electricity meters operate by continuously measuring the instantaneous voltage and current and providing the product of these to give instantaneous electrical power in watts. It is next related to time which provides the energy spent in joule or in kilo-watt hour. The most common energy meter is the electro-mechanical induction watt-hour meter.

The electromechanical induction meter operates by counting the revolutions of an aluminum disc which is made to rotate at a speed proportional to the power. The disc rotates over a scale which is properly printed to provide the read-out. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts.



Energy meters can be used to amount of electrical energy consumed by consumers, industries etc while using electrical appliances.



Fig. 2.6 : Energy meter

The ***megger*** is used to measure insulation resistance.

2.4.3 Megger

The megger is used to measure insulation resistance. It is a portable instrument and is formed by a hand-driven DC generator and a direct reading ohm meter (Figure 2.7).

The moving element of the ohm meter has two coils A and B. These are tightly mounted to a pivoted central shaft and are allowed to rotate freely over a C-shaped core (C) connected by means of flexible leads. The moving element may point in any meter position when the generator is not in operation.

As current provided by the hand-driven generator flows through Coil B, the coil will set at right angles to the field of the permanent magnet. With the test terminals open, giving an infinite resistance, no current flows in Coil A. Thereby, Coil B will move it to the extreme counter-clockwise position. It is marked as infinite resistance.

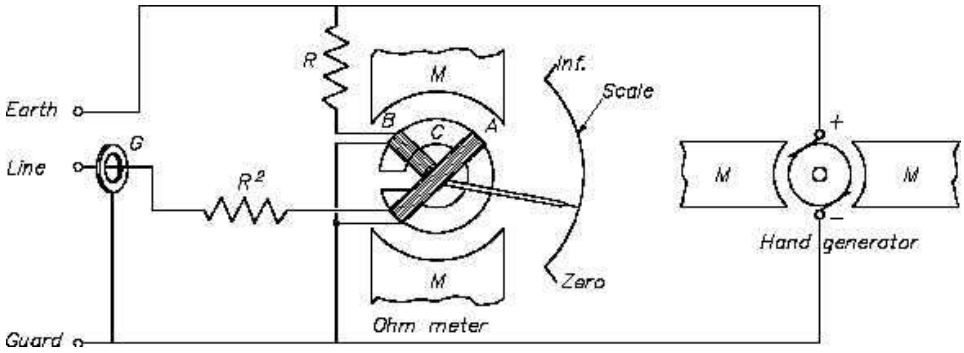


Fig. 2.7 : Megger

Coil A is wound in a manner to produce a clockwise torque on the moving element. With the terminals marked “line” and “earth” shorted, giving a zero resistance, the current flow through the Coil A is sufficient to produce enough torque to overcome the torque of Coil B. The pointer then moves to the extreme clockwise position, which is marked as zero resistance. Resistance (R^l) will protect Coil A from excessive current flow in this condition.

When an unknown resistance is connected across the test terminals, line and earth, the opposing torques of Coils A and B balance each other so that the instrument pointer comes to rest at some point on the scale. The scale is calibrated such that the pointer directly indicates the value of resistance being measured.

Megger is frequently used for measurement of insulation value of lines, transformers, breakers etc. After completion of measurement both terminals should be shorted to discharge the voltage remained, otherwise there is possibility for getting shock due to this voltage. Similarly while taking reading or while operating megger, the two terminals should not be touched.

2.4.4 Earth Resistance Meter

Earth resistances become vital in such situations where an electrical appliance should be provided with a connection that has a flow continuity with ground. The continuity check between the electrical appliance and ground is measured using earth resistance meters.

Ground resistance testers can be used to take different measurements like grounding system resistance, insulation resistance, earth continuity, current leakage, ground bond, grounding system resistance and insulation resistance. Such a device is important for maintaining the safety of instruments that come into contact with people. These tests are performed to confirm the electrical integrity of an instrument.

Most ground resistance testers have an analog or digital display, or an LED indicator. Analog meters display values on a dial, typically with a needle that moves when a signal is applied. Digital meters provide a numeric reading. Light emitting diode (LED) and liquid crystal display (LCD) are common types of digital displays. LED indicators use a light to indicate that a test is occurring. In some models, the LED light blinks on and off throughout the test.

There are 3 terminals of an Earth Tester meter. The first two terminals of the meter are connected to earth as far as cables can. Two rods are fixed into the soil with the help of a small hammer and then connect two knobs of the meter with these rods. The third terminal of the meter is connected to the earth pit, of which the earth resistance is to be measured. The meter reading will indicate the resistance of the earth pit. The best resistance of an earth pit must be less than one.

A earth resistance meter also can work as a ground detector.

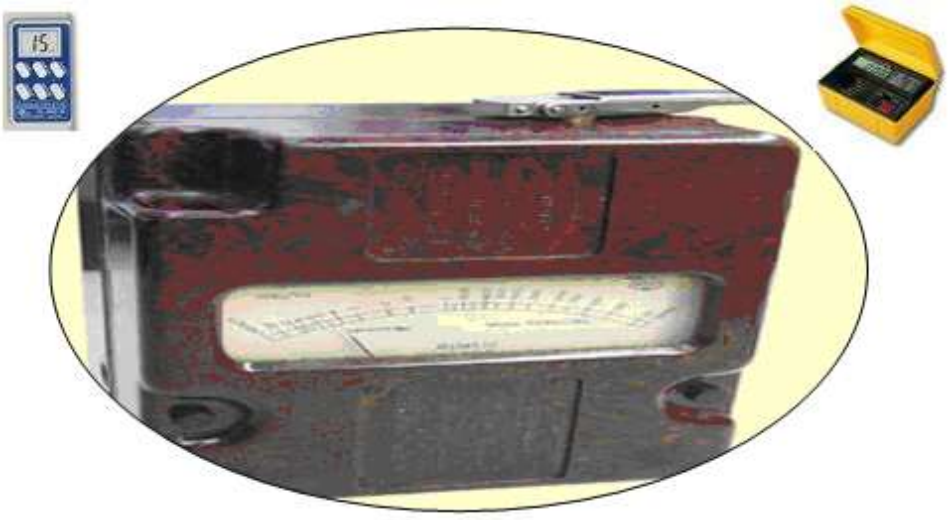


Fig. 2.8 : Earth Resistance Meter

2.4.5 Power Factor Meter

Power factor is related to the phase differences between voltages and currents flowing through a circuit. Power factor determines phases in a 3-phase circuit and determines the quality

of power delivery in a distribution arrangement. Power factor meters are used to measure the phase differences that exists between different phases connected to an electrical appliance.

A power factor meter is a type of electrodynamometer. It works using the movement of an arrangement formed by two movable coils set at right angles to each other. A power factor meter, connected for measurements in a 3-phase circuit, is shown in Figure 9. It consists of two stationary coils, S and S^1. These are connected in series to the phase marked B. Coils M and M^1 are mounted on a common shaft, which is free to move. These coils have no restraint or control springs. These coils are connected from Phase B to Phase A and from Phase B to Phase C with associated series resistors. At a power factor of unity, one current flows shows a phase lead while the other shows a lags in Phase B by 30°; thus, the coils are balanced in the position. A change in power factor will cause the current of one potential coil to add in phase while the other potential coil to be more out of phase with the current in Phase B. As a result the moving element and pointer take new positions and maintain balance to show the new power factor.

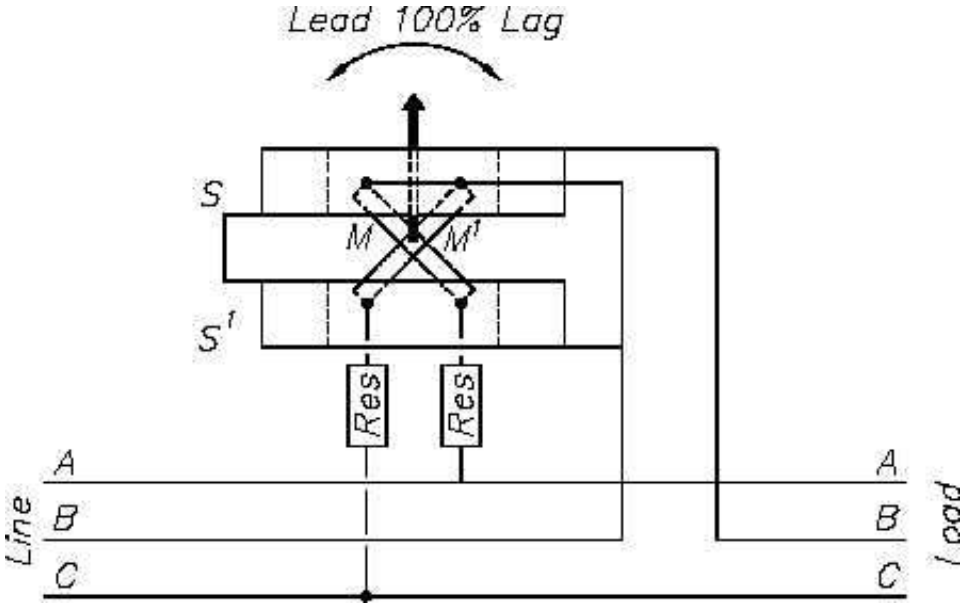


Fig. 2.9 : Power Factor meter



CHECK YOUR PROGRESS

Q.2. Find True or False :

a) Tong testers find out root mean square (RMS) values of current without any consideration to waveforms.

b) Power factor is related to the phase differences between voltages and currents flowing through a circuit.

c) The continuity check between the electrical appliance and ground is measured using earth resistance meters.

2.5 EXTENSION OF RANGE OF MEASUREMENT INSTRUMENTS

The basic electrical measurement instrument is the milli-ammeter. It can be used for measurement of both voltage and current. This is a sensitive instrument which gives full scale deflection for currents of only a few milli-amperes. This device can be suitably modified to measure both voltage and current of higher magnitudes. Such modifications provide range extension of the device. The following sections provide some of the fundamental principles related to the modifications usually carried out for these applications.

2.5.1 RangeExtension of a Voltmeter

The milli-ammeter is converted into a voltmeter by connecting a high value resistance (called a **multiplier**) in series with it as shown in Figure 2.10.

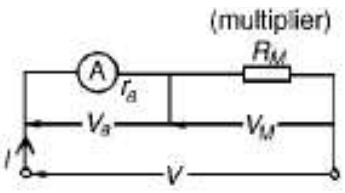


Fig. 2.10 : Conversion of an ammeter into voltmeter

From the diagram, $V = V_a + V_M = Ir_a + IR_M$.

Thus the value of the multiplier, $R_M = \frac{V - Ir_a}{I}$

The range of this instrument can be extended further to enable it measure higher voltage levels.

For measuring voltages of higher ranges, a resistance of higher value is connected in series with the instrument to limit the current in the coil to a safe value. This value of current should never exceed the current required to produce the full- scale deflection. The high resistance connected in series with the instrument is called a multiplier. A multiplier is made of magnanin or other suitable alloy having a negligible coefficient of resistance. It therefore also serves as swamping resistor for the instrument coil.

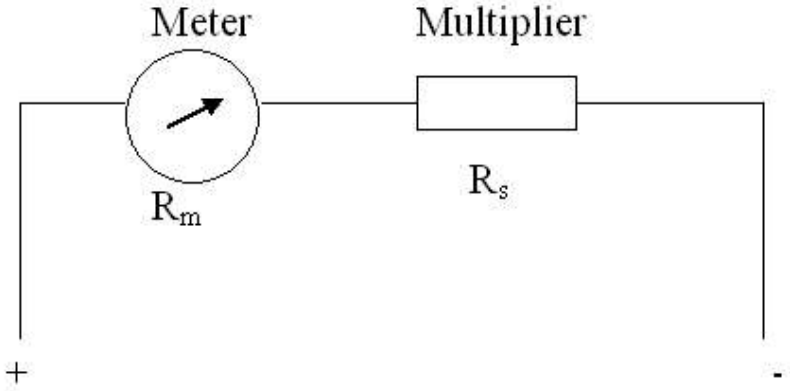


Fig. 2.11 : Extension of range of a voltmeter

The value of the multiplier resistance maybe calculated as below:

Let V = voltage to be measured, V

I = circuit current to give full scale deflection, A

I_m = meter current, A

R_m = meter resistance, Ω

R_s = resistance of multiplier, Ω

Since the same current flow through the instrument and multiplier

$$I = I_m$$

By Ohm's law,

Total circuit voltage = total circuit current X total circuit resistance

$$V = I_m (R_m + R_s)$$

For extension of voltage ranges, an arrangement for practical purposes maybe shown as in Figure 2.12.

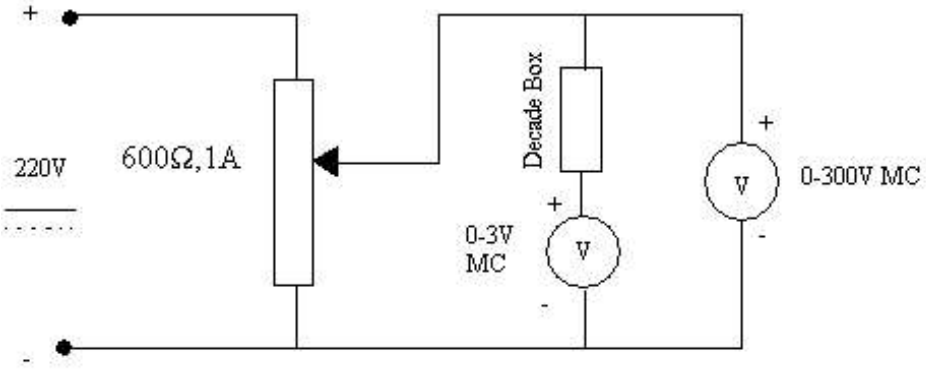


Fig. 2.12 : Arrangement for extension of range of a voltmeter

2.5.2 Extension of Range of an Ammeter

An ammeter can be suitably modified to measure currents of larger values. For such purposes the ammeter is connected in parallel with a low – value resistance so as to divert a portion of the current. Such a diverting resistor is called a shunt.

