ELECTRICIAN

TRADE THEORY

NSQF LEVEL - 4.5

VOLUME - 1

HANDBOOK FOR CRAFTS INSTRUCTOR TRAINING SCHEME

कौशलं बलम्
Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
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A Comprehensive Training Program
under Crafts Instructor Training Scheme (CITS)
for Instructors

HANDBOOK ON TECHNICAL INSTRUCTOR TRAINING MODULES

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सत्यमेव जयते

भारत सरकार
कौशल विकास एवं उद्यमिता मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT AND ENTREPRENEURSHIP

Foreword

In today's rapidly evolving world, the role of skilled craftsmen and women is more crucial than ever. The Craft Instructor Training Scheme (CITS) stands at the forefront of this transformation, shaping the educators who will train the next generation of artisans and technicians. This book aims to provide an in-depth understanding of the subject, exploring its significance, methodologies, and impact on vocational training.

The Craft Instructor Training Scheme was established with the objective of enhancing the quality of instruction in industrial training institutes and other vocational training institutions. By equipping instructors with advanced skills and knowledge, the scheme ensures that they are well-prepared to impart high-quality training to their students. This, in turn, contributes to the creation of a highly skilled workforce capable of meeting the demands of modern industry.

The initial chapters provide the importance of specialized instructor training. Following this, detailed chapters delve into the curriculum covering advanced techniques, safety protocols, and instructional strategies. Each section is designed to offer both theoretical insights and practical applications, ensuring a well-rounded understanding of the subject.

The book offers recommendations for overcoming obstacles and enhancing the effectiveness of the program, with the ultimate goal of producing highly skilled instructors capable of shaping the future workforce.

This book is intended for a diverse audience, including current and aspiring instructors, vocational training administrators, policymakers, and industry stakeholders. It serves as a valuable resource for understanding the intricacies of the subject and its pivotal role in vocational education.

I extend my heartfelt gratitude to all contributors who have shared their experiences and expertise, enriching this book with their valuable insights. Special thanks to the contribution of the development team, reviewers and NIMI that have supported this endeavor, providing essential data and resources.

It is my sincere hope that this book will inspire and guide readers in their efforts to enhance vocational training, ultimately contributing to the development of a skilled and competent workforce.

ATUL KUMAR TIWARI, I.A.S.
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DIRECTORATE GENERAL OF TRAINING

FOREWORD

The Craftsmen Training Scheme (CTS) implemented by the Directorate General of Training (DGT) provides skill training to the youth and ensures a steady flow of skilled manpower for the industry. It aims to raise quantitatively and qualitatively the industrial production by systematic training, and to reduce unemployment among the youth by providing them with employable skills.

The Craft Instructor Training Scheme (CITS) is an indispensable part of the Craftsmen Training Scheme (CTS). It offers comprehensive training both in 'skills' and in 'training methodology' to the instructor trainees to make them conversant with techniques of transferring hands-on skills.

I congratulate NIMI for taking the initiative of preparation of the course content for CITS. This will help institutionalize the mechanism for imparting training to the trainers all across the ecosystem. I also extend my gratitude to the Instructors and Officials of National Skill Training Institutes (NSTIs) and the DGT for their invaluable contribution in preparation of the CITS course content.

As we navigate the complexities of a rapidly changing world and the technological disruptions, the significance of CTS and CITS has increased manifold. It not only empowers individuals with practical skills but also lays the foundation for a prosperous future. I am confident that this book will serve as a guiding light to all instructor trainees for skill development and nation-building.

(Trishaljit Sethi)

PREFACE

The Craft Instructor Training Scheme is an indispensable module of the Craftsmen Training Scheme, which has been an integral part of the Indian skill development industry since its inception. This program aims to equip instructors with the necessary skills and teaching methodology to effectively transfer hands-on skills to trainees and promote a holistic learning experience. The first Craft Instructor Training Institute was established in 1948, followed by six more institutes across India in 1960. Today, these institutes, including the National Skill Training Institute (formerly Central Training Institute for Instructors), offer the CITS course, which is mandated by the Directorate General of Training (DGT).

The Craft Instructor training program is designed to develop skilled manpower for industries. The course aims to offer instructors an opportunity to improve their instructional skills, engage learners effectively, offer impactful mentoring, and make efficient use of resources, leading to a more skilled workforce in various industries. The program emphasizes collaborative and innovative approaches to teaching, resulting in high-quality course delivery. Overall, the Craft Instructor Training Scheme is a pivotal program that helps instructors grow in their careers and make a significant contribution to society. This program is essential for developing skilled manpower and promoting a robust learning environment that benefits both trainees and instructors alike.

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following experts to bring out this Instructional material **(Trade Theory)** for **CITS Electrician (Common for Wireman) (Volume - I of II) (NSQF Level - 4.5)** under the **Power** Sector for **Instructors**.

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

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

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

ABOUT THE TEXT BOOK

The Vocational Instructor Training Program is a comprehensive initiative designed to equip aspiring students with the necessary skills and knowledge to effectively teach in vocational education settings. This program encompasses a range of pedagogical strategies, instructional techniques, and subject-specific content tailored to the diverse vocational fields. Participants engage in coursework that covers curriculum development, assessment methods, classroom management, and the integration of industry-relevant technologies. Practical experience and hands-on training are emphasized, allowing participants to apply theoretical concepts in real-world teaching environments. Through collaborative learning experiences and mentorship opportunities, aspiring vocational instructors develop the confidence and competence to facilitate engaging and impactful learning experiences for their students. This training program aims to cultivate a new generation of educators who are not only proficient in their respective vocational fields but also adept at fostering the success and employability of their students in today's competitive workforce.

This text book covers communication, self-management, information and communication technology, entrepreneurial and green skills. It has been developed as per the learning outcome-based curriculum.

G C Rama Murthy,
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CONTENT

MODULE 1 : Safety Practices

LESSON 1- 4: Safety rules - safety signs

Objectives

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

- explain the necessity of safety rules
- explain how to treat a person for electric shock/injury
- state the effects of a fire break out and causes of fire in workshop
- state the methods of operation of fire extinguishers of extinguishing of fire
- list the tools necessary for an electrician.

Electricity is invisible: Therefore, while working in electrical installations one should always first take care of one's own safety. A little carelessness can result in an accident, which many times can be fatal. Therefore, electricity needs certain precautions of handling it to avoid danger. The following "Do Nots" (precautions) should always be observed before starting work on electrical equipment and apparatus :

i Do not forget that electric shocks are generally received by the worker and can be avoided. Be careful.

ii Do not forget to put off the main switch (if near it) in the case of a person still in contact with a live conductor or apparatus.

iii Do not attempt to disengage a person in contact with a live apparatus which you cannot switch off immediately. Insulate yourself from the earth by standing on a rubber mat or dry board of wood before attempting to get him clear. Even then do not touch his body; push him clear with a piece of dry wood.

iv Make sure electrical equipment is properly connected, grounded and in good working order.

v Do not access, use or alter any building's electrical service, including circuit breaker panels, unless you are specifically qualified and authorized to do so.

vi Always switch-off before replacing a blown fuse.

vii Replace the fuse according to the capacity. Don't wire it for more capacity than it is desired.

viii In case of electrical wire, put the main switch off immediately if you can do it, never throw water on the fire or the live conductor. It is dangerous because water is good conductor of electricity. Throw dry sand or dust on the fire. Use fire extinguisher but before use make sure that it is suitable for that purpose. Liquid CO2 or CCL4 extinguisher or general ly use.

ix Do not forget to put on your safety belt before starting work on a pole. If a ladder is used, it must be held by another person to avoid slipping.

x Do not forget to discharge the overhead lines by earthing or by other suitable means.

xi Do not forget to connect a switch on a live conductor.

xii Do not forget to earth all metallic coverings of the electrical wiring installation.

xiii Do not add water to acid while preparing an electrolyte. Always add acid to water.

xiv Do not bring a naked flame near an accumulator. Also keep the room where the accumulator is housed well ventilated.

xv Do not forget that safety depends upon good earthing; so always keep the earth connections in a good condition.

Rescue of person who is in contact with live wire (Fig 1)

When a person comes in contact with a live wire, the electric current starts flowing through the body to the earth. The value of the current depends upon the voltage, more voltage more current and less voltage less current. The current flowing through the body, sometimes the current is high and the heart stops its working and the person cannot breath, so when a person comes in contact with the live wire and is suffering from the electric shock, the following steps must be taken.

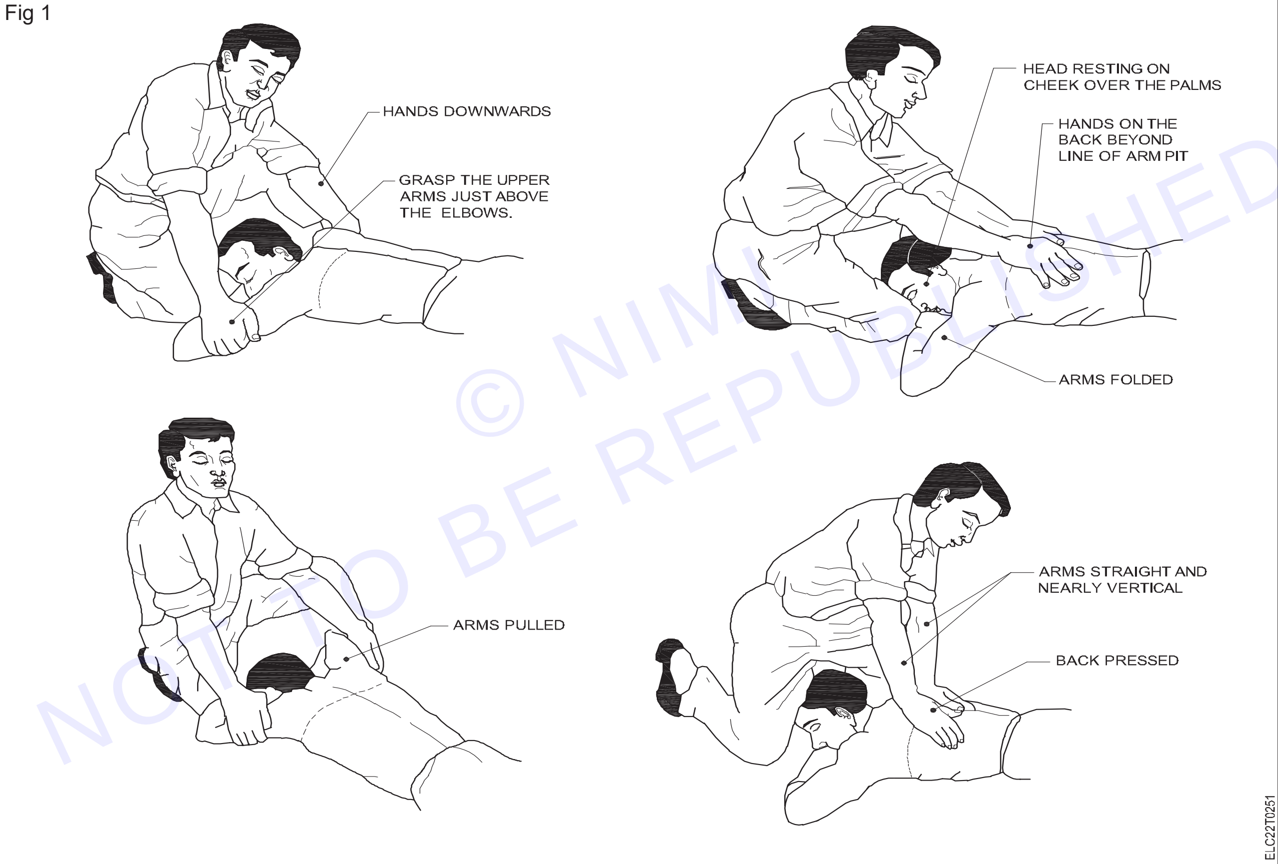
i Removal from the electric shock – If a person is in contact with the live conductor, put the main switch off; if it is near and with in approach. If you cannot switch off immediately then insulate yourself on a wooden article like chair, table or any board etc. And pull the patient from the conductor. If it is not possible then use a dry coat or rope to remove the patient from the contact of electricity.

ii Extinguish the spark if any,and send for doctor immediately or inform the nearewst power house or sub-station.

iii Mean while the doctor comes try for artificial respiration.

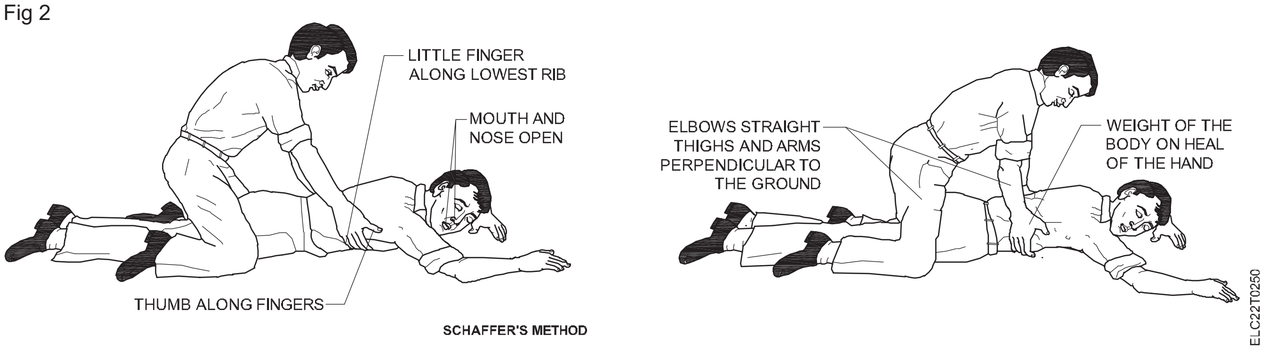
Rescue of person who is in contact with live wire. Treat a person for electric shock/injury.

Fig 1



Schaffer's method (Fig 2)

Fig 2



Neilson's method

Mouth to nose method (Fig 3)

Fig 3

Safety practice - Safety signs

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

- state the responsibilities of employer and employees
- state the safety attitude and list the four basic categories of safety signs.

Responsibilities

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

Employer's responsibilities

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

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

Employee's responsibilities

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

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

Rules and procedure at work

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

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

Safety signs

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

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

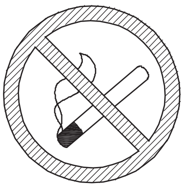
The four basic categories of signs are as follows:

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

- **Prohibition Signs:**

Prohibition signs

Fig 1



Prohibition signs	SHAPE	Circular
	COLOUR	Red border and cross bar. Black symbol on white background
	MEANING	Shows it must not be done
	Example	Nosmoking

- **Mandatory Signs:**

Mandatory signs

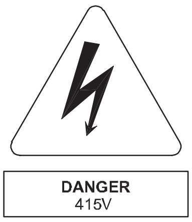
Fig 2

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

- **Warning Signs:**

Warning signs

Fig 3



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

- **Information Signs:**

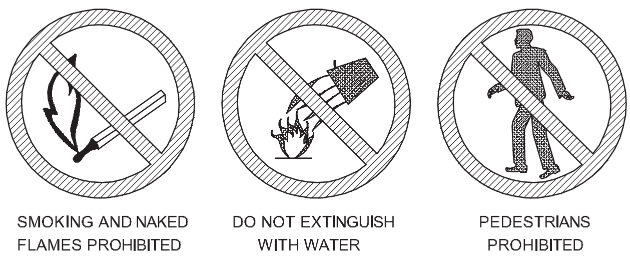
Information signs

Fig 4

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

Prohibition signs

Fig 5



Mandatory signs

Warning signs

Fig 6

MANDATORY SIGNS

Fig 7

WARNING SIGNS

ELC22T0255

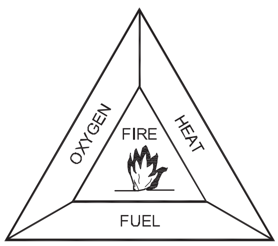
Fire - Types - Extinguishers

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

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

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

Fig 1



ELC22T0256

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

Heat: Every fuel will begin to burn at a certain temperature. It varies and depends on the fuel. Solids and liquids give off vapour when heated, and it is this vapour which ignites.

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

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

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

Removing any one of these factors will extinguish the fire.

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

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

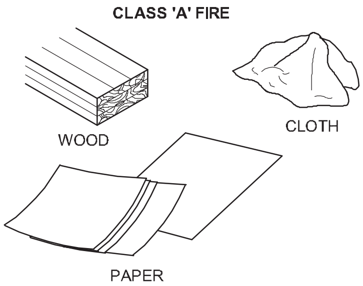
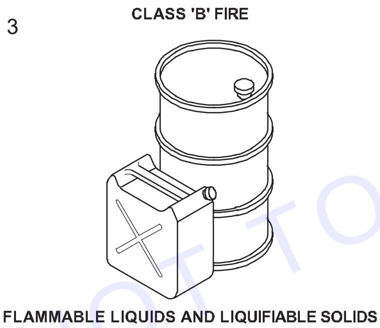
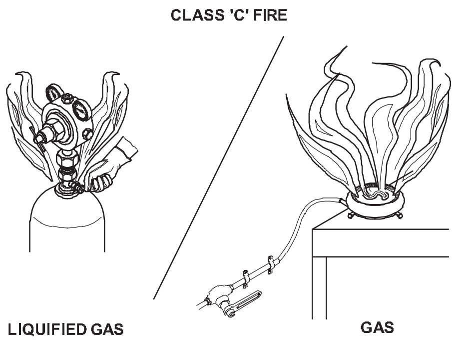
Fire Classification and Fuel	Extinguishing Method
Fig 2 	Most effective ie., cooling with water. Jets of water should be sprayed on the base of the fire and then gradually upwards.
Fig 3 	**Should be smothered :** The aim is to cover the entire surface of the burning liquid. This has the effect of cutting off the supply of oxygen to the fire. Water should never be used on burning liquids. Foam, dry powder or CO2 may be used on this type of fire.
Fig 4 	Extreme caution is necessary in dealing with liquefied gases. There is a risk of explosion and sudden outbreak of fire in the entire vicinity. If an appliance fed from a cylinder catches fire - shut off the supply of gas. The safest course is to raise an alarm and leave the fire to be dealt with by trained personnel. Dry powder extinguishers are used on this type of fire.

Fig 5

Special powders have now been developed which are capable of controlling and/or extinguishing this type of fire.

The standard range of fire extinguishing agents is inadequate or dangerous when dealing with metal fires.

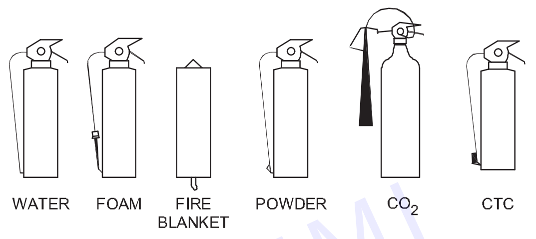
Fire on electrical equipment.

Halon, Carbon dioxide, dry powder and vapourising liquid (CTC) extinguishers can be used to deal with fires in electrical equipment. Foam or liquid (eg. water) extinguishers must not be used on electrical equipment under any circumstances.

Types of Fire Extinguisher

Many types of fire extinguishers are available with different extinguishing 'agents' to deal with different classes of fires. (Fig 6)

Fig 6



Water-filled extinguishers: There are two methods of operation. (Fig 7)

- Gas cartridge type
- Stored pressure type

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

Foam extinguishers (Fig 8): These may be of stored pressure or gas cartridge types.

Most suitable for

- flammable liquid fires
- running liquid fires

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

Fig 7

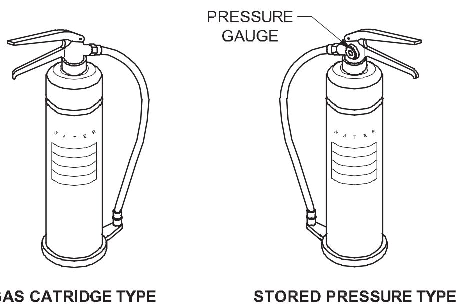
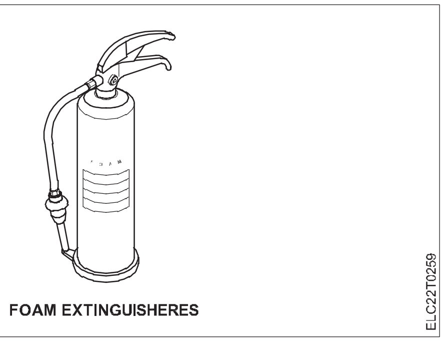


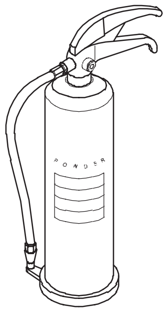
Fig 8



Dry powder extinguishers (Fig 9): Extinguishers fitted with dry powder may be of the gas cartridge or stored pressure type. Appearance and method of operation is the same as that of the water-filled one. The main distinguishing feature is the fork shaped nozzle. Powders have been developed to deal with class D fires.

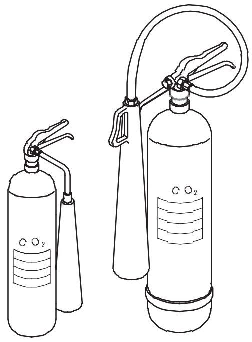
Carbon dioxide (CO_2): This type is easily distinguished by the distinctively shaped discharge horn. (Fig 10).

Fig 9



DRY POWDEER EXTINGUSHERS

Fig 10



CARBAN DIOXIDE(CO_2)

ELC22T0260

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

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

The general procedure in the event of a fire:

- Raise an alarm.
- Turn off all machinery and power (gas and electricity).
- Close the doors and windows, but do not lock or bolt them. This will limit the oxygen fed to the fire and prevent its spreading.
- Try to deal with the fire if you can do so safely. Do not risk getting trapped.
- Anybody not involved in fighting the fire should leave calmly using the emergency exits and go to the designated assembly point.
- Analyze and identify the type of fire. Refer Table1.

Table 1

Class 'A'	Wood, paper, cloth, solid material
Class 'B'	Oil based fire (grease, gasoline, oil) liquifiable gases
Class 'C'	Gas and liquifiable gases
Class 'D'	Metals and electrical equipment

Fire extinguishers are manufactured for use from the distance.

Caution

- **While putting off fire, the fire may flare up**
- **Do not be panick belong as it put off promptly.**
- **If the fire doesn't respond well after you have used up the fire extinguisher move away yourself away from the fire point.**
- **Do not attempt to put out a fire where it is emitting toxic smoke leave it for the professionals.**
- **Remember that your life is more important than property. So don't place yourself or others at risk.**

In order to remember the simple operation of the extinguisher. Remember P.A.S.S. This will help you to use the fire extinguisher.

P for Pull

A for Aim

S for Squeeze

S for Sweep

Personal Protective Equipments (Fig 11)

Fig 11

Fire fighting equipments

There are many different types of firefighting equipment. Some of this equipment can be used by anyone, while others must be operated by a member of the fire brigade.

Here is an overview of the different types of firefighting equipment that are currently available.

Fire extinguishers (Fig 12)

A fire extinguisher should never be used to prop open a door. It should always be fixed to the wall, and it should be checked monthly by a service technician.

Most modern fire extinguishers are developed to deal with many different fire scenarios. Fire extinguishers can be filled with powder, water additive, foam, or carbon dioxide. Liquid CO2 or CCL4 extinguisher or general ly use for electrical fire.

When choosing a fire extinguisher, be sure to pick one that will fight the fires that are most likely to develop in your business or home.

Fig 12

Fire hoses (Fig 13)

The fire hose reel lets out a powerful stream of water that extinguishes large fires. The hoses usually come in a fire hose reel, which holds 30 metres of tubing.

This makes the hose easy to unravel so a fire can be fought quickly. Fire brigades can also attach different nozzles to the end of the hose to fight a variety of fire situations.

A fire hose is one of the standard types of fire-fighting equipment, and it is effective against even the largest fires.

Fig 13

Fire buckets (Fig 14)

A fire bucket is considered the simplest piece of firefighting equipment, but still serves a purpose. The standard red bucket has the word ‘Fire’ written on it and it is made of metal or plastic.

It can be filled with sand, water or you can fill it with a flame smothering powder like Flamezorb. To use, dump the bucket over the fire and keep repeating the process until the fire is out.

Fig 14

Fire welding blankets

Fire blankets are used to smother small fires that start in the workplace or at home. Economy fire blankets or white kitchen blankets are a good choice for a small kitchen or for a caravan.

A larger workshop or restaurant kitchen should have a 1.2m x 1.2m blanket in case of emergencies.

If you work in a commercial kitchen or in a place that stores flammable liquids, you’ll want the large 1.8m x 1.75m fire blanket. These blankets have a special pull tab that allows you to open them quickly.

Welding blankets are used to protect welders from sparks and splatter. These blankets come in three different weights and sizes.

Using firefighting equipment

It’s important to have fire safety equipment at hand both at home and at work. You never know when a fire is going to start, so having a fire bucket, fire blanket, or fire extinguisher could save your life.

It’s also important to remember that things like a fire hose, firefighting foam Equipment, and dry risers can only be used by trained members of a fire brigade.

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

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

- list the tools necessary for an electrician
- specify the tools and state the use of each tool.

It is important that the electrician uses proper tools for his work. The accuracy of workmanship and speed of work depend upon the use of correct tools.

Listed below are the most commonly used tools by electrician.

Pliers

The pliers used for electrical work will be of insulated grip.

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

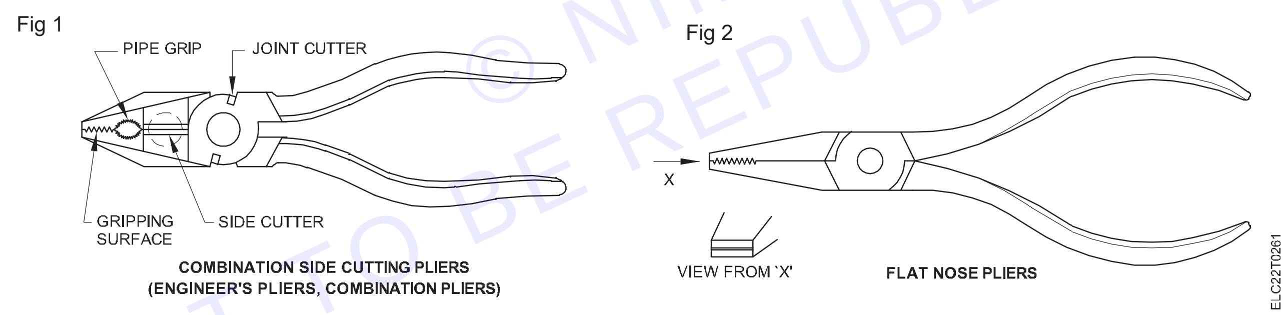
Size 150 mm, 200 mm etc.

It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work.

2 Flat nose pliers BIS 3552 (Fig 2)

Size 100 mm, 150 mm, 200 mm etc.

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



3 Side cutting pliers (Diagonal cutting pliers) BIS 4378 (Fig 3) Size 100 mm, 150 mm etc.

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

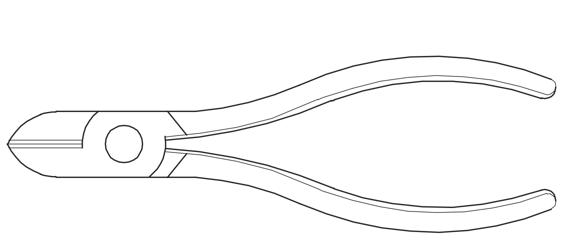
4 Screwdriver BIS 844 (Fig 4)

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

eg. 150 mm x 0.6 mm x 4 mm

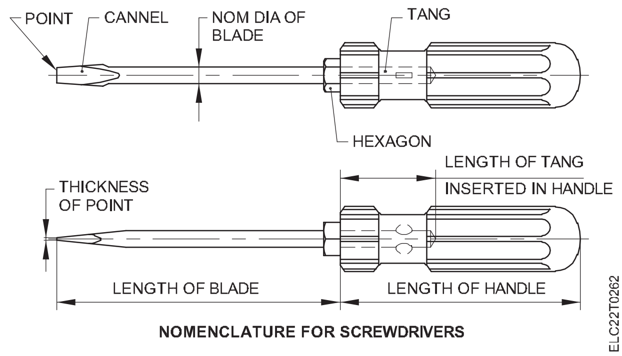
200 mm x 0.8 mm x 5.5 mm etc.

Fig 3



DIAGONAL CUTTING PLIERS/NIPPER

Fig 4



NOMENCLATURE FOR SCREWDRIVERS

The handle of screwdrivers is either made of wood or cellulose acetate.

5 Neon tester BIS 5579 - 1985 (Fig 5)

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

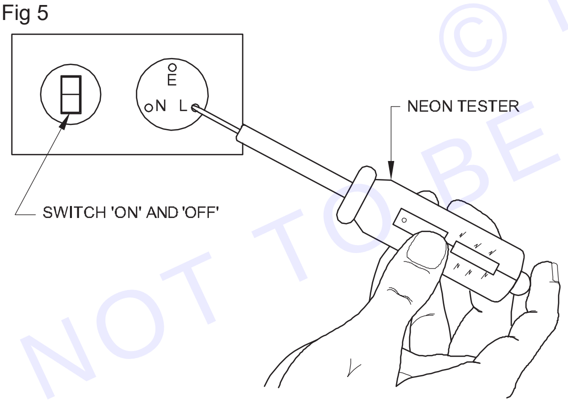
It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amps at the maximum voltage, a high value resistance is connected in series with one of the electrodes.

6 Electrician's knife (Double blade) (Fig 6)

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

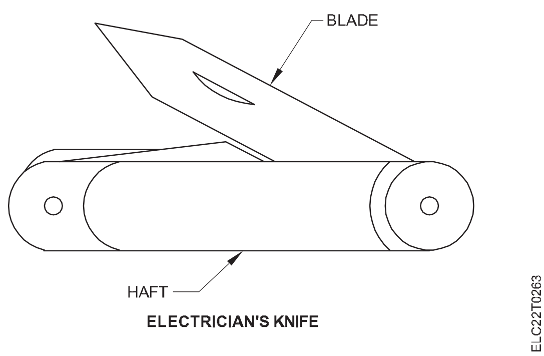
It is used for skinning the insulation of cables and cleaning the wire surface. One of the blades which is sharp is used for skinning the cable.

Fig 5



NEON TESTER

Fig 6



ELECTRICIAN'S KNIFE

7 Hammer ball pein (Fig 7)

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

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

8 Try-square (Engineer's square) (Fig 8) BIS 2103

This is specified by its blade length.

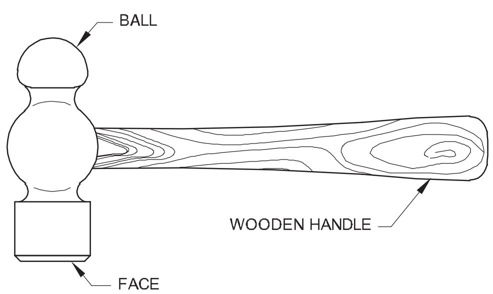
Eg. 50 mm x 35 mm

100 mm x 70 mm

150 mm x 100 mm etc.

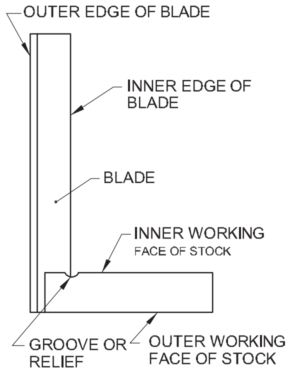
Do not use it as a hammer.

Fig 7



BALL PEIN HAMMER

Fig 8



TRY-SQUARE

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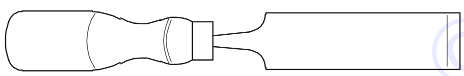
9 Firmer chisel (Fig 9)

It has a wooden handle and a cast steel blade of 150 mm length. Its size is measured according to the width of the blade eg. 6 mm, 12 mm, 18 mm, 25 mm. It is used for chipping, scraping and grooving in wood.

10 Tenon-saw (Fig 10) BIS 5123, BIS 5130, BIS 5031

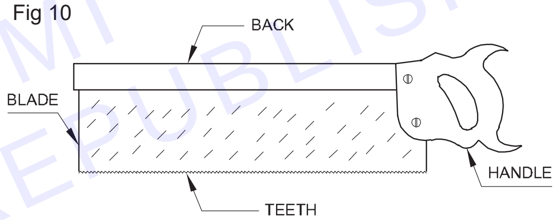
Generally the length of a tenon-saw will be 250 or 300 mm. and has 8 to 12 teeth per 25.4 mm and the blade width is 10 cm. It is used for cutting thin, wooden accessories like wooden batten, casing capping, boards and round blocks.

Fig 9



FIRMER CHISEL

Fig 10



TENON-SAW

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11 Files (Fig 11) BIS 1931

These are specified by their nominal length.

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

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

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

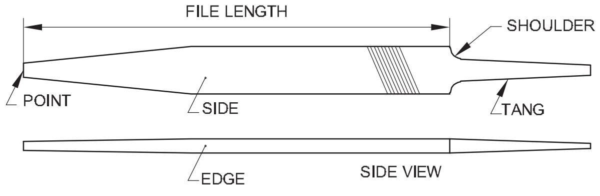
12 Bradawl square pointed (or poker) (Fig 12)

BIS 10375 - 1982

It is specified by its length and diameter eg. 150 mm x 6 mm.

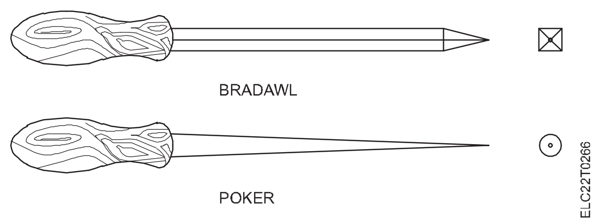
It is a long sharp tool used for making pilot holes on wooden articles to fix screws.

Fig 11



FILE

Fig 12



13 Centre punch (Fig 13) BIS 7177

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

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

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

14 Mallet (Fig 14)

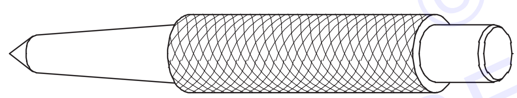
The mallet is specified by the diameter of the head or by the weight.

eg. 50 mm x 150 mm

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

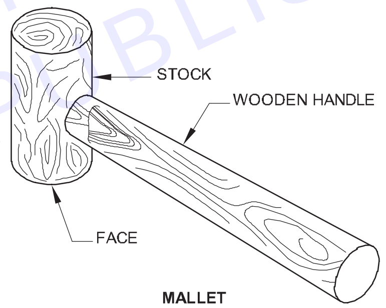
It is made out of hard wood or nylon. It is used for driving the firmer chisel, and for straightening and bending of thin metallic sheets. Also it is used in motor assembly work.

Fig 13



CENTRE PUNCH

Fig 14



MALLET

15 Flat cold chisel (Fig 15) BIS 402

Its size is given by the nominal width and length.

ie. 14 mm x 100 mm

15 mm x 150 mm

20 mm x 150 mm

The body shape of a cold chisel may be round or hexagon.

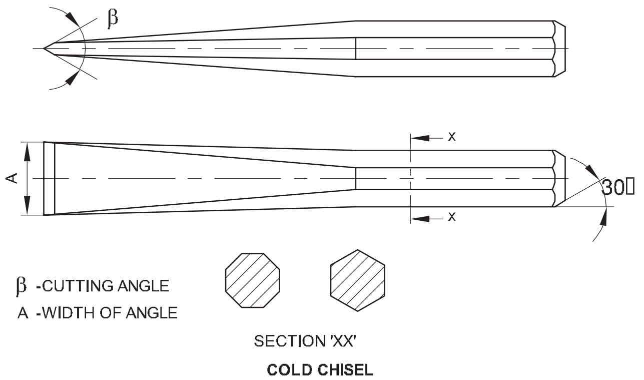
The cold chisel is made out of high carbon steel. Its cutting edge angle varies from 35° to 45°. The cutting edge of the chisel is hardened and tempered. This chisel is used for making holes on wall etc.

16 Rawl plug tool and bit (Fig 16)

Its size depends upon the number. As the number increases, the thickness of the bit as well as the plug also decreases. Eg. Nos.8, 10, 12, 14 etc.

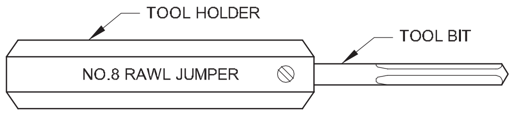
A rawl plug tool has two parts, namely the tool bit and tool holder. The tool bit is made of tool steel and the holder is made of mild steel. It is used for making holes in bricks, concrete wall and ceiling. Rawl plugs are inserted in them to fix accessories.

Fig 15



COLD CHISEL

Fig 16



RAWL PLUG TOOL

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17 Spanner: double ended (Fig 17) BIS 2028

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

The sizes, indicated in double-ended spanners are

10-11 mm

12-13 mm

14-15 mm

16-17 mm

18-19 mm

20-22 mm.

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

18 Hacksaw frame and blade

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours.

Types of hacksaw frames

Bold frame: Only a particular standard length of blade can be fitted.

Adjustable frame (flat): Different standard lengths of blades can be fitted.

Adjustable frame tubular type (Fig 18): This is the most commonly used type. It gives a better grip and control while sawing.

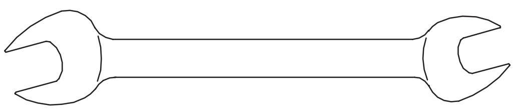
Hacksaw blades : The hacksaw blade is a thin, narrow, steel band with teeth and two pin holes at the ends. It is used along with a hacksaw frame. These blades are made of either low alloy steel (la) or high speed steel (hs) and are available in standard lengths of 250mm and 300mm.

For proper working, it is necessary to have frames of rigid construction.

Types of hacksaw blades

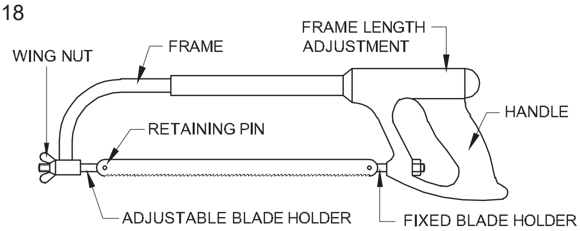
All-hard blades: The width between the pin holes is hardened all allong the length of the blade.

Fig 17



DOUBLE ENDED OPEN JAW SPANNER

Fig 18



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Flexible blades: For these types of blades only the teeth are hardened. Because of their flexibility, these blades are useful for cutting along curved lines (Fig 19).

Saw blades for hacksaws are available with small and large cutting of teeth, depending on the type and size of material they are to cut. The size of the teeth is directly related to their pitch, which is specified by the number of teeth per 25mm of the cutting edge. Hacksaw blades are avaialable in pitches of: (Fig 20)

- 14 teeth per 25 mm
- 18 teeth per 25 mm
- 24 teeth per 25 mm
- 32 teeth per 25 mm.

Fig 19

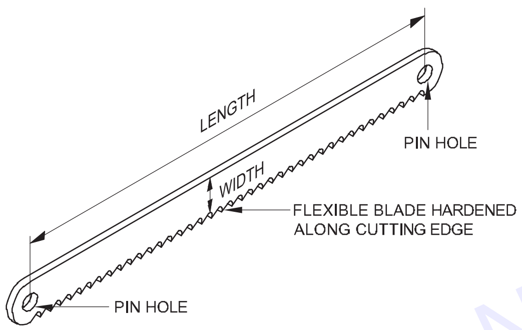
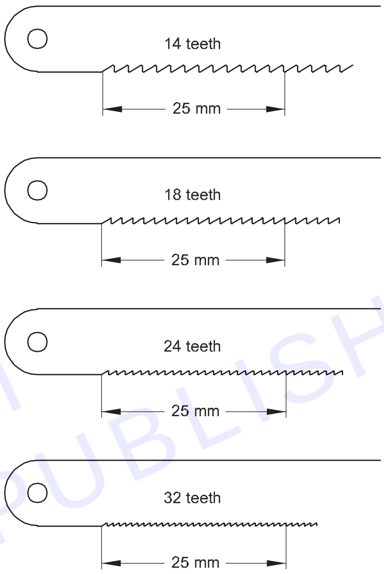


Fig 20



ELC22T0270

Standard and standardisation

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

- state what is meant by standardisation and standard
- state the names of various standard organisation
- read and interpret the basic concept of electrical code 2011
- state the types of injury caused by the improper lifting method
- describe the procedure to be followed for moving heavy equipmental.

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

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

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

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

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

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

The standard organisation and the respective countries are given below:

BIS - Bureau of Indian Standard (ISI) - India

ISO - International standard Organisation

JIS - Japanese Industrial Standard - Japan

BSI - British Standards Institution BS(S) - Britain

DIN - Deutche Industrie Normen - Germany

GOST - Russian

ASA - American standards association - America

Advantages of BIS(ISI) certification marks scheme:

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

To manufacturers

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

To consumers

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

Introduction to National Electrical Code - 2011

National Electrical Code - 2011

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

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

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

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

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

Section 2 covers definition of items with references.

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

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

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

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

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

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

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

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

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

Section 12 covers general criteria for selection of equipment.

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

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

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

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

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

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

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

Section 20 gives frequently referred tables in electrical engineering work.

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

Lifting and handling of loads

Many of the accidents reported involve injuries caused by lifting and carrying loads. A electrician may need to install motors, lay heavy cables, do wiring, which may involve a lot of lifting and carrying of loads. Wrong lifting techniques can result in injury.

A load need not necessarily be very heavy to cause injury. The wrong way of lifting may cause injury to the muscles and joints even though the load is not heavy.

Further injuries during lifting and carrying may be caused by tripping over an object and falling or striking an object with a load.

Crushing of feet or hands

Feet or hands should be so positioned that they will not be trapped by the load. Timber wedges can be used when raising and lowering heavy loads to ensure fingers and hands are not caught and crushed.

Safety shoes with steel toe caps will protect the feet. (Fig 1)

Preparaing to lift : Load which seems light enough to carry at first will become progressively heavier, the farther you have to carry it.

The person who carries the load should always be able to see over or around it.

The weight that a person can lift will vary according to:

- Age
- Physique, and
- Condition

It will also depend on whether one is used to lifting and handling heavy loads.

What makes an object difficult to lift and carry?

1 Weight is not the only factor which makes it difficult to lift and carry.

2 The size and shape can make an object awkward to handle.

3 Loads high require the arms to be extended in front of the body, place more strain on the back and stomach.

4 The absence of hand holds or natural handling points can make it difficult to raise and carry the object.

Correct manual lifting techniques

1 Approach the load squarely, facing the direction of travel

2 The lift should start with the lifter in a balanced squatting position, with the legs slightly apart and the load to be lifted held close to the body.

3 Ensure that a safe firm hand grip is obtained. Before the weight is taken, the back should be straightened and held as near the vertical position as possible. (Fig 2)

Fig 1

Fig 2

ELC22T0271

4 To raise the load, first straighten the legs. This ensures that the lifting strain is being correctly transmitted and is being taken by the powerful thigh muscles and bones.

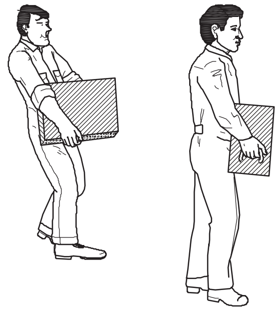
5 Look directly ahead, not down at the load while straightening up, and keep the back straight; this will ensure a smooth, natural movement without jerking or straining (Fig 3)

6 To complete the lift, raise the upper part of the body to the vertical position. When a load is near to an individual's maximum lifting capacity it will be necessary to lean back on the hips slightly (to counter balance the load) before straightening up. (Fig 4)

Keeping the load well near to the body, carry it to the place where it is to be set down. When turning, avoid twisting from the waist - turn the whole body in one movement.

Fig 3

Fig 4



ELC22T0272

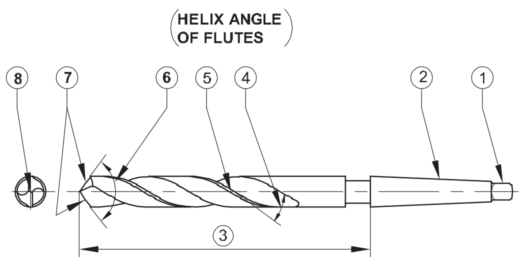
Drills and drilling machines

Objectives: At the end of this lesson you shall be able to:
- state the functions of drills
- name the parts of a drill
- name the drill bit holders
- state the uses of countersunking bits.

Drill: Drilling is a process of making holes on workpieces by using a drill.

Parts of a drill (Fig 1)

Fig 1



- Tang (1)
- Shank (2)
- Body (3)
- Flute (4)
- Land (5)
- Point angle (6)
- Cutting lip (7)
- Chisel edge (8)

Tang: Tang is the part that fits into the slot of the drilling machine spindle.

Shank: This is the driving end of the drill which is fitted on the machine. Shanks are of two types.

- Taper shank: for larger diameter drills.
- Straight shank: for smaller diameter drills.

The shank may be parallel or tapered.(Figs 2 & 3) Drills with parallel or straight shanks are made in small sizes, up to 12mm (1/2 in) diameter and the shank has the same diameter as the flutes.

Fig 2

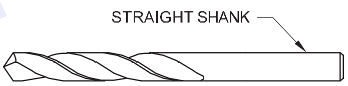
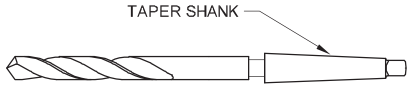


Fig 3



Taper shank drills are made in sizes from 3mm (1/8 in) diameter up to 50mm (2 in) diameter.

Body: The body is the portion between the point and shank.

Flutes: Flutes are the spiral grooves which run to the length of the drill.

The flutes help:

- to form the cutting edges
- to curl the chips and allow them to come out (Fig 4)
- the coolant to flow to the cutting edge.

Land/margin: Land/margin is the narrow strip which extends to the entire length of the flutes. The diameter of the drill is measured across the land/margin.

Body clearance: Body clearance is the part of the body which is reduced in diameter to cut down the friction between the drill and the hole being drilled.

Fig 4

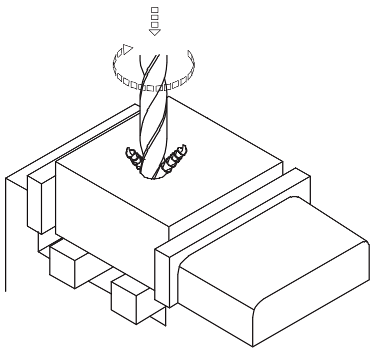
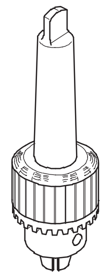


Fig 5



Web: Web is the metal column which separates the flutes. It gradually increases in thickness towards the shank.

Drill bit holder

Drill chuck: Drill chuck is attached to the main spindle for straight shank basis. (Fig 5)

Sleeve: This is used to match bit tapers and the spindle taper holes. (Fig 6a)

Socket: This is used when the main spindle length is too short, and the bit is changed frequently. (Fig 6b)

Taper shank drills are held in taper sockets in the machine.(Fig 6c)

The tang on a taper shank drill enables easy removal of the drill from the socket at the end of the drilling work. This is done using a drift. (Fig 7) The tang also serves to prevent the drill from rotating in the socket.

Use of a coolant: A coolant is used to cool the cutting tool and the job.

Fig 6

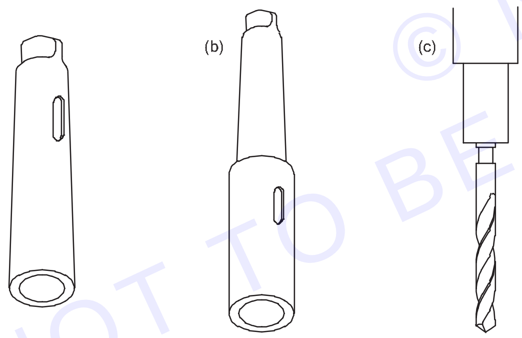
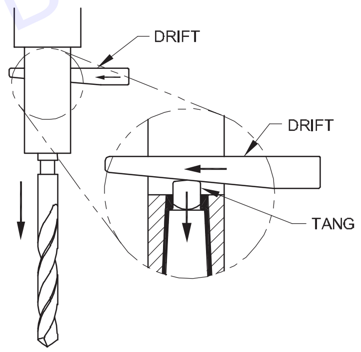


Fig 7



Drilling machines

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

- state the types of hand drilling machines and their uses
- state the parts of bench and pillar drilling machine
- explain the features of machine vice.

Making holes in sheet metal by using solid punches is a slow and inefficient process.

It is necessary to drill holes when working with heavy material.

The holes can be drilled by hand or by machine. When drilling by hand, a hand drilling machine (Fig 1) or the electric hand drilling machine (Fig 2) is used.

Twist drills are used as a cutting tool for drilling holes. The hand drill is used for drilling holes up to 6.5 mm diameter.

The portable electric hand drilling machine is a very popular and useful power tool. It comes in different sizes and capacities.

The handle shown in Fig 2 is called a pistol grip handle.

The parts of an electric hand machine are shown in Fig 2.

Fig 1

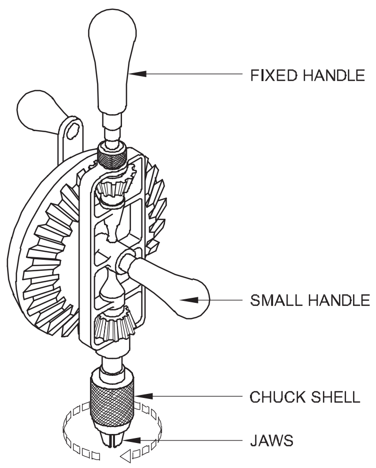
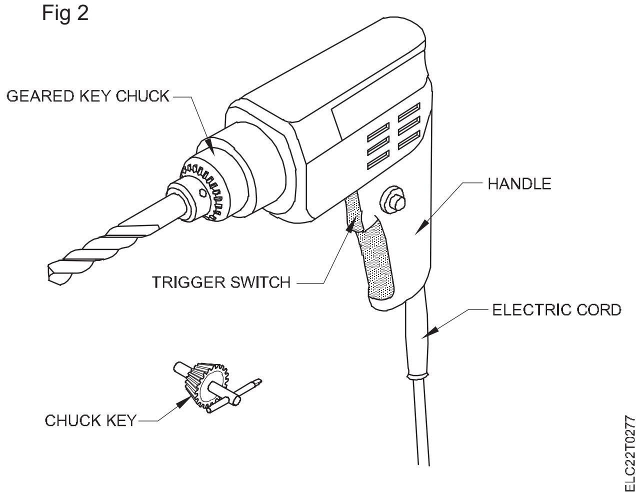


Fig 2



Precautions to be observed : Make sure the holes are properly located and punched with a centre punch.

Be sure the drill is properly centred in the chuck by turning (rotating).

Be sure the work is mounted properly in a holding device such as a vice or `G' clamp.

Check the centering of the drill after the point has just started in the metal. Relocate the hole with a centre punch, if necessary. Feed the drill with a light, even pressure.

Types of Electric Drilling Machines: Some of the electric drilling machines are listed here.

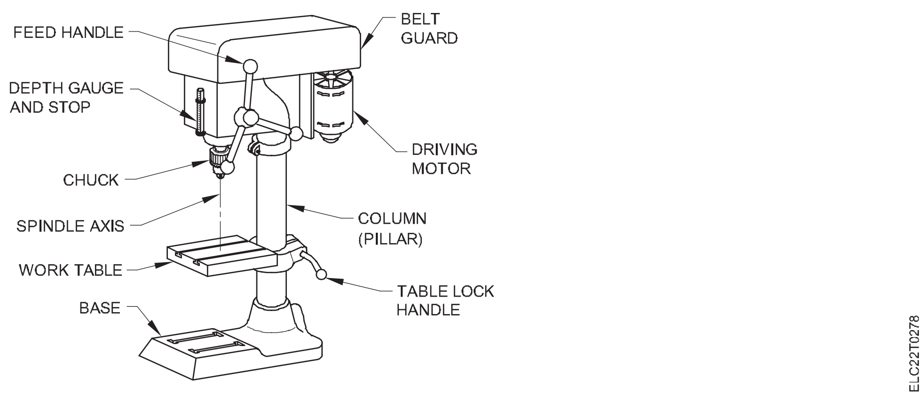
- The sensitive bench dilling mchine
- The pillar drilling machine
- The radial arm drilling machine. (Radial drilling machine)

(As you are not likely to use the column and radial type of drilling machines now, only the sensitive and pillar type machines are explained here.)

Sensitive bench driling machine: The simplest type of sensitive bench drilling machine is shown in the (Fig 3) with its various parts marked. This machine is used for light duty work. (Fig 3)

This machine is capable of drilling holes up to 12.5mm diameter. The drills are fitted in the chuck or directly in the tapered hole of the machine spindle.

The pillar drilling machine: This is an enlarged version of the sensitive bench drilling machine. These drilling machines are mounted on the floor and are driven by more powerful electric motors. They are used for heavy duty work. Pillar drilling machines are available in different sizes. Large machines are provided with a rack and pinion mechanism for moving the table for setting the work.



MODULE 2 : Basic Electrical Circuits

LESSON 5-12 : Ohm's law, series & parallel, kirchhoff's law, wheatstone bridge, condutors insulators wire joints soldering

Objectives

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

- define electricity and atom
- define the fundamental terms, wheatstone bridge
- state ohm's law, kirchhoff's law and apply in on electrical circuit
- state conductor insulators different types of wire joints & their uses
- state the necessity of soldering and types of soldering.

Fundamentals (Fig 1)

Matter

Matter is anything that has mass and occupies space.

Eg: Solid, liquid and gases

Molecules

Smallest particles of a substances that has all the property of substances

Atom

The simplest particles of a molecule. The atoms are the building block of the matter.

ATomic structure

An atom consists of a central nucleus of positive charge around which small negatively charged particle, called electrons revolve in different path or orbits.

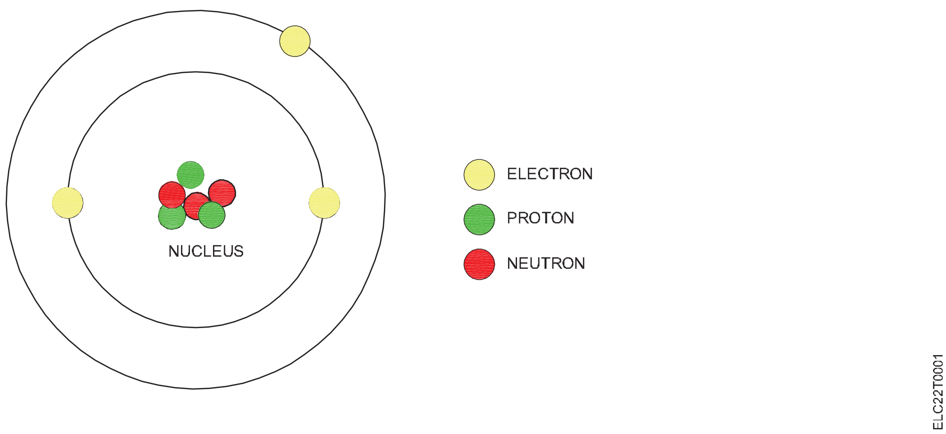
Nucleus

It is the central part of an atom. It contains proton and neutron

Proton

It has positive electric charge. It is almost 1840 times heavier than the electron. Do not take active part in the flow or transfer electricity.

Fig 1



Neutron: It is the same mass as the proton but no charge. There for the nucleus of an atom is positively charged. The sum of protons and neutrons constitutes the entire weight of an atom and is called atomic weight.

Atomic weight=Number of proton + Number of neutron.

Electrons

It is the small particle revolving round the nucleus. It has negative electric charge, having negligible mass. The charge on an electron is equal but opposite to that on a proton. Number of electron is equal to the number of proton in an atom under ordinary condition. Therefore, an atom is neutral as a whole. The number of proton or electron in an atom is called atomic number.

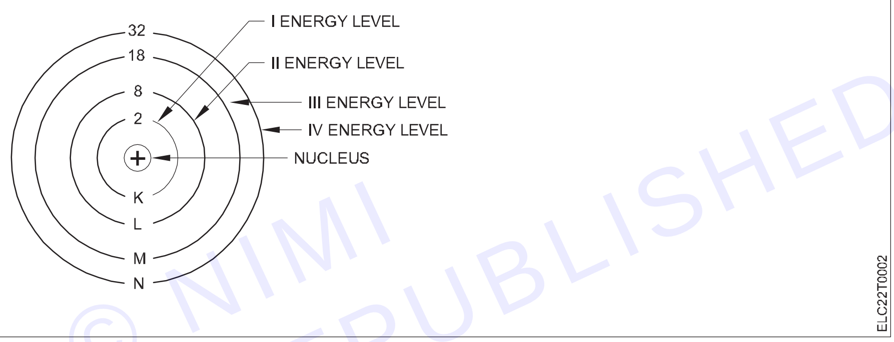
Charge on an electron, e =1.602 X 10^{-19} coulomb.

Mass of electron, m = 9X10^{-31} kg.

Radius of an electron, r = 1.9X 10^{-15} meter.

The ratio of e/m of an electron is small. this means that mass of an electron is very small as compared to its charge. It is due to the property of an electron that its very mobile and is gently influenced by electric or magnetic field. (Fig 2)

Fig 2



Energy shell: Electron in an atom revolves around the nucleus in different orbits or paths called shell. The number of electron in any orbits given by $2n^2$

Where ‘n’ is the number of orbit.

For e.g. First orbit contains - $2X1^2$ = 2electron.

Second orbit contains - $2X2^2$ = 8 electrons….and so on.

The energy of an electron is increased as its distance from the nucleus increases. Thus, an electron in the second orbit possesses more energy than the electron in the first orbit; the electron in the third orbit has higher energy than second orbit. It is clear that in the last orbit possess very high energy as compared to the electrons in the inner orbit.

Valence electron: The electron in the outermost orbit of an atom are known as valence electron. The max.number of valence electron can be 8. These valence electrons play an important role in determining physical, chemical and electrical properties of material. These electrons determine whether or not the material is chemically active; metal or non-metal or, a gas or solid.

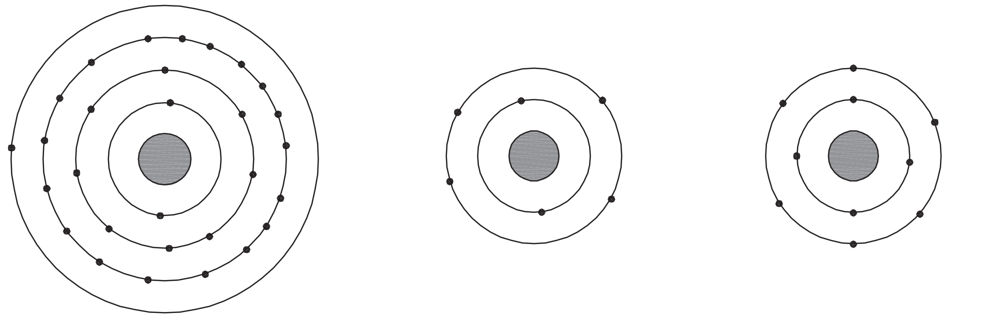
Free electron: The greater the energy of valence electron, the lesser it is bound to the nucleus. The valence electron possesses so much energy, they are loosely attached the nucleus. These loosely attached valence electrons move within the material. The valence electron which are loosely attached to the nucleus are known as free electrons. (Fig 3)

Fig 3

Conductors, insulators and semi-conductors

Conductor: It is a substance which has a large No. of free electrons. Conductors allow the flow of electric current. The number of valence electrons of a conductor is less than four. Most metals are good conductors. Eg; copper, Al etc. (Fig 4)

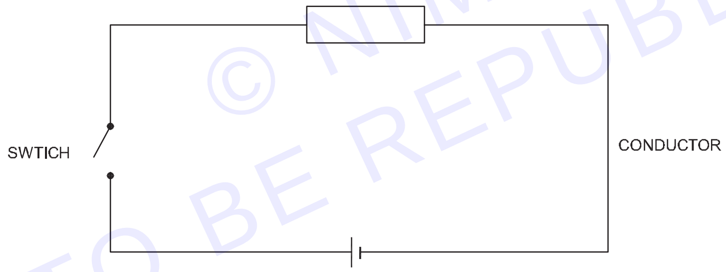
Fig 4



Insulators: Which has practically no free electron at ordinary temperature.therefore, an insulator does not conduct electric current. No. of valence electron in the insulator is more than four.

Semi-conductors: Characteristics of semiconductor is in between conductor and insulator.it has very few free electrons at room temperature. consequently' a semiconductor practically conducts no current. The number of Valence electrons in the semiconductor is four. (Fig 5)

Fig 5



Eg; silicon and germanium

Electrical circuit

Simple electrical circuit consist of

An Energy Source (Cell)

Conductor

A load (Resistor)

A control device (Switch)

Definitions of electrical terms

Current: The flow of electrons in one direction along any path or around any circuit is called electric current. Its symbol is I and its unit s ampere (A). The instrument which is used to measure current is called 'AMMETER', which is always connected in series with the circuit.

Electro Motive Force (EMF): The force which causes current to flow in the circuit is called EMF. Its symbol is E and is measured in volts (V) The EMF of an electrical source may be referred as its voltage.

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

EMF=VT+IR

Potential difference

The difference of electrical potential between two points in an electric circuit. It's always less than EMF. Its symbol is V and is also measured in volts. The instrument that measures the P.D. is called 'VOLTMETER '. It is always connected in parallel with the circuit whose voltage is to be measured.

Conductance

The property of a conductor to conduct electricity is called conductance. Its symbol is G It unit is 'mho'. Good conductors have good conductance.

Resistance

The property of a material to oppose the flow of electric current through them is called resistance. The resistance of each material is depending upon its composition, length, area and temperature. Its unit is ohm (Ω).