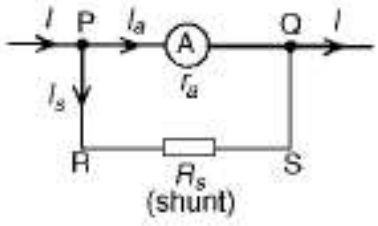


Fig. 2.13 : Extending the range of an ammeter

From Figure 2.13, $V_{PQ} = V_{RS}$. Hence $I_a r_a = I_S R_S$. The value of the shunt resistance can thus, be given as

$$R_s = \frac{I_a r_a}{I_s}$$

To calculate the value of shunt resistance the following points should be noted:

1. The meter current I_m should never exceed the current required to produce full scale deflection.
2. Since the arrangement shown in figure is simply a parallel circuit, current to be measured = instrument current + shunt current ie. $I = I_a + I_s$.

For practical purposes, the arrangement shown in Figure 2.14 maybe used.

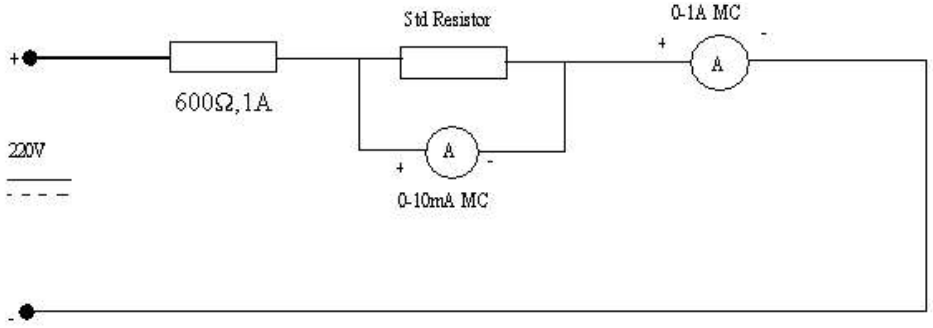


Fig. 2.14 : Arrangement for extension of range of an ammeter

2.5.3 Loading Effect of Voltmeter

While making measurements with a voltmeter it is important to know the sensitivity rating of the instrument. The rating, generally printed on the meter dial, specifies the resistance of the meter for one volt range. The sensitivity of a voltmeter is defined as

$$S_v = \frac{1}{I_{fp}} = \frac{1}{I_m}$$

where I_{fp} is the current required for full scale deflection.

The sensitivity of a voltmeter is an important factor when selecting a meter for a certain voltage measurement. A low resistance voltmeter may give correct readings while measuring voltages in low resistance circuits but is certain to produce unreliable readings in high resistance circuits. A voltmeter, when connected across two points in a very resistive, circuit acts as a shunt for that portion of the circuit. The meter will then give a lower voltage drop than existed before the meter was connected. This effect is called the loading effect of a voltmeter and results primarily due to low sensitivity of the instrument.

2.5.4 Voltage Drop Effect of an Ammeter

The ammeter is connected in series in a network to measure a current. The arrangement maybe shown as below (Figure 2.15).

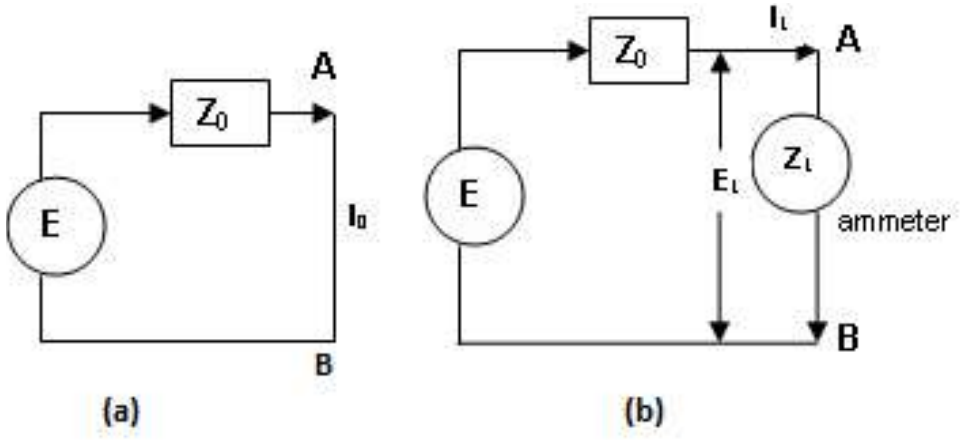


Fig. 2.15 : Arrangement to show voltage drop effect of ammeter

The network shown in (a) has a voltage E while has an impedance of Z_0. When points A and B are shorted current flows in the network. The current is given as

$$I_0 = \frac{E}{Z_0} \quad \Rightarrow E = I_0 Z_0$$

But when an ammeter is inserted between A and B as shown in (b), the impedance of the circuit increases and modifies the value of the current flowing. The measured current then becomes

$$I_L = \frac{E}{Z_0 + Z_L}$$

This can be called the measured current.

In order that the measured current be equal to the actual value of the current, $Z_0 >> Z_L$. This means that the impedance of the ammeter should be very small as compared to the output impedance of the source else the ammeter will be a source of voltage drop. This is a loading effect shown by the ammeter.



CHECK YOUR PROGRESS

Q.3. Find True or False :

a) The basic electrical measurement instrument is the milli-ammeter

b) The milli-ammeter is converted into a voltmeter by connecting a low value resistance.

c) An ammeter can be suitably modified to measure currents of larger values by using a shunt resistor.

d) Sensitivity of a voltmeter is printed on the instrument.

2.6 HIGH VOLTAGE TESTING AND MEASUREMENTS

High voltage applications are common due to the over – reliance of the present life-style on electricity. Right from the stage of generation of electricity to its distribution to the consumer, high voltage applications are critical for consumer and industrial applications. Hence, high voltage measurements and testing forms an essential component of any installation.

High voltage testing and measurement equipments can be classified into two categories:

1. Methods for measurement of RMS values and
2. Methods for measurement of peak values of voltage.

Among the RMS measurement methods three are three primary methods:

a) Electro-static voltmeters– Among these methods the *attracted disc voltmeter* is a complex device and is not preferred. A large disc space is necessary to avoid flashover and corona. With appropriate modifications, this instrument in a form called absolute high voltage attracted disc voltmeter, is used with a voltage difference of 300 KV and a disc spacing of just 3 cm. But these devices become unstable at times and requires care while handling voltages beyond a certain range.

Another sub-type called attracted sphere voltmeter designed using electro-static force between two spheres can handle forces between 4.2 to 7.5 N with gaps of 100 mm and 500 mm while measuring voltages even upto 1 MV.

The other sub-class in this category called the oscillating ellipsoid voltmeter uses two electrodes and produces high degree of accuracy.

b) Transformer ratio method– This method the primary voltage of a high voltage testing transformer is measured with a low voltage voltmeter and the secondary voltage obtained is given as $V_s=nV_p$ where n is the turns ratio, V_s is the voltage across the secondary and V_p is the voltage across the primary. This is a simple method but is not accurate. It is, however, convenient for use and continuous measurement only after proper calibration.

c) Potential divider method– In this method, a potential divider is connected across the secondary winding (high voltage winding) of a high voltage testing transformer. A definite fraction of the secondary voltage is measured using a low voltage electrostatic voltmeter. Two types of potential divider arrangements can be formed- one resistance potential divider and the other capacitance potential divider. This method is suitable only under appropriately arranged set-ups.



CHECK YOUR PROGRESS

Q.4. Find True or False :

a) Measurement of RMS values is a class of high voltage testing.

b) Electro-static voltmeters are used for measurement of RMS values of high voltages. .

c) Attracted sphere voltmeter can be used for measurement upto 1 MV.

2.7 CALIBRATION

Calibration is the process through which performance of instruments can be gauged and compared against known standards. It helps to identify errors and accuracy. Calibration of an instrument involves comparison of the instruments performance and capacity with a primary standard, a secondary standard that has a higher accuracy or an instrument which has a known accuracy and a verified capacity.

2.7.1 Necessity of Calibration

All instruments must be calibrated against some known standards before use. The behaviour of an instrument can be predicted only after doing appropriate calibration. The reading given by a particular instrument is acceptable only after the instrument has been calibrated using a primary standard, a secondary standard of higher accuracy or an instrument which has a know accuracy and a verified capacity. Instruments not calibrated can cause errors and be a source of inaccurate measurements.

2.7.2 Types of Calibration

Calibration can be of two types: static and dynamic. This classification is based on the division of instrument and measurement systems that exist due to the individual operations procedure. Static calibration is done with instruments that measure quantities which vary slowly or remain constant. Under these circumstances, the characteristics derived can be used to provide a meaningful description of the measured quantity and use a standard instrument to calibrate the meter used for measurement. The accuracy ot the reading shown by the meter shall depend upon the effectiveness of the calibration.

The other type of calibration is done in case of quantities that show rapid variations. A dynamic relation exists between input

and output in such cases. The instrument used for measurement of such quantities must be calibrated against a known standard or an instrument during the run- time or operations time which captures the varying nature of the quantity and the considers the dynamic nature of the operation.



CHECK YOUR PROGRESS

Q.5. Find True or False :

a) Calibration is the process through which performance of instruments can be gauged and compared against known standards.

b) All instruments must be calibrated against some unknown standards before use.

c) Calibration can be of two types: static and dynamic.



2.8 LET US SUM UP

- As the name suggest, a multi-meter is a versatile instrument that combines several functions into one unit.
- Analog multi-meters are commonly used electrical instruments implemented using a galvanometer.
- The digital multi-meter or DMM is a versatile device that can be used to measure both ac and dc voltage and current from say micro to a few tens or hundred ranges.
- Tong tester is a special purpose current probe which allows measurement of current without having to disconnect the conductor from the circuit.
- Energy meters can be used to amount of electrical energy consumed by consumers, industries etc while using electrical appliances.

- The megger is used to measure insulation resistance.
- Earth resistances become vital in such situations where an electrical appliance should be provided with a connection that has a flow continuity with ground.
- A power factor meter is a type of electrodynamometer. It works using the movement of an arrangement formed by two movable coils set at right angles to each other.
- The basic electrical measurement instrument is the milli-ammeter. It can be used for measurement of both voltage and current.
- *High voltage testing and measurement* equipments can be classified into two categories: Methods for measurement of RMS values and Methods for measurement of peak values of voltage.



2.9 FURTHER READINGS

1) Thareja B L, *Electrical Technology*, Khanna Publications
2) Sawhney A K, Electronics Measurement and Instrumentation, Dhanpat Rai & Co (Pvt) Ltd
3) Hughes E, Smith I M, *Electrical Technology*, ELBS



2.10 ANSWER TO CHECK YOUR PROGRESS

Ans. to Q. No. 1 : a) True, b) True, c) True, d) False, e) True.

Ans to Q. No. 2 : a) True, b) True, c) True

Ans to Q. No. 3 : a) True, b) True, c) True, d) False

Ans to Q. No. 4 : a) True, b) True, c) True

Ans to Q. No. 5 : a) True, b) False, c) True



2.11 MODEL QUESTIONS

Q.1. Why a multi-meter is a versatile instrument?

Q.2. What are the two broad classes of high voltage electrical measurement instruments?

Q.3. Describe the methods which can be used to extend the range of a voltmeter and an ammeter.

Q.4. Describe the working of a megger.

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UNIT 3 : EARTHING

UNIT STRUCTURE

3.1 Learning Objectives

3.2 Introduction

3.3 Earthing and its Importance

3.4 Basic Considerations of Earthing

- 3.4.1 Measurement of Soil Resistivity

3.5 Types of Ground Connections

- 3.5.1 Pipe Earthing
- 3.5.2 Plate Earthing

3.6 Ground Testing

3.7 Let Us Sum Up

3.8 Further Readings

3.9 Answers to Check Your Progress

3.10 Model Questions

3.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- know about earthing and its importance.
- understand the basic considerations of earthing.
- describe how measurement of soil resistivity is done.
- go through the requirements and types of earthing.

3.2 INTRODUCTION

In this unit, you will learn the basic principles behind earthing and its importance. You will also learn about the basic considerations which are taken into account while doing earthing and the accessories that are required to do grounding in an electrical system. The unit shall also inform you regarding the types of earthing, the methods in which these are implemented and the testing associated.

3.3 EARTHING AND ITS IMPORTANCE

A grounding system is an essential component of an electrical system. It allows the excess charges to flow through without causing damage to the system. Without an effective grounding system, the user is exposed to the risk of electric shock. An electrical system without an effective ground is always hazardous. An earthing is a conducting connection, whether intentional or accidental between an electrical circuit or equipment and the earth, or to some conducting body that permits excess electric current to flow to or sink into the earth.

Earth grounding is an intentional connection from a circuit conductor usually the neutral to a ground electrode placed in the earth. Equipment grounding is to ensure that operating equipment within a structure is properly grounded. The grounding systems are required to be kept separate except for a connection between the two systems to prevent differences in potential from a possible flashover from a lightning strike.

By putting proper grounding in an electrical, system, safety is ensured and it becomes less risky for operation and use. Grounding connections provide a safe path for the dissipation of fault or excess currents, lightning strikes, static discharges etc.

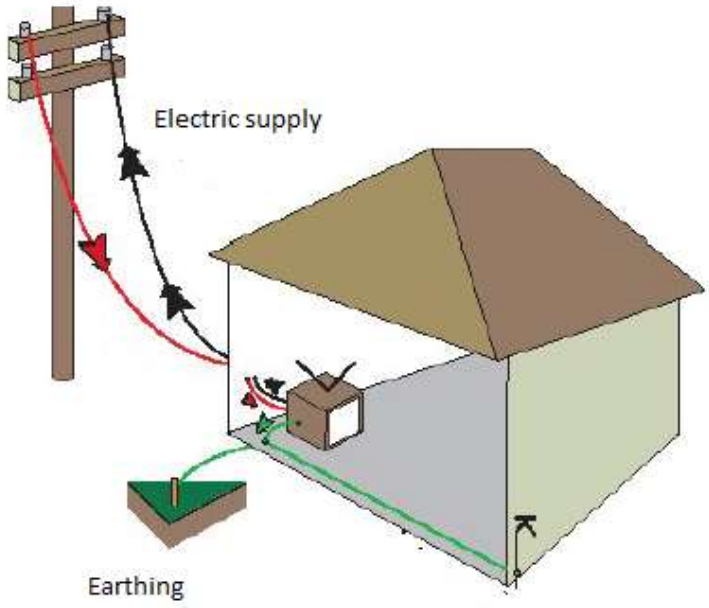


Fig. 3.1 : Shielded, twisted and coaxial cable

All earthing conductors should be of high conductivity G.I. / Aluminum / copper and is protected against mechanical injury or corrosion.

Main earthing conductors are taken from the earth connections at the main switchboards to an earth electrode with which the connection is to be made. Sub-earthing conductors runs from the main switchboard to the sub-distribution boards. Final distribution boards earthing conductors shall runs from sub-distribution boards.

Earthing conductors, outside the building, should be laid 600 mm below the finished ground level.

Neutral conductor, sprinkler pipes or pipes conveying gas, water or flammable liquid, structural steel work, metallic enclosures for cables and conductors, metallic conduits and lightning protection stem conductors must not be used as a means of earthing an installation or even as a link in an earthing system. The electrical resistance of metallic enclosures for cables and conductors measured between earth connections at the main switchboard shall be low enough to permit the passage of current necessary to operate fuse or circuit breakers and shall not exceed one ohm.

When there is evidence that the soil is aggressive to copper, buried earthing conductors should be protected by suitable serving and sheathing so that the earthing conductor is not damaged by corrosion.



CHECK YOUR PROGRESS

Q.1. Find True or False :

a) A grounding system allows the excess charges to flow through without causing damage to the system.

b) Earthing conductors, outside the building, should be laid 600 mm below the finished ground level.

c) By removing proper grounding in an electrical, system, safety is ensured and it becomes less risky for operation and use.

3.4 BASIC CONSIDERATIONS OF EARTHING

To prevent damage and ensure proper operation of electrical equipment, dissipation of lightning energy and return paths for ground fault currents is a necessity. These equipments include computers, other electrical and electronic equipments like Magnetic Imaging equipment, Telecom Installations & Microwave Towers, CNC Machines and other Sophisticated Electronic equipment used in different Industries Offices and Electric Power Substations. Proper grounding has other benefits, such as Enhanced Personnel Safety, Reduction in System Noise and protection from unwanted voltages, currents and Power Surges and protection from Lightning. Without a proper “Low-Impedance Ground”, standard protection devices such as breakers - or transient voltage surge and lightning protection systems - are rendered ineffective. When grounding systems are installed they are required to meet certain resistance criteria, such as 10, 5, 3 or 1 ohm. Unfortunately most grounding systems are not properly maintained and tested after installation.

There are confusions regarding proper ground and the appropriate ground resistance value that needs to be selected. Ideally a ground should be of zero ohms resistance. A single electrode consisting of a rod, pipe, or plate which does not have a resistance to ground of 25 ohms or less should be augmented by one additional electrode. This does not mean that the value of the ground now has to be 25 ohms or less. The ground resistance values objectives vary from industry to industry. Telecommunications industry has often used 5 ohms or less as their value for grounding and bonding. The goal in ground resistance values is to achieve the lowest ground resistance value possible that makes sense economically and physically. Grounding is done with the help of electrodes.

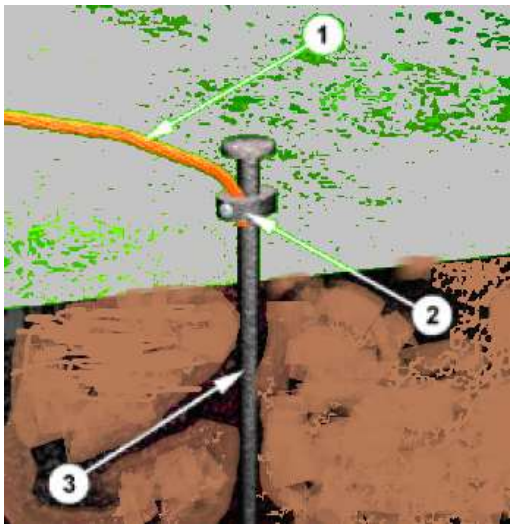


Fig. 3.2 : Ground electrode components

The essential components of a ground electrode are as below:

1. Ground conductor
2. Connection/bonding of the conductor to the ground electrode and
3. Ground electrode.

The resistance of a ground electrode has three basic components:

A) The resistance of the ground electrode itself and the connections to the electrode. The resistance of the ground electrode and its connection is generally very low. Ground rods are generally made of highly conductive / low resistance material such as steel or copper

B) The contact resistance of the surrounding earth to the electrode. This resistance is found to be almost negligible provided that the ground electrode is free of paint, grease, etc. and that the ground electrode is in firm contact with the earth.

C) The resistance of the surrounding body of earth around the ground electrode. The ground electrode is surrounded by earth which is made up of concentric shells all having the same thickness. Those shells closest to the ground electrode have the smallest amount of area resulting in the greatest degree of resistance. Each subsequent shell incorporates a greater area resulting in lower resistance. This finally reaches a point where the additional shells offer little resistance to the ground surrounding the ground electrode.

3.4.1 Measurement of Soil Resistivity

Resistance offered by soil while inserting a ground connection is an issue which plays a significant role in determining the quality of the earthing. The soil surrounding the ground electrode generates a resistance which must me know in order to make the design of the earthing proper. The reason for measuring soil resistivity when selecting a location for installing a ground connection with an electrical appliance must have the lowest possible resistance value. This ensures smooth passage of the excess charges to ground. Once a site has been selected, measuring the soil resistivity will give the information necessary to design and build a ground field that will meet the ground resistance requirements. These are primarily important for cases where there are high power applications involved.

There are a number of factors affecting soil resistivity. The first one is the soil composition. Soil is rarely homogenous and the resistivity of the soil will vary geographically and at different depths.

The second factor affecting soil resistivity is moisture or the amount of water in the ground. Moisture content changes seasonally, varies according to the nature of the sub layers of earth. Since soil resistivity is so closely related to moisture and moisture is present in the soil we can logically assume that as moisture increases resistivity will decrease and vice versa.

The third factor related is temperature.

Soil resistivity will vary through out the year whenever seasonal changes bring about a change in the moisture and temperature content of the soil. For a grounding system to be effective it should be designed to withstand the worst possible conditions. Since soil and water are generally more stable at deeper strata, the ground rods be placed as deep as possible into the earth, the water table if possible. Ground rods should also be installed where there is a stable temperature.

The ground resistivity offered by different types of soil at varying depths is shown in Table 3.1 below:

Table 3.1 : Ground resistivity variation with soil types and depth

Type of Soil	Soil resistivity R_E	Earthing Resistance (W)					
		Earthing rod m depth			Earthing strip m		
	Ohm m	3	6	10	5	10	20
Moist humus soil, moor soil, swamp	30	10	5	3	12	6	3
Farming soil loamy and clay soils	100	33	17	10	40	20	10
Sandy clay soil	150	50	25	15	60	30	15
Moisty sandy soil	300	66	33	20	80	40	20
Dry sand soil	1000	330	165	100	400	200	100
Concrete 1: 5	400	–	–	–	160	80	40
Moist gravel	500	160	80	48	200	100	50
Dry gravel	1000	330	165	100	400	200	100
Stoney soil	30,000	1000	500	300	1200	600	300
Rock	10^7	–	–	–	–	–	–

The formula used for calculating soil resistivity is given as:

$$\rho = 2 \pi A R$$

Where: ρ = the average soil resistivity to depth A in ohm - cm

π = is the constant 3.1416

A = the distance between the electrodes in cm

R = the measured resistance value in ohms from the test instrument



CHECK YOUR PROGRESS

Q.2. Find True or False :

a) Ideally a ground should be of zero ohms resistance.

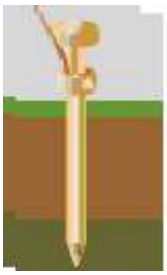
b) A single electrode consisting of a rod, pipe, or plate which does not have a resistance to ground of 25 ohms or less should not be augmented by one additional electrode.

c) The resistance of the ground electrode and its connection is generally very high.

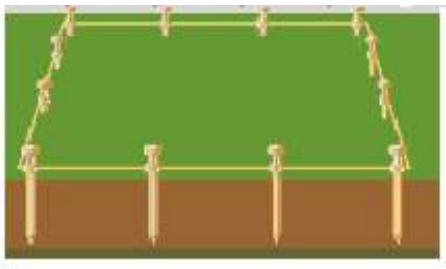
d) There are a number of factors affecting soil resistivity. The first one is the soil composition.

3.5 TYPES OF GROUND CONNECTIONS

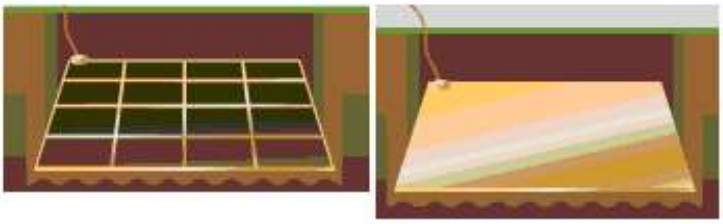
In the most rudimentary form, two types of grounding systems are observed. These are simple and complex. Simple grounds consist of a single earthing electrode driven into the ground. The use of a single ground electrode is the most common form of grounding. It is commonly used with houses, residential complexes and is easy to install. Complex grounding systems are required to provide effective earthing connection where the electrical power involvement is larger. Complex grounding systems consist of multiple ground rods connected, mesh or grid networks, ground plates and ground loops. These systems are typically installed at power generating substations, central offices, mobile network towers and similar installations.



(a) Single electrode



(b) Multi-eletrode ground connection



(c) Mesh network of electrodes (d) Plate electrode

Fig. 3.3 : Types of ground connectors

3.5.1 Pipe Electrode Earthing

Earthing electrode consists of a metallic pipe (of Aluminum or Copper). It should have a diameter of 40 mm or above and should be not less than 3 meters long. The pipe electrode shall is cut tapered at the bottom and provided with holes of 12 mm diameter drilled at 75 mm interval upto 2.5 meters length from bottom. The electrode is buried vertically in the ground as far as practicable below permanent moisture level. The depth of burial should not be, in any case, less than 3 meters below ground level. The electrode should be in one piece with no joints in the structure. Earth electrode must not be located close to a metal fence. It should be kept clear of the building foundations and in no case; it should be nearer than 2 meters from the outer face of the wall.

The pipe earth electrode should be kept vertically and surrounded with 150mm thick layer of charcoal dust and salt mixture upto a height of 2.5 meters from the bottom. At the top of the electrode a metallic threaded cap is provided for watering the earth. The main earth conductors are connected to the electrode just below the metallic cap, with proper terminal lugs and check nuts. The metallic cap over the pipe and earth connection should be kept in a chamber, approximately 300 mm length x 300 mm wide and 300 mm deep. The chamber shall be provided with a cast iron inspection cover resting over a strong metallic frame.

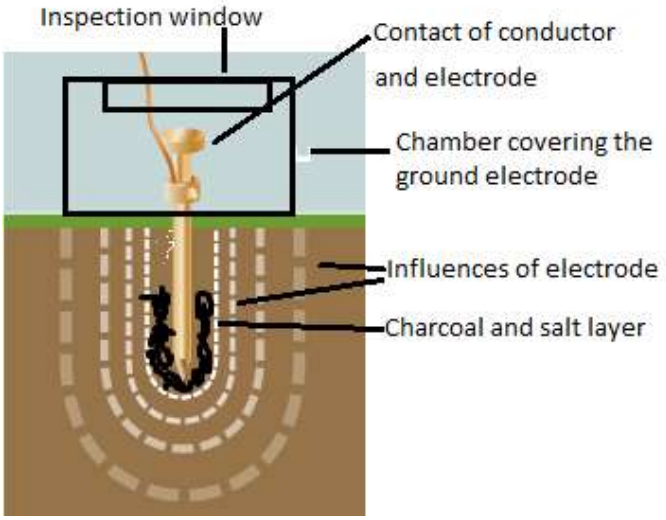


Fig. 3.4 : Single electrode ground connection

3.5.2 Plate Electrode Earthing

Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mm x 12 mm thick. The plate electrode is buried below land that permanently has moisture. The depth, in any case, must not less than 3 meters below ground level. The earth plate is placed vertically and surrounded with 150 mm thick layer of charcoal dust and salt mixture. A 20 mm metallic pipe is connected from the top edge of the plate to the ground level. The top of the pipe is provided with a metal threaded cap for watering the earth through a pipe.