Representation of emf, current & resistance

Quantity	Symbol	Unit of Measurement	Unit Abbreviation
Current	1	Ampere ("Amp")	A
Voltage	E or V	Volt	V
Resistance	R	Ohm	Ω

Ohm's law (Fig 6)

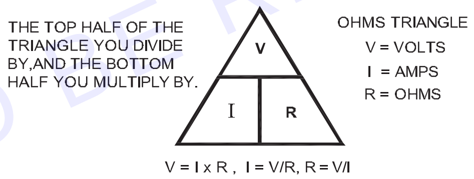
G .S. Ohm established this law which gives the relation between current, voltage and resistance in a closed electric circuit.

OHM's law states that in a closed circuit the current t(I) flowing through a conductor at constant temperature is directly proportional to the voltage(V) across the conductor and inversely proportional to its resistance(R).

I α V

I=V/R

Fig 6



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Laws of resistance

The resistance, R offered by conductors depends on the following factors

1 The resistance of the conductor varies directly with its length(l).

2 The resistance of the conductor varies inversely proportional to cross sectional area(a).

3 The resistance of the conductor depends on the material with which it is made of(ρ)

It also depends upon temperature of the conductor. Ignoring the last factor for the time being we can say that

$R=\rho\ l/a$

Specific resistance (Resistivity) (Fig 7): It may be defined as the resistance offered to a current if passed between the opposite faces of the unit cube of the material. Specific resistance (resistivity) is measured in ohm-centimeter.

Problem: Q. If a10m of Eureka wire 0.14 cm in diameter has the resistance of 2.5Ω. find the specific resistance.

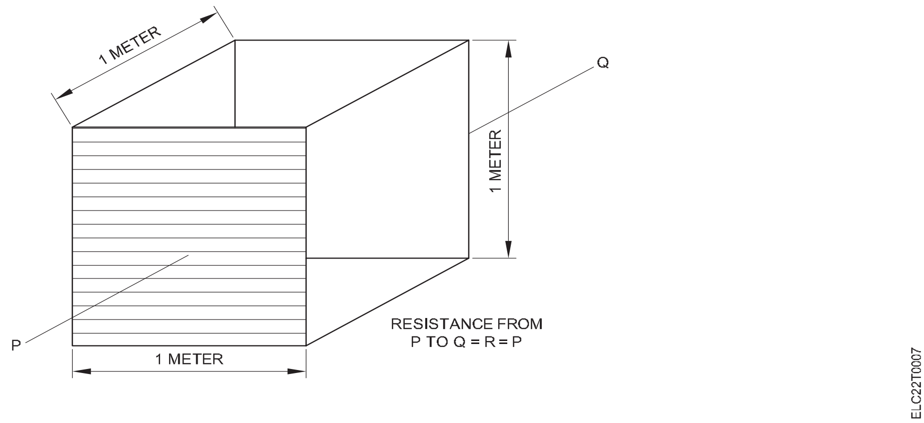
Solution

Length of wire, L=1000 cm

Diameter, d=.14cm

Resistance=2.5Ω

Fig 7



Area=A=πr^2

P=(R x a)/l=38.5micro-ohm centimeter

Krichhoff's laws: Kirchhoff's laws are used in determine the equivalent resistance of a complex network and the current flowing in the various conductors.

Kirchhoff's current law also called Kirchhoff's first law or Kirchhoff's point rule or Kirchhoff's junction rule (or nodal rule).

"At any node (junction) in an electric circuit the sum of current flowing into a node is equal to the sum of current flowing out of that node or the algebraic sum of current in a network of conductors meeting at a point is zero".

ie; $\Sigma I=0$

For example;

At node A the current entering= the current leaving

i2+i3=i1+i4

Problem

If the currents exiting from junction "a" are to be of 2 amps each, what is the value for the current entering the junction?

Recall the junction rule for this case ; $I_I=I_2+I_3$

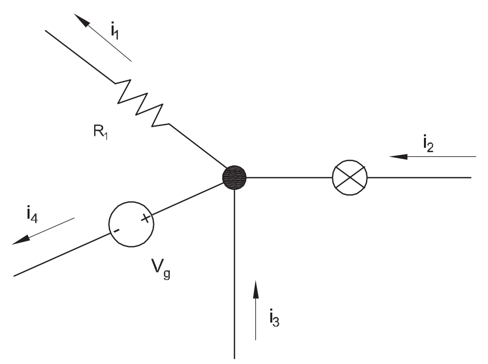
We know the following values:

$I_2=I_3=2_{amps}$

Then, we can solve for current entering the junction I_1=2+2=4amps

Applicable only for junctions in a network.

Fig 8



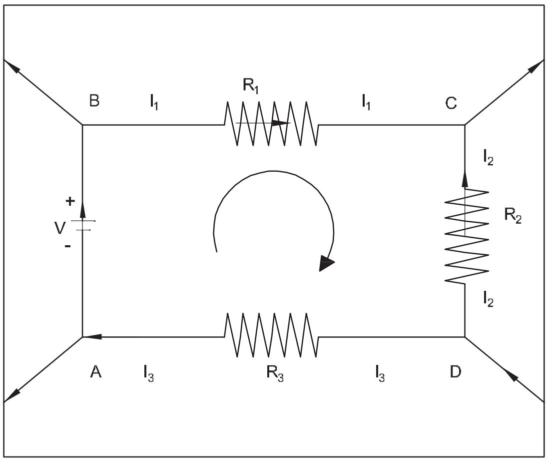
Kirchhoff's voltage law (Fig 9)

This law is also called Kirchhoff's second law, Kirchhoff's loop rule, and Kirchhoff's mesh rule.

"The algebraic sum of the products of the resistances of the conductors and the currents in them in a closed loop is equal to the total emf available in that loop or the sum of the emfs in any closed loop is equivalent to the sum of the potential drops in that loop."

Ie; ΣIR+Σemf=0

Fig 9



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Some Popular Conventions We Generally use During Applying KVL

- The resistive drops in a loop due to current flowing in clockwise direction must be taken as positive drops.
- The resistive drops in a loop due to current flowing in anti-clockwise direction must be taken as negative drops.
- The battery emf causing current to flow in clockwise direction in a loop is considered as positive.

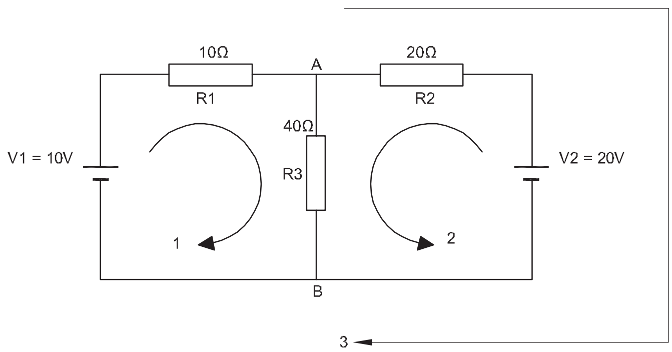
The battery emf causing current to flow in anti-clockwise direction is referred as negative.

Problem

Q)Determine the current flowing through 40Ω resistor.

The circuit has 3 branches, 2 nodes(A And B) and 2 independent loops. Using Kirchhoff's current law KCL equations are given as: at node A: $I_1+I_2=I^3$ at nUsing Kirchhoff's Voltage Law, (Fig 10)

Fig 10



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KVL the equations are given as;

Loop 1 is given as : $10 = R_1 I_1 + R_3 I_3 = 10I_1 + 40I_3$

Loop 2 is given as : $20 = R_2 I_2 + R_3 I_3 = 20I_2 + 40I_3$

Loop 3 is given as : $10 – 20 = 10I_1 – 20I_{2ode}$ B: $I_3= I_1$+I2As I_3 is the sum of $I_1 + I_2$ we can rewrite the equations as;

Eq. No 1 : $10 = 10I1 + 40(I_1 + I_2) = 50I_1 + 40I_2$

Eq. No 2 : $20 = 20I2 + 40(I_1 + I_2) = 40I_1 + 60I_2$

We now have two “Simultaneous Equations” that can be reduced to give us the values of I_1 and I_2

Substitution of I_1 in terms of I_2 gives us the value of I_1 as - 0.143 Amps

Substitution of I_2 in terms of I_1 gives us the value of I_2 as +0.429 Amps

As : $I_3 = I_1 + I_2$

The current flowing in resistor R3 is given as :

-0.143 + 0.429 = 0.286 Amps

and the voltage across the resistor R_3 is given

0.286 x 40 = 11.44 volts

The negative sign for I1 means that the direction of current flow initially chosen was wrong, but never the less still valid. In fact, the 20v battery is charging the 10v battery.

Kirchhoff’s voltage law is one of the most fundamental laws of circuit theory and required for almost all circuit calculations to find voltages at different points.

The relation between current and voltage

- Current is the rate at which the charge is flowing.
- Voltage is the difference in charge between two points.
- The relation between the current(I) and voltage(V) is provided by the Ohm’s law. It states that, the current is directly proportional to the voltage provided the temperature remains constant.

  $V \alpha I$

Now, we introduce a constant of proportionality (R)

i.e., V=IR

This is the relationship between the current(I), voltage(V) and the resistance(R) as defined by the Ohm’s law. This can be further manipulated into I=V/R and R=V/I whenever required.

Here R is the resistance, which is the material’s tendency to resist the flow of charge.

Combination of resistance: Two or more resistances are connected in different ways is known as combination of resistance. Combination of resistance increase or decrease the total value of resistance.

Type of combinations of resistance

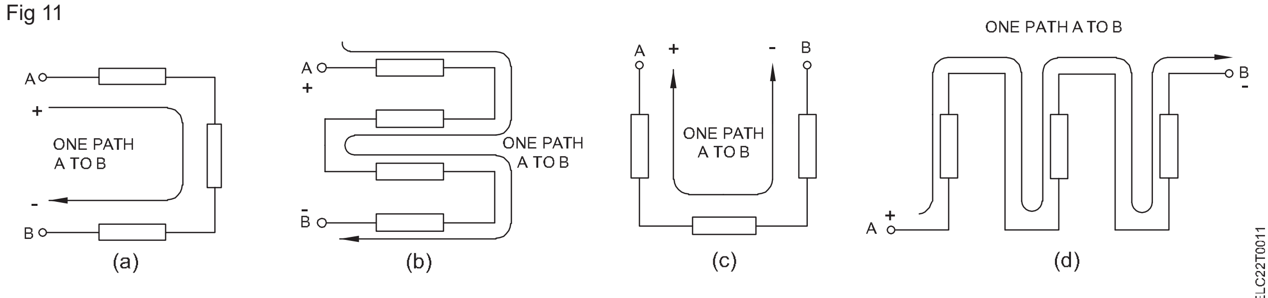
1 Series combination of resistance

2 Parallel combination of resistance

3 Series – Parallel combination of resistance

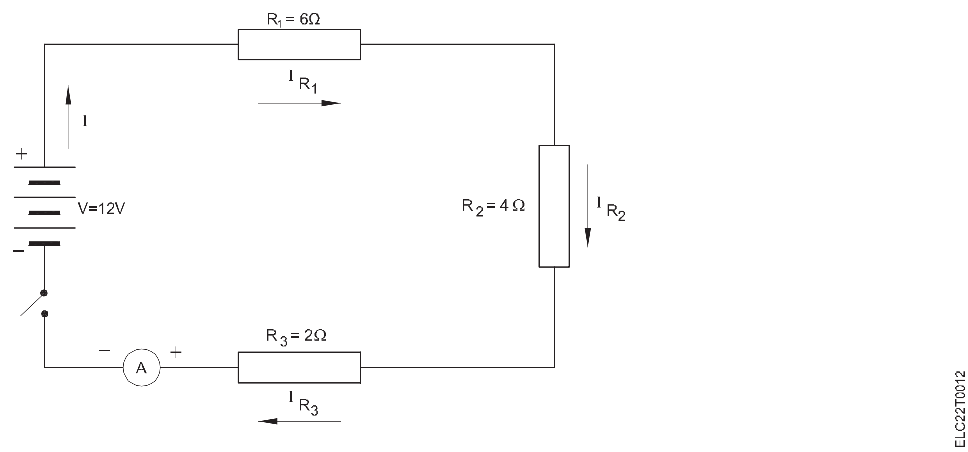
Series combination of resistance: In series circuit means two or more resistors are connected back to back. In the below figures shows various type connection of series combinations. (Fig 11)

Fig 11



Current in series circuits: The current relationship in a series circuit from the figure is $I=I_{R1}=I_{R2}=I_{R3}$. We can conclude that there is only one path for the current to flow in a series circuit. Hence, current is the same throughout the circuit (Fig 12)

Fig 12

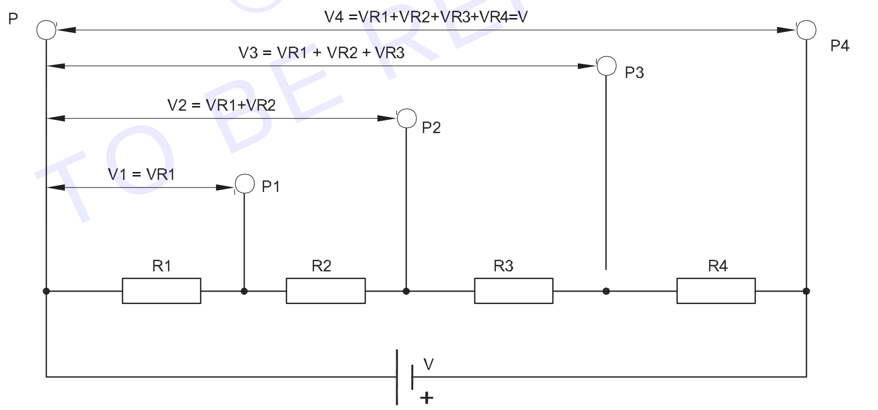


Resistance in series circuit (Fig 13) : The total resistance in series circuit is equal to the sum of the individual resistance around the series circuit Tis statement can be written as $R=R_1+R_2+R_3+$......Rn. Where R is the total resistance, R_1, R_2, R_3,.......Rn are the resistance connected in series. When a circuit has more than one resistor of the same value in series, the total resistance is R= r X N. Where r is the value of each resistor and N is the number of resistors in series.

Voltages in series circuit In DC circuit voltage divides up across the load resistors, depending upon the value of the resistor so that the sum of the individual load voltages equals the source voltage.

$V=V_{R1}+V_{R2}+V_{R3}+V_{R4}$

Fig 13



Related problem (Fig 14)

To find out the voltage drop of each resistor and total voltage drop of given series circuitTotal resistance of the circuit Rt =100+100+100+100=400 ohms

Voltage of the circuit V=100v

The current flowing through the circuit would be=100/400=0,25 amps

V_{R1} =0.25 x 100=25V

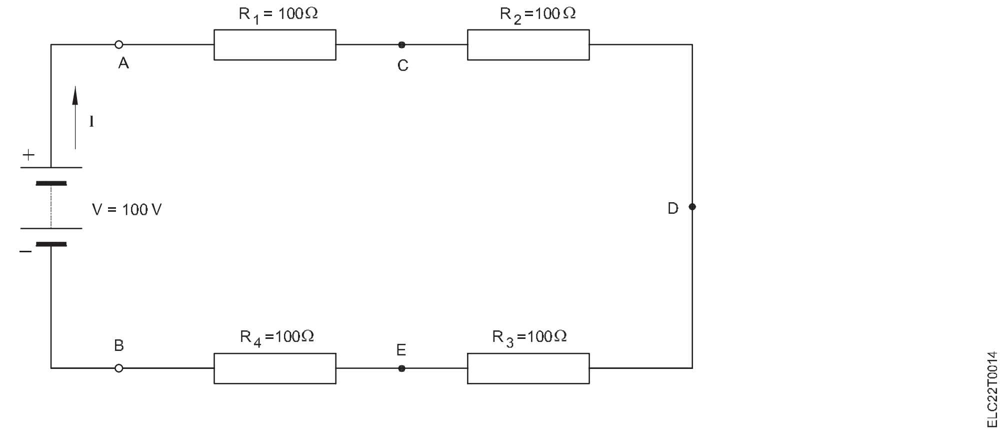
V_{R2} =0.25 x 100=25V

V_{R3} =0.25 x 100=25V

V_{R4} =0.25 x 100=25V

$V_{total}=V_{R1}+V_{R2}+V_{R3}+V_{R4}$ =25+25+25+25=100V

Fig 14



Appliction of ohms law in series circuit (Fig 15)

Applying ohms' law to series circuit, the relation between various current could be stated as below

Ohm's law state that I=V/R

In series circuit $I=I_{R1}=I_{R2}=I_{R3}$

This could be stated as $=V/R=V_{R1}/R1+V_{R2}/R2+V_{R3}/R3$

Supply voltage $V=V_{R1}+V_{R2}+V_{R3}$

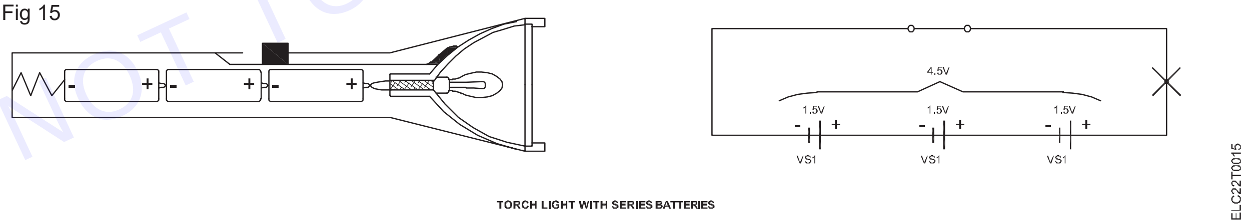
$IR=R1I_{R1}+R2I_{R2}+R3I_{R3}$

Total resistance= R =R1+R2+R

Application of series circuit

- Cells in torch light
- Fuse in circuit
- Overload coil in motor starters
- Multiplier resistance of a voltmeter

Fig 15



Parallel combinatiom of resistance (Fig 16)

Parallel combination of circuit means two or more resistors its starting points are joined in a one point and other ends of resistors are joined in another one point.

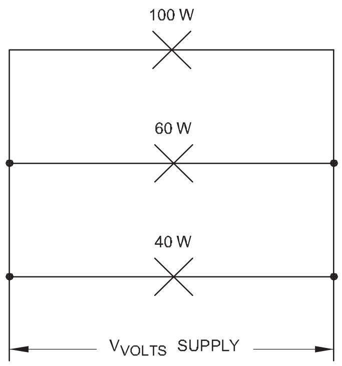
Parallel combination circuits are more used in house wiring installation

Voltages in parallel combination

Figure shows parallel circuit diagram. We can conclude that the voltage across the parallel circuit is the same as the supply voltage

That is V=V1=V2=V3

Fig 16



PARALLEL CIRCUIT

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Current in parallel circuit (Fig 17)

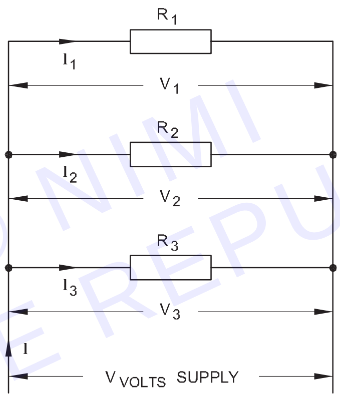
Current in resistor R_1 $=I_1$ $=V_1$ $/R_1$

Current in R_2 $=I_2$ $=V_2/R^2$

Current in R_3=I_3=V_3/R_3

Total current I in the parallel circuit is the sum of the individual branch current i.e. $I = I_1+I_2+I_3$

Fig 17



VOLTAGE IN PARALLEL CIRCUIT

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Resistance in parallel circuit (Fig 18)

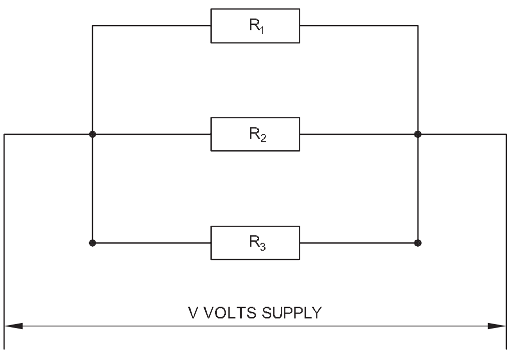
We have also seen $I = I_1 + I_2 + I_3$ or

$V/R = V/R_1 + V/R_2 + V/R_3$,

Therefore $1/R = 1/R_1 + 1/R_2 + 1/R_3$

The above equation reveals that in parallel a circuit, the reciprocal of the total resistance is equal to the sum of the reciprocal of the individual branch resistance. By the application of ohm's law we can write R = V/I ohms, I = V/R amps

Fig 18



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Application of parallel circuit

An electrical system in which one section can fail and other sections continue to operates as parallel circuits. The electric system used in homes consist of many parallel circuits.

An automobile electrical system uses parallel circuit for lights, horn, radio etc.

Comparison between series and parallel circutit

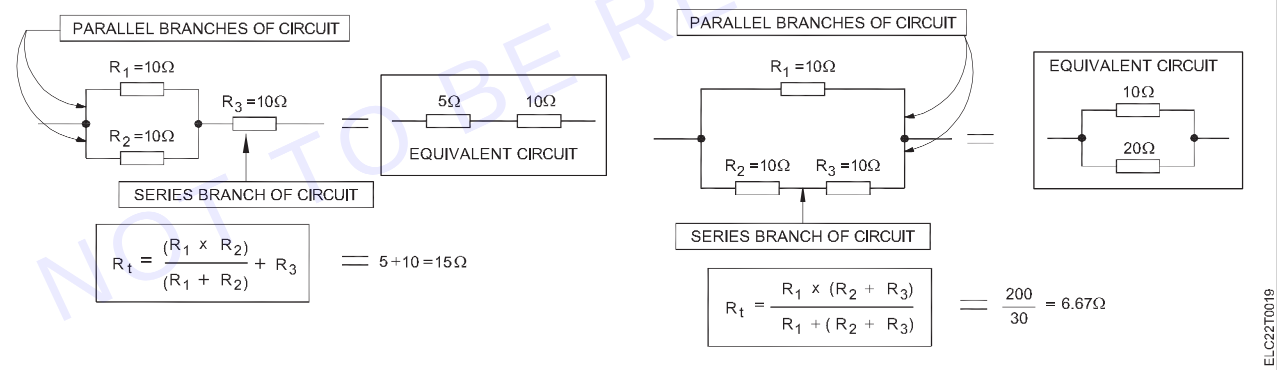
Sl No	Series Circuit	Parallel Circuit
1	The sum of voltage drops across the individual resistance equals the applied voltage	The applied voltage is the same across each branch
2	The total resistance is equal to sum of the individual resistance that make up the circuit	The reciprocal of total resistance equals the sum of the reciprocal of the resistances. The resultant resistance is less than the smallest resistance of the parallel combination
3	Current is same in all parts of the circuit	Current divides in each branch according to the resistance of each branch
4	Total power is equal to the sum of the power dissipated by the individual resistances	Same as series circuit.

Series parallel combination of resistance (Fig 19)

A part of series and parallel circuit form in a single circuit is known as series parallel combination circuit. A series parallel combination appears to be very complex circuit

The two basic arrangement of two series parallel circuit is shown in figure.

Fig 19



Application

Series-parallel circuit be can be used to form a specific resistance value which is not available in the market and can be used in the voltage divider circuits

Classification of resistance

Low resistance

- 1 ohm and below 1 ohm

  Example-Armature winding, ammeter shunt, contact resistance

Method used for the measurement

- Kelvin double bridge
- Ammeter voltmeter method
- potentiometer method

Medium resistance

- Above 1 ohm up to 100,000 ohms (100 k ohms or 0.1 m ohms)

  Example-resistance of bulb, heater, motor starters

Method used for the measurement

- Ammeter voltmeter method
- Wheat stone bridge
- substitution method
- ohmmeter method

High resistance

- 0.1 M ohm (100 k ohms) and above
- Example- insulation resistance, carbon composition resistor

Methods used for measurement

- Direct deflection method
- loss of charge method
- meg ohm bridge
- megger

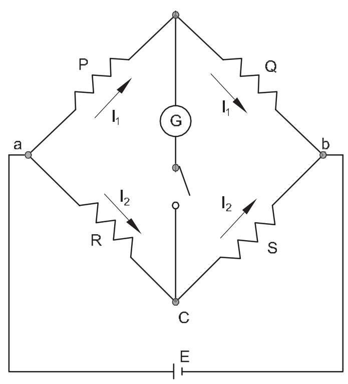
Wheat stone bridge (Fig 20)

- Measurement of medium resistance
- Comparison type instrument
- Null type instrument so accuracy (0.1%) is high

For balance $I_1 P = I_2 R$

- For galvanometer current to be zero $I_1 = I_3 = E/P+Q$, $I_2 = I_4 = E/R+S$
- $P/P+Q = R/R+S$
- $QR = PS$
- $R = S\ P/Q$
- R=Unknown resistance
- S=Standard arm
- P, Q=Ratio arm

Fig 20



WHEATSTONE BRIDGE

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Limitations of wheastone bridge

- Not suitable for very high Resistance measurement due to overheating of arms, leakage over insulation of bridge arms by the application of high EMF. So inaccurate
- Not suitable for the low resistance measurement due to contact resistance drop. so inaccurate

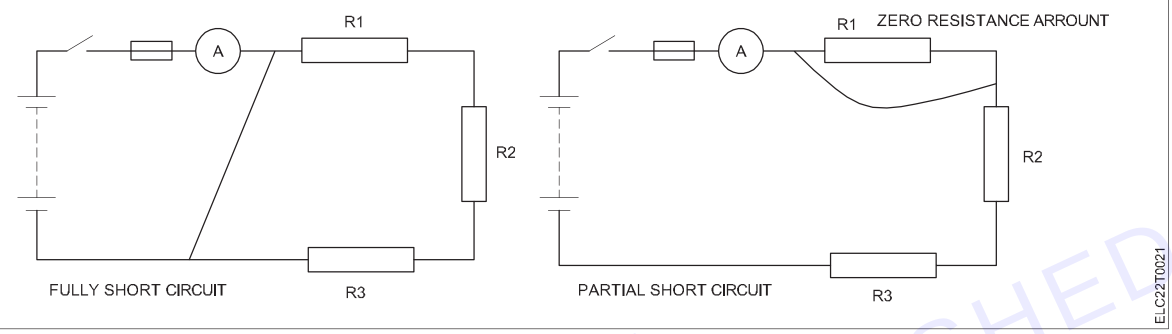
Short and open circuit in series circuit

Short circuit (Fig 21)

A short circuit is a path of zero or very low resistance compared to the normal circuit resistance in series circuit short circuit may partial or full.

Short circuit causes an increase in high current passes through the circuit

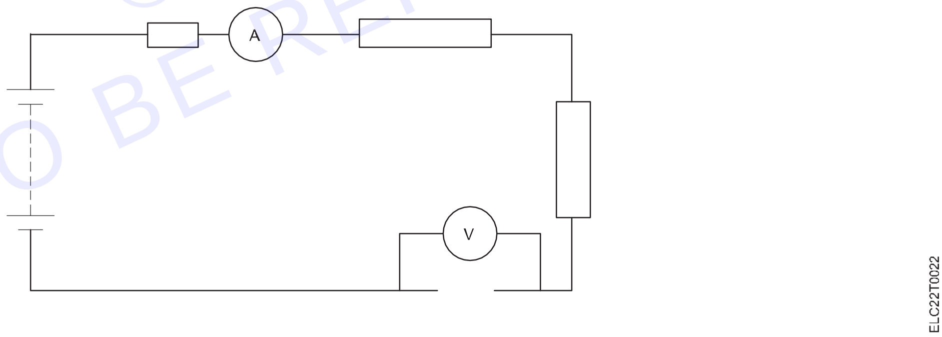
Fig 21



Open circuit in a series circuit (Fig 22)

An open circuit result whenever a circuit is broken or is incomplete and there is incomplete and there is no current flows through the circuit. Any ammeter in the circuit will indicate no current.

Fig 22



Causes for open circuit

Improper contact of switches, burnt out resistors.

Effects of open in series circuit

1 No current flows in the circuit

2 No device in circuit

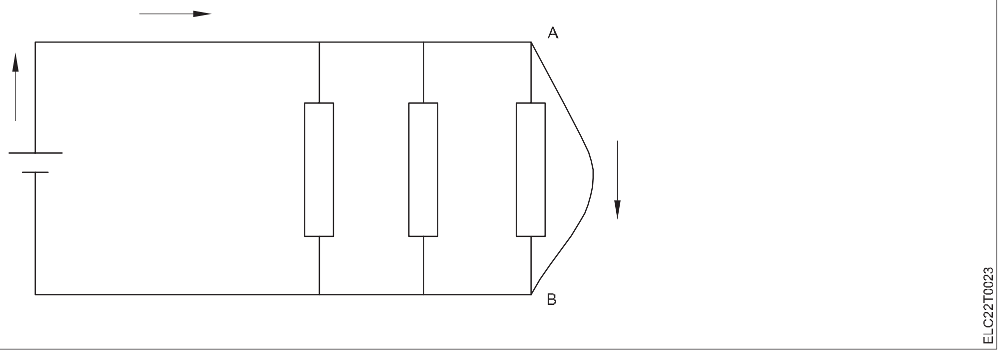
3 Total supply voltage appear across the open

Short and open in parallel circuit

Short circuit (Fig 23)

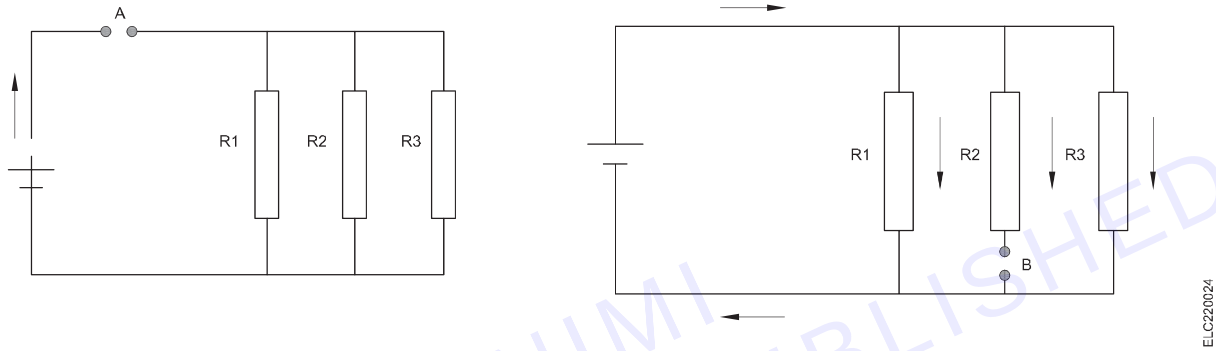
Shows a parallel circuit with short between point ‘a’ and ‘b’. This causes reduction of circuit resistance almost ‘zero’. There for the voltage drop will be almost ‘zero’. Then the result is that a very high current passes through the short circuit. Short circuit may causes burning of the circuit elements like cables, switches etc. To avoid burning of circuit components safety devices like fuse.

Fig 23



Open circuit: An open in the common line of a point A shown in figure. Then cause no current flow in the circuit where as an open in the branch at point B causes no current flows only in that branch. (Fig 24)

Fig 24

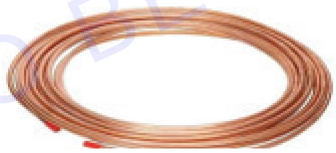


Conductors and cable

Classification of conductors

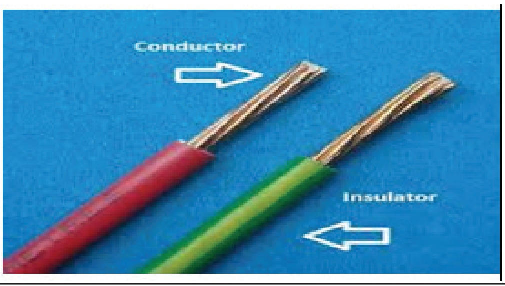
Bare conductor: Which are not covered with insulation. The most use of bare conductors is in overhead lines and earth conductor. forearthing also bare conductors are used. (Fig 25)

Fig 25



Insulated conductor: Which are covered with insulation.the insulation separates the conductor electrically from other conductors and from the groundings. It allows conductors to be grouped without danger. Used for indoor wiring and underground distribution system (Fig 26)

Fig 26



Solid conductor

There will be only one conductor in the core. Used for bus bars and winding of machines.

Stranded conductor: There will be a number of smaller sized conductor's twister to form the conductor. Used in cables and overhead lines

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

Copper: It has Reddish colour. It has best conductivity next to silver. It has Largest current density compared to other metals. Hence the volume required to carry a given current is less for given length. It can be drawn in to thin wires(malleable) and sheets(ductile). It has a high resistance to atmospheric corrosion; hence it can serve for a long time. It can be joined without any special provision to prevent electrolytic action. It is durable and has high scrap value. Next to copper aluminum is the metal used for electrical conductors.

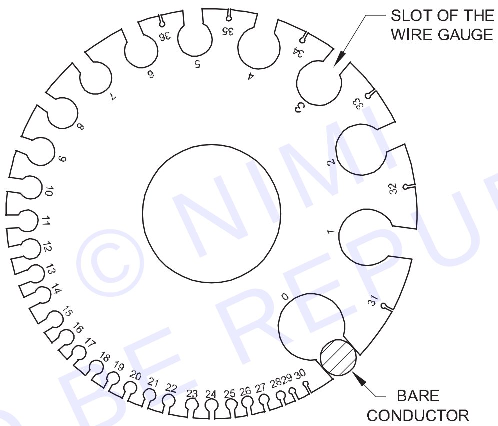
Aluminium: It has Whitish colour. When compared to copper conductivity is 60.6 percent. hence for same current capacity, the cross-section for the aluminum wire should be larger than that for the copper wire. It is Lighter in weight. It is Malleable and ductile. But losses its tensile strength on reduction of the cross-sectional area. It is cheaper than copper.

Measurement of wire size: While selecting the cable size, the electrician has to take in to consideration the proposed connected load, future changes in load' the length of the cable run and the permissible voltage drop in the cable. To measure the size of conductors we use normally a standard wire gauge or a micro meter for more accurate result.

1 Using a Standard Wire Gauge (Fig 27)

Size of the conductor is given by the standard wire gauge number. Each number has an assigned diameter in inch or mm. measure the wire size in SWG numbers from 0 to 36. It should be noted that the higher the number of wire gauge the smaller is the dimeter of the wire.

Fig 27



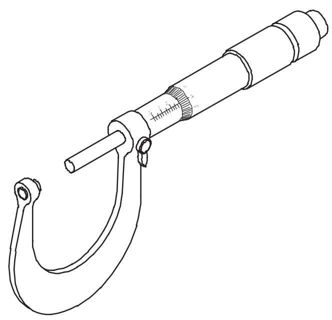
STANDARD WIRE GAUGE

While measuring the wire, the wire should be cleaned and then inserted the slot of the wire gauge to determine the wire gauge number. The slot in which the wire just slides in is the correct slot and the SWG number could be read in the gauge directly.

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

2 According to the diameter of the conductor (Fig 28)

Fig 28



3 According to the cross-sectional area of conductor.

2 and 3 are find using micrometer

Terms used in electrical cables

Wire

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

CABLE

A length of insulated conductor (single or stranded) or two or more conductors, each provided with its own insulation, which are laid up together

TYPES

1 **Armoured cable:** Provided with a wrapping of metal, serving as a mechanical protection.Used for underground system

2 **Flexible cable:** Contain one or more cores, each formed of a group of wires. The diameter of wires sufficiently small afford flexibility

Types of cables

1 VIR (Vulcanized Indian Rubber) cable4.PVC (Poly Vinyl Chloride) cable

2 TRS (Tough Rubber Sheathed) or5.Weather proof cable

CTS (Cab Tire Sheathed) cable6. Flexible cable

3 Lead sheath cable

Wire joints - Types - Soldering methods

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

- state the different types of wire joints and their uses
- state the necessity of soldering and types of soldering
- state the purpose and types of fluxes
- explain the different method of soldering and techniques of soldering
- explain the type of solder and flux used for soldering aluminium conductor.

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

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

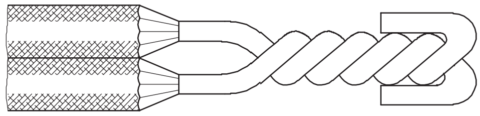
Some of the commonly used joints are listed below.

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

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

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

Fig 1



RAT TAIL JOINT

Fig 2

MARRIED JOINT

ELC22T0027

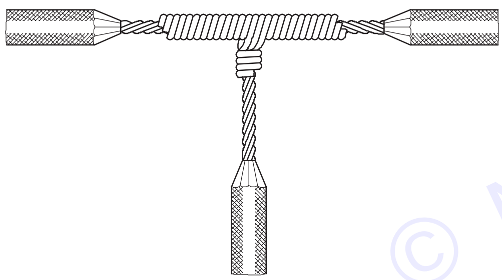
As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

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

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

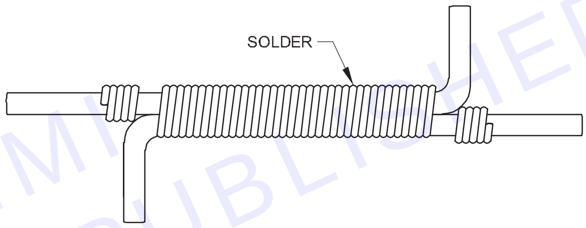
It is also used both for inside and outside wiring where single conductors of diameter 4 mm or more are used.

Fig 3



TEE JOINT

Fig 4



BRITANNIA JOINT

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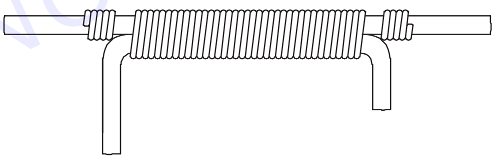
Britannia tee joint: This joint (shown in Fig 5) is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

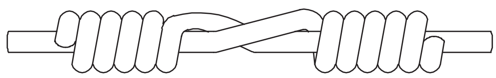
Western union joint (Fig 6): This joint is used in overhead lines for extending the length of wire where the joint is subjected to considerable tensile stress.

Fig 5



BRITANNIA TEE JOINT

Fig 6



WESTERN UNION JOINT

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

Tap joints in single stranded conductors of diameter 2 mm or less : By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

The following types of taps are commonly used.

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

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

Fig 7

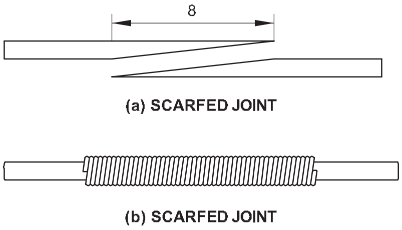
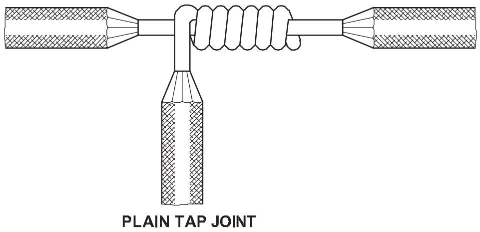


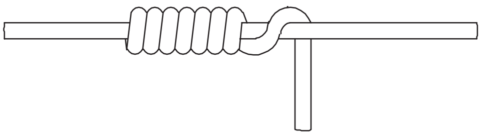
Fig 8



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

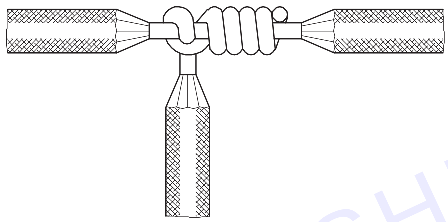
Knotted tap joint : (Fig 10) A knotted tap joint is designed to take considerable tensile stress.

Fig 9



AERIAL TAP JOINT

Fig 10



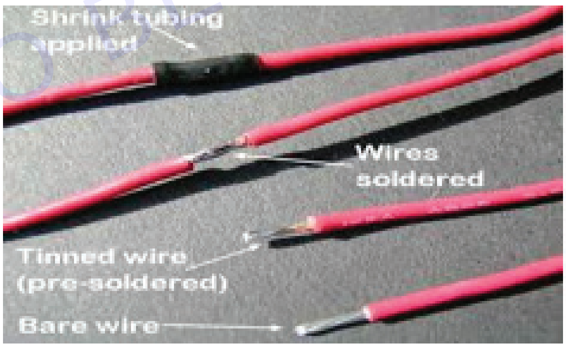
KNOTTED TAP JOINT

ELC22T0031

Soldering - types of solders, flux and methods of soldering

Soldering: Soldering is the process of joining two metal plates or conductors without melting them, with an alloy called solder whose melting point is lower than that of the metals to be soldered. The molten solder is added to the two surfaces to be joined so that they are linked by a thin film of the solder which has penetrated into the surfaces. (Fig 11)

Fig 11



Classification of soldering

1 Soft Soldering

2 Hard Soldering

 a Silver Soldering

 b Brazing

Necessity of soldering

1 To get good electrical conductivity

2 To get good mechanical strength

3 Also avoid corrosion

Solder: It is the metal alloy used as a bonding agent in soldering. It is an alloy of Tin and Lead (Fig 12).

Fig 12

Comparison &application of solders

Type of solder	Composition	Working temp.	Application
Tinman's solder	Tin-50% Lead-50%	200°c	Fine soldering
Electrician's solder	Tin-60% Lead40%	185°c or 365°F	Tinning and soldering electrical joints
Fine solder	Tin-90% Lead-10%	219°c or 426°F	
Plumber's solder	Tin-35% Lead-65%	237°c or 459°F	Heavy duty soldering

Flux (Fig 13)

Flux is a substance used to dissolve oxides on the surface of conductors and to protect against re-oxidisation during the soldering process. It is in solid or liquid form

Fig 13

Necessity of fluxes

1 To make the soldering surface free from oxides and dirt

2 Prevent re-oxidation during soldering operation there by making the solder to adhere to the surface to be soldered.

3 Facilitate the flow of solder through the surface to be soldered.

Comparison of flux

Type of flux	Metals used	Type of solder
Zinc chloride	Cast iron, Wrought iron, Mild steel, Cast steel, Brass, Bronze, Copper	Tinman's solder
Hydrochloric acid(10%) diluted with water (90%)	Copper, Brass, Tin plate, Gun metal	Coarse solder
Sal ammonia rosin	Copper, Brass, Tin plate, Gunmetal	Coarse solder
Resin	Joining electrical conductors	Electrician's solder
Tallow	Joining electrical conductors	Electrician's fine solder

Fluxes shown above 1, 2 and 3 are not recommended for electrical purpose. They are highly corrosive, hygroscopic and the residues are electrically conductive.

Soldering techniques

1 Tinning the soldering iron.

2 Cleaning the parts to be soldered.

3 Applying the flux

4 Applying the solder.

Methods of soldering

1 Soldering with soldering iron

2 Soldering with soldering gun.

3 Soldering with flame.

4 Dip soldering.

5 Machine soldering.

6 Soldering with pot and ladle.

1 Soldering with soldering iron

This is the most commonly and widely used soldering method. It is simple & inexpensive.

Steps in soldering

1 Clean the surface to be soldered

2 Applying flux on the surface

3 Heat the joint using soldering iron

4 Keep the solder over the surface

5 Solder melts and spread over the surface

Rating of soldering iron

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

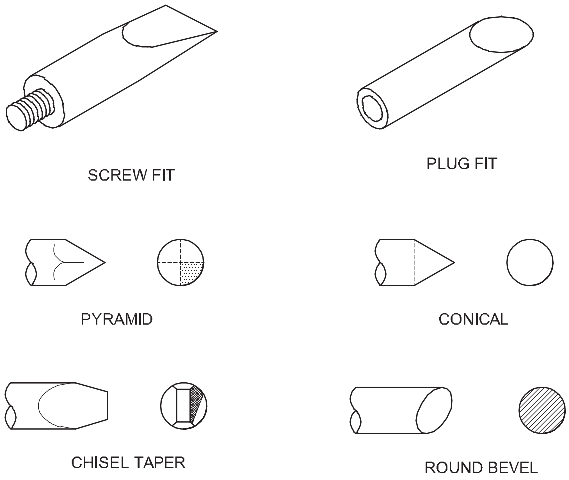
Soldering bit

Soldering bits are made of copper. It is of two types

1 Iron plated

2 Un-plated

Care of the bit: Un plated bits become pitted quickly and get covered in oxide. If the iron is in constant use this will occur within a few hours. To make good soldered joint bit must be maintained clean, smooth and correctly shaped.



SHAPES OF SOLDERING BITS

ELC22T0032

Dressing the bit

To dress an un plated bit follow the procedure stated below

1 Switch off, unplug the iron and allow it to cool.

2 Remove the bit from the iron if possible.

3 Mount the bit in a vice.

4 File to shape.

Iron plated bits are not dressed. It is replaced by new one when the bit is worn out.

Cleaning the bit

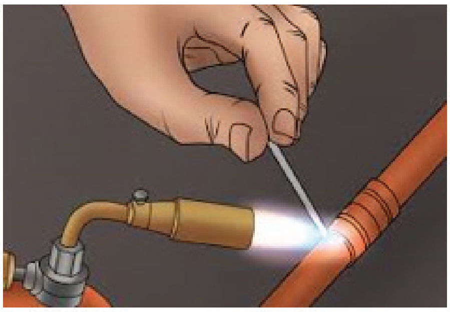
Bits are cleaned when the iron is in hot condition. Un-plated bits are cleaned by using sponge pad or wire brush. Iron plated bits are cleaned using sponge pad only.

2 Soldering withsoldering gun

It is used for individual soldering, Servicing and repair work. The electric current flowing through a wire coil heating it. The temperature is difficult to check and overheating occur.

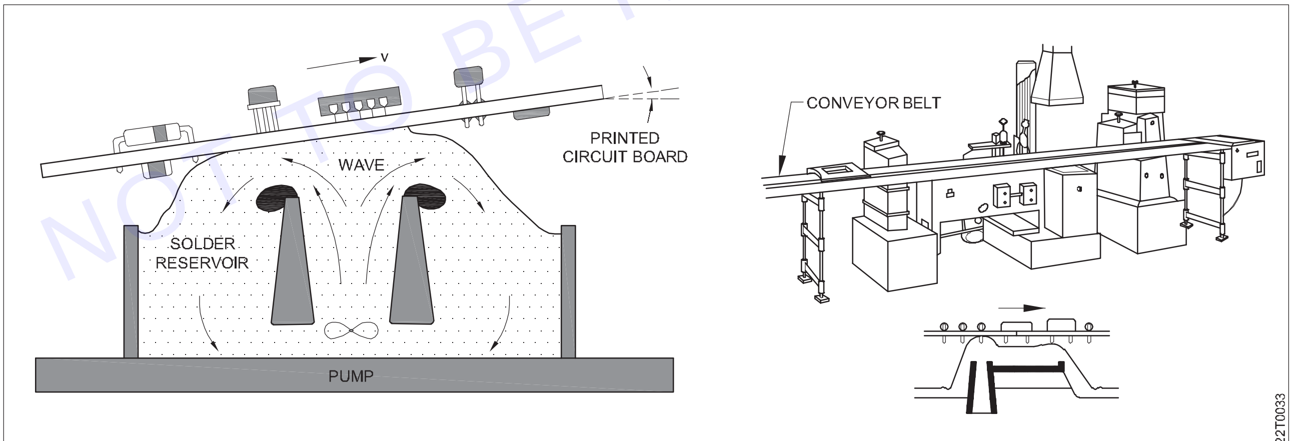
3 Soldering with a flame

It is used when the heat capacity of the soldering iron is insufficient. It is used in larger jobs like piping and cable work, vehicle body repairs etc. Cleaned, flux coated joint surface is heated with blow lamp and solder is kept over the heated surface and it melts and spread over the soldering surface. This method requires skilful management of flame.



4 **Dip soldering:** It is used for quantity production and tinning work. Components to be soldered on PCB are dipped in to the bath of a molten solder which is heated electrically. The solder is kept in motion by an agitator to avoid oxide films. The temperature can be controlled very accurately

5 **Machine soldering:** It is used for bulk production like component soldering. In this method the molten solder is in rapid motion to avoid oxide film formation. The molten solder comes in to direct contact with the components ends to soldered.



MACHINE SOLDERING

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

1 Resistance soldering

2 Induction soldering

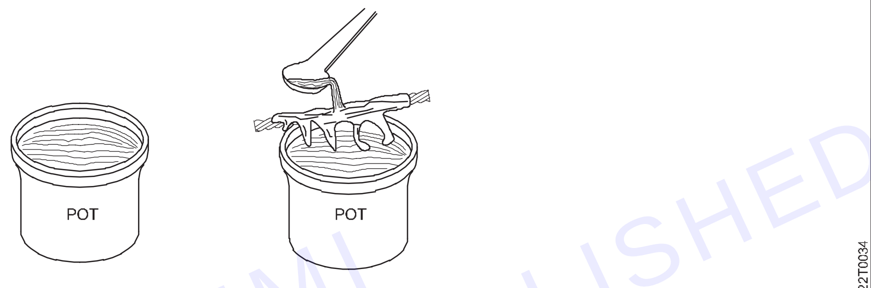
3 Oven soldering

4 Soldering in vegetable oil

5 Soldering by hot gas

6 Soldering with pot and ladle

Used for soldering large size jobs like UG cable joints. The solder is kept in a pot which is heated by blowlamp or charcoal. Initially soldering surface is cleaned and a coat of flux is given. Heating the soldering surface is pouring the molten solder over it. After several pouring the surface attains the same temperature of molten solder. Then apply a coat of flux, and a molten solder is poured slowly and a fine layer of solder is formed.



POT AND LADLE METHOD OF SOLDERING

Soldering aluminium cable

Soldering of aluminium conductors is more difficult than copper because of tenacious, refractory and stable nature of aluminium oxide film which forms immediately on any aluminium exposed to air. This oxide film does not allow the solder to wet the surface to be soldered and also prevents the solder from entering the interior surface by capillary action. Hence special solders and fluxes are used for aluminium soldering.

Solders used in aluminium soldering

A special type solder having a small percentage of zinc is used for aluminium soldering. The brand name of solders available in the market – ALCAP, Ker-al-lite.

Flux

In soldering aluminium conductor's organic fluxes of reaction type free from chlorides are used. The composition of organic fluxes de-composes at 250°c to effect the removal of the oxide film and helps to spread the molten solder over the surface.

Commercial name – Kynal flux, Eyre No:7

Disadvantage

It will char at 360°c

Soldering process maintained up to 360°c.

Soldering precautions

Inspect the iron regularly for physical damage especially the power cord.

Keep the iron in a stand when not in use.

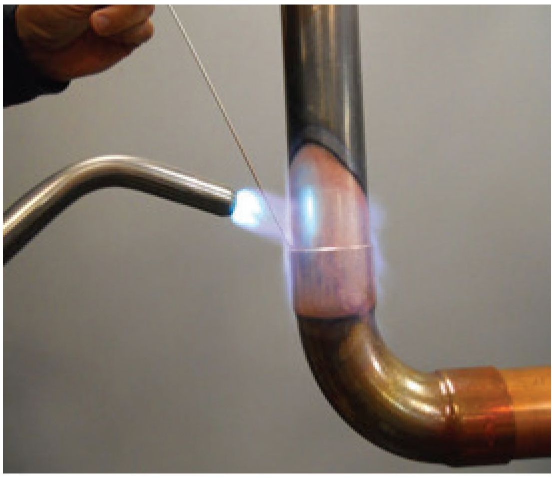
Keep the iron away from all part of the body and from its own power code.

A proper earth connection may be made to all mains connected.

Do not inhale the toxic fumes produced during soldering

Brazing

It is the metal joining process by melting a filler metal in to the joint having a lower melting point than the joined metal. The working temperature of brazing is above 450°c and the working temperature of soldering is below 450°c



Filler metal

Filler metal	Application
Nickel	Alloy steel, Nickel / Cobalt alloys, Copper alloys
Cobalt	Cobalt alloys
Aluminium	Aluminium alloys
Copper	Alloy steel, Copper alloys, Cast iron, Stainless steel

Flux used

White brazing flux	Black brazing flux
Composition of potassium salts and Boron	It is white brazing flux with more Boron
High cost	High cost

MODULE 3 : Heating Effect, Cells and Batteries

LESSON 13-19 : Chemical effects faraday law of electrolysis, heating joulet low cells & batteries

Objectives

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

- state the chemical effect of electrical current, law's of electrolysis
- state the basic principle of electroplating
- state the principle and construction of primary & secondary cells
- explain charging methods, care & maintenance of batteries
- state heating of electric current & Joules law
- state principle & operation of solar cell.

Electricity is one of today's most useful source of energy. Electricity in motion is called electric current. Electricity almost used necessity in modern equipment and machinery. Electricity does not move is called static electricity.

Eg: Attraction of paper to the comb.

When an electric current flows through a circuit various effects are produced, such as

- Chemical Effect.
- Heating Effect.
- Magnetic Effect.
- Special ray effect.
- Shocking effect.

Chemical effects of electric current

When an electric current is passed through a conducting liquid (electrolyte) it is decomposed into its constituents due to chemical action.

Electrolysis

The process of decomposing liquids by the passage of electric current through the liquid is called electrolysis

For electrolysis to work, the ions must be free to move. The atom which loses or gains an electron and thus possesses electric charge is called an ion. Ions are free to move when an ionic substance is dissolved in water or when melted.

Here is what happens during electrolysis

- Positively charged ions move to the negative electrode during electrolysis which are known as cations. They receive electrons and are reduced.
- Negatively charged ions move to the positive electrode during electrolysis which are known as anions. They lose electrons and are oxidized.

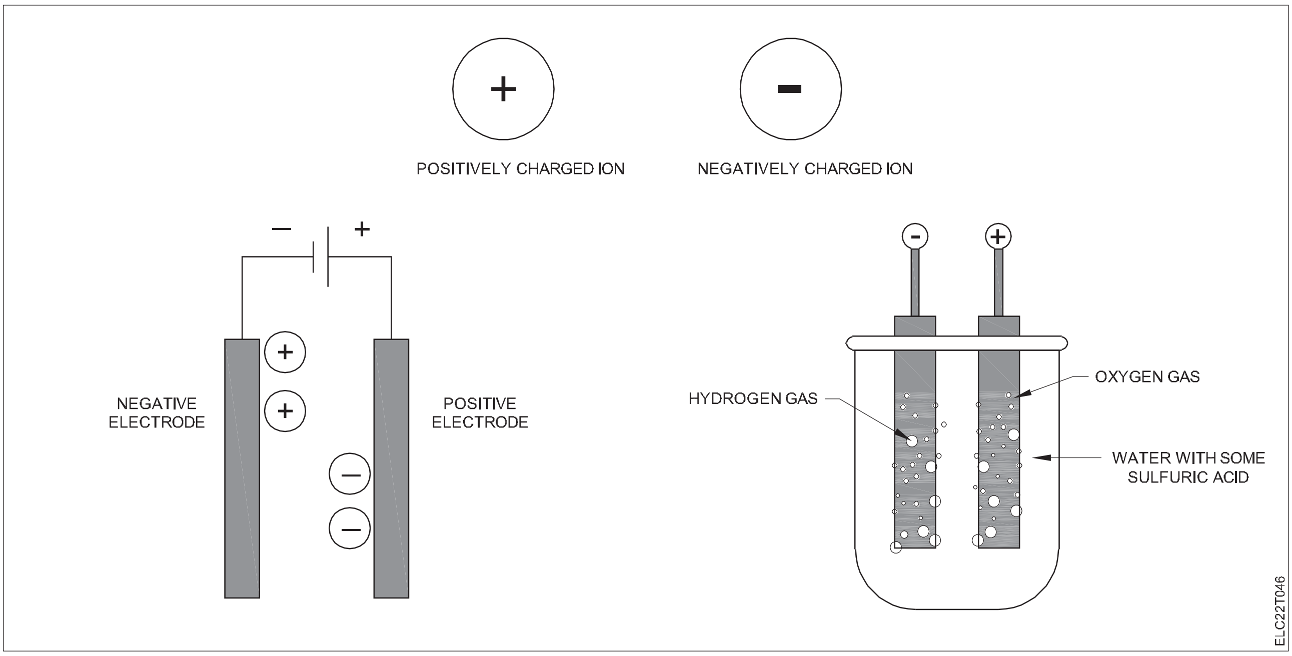
The conduction of electric current through an electrolyte together with the resulting chemical changes is called electrolysis.

When DC is passed through water it decomposes into hydrogen and oxygen.

Terms and defenitions

Electrolyte

Electrolyte is a solution or paste capable of conducting an electric current because of its dissociation into positive and negative ions.



Electrodes

The conductor or terminal, usually metallic through which an electric current enters or leaves is called an electrode.

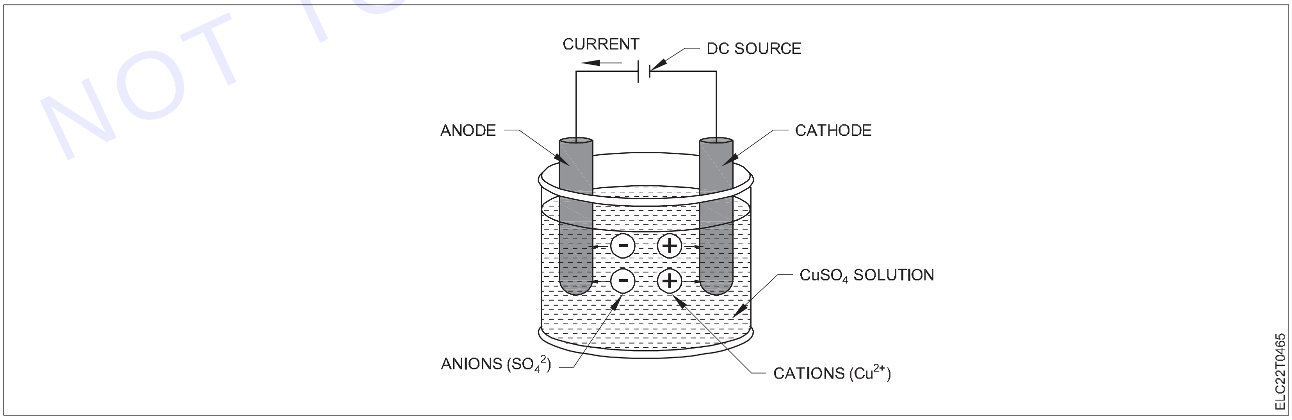
Anode

One terminal of a device that loses electrons in the external circuit during normal operation is called anode. In a battery negative electrode is the anode and positive electrode is the cathode.

Electrolysis of copper sulphate solution

Consider solution of copper sulphate ($CuSO_4$). Two copper electrodes are placed in the solution. When $CuSO_4$ is dissolved in water, its molecules split up into Cu++ and SO_4- ions. When these electrodes are connected to a battery the Cu++ ions go to the negative electrode and SO_4- ions go towards the positive electrodes.

The movement of the ions constitutes a flow of electric current through the electrolyte. In external circuit the current is due to the motion of electrons.



Faraday's laws of electrolysis

Faraday determined two laws which govern the phenomenon of electrolysis.

First law: The mass of the substance liberated or deposited at an electrode during electrolysis is directly proportional to the quantity of electric charge passed through the electrolyte.

$M \alpha \theta$

$M = z\theta$

$M = zIt \ (\theta = It)$

Where 'z' is called electrochemical equivalent (E C E) of the substance.

M = mass of material deposited.

Q = quantity of electricity passed through the electrolyte.

I = the current.

t = time in seconds for which current is passed.

Second law: If the same quantity of electric charge is passed through different electrolytes, the masses of the substances liberated or deposited are proportional to their chemical equivalent weight.

$$\text{Equivalent weight} = \frac{\text{Atomic weight}}{\text{Valency}}$$

Electrochemical Equivalent (ECE)

ECE of a substance is the mass of the substance liberated or deposited in electrolysis by the passage of 1 coulomb of charge. Its SI unit is kilogram/coulomb. It has the same value for one element but different for other element.

Problem:

25x25 cm metal plate is to be copper plated. If the current is adjusted to 5ampere and has been passed for 40 minutes, find the thickness of deposited copper. Take ECE of copper= 0.000329 gm per coulomb and density= 8.2.

Area of plate = 25x25 = 625 sq cm.

Area of both the sides = 2x625 = 1250 sq cm

We know M=Zit and mass= density x volume (volume = area x thickness)

M = 0.000329x5x40x60

M = 8.9x1250x thickness

$$\text{Thickness} = \frac{329 \times 5 \times 40 \times 600}{1250 \times 89 \times 1000000} = 0.0003459 \text{ cm}$$

Application of electrolysis

- Electroplating.
- Electro refining of metals.
- Electro typing

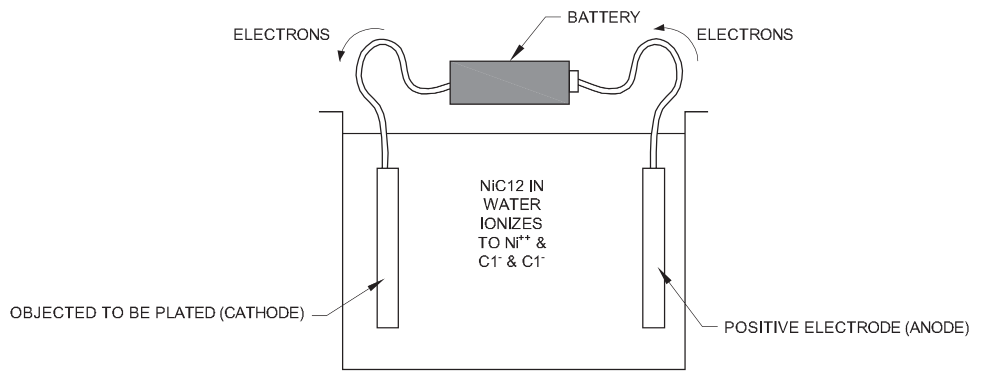
Electroplating

Electroplating is the deposition of a metal coating on a metallic or other conductive surface by electrolysis in an electrolytic cell. Electroplating is widely used in giving an attractive appearance and finish to all types of industrial products. In this process inferior metals are coated with costly metals such as silver, chromium etc to give better appearance and rust proof surface.