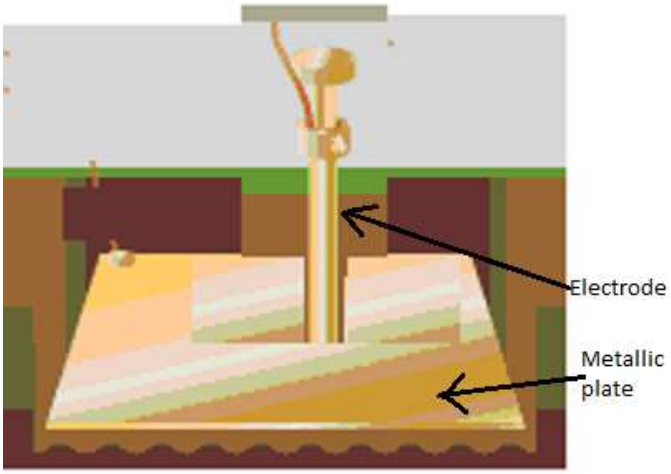


Fig. 3.5a : Plate and electrode connected ground connection

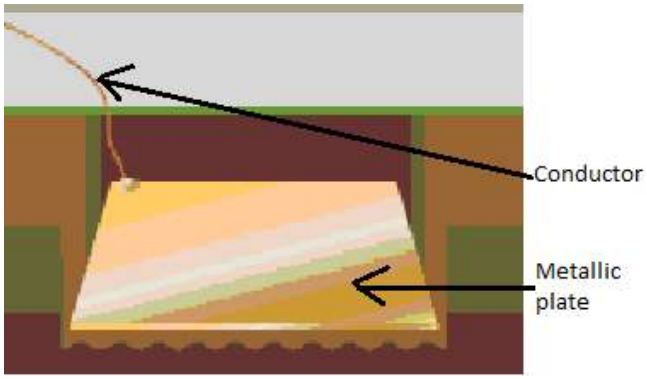


Fig. 3.5b : Plate ground connection



CHECK YOUR PROGRESS

Q.3. Find True or False :

a) In the most rudimentary form, two types of grounding systems are observed. These are simple and complex.

b) The use of a single ground electrode is the most common form of grounding.

c) Earthing electrode consist of a metalic pipe (of Aluminum or Copper). It should have a diameter of 40 mm or above and should be not les than 3 meters long.

d) Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mm x 12 mm thick.

3.6 GROUND TESTING

Soil resistivity is most necessary when determining the design of the grounding system for new installations. There are four types of earth ground testing methods available:

- Soil Resistivity (using stakes)
- Fall-of-Potential (using stakes)
- Selective (using 1 clamp and stakes)
- Stakeless (using 2 clamps only)

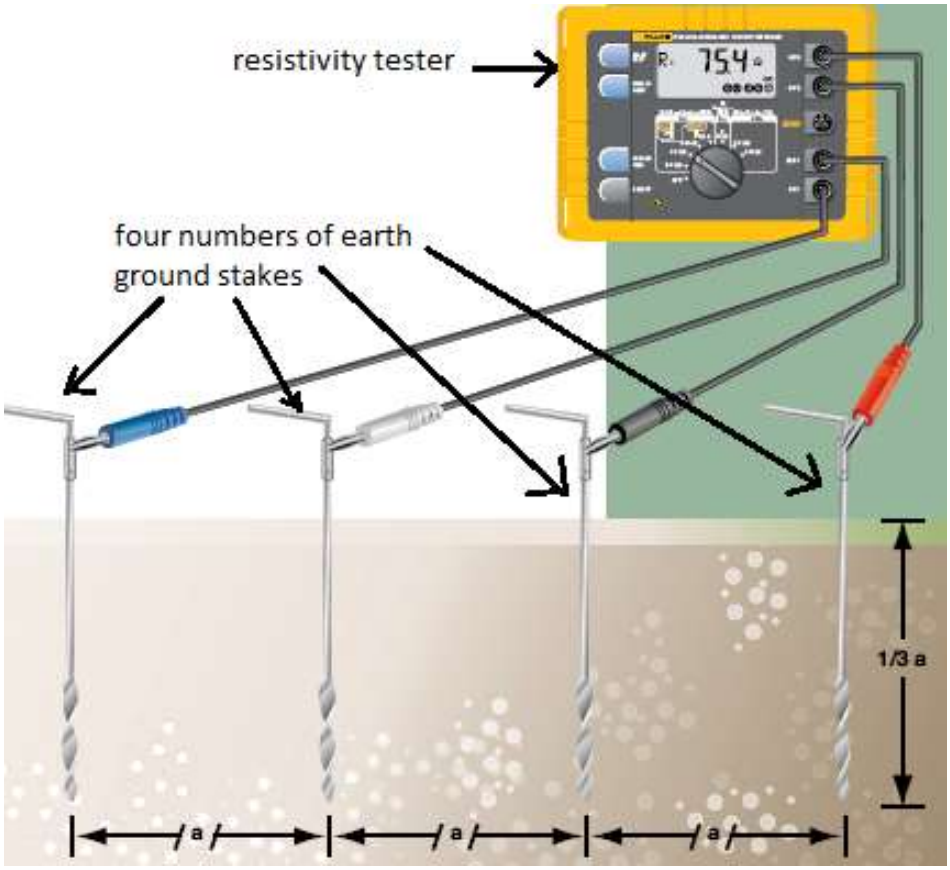


Fig. 3.6 : Ground resistivity testing using stakes

Four earth ground stakes are positioned in the soil in a straight line, equidistant from one another. The distance between earth ground stakes should be at least three times greater than the stake depth. So if the depth of each ground stake is one foot (.30 meters), the distance between stakes is greater than three feet (.91 meters). The resistivity tester generates a known current through the two outer ground stakes and the drop in voltage potential is measured between the two inner ground stakes. The resistivity tester automatically calculates the soil resistance.

Stakeless measurement only measures individual ground rod resistances in parallel to earth grounding systems.



CHECK YOUR PROGRESS

Q.4. Find True or False :

a) Soil resistivity is most necessary when determining the design of the grounding system for new installations.

b) Stakeless measurement only measures individual ground rod resistances in parallel to earth grounding systems.

c) In the ground testing method with stakes, four earth ground stakes are positioned in the soil in a straight line, equidistant from one another.



3.7 LET US SUM UP

- A grounding system is an essential component of an electrical system. It allows the excess charges to flow through without causing damage to the system.
- Main earthing conductors are taken from the earth connections at the main switchboards to an earth electrode with which the connection is to be made.
- Earthing conductors, outside the building, should be laid 600 mm below the finished ground level.
- When there is evidence that the soil is aggressive to copper, buried earthing conductors should be protected by suitable serving and sheathing so that the earthing conductor is not damaged by corrosion.
- When grounding systems are installed they are required to meet certain resistance criteria, such as 10, 5, 3 or 1 ohm.
- The goal in ground resistance values is to achieve the lowest ground resistance value possible that makes sense economically and physically.

- Resistance offered by soil while inserting a ground connection is an issue which plays a significant role in determining the quality of the earthing.
- There are a number of factors affecting soil resistivity. The first one is the soil composition. The second factor affecting soil resistivity is moisture or the amount of water in the ground. The third factor related is temperature.
- In the most rudimentary form, two types of grounding systems are observed. These are simple and complex. Simple grounds consist of a single earthing electrode driven into the ground. The use of a single ground electrode is the most common form of grounding.
- Earthing electrode consist of a metalic pipe (of Aluminum or Copper). It should have a diameter of 40 mm or above and should be not les than 3 meters long.
- Earthing electrode is also formed by a plate. It must have a dimension not less than 600 mm x 600 mm x 12 mm thick. The plate electrode is buried below land that permanently has moisture.
- There are four types of earth ground testing methods available. These are– Soil Resistivity (using stakes), Fall-of-Potential (using stakes), Selective (using 1 clamp and stakes) and Stakeless (using 2 clamps only).



3.8 FURTHER READINGS

1) Johnson, (1st) (2003), *"Process Control and Instrumentation Technology"*, New Delihi, Pearson Education
2) Swhney K, (11th) (1997). *"Electrical and Electronics Measurement and Instrumentation"*, New Delhi, Dhanpat Rai.
3) (1956) Indian Electricity Rules.
4) Thereja B. L. *"Electrical Technology"*, Khanna Publishing,
5) Hughes E, Smith I M, *Electrical Technology*, ELBS



3.6 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1 : a) True, b) True, c) False

Ans. to Q. No. 2 : a) True, b) False, c) False, d) True

Ans. to Q. No. 3 : a) True, b) True, c) True

Ans. to Q. No. 4 : a) True, b) True, c) True



3.9 MODEL QUESTIONS

Q.1. Why is earthing so essential? Mention a few points to justify your answer.

Q.2. What are the basic considerations that are followed while doing an earthing connection?

Q.3. What are the different methods of installing an earthing?

Q.4. Write short notes on ground testing.

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UNIT 4 : POWER CONDITIONING APPLIANCES

UNIT STRUCTURE

4.1 Learning Objectives

4.2 Introduction

4.3 Power Conditioning and its Importance

4.4 Different Power Conditioning Appliances

- 4.4.1 Battery
- 4.4.2 Inverter
- 4.4.3 Diesel Generator set
- 4.4.4 Stabilizer
- 4.4.5 UPS

4.5 Change Over Switch

4.6 Connection of Water-Pump and Geyser

4.7 Let Us Sum Up

4.8 Further Readings

4.9 Answer to Check Your Progress

4.10 Model Questions

4.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- know about power conditioning and its importance.
- understand the different power conditioning appliances.
- describe how changeover switches are connected.
- go through the requirements of fitting a water pump and a geyser.

4.2 INTRODUCTION

In this unit, you will learn the basic principles behind power conditioning and its importance. You will also lean about the working of different power conditioning appliances. The unit shall also inform you how changeover switches are connected. You will also know about the requirements of fitting a water pump and a geyser

4.3 POWER CONDITIONING AND ITS IMPORTANCE

Power conditioning appliances are essential parts of an electrical system. These are used to provide continuous supply of electric power to appliances. Moreover, power conditioning appliances provide regulated supply for use. Regulated power supply is required for longevity and smooth operation of electrical appliances. Variation in rated power supply requirements to electrical instruments and appliances cause damage. The damage is caused by accidental surge of supply for which rated power limits can be exceeded for which a particular appliance may get damaged. Moreover, fluctuation is power supply causes disruption of smooth operation of appliances which at times may prove to be hazardous also. These can be prevented by the use of power conditioning systems. Accidental failure of power supply systems leading to disruption of operation of appliance requires power conditioning systems. Some of the common power conditioning systems is described in the sections below.

4.4 DIFFERENT POWER CONDITIONING APPLIANCES

4.4.1 Battery

Battery is a source of electrical power. It provides DC voltage by converting chemical energy into electrical energy. The battery doesn't hold electrical energy but a chemical process provides electrical output.

A material must contain charged particles to be able to conduct electric current. In solids, the current is carried by electrons. In liquids and gases, the current is carried by the part of a molecule which has acquired an electric charge, called ions. Distilled water contains no ions and is a poor conductor of electricity whereas salt water contains ions and is a fairly good conductor of electricity.

Electrolysis is the decomposition of a liquid compound by the passage of electric current through it. Practical applications of

electrolysis include the electroplating of metals. An electrolyte is a compound which will undergo electrolysis. Examples include salt water, copper sulphate and sulphuric acid.

Electroplating uses the principle of electrolysis to apply a thin coat of one metal on another metal. Some practical applications include the tin-plating of steel, silver-plating of nickel alloys and chromium-plating of steel. If two copper electrodes connected to a battery are placed in a beaker containing copper sulphate as the electrolyte it is found that the cathode (i.e. the electrode connected to the negative terminal of the battery) gains copper whilst the anode loses copper.

The purpose of an electric cell is to convert chemical energy into electrical energy. A simple cell comprises two dissimilar conductors (electrodes) in an electrolyte. Such a cell is shown in Figure 4.1, comprising copper and zinc electrodes.

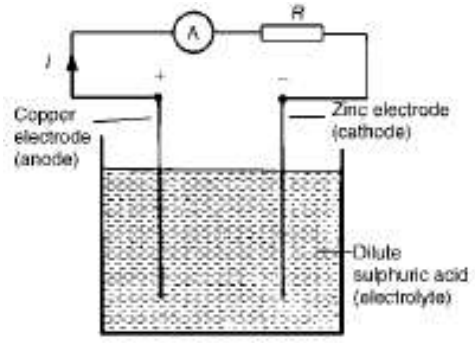


Fig. 4.1 : A simple electric cell used to produce electricity from chemical process

An electric current is found to flow between the electrodes. Other possible electrode pairs exist, including zinc-lead and zinc-iron.

When two metals are used in a simple cell the electro-chemical series may be used to predict the behavior of the cell:

- The metal that is higher in the series acts as the negative electrode, and vice-versa. For example, the zinc electrode in the cell shown in Figure 5.1 is negative and the copper electrode is positive.

- The greater the separation in the series between the two metals the greater is the e.m.f. produced by the cell.

The electrochemical series is representative of the order of reactivity of the metals and their compounds:

- The higher metals in the series react more readily with oxygen and vice-versa.
- When two metal electrodes are used in a simple cell the one that is higher in the series tends to dissolve in the electrolyte.

The electromotive force (e.m.f.), *E*, of a cell is the p.d. between its terminals when it is not connected to a load (i.e. the cell is on 'no load'). The e.m.f. of a cell is measured by using a high resistance voltmeter connected in parallel with the cell. The voltmeter must have a high resistance otherwise it will pass current and the cell will not be on no-load.

There are two broad types of batteries:

- Primary cell and
- Secondary cell.

Primary cell : Primary cells cannot be recharged, that is, the conversion of chemical energy to electrical energy is irreversible and the cell cannot be used once the chemicals are exhausted. Examples of primary cells include the Leclanch´e cell and the mercury cell.

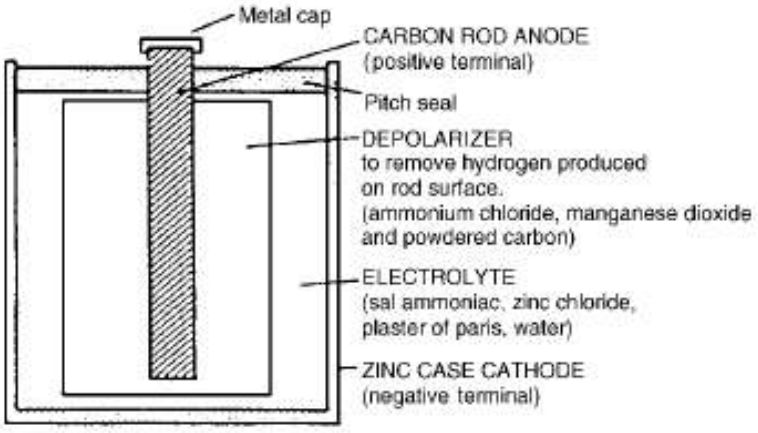


Fig. 4.2 : Dry Lechlanche cell

Secondary cell : Secondary cells can be recharged after use, that is, the conversion of chemical energy to electrical energy is reversible and the cell may be used many times. Examples of secondary cells include the lead-acid cell and the alkaline cell. Practical applications of such cells include car batteries.

Lead-acid cell : A typical lead-acid cell is constructed of:

1. A container made of glass, ebonite or plastic.
2. Lead plates
   - the negative plate (cathode) consists of spongy lead
   - the positive plate (anode) is formed by pressing lead peroxide into the lead grid.

   The plates are interleaved as shown in the plan view of Figure 4.3 to increase their effective cross-sectional area and to minimize internal resistance.

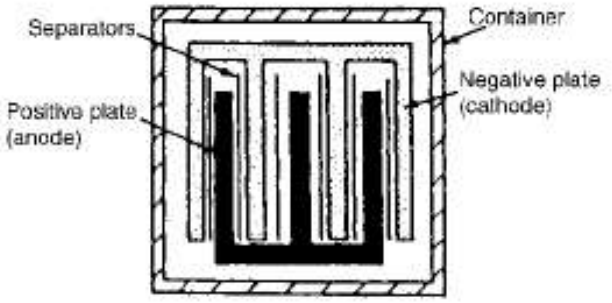


Fig. 4.3 : Lead-acid cell

3. Separators made of glass, celluloid or wood.
4. An electrolyte which is a mixture of sulphuric acid and distilled water.

The relative density (or specific gravity) of a lead-acid cell, which may be measured using a hydrometer, varies between about 1.26 when the cell is fully charged to about 1.19 when discharged. The terminal p.d. of a lead-acid cell is about 2 V. When a cell supplies current to a load it is said to be discharging. During discharge the lead peroxide (positive plate) and the spongy lead (negative plate) are converted into lead sulphate, and the oxygen in the lead peroxide combines with hydrogen in the electrolyte to form water. The electrolyte is therefore weakened and the relative

density falls. The terminal p.d. of a lead-acid cell when fully discharged is about 1.8 V. A cell is charged by connecting a DC supply to its terminals, the positive terminal of the cell being connected to the positive terminal of the supply. The charging current flows in the reverse direction to the discharge current and the chemical action is reversed.

Alkaline cell : There are two main types of alkaline cell—the nickel-iron cell and the nickel-cadmium cell. In both types the positive plate is made of nickel hydroxide enclosed in finely perforated steel tubes, the resistance being reduced by the addition of pure nickel or graphite. The tubes are assembled into nickel-steel plates. In the nickel-iron cell, the negative plate is made of iron oxide. In the nickel-cadmium cell the negative plate is made of cadmium. The electrolyte in each type of cell is a solution of potassium hydroxide which does not undergo any chemical change and thus the quantity can be reduced to a minimum.

Advantages of an alkaline cell (for example, a nickel-cadmium cell or a nickel-iron cell) over a lead-acid cell include:

- More robust construction
- Capable of withstanding heavy charging and discharging currents
- without damage
- Has a longer life
- For a given capacity is lighter in weight
- Can be left indefinitely in any state of charge or discharge without
- damage
- Is not self-discharging

Disadvantages of an alkaline cell over a lead-acid cell include:

- Is relatively more expensive
- Requires more cells for a given e.m.f.
- Has a higher internal resistance
- Must be kept sealed
- Has a lower efficiency

4.4.2 Inverter

An inverter is an electrical device that converts direct current (DC) to alternating current (AC). There are two main types of inverter. These are: modified sine wave or square wave inverter and pure sine wave inverter. The output of a modified sine wave inverter is similar to a square wave output. It is simple and low cost and is compatible with most electronic devices, except for sensitive or specialized equipment, for example certain laser printers. A pure sine wave inverter produces a nearly perfect sine wave output (<3% total harmonic distortion). Thus it is compatible with all AC electronic devices.

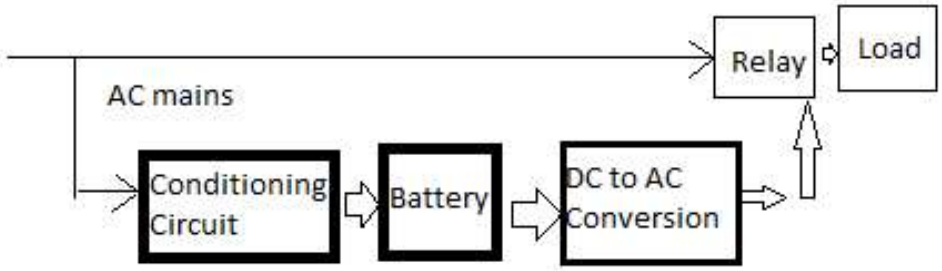


Fig. 4.4 : Inverter arrangement with AC mains

An inverter converts the DC electricity from sources such as batteries, solar panels, or fuel cells to AC electricity. The block diagram of a basic inverter maybe shown as in Figure 4.5.

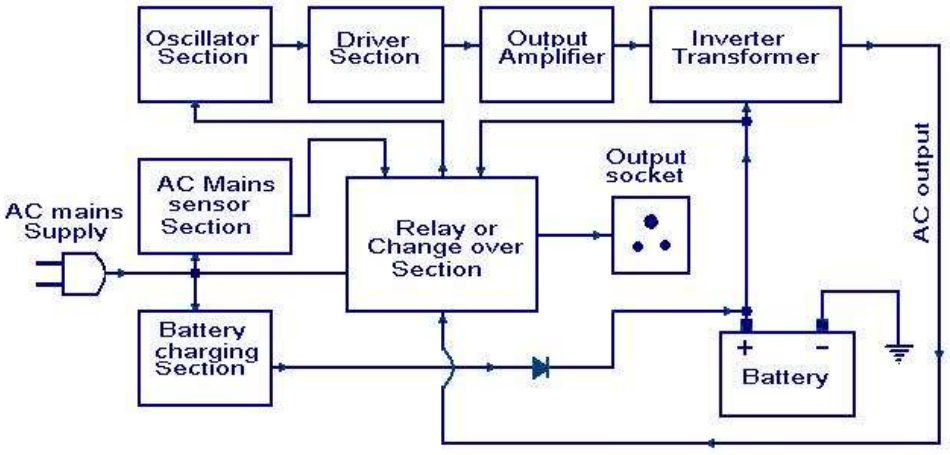


Fig. 4.5 : Block diagram of an inverter

When the mains supply is available, the AC mains sensor detects it and the supply goes through a relay to the load and battery charging section of the inverter. The load will by driven by the line voltage in this situation. Also the line voltage charges the battery so as to convert the AC to a DC voltage in a regulated form.

When the AC mains power supply is off, an oscillator inside the inverter generates a 50Hz drive signal. This drive signal is amplified by the driver section and passed on to the output section. There is a switching section formed by transistors which upon receiving the drive signal start switching between ON & OFF states at a rate of 50 Hz. This switching action transistors cause a 50Hz current to the primary of the inverter transformer resulting in a 220V AC or 110V AC (depending on the winding ratio of the inverter transformer) at the secondary or the inverter transformer. This secondary voltage is made available at the output socket of the inverter by a changeover relay.

A 12 V 100 W inverter circuit is shown in Figure 4.6.

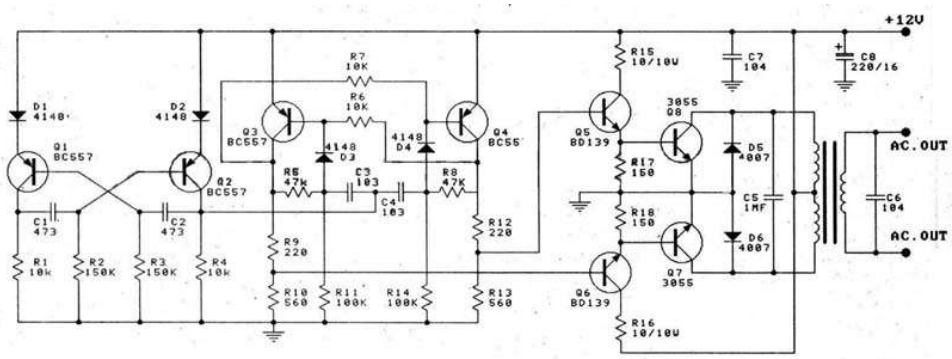


Fig. 4.6 : 12V 100W inverter circuit

4.4.3 Diesel Generator Set

Diesel electric generators are essential components of a power conditioning arrangement as they provide supply of electricity over extended periods of time with higher power ratings at lower cost than inverters. They need diesel to generate electricity.

The process of generation of electricity by such generators is related to the rotation of a coil at constant angular velocity symmetrically between the poles of a magnet system.

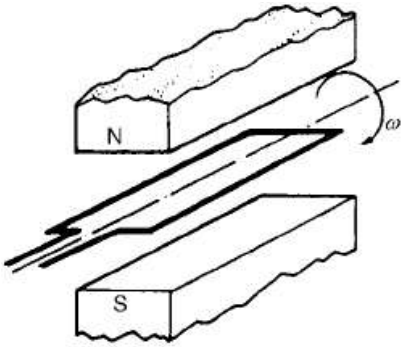


Fig. 4.7 : Rotation of electric coil symmetrically across two magnets

As the coil rotates symmetrically between the magnets, the magnetic flux varies for which a time varying current is generated in the coil. This time varying current is similar to that of an AC signal. A single phase AC generator is depicted in Figure 4.8. A magnet is rotated between two coil windings.

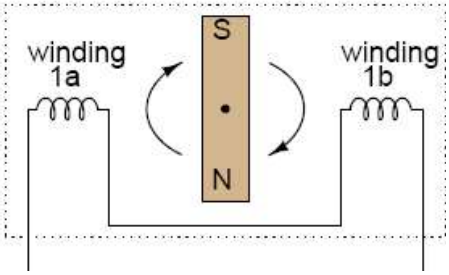


Fig. 4.8 : Single-phase AC generator

In a three-phase AC generator, there are three separate winding across which the magnet rotates.

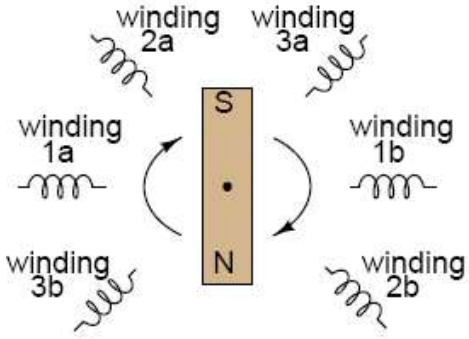


Fig. 4.9 : Coil positions across a magnet in a 3-phase generator

The rotating magnetic field passes by three sets of wire windings, each set spaced 120° apart around the circumference of the machine for which the required phase differences are generated.

While the DG set is installed certain electrical accessories are required for smooth interaction with the AC mains. These include auto change over switches, voltage monitor relay, stop solenoid switches, electro mechanical and electronic hour meters, oil pressure sensors and switches, high water temperature sensors and related fitting accessories.

4.4.4 Stabilizer

A stabilizer is a system which is used to provide a regulated AC voltage supply to an appliance. A stabilizer is designed to automatically maintain a constant voltage level. It may use an electromechanical mechanism, or electronic components to regulate one or more AC or DC voltages.

A basic stabilizer maybe thought of to be an arrangement with a filtering circuit formed by capacitors, inductors, resistors and their combinations. When a voltage stabilizer is connected into an outlet, it passes the electric current to the load through such a conditioning circuit. The conditioning circuit, formed by a series of capacitors, inductors or capacitor-inductor-resistor circuits, performs certain filtering operation. The capacitors present maintain their charge even if the amount of power from the outlet fluctuates. Any device plugged into the stabilizer will draw its power from the capacitors instead of directly from the outlet. As a device drains power from the capacitors, the power coming in from the outlet will continue to recharge them. Due to resistance in the stabilizer's circuitry, its power to devices is lower than the ideal voltage from the outlet. This means devices may function slightly slower when connected to a voltage stabilizer.

A simple stabilizer or a voltage regulator can be formed by certain electronic components. A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes) or zener diodes. Zener diodes of specific rating provide constant output voltage despite variation in input. But these are suitable for low power applications. For high power AC, servo stabilizers are used. There is an electro-mechanical process that stabilizes three-phase AC supplies. Such arrangements are seen in servo stabilizers. A servo-mechanism is used to select the appropriate tap on an autotransformer with multiple taps. It may also be done by moving a wiper on a continuously variable autotransformer. If the output voltage is not in the acceptable range, the servomechanism switches connections or moves the wiper to adjust the voltage into the acceptable region.

Another option, called a ferroresonant transformer or constant-voltage transformer, uses a a high-voltage resonant winding and a capacitor to produce a nearly constant average output with a varying input.

4.4.5 UPS

UPS stands for uninterrupted power supply. An UPS is formed by an inverter, battery and a switching arrangement such that power can be supplied to an appliance without disturbance even in the event of a power failure though for a limited amount of time. An UPS uses batteries and an inverter to supply AC power when main power is not available. When main power is restored, a rectifier supplies DC power to recharge the batteries. A relay is used to switch between AC ON and OFF states.

There are two main topologies of UPS- off-line and on-line.

In the off-line UPS, the load is directly connected to the AC mains. When under-voltage conditions are observed, the UPS transfers the load to the battery. When the AC mains become

normal the load is transferred back. So in case of the off-line UPS, there is a transfer of load every time there is a fluctuation in the AC mains condition. When AC becomes normal again, the UPS either becomes idle or continues to charge the battery. It is a low cost, simplified topology suitable for individual, less critical applications.