Low pressure DC is always used for electroplating. It varies from 1 to 16 V depending upon the rate of plating. The value of current is adjusted according to the metal deposited. The shunt dynamo is usually used for electroplating. It delivers large current at low pressure and it requires a large commutator and brush gear. The generated voltage of dynamo is controlled by the voltage regulator.

Nickel plating

The object and metal being plated is immersed in tank which containing the electrolyte. When PD is applied positive ions drift to the cathode and metal is deposited on the object. The negative ions drift to the anode ie the metal being plated is dissolves. The amount of metal deposited is directly proportional to the number of electrons. This relationship is a reflection of faradays law of electrolysis. The object to be plated is made cathode. The anode is usually the metal being plated. The article to be plated must have a chemically cleaned surface. The object is immersed in a solution which contain the metal salt of the metal being plated. The solution is called electrolyte.



NICKEL CHLORIDE ELECTROLYTE

Conditions for electroplating

- The object to be plated is made cathode.
- The anode is usually the metal being plated.
- The article to be plated must have a chemically cleaned surface.ie it must not have any sort of dirt, rust and greasy surface.
- The object is immersed in a solution which contain the metal salt of the metal being plated.
- The solution is called electrolyte.

The electrolyte is contained in a wooden reinforced cement concrete tank which is known as" vat". The anode as well as the article to be plated are to be hung from conducting wires so as to dip in the solution. The value of current is adjusted according to the metal deposited on the surface area of the article. The time required for electroplating can be calculated if we know the mass of the metal deposited and E.C.E with the formula M= ZIt

Therefore, time t=M/IZ

Applications for electroplating:

- Alter the appearance of the object

  Ex: Gold plating.
- Provide protective coating.

  Ex: Iron is coated with zinc to avoid rusting.
- Give the articles special surface properties.

  Ex: To make solder easier tin or lead is applied to copper.

Silver plating:

* Silver potassium cyanide is used as electrolyte.
* Silver plate is used as anode and job to be made cathode.

Heating effect of electric current

When current flows through a metallic conductor, the free electrons in the metal start moving from the end which is at lower potential. These moving free electrons collide with the atoms of the metal. At each collision, a part of kinetic energy of electron converts into heat and slowly the temperature of the conductor begins to rise. Thus, the production of heat energy in a conductor by the electric current flowing through it is called the heating effect of the current.

Joule's law

Heating effect of electric current is studied by James Prescott Joule and he enunciated various factors that affect the heat generated

Joule's law can be stated as: The quantity of heat (H) generated in a conductor of Resistance (R), when a current (I) flows through it for a time (t), is directly proportional to:

The square of current,

The resistance of the conductor,

The time at which the current flows

According to Joule's Law the heat produced,

$H \propto I^2Rt$

Where

I is the current,

R is the resistance

T is the resistance

Let V be the potential difference applied between two terminals of a conductor of resistance R,

Then current I = V/R

If the current I is passed through a conductor for time t,

then charge Q = It.

Potential difference is the work done (w) during flow of charge Q is given by:

Work = Potential difference X charge

W = V.Q

Put V = IR and Q = It

Then $W = I^2Rt$

When current flows through a conductor, the work done (I^2Rt) is converted into heat.

Thus Heat produced, $H = I^2Rt$ joule (current I is in ampere, resistance in ohm and time in second)

Usually heat energy expressed in calorie.

$H = \frac{I^2Rt}{J}$ calorie,

where J is Joule's constant or mechanical equivalent of heat

And J = 4.187 calorie

Hence, heat produced in a conductor in terms of calorie is given by

$H = \frac{I^2Rt}{4187}$ calorie $\qquad H = \frac{V^2\, t}{RX4187}$ calorie

$H = \frac{V^1\, t}{RX4187}$ calorie $\qquad H = \frac{Wt}{4187}$ calorie

UNIT OF HEAT

Kilocalorie (kcal) is the unit of heat in MKS system

It is defined as the amount of heat required to increase the temperature of one kg of water by 10 C.

4.187 joule = 1 calorie

4187 joules = 1 kilocalorie

1 joule = 0.24 calorie

Temperature

Temperature is the measure of heat. Thermometer is generally used for measuring temperature. Pyrometer is used to measure high temperature

Different scales used for measuring temperature are

1 Celsius °C

2 Fahrenheit °F

3 Kelvin K

Basic unit of temperature in SI system is Kelvin.

Many physical properties of materials are effected by temperature including the phase (solid, liquid, gaseous), density, conductivity etc.

Application of heating effect of electric current

In an electric circuit, the unavoidable heating can increase the temperature of the components and also alter their properties. However, heating effect of electric current has many useful applications. The most common examples are electric iron, electric toaster, electric oven, electric kettle and electric heater.

Related problem

1)Two heaters H1 and H2 are connected in parallel across the supply voltage V. When the heater H1 generates 250 kcal heat in 20sec and the heater H2 generates 1000kcal in 40 sec. If the resistance of the heater H1 is 10ohm what is the resistance of heater H2? When both heaters are connected in series and voltage V is applied across them, how much heat will be produced in kcal in 5sec?

Heat produced by heater H1 = $\frac{v^2 t}{R_1 x J}$ kcal

$$\frac{v^2 x20}{Jx10} = 250$$

$$\frac{v^2}{J} = 125 \text{ kcal} \quad \text{-----------------(1)}$$

Heat produced by heater H2 = $\frac{v^2 t}{R_2 x J}$ kcal

$$\frac{v^2 x40}{Jx10} = 1000 \text{ kcal} \quad \text{-----------------(2)}$$

Therefore, $\frac{250}{1000} = \frac{20 \times R_2}{10 \times 40}$

R_2 = 5 ohm

When both heaters are connected in series

$$= \frac{v_2\, t}{(R_1 + R_2) \times J} \text{ kcal}$$

$$= \frac{125 \times 5}{(10+5)} \text{ kcal}$$

= 41.666 kcal

Cells and batteries

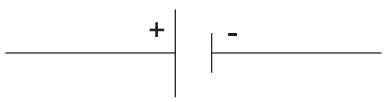
LAW OF CONSERVATION OF ENERGY

Energy can neither be created nor destroyed but it can transfer from one form to another form

Cell

A cell is an electrochemical device that converts chemical energy into electrical energy

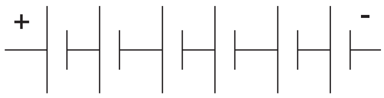
Symbol



Battery

Battery is a collection of cells that converts chemical energy into electrical energy.

Symbol



Classification of cellbased on the electrolyte

1 Wet Cell

2 Drycell

Based on the electrical properties

1 Primary Cell

2 Secondary Cell

3 Reserve Cell

4 Fuel Cell

Wet cell

It is an electric cell in which the electrolyte is in the form of liquid. The other name of this cell is flooded cell .This cells must be operated in an upright position Wet cells were a precursor to dry cells and are commonly used as a learning tool for electrochemistry.

Dry cell

Dry cell is a cell in which the electrolyte exists in the form of paste, with only enough moisture to allow current to flow.

Primary cell

These are cell, it converts chemical energy into electrical energy and cannot be rechargeable. Primary batteries are designed to be used until exhausted of energy then discarded. Their chemical reactions are generally not reversible, so they cannot be recharged. When the supply of reactants in the battery is exhausted, the battery stops producing current and is useless

Secondary cell

The cell that can be recharge by sending electric current in reverse direction to that of discharging.Secondary batteries can be recharged; that is, they can have their chemical reactions reversed by applying electric current to the cell. This regenerates the original chemical reactants, so they can be used, recharged, and used again multiple times

Reserve cell

It is also called standby battery. It is a primary battery where part is isolated until the battery needs to be used. A reserve battery can be stored unassembled (inactivated and supplying no power) for a long period (perhaps years). When the battery is needed, then it is assembled (e.g., by adding electrolyte); once assembled, the battery is charged and ready to work.

Uses: Used in Missiles, Bomb, Various weapon systems etc.

Fuel cell

Device that converts the chemical energy from a fuel into electricity through a chemical reaction of +vely charged hydrogen ions with oxygen or another oxidising agent.

Uses: Used in Satellite, Space capsule etc.

Types of primary cell

- Voltaic cell.
- Carbon-zinc cell (Leclanche cell or Dry cell)

- Alkaline cell
- Mercury cell
- Silver oxide cell
- Lithium cell

Types of secondary cell

1 Lead acid cell

2 Alkaline cell or nickel-iron cell

Simple voltaic cell

In 1800, Volta invented the first true battery which came to be known as the voltaic pile. The voltaic pile consisted of pairs of copper and zinc discs piled on top of each other, separated by a layer of cloth or cardboard soaked in brine (i.e., the electrolyte).

Construction and working of voltaic cell

It consists of a glass container in which Copper plates and Zinc plates are immersed in dilute sulphuric acid. The zinc plate act as negative electrode while the copper plate act as positive electrode. When the Copper and Zinc plates are joined by awire and dipped into dilute sulphuric acid the following observations are made:

The Zinc rod slowly dissolves in the sulphuric acid.Bubbles of Hydrogen are formed on the copper plate.A current of electrons drifts through the wire from the Zinc to Copper.Dilute sulphuric acid ionises according to the equation.

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$

Zinc atoms dissolves from the Zinc plate and go into solution as Zn^{2+} ions each of which leaves two electrons behind on the Zinc rod.

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

These electrons are the source of electron current which goes through the wire from the Zinc to the Copper.

At the Copper rod Hydrogen ions are discharged to form Hydrogen atoms and molecules.

$H^+ + e$ H atom

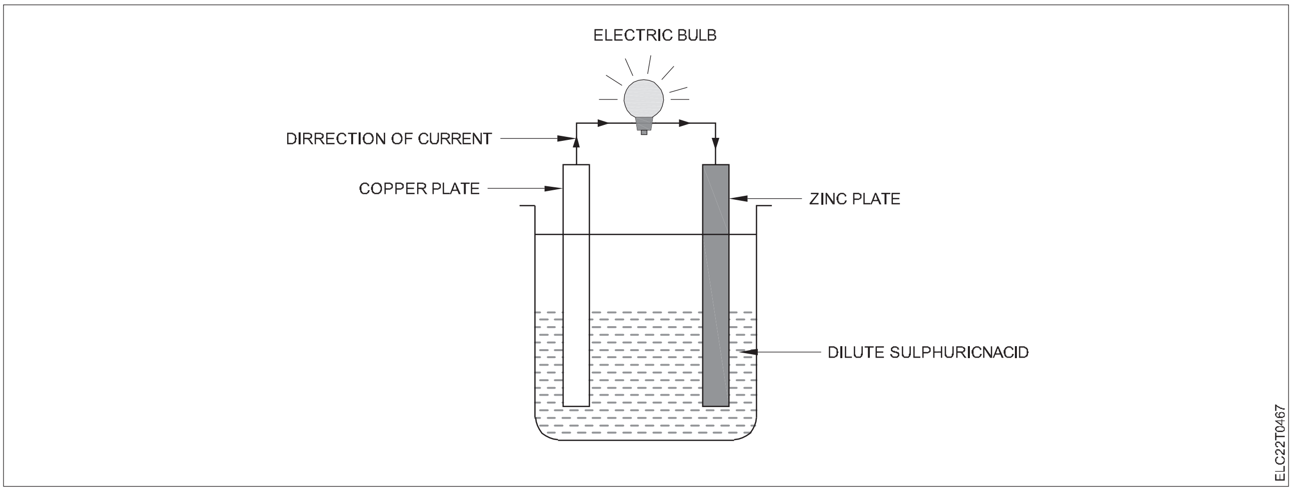
$H + H$ $H_2(g)$

Current flows from positive terminal of a cell to the negative terminal

Defects of simple voltaic cell

1 Polarisation

2 Local action



Polarisation

When a primary cell delivers current to an external circuit, chemical reactions occur inside the cell, and the products of the reaction accumulate around the internal electrodes (anode and cathode) of the cell. Very often one of these products is hydrogen, which accumulates around the cathode (positive terminal). Being a gas, this is an insulator, and so its presence increases the internal resistance of the cell.

Prevention of polarisation

- Permit the hydrogen to escape to air
- Depolariser like manganese dioxide is added
- Use material that will absorb the hydrogen (Calcium)

Local action

This is caused by the impurities present in zinc rod. When the zinc rod is immersed in acid, the zinc atoms and the impurity atoms form a large number of local cells and the zinc rod gets consumed even when the cell is not in use. This defect can be avoided by using amalgamated zinc rods. Mercury dissolves zinc and allows only zinc atoms to come into contact with acid and thus avoids formation of local cells

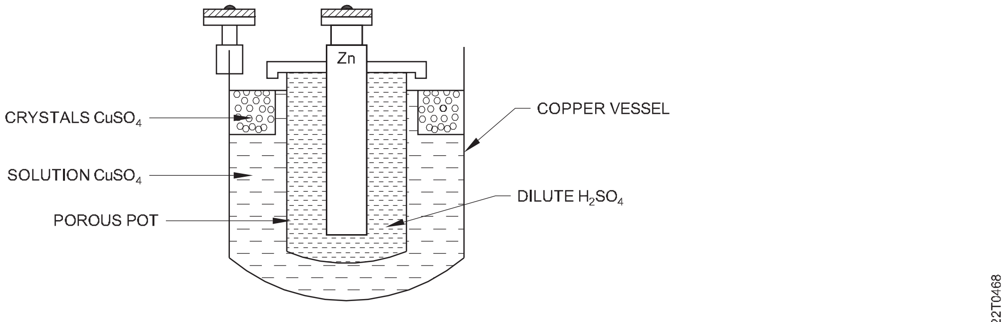
Prevention of local action

- Use pure zinc
- Use amalgamated zinc (mercury coated zinc)

Different types of cells and batteries

4.5-volt (3R12) battery, a D Cell, a C cell, an AA cell, an AAA cell, an AAAA cell, an A23 battery, a 9-volt PP3 battery, and a pair of button cells (CR2032 and LR44)

Daniel cell: It is a modification of simple voltaic cell, because it is similar in chemical action. It was the first cell in which a depolariser was used to avoid polarisation and amalgamated zinc road for preventing local action.



DANIELLCELL

Construction

This cell consists of an outer copper vessel, which serves as positive electrode. This vessel contains concentric solution of copper sulphate, act as the depolariser. (this solution keep saturated by placing of crystal copper sulphate). In side this vessel is a porous pot containing dilute sulphuric acid as electrolyte and amalgamated zinc rod- act as negative plate.

The chemical reaction inside the porous pot may be represented as follows;

$Zn^{++} + H_2SO_4 \longrightarrow ZnSO_4 + 2H$

The chemical reaction outside the porous pot is;

$2H + CuSO_4 \longrightarrow H_2SO_4 + Cu^{++}$

In this manner polarisation is prevented.

The EMF of the cell is1.12v and internal resistance varies from 2 - 6ohm.

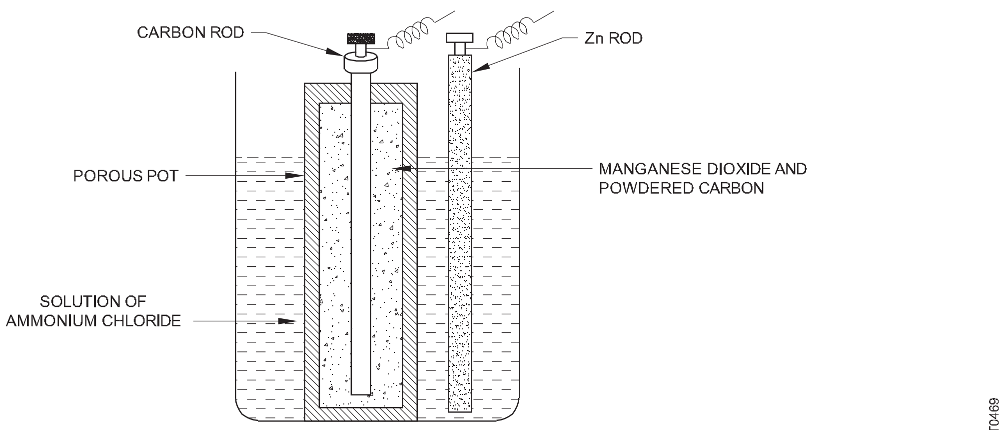
Advantages

- It is cheap and gives constant voltage
- So used in laboratories for experiment.

Leclanche cell

Construction

This cell consists of a glass jar contain solution of ammonium chloride (NH_4Cl) as the electrolyte and amalgamated zinc immersed it, as negative plate (fig) the fig also shows a porous pot containing a carbon rod as positive plate. This pot is typically packed with manganese dioxide(MnO_2) act as polariser and powdered carbon particles, serves as a conductor. A hole is provided at the top of porous pot for the gases escaping during chemical action.



LECLANCHE CELL

Working

When the cell is working Ammonium chloride react with zinc, form zinc chloride, and thus liberates ammonium gas and hydrogen ions(H^+).

The chemical reaction outside the porous pot is as follows;

$Zn + 2NH_4Cl \longrightarrow ZnCl_2 + 2NH_3 + 2H^{++}$

(zinc) +(ammonium Chloride) (zinc Chloride) + (ammonium gas) + (hydrogen ionized)

Ammonia gas is insoluble in water. When the water becomes saturated with ammonia, the gas is given off and can be detected by its smell. The hydrogen which passes through the porous pot reacts with the MnO_2 and is converted in to water (H_2O) taking oxygen from MnO_2.

The chemical reaction inside the porous pot is;

$2MnO^2 + H2 \longrightarrow Mn_2O_3 + H_2O$

(Manganese Dioxide) + (hydrogen) (Manganese peroxide) +(water)

This cell polarisation is removed but not complete because the hydrogen is liberated at quicker rate than the action of depolariser. Here, some hydrogen gas gets accumulated around the carbon rod. If a little rest is given to the cell, it becomes depolarised and cell return to its normal condition. EMF of the cell is 1.45 V, internal resistance is varying frome1-5 ohm. The cell is used for intermittent current as required in electrical bells, telephone …

Advantages

- It is very cheap as only ammonium chloride is to be changed occasionally.
- There is only one kind of solution and hence no diffusion take place.

Disadvantages

- It is not portable
- It is cannot use for constant long service.

Construction of lead acid cell

Lead acid cell consists of the following parts.

Container

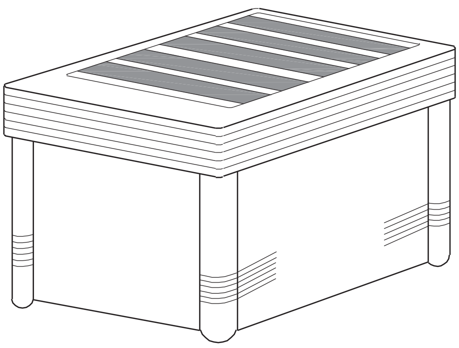
Plates

Separators

Post terminals

Container

It is made of hard Rubber(ebonite), vulcanised rubber, plastic, ceramics, and glass. Container is used to accommodate the battery plates, separators and electrolyte. The plates rest on ribs provided at the bottom of the container. The space between ribs is known as sediment chamber. For each cell separate partition are provided in the container.



Plates

Plates are of two types

1 Positive plates.

2 Negative plates.

Positive plates(P_BO_2)

Positive plates are of two types

1 Plante plate or formed plate.

2 Faure plate.

1 Plante plate

These are prepared by the process of repeated charging and discharging. They are made of lead at the beginning which changes to lead peroxide after charge.

2 Faure plate

Pasted or Faure plates are made of rectangular lead grid in to which the active material i.e. Lead peroxide (P_bO_2) is filled in the form of a paste. Colour of positive plate is dark chocolate brown.

Negative plates (P_B)

Negative plates are made of lead grid, and active material is spongy lead (P_b)which is in the form of a paste. The ampere hour capacity of lead acid cell depends up on the size of plates, number of plates, active material used, the strength of the electrolyte. The colour of negative plate is grey.

Plate connector

It is made of pure lead. All the positive and negative plates are assembled and welded separately with it forming positive and negative groups.

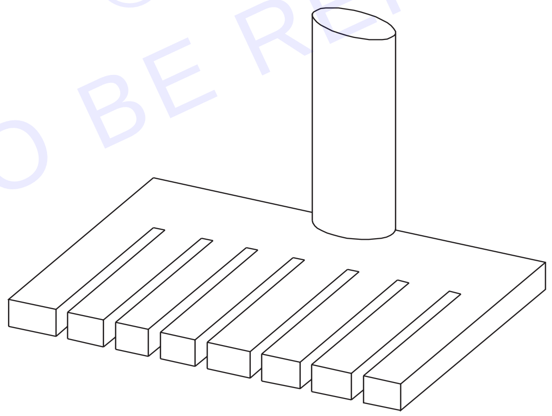


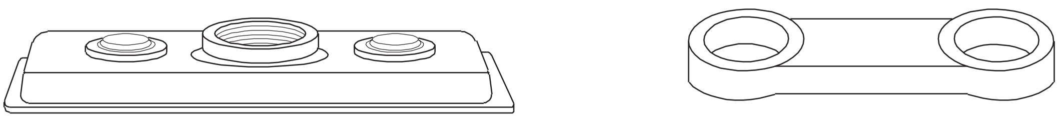
PLATE CONNECTOR

Post terminal or pillar

A small post extended upward from each group of welded plates from the plate connector forms the post terminal

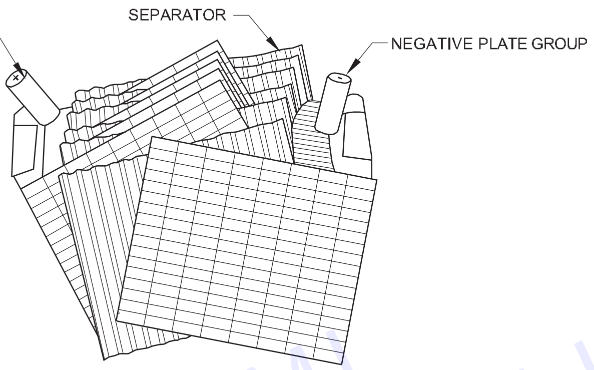
Cell connectors

These are the thick drilled bar made of pure lead. The cells are connected and welded in series to form a battery.



Cell cover

It is made of hard rubber or PVC.



CELL ELEMENT PARTLY ASSEMBLED

Vent plugs or filler caps

They are made of polystyrene or rubber and are usually screwed in the cover. It prevents the escape of electrolyte and allows free exit of gas. It can be easily removed for topping up or taking hydrometer reading.

Seperators

These are made of thin sheets of chemically treated porous wood or micro porous rubber or glass wool mat or perforated PVC. They are used to avoid short in between the positive and negative plates.

Electrolyte

The electrolyte used in a lead acid cell is dilute sulphuric acid (H_2SO_4). The specific gravity of the electrolyte is 1.24 to 1.28. Specific gravity of electrolyte is measured by using hydrometer. It varies according to the manufacturer's specification.

Chemical action

If two cells are connected dipped in dilute sulphuric acid and connected to a DC supply main, current flowing through the electrolyte splits up into hydrogen and sulphate ions. The hydrogen ions travel towards the negative plate and it has positive charge.

Chemical action during discharging of storage cell

Consider a cell has fully charged at the instant anode is lead per oxide (pbo2) and the cathode is lead (pb).The lead ions of the negative plate go into the electrolyte and there is hydrogen ions to collect on the positive plate.

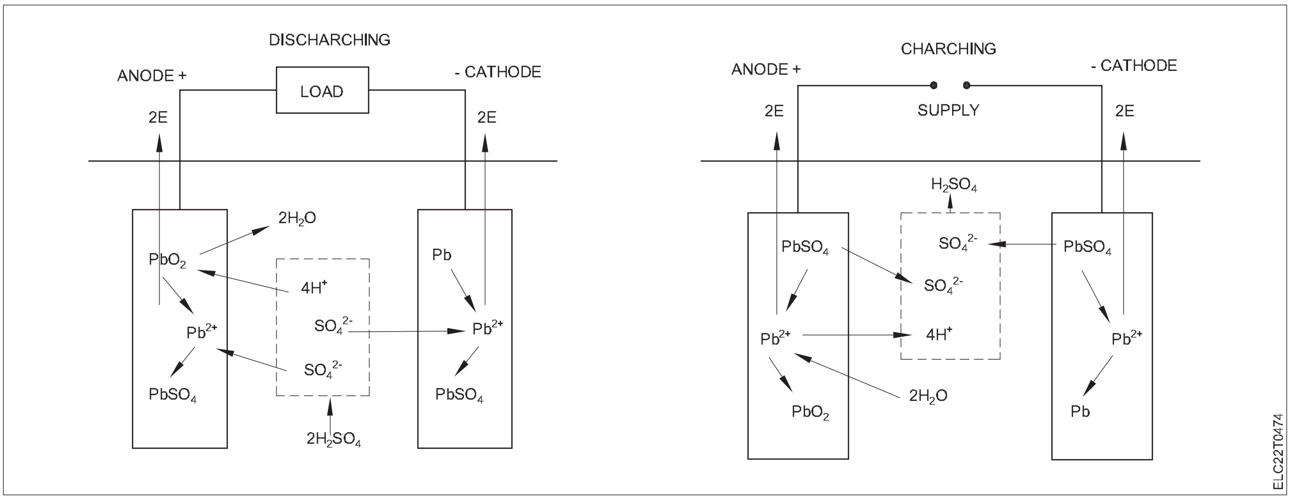
For every positively charged pb^{++} ions entering into the solution two electrons are lift behind on the plate. For every positively charged hydrogen atoms deposition on the positive plate on negatively charged sulphate ions is left in the solution.

When plates are connected through a resistance R the electrons flow from negative plate to anode and that in case more lead ions go into the electrolyte and more hydrogen ions are attracted by the anode. At the negative plate sulphuric acid molecules attract the lead ions and lead sulphate is formed.

Negative Plate Pb + H_2So_4 = $pbSo_4$

Positive Plate $Pbo_2 + H_2 + H_2So_4 = pbSo_4 + 2H_2O$

When the cell is discharged both plates are $pbSo_4$



Chemical action during charging

During discharging both plates are changed to lead sulphate. On the charging positive supply terminal is connected to the anode of the cell. So that the current in the electrolyte is passing from cathode to anode in the electrolyte. Sulphate ions moves to the anode and hydrogen ions react with the lead sulphate ions which enter into the solution.

Positive Plate

$PbSo_4 + So_4 + H_2So_4 = pbo_2 + 2H_2So_4$

Negative Plate

$PbSo_4 + H_2 = Pb + H_2So_4$

During charging

1 Both anode and cathode become lead sulphate it is whitish in color

2 Due to formation of water specific gravity of acid decreases

3 Voltage of the cell decreases.

4 The cell gives out energy

During discharging

1 The anode become dark chocolate brown and cathode becomes gray metallic color

2 Due to consumption of water, specific gravity of sulphuric acid is increased

3 Voltage of the accumulator rises

4 Energy is absorbed in the cell

Indications of fully charged cell

1 The visible indications of fully charged cell

2 The color of the electrodes positive plate chocolate brown and negative plate slate gray color

3 The gassing at the electrodes. A fully charged accumulator gives of oxygen and hydrogen freely as gas bubbles

Preventive maintanance of lead acid cell

The following steps should be adopted for Preventive maintenance of lead acid battery.

- Level of the electrolyte: - Before putting a battery on charge, always maintain the level of the electrolyte 15 mm above the plates. For this distilled water should be added.

- Polarity: - The positive terminal of the battery is connected to the positive of supply and negative terminal is connected to the negative terminal of the supply.
- The vent plug: -Should be kept loose for the liberation of gas during charging.
- The battery terminal should be kept clean. A thin layer of Vaseline or petroleum jelly should be applied over them to prevent corrosion.
- A battery: - should not be charged or discharged at high rate continuously
- A battery: - should never be discharged beyond 1.8V, otherwise the lead sulphate changes into an insoluble salt.
- The battery: - should be recharged as soon as possible after discharge.
- The battery charging room: - should be well ventilated because the gases liberated during charging are flammable in and explosive nature.
- A discharge battery: - should not be tested with a high rate discharge cell tester. It should be applied to a charged cell for not more than 10s.
- The Specific gravity: - of the electrolyte should be checked before and after a battery is put on charge.
- Preparing the electrolyte: - the acid should always be added drop by drop into the water and not vice versa.
- If the battery: - is not being used for long period, then it should be put on trickle charge.

Topping up

If the level of the electrolyte on the surface of the plate is less than 10 to 15 mm then some distilled water should be added in the cell. This process is known as topping up.

Trickle charging

The continuous charging of a battery at low rate for keeping the battery ready in good working condition is called trickle charging. This value of charging current is approximately 2% of the full charging current of the battery.

Testing of battery

Preparation of Electrolyte

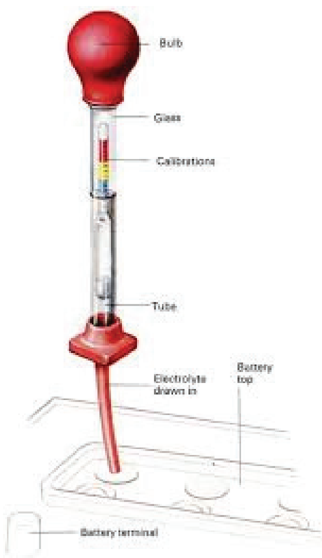
- The electrolyte for the cell can be prepared by adding sulphuric acid to distilled water drop by drop and not vice-versa (AAA principle)
- A glass rod should be used for stirring the electrolyte
- While preparing electrolyte the sp. Gravity decreases as the temperature increases. Therefore, the electrolyte should be allowed to cool to room temperature before filling

Specific. Gravity.....1.200-1.300

Use of hydrometer &high rate discharge cell tester

Indication of fully charged cell,

- Color of plates
- Specific gravity (increases from 1.180 to1.280)
- Gassing occur on both plates
- Voltage/cell (rises from 1.8 to 2.2V)
- High rate discharge cell tester-The voltage of fully charged cell is tested on load



Hydrometer

Main parts,

Rubber bulb, Glass tube, Float, Flexible rubber tube.

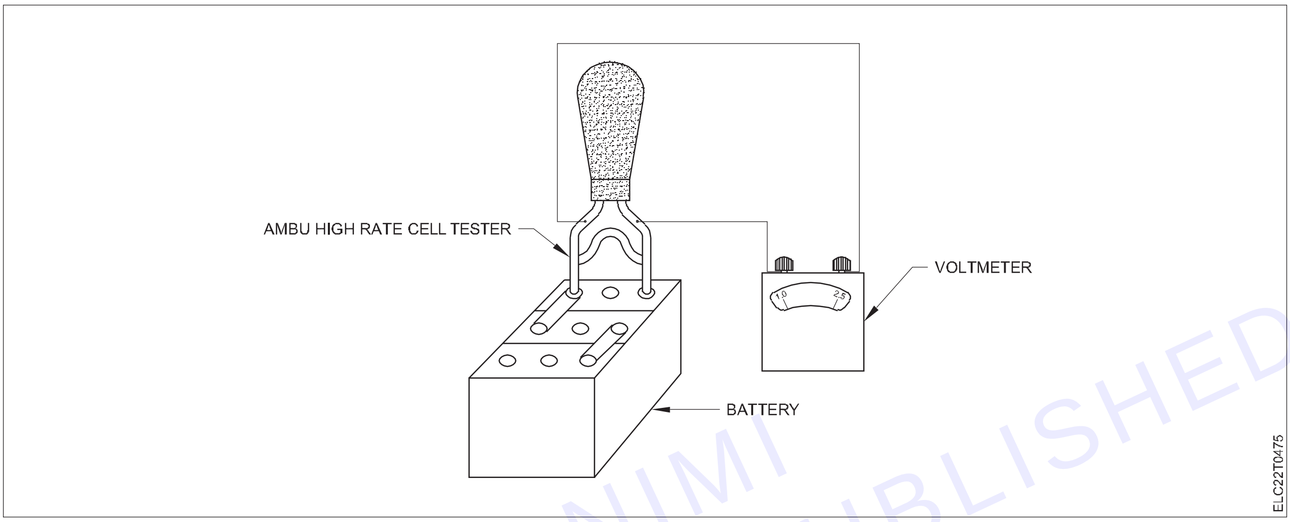
The specific gravity of electrolyte is measured with a hydrometer

- It measure relative density of electrolyte.

- Strength of electrolyte depends on charging
- Full charge......1.26
- 50% charge.....1.20
- Discharge........1.15

HIGH RATE DISCHARGE CELL TESTER

It is used to find out the internal condition of the cell. It consist of wooden handle having two pointed metal strips parallel to each other B/W them is provided a load of low resistance. A low range voltmeter (0-3V) is connected parallel.



- A fully charged cell in good condition reads in the range of full charge
- A sulphated or old battery shows the discharge reading.

Battery tester

The meter shows three colours according to battery conditions

- Red-fully discharged
- Yellow-half charge
- Green-fully charged

The voltage of each cell is measured with a MC Voltmeter

- Fully charged cell……..(2.5-2.6V)
- Fully discharged cell….(1.8-1.6V)

Nickel iron (Ni- Fe) CELL / Alkaline cell

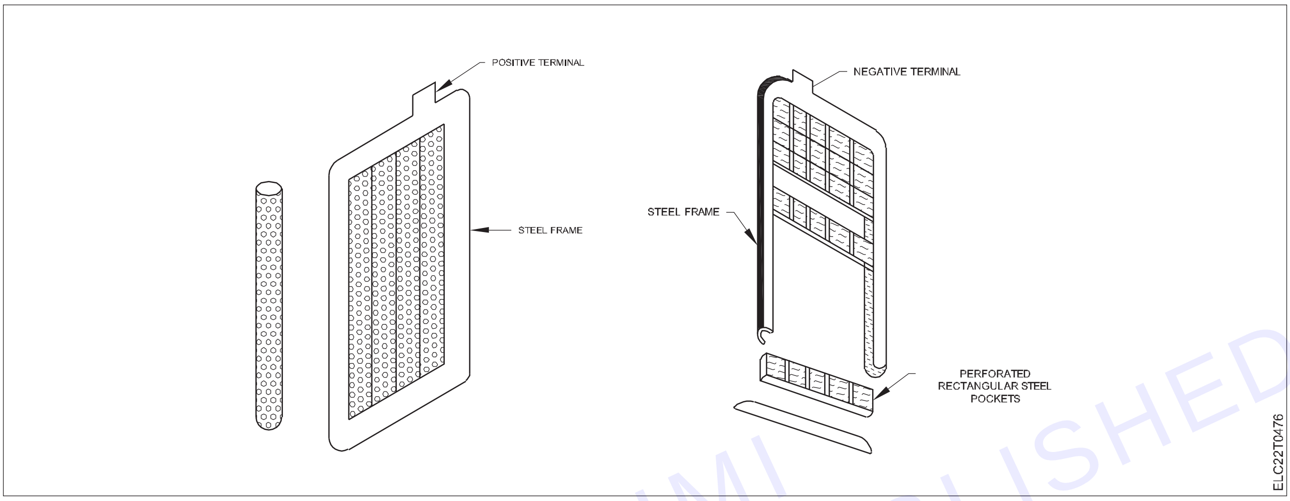
Construction of Nickel iron cellPositive plate, Negative plate, Electrolyte, Separator.

Positive plate

Consist of many perforated steel tubes which contains nickel hydroxide (Ni(OH)4). To increase the conductivity of Ni(OH)4 pure nickel flakes are added. Steel tube is about 15mm diameter and 100mm in length contain nearly 300 such layers. Tubes are then compressed in a nickel plated steel frame, this forms positive plate.

Negative plate

Consist of many rectangular perforated steel pocket into which powered iron oxide is filled. To increase the conductivity small amount mercury is added to pocket. These pockets are clamped in a steel grid, which forms the negative plate. Negative plate is always one more in number than positive plate.



Electrolyte

Electrolyte is potassium hydroxide (KOH) of specific gravity 1.22. pecific gravity is constant during discharging and charging. Ell always kept sealed to avoid the hydroxide combine with carbon dioxide, which decreases the capacity of the cell. For increasing capacity of the cell, small quantity of lithium hydroxide (LiOH) is added to the electrolyte.

Container

Container consist of a steel box The inside and top of the cell cover is given a thick layer of insulating compound to avoid short circuiting as it is made of steel container is air tight and a small hole is provided in the vent plug which allows the gases to escape.

Separator

Separator is made of perforated hard rubber.

These are placed in between the plates to avoid short circuiting

Operation

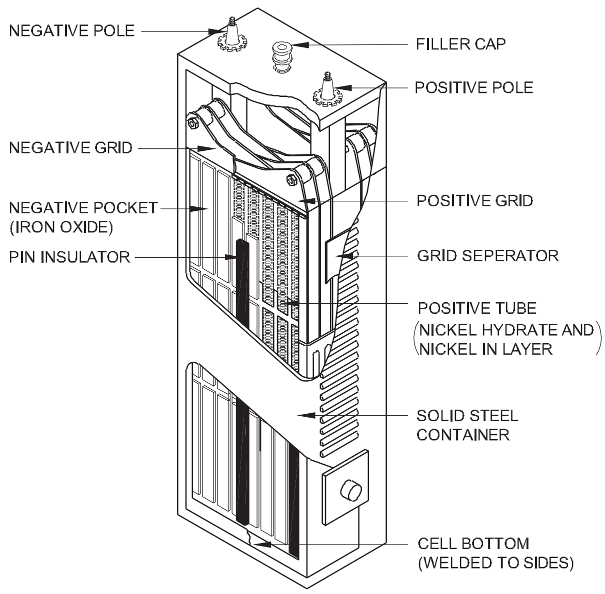
Chemical changes:

The molecules of electrolyte (KOH) dissociate in to K+ and OH- ions

During discharging

When the cell is fully charged the positive plate is of nickel hydroxide(Ni(OH)4) and the negative plate is of iron(Fe). When the cell is discharged a current flows from positive plate to negative plate outside the cell and from negative plate to positive plate inside the cell. The current through the electrolyte breaks it in to potassium ions Ni(OH)4 and hydroxide ions(OH-). The K+ ions move towards +ve plate (anode)and reduce Ni(OH)4 and The OH- ions move towards -ve plate (cathode Fe)

- K+ ions move towards +ve plate(anode)and reduce Ni(OH)4 to Ni(OH)2
- The OH ions move towards – ve plate (cathode) and oxides iron.



Positive plate

$Ni(OH)_4 + 2K \rightarrow Ni(OH)_2 + 2KOH$

(nickel hydroxide) (potassium) (nickel of lower hydroxide) (potassium hydroxide)

Negative plate

$Fe + 2OH \rightarrow Fe(OH)_2$

(iron) (hydroxide of potassium) (ferrous hydroxide)

During charging

During charging the current flows through the electrolyte in the direction from the positive plate to negative plate. This current splits up the electrolyte in to potassium ions (k+) and hydroxide ions (OH-). The k+ ions move towards the negative plate and the OH- ions to the positive plate.

- K+ ions move towards -ve plate and OH- ions go to +ve plate

+VE PLATE :

$Ni(OH)_2 + 2OH \rightarrow Ni(OH)_4$

(nickel of lower hydroxide) (hydroxide of potassium) (nickel hydroxide)

- VE PLATE :

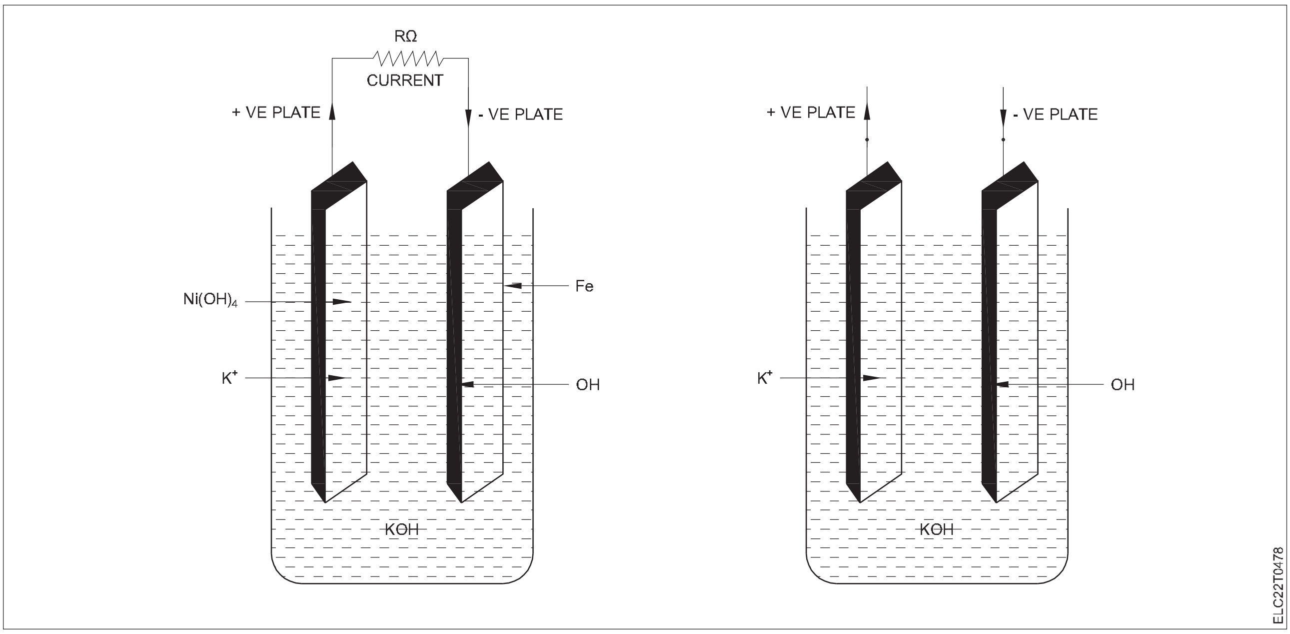
$Fe(OH)_2 + 2K \rightarrow Fe + 2KOH$

(ferrous hydroxide) (potassium) (iron) (potassium hydroxide)

The chemical action during charging and discharging can be summed up in a single equation.

$$Ni(OH)_4 + KOH + Fe \rightleftharpoons Ni(OH)_2 + KOH + Fe(OH)_2$$

Hydrated nickel oxide, Potassium hydroxide, Ferrous, Nickel hydroxide, Ferrous hydroxide



- It is observed that no water is formed in the reaction. So that the specific gravity remain unchanged during charging and discharging.
- So that the cell is not damaged if kept long time in a fully discharged state

Characteristics

- Emf fully charged state ----- 1.4 V
- Reaches to 1.2 V on discharge
- Emf fully discharged state ----- 1.15 V
- Mechanical strength is good since they are made of steel.
- The cell can withstand heavy charge and discharge currents.
- Internal resistance is large and efficiency is lower than lead acid battery.
- With increase in temperature of the cell the capacity increases.

Comparison between charge & discharge states

During discharge

- The negative plate turns in to ferrous hydroxide
- The positive plate turns in to lower hydroxide of nickel
- The specific gravity of electrolyte remains constant
- The per cell voltage falls from 1.4 V to 1.15

During charging

- The negative plate turns in to iron
- The positive plate turns in to l nickel hydroxide
- The specific gravity of electrolyte remains constant
- The per cell voltage increases from 1.15 to 1.4 V

Comparison : Lead acid cell and Edison cell

(The relative strong and weak points of the two cells have been summarized below)

S.No	Particulars	Lead-acid cel	Edison Cell
1	Positive plate	PbO, Lead Peroxide	Nickel hydroxide $Ni(OH)_4$ or Nickel Oxide (NiO_2)
2	Negative plate	Sponge Lead	Iron
3	Electrolyte	Diluted H2SO4	KOH
4	Average emf	2.1 V/Cell	1.2 V/Cell
5	Internal Resistance	Comparatively low	Comparatively higher resistance
6	Efficiency : amp-hour watt-hour	90-95% 72-80%	Nearly 80% About 60%
7	Cost	Comparatively less than alkaline cell	Almost twice that of Pb-acid cell (Easy maintenance)
8	Life	Gives nearly 1250 charges and discharges	Five years atleast
9	Strength	Needs much care and maintenance. Sulphation occurs often due to incomplete charge or discharge	Robust, mechanically strong, can withstand vibration, light, unlimited rates of charge and discharge. Can be left discharged, free from corrosive liquids and fumes.

Applications

Due to their high mechanical strength, lightness and free from acid fumes they have been found to be very satisfactory for the following applications

- Traction purpose
- Mine locomotives
- Submarines
- Industrial trucks
- Aero planes

Similarity of operation NI-FE &NI-CD

- The electrolyte is same for nickel-iron and nickel-cadmium cell .ie potassium hydroxide(KOH)
- When the cell is discharged the positive plate is converted in to Ni(OH)2

The specific gravity of electrolyte is remain unchanged during charge or discharge

Nickel cadmium cell

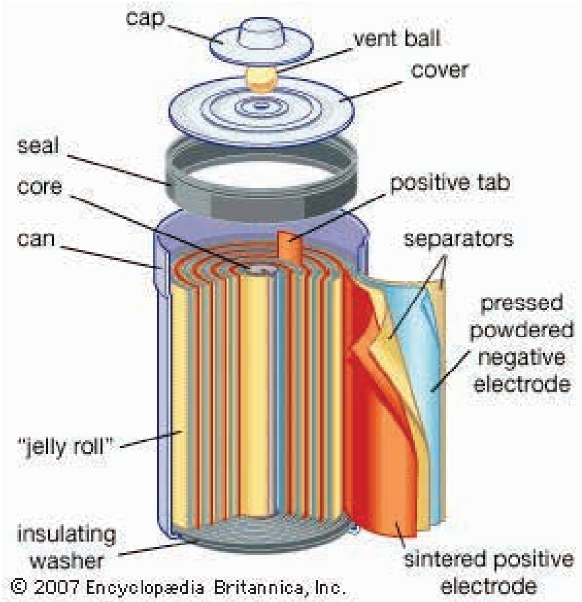
Nickel cadmium cell is similar to nickel iron nickel hydroxide Ni(OH)2 for the positive electrode. Cadmium Cd as the negative electrode. Potassium hydroxide (KOH)electrolyte

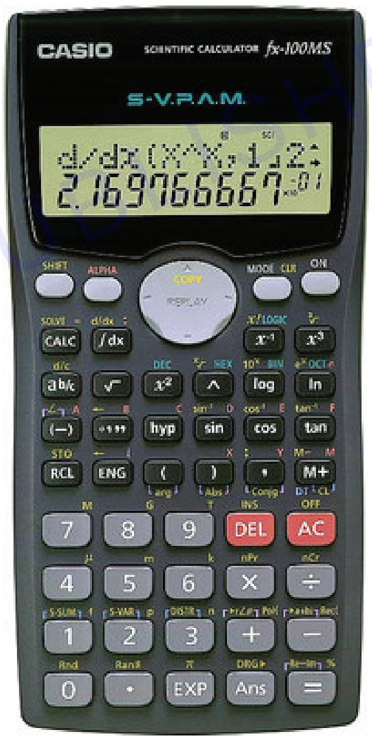
NI-CD Cell operation

- It consist of cadmium anode and a metal grid containing a paste of NiOH2 acting as a cathode.
- The electrolyte is KOH (potassium hydroxide)

Working (discharging)

- When the Ni-Cad battery operates, at the anode cadmium is oxidized to Cd2+ ions and insoluble Cd(OH)2 is formed.
- It produces about 1.4V





Reactions:

At anode

$$Cd(OH)_2 + 2e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Cd + 2OH^-$$

At cathode

$$Ni(OH)_2 + OH^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} NiOOH + H_2O + e^-$$

Over all reaction

$$Cd(OH)_2 + 2Ni(OH)_2 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} 2NiOOH + 2H_2O$$

Advantages

- Fast and simple charge
- Good load perfomance
- Smaller and lighter
- Long life than lead acid cell
- It can be packed in a sealed container

Applications

- Calculator
- Electronic flash unit
- Cord less appliances

Grouping of cells

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

- state the purpose of cells connected in series and parallel
- explain series connections, parallel connection and series-parallel connection of cells.

Grouping of cells: Often an electric circuit requires a voltage or current that a single cell is not capable of supplying alone. In this case it is necessary to connect groups of cells in various series and parallel arrangements.

Series connections: Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell (Fig 1).

Identical cells are connected in series to obtain a higher voltage than is available from a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages of all the cells. However, the ampere hour (AH) rating remains equal to that of a single cell.

Example: Suppose three `D' flashlight cells are connected in series (Fig 2). Each cell has a rating of 1.5 V and 2 AH The voltage and ampere hour rating of this battery would be:

V Battery = V per cell x No.of cells

= (1.5V) (3)

= 4.5 V

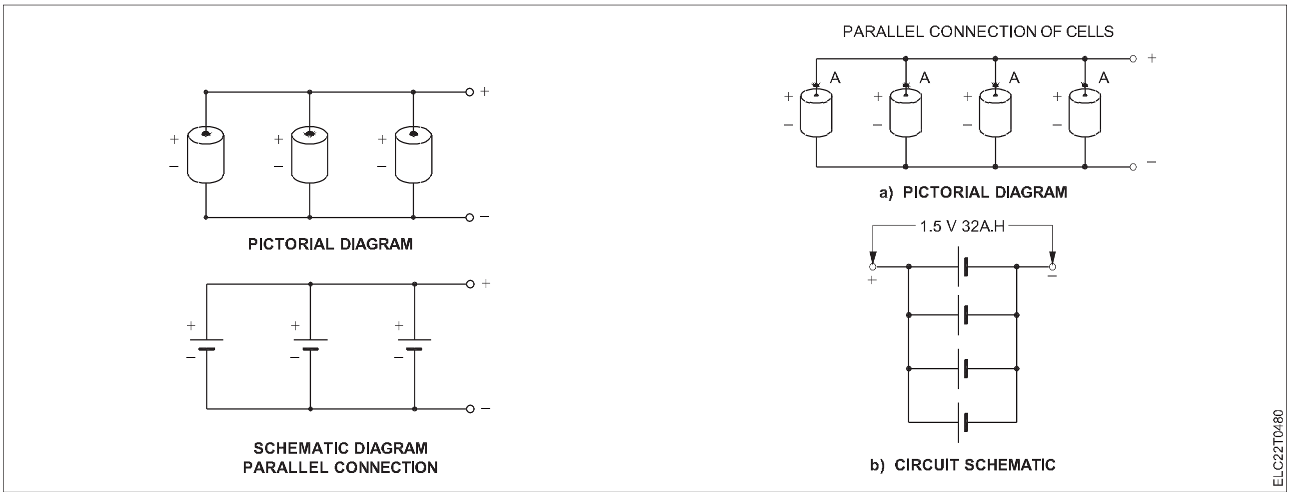
AH Battery rating = AH rating of 1 cell

= 2 AH

Parallel connection: Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together (Fig 3).

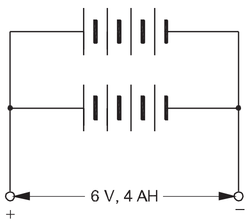
Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere hour rating is equal to the sum of the ampere hour ratings of all the cells. However, the output voltage remains the same as the voltage of a single cell.

Assignment : Suppose four cells are connected in parallel (Fig 4). Each cell has a rating of 1.5 V and 8 AH. The voltage and ampere-hour rating of this battery would be:



Series-parallel connection: Sometimes the requirements of a piece of equipment exceed both voltage and ampere hour rating of a single cell. In this case a series-parallel grouping of cells must be used (Fig 5).

The number of cells that must be connected in series to have voltage rating is calculated first and then the number f parallel rows of series connected cells is calculated for required ampere-hour rating.



SERIES-PARALLEL CONNECTION

Battery charging method - Battery charger

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

- state the necessity of charging a battery
- describe the preparation of electolyte
- describe the use of a hydrometer and high rate discharge tester
- state the precautions to be followed while charging and discharging a battery
- describe the different types of charging methods of secondary cells
- explain the purpose, construction and working principle of battery charger.

Necessity of charging: During discharge, due to chemical reaction, the active electrodes become smaller and the internal resistance becomes high causing a low output. To reverse the action, send a current (DC) through the battery or cell in the opposite direction to that of the discharge. This process is called charging. The charging can be done through a battery charger.

Battery chargers: When the chemical reaction in a rechargeable battery has ended, the battery is said to be discharged and can no longer produce the rated flow of electric current. This battery can be recharged, however, by passing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery.

When charging a battery, the negative lead of the charger must connect to the negative lead of the battery and the positive lead of the charger to the positive lead of the battery

A simple variable-voltage DC power supply works well as a battery charger.

Charging current: When charging any battery, it is important to set the charging current to a value recommended by the manufacturer. This current is set by adjustment of the output voltage on the charger and read by an ammeter connected in series with the charger and battery (Fig 1). When the battery and charger are at the same voltage, no current flows. The charger voltage is set to a value higher than that of the battery to produce a current flow.

Before charging the battery or cell the following points are to be observed to ascertain the condition of the battery.

1 Specific gravity of the electrolyte

2 Voltage of each cell of the battery

3 Ampere hour capacity of each cell.

Electrolyte

The electrolyte used in a cell is dilute sulphuric acid having a specific gravity between 1.21 and 1.3.

Specific gravity

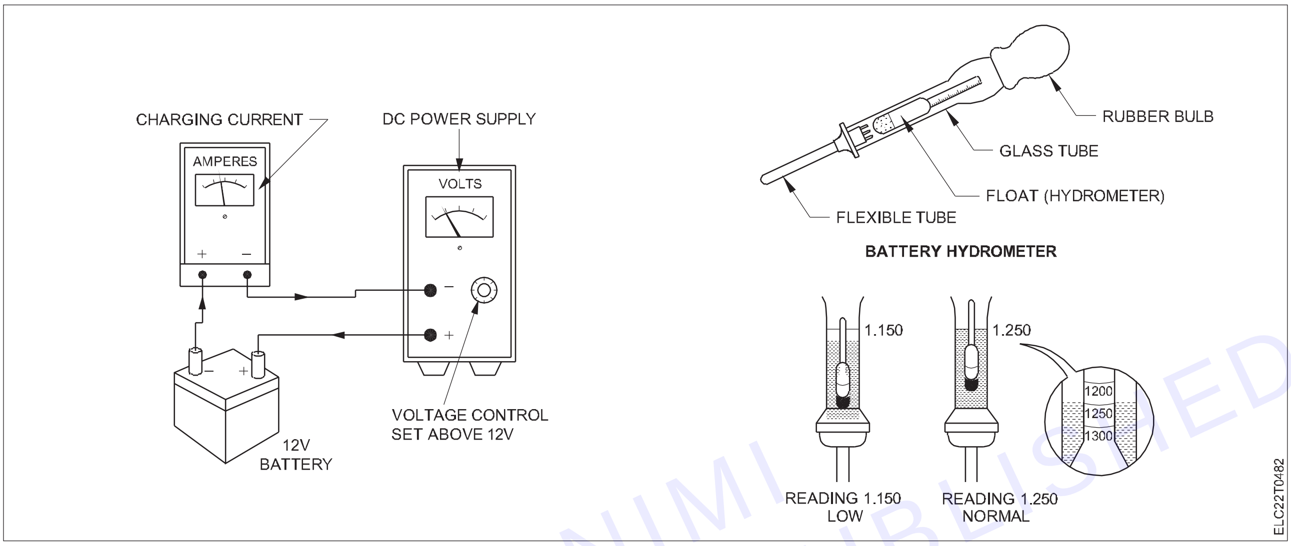
The ratio of the mass of a given volume of liquid to the mass of the same volume of the water at 4°C, is known as specific gravity of the liquid.

$$\text{Specific gravity} = \frac{\text{(mass of given volume of liquid)}}{\text{(Mass of the same volume of water at 4°C)}}$$

Instrument for testing the condition of cells:

Hydrometer : The specific gravity of an electrolyte is measured with a hydrometer (Fig 2).

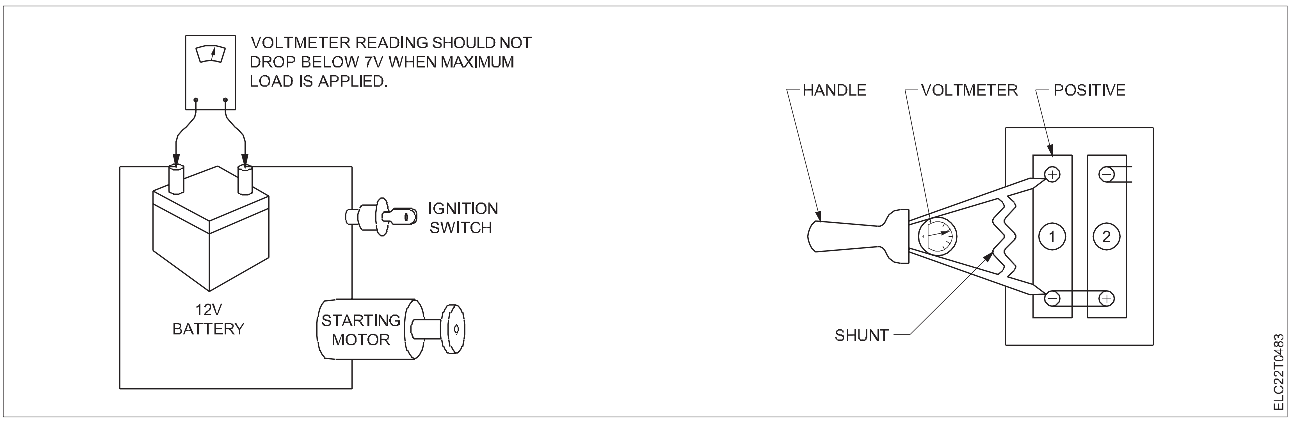
The charged condition of battery can be tested by means of a battery hydrometer. This instrument measures the relative density of the battery electrolyte. Since the strength of the electrolyte varies directly with the state of charge of each cell, you need only to find what specific gravity of sulphuric acid remains in each cell electrolyte to determine how much energy is available.



Cell condition	Hydrometer reading
Full charge	1.26
50% charge	1.20
Discharged	1.15

Voltage tests of lead-acid batteries, like primary cells, should be conducted under load. To make a simple light load voltage test of a car battery, check the value of the battery output voltage with and without the headlights on. A maximum load voltage test can be made by metering the battery voltage while operating the starting motor (Fig 3). In the case of a 12V battery, a drop of battery output voltage below 7V indicates the battery is defective or not fully charged.

High rate discharge tester: The internal condition of the cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance (Fig 4). The two terminal prods are pressed on to the terminals of a cell for testing. A fully charged cell which is in good condition reads in the range of full charge.



The meter is having three colours red, yellow and green - red for fully discharged, yellow for half charge, green for fully charged condition of the cell respectively.

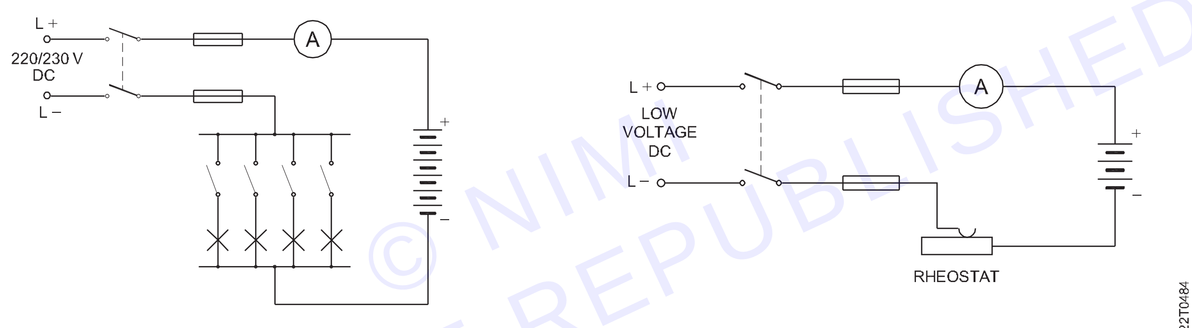
The methods of charging the secondary cells are:

- constant current method
- constant potential method
- rectifier method.

Constant current method: This method is used where the supply is high voltage DC 220 V, 110 V, etc. but the battery is of low voltage 6 V, 12 V, etc. The emf of the battery is small in comparison to the supply voltage so a lamp-load or a variable resistor is connected in series with the battery (Fig 5). This causes a loss of energy, so, the method is inefficient.

Use: For charging more number of cells at constant current rating.

Constant potential method: In this method, the voltage is maintained at a fixed value about 2.3 V per cell; the current decreases as the charging proceeds. A variable resistor is connected in series, so a voltage source of 2.5 to 2.6 V per cell is required. For a 12 V motor car battery, the charging dynamo is of about 15 V. In comparison to the constant current method less power is wasted for charging and less time is taken. Fig 6 shows the connections for a constant potential method of charging batteries.



CONSTANT CURRENT METHOD

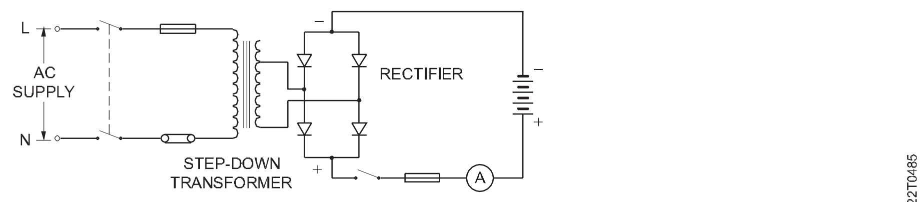
CONSTANT VOLTAGE METHOD

Use: For charging batteries of constant voltage rating.

Rectifier method: A rectifier for battery charging is generally made of diodes connected in the form of a bridge (Fig 7). A transformer is used to step down the AC voltage to that suitable for diodes. Ammeter, voltmeter, switches and fuses are also used in the rectifier set.

Trickle charge: When the battery is charged at a very low rate, that is 2 to 3% of the normal rate for a long period, it is said to be a trickle charge.

Use: For central or sub-station batteries and for emergency lighting systems.



RECTIFIER METHOD

Solar cells

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

- state the necessity of tapping natural resources for energy
- state about the solar cell /photo voltaic cell
- explain the basic principle, construction and characteristics of the solar cell.