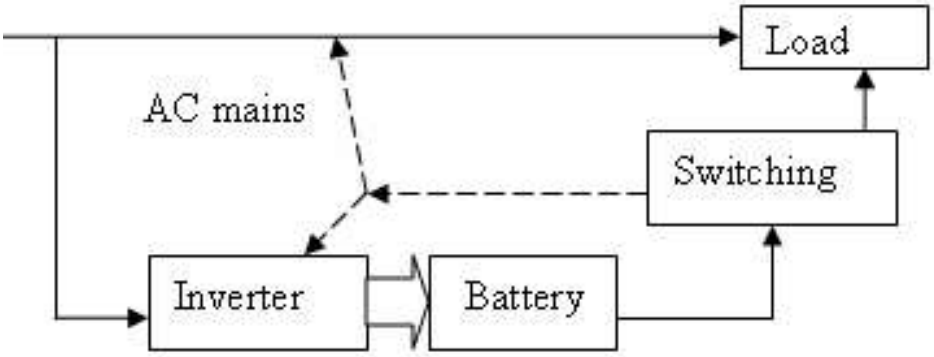


Fig. 4.10 : Off-line UPS topology

In an on-line UPS, the load is driven by the battery only irrespective of the AC mains condition. As the inverter is always on, there is no transfer of load involved. When the main power is on, it is rectified and put in parallel to the battery. As the battery delivers the power to the load, all transient related effects are removed and the power delivered to the load is a pure sine wave. The topology is complex, costly and is suitable for critical applications.

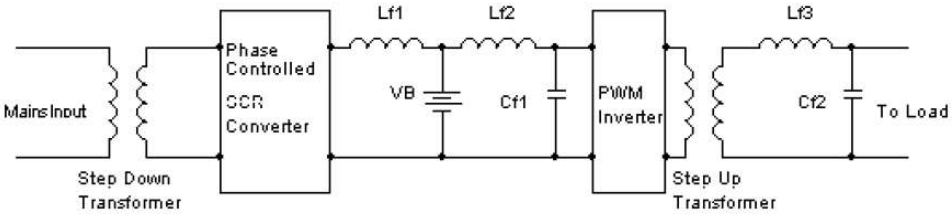


Fig. 4.11 : On-line UPS topology



CHECK YOUR PROGRESS

Q.1. Find True or False :

a) Regulated power supply is required for longevity and smooth operation of electrical appliances.

b) Battery provides AC voltage by converting chemical energy into electrical energy.

c) Electrolysis is the decomposition of a liquid compound by the passage of electric current through it.

d) Primary cells can be recharged.

e) In secondary cells, the conversion of chemical energy to electrical energy is reversible.

f) An inverter is an electrical device that converts DC to AC.

g) In a diesel generator, the process of generation of electricity by such generators is related to the rotation of a coil at constant angular velocity symmetrically between the poles of a magnet system.

h) There is an electro-mechanical process that stabilizes three-phase AC supplies.

i) In the off-line UPS, the load is indirectly connected to the AC mains.

j) In an on-line UPS, the load is driven by the battery only irrespective of the AC mains condition.

4.5 CHANGE OVER SWITCH

Changes over switches are essential for smooth transition between electric supply and back-up power systems. Change over switches ensures a smooth and uninterrupted power supply to appliances. Without these important elements power supply gets disrupted despite having back-up

facilities. These switches also ensure safety of the appliances by preventing multiple supplies. Manual change over methods are commonly seen but if not carefully handled can lead to hazardous situations.

Normally single, double and four pole changeover switches are available for domestic and specially industrial use. Application involves power from multiple sources. These are placed in deep drawn sheet steel enclosure with several current ratings normally between 15 - 100 Amps. Steel Sheet enclosures are designed with quality powder coating and are tested rigorously with anti - rust conditioning to ensure smooth and lasting finish against corrosive / humid atmosphere. Brass, phosphorus bronze, copper etc are used as contacts with heavy silver plating to improve the high conductivity and to protect from pollutants. Also porcelain materials are used as isolator media with door interlocking to ensure the safety of the personnel. The changeover switches are also provided with two external terminals to ensure complete earthing.



Fig. 4.12 : Manual change over switch

Automatic changeover switches are a bit different. These have a mechanism which uses a relay to change between states. When the electric supply is on it maybe called a state. The other can be a connection from the genset. The built-in mechanism enables the relay to be in 'On' position only while the genset is in use while functioning on main supply the relay remains in 'Off' position. There is a minimal loss in switching between states.



Fig. 4.13 : Automatic change over switch

There are advanced versions of the changeover switches as well. Automatic changeover switches with advanced features allow unrestricted supply from mains. When the main supply fails and standby generator supply is on, it connects the DG power to each consumer in sequence and starts monitoring its load. The generator current allotment is software calibrated and sealed in each auto changeover unit as per buyer's specification and is available on all load circuits. When ever the load current exceeds the allotment, power is automatically switched off for 8/10/12 seconds, and then automatically restored. Such systems are available for domestic and industrial applications.



CHECK YOUR PROGRESS

Q.2. Find True or False :

a) Change over switches ensures a smooth and uninterrupted power supply to appliances.

b) Manual change over methods are commonly seen but if not carefully handled can lead to hazardous situations.

c) When the electric supply is on it maybe called a state. The other can be a connection from the genset.

4.6 CONNECTION OF WATER-PUMP AND GEYSER

Water pump and geyser require special wiring to ensure their smooth operation.

There are pumps and geysers of varied capacities hence require different wirings. But for domestic applications both of these appliances can follow some basic guidelines. These are as follows:

- The connections must be done using a single multi-strand conductor connected directly to the switchboard from the main switch.
- The conductor must follow the power rating with appropriate insulation.

- The switch board must be properly grounded.
- All sockets must be atleast above 5 Amps rating.
- The connection should be done via fuse, MCB and isolator arrangements so that appropriate safety pre-cautions are observed.
- The mounting of the pump and the geyser should be carefully done so that these are not dislocated while being operated.

The pump has a specific electricity requirement and is related to its capacity. It must fulfill the following requirements:

- The rate of speed that water flows from the source to the discharge point, measured in liters per minute. It provides the power to move water quickly.
- The vertical distance from the water source to the pump which the appliance can handle. This ability is linked to the power rating of the pump.
- The total height from the source of the water to the destination or drainage point ensures smooth delivery of the water. This capacity determines the time required to fill-up a storage facility.

The electric connection should conform to these conditions attached to a pump. The connection should therefore ensure safe and hazard-free operation while running the pump. Accidental fire and electric shock are two possibilities if wiring is not proper.

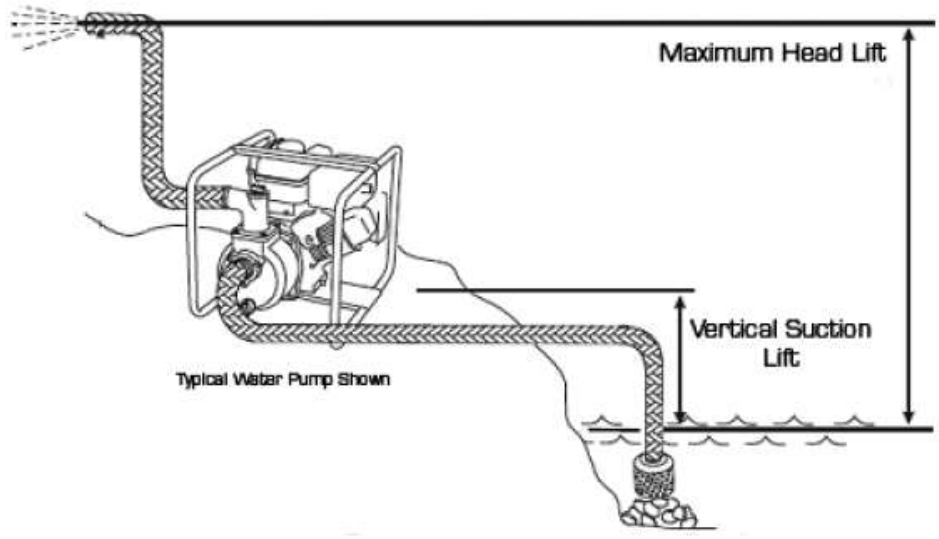


Fig. 4.14 : Water pump and its considerations

Geysers require special wiring and appropriate connection for safe and hazard –free operation.

A geyser has a heating element fitted in the side of the inner water container. The heat-generating side is submerged in water. Another key component is the thermostat unit fitted parallel to the element to control the temperature. It is done by switching the element off after the desired temperature is attained. The element is made with nickel-chrome (nichrome) wire, which is resistive in nature. When electricity flows through it, heat is generated and is used to raise the temperature of water.

The nichrome element requires atleast 5-15 Amp current flow to generate sufficient heat for domestic application. Geysers, normally, are available in 6L, 10L, 15L, 25L 35L etc capacities and heating range from 30 to 80 degree Celsius.



Fig. 4.15 : Electric geyser

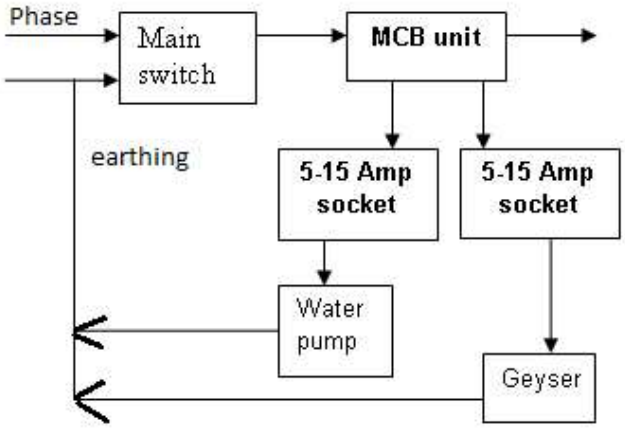


Fig. 4.16 : Electrical connection layout of water pump and electric geyser



CHECK YOUR PROGRESS

Q.3. Find True or False :

a) For water pump and geyser, The connections must be done using a single multi-strand conductor connected directly to the switchboard from the main switch.

b) A geyser has a heating element fitted in the side of the outer water container.

c) The heat-generating side is submerged in water.



4.7 LET US SUM UP

- Power conditioning appliances are essential parts of an electrical system. These are used to provide continuous supply of electric power to appliances.
- Regulated power supply is required for longevity and smooth operation of electrical appliances.
- Battery is a source of electrical power. It provides DC voltage by converting chemical energy into electrical energy. The battery doesn't hold electrical energy but a chemical process provides electrical output.
- Primary cells cannot be recharged, that is, the conversion of chemical energy to electrical energy is irreversible and the cell cannot be used once the chemicals are exhausted.
- Secondary cells can be recharged after use, that is, the conversion of chemical energy to electrical energy is reversible and the cell may be used many times.
- An inverter is an electrical device that converts direct current (DC) to alternating current (AC).

- There are two main types of inverter. These are: modified sine wave or square wave inverter and pure sine wave inverter.
- The process of generation of electricity by diesel generators is related to the rotation of a coil at constant angular velocity symmetrically between the poles of a magnet system.
- While the DG set is installed certain electrical accessories are required for smooth interaction with the AC mains. These include auto change over switches, voltage monitor relay, stop solenoid switches, electro mechanical and electronic hour meters, oil pressure sensors and switches, high water temperature sensors and related fitting accessories.
- A stabilizer is a system which is used to provide a regulated AC voltage supply to an appliance. A stabilizer is designed to automatically maintain a constant voltage level.
- UPS stands for uninterrupted power supply. An UPS is formed by an inverter, battery and a switching arrangement such that power can be supplied to an appliance without disturbance even in the event of a power failure though for a limited amount of time. UPS stands for uninterrupted power supply. An UPS is formed by an inverter, battery and a switching arrangement such that power can be supplied to an appliance without disturbance even in the event of a power failure though for a limited amount of time.
- In the off-line UPS, the load is directly connected to the AC mains. When under-voltage conditions are observed, the UPS transfers the load to the battery.
- In an on-line UPS, the load is driven by the battery only irrespective of the AC mains condition. As the inverter is always on, there is no transfer of load involved.
- Change over switches ensures a smooth and uninterrupted power supply to appliances. Without these important elements power supply gets disrupted despite having back-up facilities.
- Water pump and geyser require special wiring to ensure their smooth operation.



4.8 FURTHER READINGS

1) Process Control and Instrumentation Technology- Johnson, Pearson Education, 1st Ed., New Delhi, 2003.
2) Electrical and Electronics Measurement and Instrumentation- A. K. Sawhney, Dhanpat Rai & Co., Eleventh Ed., New Delhi, 1997.
3) Indian Electricity Rules, 1956.
4) Electrical Technology- B.L. Thareja, Khanna Publishing,
5) Electrical Technology- Edward Hughes and Ian McKenzie Smith, ELBS



4.9 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1 : a) True, b) False, c) True, d) False, e) True, f) True, g) True, h) True, i) False, j) True

Ans. to Q. No. 2 : a) True, b) True, c) True

Ans. to Q. No. 3 : a) True, b) Fase, c) True



4.10 MODEL QUESTIONS

Q.1. What are power conditioning appliances? Mention a few points to justify your answer.

Q.2. What is a battery? Describe how it works. What are its main types?.

Q.3. What are the different types of inverters? Briefly write about each of them.

Q.4. Write short notes on the following:

a) Change over switch
b) Stabilizer
c) On-line UPS
d) Secondary battery.

* * * * * * * * * *

UNIT 5 : ELECTRICAL ESTIMATION AND COSTING

UNIT STRUCTURE

5.1 Learning Objectives

5.2 Introduction

5.3 Estimating and Costing Fundamentals

5.4 Estimation of Single and Three Phase Wiring

5.4.1 Steps for Estimation and Costing of Electrical Installations

5.4.2 Costing calculations and Schedule of Rates

5.5 Estimation and Costing of House Wiring and Electrical Installations

5.6 Let Us Sum Up

5.7 Further Readings

5.8 Answers to Check your Progress

5.9 Model Questions

5.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- explain the estimation of electrical installations related to house wiring
- estimate the costing involved in materials for wiring
- estimate the costing involved in using labour for electrical wiring works
- follow proper estimation method using electrical measurements.