Heat energy

Heat energy is the most sought energy for human being to cook the food as well as to keep warm in cold climate. However the use of wood as the fuel for fire, has ended up in deforestation and resulted in drought.

Search of fuel led the man to use coal and then oil. However these commodities are fast dwindling and after few hundred years both may completely vanish from earth. As such it is essential that human race should find alternative source of energy from nature.

Hence the use of natural resources like heat from sun thought by several scientists and one of the solutions to the energy crisis is the invention of solar cells.

Solar cell / Photovoltaic cell

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. They are used as a photo-detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

- The absorption of light, generating electron-hole pairs extraction.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

The solar cells is essentially a large photo diode designed to operate as photo voltaic device and to give as much output power as possible. When these cells are under the influence of light rays from sun, they give out about 100 mw/cm2 power.

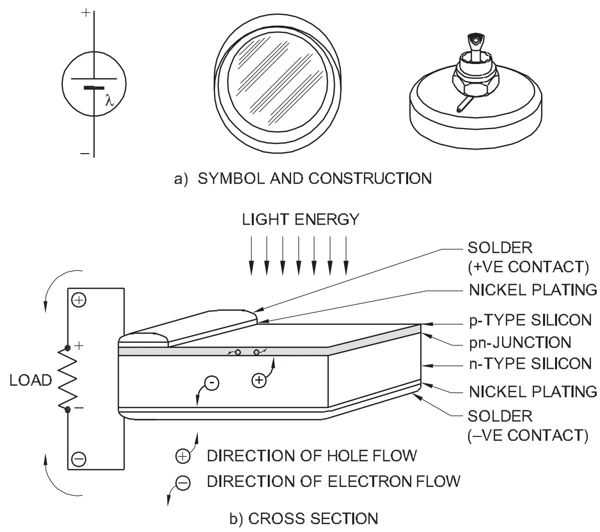
Fig 1 shows the construction, symbol and cross section of a typical power solar cell. The top surface consist of a extremely thin layer of P-type material through which light can penetrate to the junction.

The nickel plated ring around the P-type material is the positive output terminal, and the bottom plating is the negative output terminal. Commercially produced solar cells will be available in flat strip form for efficient coverage of available surface areas.

According to different manufacturing standards, the output power varies from 50mw/cm2 to 125mw/cm2 . The graph shows the characteristic of a solar cell which gives 100mw/cm2. Considering the characteristic curve it is apparent that the cell will deliver an output current of 50mA when the output terminals are short circuited then the output voltage will be zero.

On the other hand open circuited voltage of the cell will be 0.55mv but the output current is zero. Therefore again the output power is zero. For maximum output power the device must be operated at the knee of the characteristic. In solar cells the output power decreases at high temperature.

Several cells must be connected in series to produce the required output voltage, and number of parallel groups to be provided as per the required output current.



CONSTRUCTION AND CROSS SECTION OF A SOLAR CELL.

MODULE 4 : Electrical Wiring Practice, Earthing

LESSON 20-25 : National codes, common electrical acccessories , types of wiring earthing

Objectives

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

- state NEC, general wiring roles BIS symbols used for electrical accessories
- classify specific, user of the accessories in domestical wiring
- state the IE rules related to safety & electrical supply
- explain wiring of MCB, MCCB, ELCB, residual current circuit breaker
- state the types of wiring testing methods - domestic wiring instrumental megger
- earthing types of earthing methods reducing earth resistance, earth tester.

National electrical code

Thousands of people die every year due to electrical accidents fire has destroyed property worth million of rupees. Fires in building are due to electrical reasons. The main reasons for electrical accidents are poor design and quality of electrical installations, maintenance, workmanship issues & very old installations.

Bureau of Indian Standards 9BIS) through its electrical installations sectional committee. (ETD-20) under ETDC is responsible for the preparation of Indian Standards for Safety and related matters in its designing, erection & maintenance of electrical installations

BIS has revised the National Electrical code of India which was released on January 6, 2023. BIS updated the NEC to align with international practices.

This state of the art code establishes the basics of electrical safety in India.

The NEC consists of 8 parts and 49 sections covering different aspects of electrical installations.

Part 1: General & common aspects (22 sections)

Part 2: Electrical installations in standby generating stations & capacitive substations (2 sections)

Part 3: Requirement for special installation or location (22 sections)

Part 4: Electrical installations in industrial buildings

Part 5: Outdoor installation (3 sections)

Part 6: Electrical installtions in agriculture premises

Part 7: Electrical installations in hazardous areas

Part 8: Solar Photovoltaic (PV)

Power supply systems

Protection measures

The NEC provides protection measures including

1 Protection against electric stock

2 Protection against thermal effect

3 Protection against over current & short circuit current

4 Protection against, erction & verification of electrical installation.

Wiring system

Wiring: A network of wires connecting various accessories for distribution of electrical energy from the supplier meter board to the numerous consuming devices through controlling and safety devices.

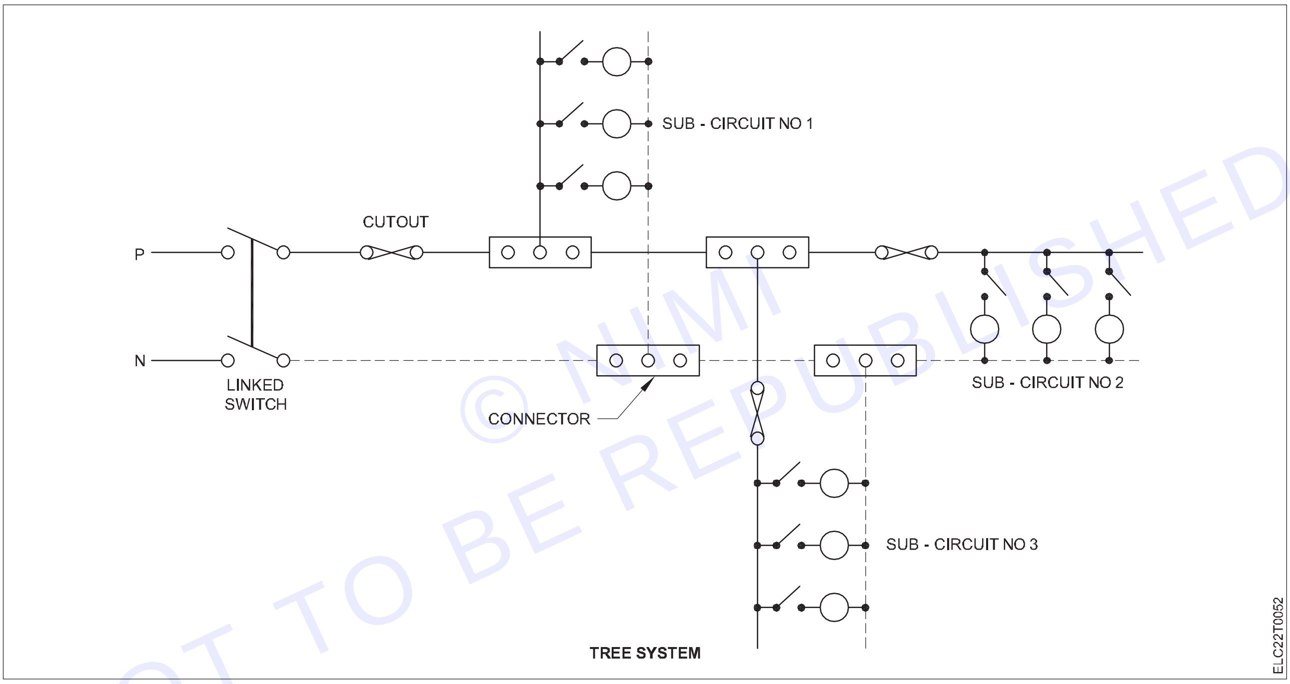
Systems of distribution of electrical energy: Since as per recommendation of Indian Standard the maximum number of lights, fans and 5A socket outlets that can be connected in one circuit is 10 and the maximum load that can be connected in such a circuits 800W, in case more load or points are required to be connected to the supply, then it is to be done by having more than one circuit. There are two systems are used for distribution of electrical energy in more than one circuit

1 Tree system

2 Distribution board system

1 Tree system

In this system small branches are taken from the main branch as shown in fig.



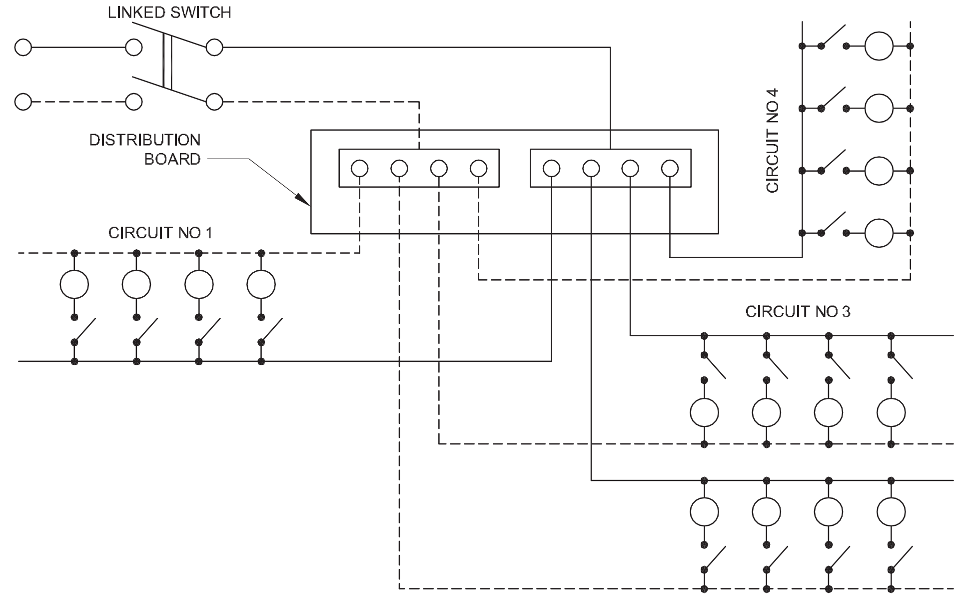
And the wiring system resembles a tree, as each branch is taken off, a fuse is inserted.

This system used to be employed in early days. Now a day it is no more adopted due to the following draw backs.

Dis advantages

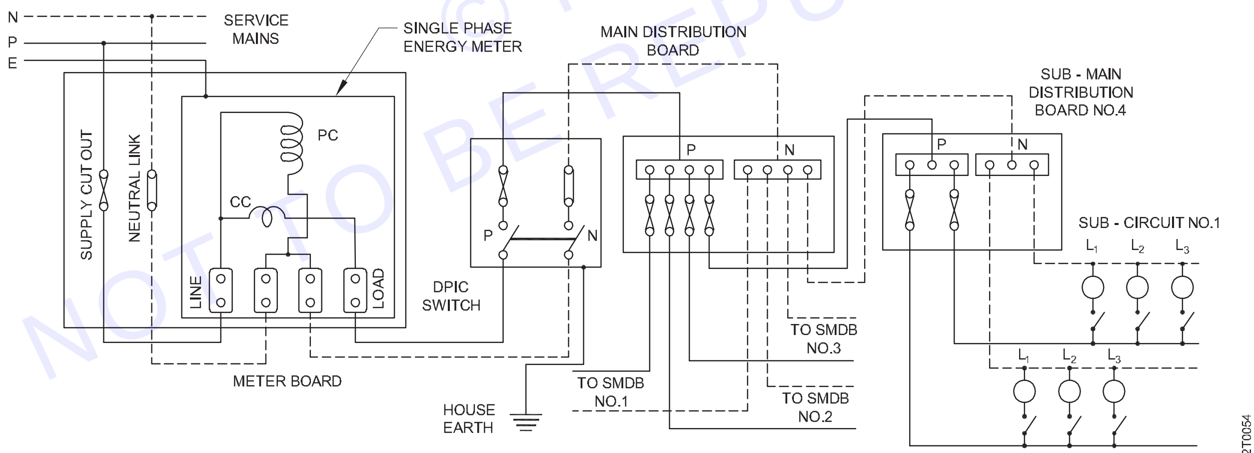
- The voltage across all lamps does not remain same, lamp in the last branch will have least voltage across them on account of voltage drop in leads.
- A number of joints are involved in every circuit.
- Fuses are scattered
- In case occurrence of fault all the joints have to be located and if some of these joints are concealed floor or roofs space, a lot of difficult are faced.

2 Distribution board system: Which is most commonly adopted system for distribution of electrical energy in a building. The fuses of various circuits are grouped together on distribution board.the two copper strips called Bus bars are connected to the supply mains through a DP switch, so switched off whole circuit, if required. A fuse is inserted in phase pole of each circuit, so that each circuit is connected up through its own particular fuse. The distribution board shown in fig. has 4 ways for 4 circuit but no limit to the no. of ways or circuit, provided the cable feeding, the board is large enough to carry the total current.



DISTRIBUTION BOARD SYSTEM

In large buildings, if only one distribution board were used, some of the point would be at a considerable distance from it. and in such cases it is advisable to employ sub- distribution board either to save cable or to prevent too great voltage drop at the more distant point.in such cases main DB controls the circuit to each sub-DB as shown fig. the sub distribution board are installed near the load.



TYPICAL HOUSE - WIRING CIRCUIT

Advantages

- Fault finding is very easy.
- The voltage available at different point of the circuit will be same.
- Renewal or extension of circuit is easy.
- Good appearance.

Disadvantages

- Length of cable is more.
- So the initial erecting cost is more

Methods of wiring

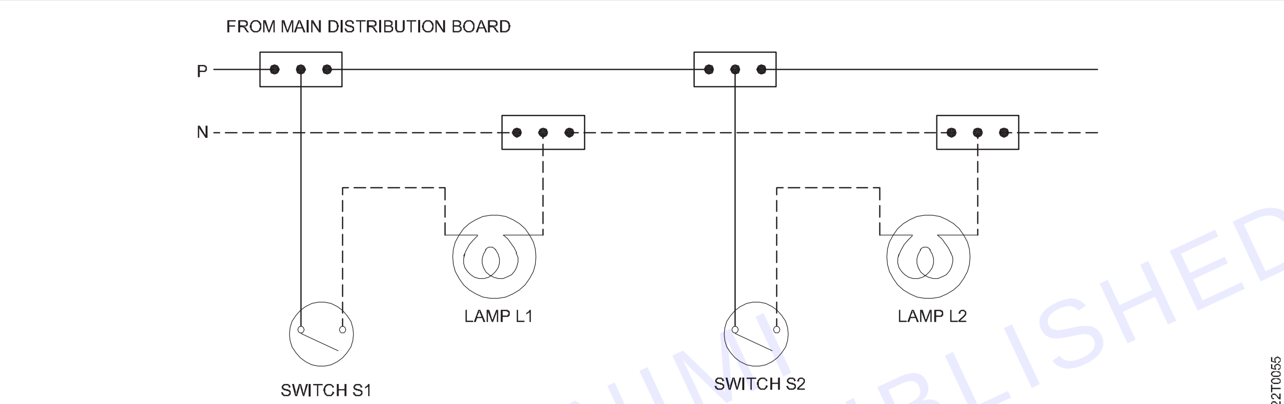
There are two methods of wiring

1 Joint box or tee system

2 Loop in system

1 Joint box or tee system

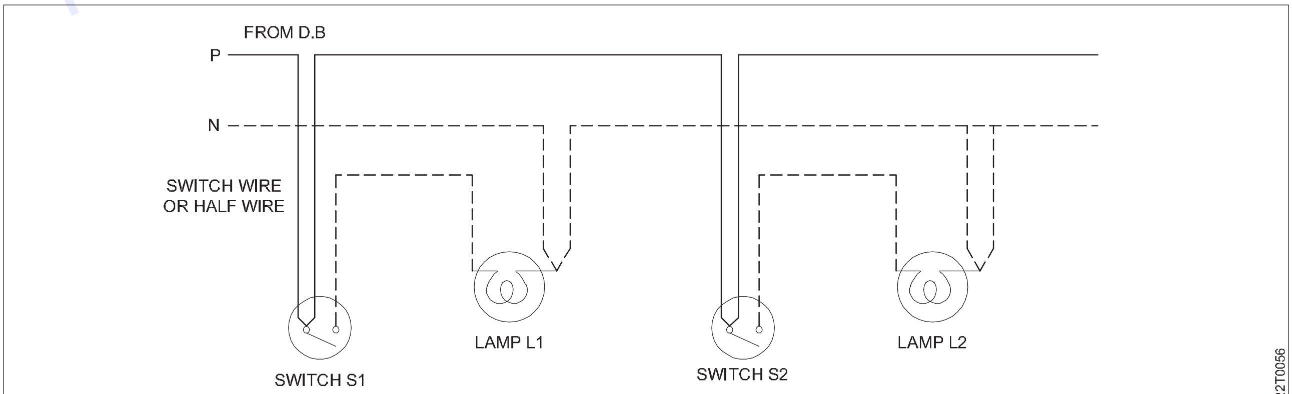
- In this system the connection to the lamp are made through joints made in joint boxes by means of suitable connectors or joint cut outs.
- In this method though there is a saving in the quantity of wire or cable required but the same offset by extra cost of joint boxes.
- Now-a-days the use of this system is limited to temporary installation only assist cost is low.



JOINT BOX SYSTEM

2 Loop in system

- This system is universally employed for connection of various lamps or other appliances in parallel.
- In this system, when a connection is needed to a light or switch, the feed conductor is looped by direct to the terminal and then carrying it forward to the next point
- The switch and light feeds are carried round the circuit in series of loops from one point to another until last point reached.
- The phase conductor is looped in switch board or box only.
- Neutral wire is looped either in switch board or light or fan.



LOOP - IN SYSTEM

General rules for wiring

The followings are some of the BIS regulations pertaining to wiring installation.

1 All the BIS regulations are recommended by the National Electric Code(NEC).All fitting, accessories and appliances used for wiring shall conform to Indian standard (IS mark).

2 Sub circuit

May be dividein to two groups

a lighting and fan sub circuit

b Power sub circuit

Light and fan sub circuit

- Light and fan may be wired on a common circuit
- Each sub circuit have not more than a total of ten point of light, fan and 5A socket outlets
- The load on each sub circuit shall be restricted to 800W

Power sub circuit

- The load on each sub circuit should normally restricted to 3000W
- The point of each sub circuit not more than two (If the load is exceeding 3000W, the wiring for that sub circuit shall be done in consultation with the supply authority)

3 The current rating of the main switch and distribution board should be calculated according to the total load current.

4 All plug and sockets outlets shall be of 3 pin type, the appropriate pin being connected permanently to the earth system.

5 3pin ,16A sockets shall be controlled by individual switch, shall be located immediately adjacent to it.

6 In situation, where accessible to children, it is recommended to use shuttered or inter locked socket out lets.

7 A socket of rating higher than 16A, should be connected to double pole switch of appropriate rating.

8 Depending on size of kitchen, 1 or 2 three pin sockets shall be provided,

A recommended schedule of socket out lets is given below

Location	6A Outlets	16A Outlets
Bedroom	2 to 3 Nos.	1 No.
Living room	2 to 3 Nos.	2 Nos
Kitchen	1 No	2 Nos.
Dining room	2 Nos	1 No.
Garage	1 No	1 No.
Refrigerator	-	1 No.
Air-conditioners	-	1 No.
Verandah	1 No.	1 No.
Bathroom	1 No.	1 No.

9 All the metal covering should be earthed.

10 Double earthling should be provided with all machines.

11 No switch or fuse should be installed in the earth wire.

12 A live wire must be protected by a fuse of current rating depend up on current rating of load.

13 All switches should be connected through live wire.

14 The switches and starters of motors should be easily accessible to the apparatus.

15 Water proof light fittings should be used for outdoor lightings.

Mounting level of the accessories and cables

- Height of the main and branch distribution board should be not more than 2 meter from the floor level.
- Front clearance of one meter should also provided
- Switch shall be installed at any height 1.3 meter above the floor level.
- All the light fittings shall be at a height of not less than 2.25 meter from the floor.
- Socket outlets shall be installed either .25 or 1.3 meter above the floor as desired.
- No socket out let's shall be provided in bathroom at a height less than 1.3 meter.
- Clearance between the bottom point of ceiling fan and the floor shall be not less than 2.4 meter. Minimum clearance between the ceiling and the plane of the blades of the fan not less than 30 cm.
- The cable shall be run any desired height from the ground level.

Factors for selection of wiring

- Safety
  - The first and foremost consideration is safety to the person using electricity against leakage or shock.
- Durability
  - The type of selected wiring must be durable and also in accordance with accessed life and type of building.
- Appearance:
  - Wiring must provide a good look after its installing.
- Mechanical protection
  - Wiring must be protected from mechanical damage during its use.

Systems of wiring

The types of internal wiring usually employed in our country are

1 Cleat Wiring.

2 Casing and Capping (Wooden/ PVC) Wiring.

3 CTS or TRS or PVC Sheathed Wiring.

4 Lead Sheathed or Metal Sheathed Wiring

5 Conduit Wiring

  a Rigid Steel Conduit Wiring.

  b Rigid Non Metallic Conduit Wiring.

a Open / Surface Wiring

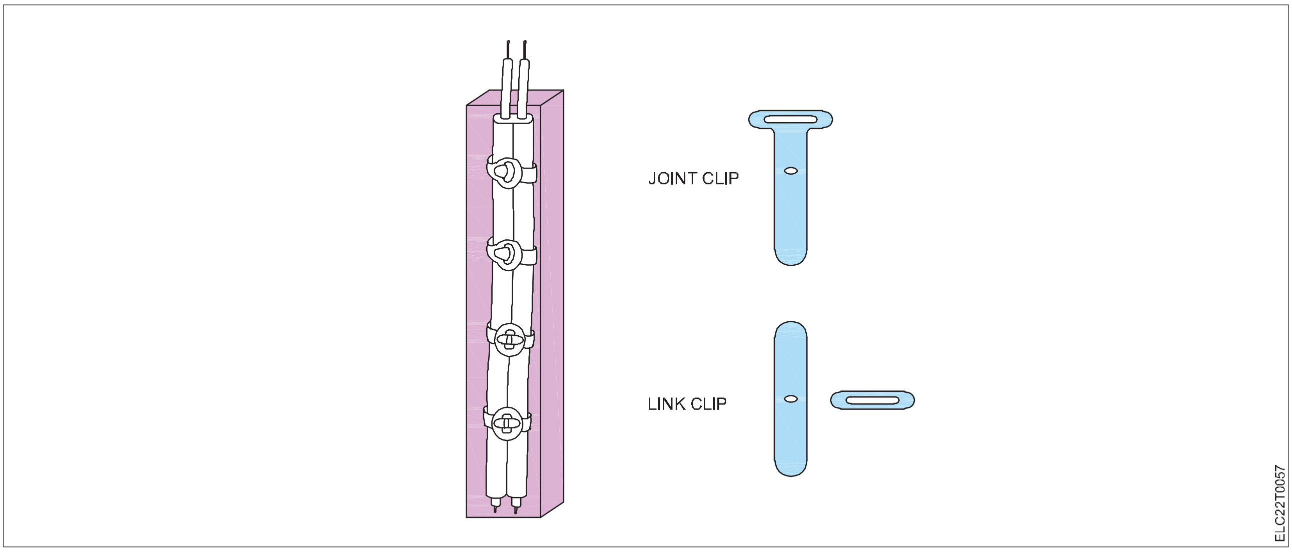
b Concealed / Recessed / Under Ground Type

CTS or TRS wiring

In this wiring system, single, twin or three core tough rubber sheathed cables are used. TRS cable should not be exposed to sun and rain.

PVC sheathed cables are used for medium voltage installation. PVC sheathed cables may be installed under the exposed condition of sun, rain or damp places and where acids and alkalies are present.

TRS cables are fixed on well-seasoned perfectly straight and well varnished wooden battens. TRS cables are fixed on the batten by means of joint clips. The thickness of batten is 10 to 19 mm and width is 10 to 50 mm (depends up on total width of the cable .Wooden plugs are used for fixing the batten fixed at an interval not exceeding 75 cm.



The bending radius of cable should be not less than six times the overall diameter of the cable. All cables taken through the floor shall be enclosed in an insulated heavy gauge steel conduit extending 1.5- metre above the floor. TRS cables shall not be buried directly in plaster, they may be taken in teak wood channel or conduit buried in the wall

In case of additional circuits to be wired in the existing installation the increased cables are laid on new battens laid in parallel to existing one.

Link clip and joint link clip

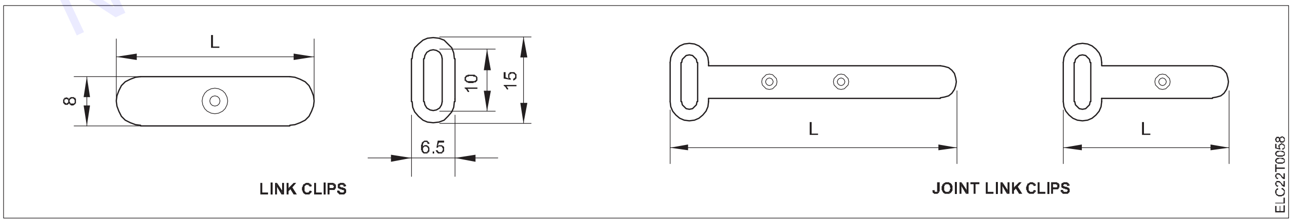
It is of 2 types

1 Link clip with separate linking eye

2 Link clip with combined linking eye

They are available in sizes of 25,32,40,50,63 and 80 mm. Out of which up to 40 mm clips have one hole while above that have two holes for fixing. The thickness of link clip is 0.32 mm and are made of tin or brass or brass coated tin or aluminium.

According to BIS link clips are packed in boxes at the rate of 100 clips per box. If linking eyes are separate part 5% excess of linking clips are provided. One single clip shall not hold more than two twin core TRS or PVC sheathed cable up to 1.5 square mm. Above this a single clip shall hold a single cable.



Advantages

1 Protection from dampness is excellent.

2 Semi skilled labours are required.

3 Less cost.

4 Very long life.

5 Good mechanical protection.

6 Very good appearance.

Disadvantages

1 Good workmanship is required.

2 It is not used under the situations open to sun and rain.

Application

1 Used for lighting purposes in domestic, commercial or industrial buildings except in workshops where it is liable to mechanical injury.

Lead sheathed wiring system

1 It is used for low voltage installation.
2 It is not suitable where acids and alkalies are present
3 Single, two and three core lead covered VIR cables are used
4 The cables are fixed to the wooden batten (thickness more than 10 mm) by means of nails and joint clips or link clips
5 Clip distance for horizontal run-10.cm,for vertical run -15.cm
6 The wooden battens are fixed on the wall by means of wooden screws at a distance of minimum 60.cm and max. 75. cm
7 When lead sheathed wiring system pass through a floor or a wall, the cable must pass through conduits
8 The bending radius of these cable should be not less than 10.cm
9 The lead sheath should always be electrically continuous and properly earthed.

Advantages

1 There is sufficient mechanical protection to the cable due to the lead sheathing on the cable

2 Protection from fire is also good

3 This system provides good protection from dampness if the ends of the cables are properly sealed

Disadvantages

1 Expensive

2 Lead sheath of the cable can be damaged due to the bad workmanship

3 Not suitable where fumes and acids are present

Application

1 It is used in low voltage installation.

2 It is used in damp places with protective covering.

3 It is not used in places where chemical corrosion may occur.

Conduit wiring

Types

Surface conduit (PVC &Metal) Done on wall surfaces

Concealed conduit (PVC)Done inside concrete plaster or wall

Types of conduit

1 Rigid steel conduit

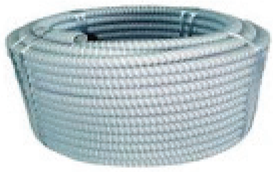
2 Rigid non-metallic conduit

3 Flexible steel conduit

4 Non -metallic conduit

Rigid

Flexible



Selection of the type of conduit

It depends up on:

Location- out door or in door

Atmosphere- dry or damp or explosive or corrosive

Working temperature

Physical damage due to mechanical impact

Weight of conduit runs

Cost

Size of metal conduit

Size in mm (metal conduit)	Thickness (heavy gauge)in mm	Thickness (light gauge)in mm
16	1.6	1
19	1.8	1
25	1.8	1.2
32	1.8	1.2
38	2	1.2
50	2.24	1.2
64	2.5	1.2
Non-metal(16-64)	2 or more than 2	Less than 1.5

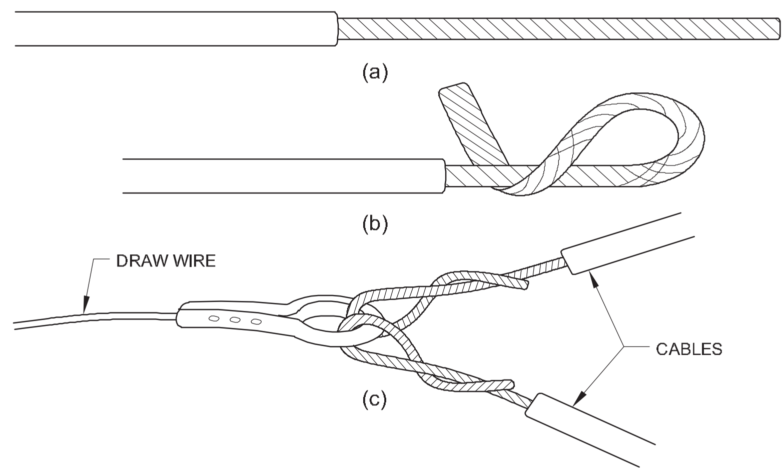
Size of conduit & permissible number of cables of 250 volt grade

Size of cable	Size of conduit					
Cross sectional area(sq.mm)	16	19	25	32	38	51
1	5	7	13	20	-	-
1.5	4	6	10	14	-	-
2.5	3	5	10	14	-	-
4	2	3	6	10	14	-
6	-	2	5	8	11	-
10	-	-	4	7	9	-
16	-	-	2	4	5	12
25	-	-	-	2	2	6
35	-	-	-	-	2	5
50	--	-	-	-	2	3

Surface conduit wiring: This system of wiring is suitable for low and medium voltage wiring installation. VIR or PVC cables are run in metal or PVC pipes known as conduit. Metal pipes provide good mechanical protection and reduce risk of fire. The cables are drawn through the conduit by means of steel wire known as fish wire (draw spring).Commonly used pipe sizes are – 12-mm to 75-mm(.5” to3”).The size of the conduit depends up on the dia- and number of cables. Conduits are fixed on the walls by means of saddles. Spacing between saddles or supports is 60 cm for rigid non- metallic conduit as per NE code. Rigid PVC conduits are not suitable for the working temperature of conduits and fitting may exceed 55°c

Fastening cable with draw spring

Wires are drawn through the conduits by means of draw spring



METHODS OF FASTENING THE CABLES WITH DRAW SPRING

Cold bending of pvc pipe (by using bending spring)

PVC conduit, not exceeding 25.mm diameter can be bend cold by using bending spring

Comparison between metal and pvc conduit wirings

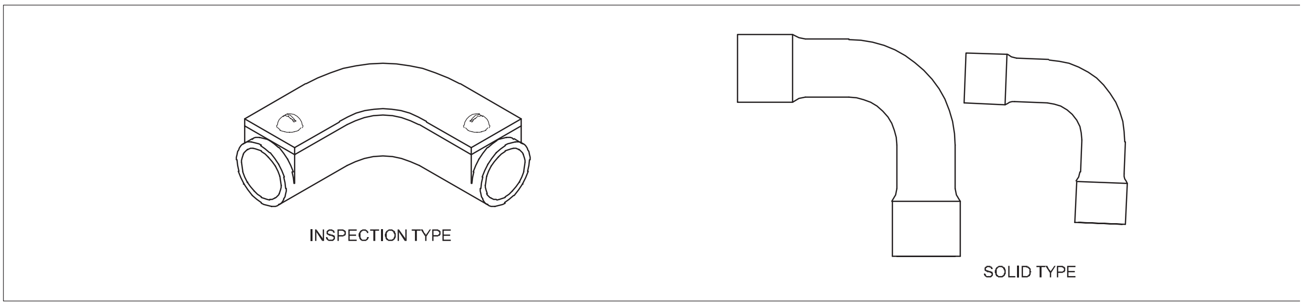
Sl. No:	Metal conduit	PVC conduit
1	Provides good physical protection to cables	Comparatively poor
2	Weighs more for a given length	Lighter
3	Needs skill and time for installation	Needs less skill and time
4	Risk of electric shock due to leakage	No risk as PVC is an insulator
5	Good earth continuity available through the pipe itself	Not possible .Separate earth wire is required
6	Can be used in gas tight and explosive -proof installation.	Not suitable
7	Not resistant to corrosion, needs protective coating	Resistant to corrosion
8	Large ambient temperature range	Suitable for limited temperature range .Above 60°c the conduit starts melting and very low temperature the conduit cracks
9	Fire resistant	Not fire resistant
10	More costly	Less costly

Non metallic conduit accessories

1 Couplers
2 Elbows
3 Bents
4 Tees
5 Boxes (Circular boxes and Rectangular boxes)

Bends

A bend gives a diversion of 90° in the turn of a conduit with a large sweep . It is of two type



Couplers

Couplers are used to join two pipes to extend the length.

Push type couplers

The conduit shall be pushed right through the interior of the fittings

It is of two types

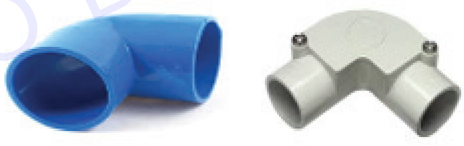
TYPES OF COUPLERS

Inspection type and solid type couplers

Elbows

Elbows are used at sharp ends ofnear by wall or roofs .

It is of two types, solid type and inspection type.



Solid type Inspection type

Tees

These are used to take diversion from the main line either to drop to switch points or to the light points . It is of two types

Inspection type

Solid

Circular boxes

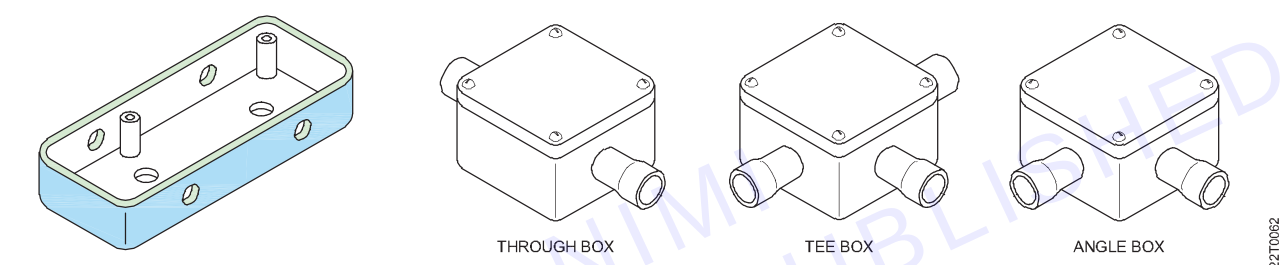
For small boxes have 2 cover fixing screw dia. not less than 2.8 mm. For large boxes have 4 cover fixing screw dia. not less than 4.mm.They are available in One way ,Two way ,Three way, Four way.

Rectangular boxes

These boxes are provided with two machine screws of dia. Not less than 2.8mm for fixing the cover. They can be used as junction box or switch board for fixing flush type switches

Various types of rectangular boxes are

Through box , tee box , angle box



TYPES OF BOXES (JUNCTION BOXES)

PVC saddle

Saddles are used to hold pipes in position

Steel conduit wiring accessories

Metallic coupler	3 way junction box	Steel Bends
		

Concealed wiring: In this system small channels are formed in the walls and ceilings etc. When the building is in under construction. The conduits are erected in these channels by using nails. Wires are drawn through the pipe after plastering work. Inspection boxes are provided to permit periodical inspection and facilitate removal of wires. All outlets such as switches and wall socket either of flush mounting or surface mounting type. Metal conduit pipe should not used as a earth continuity conductor. For earth continuity , separate earth continuity conductor is drawn through the conduit .

Application

1 Industrial work shop

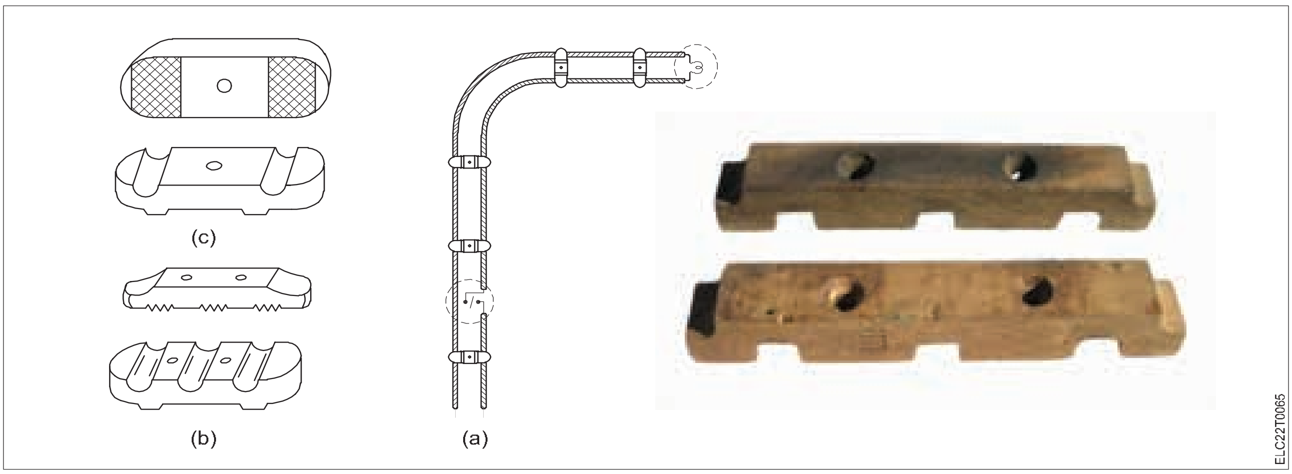
2 Public buildings

3 Domestic wiring

Advantages and disadvantages of consealed wiring

Advantage	Disadvantage
No risk of fire and good protection against mechanical injury.	Very expensive system of wiring.
The lead and return wire can be carried in the same tube.	Requires good skilled workmanship.
Earthing and continuity is assured.	
Water proof and trouble shooting is easy.	Erection is quiet complicated and time consuming.
Shock proof with proper earthing and bonding.	Risk of short circuit under wet conditions (due to consideration of water in tube)
Durable and maintenance free.	
Aesthetic in appearance.	

Cleat wiring



It is a simple system and cheapest method of wiring. Mainly used for temporary wiring purpose. It is installed 1.5 metres above the ground level. Single core VIR or PVC insulated cables are used. Porcelain or wooden cleats of two way , three way, four way etc are available. For fixing cleats on wall wooden plugs (gutties) and wood screws are used. For avoiding sag in the cable , cleats are provided every 60.cm distance. In branch circuit the distance between cable should be 2.5 cm. In sub main circuit the distance between cable should be 4 cm. The cables are prevented to avoid coming in contact with other conductors , gas or water mains. Cross - cleated cables should be separated by an insulating bridge piece which should at least maintain a distance of 1.3 cm between the cable. In this wiring , joints are to be maid in wooden or other insulating material junction boxes with porcelain connectors inside. Two wires should never be placed in the same grove of the cleats. Life of this wiring is approximate 5 – years. This wiring is not used in damp walls or ceiling. Wiring must be enclosed in conduit if the wire is passing through a wall or a floor.

Advantage

The wiring can be completed very fast.

Faults can easily be located

Disadvantage

It collects dust over the wire

There is no protection from mechanical injury

Casing and capping

Wooden casing and capping wiring

This wiring is suitable for low voltage domestic installation. In this system of wiring vulcanised rubber-insulated cables or PVC insulated cables are used. It is not suitable in damp places. The casing and capping should be of well seasoned teak wood or any other hard wood . Before the installation of casing capping it should be well varnished from all sides with shellac varnish. The casing is fixed by means of flat head counter sunk wooden screws to the wooden plugs(gutties) on wall or ceiling. The distance between two casing fixing wooden screws is not exceeding 90 cm for sizes up to 64 mm and not exceeding 60 cm for sizes above 64mm casing . The capping is fixed on casing by means of round head brass screws at a distance not exceeding 15 cm cross-wise for all sizes up to 64 mm casing capping. For cap sizes above 64.mm the screws are fixed at an interval of 22.5.cm cross-wise on capping. The life of this wiring is approx. 20 years. While laying out the casing try to avoid corners and crossing of cables as far as possible .If this cannot be avoided ,then use wooden corners and bridge pieces. This type of wiring is commonly used in residential and office buildings. The selection of casing and capping size depends up on the number of wires drawn through the groves. Any number of wires of the same polarity , either phase or neutral , may be laid in the same grove. The opposite polarity of wires should never be laid in one grove. In this type of wiring, there is a clearance of 0.32 cm thick space between the wall or ceiling and the casing by means of porcelain insulators .

Advantage

- Mechanical protection is good

Disadvantage

- There is great risk of fire in this system
- It is difficult to find fault
- If it is not damp proof it absorbs moisture easily
- Its erection is not very simple and requires more time
- Skilled labour is required

PVC casing capping

Nowadays wooden casing capping is replaced by PVC casing capping

Comparison of different systems of wiring

Particulars	Cleat wiring	Casing and Capping wiring	Batten Wiring	Lead sheathed wiring	Conduit Wiring
Material	Cleats , VIR or PVC cables, screws Gutties , Block board etc	Casing and capping (T.W, PVC). VIR/PVC wires Wooden Gutties Screws, Block and Boards	T.W batten TRS/CTS wires Gutties Screws Nails Link clips Blocks and Boards	T.W Batten Lead covered wire Gutties Screws, clips Board and Blocks	Conduits Bent and Sockets and other accessories VIR or PVC cables Nails Gutties Block sand Boards
Cost	Cheap	Fairly expensive	Cheap	Expensive	Expensive
Life	Short	Fairly long	Long	Long	Very Long
Mechanical protection	None	Fair	Fair	Good	Very Good
Protection from fire	No protec tion	Bad	Fair	Good	Very Good
Safety from Dampness	No protec tion	Fair(PVC) Little(wooden)	Good	Good	
Labour	Skilled	Highly Skilled	Skilled	Skilled	Highly Skilled
Extension and renewal	Easy	Difficult	Easy	Difficult	Not so easy and costly
Time required for erection	Short	Fairly long	Short	Fairly long	Very much longer
General reliability	Poor	Good	Good	Fairly good	Very good
Appearance	Bad	Good	Good	Good	Very good
Nature of Application	Temporary	Domestic, Office	Domestic and office building	Domestic and office building	Domestic, Office, Work shop

Fuses

A fuse is a safety device connected in series to the circuit which protect the electrical apparatus from possible damage when abnormal current flows through it. When normal current flows , the serves as a conductor but when the current flows above the predetermined value through a circuit due to short circuit , heat s produced to melt the fuse wire thus breaking the circuit to protect equipment from damage due to excessive value .

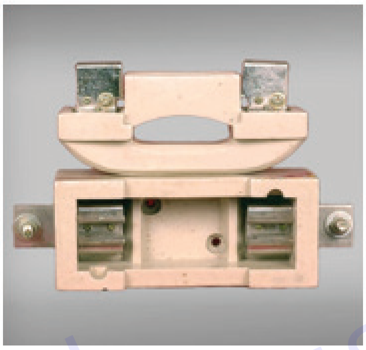
Classification of fuses

Fuses may be classified into two groups

1 Those designed to protect the circuit from short circuit only

2 Those designed to protect over load and short

Parts of fuse



1 Fuse wire 2 Fuse carrier 3 Fuse carrier contact 4 Fuse base 5 Fixed contact

Fuse wire

Fuse wire are bare wires made of easily melting material having high specific resistance usually standard alloy 63%tin and 37% lead it is used low current say up to 5 A and tinned copper for large value of current .

Fuse carrier

The part to which the fuse wire is fitted is called fuse carrier and is made of porcelain.

Fuse carrier contact

These are the contact strip which engage or disengage the fixed contacts of the fuse base and have a fuse wire attached to them.

Fuse base

It is the fixed part of the fuse and is made of porcelain .

Fixed contact

These contact are provided in the porcelain base of the fuse and engage with the fuse carrier contacts

Minimum fusing current

Minimum fusing current is the least value of current at which the fuse wire is melt .

Current rating of fuse element

Fuse element current which it can carry without melting . It is the value is always less than the minimum value of fuse current.

Fusing factor

The ratio of minimum fusing current and rating current of the fuse element is called fusing factor. Fusing factor always greater than unity

Types of fuses

Two types of fuses are used

Rewireble (kit kat fuses)

These are mostly used in domestic installations. These fuse consist of a porcelain base and having two fixed contacts for connecting the incoming and outgoing cables. These fuses are low rupturing capacity.

Cartridge fuse

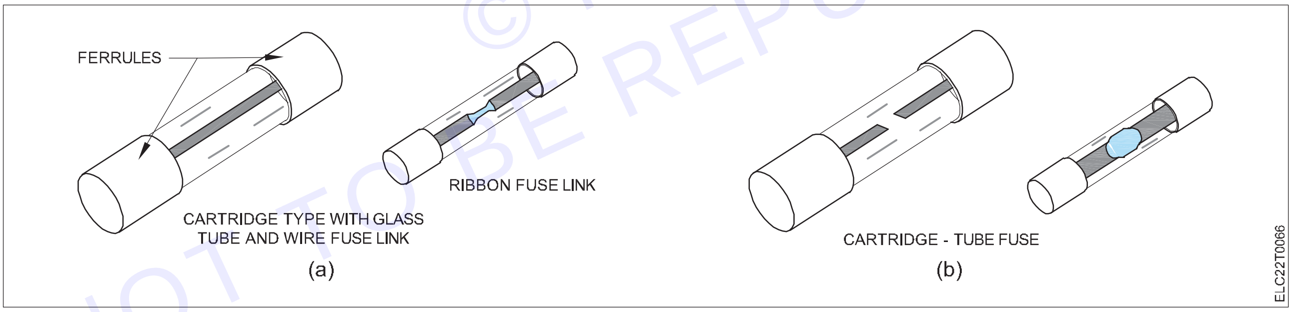
Can be classified into two groups

Low repturing capacity fuses

These are used to domestic installations It is further divided into two:

Ferrule Contact And Diazed Screw Type Cartridge Fuse .

Ferrule contact:It is used for protecting electrical and electronics circuits . These are available in 25,50,100,200,250,500milli amp and also in 1 to32 amp . its body is made of glass and fuse wire is connected to two metallic caps.

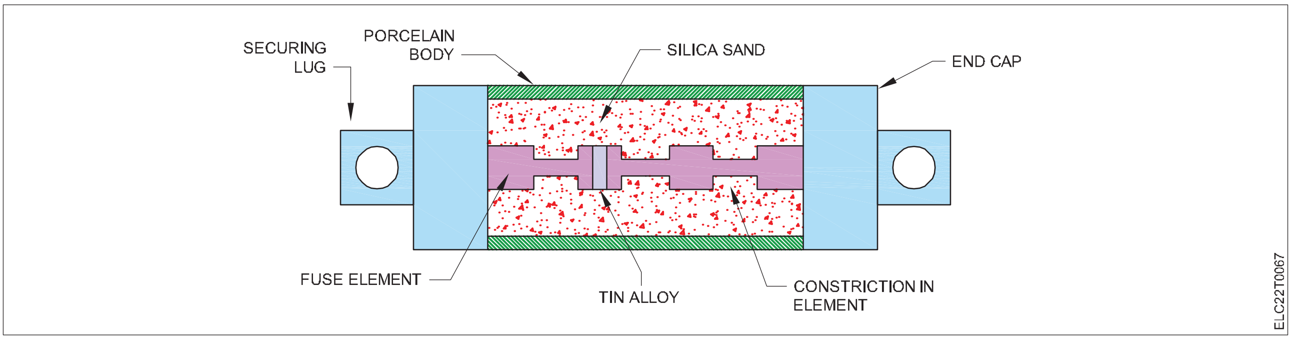


Diazed screw type cartridge fuse

This type fuse is commonly used in domestic and industrial electrical installations. It is available in current rated for 2,4,6,10,16,20,25,35,50and 63 amp.

High repturing capacity cartridge fuse

They are cylindrical in shape and are made ceramic body filled with chemically treated filling powder or silica to quench the arcing quickly without any fire hazard normally silver alloy is used for fusing element and when it melts due to excessive current it combines with the surrounded sand HRC fuse can open a short circuit with 0.013second. HRC fuses preferred in high power circuits.



Testing of installation: Before a completed installation or an addition to the existing installation is put into service, inspection and testing shall be carried out in accordance with the INDIAN ELECTRICITY RULE, 1956

The under mentioned are the tests which are generally conducted on the wiring installation before it is actually connected to the main supply.

1 Insulation test between conductors and earth

2 Insulation test between conductors

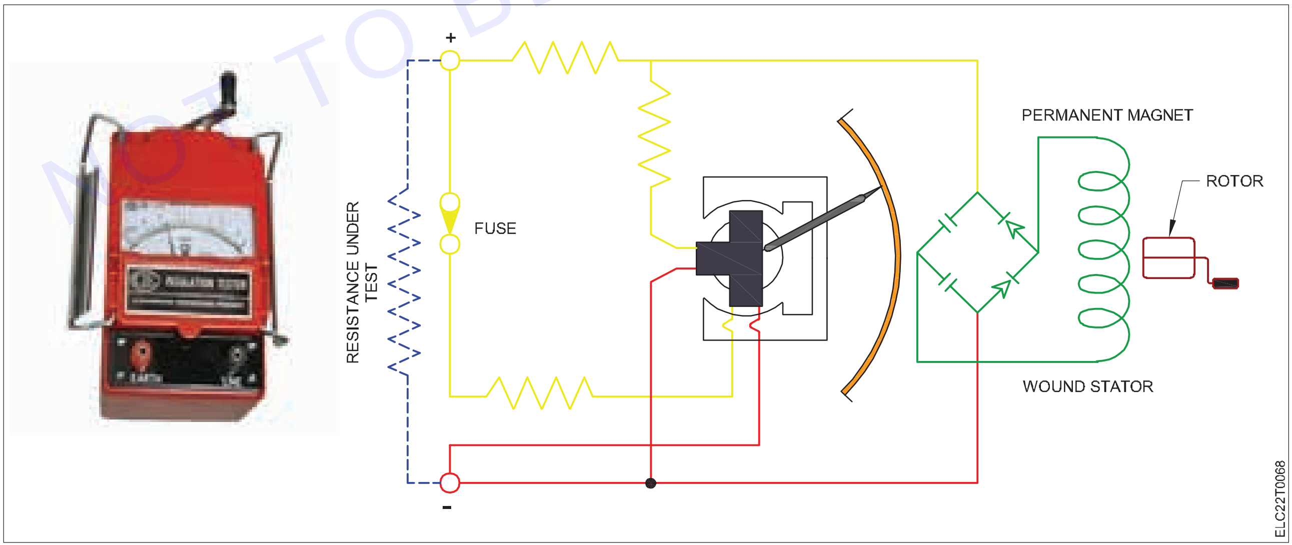
3 Continuity or open circuit test

4 Earth continuity test

5 Polarity test

Whenever a wiring system is installed it must be tested before connecting it to the supply. In the event of defects being found, these shall be rectified as soon as practicable, and the installation re-tested

The instrument used for testing installation is known as mega ohmmeter (megger)or insulation tester.



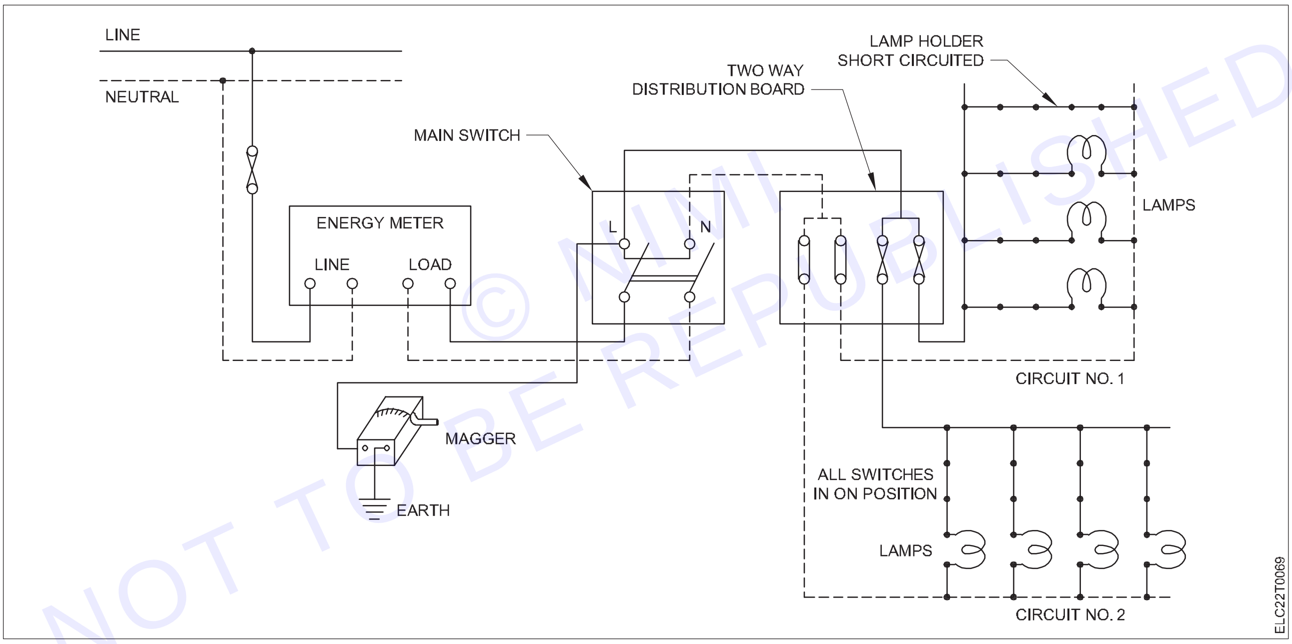
Megger

A megger is used to perform the installation testing.

It can generate low value direct current when its handle is rotated and measure high value of resistance which is connected across its terminal. Test is performed on DC volt not less than TWICE of working voltage. If the circuit is to be operated on 250V supply main, then the megger should generate 500V when its handle is rotated at its normal speed of 140 to 160 rpm. Its scale is from infinity to zero.

Nominal Rating of Equipment in Volts	Minimum Test Voltage, DC	Recommended Minimum Insulation Resistance in Megohms
250	500	25
600	1,000	100
1,000	1,000	100
2,500	1,000	500
5,000	2,500	1,000
8,000	2,500	2,000
15,000	2,500	5,000
25,000	5,000	20,000
34,500 and above	15,000	100,000

Test-1 insulation between conductors and earth



STEPS OF TEST-I (This test is done to find out the leakage current)

1 Main fuse is taken out.

2 All other fuses are in position.

3 Main switch is in OFF position.

4 All switches are in ON position

5 All the lamps are in their positions or the holders are short-circuited.

6 Socket outlets are also shorted.

7 Line and neutral terminals are shorted on the installation side.

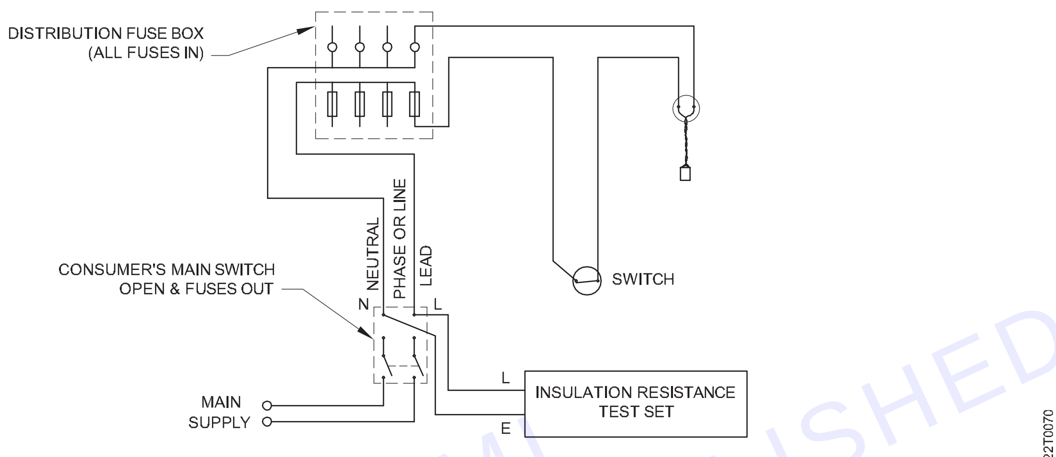
8 Connect the earth terminal 'E' of MEGGER to earth point of the system.

9 Connect the line terminal 'L' of MEGGER to phase point

TEST-I (procedure)

- Rotate the MEGGER handle to send current through circuit
- Note down the reading of the meter shown by its needle deflected over the calibrated over the MΩ scale.
- The reading of the meter gives directly the insulation resistance b/w conductors and earth.
- According to IE Regulations ,the measured value should not be less than 50MΩ/ (no of outlets) or not less than 1MΩ. (Switch, lamp holder and socket are taken as individual outlet)

Insulation resistance between conductors



INSULATION RESISTANCE TEST BETWEEN CONDUCTORS

AIM: To find the value of insulation resistance between line and neutral conductors and also to locate a short circuit if any in the complete installation.

Steps

- Remove the loop provided at the main switch.
- All the lamps and metallic connections are removed from holder and plug points.
- Rest all thing remains same that is main switch is in OFF position , main fuses with drawn , all other fuses in their position , all single pole switch in ON position.

TEST-II (procedure)

1 Connect the earth terminal 'E' of MEGGER to neutral link.

2 Connect the line terminal 'L' of MEGGER to phase point.

3 Rotate the MEGGER handle to its normal speed.

4 In this test also the measured value should not be less than 1MΩ.

5 This is the insulation resistance b/w line and neutral conductors

6 However if the reading is zero, it means that there is a short circuit in the wiring which should be removed.

Continuity test(open circuit test)

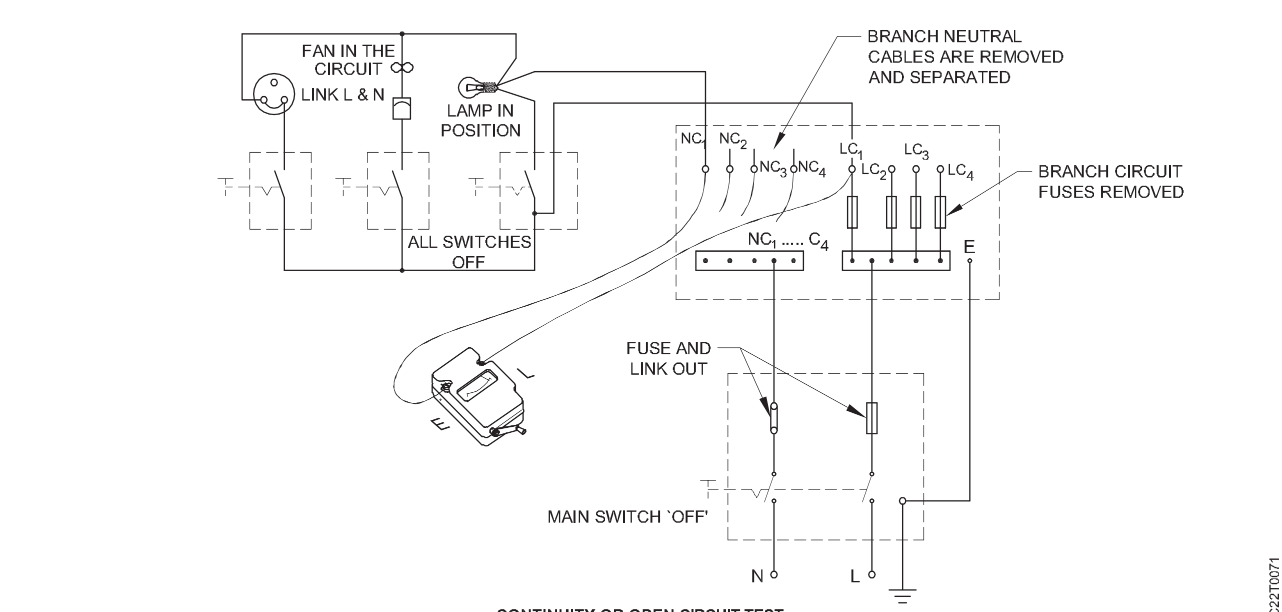
This test is carried out to check the continuity of cables in the individual sub circuits

Steps

1 S/OFF main switch

2 Remove all main and distribution circuit fuses

3 Place all bulbs in position, connect all to respective ceiling roses, regulators and switches, short all sockets out lets by linking phase and neutral.



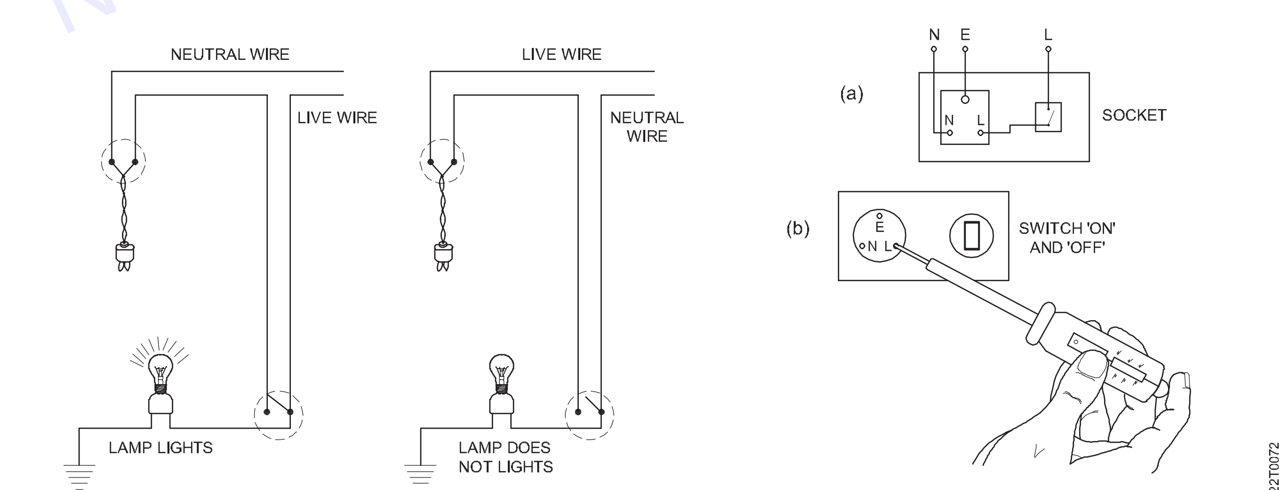
CONTINUITY OR OPEN CIRCUIT TEST

Procedure

- Connect the megger terminals E and L to the individual phase and neutral.
- Rotate the megger handle
- By switching ON and OFF one by one , the megger should show zero and infinity reading alternatively
- If the megger shows no continuity in the ON condition of switch then particular circuit is deemed to be open circuit.
- If the megger shows continuity in both ON and OFF position of switch, this indicate short in the particular circuit.