5.2 INTRODUCTION

Electrical installation work is a highly competitive business, as the contracts are usually given to firm that submit the lowest estimate as compared to others for an electrical work. If the prices of a contractor are too high, he will get no business due to high price. On the other hand if the prices of a contractor are too low, the low prices will lead to loss for the contractor and inferior quality of work. As a result, correct estimating is a

very important part of a running business. Thus we know that estimating is an art of calculating the quantities of various items and cost of the material and labour involved in executing the work.

5.3 ESTIMATING AND COSTING FUNDAMENTALS

Before starting to estimate practical electrical installation works, let us define what estimating is. Electrical Estimating is the process of ascertaining the approximate cost involved in wiring installations including load survey beforehand and testing after installation. Some important terms related to electrical estimating and costing are explained in the following. These are essentially required for all types of electrical estimation works.

Schedule of Material and Cost : The quantity and specifications of various materials required for the installation work, along with rate and total cost of material and cost of labour can be written in a tabular form for easy reference. This is called the schedule of material and cost. To estimate the cost involved, first the quantities of material required are calculated.

Price List : For proper estimating the cost rate or price list of various electrical materials is to be known. To prepare a price list, a market survey is carried out and quotations are collected from different manufacturers in the market. The cost of different materials in the form of a price list is prepared before actual estimation of works starts.

Labour Charges : Labour is the most difficult and variable item to assess. It is affected by so many factors such as site condition, skill and technical training, physical fitness etc. By vast experience, and proper records of time sheets, an intelligent estimator will be able to obtain labour charge values by the system of man-hour constant.

Overhead Charges : Overhead charges include general office expenses, rent, rates of lighting and heating, depreciation of furniture and office equipment. Overheads should be ascertained annually and a percentage figure obtained can be included in the estimate.

Contingencies : Contingencies include unexpected expenditure due to increase in cost rate of the material, loss due to floods or any other

reasons etc. The total cost is calculated by adding together the cost of material and cost of labour. To the total cost, overhead charges and contingencies charges are added, and thus the final cost of carrying out the installation is estimated.

Profit Purchase System : The estimate of material as prepared enables the engineer in charge of the works to procure all the items required for the installation. Purchasing of different items has to be done profitably. Enquiries are to be sent to the different manufacturers and quotations are collected from them. A comparative statement is prepared, so that the prices of the different manufacturers can be compared qualitatively also. Then the best suitable product is selected rate-wise or quality wise. The supply order is sent to the manufacturer along with an advance payment. The actual payment is done on producing the bills after the supply of materials. Such a system of purchase can be called as profit purchase system.

5.4 ESTIMATION OF SINGLE AND THREE PHASE WIRING

In the process of electrical estimation it is required to plan the electrical wiring for a wide variety of system types. The planning may also include repairing or renovating an existing system to accommodate an expansion or modification. This process can range from designing wiring systems to power a children's toy to powering an entire building or city. Due to the complexity of wiring plans, electrical estimation is typically performed by certified electrical professionals including wiremen. During the process of electrical estimation, electricians must consider many factors when planning how the system will be wired. This includes ensuring the device will have access to a large enough power supply to draw sufficient electrical energy, but not so much power that it overwhelms the system. It also requires the electrician to decide how the device will be controlled, and how users will send electrical signals through the control unit to various parts of the system. They must also be able to transport power into and

through the system while maintaining the desired appearance and aesthetic appeal.

Electricians involved in electrical estimation must also consider safety and legal requirements. When it comes to powering a building, for example, many cities have strict electrical codes in place to protect residents from electrical dangers and fire. National and international organizations also produce standards governing the use of electricity to power everything from cars to televisions. These codes are designed to prevent fires, reduce the risk of electric shock, and protect users from injury or death. Generally, electrical estimation begins when a client works with an electrician / wireman to create a set of project specifications. These documents tell the wireman how the device is intended to function. For a building, owners may specify where light fixtures and other devices should be placed and how they will be powered. For consumer electronics, the specifications may explain how the device will operate and what features it will perform.

The electrician then uses this information to create a set of technical specifications, outlining how much power will be needed for each of these tasks. He also creates wiring diagrams, showing what type of wires or conduits will be used and which way the electricity will travel. He includes information on the source of the power, the path it takes through a device or structure, and all the materials needed to complete this process. Using these documents and drawings, manufacturers or electrical contractors can then successfully wire a building, or construct an electronic device. These documents may also be required to secure permits or licenses for the product or structure. For doing all these estimations, the electrician or wireman follows some methods.

6.4.1 Steps for Estimation and Costing of Electrical Installations

The first step for estimation is Load calculation for a particular installation. The following steps are needed for Load calculation.

1. Draw the layout diagram of the building.
2. Place the points (electrical outlets) in the plan including meter, main switch (M.S.) and distribution box D.B (Distribution Box).
3. Place the D.B. at the central position of the rooms, such that the connections to each switch board (S.B.) is convenient.
4. Give all the horizontal dimensions of the rooms as well as the points in the room.
5. Also draw the wall diagram, looking from inside, for height of the points and verticak height of wires.
6. Mark the junctions of the wires as J_1 & J_2 or A, B etc. for easy calculation of wire/batten/conduit etc.
7. Now calculate the total points with the wattage. Also mention the sizes of the wires-
   a) For service connections.
   b) For domestic wiring.

For Wattage calculation the power requirement of some of the common electrical appliances are mentioned in Table-5.1.

Table 5.1 : Power requirement of some Household Appliances

Sl. No.	Appliance	Power requirement (Watts)
1	Radio	50-100 W
2	Refrigerator	100-200 W
3	Mixer Grinder	40-60 W (small) 250-450 W (big)
4	Electric iron	400-1000 W
5	Immersion heater	500-1000 W
6	Electric heater	100-200 W
7	Hair dryer	500 W
8	Electric Cooker	1200-1500 W
9	Microwave Oven	700-1500 W

10	Electric Kettles and Jugs	
	1.13 ltr	450-650 W
	1.7 ltr	800-1000 W
	2.3-3.4 ltr	1000-1400 W
11	Hot water tanks and wash boilers	
	36 ltr	3 kW
	45 ltr	4.5 kW
12	Water heater	1200-6000 W
13	Washing machine	300 W
14	Washing machine with heating	1-6 kW
15	Fluorescent lamp	
	5 ft	80 W
	4 ft	40 W
	2 ft	20 W
16	Incandescent lamp	40 W, 60 W, 100 W, 150 W, 200 W, 300 W, 500 W, 1000 W
17	Mercury discharge lamps	80 W, 125 W, 250 W, 400 W
18	Sodium discharge lamps	45 W, 60 W, 85 W, 140 W
19	Ceiling fans	
	900 mm	60 W
	1050 mm	65 W
	1200 mm	65 W
	1400 mm	70 W
20	Exhaust fan	
	230 mm	45 W
	300 mm	82 W
	380 mm	150 W

Some typical Electrical points required at different locations for a house wiring is shown in Table 5.2.

Table 5.2 : Electrical points at different locations for house wiring

Size of room	Lamp points	Fluores-cent tube	Socket (5A)	Socket (5/15A)	Ceiling fan	Ceiling fan (small)	Exhaust fan (large)
Bed room 5m X 4m	1	1	1	–	1	1	–
Bed room 6m X 4m	1	1	2	1	2	–	–
Drawing room (medium)	1	2	2	1	1	1	–
Drawing room (large)	2	2	2	1	–	2	–
Kitchen	2	–	1	–	1	–	–
Garage	1	–	1	–	1	–	–
Bath room	1	–	–	1	–	–	1
Verandah 4m X 2m	1	–	1	–	–	–	–
Verandah 4m X 3m	–	1	1	–	1	–	–

5.4.2 Costing Calculation And Schedule Of Rates

Schedule of rates (S.O.R.) is a booklet where the acceptable rates of supply materials or cost of electrical installations are written in details. It is kept by all the organizations where the same type of supply or same type of work is to be done from time to time. In all the installation work, transportation charges and labour charges are included or separately fixed with the work. A sample S.O.R. is shown below.

Table 5.3 : Sample Schedule of Rates

Sl. No.	Items	Rate	Amount (Rs.)
1	1.5 sq. mm PVC insulated Al cable	100 m	900.00
2	24 mm X 10 mm wooden batten	100 m	2900.00
3	76 mm X 28 mm thick round block wooden	100 nos.	4000.00
4	Wire man 1st grade	1 day	300.00

A sample price list based on S.O.R. including ten items is shown in Table 5.4.

Table 5.4 : Sample price list

Sl. No.	Items with specification	Units	Price (Rs.)	Remarks
1	2	3	4	5
1.	1.5 sq mm PVC insulated Al cable single core standard	100 m	900.00	
2.	1.5 sq mm PVC insulated Cu cable single core standard	100 m	1800.00	
3.	24 mm X 10 mm wooden batten	100 m	2900.00	
4.	76 m X 28 mm thick round block, wooden	100 nos.	4000.00	
5.	Wireman, 1st grade	Per day	300.00	
6.	Wiring of light point short point	3 m	700.00	With materials
7.	Wiring of switch board regulator & 5 A plug and 5 switches	Per board	500.00	Without materials
8.	Erection of earth electrode as per ISI specification	Per earth	5000.00	Without materials
9.	Fitting of fan	Per fan	500.00	-do-
10.	Fitting of tube set and so on	Per fan	350.00	-do-



CHECK YOUR PROGRESS

Q.1. Fill in the Blanks :

a) Estimation is the process of ascertaining the probable _____ involved in electrical wiring and installation with load _____ and testing.

b) The first step of estimation is to draw the _____ diagram of the building.

c) S.O.R. is a booklet where the acceptable _____ of supply materials or _____ of electrical installations are written in details.



LET US KNOW

The overhead charges are included in an estimated material and labour expenses. The amount varies from 10% to 15% to the total estimated cost. Overhead charges are divided into two categories: Maintenance overhead charges and Administrative overhead charges.



ACTIVITY

Collect the latest Schedule of Rates (S.O.R.) for both Civil and Electrical installation works as scheduled by CPWD as well as PWD department of Assam. These S.O.R.s can be used for making the table of costing. The prevailing rates of various electrical installations and labour charges are available in these S.O.R.s, which are followed by all the government and standard private organizations for their electrical project related works.

5.5 ESTIMATION AND COSTING OF HOUSE WIRING AND ELECTRICAL INSTALLATIONS

The house wiring and electrical installation estimation is a practical work. The same can be learnt from examples of some typical estimation problems. The following will be some typical examples of simple electrical installations of which the design and costing will be determined. The steps followed in the examples are self explanatory and the same steps can be

applied for estimation of any such electrical estimation and costing problem at hand.

Some thumb rules for estimation are mentioned below.

1. The load allowable for a single sub-circuit should be within 800 W. If the load for a particular sub-circuit exceeds 800 W, then a new Distribution Box (D.B.) needs to be installed for the loads to be wired from there.
2. The D.B.s are also installed in places where there is a scope of future expansion of the circuit. The new connections can then be made without exceeding the limit of 800 W for a particular sub-circuit.
3. The power factor (p.f.) can be assumed to be 1 for less inductive loads (e.g., light loads).
4. Corresponding to each single line shown in the Single Line Diagram (SLD) there will be two wires required to be estimated, as both the live and neutral wires are required for a circuit to be complete.
5. A 5% allowance is to be kept for the conduits for adjustment of the wastages.
6. Similarly, a 20% allowance is to be considered for the wires for adjusting with the wastages.

Example-1 : To estimate the quantities of material and their cost required for conduit wiring system used in a house having two rooms.

Steps : For the estimation of the quantities and determining the costing of the materials for the problem above, the following steps are taken.

The layout and single line diagram is drawn first assuming the room sizes to be 4m X 4m and height 3.5 m.

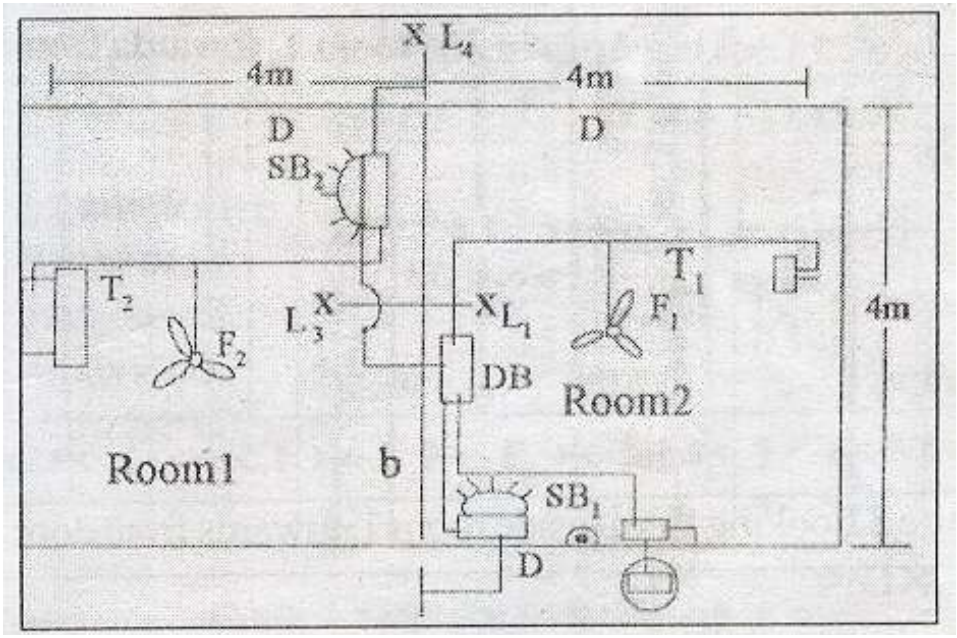


Fig. 5.1 : Layout of a house having two rooms along with the Single line diagram

From the diagram the loads are as follows:

1.	Bracket lamp (L)	4 nos. X 60 W each	=	240 W
2.	Tube light (T)	2 nos. X 40 W each	=	80 W
3.	Ceiling fan (F)	2 nos. X 60 W each	=	120 W
4.	Light plug 5 A	2 nos. X 100 W each	=	200 W
			Total =	640 W

The load is within the allowable sub-circuit load of 800 W. Still for maintenance and future extension a two-way Distribution Box (D.B.) is installed.