Test-IV (Polarity test)

- This test is applied to know whether all switches, cut-outs are correctly installed on live terminal of supply (IER-32(2)) and not on neutral, this test is performed.
- For example the lamp holder quite dead when the switch is in the OFF position. If the holder is wrongly connected in the live wire directly, the operator may get severe shock in the case of repair.

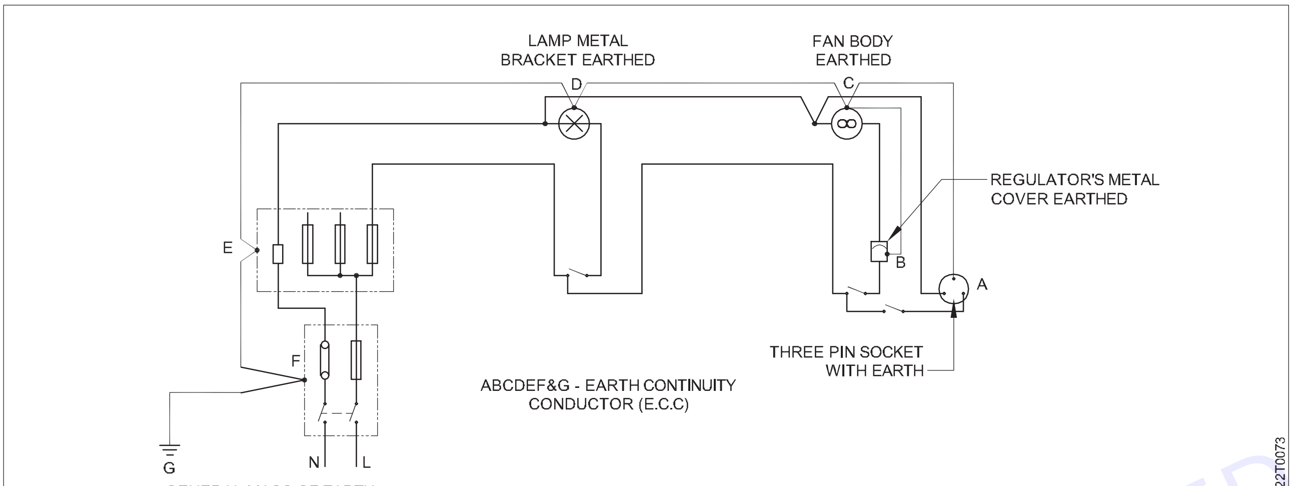


POLARITY TEST ON SOCKETS

Earth continuity test-V

- **AIM:**For safety all the metal pieces or covering such as conduit, metal covers of switches etc must be solidly connected to earth otherwise on damage of insulation, the leakage current will start giving severe shock to the person touching it.

This test is carried out with the help of 'EARTH MEGGER'.



BENDING OF PVC PIPE BY HAND

Earthing

Earthing systems

Earthing

Earthing means an electrical connection to the general mass of earthto provide safe passage to fault current to enable to operate protective devices and provide safety to personnel and Equipment.

Purpose of earthing

1 To save human body from danger of electric shock or death by blowing fuse, ie ,to provide an alternative path for the fault current flow so that it will not danger user

2 To protect buildings, machinery and applications under fault conditions ie, to ensure that all exposed conductive parts do not reach a dangerous potential

3 To provide safe path to dissipate lightning and short circuit currents

4 To provide stable platform for operation of sensitive electronic equipment's, ie to maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment's.

5 To provide protection against static electricity from friction.

An electric shock is dangerous only when the current flow through the body exceed beyond a certain milli ampere value.

The degree of danger is dependent not only current flow but also the time during which it close.

This table shows the body resistance at specified areas of contact:

Skin condition area	Resistance value
Dry skin	100000 to 600000 ohm
Wet skin	1000 ohm
Internal body to hand	400 – 600 ohm
Ear to Ear	About 100 ohm

Earth resistance required as per is specification

Distance of earth from building - 1.5 meters

Size of earth continuity conductor (ECC) – 2.9 mm2 (14 SWG) or half the installation conductor size

Earth resistance

- Large power station – 0.5 ohm
- Major power station – 1 ohm
- Small power station – 2 ohm
- In all other cases – 5 ohm

X section of earth lead should not be less than 161 mm2 for main connections & 64 mm2 for branch connections in large connections

Copper strip of 25 mmx3 mm or 25mmx6 mm for connecting electrical apparatus

Copper wire of size not less than 8 SWG (12.9 mm2) & not more than 7/0.0915 MM (64.52 MM2) used in case of smaller installations

Size of earth wire for domestic installations should be not less than 2.9 mm2 (14 SWG) or half the conductor size

Various specifications in respect to earthing as recommended by Indian Standards are given below.

- An earthing electrode should not be situated (installed) close to the building whose installation system is being earthed at least more than 1.5m away.
- The value earth resistance does not remain constant but changes with the weather, as it depend upon the moisture content of the soil
- The earth wire and earth electrode will be the same material.
- The earthing electrode should always be placed in a vertical position inside the earth or pit so that it may be in contact with all the different earth layers.The cross section of earth lead of copper wire should not be less than 8swg in case of small installations or half of the cross section of the largest current Carrying conductor.
- The cross of ECC should not be less than either 14SWG or half of the largest conductor.
- The neutral conductor of a three phase four wire system is earthed at generation and substations.

Terms used in earthing system

Earth

A connection to the general mass of earth by means of an earth electrode. An object is said to be earthed when it is electrically connected to an earth electrode.

Earth continuity conductor

Any wire, clamp, cable, cable's metallic covering, earth terminal of an electrical installation which is connected to the earth electrode is earth continuity conductor.

Earth electrode

A metal plate , pipe or other conductor or an array of conductors electrically connected to the general mass of the earth.

Earth terminal

A terminal provided on a piece of apparatus for the purpose of making a connection to earth.

Earth lead

The conductor by which the connection to the earth electrode is made.

Types of earthing

There are two major types of earthing

1 Systemearthing

2 Equipmentearthing

System earthing

The earthing associated with current carrying conductor is normally essential to the security of the system is known as system earthing. The system earthing is done at generating stations and substations.

Equipment earthing

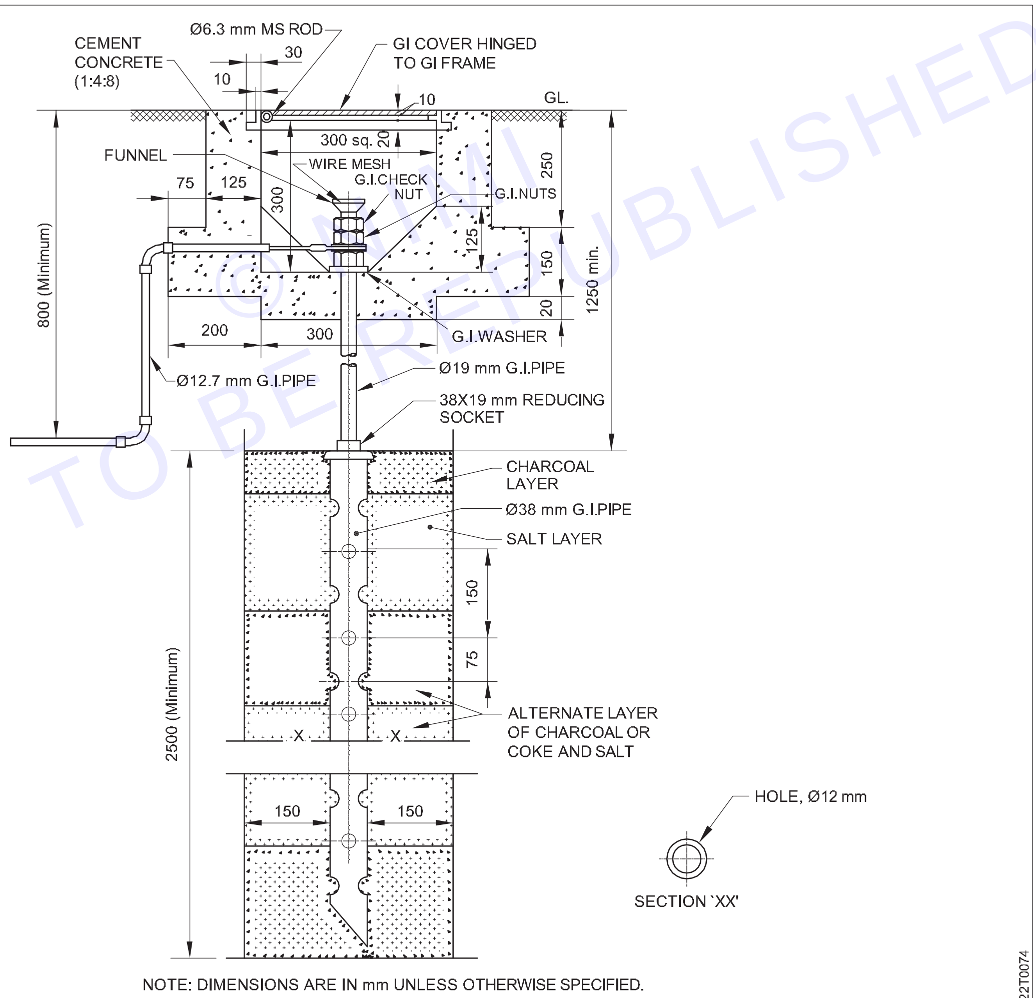
Earthing of non-current carrying metal work and conductor which is essential for the safety of human life and animals and the property is generally known as equipment earthing.

Pipe earthing

Pipe earthing is done by permanently placing a pipe in wet ground. The pipe can be made of steel, galvanized iron or cast iron. Usually GI pipes having a length of 2.5m and an internal diameter of 38mm are used. The pipe should be placed at least l.25m below the ground level through 19mm GI pipe. Earth electrode should be surrounded by alternate layers of charcoal and salt for a distance of around 15 this is to maintain the moisture level and to obtain lower earth resistance. The earth lead of sufficient gauge should be firmly connected to the electrode and it should be carried in a GI pipe at a depth of 60cm below the ground level.A funnel having a wire mesh is provided at the top of 19mm diameter pipe for water poured during summer season.

Advantages

The area of the pipe with soil is more compared with plate earthing, hence more leakage current can earth.



PIPE EARTHING

Plate earthing: In this type of earthing plate either of copper or of G.I buried in to the ground at a depth not less than 3 meter from the ground level. The earth plate is embedded in alternative layer of coke and salts for a minimum thickness of about 15 cm. The earth wire (copper wire for copper plate earthing and G.I wire for G.I plate earthing)is securely bolted to an earth plate with the help of bolt nut and washer made of copper , in case of copper plate earthing and G.I in the case of G.I plate earthing.

List of materials used in plate earthing

1 60cm x 60cm x 6.3mm GI Plate OR 19mm dia GI pipe

2 12.7mm dia GI pipe

3 Charcoal

4 60cm x 60cm x 3.15mm Copper Plate Funnel

5 Wire mesh

6 Cement concrete (1:4:8)

7 6.3mm MS Rod

8 GI Cover hinged to GI frame

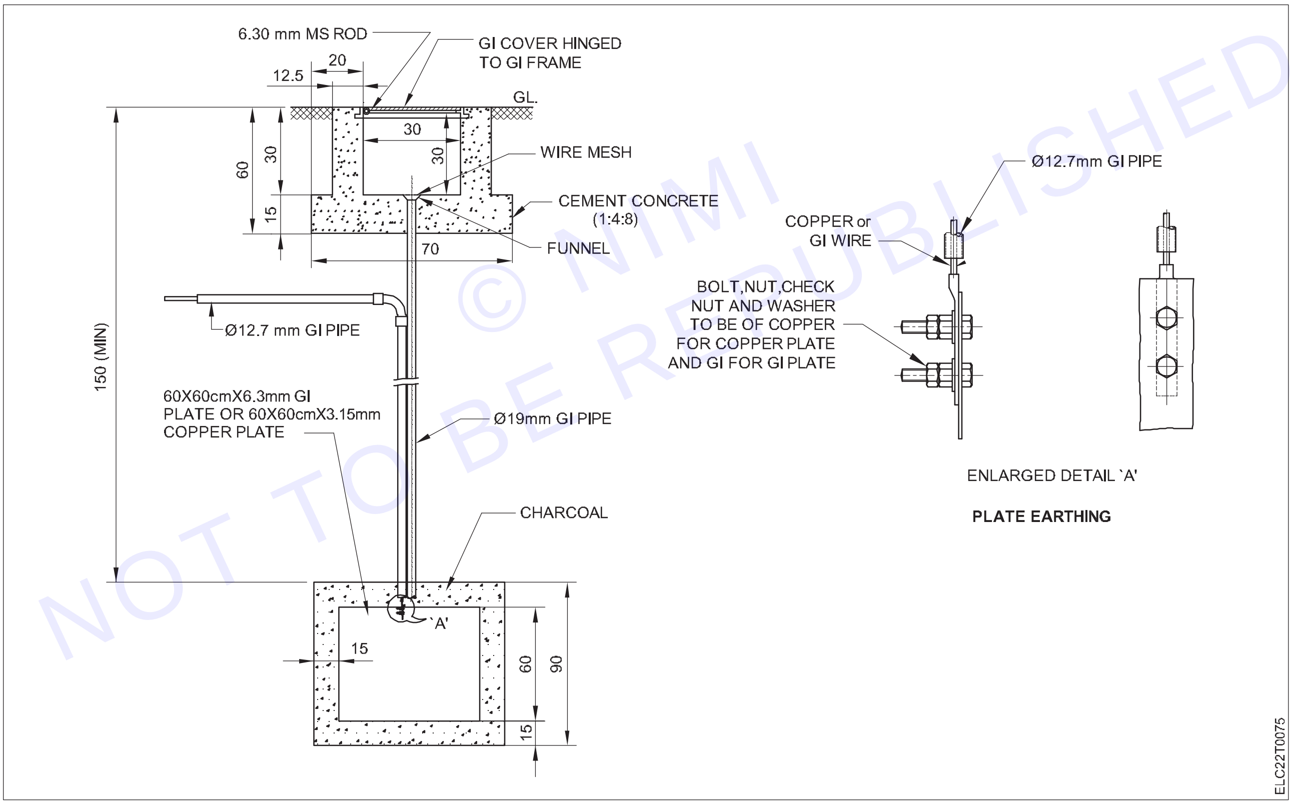


PLATE EARTHING

Methods of construction of plate earthing

Excavation on earth for a normal earth pit size is 1.5m x 1.5m x 3m.Use 60cm x 60cm x 6.3 mm GI plate. Make a mixture of wood coal powder salt& sand all in equal part. The purpose of coal and salt is to keep wet the soil permanently.

The salt percolates coal absorbs water keeping the soil wet. Care should always take by watering the earth pits in summer so that the pit soil will be wet. Coal is made of carbon which is good conductor minimizing the earth resistance.

Conductor salt use as electrolyte to form conductivity between GI plate coal and earth with humidity.

Sand has used to form porosity to cycle water and humidity around the mixture. Put GI plate of size 60cm x 60cm x 6.3 mm in the middle of mixture.

Use double GI strip size 30mm x 10mm to connect GI plate to system earthing.

It will be better to use GI pipe of size 2.5' diameter with flange on the top of GI pipe to cover GI strip from earth plate to top flange.

Cover top of GI pipe with a T joint to avoid jamming of pipe with dust and mud also use water time to time through this pipe to bottom of earth plate.

Methods of reducing resistance of earth electrode

1 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance

2 After installing the rod or pipe or plate in earth, the earth pit should be treated with layers of coke and common salt to get a lower value of earth resistance

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance

4 Soldering the earth connections or using non –ferrous clamps lowers the electrode resistance

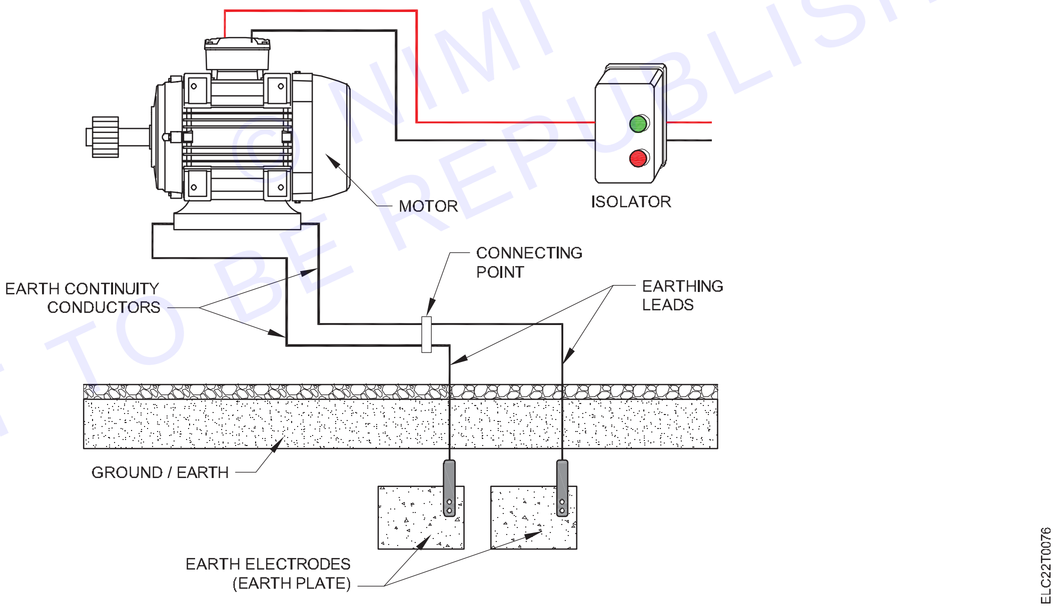
5 Avoiding rust in the earth electrode connections lowers the earth electrode res

Purpose of double earthing

1 Doubleearthing shall be provided for all electrical machines.

2 Doubleearthing is provided to machines to ensure earth continuity even if one of the earth continuity conductor is opened or damaged.

3 Doubleearthing is also reduce the resistance of earth continuity conductor.



Application

Use of plate electrode is recommended only where current carrying capacity is the prime consideration. For example:

Telecommunication, Transmission, Substations and power generations, Transformers and neutral earthing, Lightning arrestor earthing, Equipment body earthing, Water treatment plants, Heavy industries, College, Hospitals, Banks, Residential building.

Earthing-ie rules &iee regulations

- Earth pin of 3 pin lighting plug & 4 pin power plug socket should be efficiently earthed
- All metallic covering of electric supply line such as iron clad switches & iron clad DBs, GI pipes enclosing cables, down rod of fan should be earthed

- Metal casing of apparatus such as heater, refrigerator electric drills should be connected to earth
- Frame of generator, motor, transformers should be earthed by two separate connections with earth
- Neutral conductor of 3 phase 4 wire system & middle conductor of 2 phase 3 wire system should be earthed by not less than two separate earth connections at the generating station substation
- Steel transmission tower lines or poles carrying overhead conductors should be earthed at every mile (1.61km) at 4 points
- Stay wire for overhead lines should be earthed by connecting at least one strand to the earth wire

Factors influencing earth resistance

- Condition of soil
- Temperature of soil
- Moisture content of soil
- Size and spacing of earth electrode
- Depth at which electrode is embedded
- Material of conductor
- Quality of coal and dust and charcoal in the earth electrode pit

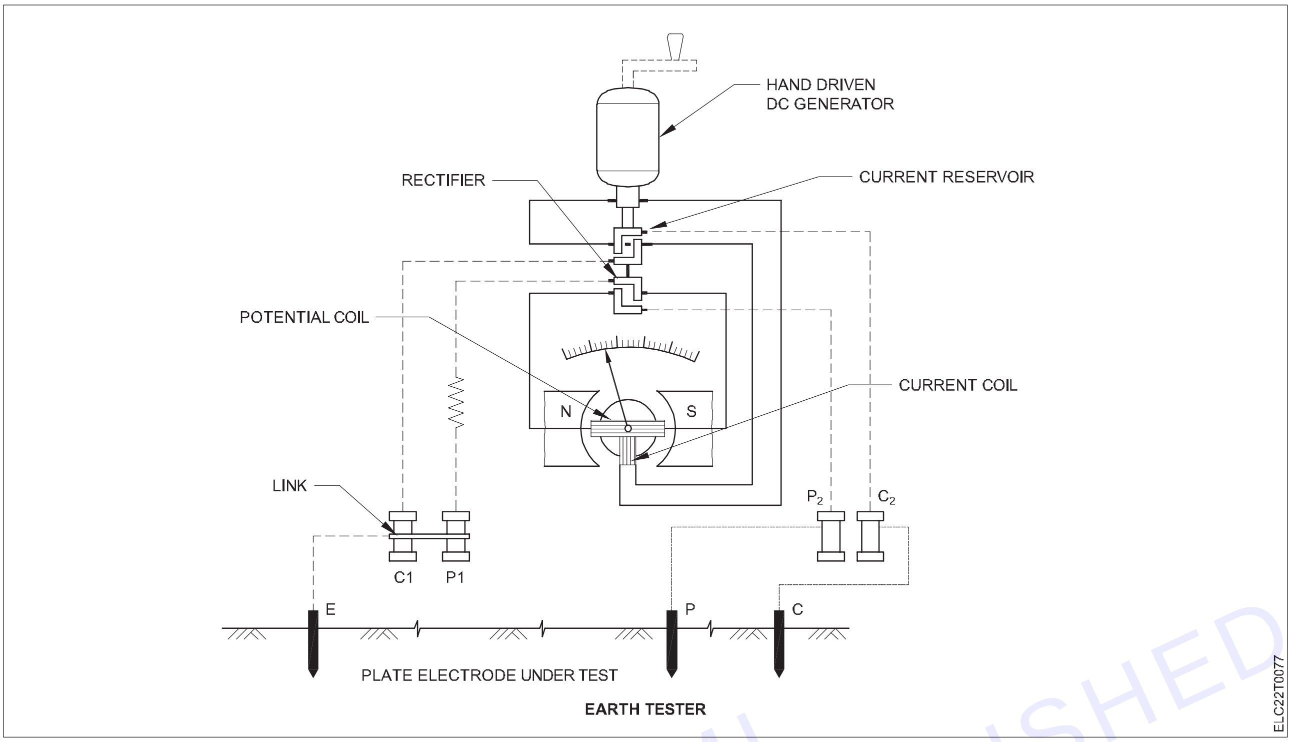
Methods for improve earth resistance

- Increase the pit depth
- Increase the plate area
- Increase the number of electrodes in parallel
- Pouring of fresh salt water (copper sulphate solution –copper plate earthing) through pipe over coal bed

Earth resistance tester working principle

Used for earth resistance measurement

- It's a special type of Megger with rotating current reverser and rectifier with commutator made up of L shaped segment
- They mounted on the shaft of the hand driven generator
- Each commutator has 4 fixed brushes
- One pair of each set of brushes is positioned that they make contact alternately with one segment and then with the other as the commutator rotates
- 2 nd pair of each set of brushes is positioned on the commutator so that continuous contact is made with one segment whatever the position of the commutator
- It has 4 terminals p1, p2, c1, c2
- P1, c1 shorted &connected to earth electrode
- P2, c2connected to auxiliary electrode P, C
- Indication depends on the ratio of the Voltage across the pressure coil and the current through the coil
- Deflection indicates the earth resistance directly
- It's a PMMC instrument can operate only in DC
- By include reverser & rectifier possible to made measurements with AC flow through soil
- Use of AC eliminates unwanted effects due to production of back emf in the soil due to electrolytic action
- Instrument is free from effect of AC &DC present in soil.



EARTH TESTER

B.I.S. Symbols used for electrical accessories

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

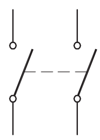
- interpret the various BIS symbols used in electrical wiring diagrams.

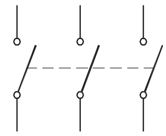
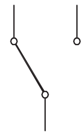
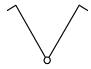
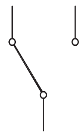
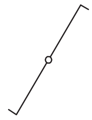
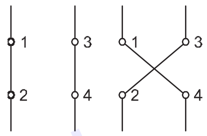
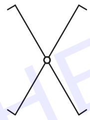
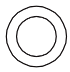
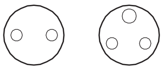
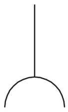
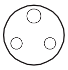
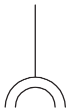
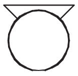
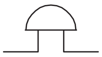
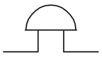
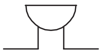
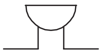
In electrotechnical engineering the symbols are used in layouts and wiring circuits to represent the electrical parts or the function of the circuit.

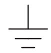
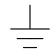
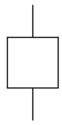
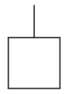
Since the drawing of the actual device is very laborious and would be drawn by each person differently, standardised symbols are used. With the help of the symbols, an electric circuit can be represented easily and can be described precisely as well.

A few examples of standard symbols recommended by B.I.S. 2032 (different parts) used for wiring are given here.

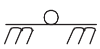
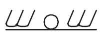
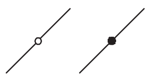
B.I.S. SYMBOLS FOR WIRING SCHEMES

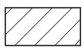
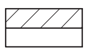
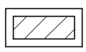
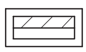
Sl. No.	Description	Symbols used in the circuit diagram	Symbols used in layout
1	One-way switch, single pole		
2	One-way switch, two poles		

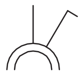
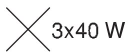
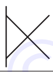
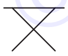
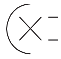
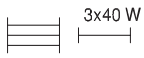
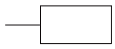
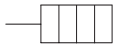
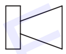
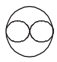
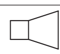
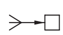
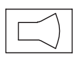
Sl. No.	Description	Symbols used in the circuit diagram	Symbols used in layout
3	One-way switch, three poles		
4	Multi-position switch single pole		
5	Two-way switch		
6	Intermediate switch		
7	Push-button or bell-push		
8	Socket outlets, 6A		
9	Socket outlets, 16A		
10	Lamp or outlet for lamp		
11	Fuse		
12	Bell		
13	Buzzer		

Sl. No.	Description	Symbols used in the circuit diagram	Symbols used in layout
14	Earth point		
15	Circuit breaker		
16	Terminal strip	11 12 13 14 15 16 6 WAY	N.A
17	Link (closed)		N.A
18	Plug and socket (male and female)		N.A
19	Ceiling rose		N.A
	N.A: Not applicable		

The B.I.S. Symbols used in the wiring is given here.

ITEMS	SYMBOLS
I Wiring	
1 General wiring	
2 Wiring on the surface	
3 Wiring under the surface	
4 Wiring in conduit	
a Conduit on the surface	
b Conduit concealed	
The type of conduit may be indicated, if necessary.	
5 Wiring going upwards	
6 Wiring going downwards	
7 Wiring passing vertically through a room	

ITEMS	SYMBOLS
II Fuse-boards	
1 Lighting circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
2 Power circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	

ITEMS	SYMBOLS
III Switches and switch outlets	
1 Single pole pull-switch	
2 Pendent switch	
IV Socket outlets	
1 Combined switch and socket outlet, 6A	
2 Combined switch and socket outlet, 16A	
3 Interlocking switch and socket outlet, 6A	
4 Interlocking switch and socket outlet 16A	
V Lamps	
1 Group of three 40 W lamps	
2 Lamp,mounted on a wall or light bracket	
3 Lamp, mounted on ceiling	
4 Counterweight lamp fixture	
5 Chain lamp fixture	
6 Pendent lamp fixture	
7 Lamp fixture with built-in switch	
8 Lamp fed from variable voltage supply	
9 Emergency lamp	
10 Panic lamp	
11 Bulk-head lamp	
12 Watertight light fitting	
13 Batten lamp-holder (Mounted on the wall)	
14 Projector	
15 Spotlight	
16 Floodlight	
17 Fluorescent lamp	
18 Group of three 40W fluorescent lamps	
VI Electrical appliances	
1 General	
If necessary, use designation to specify.	
2 Heater	
VII Bells, buzzers and sirens	
1 Siren	
2 Horn or hooter	
3 Indicator (at `N' insert number of ways)	
VIII Fans	
1 Ceiling fan	
2 Bracket fan	
3 Exhaust fan	
4 Fan regulator	
IX Telecommunication apparatus	
1 Aerial	
2 Loudspeaker	
3 Radio receiving set	
4 Television receiving set	

Wiring accessories, IE Rules

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

- classify, specify, identify and state the uses of the accessories employed in domestic wiring
- state the IE rules related to safety and electric supply.

Electrical accessories: An electrical domestic accessory is a basic part used in wiring either for protection and adjustment or for the control of the electrical circuits or for a combination of these functions.

Rating of accessories: The standard current ratings of the accessories are 6, 16 and 32 amps. The voltage rating is 240V AC as per B.I.S. 1293-1988.

Mounting of accessories: The accessories are designed to mount either on the surface or concealed (flush type).

Surface mounting type: Accessories are provided with a seating so that when mounted they project wholly above the surface on which they are mounted.

Flush-mounting type: These accessories are designed to mount behind or incorporated with a switch plate, the back of the plate being flush with the surface of the wall or switch box.

The electrical accessories used in wiring installation, are classified according to their uses.

- Controlling accessories
- Holding accessories
- Safety accessories
- Outlet accessories
- General accessories

Types of switches according to their function and place of use

1 Single pole, one-way switch
2 Single pole, two-way switch
3 Intermediate switch
4 Bell-push or push-button switch
5 Pull or ceiling switch
6 Double pole switch (DP switches)
7 Iron clad double pole, (ICDP) switch.
8 Iron clad triple - pole (ICTP) switch.

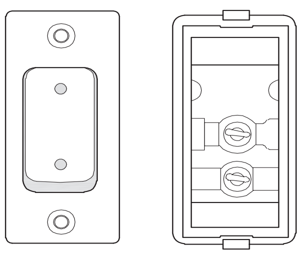
Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Single pole, one-way switch: This is a two terminal device, capable of making and breaking a single circuit only. It is used for controlling light or fan or 6 amps socket. (Fig 1)

Two-way switch: This is a three terminal device capable of making or breaking two connections from a single position (Fig 2). These switches are used in staircase lighting where one lamp is controlled from two different places.

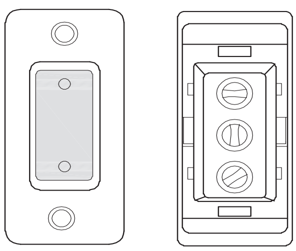
Intermediate switch: This is a four-terminal device capable of making or breaking two connections from two positions (Fig 3). This switch is used along with 2 way switches to control a lamp from three or more positions.

Fig 1



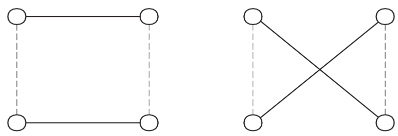
6 AMPS SINGLE POLE ONE WAY FLUSH SWITCH

Fig 2



6 AMPS TWO WAY FLUSH TYPE SWITCH

Fig 3



INTERMEDIATE SWITCH CONNECTIONS

ELC22T0080

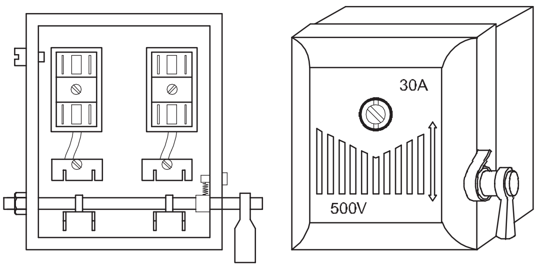
Bell-push or push-button switch: This is a two-terminal device having a spring-loaded button. When pushed it `makes' the circuit temporarily and attains `break' position when released.

Iron - Clad Double pole (ICDP) main switch : This switch is also referred to as DPIC switch and is mainly used for single phase domestic installations, to control the main supply. It controls phase and neutral of the supply simultaneously (Fig 4).

The current rating of the switch varies from 16 amps to 32 amperes.

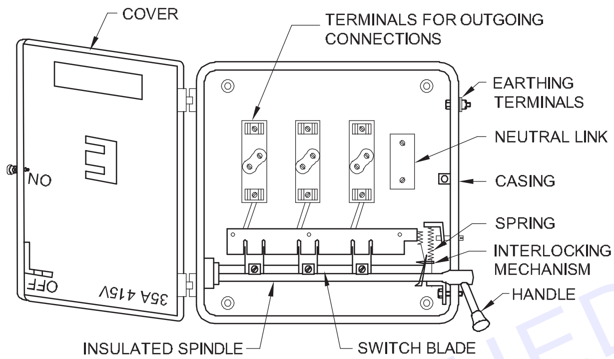
Iron - Clad Triple pole (ICTP) main switch: This is also referred to as TPIC switch and is used in large domestic installation and also in 3-phase power circuits, the switch consists of 3 fuse carriers, one for each phase. Neutral connection is also possible as some switches are provided with a neutral link inside the casing (Fig 5).

Fig 4



DPIC MAIN SWITCH

Fig 5



FUSED ICTP `N' SWITCH

ELC22T0081

The current rating of the switch varies from 16 to 400 amps.

Holding accessories

Lamp-holders : A lamp-holder is used to hold a lamp. Earlier, brass holders were most commonly used but nowadays these have been replaced by bakelite holders. These may contain solid or hollow spring contact terminals. Four types of lamp-holders are mainly available.

– Bayonet cap lamp-holders

– Screw type holders

– Edison screw type lamp-holders

– Goliath Edison screw type lamp-holders

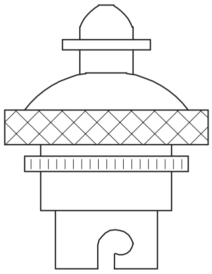
Bayonet cap (BC) lamp-holders: In this type,the bulb is fitted into the slot, and is held in position by means of two pins in the lamp cap. It has solid or hollow spring contact terminals, and the supply mains through the switch are connected to these contacts. In BC types there are two grooves on the circular construction of all types of holders.

Pendent lamp-holders: This holder (Fig 6) is used in places where the lamps are required in a hanging position. These holders are made of either brass or bakelite. An exploded view of this holder shows the parts of the holder. These holders are used along with ceiling roses for suspending the lamps from the ceiling.

Batten lamp-holders: The straight batten holder (Fig 7a) is used on a flat surface on the round block, wooden board etc. These holders are made of either brass or bakelite.

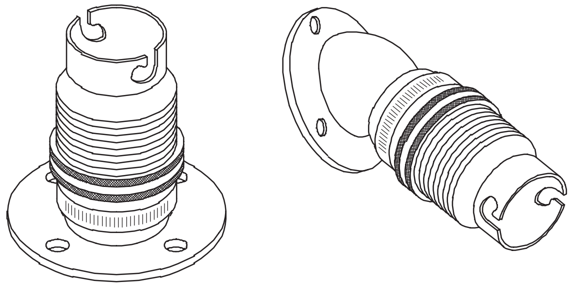
Angle holders: The angle bottom holder, (Fig 7b) is to hold the lamp in a particular angle. These are made of either brass or bakelite. These are used for advertising boards, window display, kitchens etc.

Fig 6



EXPLODED VIEW OF PENDENT HOLDER

Fig 7



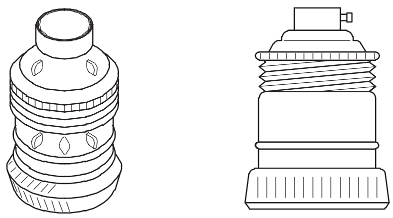
(a) BRASS BATTEN HOLDER (b) ANGLE HOLDER

Edison screw-type lamp-holders: In this type, the holder is provided with inner screw threads and the lamp is fitted in it by screwing. It has a centre contact which is connected to the live wire and the screwed cap is connected to the neutral wire.

For lamps with wattage above 200W and not exceeding 300W, Edison screw-type holders are used. (Fig 8).

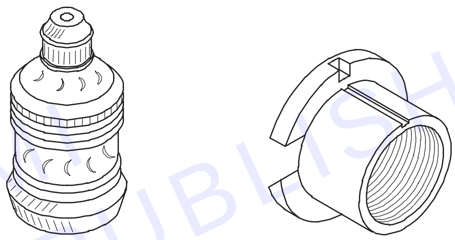
Goliath Edison screw (GES) type holders (Fig 9): The cover of this type of holder is made of porcelain. Such holders are used in studios, headlights, floodlights, focussing lights etc.

Fig 8



EDISON SCREW TYPE HOLDER

Fig 9



GOLIATH EDISON SCREW LAMP HOLDER

These holders are used for more than 300W lamps.

Specification of a lamp-holder: While specifying the lamp-holders, the type of material used for construction, type of gripping, type of mounting, working current and voltages should also be specified.

Socket outlet current rating: The standard ratings shall be 6,16 and 32 amperes and 240 volts.

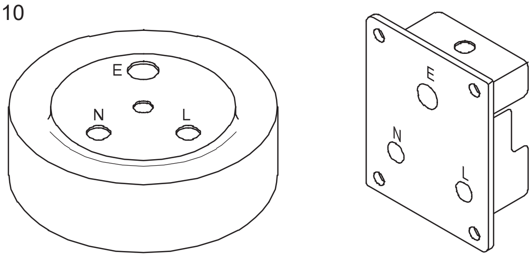
Two-pin socket: This socket is rated as 6A, 250V, having only two pins without earth connection. These are suitable only for double insulated appliances (having PVC or insulated body).

Two-pin plug top: It is used for taking the supply from the socket. It has got two pins of the same size.

Three-pin socket: This type of socket is suitable for light and power circuits. These sockets are rated as 6A, 250V or 16A, 250V, and are available as surface-mounting type and flush type (Fig 10). There are three terminals marked as Line (L) Neutral (N) and Earth (E).

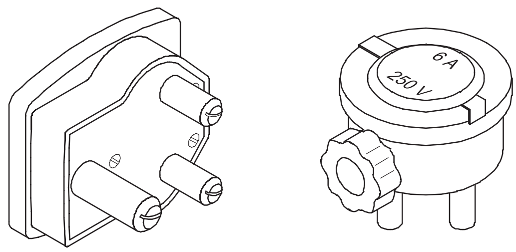
Three-pin plug top : It is used for taking the supply from the socket. It has three pins. Two are similar in size and the third one is bigger and longer which is for earth (Fig 11). These are also rated as 6A,250V or 16A, 250V. These are made of bakelite, PVC materials.

Fig 10



3-PIN 16 AMP SOCKET WITH TOP COVER FLUSH TYPE SOCKET

Fig 11



THREE-PIN PLUG TOP

General accessories : Some accessories are used for general and special purposes such as:

– appliance connectors (or) iron connectors
– adapters
– ceiling roses
  a two-plate
  b three-plate
– connectors
– distribution board
– neutral links.

Appliance connectors or iron connectors : These are used as female connectors to supply current to electric kettles, electric iron, hotplate, heaters etc. It is made of bakelite or porcelain. These are rated as 16A, 250V (Fig 12).

Adaptor (Fig 13): They are used for taking supply from a lamp holder for small appliances. They are made out of bakelite. They are available in ratings up to 6 A 250 V.

Fig 12

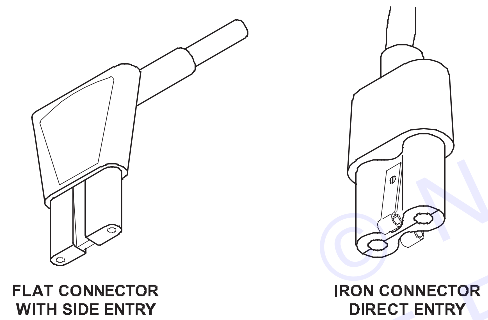
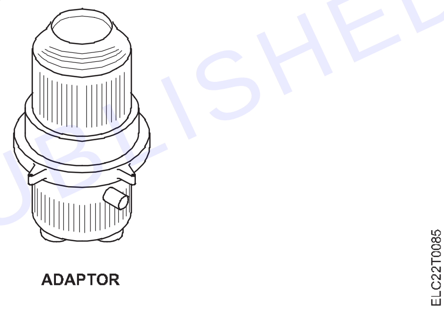


Fig 13



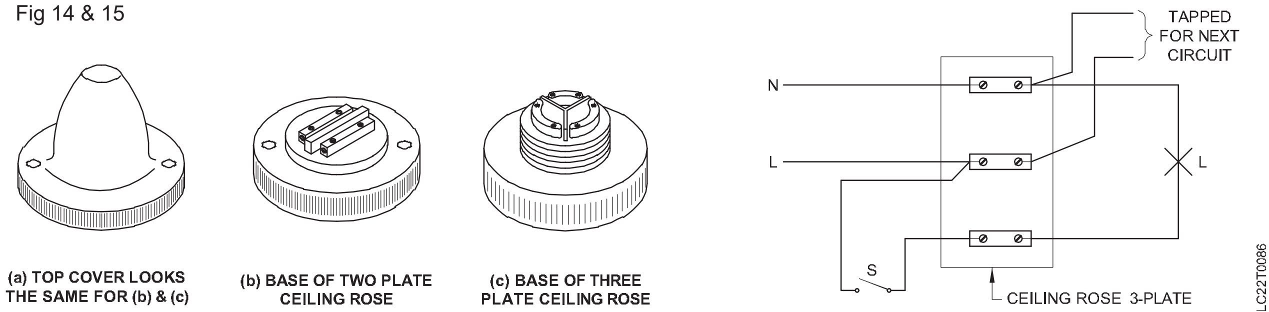
Ceiling roses: Ceiling roses are used to provide tapping points from the wiring for supplying power to fans, pendent-holders, tube lights etc. Normally flexible wires are used for tapping from the ceiling roses.

Two-plate ceiling rose (Fig 14a & b): This is made of bakelite and it has 2 terminals (phase & neutral) which are separated from each other by a bakelite bridge. The two-plate ceiling rose is used for 6A, 250V current capacity.

Three-plate ceiling rose: This type of ceiling rose has 3 terminals which are separated from each other by a bakelite bridge. It can be used for two purposes. (Fig 14c)

– Bunch light control
– To provide tapping for phase wire (Fig 15).

Fig 14 & 15

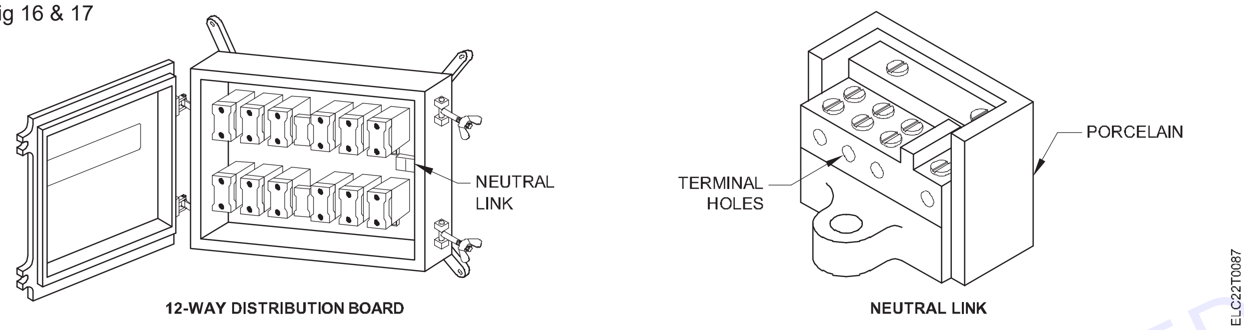


These ceiling roses are available in the rating of 6A, 250V

Distribution board (Fig 16): These are used where the total load is high and is to be divided into a number of circuits. These are used where the load is more than 800W. The number of fuses in the board is according to the number of circuits, and a neutral link is also provided so that the neutral wire can be taken for different circuits. All these branch fuses are enclosed in a metal box. These boards are available as two-way, three-way, 4,6,12-way types.

Neutral link: In a three-phase system of wiring installations, the phases are controlled through switches, and the neutral is tapped through a link called neutral link. (Fig 17). The ratings are 16A, 32A, 63A, 100A neutral link.

Fig 16 & 17



The accessories' rating shall be 240V and 6 or 16 amps from the year 1991, instead of 250V and 5 or 15 amps as per BIS 1293-1988.

Toggle switches (Fig 18)

It is an electric switch operated by means of a projecting lever that can be moved upward and downward and is also called as snap switches .

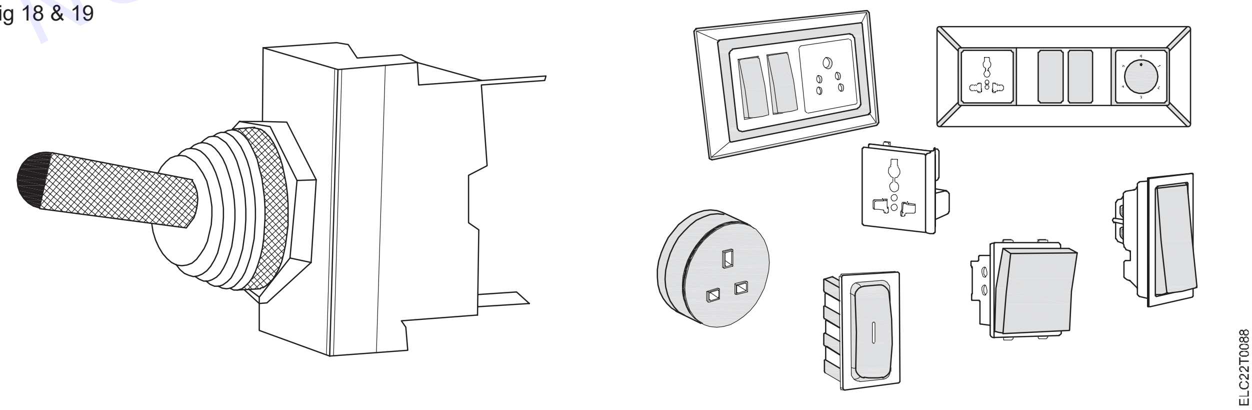
Modular switches (Fig 19)

The latest version of modular switch of different sizes and colours along with sockets combined and switches with indicators are available in market

Indian Electricity Rules - Safety Requirements

The IE rules 1956 was made under sections 37 of Indian Electricity Act 1910. Now it is redefined after the enactment of the Electricity Act 2003. The Central Electricity Authority (measures relating to safety and electric supply) Regulation (CEAR) 2010 which came into effect from 20th September 2010, in place of Indian Electricity Rules 1956.

Fig 18 & 19



Safety rules: Among safety rules, the following are important and indeed requires attention. Every rule in the Indian Electricity Rules 1956 is related either directly or indirectly to safety.

Rule 32: Switches shall be on the live conductor. No cutout, link or switch other than gang switch shall be inserted in the neutral conductor. Code of Practice of wiring shall be followed while marking the conductors.

Rule 50: Energy shall not be supplied, transformed,converted or used unless the following provisions are observed. A suitable linked switch or circuit breaker is erected at the secondary side of the transformer. Every circuit is protected by a suitable cut-out. Supply to each motor or group of motors is controlled by a linked switch or circuit breaker. Adequate precautions are taken to ensure that no live parts are exposed.

Special provisions in respect of high and extra high voltage installations

Rule 63: Approval of Inspector is necessary before energising any high voltage installations.

Rule 65: The installation must be subjected to the prescribed testing before energizing.

Rule 66: Conductors shall be enclosed in a metallic covering and suitable circuit breakers shall be provided to protect the equipment from overloading.

Rule 68: Incase of outdoor type of sub-station a metallic fencing of not less than 1.8 m height shall be erected around the transformer.

Provisions in terms of OH line

Rule 77: Clearance of lowest conductor above ground across street.

- Low and Medium Voltage lines - 5.8 m.
- High voltage Lines - 6.1 m.
- Clearance of lowest conductor above ground along a street. Low and Medium Voltage lines - 5.5 m.
- High voltage lines - 5.8 m.
- Clearance of lowest conductor above ground other than along or across the street. Low, Medium and High Voltage lines upto 11 KV if bare - 4.6m .
- Low, Medium and High upto and including 11KV, if insulated - 4.0m.
- High Voltage above 11 KV - 5.2 m.

Rule 79: Clearance of low and medium voltage lines from building,

- Vertical Clearance - 2.5 m.
- Horizontal clearance - 1.2 m.

Rule 80: Clearance from building of high and extra high voltage. Vertical Clearance High Voltage upto 33KV - 3.7m.

- Extra High Voltage above 33KV - 3.7 m, plus 0.3 m for every 33KV part there of.
- Clearance from building of high and extra high voltage - Pitched Roof . Vertical Clearance upto 11KV - 1.2m.
- Above 11KV upto 33KV - 2.2 m.
- Above 33KV - 2m. plus 0.3m for every 33KV part there of.

Rule 85: Maximum interval between supports. It shall not exceed 65 m except by prior approval of inspector.

Indian electricity rules regarding to internal wiring:

1 The minimum size of conductor used in domestic wiring must not be of size less than 1/1.12mm in copper or 1/1.40mm (1.5mm) in aluminium wire.

2 For flexible wires the minimum size is 14/0.193mm.

3 The height at which meter board, Main switch board are to be fitted 1.5 meters from ground level.

4 The casing will be run at a height of 3.0 meters from the ground level.

5 The light brackets should be fixed at a height of 2 to 2.5 meters from ground level.

6 The maximum number of points in a sub circuit is 10.

7 The maximum load in a sub circuit is 800W.

I.E. Rules regarding - Voltage drop concept:

1 **I.E. Rule 48:** The insulation resistance between the wiring of an installation and earth should be of such a value that the leakage current may not exceed 1/50000 the part or 0.02 percent of the F.L. current.

2 The permissible voltage drop in a lighting circuit is 2% of the supply voltage plus one volt.

3 The maximum permissible voltage drop in a power industrial circuit should not be more than 5% of the declared supply voltage.

4 The insulation resistance of any wiring installation should not be less than 1M .

5 The earth resistance should not exceed the value of one ohm.

I.E. Rules regarding to power wiring:

1 In a power sub circuit the load is normally restricted to 3000 watts and number of outlets to two in each sub circuit.

2 All equipment used in power wiring shall be iron clad construction and wiring shall be of the armoured cable or conduit type.

3 The length of flexible conduit used for connections between the terminal boxes of motors and starters, switches and motors shall not exceed 1.25 meters

4 Every motor, regardless of its size shall be provided with a switch fuse placed near it.

5 The minimum cross-sectional area of conductor, that can be used for power mining of 1.25 mm for copper conductor cables and 1.50 mm for Aluminium conductor cables (refer ISI recommendations). Hence VIR or PVC cables of size lower than 3/0.915 mm copper or 1/1.80 mm Aluminium can not be used for motor wiring.

Circuit Breaker (CB) - Miniature Circuit Breaker (MCB)- Moulded Case Circuit Breaker (MCCB)

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

- explain the types, working principle and parts of a miniature circuit breaker.
- state the advantages and disadvantages of MCB
- state the categories and applications of MCBs
- state the application, advantage and disadvantage of MCCBs.

Circuit Breaker

A circuit breaker is a mechanical switching device capable of making, carrying and breaking the currents under normal condition and breaking the currents under abnormal conditions like a short circuit.

Miniature circuit breaker (MCB)

A miniature circuit breaker is a compact mechanical device for making and breaking a circuit both in normal condition and in abnormal conditions such as those of over current and short circuit.

Types of MCB's

MCBs are manufactured with three different principles of operation namely

a Thermal Magnetic

b Magnetic hydraulic and

c Assisted bimetallic

Out of three MCB's thermal magnetic MCB is discussed below

Thermal magnetic MCB

The switching mechanism is housed in a moulded housing with phenolic moulded high mechanically strong switching dolly. This type of MCB is also provided with bimetallic overload release (Fig 1).

The electric current gets through two contact tips one each on moving and fixed contact of silver graphite.

An arcing chamber incorporating de-ionising arc chutes for control and quick suppression of the arc is provided in the gap between two contacts. It has a ribbed opening closed by metal grid which allows ventilation and escape of gases.

For protection against over-load and short circuit, MCB's have thermal magnetic release unit. The overload is taken care of by bimetallic strip, short circuit currents and over loads of more than 100% are taken care by solenoid.

Working

The bimetallic strip when flexing due to temperature rise caused by increasing normal rated current beyond 130% rotates a trip lever carrying an armature to which it is to brought into field of a solenoid. The solenoid is designed to attract the armature to full position at about 700% overload or instantaneous short circuit current.

For initial portion of current wise (130% to 400%) tripping of circuit breaker is due to thermal action, between 400 to 700% tripping is due to combined thermal and magnetic action and beyond 700% due to fully magnetic action.

Categories of MCBs

Certain manufacturers like Indo Kopp manufacture the MCBs in three different categories namely 'L' series, 'G' series, and 'DC' series.

'L' series MCBs

'L' series MCBs are designed to protect circuits with resistive loads. They are ideal for protection of equipment like Geysers, ovens and general lighting systems.

'G' series MCBs

'G' series MCBs are designed to protect circuits with inductive loads. G series MCBs are suitable for protection of motors, air conditioners, hand tools, halogen lamps etc.,

'DC' series MCBs

'DC' series MCBs are suitable for voltage upto 220V DC and have a breaking capacity up to 6kA.

The tripping characteristics are similar to 'L' an 'G' series. They find extensive application in DC controls, locomotives, diesel generator sets etc.,

Advantages of MCB

1 Tripping characteristic setting can be done during manufacture and it cannot be altered.

2 They will trip for a sustained overload but not for transient overload.

3 Faulty circuit is easily identified.

4 Supply can be quickly restored.

5 Tamper proof.

6 Multiple units are available.

Disadvantages

1 Expensive.

2 More mechanically moving parts.

3 They require regular testing to ensure satisfactory operation.

4 Their characteristics are affected by the ambient temperature.

Moulded Case Circuit Breakers (MCCB): Moulded case circuit breakers are similar to thermo magnetic type MCBs except that these are available in higher ratings of 100 to 800amp at 500V 3-phase.

In MCCB, thermal and magnetic releases are adjustable. A shunt release is also incorporated for remote tripping and interlocking at MCCB. MCCBs are provided with under voltages release. There are two types of MCCB.

1 Thermal magnetic type.

2 Fully magnetic type (Fig 2).

Advantages of MCCB

1 MCCBs occupy much less space in comparison to fuse switch units.

2 MCCBs provide equal amount of protection against high faults as switch gears having HRC fuses.

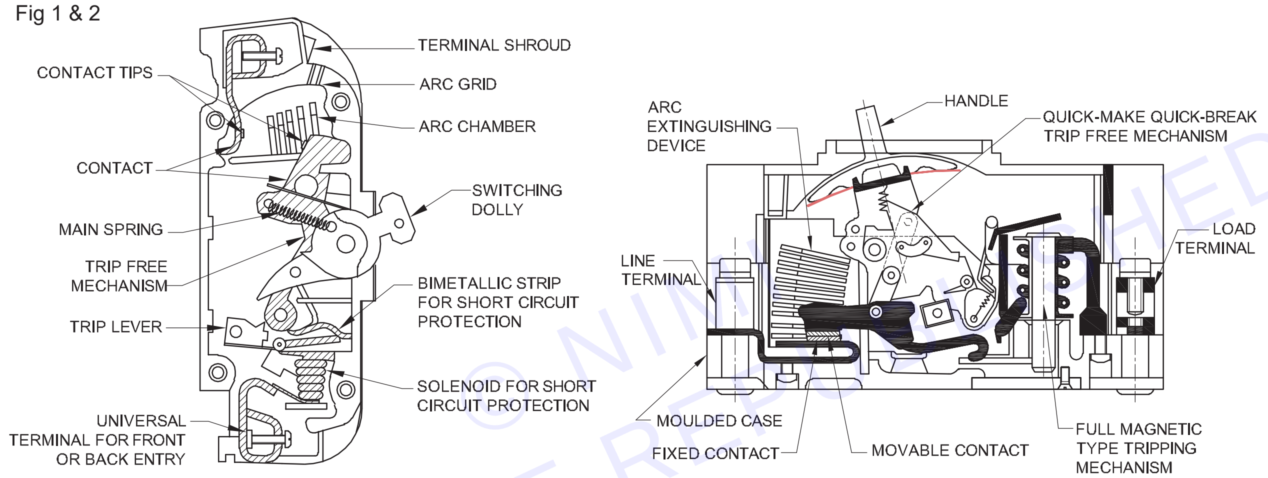
Disadvantages

1 MCCBs are much costlier.

2 Leak proof situation required.

3 Sensitivity to insulation resistance low.

Fig 1 & 2



NOTE: THE HATCHED PORTION SHOWS THE PATH OF CURRENT FROM TOP TERMINAL TO BOTTOM

THERMAL MAGNETIC TYPE MCB

FULLY MAGNETIC TYPE M.C.C.B

ELCB - types - working principle - specification

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

- explain the working principle, different types and construction of an earth leakage circuit breaker (ELCB)
- explain the technical specifications of ELCB's.

Introduction

The sensation of electric shock is caused by the flow of electric current through the human body to earth. When a person comes in contact with electrically live objects like water heaters, washing machines electric iron etc., the extent of damages caused by this current depends on its magnitude and duration.

This kind of current is called the leakage current which comes in milli-amps. These leakage current being very small in magnitude, hence undetected by the fuses/MCBs are the major cause for the fires due to electricity.

The leakage current to earth also results in the wastage of energy and excessive billing for electricity not actually used.

These residual current circuit breakers (RCCB) are popularly called as Earth leakage circuit breakers (ELCB).

Basically ELCBs are of two types namely voltage operated ELCBs and the current operated ELCBs.

Voltage operated ELCB

This device is used for making and breaking a circuit. It automatically trips or breaks the circuit when the potential difference between the protected metal work of the nstallation and the general mass of earth exceeds 24V. This voltage signal will cause the relay to operate (Fig 1).

Voltage operated ELCBs are meant to be used where it is not practicable to meet the requirements of IEE wiring regulation by direct earthing or where additional protection is desirable.

Current operated ELCB: This device is used for making and breaking a circuit and for breaking a circuit automatically when the vector sum of current in all conductors differs from zero by a predetermined amount. Current operated ELCBs are much more reliable in operation, easier to install and maintain.

Construction of current operated ELCB: It consists of a Torroid ring made of high permeability magnetic material. It has two primary windings each carrying the current flowing through phase and neutral of the installation. The secondary winding is connected to a highly sensitive electro - magnetic trip relay which operates the trip mechanism.

Working principle

The residual current device (RCD) is a circuit breaker which continuously compares the current in the phase with that in the neutral. The difference between the two is called as the residual current which is flowing to earth.

The purpose of the residual current device is to monitor the residual current and to switch off the circuit if it rises from a preset level (Fig 2&3).

Fig 1

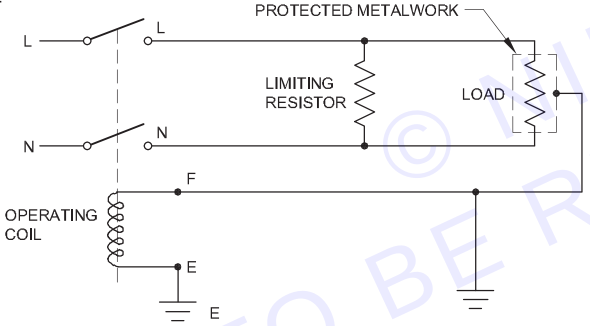
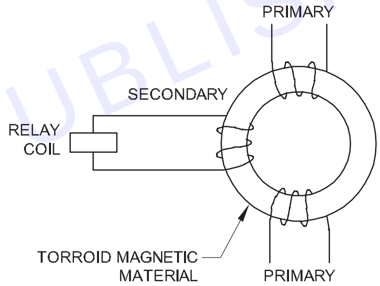
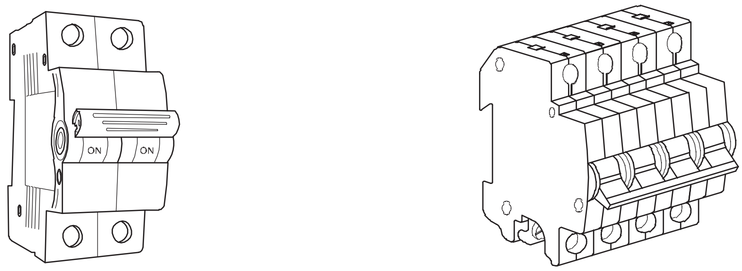


Fig 2



ELC22T0090

Fig 3



(a) 2 - POLE ELCB

(b) 4 - POLE ELCB

ELC22T0091

The main contacts are closed against the pressure of a spring which, provides the energy to open them when the device trips. Phase and neutral current pass through identical coils wound in opposing direction on a magnetic circuit, so that each coil will provide equal but opposing numbers of ampere turns when there is no residual current. The opposing ampere turns will cancel and no magnetic flux will be set up in the magnetic circuit.

In a healthy circuit the sum of the current in phases is equal to the current in the neutral and vector sum of all the current is equal to zero. If there is any insulation fault in the circuit then leakage current flows to earth. This residual current passes to the circuit through the phase coil but returns through the earth path and avoids the neutral coil, which will therefore carry less current.

So the phase ampere turns exceeds neutral ampere turns and an alternating magnetic flux results in the core. The flux links with the secondary coil wound on the same magnetic circuit inducing an emf into it. The value of this emf depends on the residual current, so it drives a current to the tripping system which depends on the difference between them and neutral current.

When tripping current reaches a predetermined level the circuit breaker trips and open the main contacts and thus interrupts the circuit.

Types domestic wiring

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

- state the types wiring used in domestic installations.

Introduction

The type of wiring to be adopted is dependent on various factors viz. location durability, safety, appearance, cost and consumer's budget etc.

Types of wiring

The following are the types of internal wiring used in domestic installations.

- Cleat wiring (for temporary wiring only)
- CTS/TRS (batten) wiring
- Metal/PVC conduit wiring, either on surface or concealed in the wall.
- PVC casing & capping wiring

Cleat wiring

This system uses insulated cables supported in porcelain cleats (Fig 1).

Cleat wiring is recommended only for temporary installations. These cleats are made in pairs having bottom and top halves (Fig 2). Bottom half is grooved to receive the wire and the top half is for cable grip.

Initially the bottom and top cleats are fixed on the wall loosely according to the layout. Then the cable is drawn through the cleat grooves, and it is tensioned by pulling and the cleats are tightened by the screw.

The cleats are of three types, having one, two or three grooves, so as to receive one, two or three wires.

Cleat wiring is one of the cheapest wirings considering the initial cost and labour, and is most suitable for temporary wiring. This wiring can be quickly installed, easily inspected and altered. When not required this wiring could be dismantled without damage to the cables, cleats and accessories. This type of wiring may be done by semi-skilled persons.

Fig 1

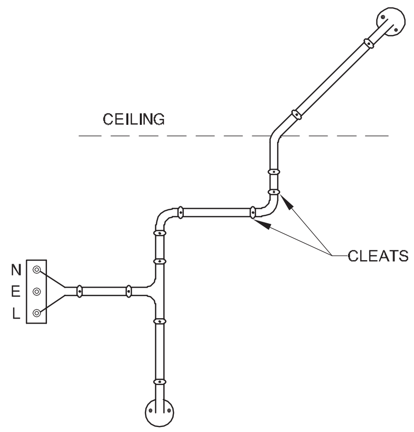
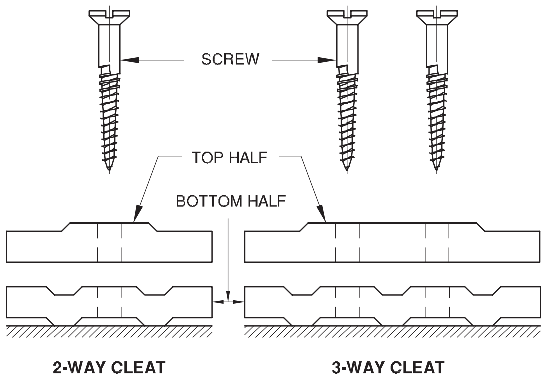


Fig 2



ELC22T0092

Types of Power wiring

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

- explain the types of electrical wiring and their application
- state the advantages and disadvantages of each types

Many wiring systems are developed to meet the safety requirements, economy of cost, easy maintenance and trouble shooting. A particular system can be chosen according to technical requirements but the system needs to be approved by the local electricity authorities. The following are the fundamental requirements for any wiring system. They are:

i For safety, switches should control the live phase wire. The second terminal of the switch called as half wire should be connected to the appliance or socket through the wire. The neutral can be connected directly to the appliance, socket or lamp.

ii For safety, fuses should be placed in the live/phase wire only.

iii To supply the rated voltage, parallel connections should be given to all lamps and appliances.

Types of wiring system: There are three types of wiring systems used for tapping supply from mains to the different branches. They are as follows.

1 Tree system

2 Ring main system

3 Distribution board system

Tree system: In this system, copper or aluminium strips in the form of bus bars are used to connect the main supply to the raising mains (Fig1). This system is suitable for multi-story buildings and the bus bar trunking space is provided in the building at a convenient location and at load centres for the purpose of economy.

At each floor the running main is connected to the sub-main board through proper cable terminations. If there are more than one flat in each floor the individual main switches for the flat get their supply from the sub-main board through a distribution network which may include an energy meter for each flat.

However the system adopted within the flat will be the distribution board system.

Advantages

1 The length of the cables required for installation will become less. Hence, the cost is less.

2 This system is suitable for high rise buildings.

Disadvantages

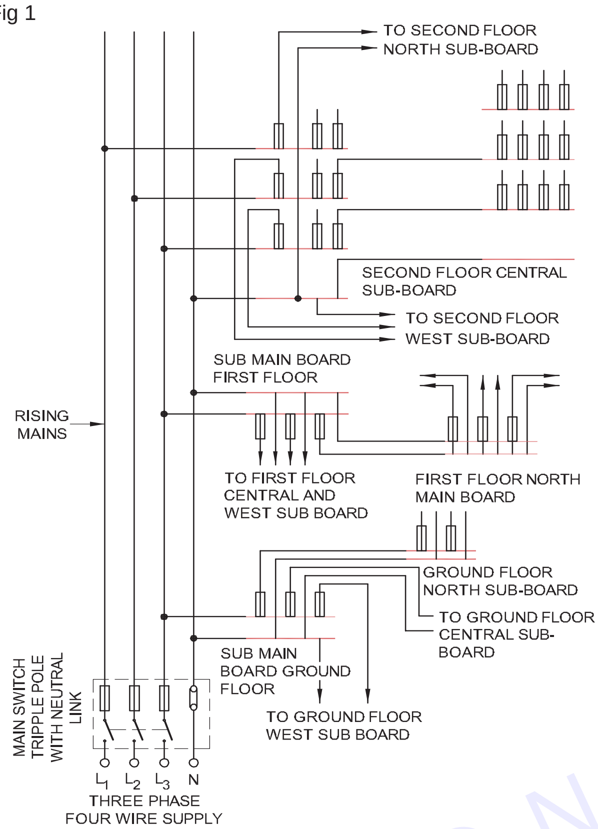
1 The voltage across the appliances which are at the farthest end of the tree system may be less when compared to the one connected to the nearest end if the bus bars size is not of sufficient size.

2 As fuses are located at different places, fault location becomes troublesome.

Ring main system: This system consists of two pairs of cables of size 4 or 6sq.mm which run through the rooms and are brought back to the main or sub-board (Fig 2&3). Tappings are taken for sockets or ceiling roses from the pair of cables through fuses and controlling switches. There may be saving of copper used because the current can be fed from both sides. As this system requires special sockets or plugs with fuses it becomes costly; and hence rarely used in India.

As per IEE regulations one ring circuit has to be there for every 100 sq metres of the floor area or part thereof. The number of power plugs fed from branch lines (spurs) should not exceed two and the total current should not exceed 30 amps. Protection for individual power plug can be provided by having built-in-fuses with the individual power plugs or by having MCB type switch and socket arrangement.

Fig 1



WIRING OF BUILDING BY TREE SYSTEM

Fig 2

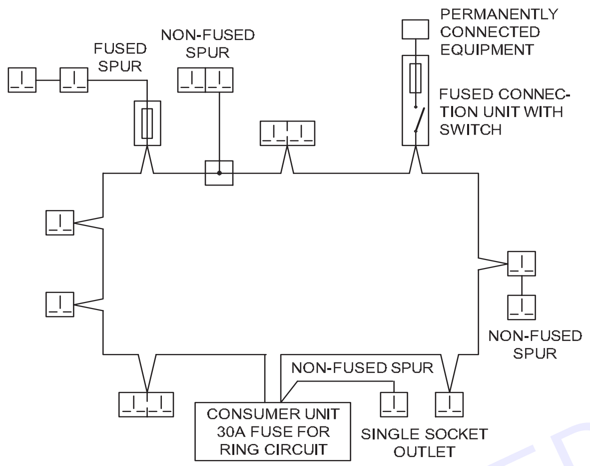
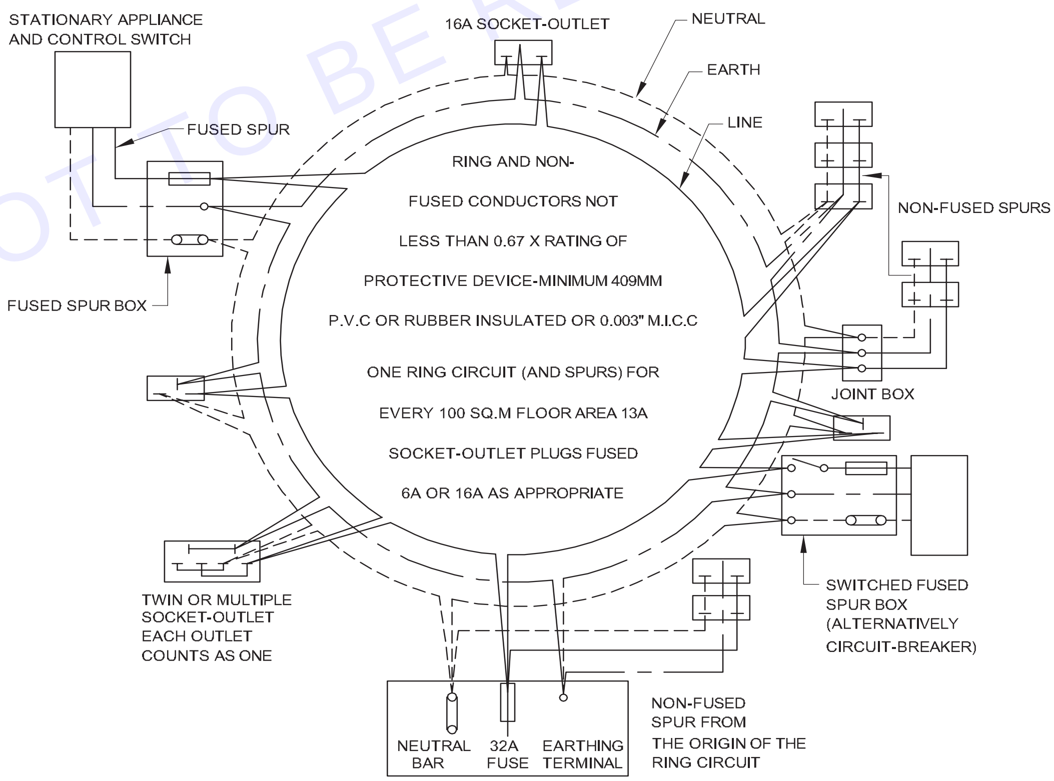


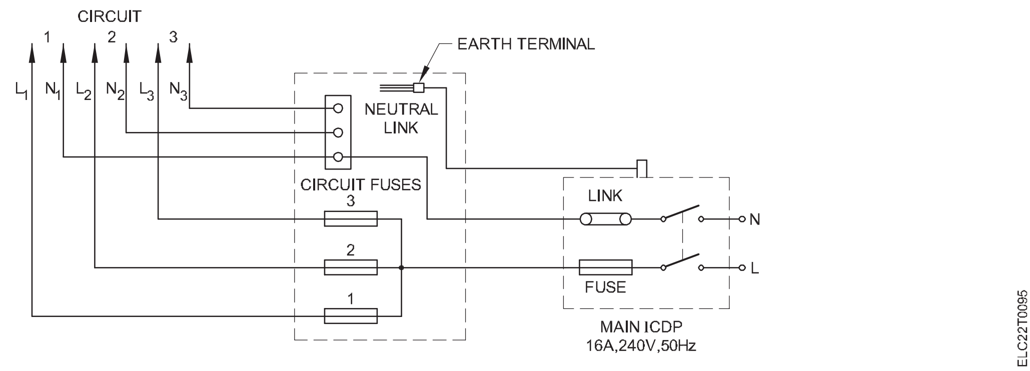
Fig 3



FUSE BOARD

Distribution board system: This is the most commonly used system. This system enables the appliances connected to the system to have the same voltage. The main switch is connected to the distribution board through suitable cables. The distribution board has a number of fuses depending upon the number of circuits required in the installation, and the phase and neutral cable of each phase are taken from the distribution board (Fig 4).

Fig 4



As each circuit can have power up to 800 watt, the phase wire which is taken from the circuit fuse of the distribution board is looped to the other light switches or fan switches of the same circuit by any one of the following ways.

No joint is allowed in the cable route except in switches, ceiling roses and joint boxes.

a **Looping out from switch and ceiling rose:** Fig 5 shows the simple looping in method which is commonly employed. The phase wire which is connected to the terminals of the switch is looped out to the next switch and so on, whereas the neutral wires are looped together from ceiling roses (Fig 5). Cable consumed in this system is very high.

b **Looping out from switch:** This system employs special switches having two terminals and one connector (Fig 6). Both the phase and neutral cables are taken to the switch for looping the cables. As these accessories are not commonly manufactured in India such a system is not used.

Fig 5

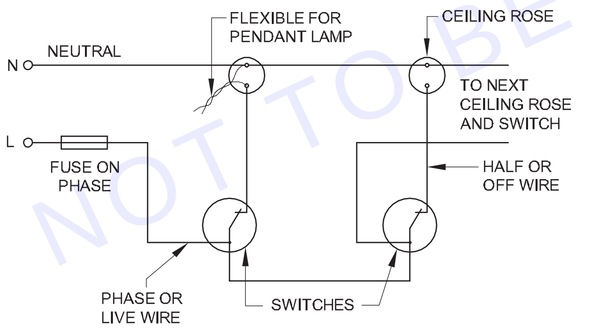
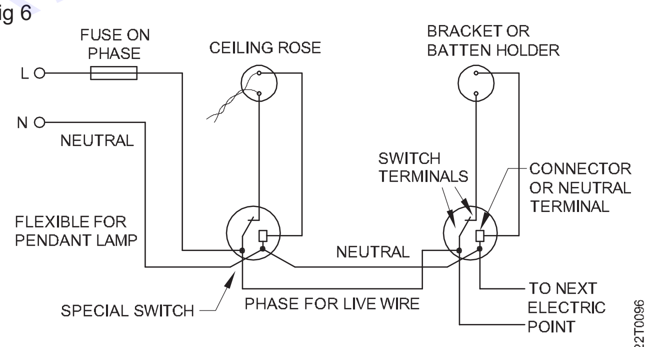


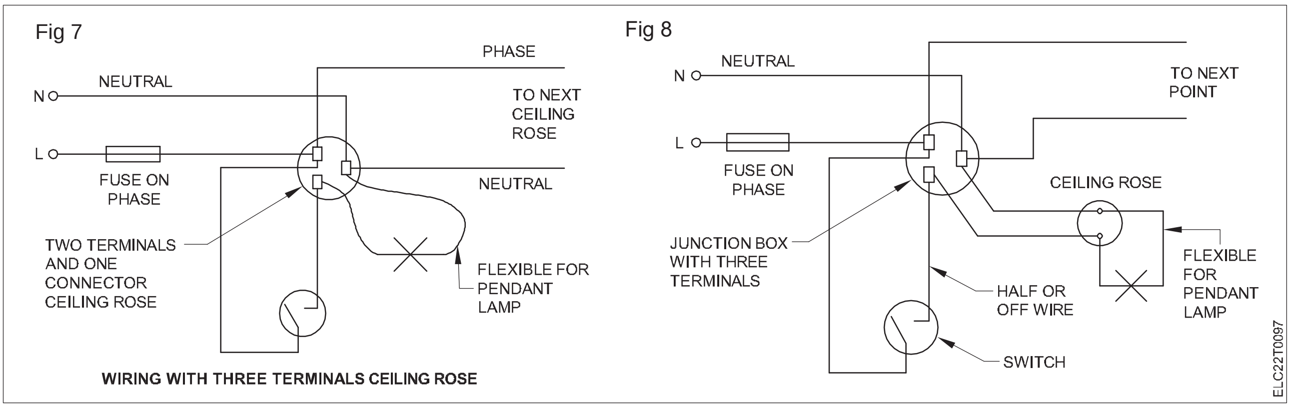
Fig 6



WIRING WITH TWO TERMINALS AND ONE CONNECTOR SWITCH

c **Looping out from 3-plate Ceiling roses:** In this type of system, three terminal ceiling roses need to be used. As this system uses less cables when compared to (a), this system is in use in some parts of India. (Fig 7)

d **Looping out with junction box:** In this system a pair of conductors from the distribution board is brought to the junction box and tappings are taken to switches, two plate ceiling roses as well as other points from the junction box. This method may be economical for lodges where a row of rooms are constructed on either side of a common corridor. (Fig 8)



Principle of laying out of domestic wiring

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

- explain the layout, installation plan, circuit -diagram, wiring diagram and state their uses
- state the B.I.S. regulation pertaining to wiring installation.

In electrical wiring work, the electrician is supplied with a layout of wiring installation and an installation plan initially.

On the basis of the layout and installation plan, the electrician should draw the circuit and wiring diagrams before the commencement of work for systematic execution of the work.

The terms used in wiring installation drawings are explained here.

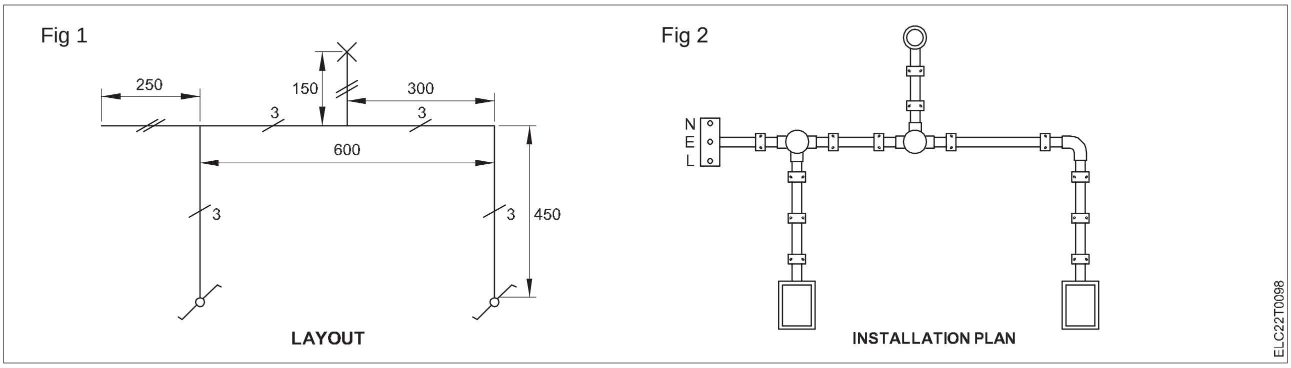
Layout diagram: Some customers give their requirements in writing. But a few can give them in the form of a layout diagram to the electrician.

The layout diagram (Fig 1) is a simplified version of the wiring diagram. Its purpose is to inform the reader quickly and exactly, what the circuit is designed for without giving any information on the circuit itself.

This type of layout diagram is used for preparing architectural diagrams, plans, etc. of a building.

In a layout diagram, it is necessary to indicate with symbols details like whether the wiring is on the surface or concealed, and the run `up' or `down', the number of wires in run, dimensions, and accessories with appropriate I.S. symbols.

Installation plan (Fig 2): This plan shows the physical position of accessories in an installation, and also gives the final appearance of the installation.



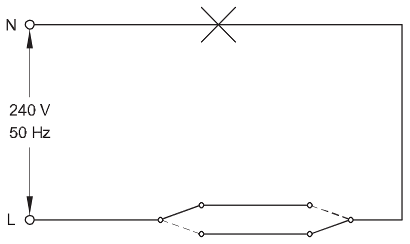
Circuit diagram (Fig 3): This shows the schematic connections of the circuit for a specific task in the simplest form, incorporating the graphical symbols.

The purpose of a circuit diagram is to explain the function of the various accessories in the circuit. Fig 3 is an example of a circuit diagram for controlling a lamp from two different places.

Wiring diagram (Fig 4): This is the diagram in which the position of the components in the diagram bears a resemblance to their actual physical position. Fig 4 also shows the wiring plan for controlling a lamp from two different places with their actual locations.

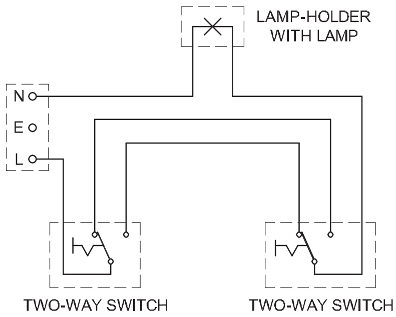
For his own good and to facilitate quick location of faults at a later stage, the customer should insist on the electrician giving him a copy of the wiring diagram soon after the completion of wiring.

Fig 3



SCHEMATIC (CIRCUIT) DIAGRAM

Fig 4



WIRING DIAGRAM

B.I.S. Regulations and the n .e. code pertaining to wiring installations

The wiring installation shell generally be carried out in conformity with the requirements of the Indian Electricity Act 1910, as updated from time to time and the Indian Electricity Rules 1956, framed thereunder, and also the relevant regulations of the electric supply authority of the concerned area (State Government).

The following are some of the extracts of B.I.S. (Bureau of Indian Standards) regulations pertaining to wiring installations. All the B.I.S. regulations are recommended by the National Electrical Code (NEC).

B.I.S. regulations pertaining to wiring installations

Wiring: Any one of the following types of wiring may be used in a residential building.

- Tough rubber-sheathed or PVC-sheathed or batten wiring.
- Metal-sheathed wiring system
- Conduit wiring system:
    a rigid steel conduit wiring
    b rigid non-metallic conduit wiring
- Wood casing wiring

Permissible load in sub circuit and power circuit

Sub-circuits - different types: The sub-circuits may be divided into the following two groups:

- Light and fan sub-circuit
- Power sub-circuit.

After the main switch, the supply shall be brought to a distribution board. Separate distribution boards shall be used for light and power circuits.

Light and fan sub-circuits: Lights and fans may be wired on a common circuit. Each sub-circuit shall have not more than a total of ten points of lights, fans and 6A socket-outlets. The load on each sub-circuit shall be restricted to 800 watts. If a separate circuit is installed for fans, the number of fans in that circuit shall not exceed ten.

Power sub-circuits: The load on each power sub-circuit should normally be restricted to 3000 watts. In no case shall there be more than two outlets on each sub-circuit.

If the load on any power sub-circuit exceeds 3000 watts, the wiring for that sub-circuit shall be done in consultation with the supply authority.

Lighting : A switch shall be provided adjacent to the normal entrance to any area for controlling the general lighting in that area. The switches should be fixed on a usable wall space and should not be obstructed by a door or window in its fully open position. They may be installed at any height up to 1.3m above the floor level.

The light fittings in kitchens should be so placed that all working surfaces are well illuminated and no shadow falls on them when in normal use.

For bathrooms, it is recommended to use ceiling lighting with the switch located outside the bathroom.

It is recommended that lighting facilities be provided for lighting of all steps, walkways, driveways, porch, carport, terrace, etc, with switches for each provided inside the house at a convenient place. If the switches are installed outdoors, they should be weatherproof.

Waterproof lighting fittings should be used for outdoor lighting.

Socket-outlets: All plugs and socket-outlets shall be of 3-pin type, the appropriate pin of the socket being connected permanently to the earthing system.

An adequate number of socket-outlets shall be placed suitably in all rooms so as to avoid the use of long lengths of flexible cords.

Only 3-pin, 6A socket-outlets shall be used in all light and fan sub-circuits. 3 pin, 16A socket-outlets shall be controlled by individual switches which shall be located immediately adjacent to it. For 6A socket-outlets, if installed at a height of 130 cm above the floor level, in situations where a socket-outlet is accessible to children, it is recommended to use shuttered or interlocked socket-outlets.

Dining rooms, bedrooms, living rooms, and study rooms, if required, shall each be provided with atleast one 3-pin, 16A socket outlet.

No socket-outlet shall be provided in the bathroom at a height less than 130 cm.

Fans: Ceiling fans shall be wired to ceiling roses or to special connector boxes. All ceiling fans shall be provided with a switch besides its regulator.

Fans shall be suspended from hooks or shackles with insulators between the hooks or shackles and also with insulators between the hooks and suspension rods.

Unless otherwise specified, all ceiling fans shall be hung not less than 2.75 m above the floor.

Flexible cords: Flexible cords shall be used only for the following purposes.

- For pendents
- For wiring of fixtures
- For connection of transportable and hand-held appliances

Mounting levels of the accessories and cables as recommended in B.I.S. and N.E.C.

Height of main and branch distribution boards should be not more than 2m from the floor level. A front clearance of 1 m should also be provided.

All the lighting fittings shall be at a height of not less than 2.25 m from the floor.

A switch shall be installed at any height 1.3 m above the floor level.

Socket-outlets shall be installed either 0.25 or 1.3 m above the floor as desired.

The clearance between the bottom point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades of the fan shall not be less than 300 mm.

The cables shall be run at any desired height from the ground level, and while passing through the floors in the case of wood casing and capping and T.R.S. wiring, it shall be carried in heavy gauge conduit 1.5 m above floor level.

References

I.S. 732-1963

I.S. 4648-1968

N.E. Code

Selection of the type and size of cable for a given wiring installation and voltage drop concept

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

- state the factors to be considered for selecting the cable for a circuit
- apply the factors and select the cable.

In order to determine the type and size of the cable for a given circuit, the following points should be taken into account.

- Suitability of the type of cable for the location of the circuit and the type of wiring.
- Size of the cable depending upon the current carrying capacity of the cable.
- Size of the cable depending upon the length of the wiring and permissible voltage drop in the cable.
- Minimum size of the cable based on the economy.

Location of the circuit and the type of wiring decide the type of cable.

It is necessary to consider whether the installation is for industry or domestic use and whether the atmosphere is damp or corrosive. Accordingly the type of cable has to be chosen.

Further the type of wiring determines the type of cable suitable for the installations.

The current carrying capacity of the cable decides the size of the cable.

In this, the first step is to find out the current expected to flow in the circuit when the total connected load is fully switched on. This current is the maximum current that would flow through the circuit in case all the loads are working at the same time. But this is not the case in actual situations.

Diversity factor

In the case of lighting installation all the lamps in a domestic installation may not be switched 'on' at the same time. Hence, it is assumed only two thirds of the lights (say 66%) only will be 'on' at a given time. This introduces a factor called 'diversity factor'.

When the connected load is multiplied by the diversity factor you get a load value which can be said as normal working load. Use of this diversity factor enables the technician to use a lesser size cable than the one calculated, based on the connected load.

Based on the working load the current in each circuit is to be calculated and the size of the cable suitable to carry the current has to be chosen.

Voltage drop in the cable

In any current carrying conductor, voltage drop takes place due to its internal resistance. This voltage drop in a premises as per BIS 732 should not be more than 3 percent of the standard supply voltage when measured between the consumer supply point and any point of the installation when the conductors are carrying the maximum current under the normal conditions of service.

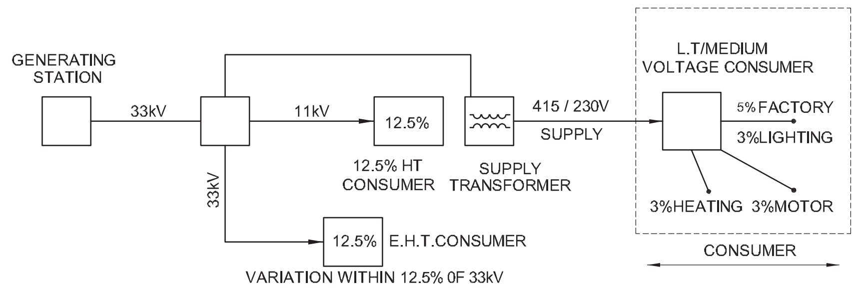
Tables 3 and 4 for aluminium cable and 5 for copper cable give the relation between voltage drop and length of the cable run for various cables. In case the voltage drop found in the cable exceeds the stipulated limit of 3% voltage drop, the technician has to choose the next bigger sized cable to maintain the voltage drop within limits.

If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the load or the cable rating whichever is minimum, to ensure the desired protection (BIS 732).

Declared voltage of supply to consumer

On the other hand according to IE Rule No.54, the voltage at the point of commencement of supply at the consumer should not vary from the declared voltage by more than 5 percent in the case of low or medium voltage or by more than 12 percent in the case of high or extra high voltage (Fig 1).

Fig 1



PERMISSIBLE VOLTAGE DROP-DIAGRAM

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At this stage it is better to remember that when current flows through a conductor, the resistance offered by the conductor produces heat. The increase in heat is proportional to the cable resistance which in turn depends upon the cross-sectional area of the cable. Since overheating damages the insulation, the conductor size must be adequate to prevent this from occurring.

While choosing the cable size, voltage drop is a more severe limitation than any other criterion. Hence, it is advisable to select the cable size only after ascertaining the permissible voltage drop. Excessive voltage drop impairs the performance of heating appliances, lights and the electric motors.

Calculation of voltage drop

In DC and single phase AC two-wire circuits

Voltage drop = Current x Total resistance of cables

= 2 IR

where I is the current and

R is the resistance of one conductor only

Wherever voltage drop is given as 1 volt drop per metre run of cable, we have to assume that both (lead and return) cables are taken into account and the cable carries its rated current. In such cases the voltage drop for X metre length of cable for a current of Y amps is calculated as given.

$$\left\{\begin{matrix}\text{Voltage}\\\text{drop}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{Length of}\\\text{the cable}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Actual current}\\\text{of the load}\end{matrix}\right\}}{\left\{\begin{matrix}\text{Metre length of}\\\text{the cable per one}\\\text{volt drop}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Rated current}\\\text{of the cable}\end{matrix}\right\}}$$

$$= \frac{XY}{\left\{\begin{matrix}\text{Metre length of}\\\text{the cable per one}\\\text{volt drop}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Rated current}\\\text{of the cable}\end{matrix}\right\}}$$

3-phase circuits

$$\text{Voltage drop} = 1.73 \times I\,R = \sqrt{3}\,IR$$

where I is the line current

R is the resistance of one core only.

The above points could be explained through the following set of examples.

Example 1

A guest house installation has the following loads connected to the three phase 415 V supply with neutral. Select a proper size of cable for this installation.

1 Lighting - 3 circuits of tungsten lighting total 2860 watts

2 Power from 3 x 30A ring circuits to 16A socket outlets for

a 1 x 7 KW Water heater (Instant)

b 2 x 3 KW Immersion heater (Thermostatically controlled)

c Cooking appliances: 1 x 3 KW cooker

1 x 10.7 KW cooker

Current demand in amperes in each of the circuit is calculated by referring the Table 1. Calculate current taking account into the diversity factor.

Assuming the declared voltage as 240 volts and the length of the longest run in a circuit as 50 metres

Permissible voltage drop at the rate of 3%

$$= \frac{3 \times 240}{100} = 7.2 \text{ Volts}$$

If the size of the conductor selected is 35.0 sq.mm which can carry 69 amps, the voltage drop at 69 amperes rating will be 1 volt for every 7.2 metres cable run.

For 50 metres cable run the voltage drop at 69 amps current rating = 50 / 7.2 volts.

Voltage drop for 65 amps

$$= \frac{50 \times 65}{7.2 \times 69} = 6.54 \text{ Volts}$$

As the actual voltage drop in the circuit, that is 6.54 volts, is well within the permissible value, of 7.2 volts, the cable selected is suitable for the installation.

Sl. No	Demand description	Current Demand (Ampere)	Diversity Factor (Table 2)	Current allowing for for (Ampere)
1	Lighting	11.9	75%	9.00
2	Power i ii iii	30 30 30	100% 80% 60%	30 24 72.00 18
3	Water heaters (inst)	29.2	100%	29.2
4	Water heaters (thermo)	25.00	100%	25.00
5	Cooker i ii	12.5 44.5	80% 100%	10.00 44.5
Total current = 213.1				
Total current demand (allowing diversity) = 189.7 amps Load spread over 3 phases = 189.7/3 = 63.23 amps, say 65 amps per phase.				

Earthing - Types - Terms - Megger - Earth resistance Tester

Objectives: At the end of this lesson you shall be able to:
- explain the reasons for system and equipment earthing
- define the terminalogy related to earthing
- state and explain the methods of preparing pipe earthing and plate earthing, according to B.I.S. recommendations
- explain the procedure for reducing the resistance of earth electrodes to an acceptable value.

Earthing

Connecting the non-condutive metal body/parts of an electrical equipment and system to the earth through a low resistance condutor is called as earthing.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and substations.

The purpose of system earthing is to:
- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

Terminology

Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Fig 1 shows the magnitude of current and its effect

Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part

Fig 1

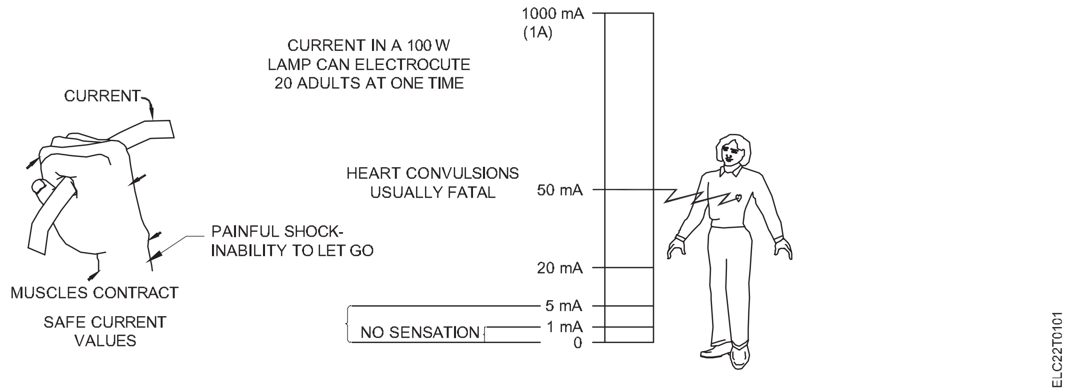


Table 1 shows the body resistance at specified areas of contact.

Table 1

Skin conditon or area	Skin conditon or area
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1:Metal body of apparatus when it is not earthed

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

The value of current through the body = $\frac{V}{R_{Body}}$

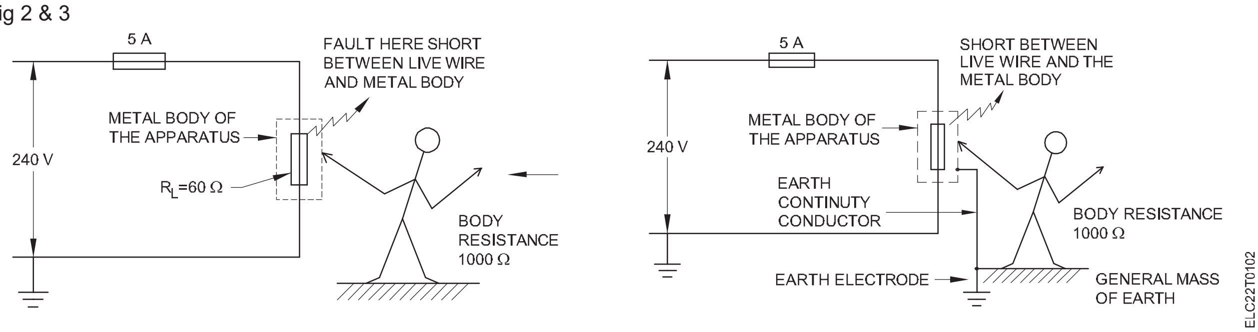
$$= \frac{240}{1000} = 0.24 \text{ amps or } 240 \text{ milliamps.}$$

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

CASE 2: **Metal body of apparatus when earthed.**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Fig 2 & 3



Assuming that the sum of the resistace of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

The leakage current = $\frac{V}{R_{Total}}$ = 240/10 = 24 amps.

This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

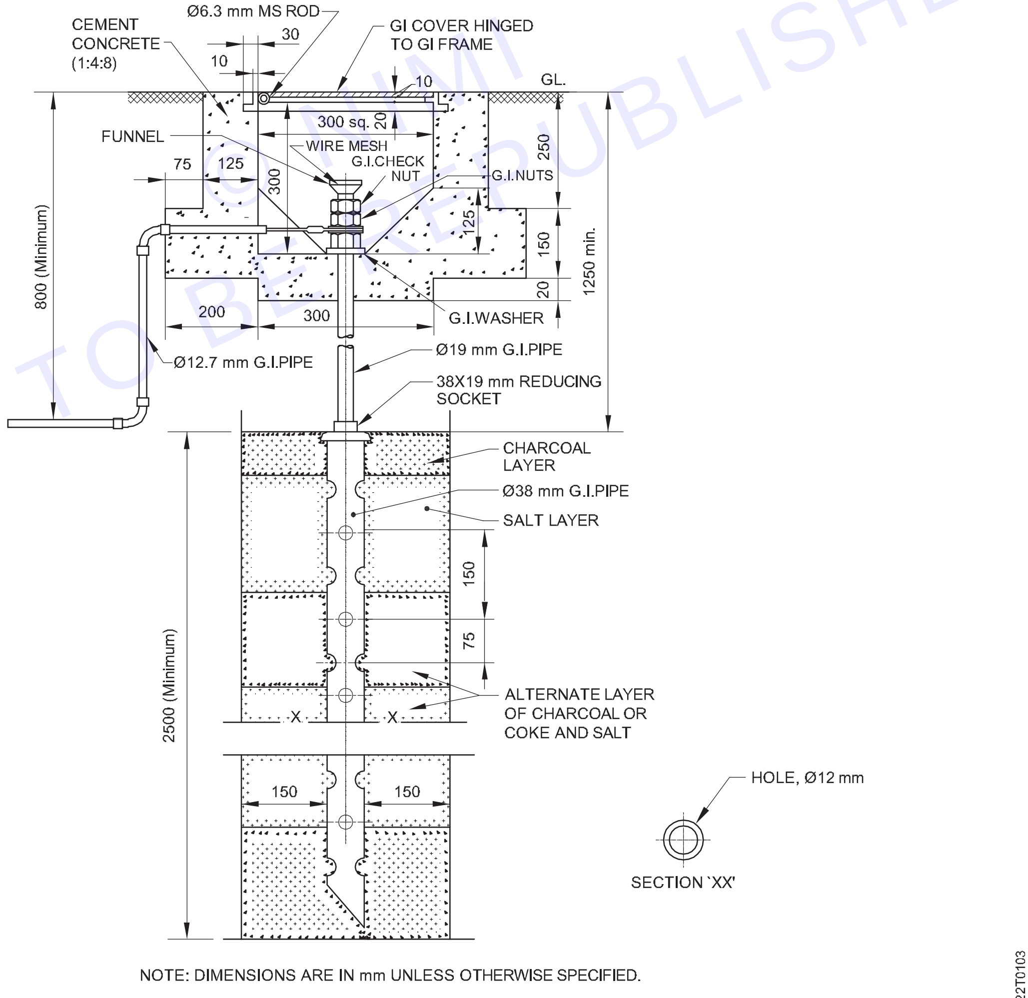
Types of earth electrodes

Rod and pipe electrodes (Fig 4): These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.

Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Fig 4



PIPE EARTHING

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. The length of the electrodes shall be atleast 2.5 m, and the inclination not more than 300 from the vertical.

Plate electrodes (Fig 5): Plate electrodes,when made of galvanised iron or steel,shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

Fig 5

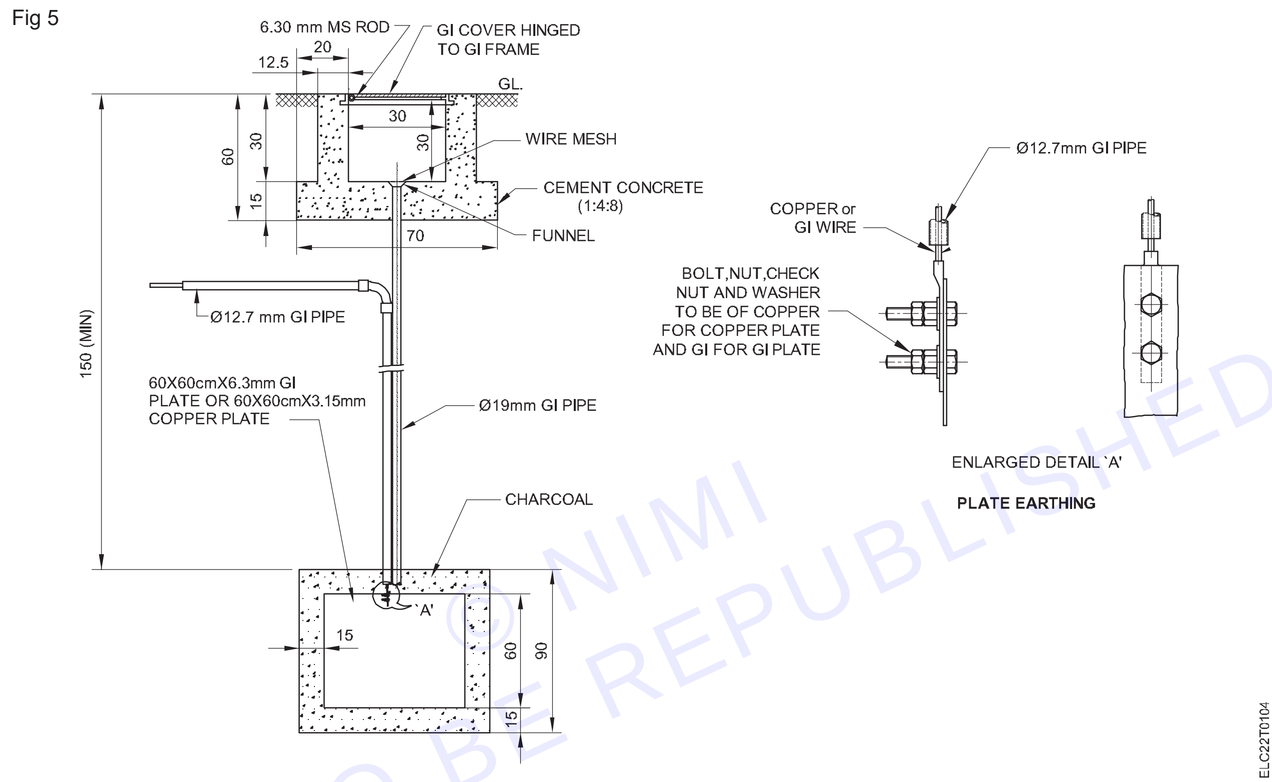


Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Plate electrodes is recommended in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atleast 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be atleast 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

The earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance.

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

Insulation resistance tester (Megger)

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

- state the working principle of an insulation tester (Megger)
- explain the construction and working of megger
- state the uses of an insulation tester like insulation test, continuity test etc.
- state the safety precautions to be observed while using an insulation tester.

Megger

It is an electrical measuring instrument generally used to measure the insulation resistance of an installation/ equipment etc in terms of Megaohms.

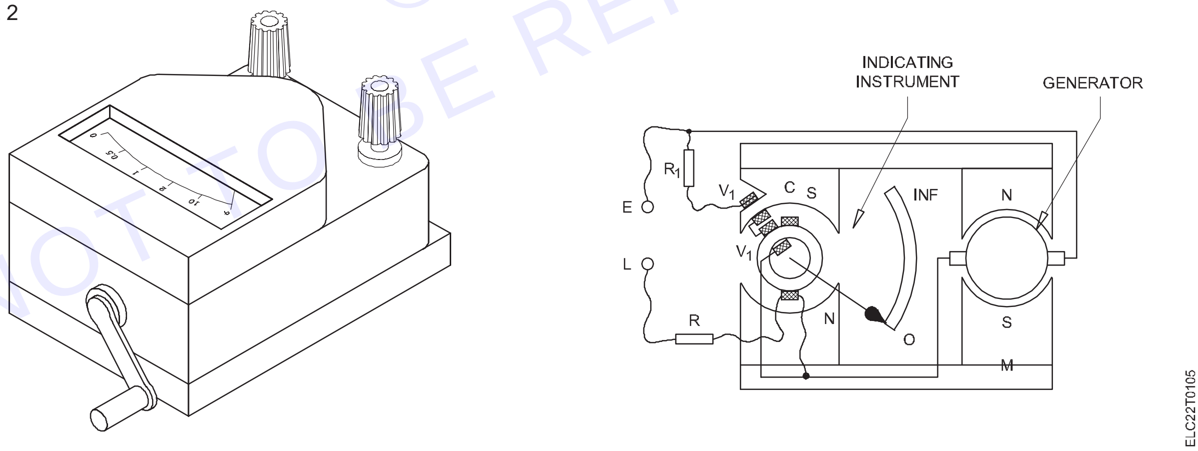
Necessity of megohmmeter

Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 1) A megohmmeter is commonly known as MEGGER.

Construction

The megohmmeter consists of (1) a small DC generator, (2) a meter calibrated to measure high resistance, and (3) a cranking system. (Fig 2)

Fig 1 & 2



A generator commonly called a magneto is often designed to produce various voltages. The output may be as low as 500 volts or as high as 1 megavolt. The current supplied by the megohmmeter is in the order of 5 to 10 milliamperes. The meter scale is calibrated: kilo-ohms (K W) and megohms(MW).

Working principle

The permanent magnets supply the flux for both the generator and the metering device. The voltage coils are connected in series across the generator terminals. The current coil is arranged so that it will be in series with the resistance to be measured. The unknown resistance is connected between the terminals L and E.

When the armature of the magnet is rotated, an emf is produced. This causes the current to flow through the current coil and the resistance being measured. The amount of current is determined by the value of the resistance and the output voltage of the generator.

The torque exerted on the meter movement is proportional to the value of current flowing through the current coil.

The current through the current coil, which is under the influence of the permanent magnet, develops a clockwise torque. The flux produced by the voltage coils reacts with the main field flux, and the voltage coils develop a counter-clockwise torque.

For a given armature speed, the current through the voltage coils is constant, and the strength of the current coil varies inversely with the value of resistance being measured. As the voltage coils rotate counter-clockwise, they move away from the iron core and produce less torque.

A point is reached for each value of resistance at which the torques of the current and voltage coils balance, providing an accurate measurement of the resistance. Since the instrument does not have a controlling torque to bring the pointer to zero, when the meter is not in use, the position of the pointer may be anywhere on the scale.

The speed at which the armature rotates does not affect the accuracy of the meter, because the current through both the circuits changes to the same extent for a given change in voltage. However, it is recommended to rotate the handle at the slip speed to obtain steady voltage.

Because megohmmeters are designed to measure very high values of resistance, they are frequently used for insulation tests.

Connection for measurement

When conducting insulation resistance test between line and earth, the terminal 'E' of the insulation tester should be connected to the earth conductor.

Precautions

- A megohmmeter should not be used on a live system.
- The handle of the megohmmeter should be rotated only in a clockwise direction or as specified..
- Rotate the handle at slip speed.

Uses of a megohmmeter

- Checking the insulation resistance
- Checking the continuity.

Specification of Megger :

Nowadays electronically operated, Meggers are available, called as push button type for general application and for industrial application motorised megger are also available. Hence a megger is basically specified based on the voltage generated by it .

Example: 250 V, 500V, 1KV, 2.5KV, 5KV.

Earth resistance tester

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

- state the precautions to be followed while selecting a site for the earth electrode
- define earth resistance tester
- explain the principle constructon and working of an earth resistance tester
- explain the method of measuring the earth resistance
- state the IE rules pertaining to earthing.

Precautions to be followed while selecting the site for earth electrode: However, even the earth electrode, either rod or plate type, implanted properly in the earth according to the specified recommendations is found to have high resistance resulting in failure of safety. The earth electrode resistance could be kept at a reasonable level.

Necessity of measuring of earth electrode resistance: The only way to ensure the acceptable value of earth electrode resistance is to measure the resistance with the use of an earth resistance tester.

Earth resistance tester: It is an electrical measuring instrument used to measure the resistance between any two points of the earth. It is also called as earth tester.

Principle: The earth tester works on the principle of the fall of potential method.

In this method the two auxiliary electrodes B and C are placed at a straight line (Fig 1).

An alternating current of lamps magnitude is passed through the electrode A to the electrode C via the earth and the potential across electrodes A and B is measured.

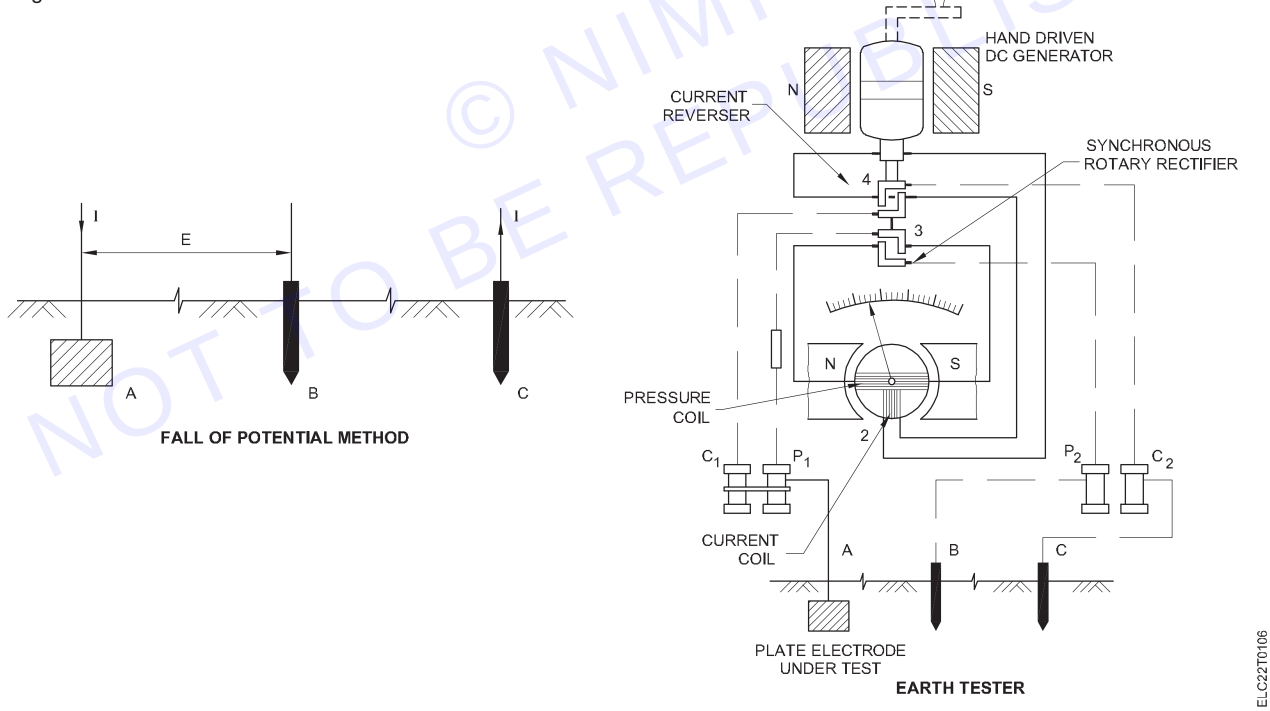
The resistance of electrodes B and C does not influence the measurement result.

This is achieved by placing the electrode C at a sufficient distance from A so that the resistance areas of A and C are quite independent. A distance of above 15 metres between electrode A and C is regarded as sufficient distance.

Construction and working of earth tester : The earth tester essentially consists of a hand drive generator which supplies the testing current and a direct reading ohmmeter (Fig 2).

The ohmmeter section of this instrument consists of two coils (potential and current coils) kept at 90o to each other and mounted on the same spindle. The pointer is attached to the spindle. The current coil carries a current proportional to the current in the test circuit whereas the potential coil carries a current proportional to the potential across the resistance under test.

Fig 1 & 2



Thus the current coil of the instrument acts as an ammeter in the fall of potential method and the pressure coil acts as the voltmeter. Since the deflection of the ohmmeter needle is proportional to the ratio of the current in the two coils, the meter gives resistance readings directly.

When DC is used in electrode resistance measurement the effect of electrolytic emf interferes with the measurement and the reading may go wrong. To avoid this, the supply to the electrodes should be AC.

To facilitate this the DC produced by the the hand generator is changed to AC through a current reverser. After the alternating current passes through the electrodes, the measurement should be done by an ohmmeter which requires DC supply.

To change the alternating voltage drop outside the instrument to direct voltage drop inside, a synchronous rotary rectifier is used (Fig 2)

Sometimes the meter needle vibrates during measurement due to the fact that strong alternating currents of the same frequency as the generated frequency enters the measuring circuit.

In such cases the handle rotating speed of the instrument may be either increased or decreased. In general these instruments are designed such that the readings are not affected by strong currents or by electrolytic emfs.

Method of earth resistance measurement: To measure the earth electrode resistance, the earth electrode is preferably disconnected from the installation. Then two spikes (the current and pressure spikes) are to be driven into the ground at a straight line at a distance of 25 metres and 12.5 metres respectively from the main electrode under test. The pressure and current spikes and the main electrode need to be connected to the instrument (Fig 1)

The earth tester has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrode.

I.e. rules pertaining to earthing

Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules 1956, as amended from time to time, and the relevant regulations of the electricity supply authority concerned. The following Indian Electricity Rules are particularly applicable to both system and equipment earthing: 32,51,61,62,67,69,88(2) and 90.

Extracts from Indian Electricity Rules, 1956

Rule no. 32: Identification of earthed and earthed neutral conductors and position of switches and cut-outs therein.

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be compiled with.

1 An indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such a conductor to be distinguished from any live conductor. Such indication shall be provided:

   a where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply

   b where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made.

2 No cut-out, link or switch other than a linked-switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:

   a a link for testing purposes or

   b a switch for use in controlling a generator or transformer.

Rule no.51: Provisions applicable to medium, high or extra high voltage installations

All metal work enclosing, supporting or associated with the installation, other than that designed to serve as ta conductor, shall, if considered necessary by the Inspector, be connected with earth.

Rule no.61: Connection with earth

1 The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage.

a The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

b In the case of a system comprising electric sypply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

c The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

d In the case of an alternating current system, there shall not be inserted in the connection with earth any impedance (other than that required solely for the operation of switchgear or instrumets), cut-out or circuit-breaker, and the result of a test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

e No person shall make connection with earth by the aid of, nor shall keep it in contact with, any water main not belonging to him except with the consent of the owner thereof and of the inspector.

f Alternating current systems which are connected with earth as aforesaid may be electrically interconnected. Provided that each connection with earth is bonded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

2 The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulation or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3 All metal casings or metallic coverings contained or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction-boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electroliers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated, all plug sockets shall be of the three-pin type and the third pin shall be permanently and efficiently earthed.

4 All earthing systems shall, before electric supply lines or apparatus are energised, be tested for electrical resistance to ensure efficient earthing.

5 All earthing systems belonging to the supplier shall, in addition, be tested for resistance on a dry day during the dry season not less than once every two years.

6 A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector when required.

Rule no.62: Systems at medium voltage

Where a medium voltage supply system is employed, the voltage between earth and any conductor forming part of the same system shall not, under normal conditions, exceed low voltage.

Rule no.67: Connection with earth

1 The following provisions shall apply to the connection with earth of three-phase systems for use at high or extra-high voltages:-

In the case of star-connected with earthed neutrals or delta-connected systems with earthed artificial neutral point

a The neutral point shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station and at the sub-station and may be earthed at any other point, provided that no interference of any description is caused by such earthing;

b In the event of an appreciable harmonic current flowing in the neutral connections so as to cause interference with communication circuits, the generator or transformer neutral shall be earthed through a suitable impedance.

2 In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be the one to be connected with earth.

3 Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.

Rule no.69: Pole type substations

1 Where platform type construction is used for a pole type substation and sufficient space for a person to stand on the platform is provided, a substantial hand rail shall be built around the said platform, and if the hand rail is of metal, it shall be connected with earth:

Provided that in the case of pole type substation on wooden support and wooden platform the metal hand-rail shall not be connected with earth.

Rule no.88: Guarding

1 Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken.

Rule no.90: Earthing

1 All metal support of overhead line and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected ordinarily at four points in every mile or 1.601 km, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fitting attached thereto shall be efficiently earthed.

2 Each stay-wire shall be similarly earthed unless an insulator has been placed in at a height not less than 10 ft. from the ground.

MODULE 5: Magnetism, AC Circuits

LESSON 26-29: Terminology used in magnetic circuit, faraday's laws of magnetism

Objectives

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

- define the terms magneticfeld, magnetic line, properties or magnet
- explain permanent magnet, principle of electro magnet
- state faraday's laws of electro magnetic induction BH curve
- explain the generation of alternating current and terms used
- explain the star and delta connection
- explain three phase power measurements.

A substance that attracts pieces of iron and steel is called a magnet. This property of the material is called magnetism. Magnetism is a force field that acts on some material and not on other material. Physical devices which posses this force are called magnets.

Earths magnetic field

Our earth itself is a huge magnet with its North Pole lies on the geometrical South Pole. Moving molten iron in Earth's outer core causes most of Earth's magnetic field. Magnetic field poles are NOT aligned with geographic poles.

Properties of magnets

1 Magnets attract objects of iron, cobalt and nickel.
2 The force of attraction of a magnet is greater at its poles than in the middle.
3 Like poles of two magnets repel each other.
4 Opposite poles of two magnets attracts each other.
5 If a bar magnet is suspended by a thread and if it is free to rotate, its South Pole will move towards the North Pole of the earth and vice versa.

Classification of magnets

Magnets are classified into two groups

1 Natural magnet
2 Artificial magnet

Temporary magnet (Electromagnet)

Permanent magnet

Natural magnet

Natural magnet occurs as an ore of iron called magnetite. Magnetite has magnetic properties and behaves like a weak magnet. Its called lodestone.

Two thousand years ago people of ancient Greece and China discovered that a lodestone would always align itself in a longitudinal direction if it was allowed to rotate freely. This property of lodestones allowed for the creation of compasses.

Electromagnets

An iron core made into a magnet by the passage of electric current through a coil surrounding it.

Permanent magnet

Different applications need magnets of different shapes and strength. The artificially prepared powerful magnets of different shapes are called artificial magnets. Nickel, Steel, ALNICO, TUNGSTEN are used to make permanent magnets.

Application of permanent magnet

Permanent magnets are used in microphone, loud speaker, magnetic compass, PMDC motor, PMMC measuring instruments etc.

Application of electromagnet

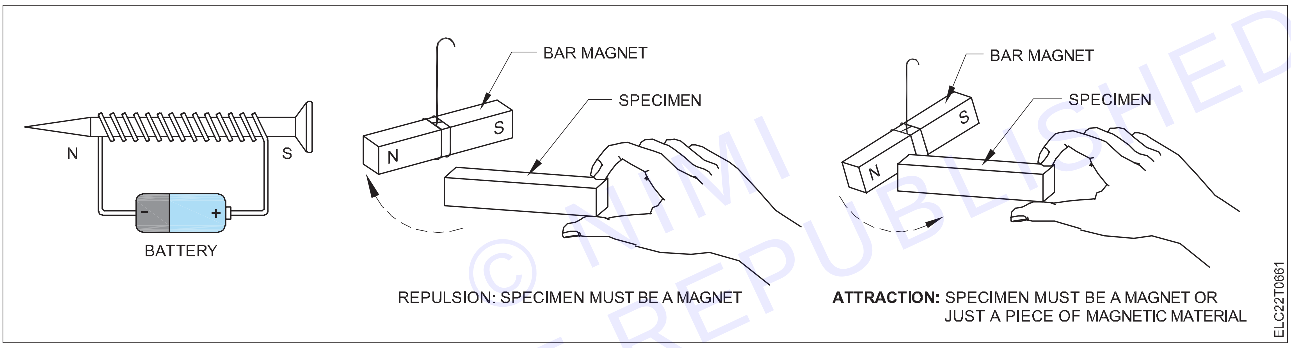
Electromagnets are used in electric bell, motor, maglev train, relay, MRI scanning etc.

Advantages

- Their strength can be increased or decreased as per requirement.
- They can be switched ON and OFF when required
- We can easily change the polarity of the magnet.
- Electromagnet can develop stronger magnetic field than permanent magnet.

Sure test of magnetism

A magnet can attract the opposite pole of other magnets well as the magnetic substance (iron cobalt nickel). So, if A magnet attracts another object, we cannot say that the other object is a magnet. But if the magnet repels the object, then we can surely say that the other object is a magnet. Because “Like poles of a magnet repel each other”.



Magnetic substances

Magnetic substances are categorized into three groups as follows:

1 Ferromagnetic substances

Those substances which are strongly attracted by a magnet are known as ferromagnetic substances.

e.g., iron, nickel, cobalt, steel and their alloys

2 Paramagnetic substances

Those substances which are slightly attracted by a magnet are known as ferromagnetic substances.

E.g., air, aluminium, manganese, platinum, copper etc

3 Diamagnetic substances

Those substances which are slightly repelled by a magnet are known as ferromagnetic substances.

e.g., bismuth, graphite, glass, paper, wood, water etc Bismuth is the strongest diamagnetic substance.

Type magnetic material	Ferromagnetic Substances	Paramagnetic Substances	Diamagnetic Substances
Magnetic susceptance, K	positive	positive	negative
Relative permeability, μr	Much greater than unity	Slightly greater than unity	Slightly less than unity

Methods of magnetization

- Touch method
- Single touch method
- Double touch method
- Divided touch method
- By means of electric current
- Induction method

Single touch method

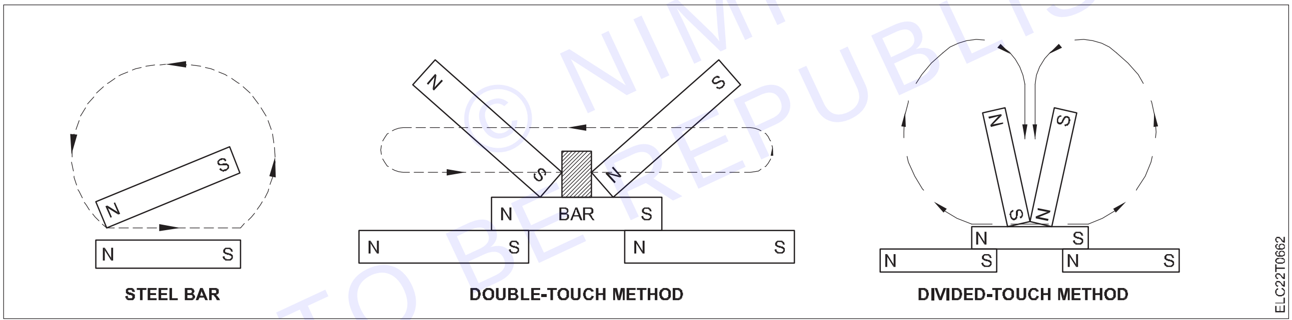
The steel bar to be magnetized is rubbed with either of the pole of the magnet (N or S).Keep the other pole away from it. Rubbing is done only in one direction. The process should be repeated for many times.