Current in the main circuit = 640/230 = 2.78 ~ 3 A.

Assume power factor (p.f.) = 1 for light load.

The size of the wire will be 1.5 mm^2 that can carry 10 A current. But for safety reasons the Main Switch (M.S.) to D.B. and D.B. to Switch Board (S.B.) are selected as 2.5 mm^2.

Assumption of height from the floor:

Ceiling	3.5 m
Ceiling fan	2.8 m
Light points	2.5 m
D.B.	1.8 m
M.S.	1.7 m
S.B.	1.5 m
Light plug	1.5 m

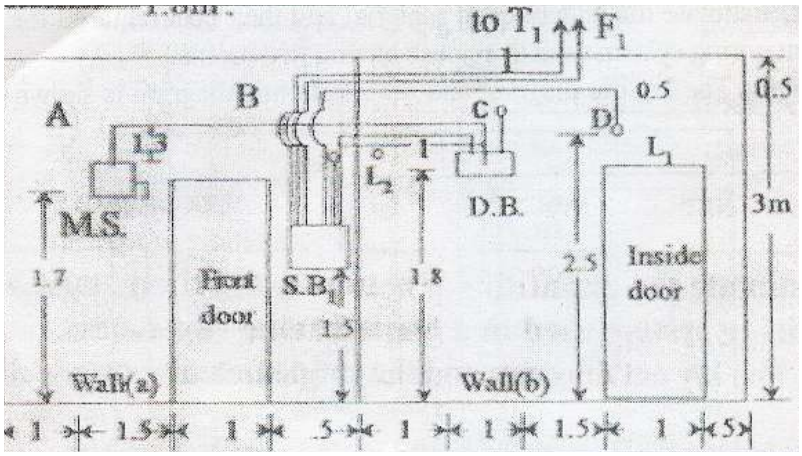


Fig. 5.2 : View from inside room 2, towards front door keeping the walls in the same plan

In Figure 5.2, the walls of room 2 are kept in the same plan. Conductors passing through walls are shown within a circle in the wall as shown at D.

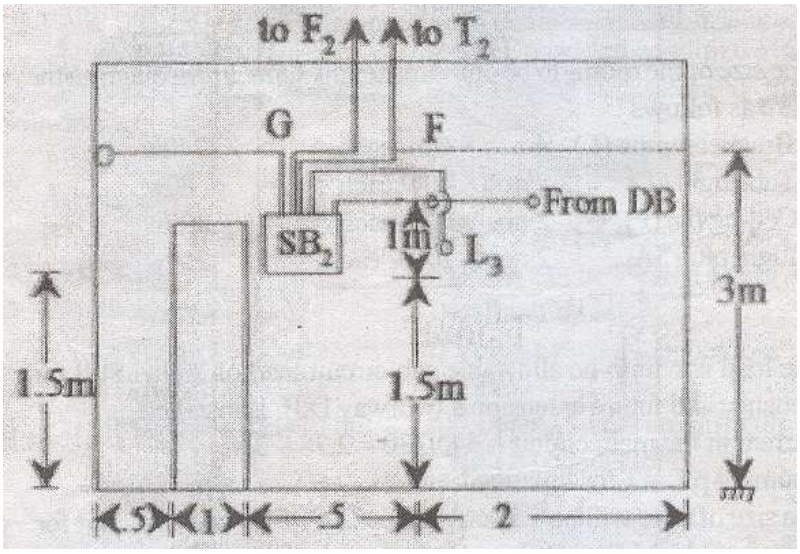


Fig. 5.3 : View from inside room 1

Calculations of conduits and wires from the figures 5.1, 5.2 and 5.3 can be done as follows:

Table 5.5 : Calculations of conduits and wires

Direction of run	Size of conduit (mm)	No. of wires	Conduit length			Wire Size	Length in (m)	Remarks
			Vertical (m)	Horizontal (m)	Total (m)			
MS to B	13 mm	2	1.3	2.5	3.8	2.5	3.8×2=7.6	
D to L1		2	0.5	-	0.5	1.5	0.5×2=1	
D to F1		4	0.5	2	2.5	1.5	2.5×4=10	
F1 to T1		2	0.5	2	2.5	1.5	2.5×2=5	
B to L2		2	0.5	–	0.5	1.5	0.5×2=1	
G to L4		2	0.5	1.5	2	1.5	2×2=4	
F to F2		2	0.5	2	2.5	1.5	2.5×4=10	
F2 to T2		2	2.5	2	2.5	1.5	2.5×2=5	
SB1 to B	50 mm	5 + 2	1.5	–	1.5	1.5	1.5×5=7.5	
						2.5	1.5×2=3	
B to C		6 + 4	1.5	1.5	1.5		1.5×6=9	
						2.5	1.5×4=6	
C to DB		6	–	1	1	1.5	1×6=6	
SB2 to G		8 + 2	1.5	–	1.5	1.5	1.5×8=12	
						2.5	1.5×2=3	
G to F		6 + 2	–	0.5	0.5	2.5	0.5×2=1	
						1.5	0.5×6=3	
F to L3		2	0.5	–	0.5	1.5	0.5×2=1	
F to F2		4	0.5	2	2.5	1.5	2.5×4=10	

From the above table–

Total quantity of 13 mm dia conduit required = 16.8 m.

Total quantity of 50 mm dia conduit required = 9.5 m.

Total quantity of 1.5 mm^2 dia wires required = 85 m.

Total quantity of 2.5 mm^2 dia wires required = 20.6 m.

Considering 5% allowance and wastage, the total length of conduit will be–

(a) 13 mm dia PVC conduit = 18 m (say)

(b) 50 mm dia PVC conduit = 11 m (say)

Considering 20% allowance and wastage, the total length of wires will be–

(c) 1.5 mm^2 = 84.5 + 20 % allowance = 113 m (say)

(d) 2.5 mm^2 = 20.6 + 5 % allowance = 22 m (say)

The estimated quantity and cost of the materials is shown in the table below.

Table 5.6 : Schedule of materials and cost

Sl. No.	Item with specification	Quantity	Cost		Remark
			Rate (Rs./ quantity)	Amount (Rs.)	
1.	PVC conduit 50 mm dia	11 m	144.50/m	1590.00	
2.	PVC conduit 13 mm dia	18 m	80.00/m	1440.00	
3.	PVC wire, 2.5 mm^2, single core, 3 strand, 250 V Al conductor	22 m	41.00/m	900.00	
4.	PVC wire, 1.5 mm^2, single core, 3 strand, 250 V Al conductor	113 m	30.00/m	3390.00	
5.	Earth wire 14 S.W.G. Al	30 m	160.00/kg	80.00	
6.	Earth wire 8 S.W.G. GI	6 m, 0.6 kg	250.00/kg	150.00	10 m = 1 kg
7.	Metal Saddle 25 mm	½ doz.	20.00/pcs	120.00	
8.	Metal Saddle 20 mm	1 doz.	20.00/pcs	240.00	
9.	Metal Saddle 13 mm	50 Nos.	20.00 /pcs	1000.00	
10.	Counter shunk wood screw 3.18X8 S.W.G.	68×2–136=12doz.	380.00/pkt	380.00	
11.	Spacing insulator	136=12 doz.	30.00/doz	360.00	
12.	Wooden Gutties	12 doz.+ 2 doz.	40.00/gros	40.00	2 doz. For switch board & earthwire

13.	(a) PVC junction box 2-way 20 mm (b) PVC junction box 25X25X13 mm (c) PVC junction box 25X20X20 mm (d) PVC junction box 4 way 20X12X13 mm	2 Nos. 1 No. 1 No. 1 No.	70.00	350.00	
14.	PVC dends 13 mm	1 doz.	60.00 /pcs.	720.00	
15.	(a) Earth set complete (b) Charcoal (c) Common salt (d) Cement concrete	 10 kg 10 kg 0.25 m^3	 70.00 /kg 7.00 /kg 6000.00/m^3	2630.00 700.00 70.00 1500.00	
16.	DPIC main switch, 15 A, 250 V, with neutral link and earth terminal	1 No.	600.00/pcs.	600.00	
17.	LCAB with N.L. 2 way	4 Nos.	400./pcs	1600.00	
18.	Teak wood switch board 20 cm X 25 cm with bakelite cover	4 Nos.	600.00/pcs.	2400.00	2 for SB1 and SB2, 2 for MS and DB
19.	Flush switch 5 A, 250 V one way	10 Nos.	150.00/pc.	1500.00	
20.	Flush socket 5 A, 250 V	2 Nos.	140.00 /pc	280.00	
21.	Ceiling roses, 2 plate, bakelite	4 Nos.	28.00/pc	112.00	
22.	Bakelite lamp with holder brass	4 Nos.	200.00 /pc	800.00	2 watertight
23.	Teak wood round block double	8 Nos.	50.00 / pc	400.00	
24.	Tube light set 40 W, 250 V with electronics chokes	2 set	320.00 / set	640.00	
25.	Ceiling fan, 3-blade, 1400 sweep	2 Nos.	1200.00/set	2400.00	

26.	Machine screws 25/30 mm long	3 doz.	10.00/doz	30.00	For each socket, ceiling rose, lamp etc.
27.	Machine screw 15 mm for S.B. bakelite sheet	2 doz.	6.00/doz	12.00	
28.	Labour charge for light point Labour charge for S.B., D.B., main fitting Labour charge for earthing	8 pt 4 pt 1 pt	60.00 /pt 80.00/pt 400.00	480.00 320.00 400.00	
29.	Cement, varnish, tape	Ls		1000.00	

Total **Rs. 28,634.00**

Miscellaneous expenses @ Rs. 10% of the total including supervision charges and profits = Rs. 2,863.00.

Therefore, Grand Total = Rs. 28,634.00 + Rs. 2,863.00 = 31,497.00.

(Rupees Thirty One Thousand Four Hundred Ninety Seven only)

N.B.: The rates of various items are indicative only. The actual rates are to be collected from the available schedule of rates from State PWD department and also from quotations obtained from some standard shops.

This is how the calculations are made for a particular house wiring or any other electrical installation work. The required materials list varies from place to place and from project to project. The same may be prepared only after consultation with the user for which the estimation is done.

Some of the general abbreviations used in the estimation tables and sheets are listed below.

L.V. – Low Voltage
H.V. – High Voltage
P.C.C – Pre Stressed Cement Concrete (Pole)
R.C.C – Reinforced Cement Concrete (Pole)
P.G. – Parallel Grooved (Clamp)
G.I. – Galvanised Iron (Wire)

S.W.G. – Standard Wire Gauge
R.S.J. – Reinforced Steel Joint (Pole for 11kV, 33kV etc.)
M.S. – Main Switch
D.B. – Distribution Box
Ph. – Phase line
N – Neutral line
Cu – Copper
P.V.C – Poly Vinyl Chloride
MΩ – Mega Ohms (10^6 units of resistance)
kΩ – Kilo Ohms (10^3 units of resistance)
W – Watt (Unit of Power)
(W) – Wattmeter
kW – Kilo Watts (10^3 units of power)
Amp – Ampere (Unit of Current), sometimes also written as A
(A) – Ammeter
V – Volts (Unit of potential difference or Electric pressure)
(V) – Voltmeter



CHECK YOUR PROGRESS

Q.2. Fill in the blanks :

a) The house wiring and electrical installation estimation is a _____ work.
b) The load allowable for a single sub-circuit should be within _____ W.
c) The power factor (p.f.) can be assumed to be _____ for less inductive loads.
d) S.W.G. stands for _____.
e) Distribution Box is abbreviated as _____.



ACTIVITY

Estimate the costing involved in electrical wiring and lighting of the house where you stay, considering the house to be newly electrified.



6.6 LET US SUM UP

In this unit we have explained to you–

- Electrical Estimating is the process of ascertaining the approximate cost involved in wiring installations including load survey beforehand and testing after installation.
- To estimate the cost involved, first the quantities of material required are calculated.
- For proper estimating the cost rate or price list of various electrical materials is to be known.
- Electricians involved in electrical estimation must also consider safety and legal requirements.
- The first step for estimation is Load calculation for a particular installation.
- Schedule of rates (S.O.R.) is a booklet where the acceptable rates of supply materials or cost of electrical installations are written in details.
- The electrical estimation and costing is a practical work which can be learnt from practice.
- The list of materials required as well as labour involved is to be determined first.
- The costing involved in purchasing the materials as well as in installation is to be determined in tabular form.
- The total cost is determined after considering the overheads.



5.7 FURTHER READINGS

1) Raina K. B., Bhattacharya S. K., *Electrical Design Estimating and Costing*, New Age.
2) Dutta S.N., *Electrical Costing, Estimating and Contracting*



5.8 ANSWERS TO CHECK YOUR PROGRESS

Ans. to Q. No. 1 : a) cost, survey, b) layout, c) rates, cost

Ans to. Q. No. 2 : a) practical, b) 800, c) 1, d) Standard Wire Gauge, e) D.B.



5.9 MODEL QUESTIONS

Q.1. Define Electrical Estimating and Costing.

Q.2. What is Schedule of Rates and why is it required for Electrical Estimating?

Q.3. What are the steps involved in Estimation of any electrical installation work?

Q.4. Give details of some assumptions made before estimating a house wiring work.

Q.5. What are overhead charges? How much overhead should normally be considered while estimating?

Q.6. A residential house of one drawing room, one bed room, one kitchen and one verandah of suitable size is to be electrified. Draw the line diagram and estimate the quantity of materials involved in the electrical installation.

Q.7. What are the requirements that should be available to prepare an electrical estimate?

Q.8. Write short notes on:

a) Schedule of material and cost
b) Contingencies
c) Profit Purchase System