Double touch method

The steel bar to be magnetized is placed over the two opposite pole ends of magnets. The rubbing magnets are placed together over the centre of the bar with a small wooden piece in between. Rubbing magnets are never lifted off the surface of the steel bar, but rubbed again and again from end to end. Finally ending at the centre where the rubbing was started.

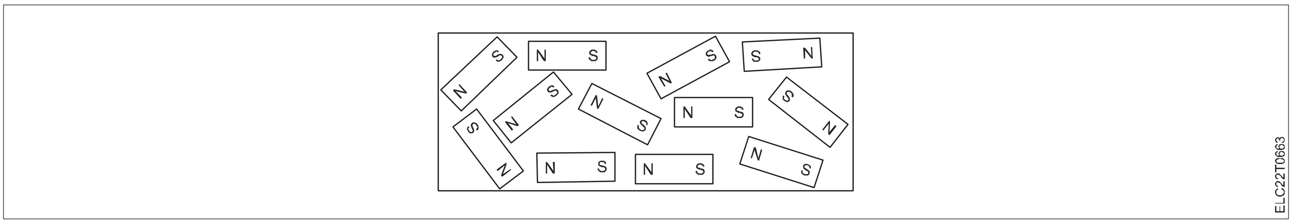
Divided touch method

Magnets are placed as in the previous case. Rubbing magnets are then moved along the surface of the steel bar to the opposite ends. Rubbing magnets are then lifted off the surface of the steel bar and placed back in the centre of the bar. The process is repeated again and again.



Molecular theory of magnetism

In magnetic material such as iron, steel, nickel, cobalt and their alloys, which are ferromagnetic material, the molecules themselves are tiny magnets ie each of them having a north pole and south pole. This is basically due to their special crystalline structure and to the continuous movement of electrons in their atoms. Under ordinary conditions, these molecules arranged themselves in a disorderly manner, the north pole and south pole of these tiny magnets pointing in all directions and neutralizing one another. Thus a non-magnetised ferromagnetic bar is one in which there is no definite arrangement of magnetic poles as shown in fig. When iron or steel is magnetized each molecule are forced to break up their groups and arrange themselves with their north pole in one side and south pole in other side. In this way one end of the bar becomes north pole and other end the south pole.



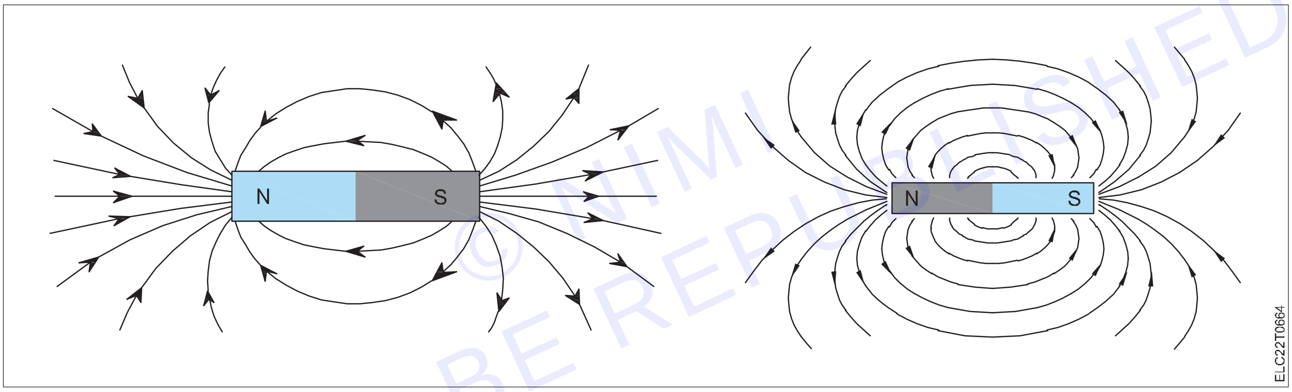
- Each molecule of a magnetic substance is a complete magnet.
- In an un-magnetised substance, the molecular magnets are arranged randomly.
- Hence the magnetic effect of any one of them is cancelled by its neighbour.
- So the entire bar does not exhibit any net magnetic property.
- When the substance is magnetized, all the tiny molecular magnets arrange themselves in parallel lines
- When the substance is heated or hammered, the molecular magnets get kinetic energy and the straight line get disturbed, thus losing the magnetic property.
- Molecular theory of magnetism was given by weber and modified by Ewing.

Magnetic field

The space around the magnet in which a magnetic pole experience a force is called a magnetic field. The magnetic field is strongest near the pole and goes decreasing as we move away from the magnet.

Magnetic lines of force

The magnetic field around a magnet is represented by imaginary lines is called magnetic lines of force. magnetic lines of force would emerge from N-pole of the magnet, pass through the surrounding medium and re-enter the S-pole. Inside the magnet each lines passes from S-pole to N- pole.



Properties of magnetic lines of force

1 Magnetic lines of force start from the North Pole and end at the South Pole.

2 They are continuous through the body of magnet

3 Magnetic lines of force can pass through iron more easily than air.

4 Two magnetic lines of force do not intersect each other.

5 They tend to contract longitudinally.

6 They tend to expand laterally.

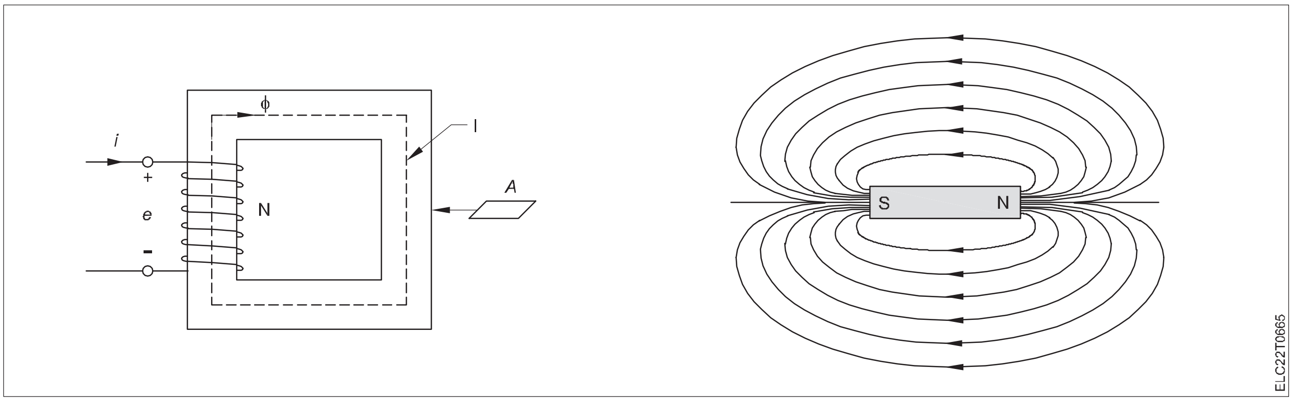
Magnetic circuit

Just as a closed path followed by electric current is called electric circuit, similarly closed path followed by magnetic flux is called magnetic circuit. Magnetic circuit usually consist of material having high permeability.

Magnetic flux

The amount of magnetic field produced by a magnetic source is called magnetic flux. Magnetic flux is denoted by Greek letter ϕ. If 10 magnetic lines come out of the north pole or enter the south pole of a magnet, then magnetic flux ϕ = 10 lines or Maxwell's. The SI unit of magnetic flux is weber.

1 wb=108Maxwell's



Magnetic flux density

It is the amount of flux passing through a defined area that is perpendicular to the direction of the flux:

Magnetic flux density = (magnetic flux) / (area)

$B = \Phi / A$

The symbol of magnetic flux density is B.

The unit of magnetic flux density is the tesla (T)

1 T = 1Wb/m2

Magnetic fieild strength

The strength of magnetic field produced around a magnet is known as magnetic field strength. Field strength at any point in a magnetic field, is numerically equal to the to the force experienced by an N pole of 1 Wb placed at that point. It is denoted by the letter H. Magnetic field strength is also known as Magnetizing force or strength of field or magnetic intensity or intensity of magnetic field.

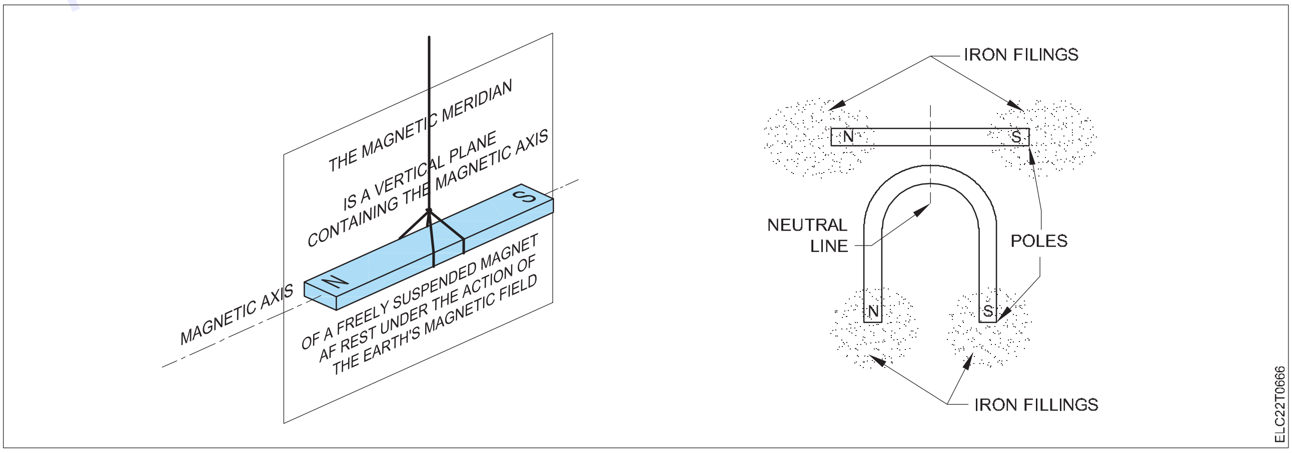
Unit of field strength is N/Wb or AT/m or oersted.

Magnetic axis

The imaginary line joining the two poles of a magnet are called magnetic axis. It is also known as magnetic equator.

Magnetic neutral axis

The imaginary line which are perpendicular to the magnetic axis and pass through the centre of the magnet are called magnetic neutral axis.



Magnetic saturation

When a piece of steel or iron fails to acquire a higher degree of magnetization however much magnetizing power is increased is known as magnetic saturation.

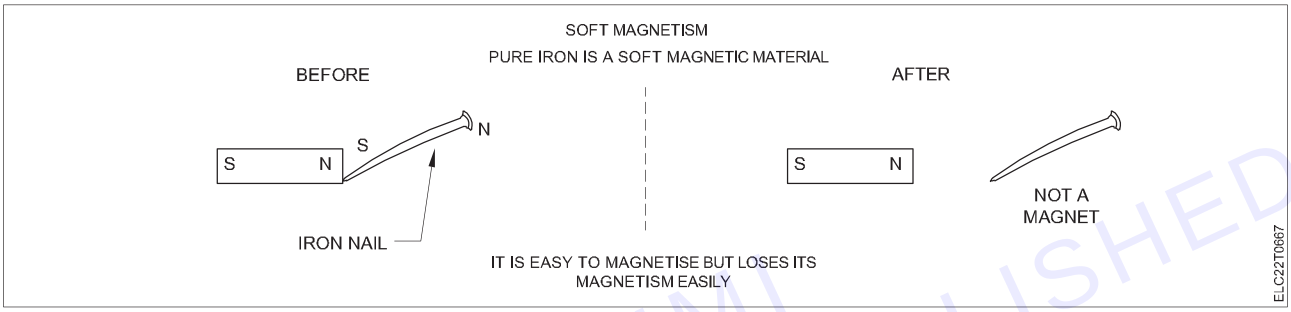
According to molecular theory of magnetism ,this would happen only when every molecule in the magnetic substance is lined up in the magnetic position.

When the B-H curve of a ferromagnetic material is drawn at a certain point the B-H curve levels off and eventually becomes horizontal line

The horizontal line indicates that there is no increase in flux density(B) for further increase in magnetising force(H). This behaviour is called magnetic saturation.ie all domains in the core material have become perfectly aligned.

Magnetic induction

The process by which a substance, such as iron or steel, becomes magnetized by a magnetic field. The induced magnetism is produced by the force of the field radiating from the poles of a magnet. It is the action by which a magnetic substance acquires a magnetic property by the presence of a magnet without actual contact



Magnetic screening

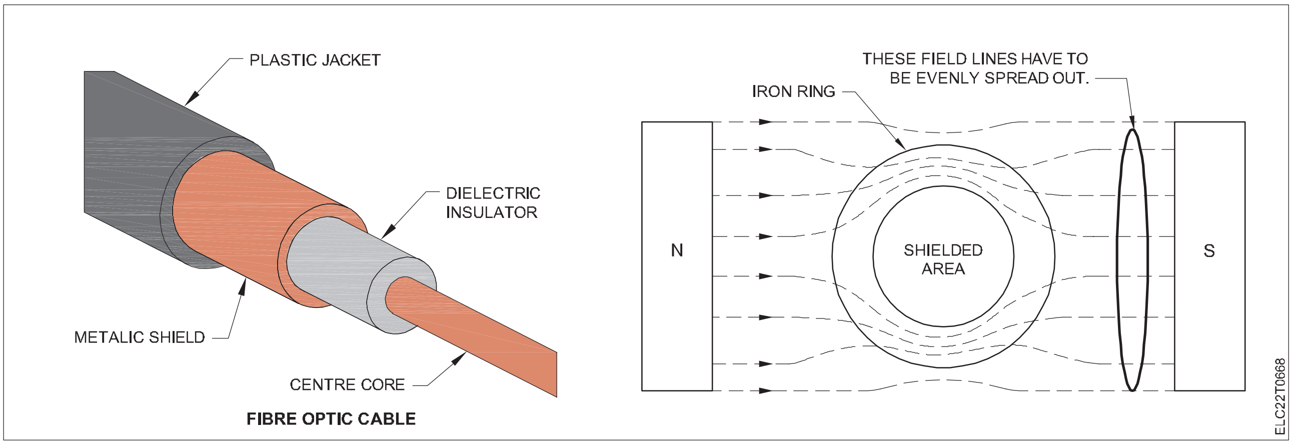
Magnetic lines can pass through any media because there is no known insulation for them. Whenever it is required to protect any instrument or device from magnetic effect, they are magnetically screened or shielded.

A space is said to be magnetically screened when the magnetic force at that point is destroyed. This can be done by placing an iron ring in the magnetic field.

Electromagnetic shielding is the practice of reducing the electromagnetic field in a space by blocking the field with barriers made of conductive or magnetic materials.

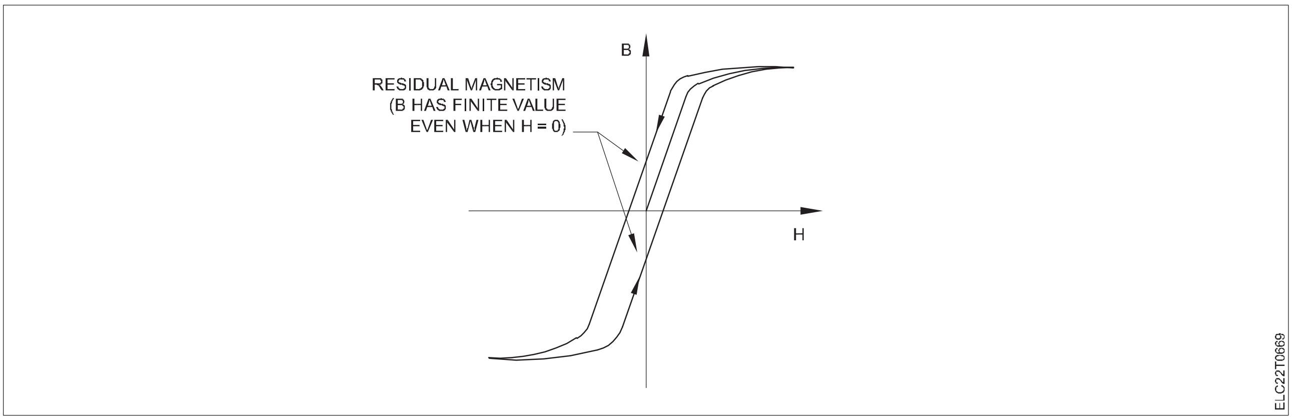
The fig.Shows the influence of a circular ring on the distribution of magnetic lines of force between the two opposite poles. The lines of force will pass through the iron ring rather than air, and there will be no lines of force inside the ring. The space which is not effected by magnetic lines of force is known as magnetically screened space.

Shielding is typically applied to enclosures to isolate electrical devices from the 'outside world', and to cables to isolate from the environment through which the cable runs. Electromagnetic shielding that blocks frequency electromagnetic is also known as RF shielding.



Residual magnetism

Residual magnetism is the magnetization left behind in a ferromagnetic material (such as iron) after an external magnetic field is removed. It is also the measure of that magnetization. Residual Magnetism is needed for instant voltage build up for DC generator. It is a material's ability to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation.



Retentivity

It is the property of retaining magnetism by a magnetic substance after the magnetization has been reduced to zero.

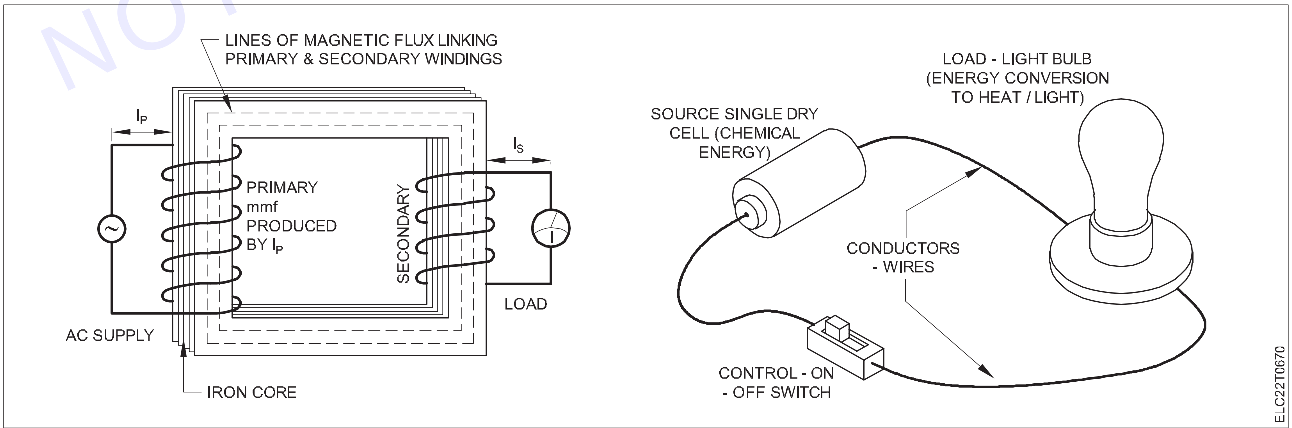
If two pieces, one of steel and other of soft iron of same dimensions are aimed at same magnetizing force, it will be observed that when the magnetizing force is removed, the two pieces does not retain the same value of magnetization

The soft iron has lesser magnetism than the piece of steel, hence their power of retaining magnetism, or say retentively is different.

Magnetic susceptibility

It is the property of an un magnetized body of acquiring induced polarity when under the influence of a magnetic field. The susceptibility of iron is much greater than that of hard steel. Magnetic susceptibility is the degree of magnetization of a material in response to an applied magnetic field. If magnetic susceptibility is positive, then the material can be paramagnetic or ferromagnetic.

Comparison between electrical and magnetic circuit



Similarities between electrical and magnetic circuits are given below

Electric Circuit	Magnetic Circuit
Path traced by the current is known as electric current.	Path traced by the magnetic flux is called as magnetic circuit.
EMF is the driving force in the electric circuit. The unit is Volts.	MMF is the driving force in the magnetic circuit. The unit is ampere turns.
There is a current I in the electric circuit which is measured in amperes.	There is flux φ in the magnetic circuit which is measured in the weber.
The flow of electrons decides the current in conductor.	The number of magnetic lines of force decides the flux.
Resistance (R) oppose the flow of the current. The unit is Ohm	Reluctance (S) is opposed by magnetic path to the flux. The Unit is ampere turn/weber.
R = ρ. l/a. Directly proportional to l. Inversely proportional to a. Depends on nature of material.	S = l/ (μ0μra). Directly proportional to l. Inversely proportional to μ = μ0μr. Inversely proportional to a
The current I = EMF/ Resistance	The Flux = MMF/ Reluctance
The current density	The flux density

There are few dissimilarities between the two circuits which are listed below:

Electric Circuit	Magnetic Circuit
In the electric circuit, the current is actually flows. ie, there is movement of electrons.	Due to mmf flux gets established and does not flow in the sense in which current flows.
There are many materials which can be used as insulators (air, PVC, synthetic resins etc) which current cannot pass	There is no magnetic insulator as flux can pass through all the materials, even through the air as well.
Energy must be supplied to the electric circuit to maintain the flow of current.	Energy is required to create the magnetic flux, but is not required to maintain it.
The resistance and conductivity are independent of current density under constant temperature. But may change due to the temperature.	The reluctance, permanence and permeability are dependent on the flux density.
Electric lines of flux are not closed. They start from positive charge and end on negative charge.	Magnetic lines of flux are closed lines. They flow from N pole to S pole externally while S pole to N pole internally.
There is continuous consumption of electrical energy.	Energy is required to create the magnetic flux and not to maintain it.

Comparison between electrical and magnetic quantities

Electric Circuit	Magnetic Circuit
e.m.f.	m.m.f.
current I (A)	flux Φ (Wb).
resistance R (Ω)	reluctance S (H−1)
R= (ρl) / A	S = l / μ0μrA
I = E / R	Φ = mmf / S

Electro magnetic induction

Whenever an electric current flows through the conductor, a magnetic field is set up around the conductor in the shape of concentric circle. It can be said that when electrons are in motion, they produce magnetic field. The convers of this is also true ie, when a magnetic field linking a conductor moves relative to the conductor, it produce a flow of electron in the conductor. This phenomenon where by an emf and hence current (ie, flow of electron) is induced in any conductor which is cut across or by a magnetic flux is known as electromagnetic induction.

Faradays laws of electro magnetic induction

Historical back ground

After the discovery of (by Oersted) that electric current produces a magnetic field, scientist began to search for the converse phenomenon from about 1821 on words. The problem is how to convert magnetism in to electricity. It is recorded the Michel faraday was in the habit of walking about with magnet in his pocket so as to constantly remind him of the problem. After nine years of continuous research and experimentation, he succeeded in producing electricity by converting magnetism in 1831.He formulated basic laws under laying the phenomenon of electro magnetism (known after his name), ie

Faradays summed up the above fact in two laws.

First law

Whenever the magnetic flux linked with a circuit changes, an emf is induced in it.

Eg: transformer action

OR

Whenever a conductor cuts magnetic flux, an emf is induced in that conductor.

Eg: Electric generator

Second law

The magnitude of the induced emf is equal to the rate of change of flux linkages or cutting.

ie, induced emf = rate of change of flux linkages. $E = \frac{\text{Change in } \phi}{\text{Time}}$

Explanation of faradays law

Suppose a coil has N number of turns and flux that it changes from initial value of ∅1Webbers to the final value of ∅ 2 Webbers in time T second.

Then, flux linkages are meant product of no. of turns and flux linked with the coil.

We have,

Initial flux linkages =NØ1 Final flux linkages =NØ2

Therefore, induced emf, e = NØ2 - NØ1 wb/s or

t

or, e = N (Ø2 -Ø1)volt

t

putting the above expression in its differential form, we get

e =d (NØ) =N dØ

dtdt

Usually a mines sign is given to the right hand expression to signify the fact that the induced emf , set up current in such a direction that magnetic effect produced by it opposes the very cause producing it(according to the Lenz's law)

- N d∅voltdt

Direction of induced emf & current

The direction of induced emf /current may be found easily by applying following two rules

Flemings right hand rule

Lenz's law

Flemings ruleis used where induced emf due to flux cutting ie, dynamically induced emf.And Lenz's law where it is change by flux linkages ie, statically induced emf.

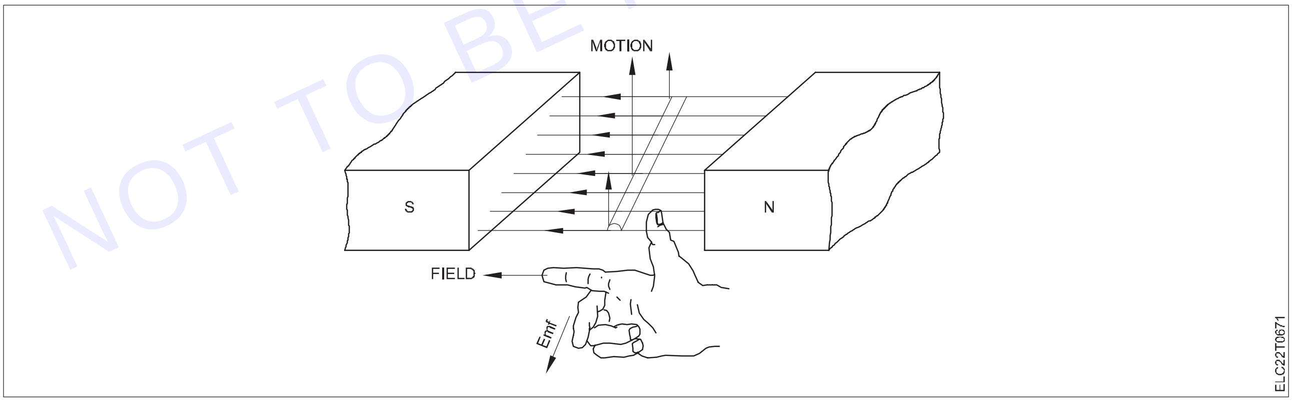
Flemings right hand rule

This rule state that, If you spread your right hand in such a way that the thumb, fore finger and middle finger are right angle to each other. The thumb direct to the motion of the conductor, the fore finger direct to the direction of magnetic flux and then the middle finger indicates the direction of induced emf / current.

Lenz's law

This law formulated by Lenz's in 1835. This law states, in effect, that electro magnetically induced current always flows in such a direction that the action of the magnetic field set up by it to oppose the very cause producing it.

An induced current will flow in such a direction so as to oppose the very cause which produces it'



AC Fundamental

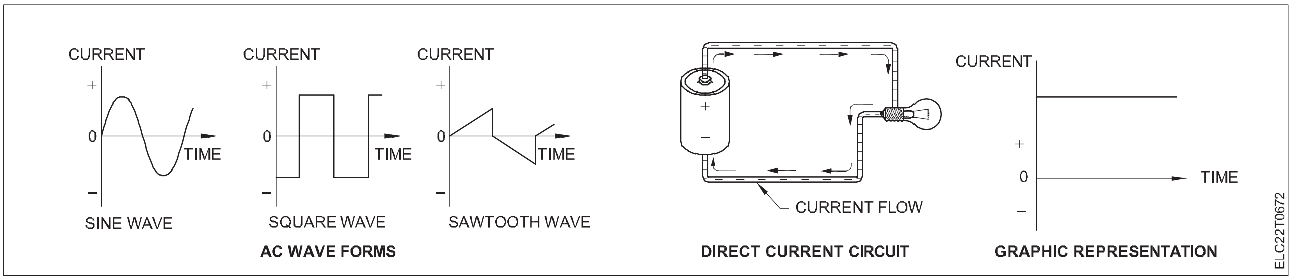
Alternating current

An alternating current circuit is one in which the direction and amplitude of the current flow change at regular intervals .The polarity of an AC source changes at regular intervals resulting in reversal of the circuit current flow .Alternating current usually changes in both value and direction. The current increases from zero to some maximum value and then drop back to zero as it flows in one direction. This same pattern is then repeated as it flows in the opposite direction.AC is produced by alternator

Direct Current

Direct current is the current that flows only in one direction in a circuit. The polarity of a DC source remains fixed and current flows in one direction only. DC is produced by Cells &Batteries , DC generator etc.

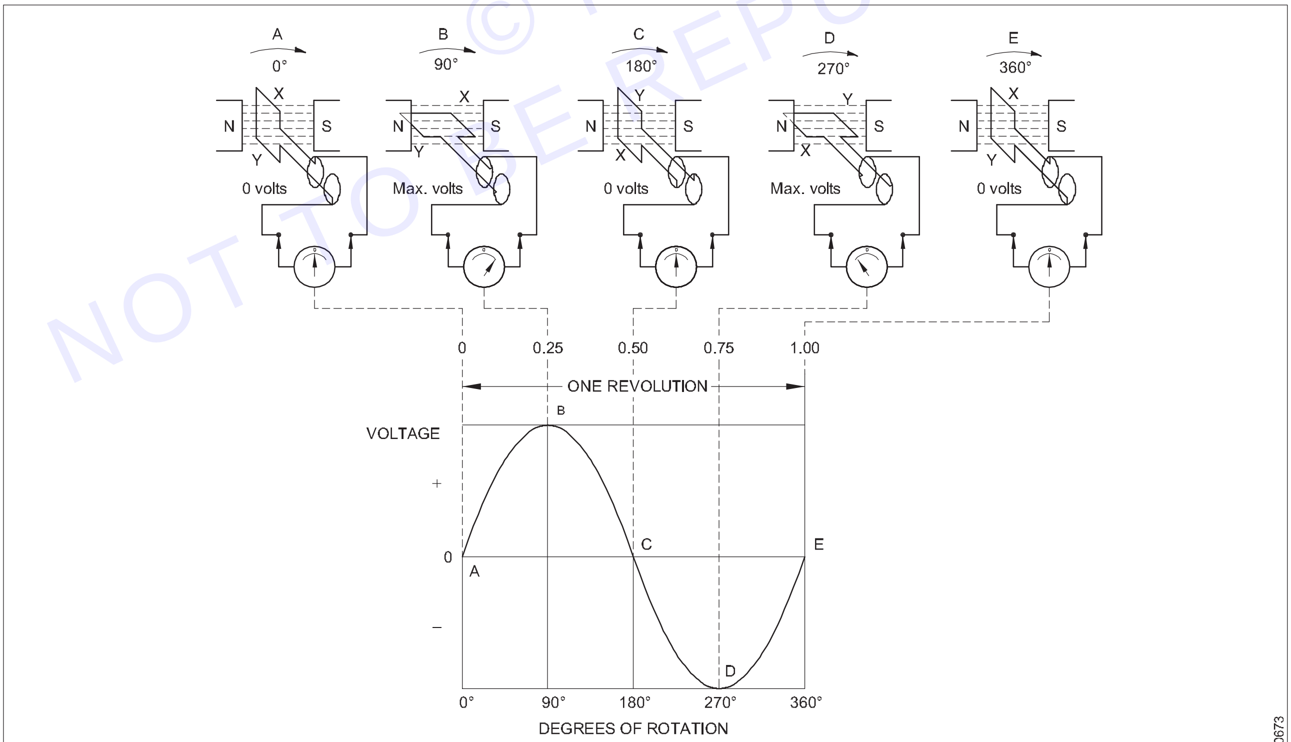
There are several types of direct current , all of them depends up on the value of the current in value of time. A constant DC current shows no variation in value over a period of time. Both varying and pulsating DC current have a changing value plotted against time. The pulsating DC current variations are uniform and repeat at regular intervals.



Generation of –AC

The shape of the voltage wave form generated by a coil rotating in a magnetic field is called a sine wave. The generated sine wave voltage varies in both voltage value and polarity. If the coil is rotated at a constant speed the number of magnetic lines of force cut per second varies with the position of the coil. When the coil is moving parallel to the magnetic field it cut no lines of force therefore no voltage is generated at these instant. When the coil is moving at right angles to the magnetic field it cuts the maximum number of lines of force . Therefore maximum or peak voltage is generated at this instant .Between these two points the voltage varies according to the sine of the angle at which the coil cuts the lines of force.

The coil shown in five specific position in figure .These are intermediate positions which occur during one complete revolution of the coil position. The graph shows how the voltage increases and decreases in amount during one rotation of the loop. Note that the direction of the voltage reverses each half cycles. This is because for each revolution of the coil each side must first move down and then up through the field.



GENERATION OF AN ALTERNATING VOLTAGE: AS THE LOOP ROTATES THROUGH THE MAGNETIC FIELD. THE AMOUNT AND POLARITY OFTHE VOLTAGE CHANGES WITH ANGLE AND DIRECTION OF MOTION.

Cycle

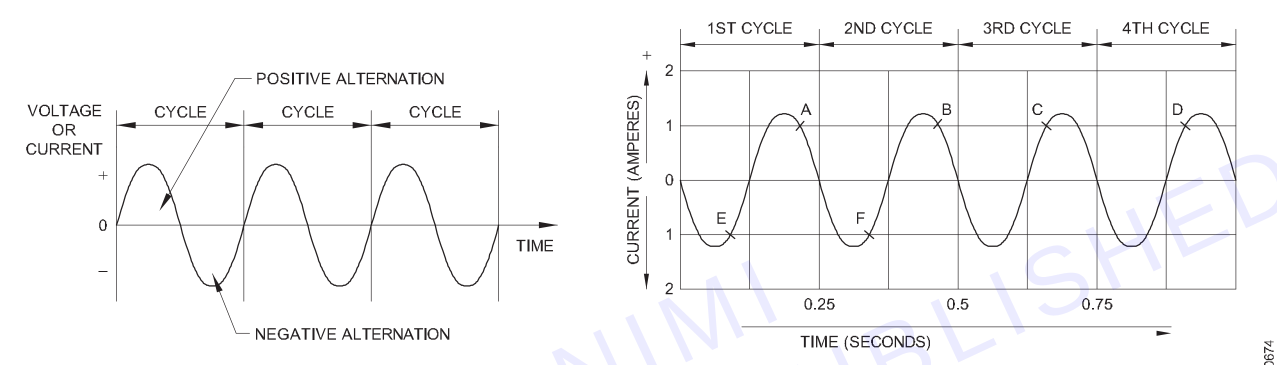
One complete wave of alternating current or voltage is known as one cycle. During the generation of one cycle of AC there are two changes or alternations in polarity of the current . These equal but opposite halves of a complete cycle are referred as alternations . In one cycle there are two half cycles known as positive& negative half cycles.

Time period

The time required to produce one complete cycle is called time period .Or Time period is the reciprocal of frequency .Its unit is second. Its symbol is T=1/f. Our supply frequency is 50 Hz and has a time period of 20ms

(T= 1/50)

In figure it takes 0.25 seconds to complete one cycle. Therefore the time period of the wave form is 0.25 seconds. The period of a sine wave need not be measured between the zero crossing at the beginning and the end of a cycle . It can be measured from any point in a given cycle to the corresponding point in the next cycle.



CYCLE, PERIOD, AND FREQUENCY. THE WAVEFORM HAS A PERIOD OF 0.25 SECONDS AND FOUR CYCLES PER SECOND.

Frequency

The number of cycles produced per second is known as frequency.SI unit of frequency is Hertz (Hz) It is the reciprocal of time period . ie. F= 1 / T. Our supply frequency 50 Hz.

Instantaneous values

The value of an alternating quantity at any particular instant is known as instantaneous value. The instantaneous value of a sine wave voltage is shown in figure .It is 3.1 volt at one micro second , 7.07 volt at 2.5 micro second and so on.

Peak value [maximum value]

The peak value of a sine wave refers to the maximum voltage or current of a sine wave. There are two equal peak values occur during on cycle.

The peak value of current is represented as I_m

Peak to peak value

The peak to peak value of a sine wave is its total overall value from one peak to the other. It is equal to two times the peak value. The peak to peak value of current and voltage denoted by I_{p-p} andV_{p-p} respectively.

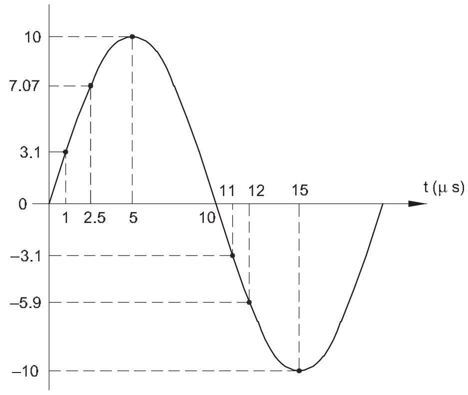
$V_{p-p} = 2\ V_{max}$

Average value

The average value of AC is given by that direct current which transfers across any circuit in a given time the same charge as transferred by the AC in the same circuit

$V_{av} = 0.637\ V_m$

$I_{av} = 0.637\ I_m$



EXAMPLE OF INSANTANEOUS VALUES OF A SINE WAVE VOLTAGE

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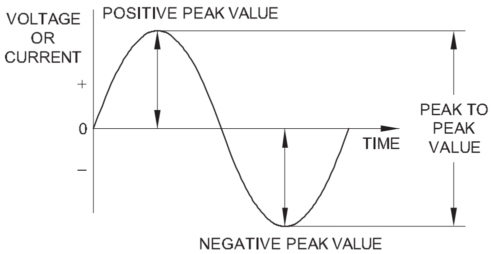
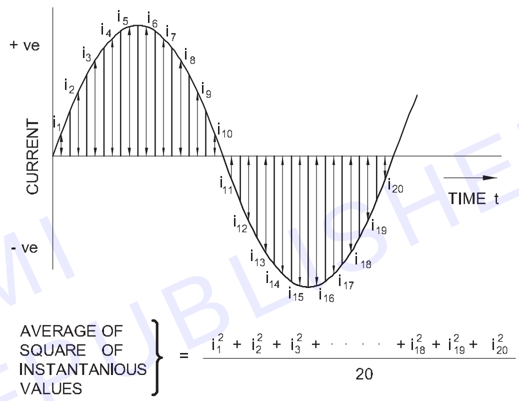


PEAK TO PEAK VALUE OF A SINE WAVE



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In the case of AC there are two half cycles which are exactly opposite to each other therefore the average value over a complete cycle is zero. The average value over a half cycle is obtained as per above figure is

$I_{av}=(i_1 + i_2 + i_3 +............+ i_n) / n$

RMS value [effective value]

The effective value of an alternating current is that value which will produce the same heating effect as specific value of a steady directcurrent.For determining RMS value of an alternating current its instantaneous values are taken at several points of time during a cycle. These values are then squared , added and then averaged . The square root of this average value gives RMS value of the AC (or emf)

$V_{rms} = 0.707\ V_m$

$I_{rms} = 0.707\ I_m$

Form Factor

It is the ratio of effective (rms)value to average value of half cycle

Form factor = Irms / Iav

= (Im X .707)/Im X 0.637

= 0.707/0.637

Form factor = 1.11

COMPARISON : AC & DC

S.No	Alternating current	Direct current
1	Its polarity and magnitude periodically changes	Its polarity and magnitude remains constant
2	The current can flow through a condenser	The current can not flow through a condenser
3	I=V/Z	I=V/R
4	Power depends up on power factor of the circuit and given by W = V x I x cose	Power in DC circuit is given by W = V x I
5	AC machines are cheap and require less maintenance	DC machines are costly and require more maintenance
6	The speed control of AC motor is more difficult as well as costlier	The speed control of D C motor is easier and more economical
7	AC can easily and economically be changed in to DC	Conversion of DC to AC is not easy
8	The voltage can easily be stepped up or down by transformers and hence its transmission and distribution is more economical	DC voltage cannot be varied so easily

Terminology in AC circuits

Crest Factor or Amplitude Factor

The ratio of the maximum value to the RMS value is known as the crest factor

For a sinusoidal current ;

Crest factor = I max / I RMS

= Imax / I max X 0.707

= 1 / 1x 0.707 = 1.414

For a sinusoidal voltage;

Crest Factor = E max / E RMS

= E max / E max X 0.707

= 1 / 1 x 0.707 = 1.414

Scalar Quantity

A scalar quantity is that which has only magnitude but no direction

Eg: Time,Distance ,speed , mass , length etc.

Vector Quantity

A vector quantity has both direction as well as magnitude

Eg: Force , alternating current or voltage etc.

Phase

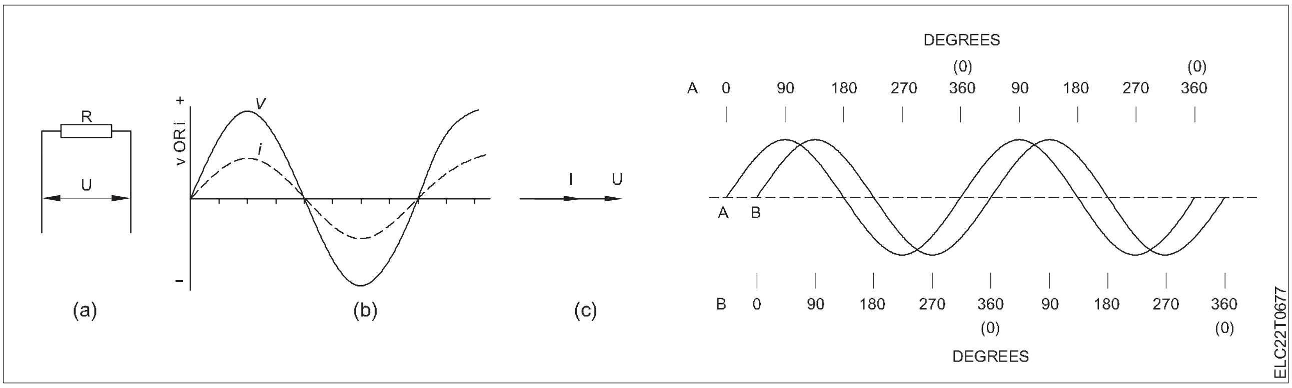
The development of an AC quantity through different stages is known as phase During one complete cycle an alternating current goes through various stages .The development of these stages [from zero to maximum and maximum to zero (in positive half cycle) and again rises in the reverse direction (negative half cycle) and finally falls down to zero.] is known as phase

Inphase quantity

When two alternating quantities(current and voltage) attain their maximum and minimum values simultaneously , then these quantities are said to be in-phase.

Out of phase or (phase difference)

When two alternating quantities do not reach their maximum and minimum values simultaneously, then they are out of phase. Phase difference is measured in electrical degrees or radiance .

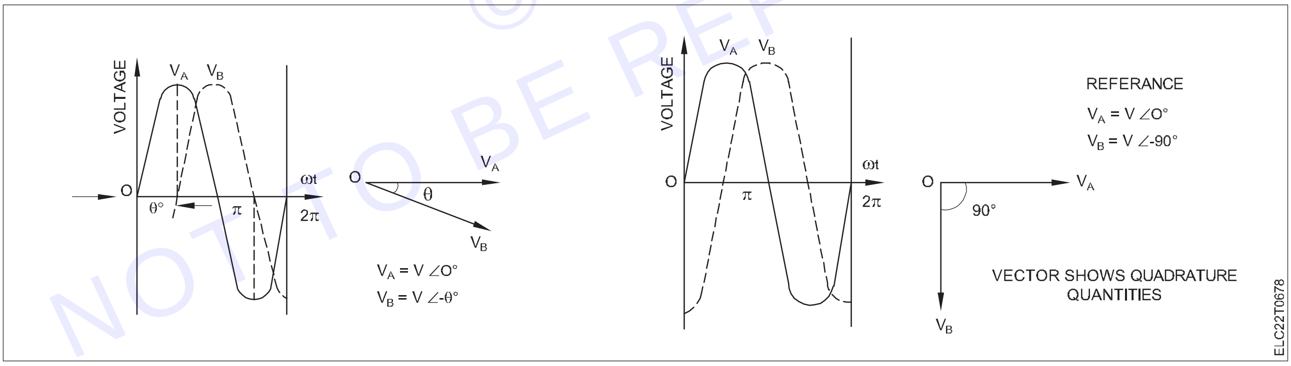


Phase angle

It is the angular displacement between two alternating quantities. Phase angle is measured in electrical degrees or radians. In figure VB is lagging VA by an angle ɵ.

Quadrature quantities

When the phase difference between two alternating quantities is 90° electrical ,they are said to be quadrature quantities. In figure VB is lagging VA by 90°



Anti-phase quantities

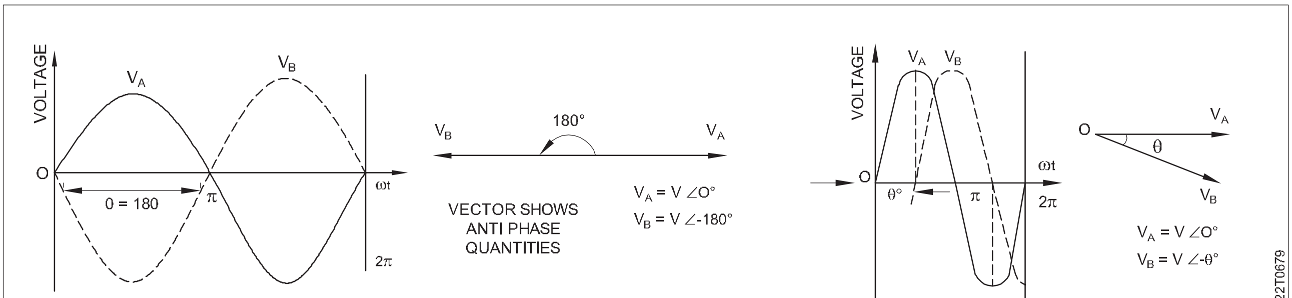
When two electrical quantities are out of phase by 180° electrical, they are said to be anti-phase quantities.

Leading quantities

The alternating quantity that reaches its maximum value earlier than the other quantity is known as the leading quantity. In figure VA leads VB by an angle ɵ.

Lagging quantities

The alternating quantity that reaches its maximum value later than the other quantity is known as the lagging quantity. In figureVBlagsVA by an angle ɵ.



ANTIPHASE QUANTITIES

Inductive reactance

The opposition due to inductance of the coil in an AC circuit is called inductive reactance. It is denoted by XL . It is measured in ΩIf L is the inductance of a coil, then its inductive reactance will be

XL = 2πfL

Where:

f supply frequency in Hertz

L inductance of the coil in Henry

XL Inductive reactance in Ohms.

From the formula.

XL = 2πfL,

Inductance L =XL/2 πf

Capacitive reactance

The opposition due to capacitance of a capacitor is called capacitive reactance. It is denoted by Xc. It is measured in ΩIf C is the capacitance of a condenser , then its capacitive reactance will be

XC= 1/2πfc

Where;

f is the supply frequency

c is the capacitance of the circuit

XC = Capacitive reactance in Ohms

From the formula ,

Xc = 1 / 2πfC

Capacitance C = 1 / 2πfXc

Impedance

The vector sum of resistance and reactance connected in an AC circuit is called impedance

OR

The total opposition offered by resistances and reactance in an AC circuit is called impedance. It is denoted by the letter Z.

$$Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

The impedance , resistance and reactance can be denoted by the sides of a right angled triangle whose two sides enclose an angle ɵ°

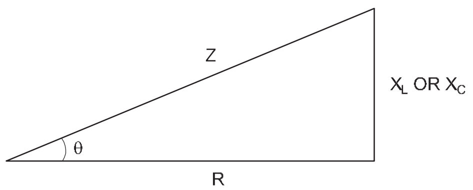
Z - hypotenuse

R - adjacent side

X - opposite side

AC Circuits - The impedance Triangle

For a series AC circuit the relationship between reactance, resistance and impedance can be remembered and resolved through the use of trigonometry.



Impedance (Z) is found by use of Pythagoras theorem, The angle ɵ is found using the trig identity

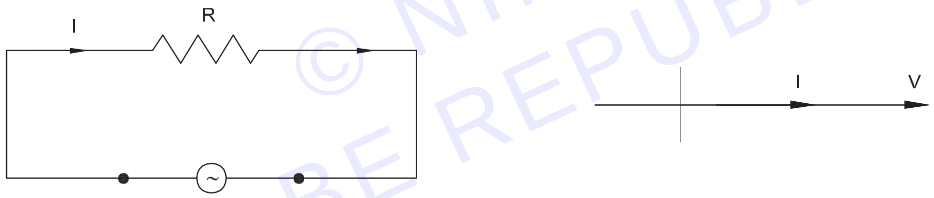
$$\tan \theta = \frac{X}{R}$$

$$\text{or } \theta = \tan^{-1}\left(\frac{X}{R}\right)$$

The angle ɵ represent the circuit phase angle.

Circuit containing pure resistance

A pure resistance circuit is that which has no inductance and capacitance



In Ohm's Law

I = V/Z

Z = Total opposition of the circuit

Z = R Purely resistive circuit

Purely resistive circuit voltage and current are in phase

$$W = I^2R$$
$$= I \times I \times R = V/Z \times I \times R$$
$$= V \times I \times R/Z$$
$$= V \times I \times \cos \phi$$
$$W = V \times I \times \cos\phi$$

Power when the circuit is falling in the negative half cycle

$$W = (-I^2)R = I^2 R$$

In this also the case power is positive so it is shown in the upper half of the cycle. This is true only for resistive circuit.

$W = I^2 R$

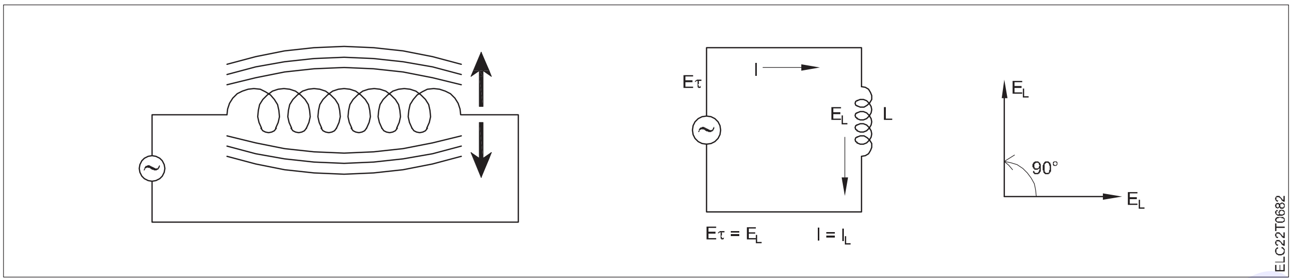
$\cos \phi = R/Z \quad (R = Z)$

$R/Z = 1$

Now power factor of the resistive circuit is one and there for it is phase angle is one

Power developed = V x I

AC Circuit containing pure inductance only



Inductance circuit there is no resistance and capacitance

Apure inductance is a coil wounded on a laminated iron core with a few turns of thick wire . If an AC voltage 'V ' is applied across such a circuit a current will flow through it .The magnitude of the current is given by

$I = V/Z \quad Z = XL$

$V/XL = I$

$XL = 2\pi fL$

XL = inductive reactance

A pure inductive circuit current not in phase with voltage by 900 electrical

$W = V \times I \times \cos\phi$

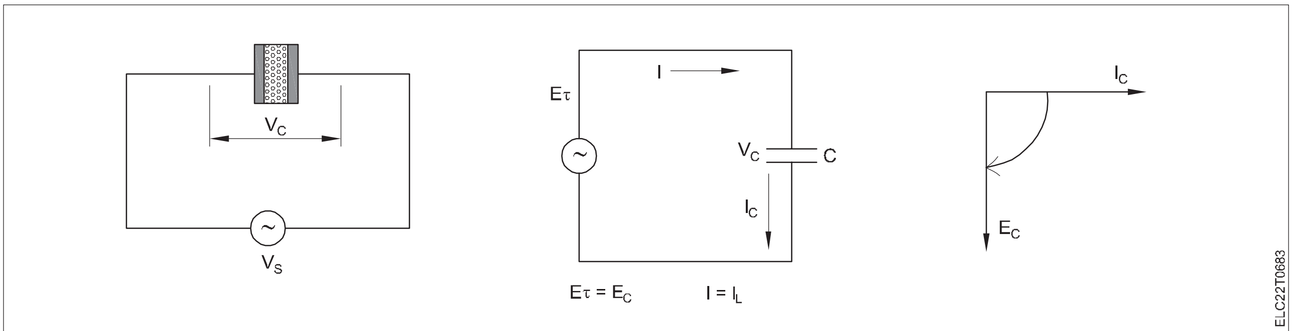
$\cos \phi = R/Z \qquad R = 0$

Hence $W = V I \cos\phi$

$= V \times I \times 0 = 0$

In pure inductive circuit value of resistance is zero, there is no resistive potential drop in the circuit hence the power developed is zero

AC Circuit containing pure capacitance only



In an AC is applied across pure capacitive circuit

Current will flow through the circuit is given by

I = V/Z

Z = Xc

I = V/Xc

Pure capacitive circuit the current does not remain in phase with the voltage but leads the voltage by 900 electrical

In pure capacitive circuit the power consumed in a circuit is zero , it has no resistance

Cosφ = R/Z = 0

Power P = V x I x 0 = 0

AC Circuit containing

Resistance and inductance in series

A series circuit having resistance (R) and inductance (L) are connected acoss ac supply voltage (V) and freequeny (f). In pure resistive circuit current remains phase with voltage and pure inductive circuit circuit current lags behind voltage by 900

VR - Voltage drop across resistance (I R)

VL - Voltage drop across inductance (I XL)

Applied voltage across circuit (IZ) and is the vector sum of VR amd VL

$V_R^2 + V_L^2 = V^2$

$V = \sqrt{(V_R^2 + V_L^2)}$

$= \sqrt{(IR^2 + IX_L^2)}$

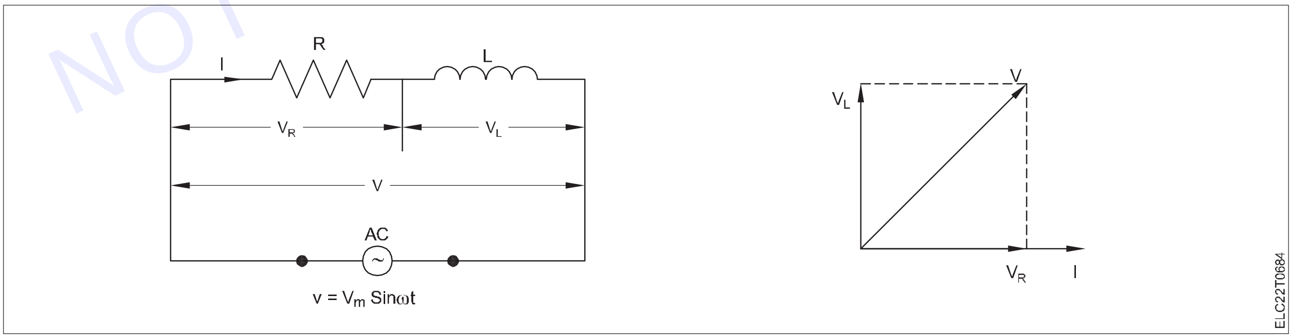
$V = I\sqrt{(R^2 + X_L^2)}$

$V/I = \sqrt{(R^2 + X_L^2)}$

V/I = Total impedance in the circuit (Z)

Power in a circuit W = V X I X cosφ

Cos φ = R/Z



AC Circuit containing resistance and capacitance in series

series circuit having resistance and capacitance in series connected across an ac supply voltage and frequency pure resistive circuit current in phase with voltage and pure capacitive circuit current leads voltage by 900 electrical. The applied voltage V is the vector sum of voltage across resistance VR and voltage across capacitance VC.

$V^2 = VR^2 + VC^2$

$V = \sqrt{(VR^2 + VC^2)}$

$= \sqrt{(IR)^2 + (IXC)^2}$

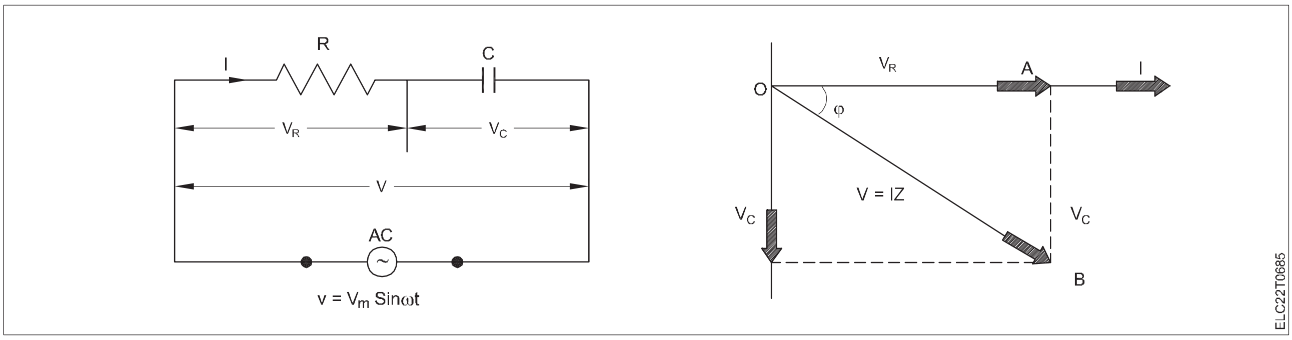
$V = \sqrt{R^2 + XC^2}$

$V/I = \sqrt{R^2 + XC^2}$

$V/I = Z$

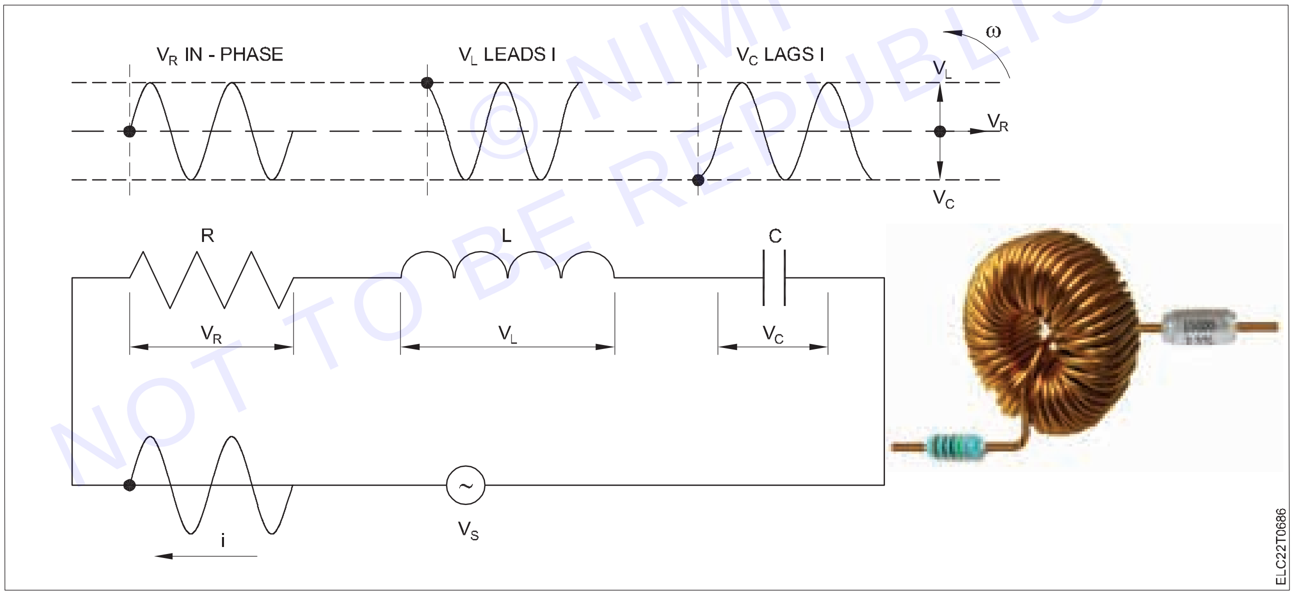
Power = V I Cosф

Cos ф = R/Z



RLC Series circuit

Let us consider a resistance R ohm , inductance L henry and capacitance C in farad are connected in series with supply(Vs)



Let,

VR=I.R=voltage drop across R(in phase with I)

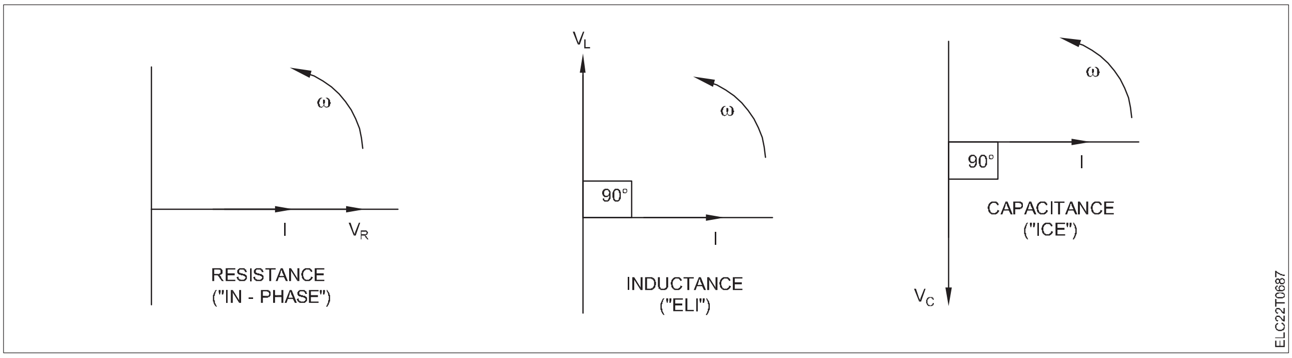
VL=IXL=voltage drop across L (leading I BY 90)

VC=I.XC=voltage drop across capacitor (lagging behind I by 90)

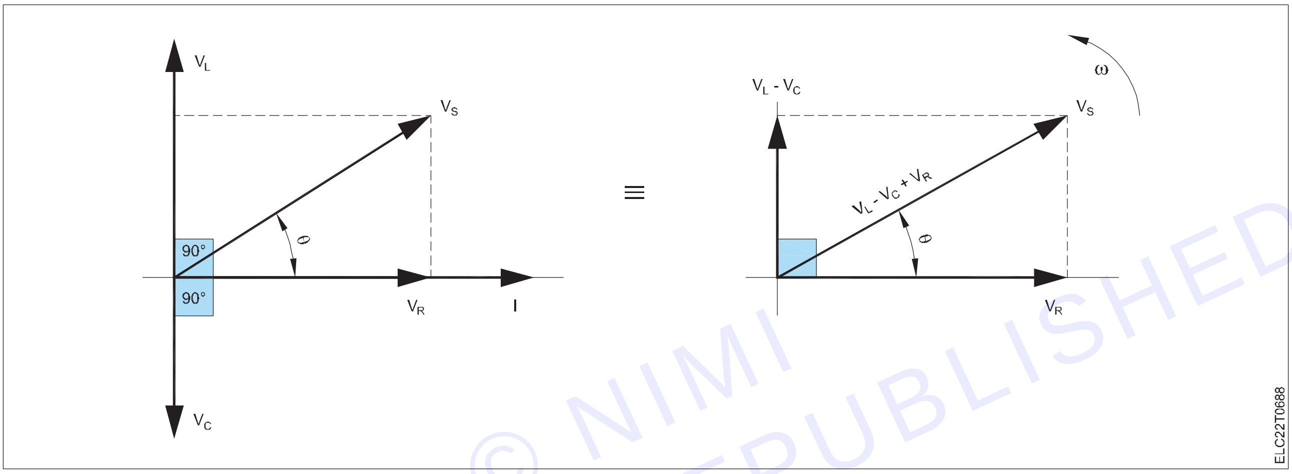
XL , Inductive reactance(XL=2∏fL or ωL)

XC ,Capacitive reactance(XC=1/2∏fC or 1/ωC)

Vector diagram shows relation between voltage and current in pure resistive, inductance and capacitance



Vector Diagram Shows Relation Between Supply Voltage And Current In RLC Series Circuit



Relation between resistance, reactance and impedance

$VS^2 = (VL - VC)^2 + VR^2$

$= (I.XL - I.XC)^2 + (I.R)^2$

$= I^2 (XL - XC)^2 + I^2.R^2$

$= I^2 (XL - XC)^2 + R^2$

VS=I.Z (where z is the total resistance of the circuit or impedance)

$I^2.Z^2 = I^2 (XL-XC)^2 + R^2$

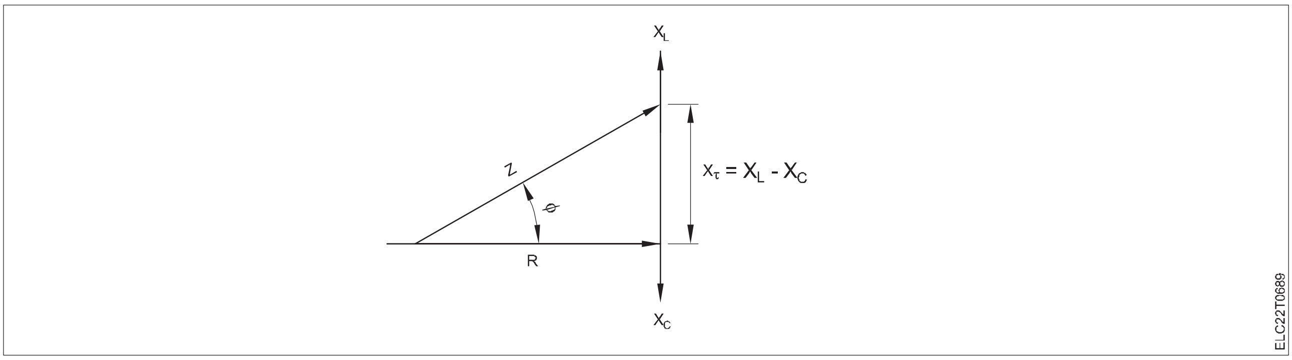
$Z^2 = (XL-XC)^2 + R^2$

Relation between impedance (Z), Resistance and reactance(X)

$$\text{impedance } Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega c}\right)^2}$$

$$\cos\phi = \frac{R}{Z} \quad \sin\varphi = \frac{X_l - X_c}{Z} \quad \tan\varphi = \frac{X_l - X_c}{R}$$

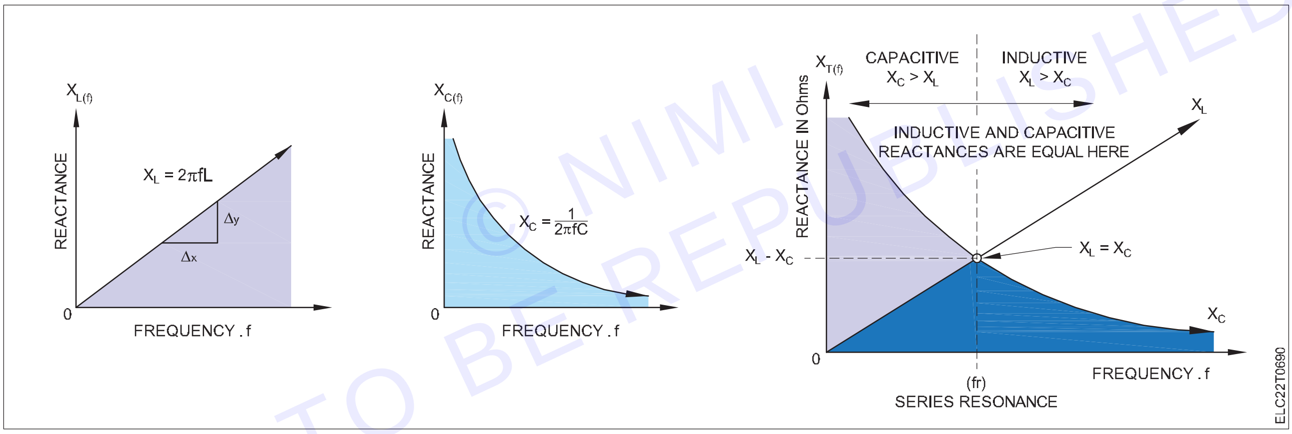
$$Z^2 = R^2 + (X_L - X_C)^2$$



In RLC series circuit,

- Current is same in all three elements
- Voltage across each component depends on their resistance (reactance)
- Total voltage (VS) is the vector sum of individual voltages (i.e. VR, VL, and VC)
- Total opposition to the current flow in the circuit is known as impedance, Z
- The angle between voltage and current is ‘ф’ can be found out from any of the formula.

Frequency response curve



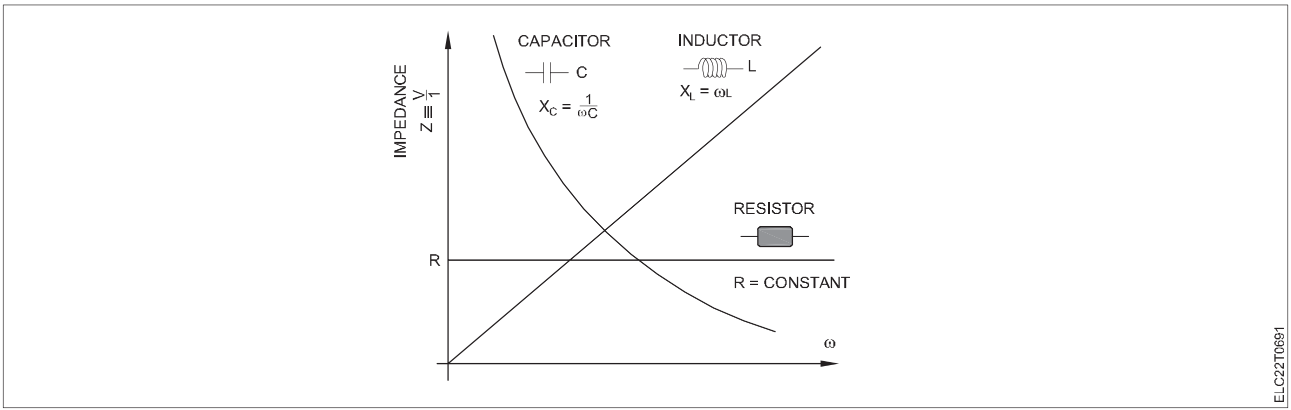
- Resistance is independent of frequency.
- Inductive reactance directly proportional to frequency
- Capacitive reactance inversely proportional to frequency
- At a particular frequency the XL=XC is called resonance frequency
- When a circuit possess inductance and capacitance in such a way that , XL=XC , it is said to be at resonance
- At resonance Z = R
- The frequency at which XL=XC is called resonance frequency fr

$$X_L = X_C = 2\pi fL = \frac{1}{2\pi fC}$$

$$f^2 = \frac{1}{2\pi.2\pi 2} = \frac{1}{4\pi^2 LC}$$

$$f = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$\therefore f_1 = \frac{1}{2\pi\sqrt{LC}}(HZ) or\ \omega_r = \frac{1}{\sqrt{LC}}(rads)$$



RLC Circuit at resonance

- XL=XC
- Z=R
- Current is maximum
- Impedance is minimum
- Supply voltage and circuit current are in phase
- The series circuit is known as Accepter circuits.

RLC Parallel circuit- consist of resistance, inductance and capacitance connected in parallel

When resistance R in ohm , inductance L in Henry and capacitance C in Fared are connected in parallel to the supply voltage is called a simple RLC parallel circuit.

- Supply voltage across all the component are same(VS)
- IR is current through the resistance which is in phase with VS
- IL is current through the inductor lags behind voltage VS
- IC is the current through capacitor leads the voltage VS
- In RLC parallel circuit, the supply voltage 'Vs' is same across all 3 components .Therefore Vs is taken as reference

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

$$I_L = \frac{V}{X_L} = \frac{V}{2\pi fL}$$

$$I_C = \frac{V}{X_C} = V.2\pi fL$$

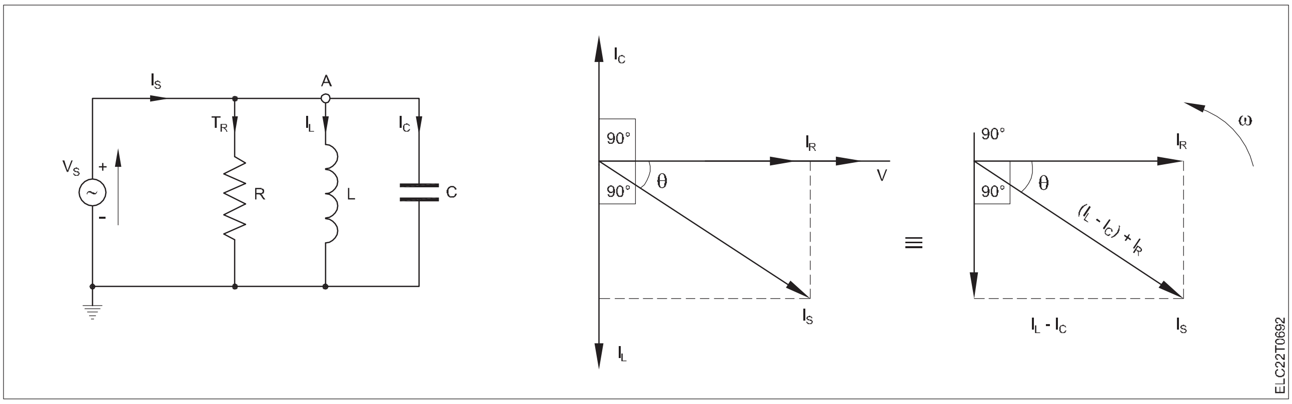
Therefore, I_T = vector sun of $(I_P + I_L + I_C)$

$$I_T = \sqrt{I^2{}_R + (I_L + I_C)}$$

$$I_R^2 + (I_L - I_C)^2$$

$$I_T = \sqrt{I^2{}_R + (I_L + I_C)^2}$$

$$\therefore I = \sqrt{\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_L} - \frac{V}{X_C}\right)^2} = \frac{V}{Z} \qquad \text{where : } I_R = \frac{V}{E}, I_L = \frac{V}{X_L}, I_C = \frac{V}{X_C}$$



$$R = \frac{V}{I_R} \quad X_L = \frac{V}{I_L} \quad XI_C = \frac{V}{I_C}$$

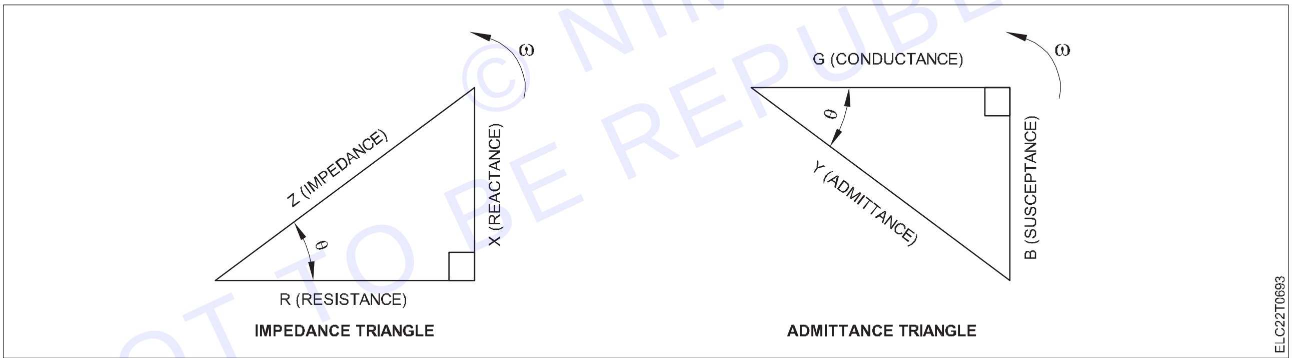
$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}}$$

$$\therefore \frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$$

$$Y = \sqrt{G^2 + (B_L - B_C)^2}$$

$$\text{where : } Y = \frac{1}{Z} \qquad G = \frac{1}{R_L}$$

$$B_L = \frac{1}{\varpi L} \qquad B_C = \varpi C$$



RLC Parallel circuit-at resonance

Consider an ideal parallel resonant circuit,

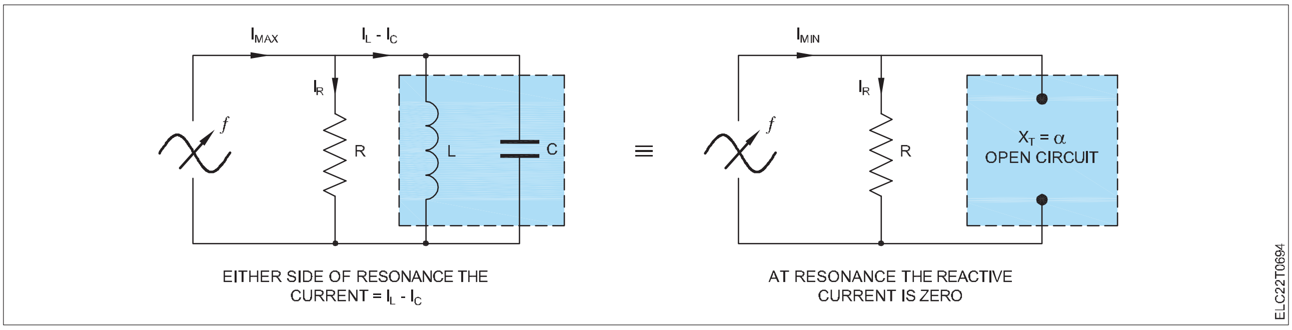
it consists of ideal resistance less inductor connected parallel with a perfect insulator. when the frequency of the applied voltage is such that xl=xc it become parallel resonant circuit. it means that the capacitor discharges exactly at the instant when the coil needs current to build up its magnetic field .it is so because there is a phase difference of 1800 between current drawn by the two. current drawn by the supply is zero (ideal case) and circuit offer maximum impedance to the circuit

at resonance,

XL= XC

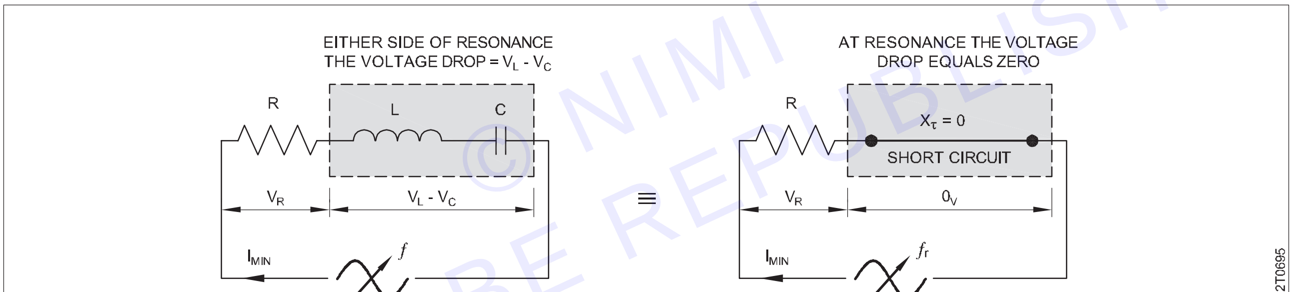
Z = R (maximum)

I = minimum

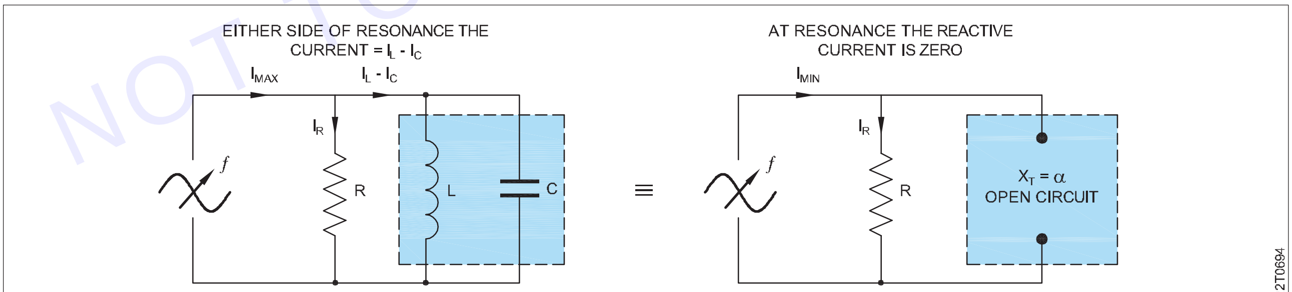


Comparison between series parallel circuits

RLC Series	RLC Parallel
• Current is taken as reference • Supply voltage is the vector sum of branch voltage • KVL is applicable to series cir-cuits. • At resonance Z=R , circuit imped-ance is minimum and current is maximum • RLC series circuit is known as ACCEPTER circuit.	• Voltage is taken as reference • Total current is the vector sum of branch current • KCL is applicable to parallel cir-cuits • At resonance Z=R , circuit im-pedance is maximum and cur-rent is minimum • RLC parallel circuit is known as REJECTOR circuit



SERIES RESONANCE



PARALLEL RESONANCE

Importance of RLC circuit in Electrical Engineering

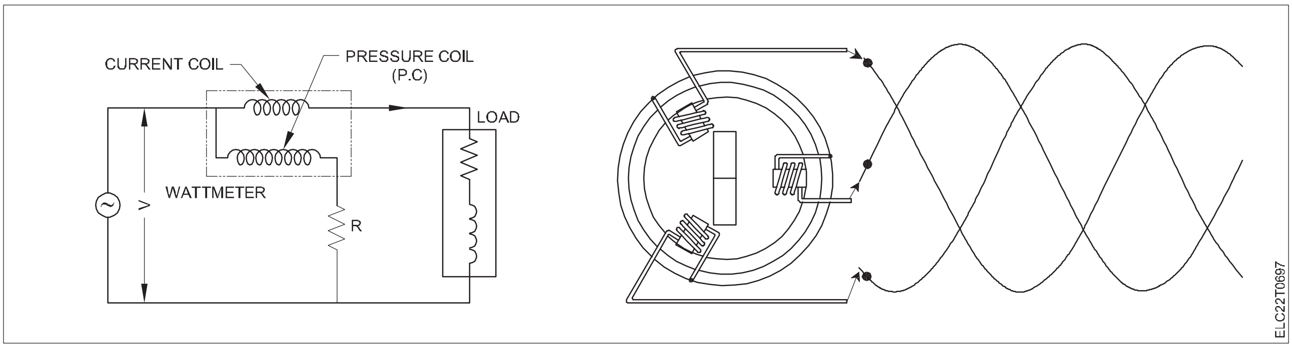
- We know that all the conducting parts have its own resistance .In addition to that inductance and capacitance are the two distributed parameters which must be considered while designing large capacity electrical machines , transmission lines and cables
- Active power depends on power factor which depends on RLC parameters.
- In electronics RLC circuits have wide range of use.

Single phase wattmeter connection

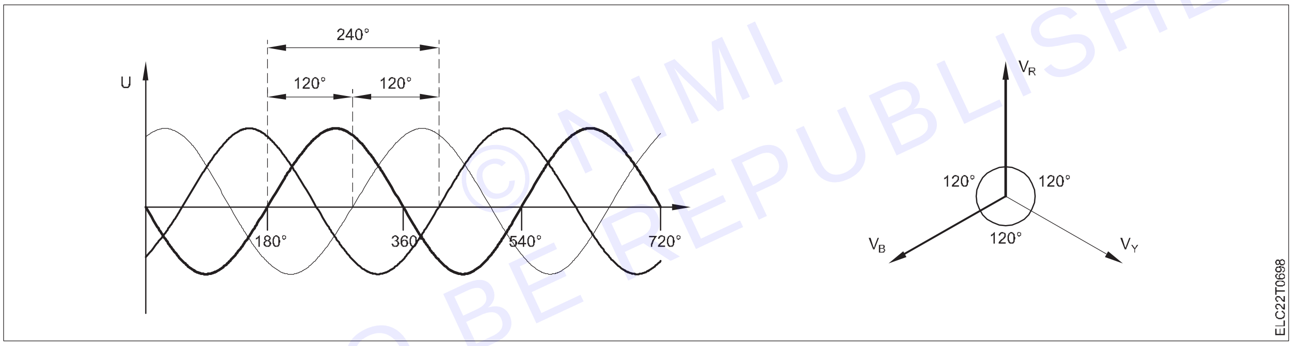
WA power measuring meter called wattmeter.Wattmeter mainly consist of two coils ,they are current coil and pressure coilIn wattmeter current coil connected in series with the supply and pressure coil connected in parallel to the supply line. The wattmeter takes the power factor of the circuit in to account and always indicates true power

Three phase system

In a three phase system three electrically insulated windings are wound on the armature and a phase difference of 120 degree electrical is kept between them.



The emf generated has same max value, frequency and wave length. The induced emf has a phase difference of 120 deg electrical.



Instantaneous values of phase voltages are,

E_R=EmSinwt

E_Y= EmSin(wt-120)

E_B= EmSin(wt-240)

Sum at any instant **ER+EY+EB = 0**

A three phase system can either supply three single phase circuits or a single three phase circuit. The current in different phases depends upon the nature of load and the phase angle between voltage and current.

Balanced load

If the load is such that the same current flows through each of the three phases and the angle of phase difference between each current and voltage is also same, this load is said to be a balanced load.

Unbalanced load

If the magnitude or phase angle of the currents is different, the load is unbalanced load.

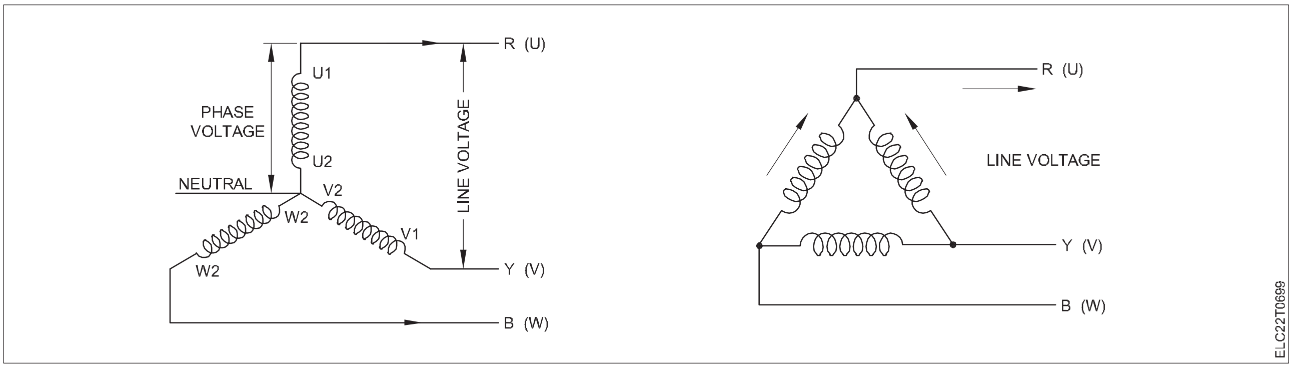
Phase sequence

The sequence of attaining the maximum value of the induced emf is called phase sequence, RYB, ABC, 123.

Definitions of fundamental terms

- Line voltage (V_L).

- Phase voltage (V_{ph}) .
- Line current (I_L).
- Phase current (I_{ph}).
- Phase power.
- Total power.



Line voltage (V_L)

The voltage between any two phases of the supply system is called line voltage.

Phase voltage (V_{ph})

The voltage between one of the phase and the neutral terminal is known as phase voltage.

Line current (I_L)

The current flowing between any two phases of the winding is termed as line current.

Phase current (I_{ph})

The current flowing through any of the phase winding is called phase current

Phase power

The power measured between a phase and the neutral terminal is known as phase power.

Total power

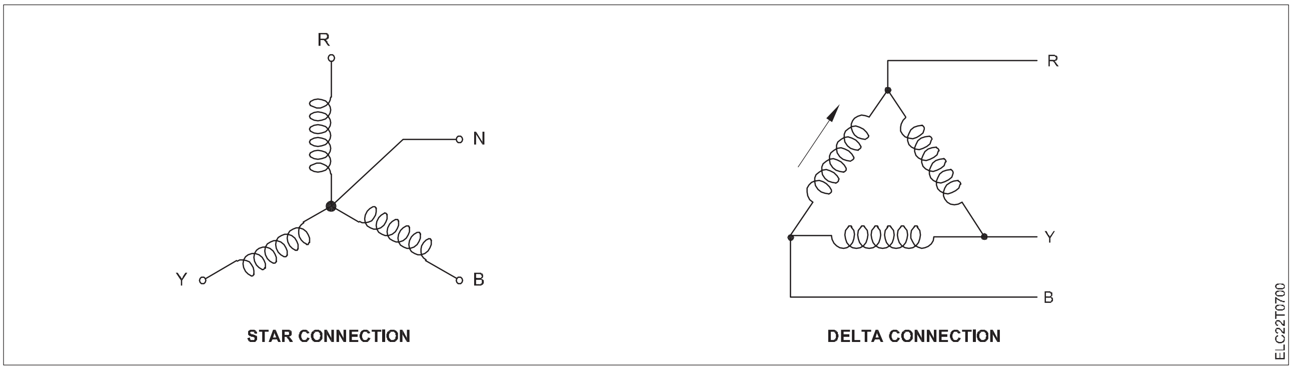
In a three phase system, the total power measured between the three phases is called total power.

Methods of connecting three phase windings

There are two ways of connecting three phase winding

1 Star connection.

2 Delta connection.



Star connection

The three ends of the three windings are connected together to form a common or neutral point.

It is clear that current flowing through phase windings will be same as that flowing through the line.

Line current (I_L)=Phase Current (I_{ph})

But line voltage V_L is not same as phase voltage V_{ph}. Because two phase winding is connected between two lines.

Voltage generated in each phase is the phase voltage. They are represented by OE_A,OE_B& OE_C. Which are 120 deg elect apart.The vector difference of OE_A and OE_B yields line voltage.

According to parallelogram law

$$E_{AB}^2 = E_A^2 + E_B^2 + 2E_AE_B \quad \cos 60^\circ$$

$$(\because \cos 60^\circ = \tfrac{1}{2})$$

$$E_{AB}^2 = E_A^2 + E_B^2 + E_AE_B$$

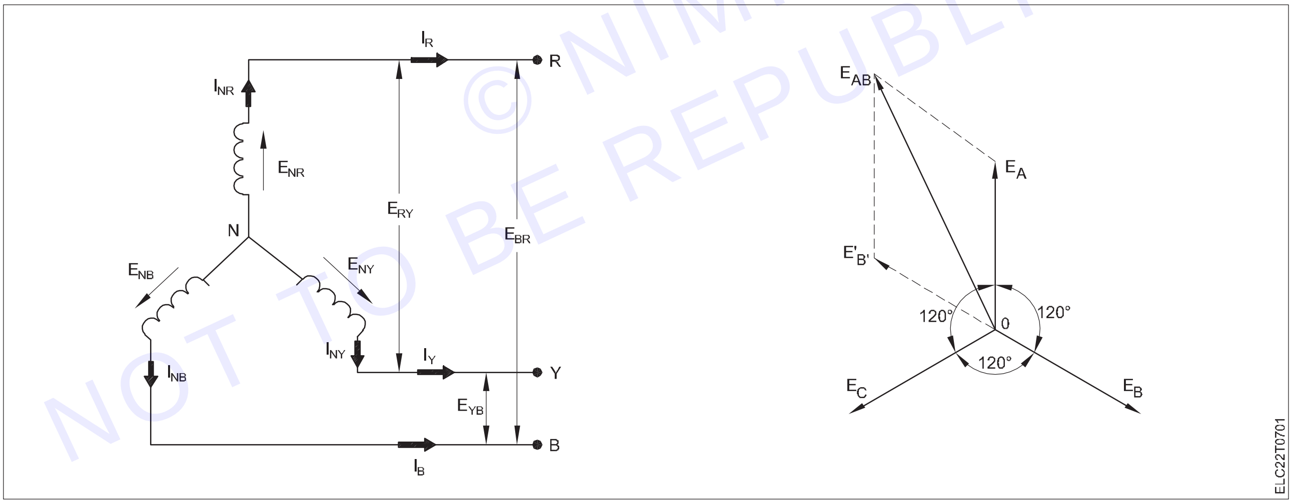
Let $E_A = E_B = E$ (phase voltage)

$$\therefore \quad E_{AB}^2 = E^2 + E^2 + E^2 = 3E^2$$

Line voltage, $E_{AB} = \sqrt{3}\,E$

It means the line voltage in star connection is $\sqrt{3}$ times the phase voltage, i.e.

$$V_L = \sqrt{3}\,V_{ph}$$



In star connection,

Line voltage = √3phase voltage

Delta connection

Three coils of three phase winding can also be connected in delta as shown in figure. The three junctions thus formed are taken as phase wires.

Only one phase winding is included between any two lines .

Line voltage (V_L) = Phase voltage(V_{ph})

But line current is not equal to phase current.

$$I_{AC}^2 = I_A^2 + I_C^2 + 2I_AI_C\cos60°(\because \cos60 = \frac{1}{2})$$

$$= I_A^2 = I_C^2 + I_AI_C$$

Let $I_A = I_C = I(\text{phasecurrent})$

$$\therefore I_{AC}^2 = I^2 + I^2 + I^2$$

$$I_{AC}^2 = 3I^2$$

Linecurrent, $I_{AC}^2 = \sqrt{3}I$

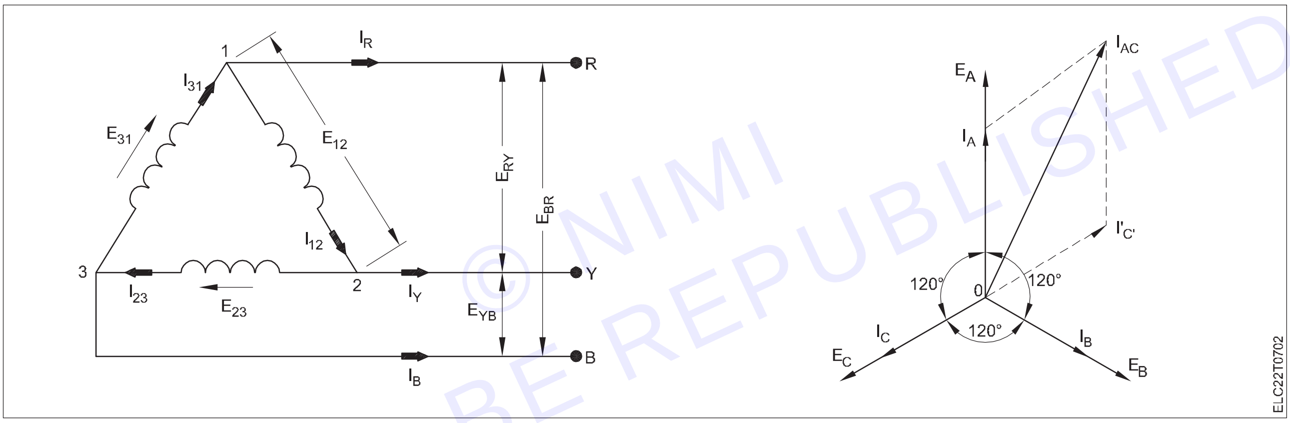
It showns that the line current in delta connection

is $\sqrt{3}$ times the phase current,

i.e. $I_L = \sqrt{3}I_{ph}$

In delta connection,

Line current = $\sqrt{3}$ phase current



3-Phase AC fundamentals

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

- state and describe the generation of 3-phase system with single loops
- state the advantages of the 3-phase system over a single phase system
- state and explain the 3-phase, 3-wire, and 4-wire system
- state and explain the relation between phase and line voltage.

A three-phase power consumer is provided with the terminals of three phases. (Fig 1)

One great advantage of a three-phase AC supply is that it can produce a rotating magnetic field when a set of stationary three-phase coils is energized from the supply. This is the basic operating principle for most modern rotating machines and, in particular, the three-phase induction motor.

Further, lighting loads can be connected between any one of the three phases and neutral.

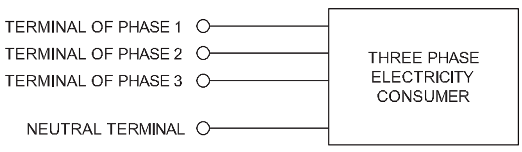
Review: Further to the above two advantages the following are the advantages of polyphase system over single phase system.

- 3-phase motors develop uniform torque whereas single phase motors produce pulsating torque only
- Most of the 3-phase motors are self starting whereas single phase motors are not
- Power factor of 3-phase motors are reasonably high when compared to single phase motors

- For a given size the power out put is high in 3-phase motors whereas in single phase motors the power output is low.
- Copper required for 3-phase transmission for a given power and distance is low when compared to single phase system.
- 3-phase motor like squirrel cage induction motor is robust in construction and more are less maintenance free.

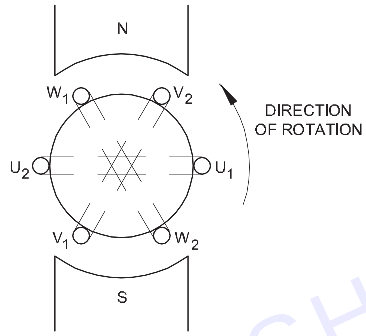
Three-phase generation: To generate three-phase voltages, a similar method to that used for generating single-phase voltages is employed but with the difference that, this time, three wire loops U_1, U_2, V_1, V_2 and W_1, W_2 rotate at a constant angular speed about the same axis in the uniform magnetic field. U_1, U_2, V_1, V_2 and W_1, W_2, are displaced 120° in position with respect to each other, permanently. (Fig 2)

Fig 1



3 - PHASE SUPPLY

Fig 2



SIMPLIFIED THREE – PHASE ALTERNATOR

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For each wire loop, the same result is obtained as for the alternating voltage generator. This means that an alternating voltage is induced in each wire loop. However, since the wire loops are displaced by 120° from each other, and a complete revolution (360°), takes one period, the three induced alternating voltages are delayed in time by a third of a period with respect to each other.

Because of the spatial displacement of the three wire loops by 120°, three alternating phase voltages result, which are displaced by one third of a period, T, with respect to each other. (Fig 3)

To distinguish between the three phases, it is a common practice in (heavy current) electrical engineering to designate them by the capital letters U,V and W or by a colour code red, yellow and blue. At a time 0, U is passing through zero volts with positively increasing voltage. (Fig 3a) V follows with its zero crossing 1/3 of the period later (Fig 3b), and the same applies to W with respect to V. (Fig 3c)

In three-phase networks, the following statements can be made about the three-phase voltages.

- The three-phase voltages have the same frequency.
- The three-phase voltages have the same peak value.
- The three-phase voltages are displaced by one third of a period in time with respect to each other.
- At every instant in time, the instantaneous sum of the three voltages

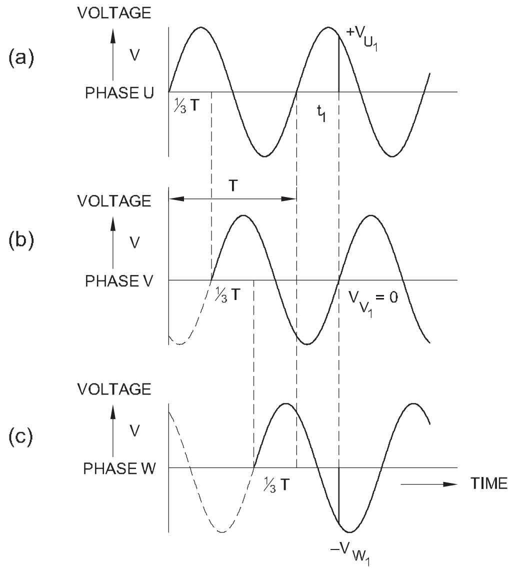
  $V_U + V_V + V_W = 0.$

The fact that the sum of the instantaneous voltages is zero. At time t_1, U has the instantaneous value V_U. At the same time, $V_V = 0$, and the instantaneous value for W is V_W. Because V_U and V_W have the same value but are opposite in sign, it follows that

$$V_{U1} + V_{V1} + V_{W1} = 0.$$

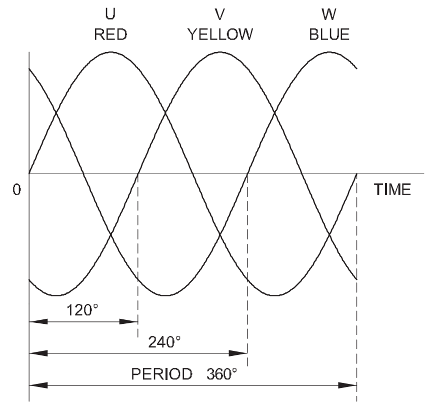
The three voltages of the same amplitude and frequency are shown together in Fig 4.

Fig 3



PHASE DISPLACEMENT OF 3 - PHASE

Fig 4



COMBINED WAVE - FORMS OF THREE PHASE SUPPLY

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Three-phase network: A three-phase network consists of three lines or phases. In Fig 5, these are indicated by the capital letters U, V and W.

The return lead of the individual phases consists of a common neutral conductor N, which is described later in more detail. Voltmeters are connected between each of the lines U, V and W, and the neutral line N. They indicate the RMS (effective) values of the voltages between each of the three phases and neutral.

These voltages are designated as phase voltages V_{UN}, V_{VN} and V_{WN}.

The individual, phase voltages all have the same magnitude. They are simply displaced from each other by one third of a period in time. (Fig 6)

The individual instantaneous, peak and RMS values are the same as for a single-phase alternating voltage.

Line and phase voltage: If a voltmeter is connected directly between line U and line V (Fig 7), the RMS value of the voltage V_{UV} is measured, and this is different from any of the three phase voltages.

Its magnitude is directly proportional to the phase voltage. The relationship is shown in Fig 6, where the time-variation wave- forms of V_{UV} and the phase voltages V_{UN} and V_{VN} are drawn.

V_{UV} has a sinusoidal wave-form and the same frequency as the phase voltages. However, V_{UV} has a higher peak value since it is computed from the phase voltages V_{UN} and V_{VN}. The varying positive and negative instantaneous values of V_{UN} and V_{VN} at a particular time produce the instantaneous value of V_{UV}. V_{UV} is the phasor sum of the two phase voltages V_{UN} and V_{NV}.

This combination of phase-displaced alternating voltages is called phasor addition.

The voltage across phase-to-phase is called the line voltage.

Relationship between line and phase voltage: The possibility of combining pairs of phases in a generator is a basic property of three-phase electricity. The understanding of this relationship will be enhanced by studying the following illustrative example which explains the concept of phase difference in a very simple way.

Fig 5

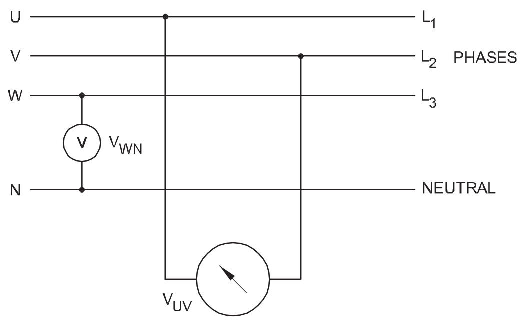
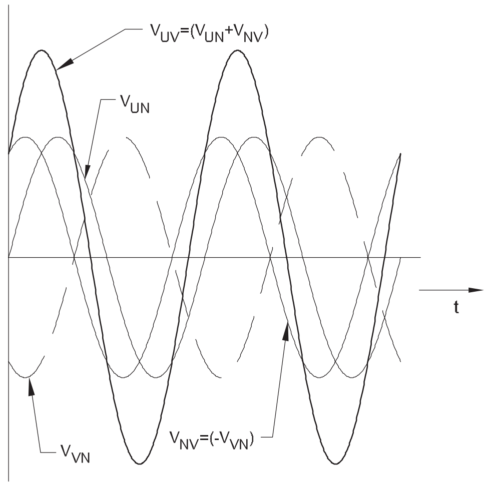


Fig 6



The phase voltages V_{UN} and V_{VN} are separated in phase by one third of a period, or 120° between the two phasors. (Fig 7)

The phasor sum of the two phase voltages V_{UN} and V_{NV} can be obtained geometrically, and the resultant phasor so obtained is the line voltage V_{UV} through the relation $V_{UV} = V_{UN} + V_{NV}$.

Note that to obtain the line voltage V_{UV} the measurement is made from the U terminal through the common point N to the V terminal, for a star connection.

This fact is illustrated in Fig 8. Starting with the phasors V_{UN} and V_{VN} (Fig 7), the phasor $V_{VN} = V_{NV}$ is produced from the point N. The diagonal of the parallelogram with sides V_{UN} and V_{NV} is the phasor representing the resulting line voltage V_{UV}.

It can be concluded, therefore, that in a generator the line voltage V_L is related to the phase voltage V_P by a multiplying factor. This factor can be shown to be $\sqrt{3}$, so that

$V_L = \sqrt{3} \times V_P$

In a three-phase generating system, the line voltage is always times the phase-to-neutral voltage. The factor relating the line voltage to the phase voltage is .

It was shown that the line voltage is greater than the phase voltage. Here is a numerical example.

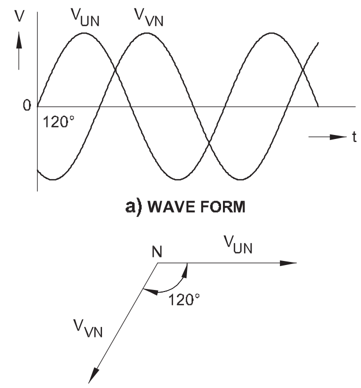
The RMS phase voltage in a three-phase system is 240V. Since the ratio of line voltage to phase voltage is $\sqrt{3}$ the RMS line voltage is

$V_L = \sqrt{3} \times V_P = \times 240$

$= 415.68V$

or rounded down, $V_L = 415V$.

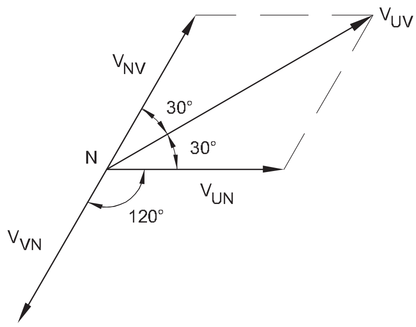
Fig 7



a) WAVE FORM

b) VECTORS

Fig 8



PHASOR DIAGRAM

Systems of connection in 3-phase ac

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

- explain the star and delta systems of connection
- state phase relationship between line and phase voltages and current in a star connection delta connection
- state the relationship between phase and the voltage and current in star and delta connection.

Methods of 3-phase connection: If a three-phase load is connected to a three-phase network, there are two basic possible configurations. One is `star connection' (symbol Y) and the other is `delta connection' (symbol D).

Star connection: In Fig 1 the three-phase load is shown as three equal magnitude resistances. From each phase, at any given time, there is a path to the terminal points U, V, W of the equipment, and then through the individual elements of the load resistance. All the elements are connected to one point N: the `star point'. This star point is connected to the neutral conductor N. The phase currents iU, iV, and iW flow through the individual elements, and the same current flows through the supply lines, i.e. in a star connected system, the supply line current (IL) = phase current (IP).

The potential difference for each phase, i.e. from a line to the star point, is called the phase voltage and designated as VP. The potential difference across any two lines is called the line voltage VL. Therefore, the voltage across each impedance of a star connection is the phase voltage VP. The line voltage VL appears across the load terminals U-V, V-W and W-U and designated as VUV, VVW and VWU in the Fig 1. The line voltage in a star-connected system will be equal to the phasor sum of the positive value of one phase voltage and the negative value of the other phase voltage that exist across the two lines (Fig 2).

Thus

$V_L = V_{UV}$ = (phasor V_{UN}) - (phasor V_{VN})

= phasor $V_{UN} + V_{VN}$.

Fig 1

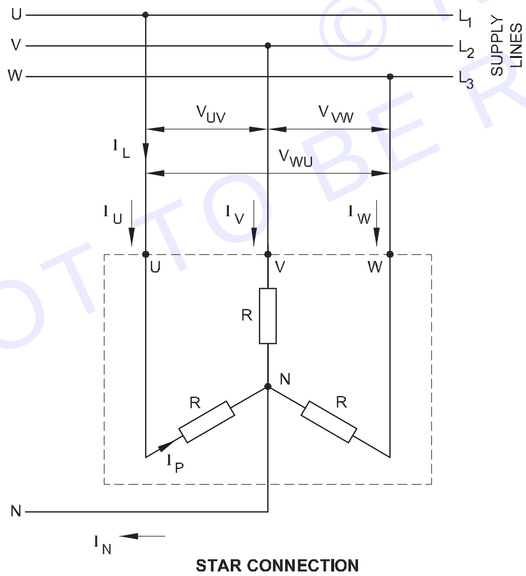
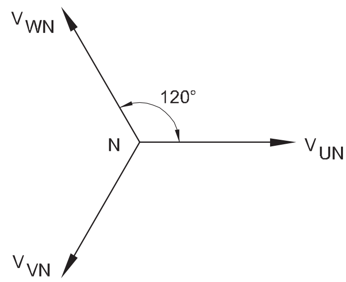


Fig 2



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In the phasor diagram (Fig 3)

$V_L = V_{UV} = V_{UN} \text{ Cos } 30° + V_{NV} \text{ Cos } 30°$

But Cos 30° $= \frac{\sqrt{3}}{2}$

Thus as $V_{UN} = V_{VN} = V_P$

$V_L = \sqrt{3}\, V_P$.

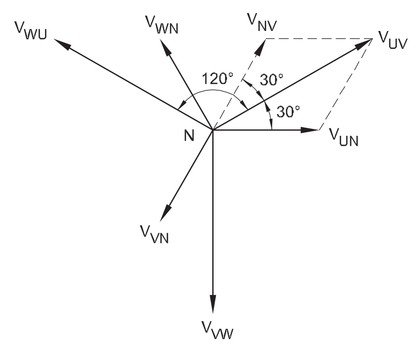
This same relationship is applied to V_{UV}, V_{VW} and V_{WU}.

In a three-phase star connection, the line voltage is always $\sqrt{3}$ times the phase-to-neutral voltage.

The factor relating the line voltage to the phase voltage is $\sqrt{3}$ (Fig 3).

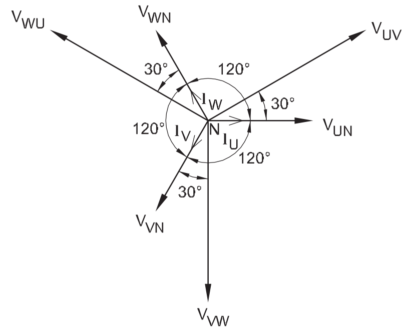
The voltage and current relationship in a star connection is shown in the phasor diagrams. (Fig 4) The phase voltages are displaced 120° in phase with respect to each other.

Fig 3



PHASOR DIAGRAM

Fig 4



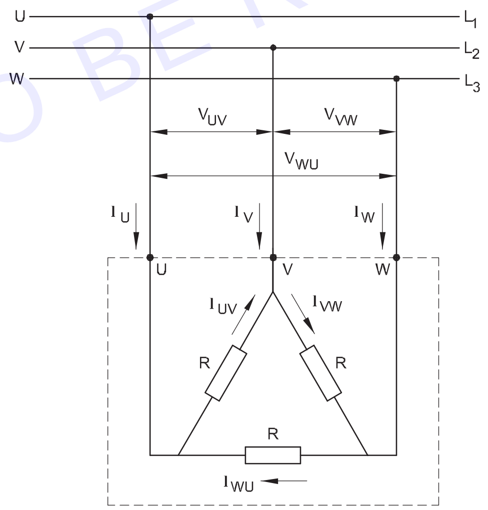
PHASOR DIAGRAM OF STAR CONNECTION

Derived from these are the corresponding line voltages. The line voltages are displaced 120° in phase with respect to each other. Since the loads in our example are provided by purely resistive impedances, the phase currents I_P (I_U, I_V, I_W) are in phase with the phase voltages V_P (V_{UN}, V_{VN} and V_{WN}). In a star connection, each phase current is determined by the ratio of the phase voltage to the load resistance R.

Delta connection: There is a second possible arrangement for connecting a three-phase load in a three-phase network. This is the delta or mesh connection (Δ).(Fig 5)

The load impedances form the sides of a triangle. The terminals U, V and W are connected to the supply lines of the L_1, L_2 and L_3.

Fig 5



In contrast to a star connection, in a delta connection the line voltage appears across each of the load phases.

The voltages, with symbols V_{UV}, V_{VW} and V_{WU} are, therefore, the line voltages.

The phase currents through the elements in a delta arrangement are composed of I_{UV}, I_{VW} and I_{WU}. The currents from the supply lines are I_U, I_V and I_W, and one line current divides at the point of connection to produce two phase currents.

The voltage and current relationships of the delta connection can be explained with the aid of an illustration. The line voltages V_{UV}, V_{VW} and V_{WU} are directly across the load resistors, and in this case, the phase voltage is the same as the line voltage. The phasors V_{UV}, V_{VW} and V_{WU} are the line voltages. This arrangement has already been seen in relation to the delta connection.

Because of the purely resistive load, the corresponding phase currents are in phase with the line voltages. (Fig 6)

Their magnitudes are determined by the ratio of the line voltage to the resistance R.

On the other hand, the line currents I_U, I_V and I_W are now compounded from the phase currents. A line current is always given by the phasor sum of the appropriate phase currents. This is shown in Fig 7. The line current I_U is the phasor sum of the phase currents I_{UV} and I_{UW}. (See also Fig 7)

Hence, $I_U = I_{UV} \cos 30° + I_{UW} \cos 30°$

But $\cos 30° = \frac{\sqrt{3}}{2}$

Thus $I_L = \sqrt{3}\ Iph$

Thus, for a balanced delta connection, the ratio of the line current to the phase current is $\sqrt{3}$.

Thus, line current = $\sqrt{3}$ x phase current.

Application of star and delta connection with balanced loads

An important application is the `star-delta change over switch' or star-delta starter.

Application of star connection: Alternators and secondoary of distribution transformers, have their three, single-phase coils interconnected in star.

Assignment: Three identical coils, each of resistance 10 ohms and inductance 20mH is delta connected across a 400-V, 50Hz, three-phase supply. Calculate the line current.

Fig 6 Fig 6

Neutral in 3-phase system

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

- explain the current in neutral of a 3-phase star connection
- state the earthing the neutral.

Neutral: In a three-phase star connection, the star point is known as neutral point, and the conductor connected to the neutral point is referred as neutral conductor (Fig 1).

Current in the neutral conductor: In a star-connected, four-wire system, the neutral conductor N must carry the sum of the currents I_U, I_V and I_W. One may, therefore, get the impression that the conductor must have sufficient area to carry a particularly high current. However, this is not the case, because this conductor is required to carry only the phasor sum of the three currents.

I_N = phasor sum of I_U, I_V and I_W

Fig 2 shows this phasor addition for a situation where the loads are balanced and the currents are equal. The result is that the current in the neutral line I_N is zero.

Therefore, for a balanced load the neutral conductor carries no current.

Earthing of neutral conductor: Supply of electrical energy to commercial and domestic consumers is an important application of three-phase electricity. For `low voltage distribution' - in the simplest case, i.e. supply of light and power to buildings - there are two requirements.

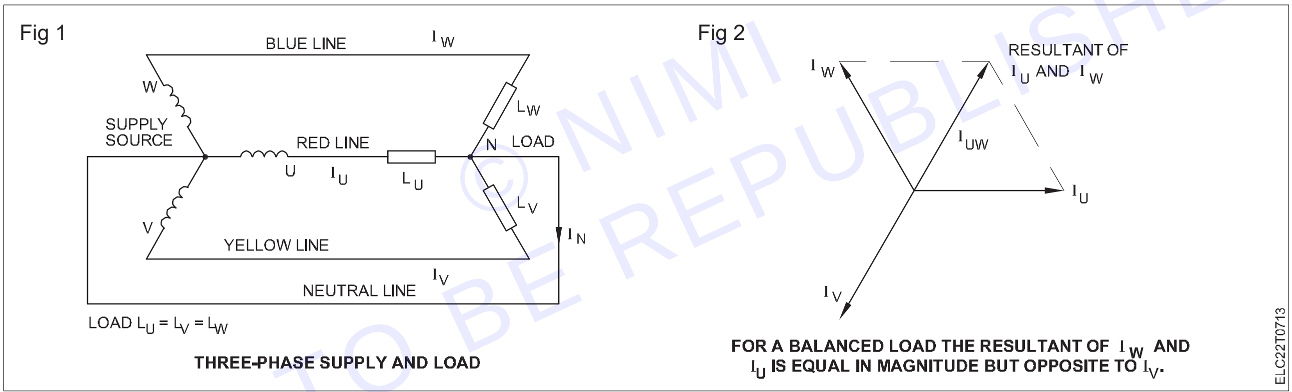
1 It is desirable to use conductors operating at the highest possible voltage but with low current in order to save on expensive conductor material.

2 For safety reasons, the voltage between the conductor and earth must not exceed 250V.

A voltage distribution system according to criterion 2, only possible with a low line voltage below 250 V. However, this is contrary to criterion 1. On the other hand, with a star connection, a line voltage of 415V is available. In this case, there is only 240V between the supply line and the neutral conductor. Criterion 1 is satisfied and, to comply with 2, the neutral conductor is earthed.

Indian Electricity Rules: I.E.Rules insist that the neutral conductor must be earthed by two separate and distinct connections to earth. Rule No.61(1)(a), Rule No.67(1)(a) and Rule No.32 insist on the identification of neutral at the point of commencement of supply at the consumer's premises, and also prevent the use of cut outs or links in the neutral conductor. BIS stipulate the method of earthing the neutral. (Code No.17.4 of IS 3043-1966)

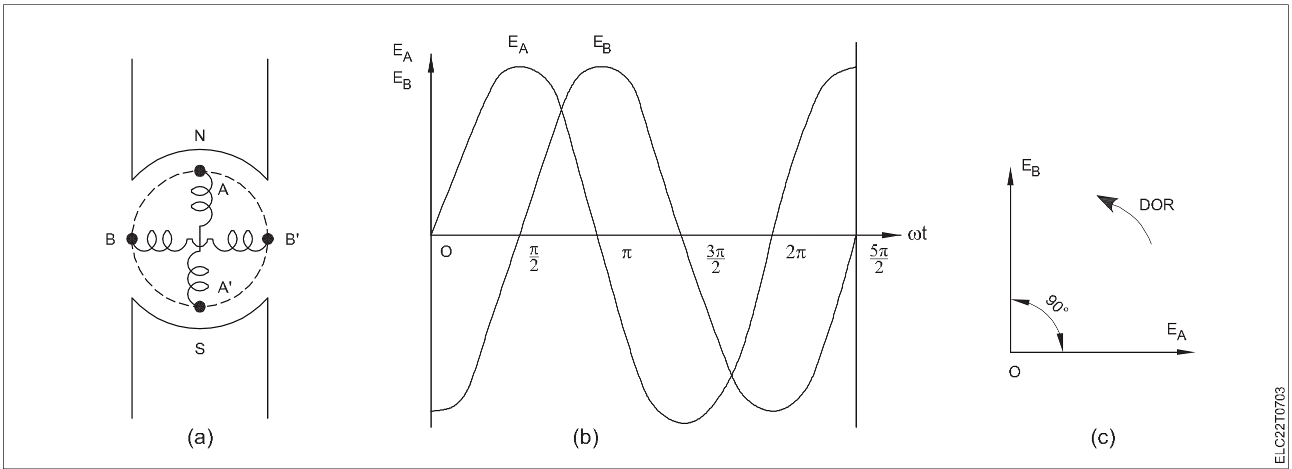
Cross-sectional area of neutral conductor: The neutral conductor in a 3-phase, 4-wire system should have a smaller cross-section. (half of the cross-section of the supply lines).



Two phase system

Two electrically insulated windings are placed 90 degree electrical apart in a uniform magnetic field.

If the windings are rotated with constant angular velocity, the EMF generated will have a phase difference of 90 degree.



Instantaneous values of voltage,

EA=EmSin wt.

EB=EmSin (wt-90).

As the two windings are wound on the same armature and have same number of turns, the generated EMF in the two coils have the same maximum value, frequency and wave length.

The voltage between two phases is the vector sum of voltage generated in two windings.

$AB^2=OA^2+OB^2$

OR

$ER^2= EA^2+ EB^2$

EA and EB are phase voltages and are equal

Therefore

$ER^2=E^2+E^2$

$ER^2=2E^2$

$ER=\sqrt{2}E$

- This means that the line voltage in two phase system is $\sqrt{2}$ times phase voltage.

Power derivation in star connection

The total power in the circuit is quite logically,the sum of the powers in the three phases. For balanced load power consumed in each phase is same

Total power = 3 × power in each phase

$3 \times V_{ph} I_{ph} \cos Ø$

For star connection $V_{ph} = V_L /\sqrt{3}$;$I_{ph} = I_L$

$P = 3 \times V_L /\sqrt{3} \times I_L \cos Ø$

$=\sqrt{3} V_L I_L \cos Ø$

Ø is the phase difference between a phase voltage and corresponding phase current.

Note that in either case star or delta ,the expression for the total power is same provided that the system is balanced

Related problems

1.A three phase 415 V A.C induction motor requires a current of 50 A . Calculate its H.P at a P.F of 0.8 and efficiency 90 %

Solution

Line voltage V_L= 415 V

Line current I_L = 50A

Power factor cosØ = 0.8

Efficiency of motor = 90%=0.9

As it is 3 phase motor :

Input power= √ 3.VL .IL.cosØ

= 1.732 x 415 x 50 x 0.8 watts

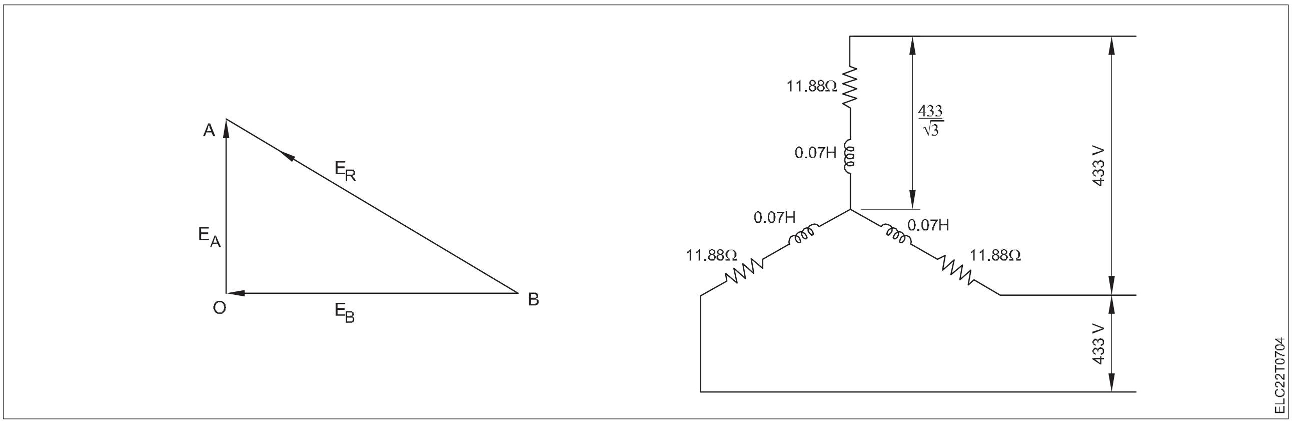
Out put of motor = input to motor x efficiency

= 1.732 x 415 x 50 x 0.8 x 0.9 watts

= 1.732 x 415 x 50 x 0.8 x 0.9 / 735.5 ….1 H,P = 735.5 watts

= 35.18 H.P

Example : Three coils each with a resistance of 11.88 Ω and an inductance of 0.07 H are connected in star to a three - phase 433V, 50 Hz supply. Find (a) the line current and the total power absorbed.(b) If these three coils are connected in delta to the same supply. Calculate the line current and the total power absorbed.



Solution

(a) *In star connection,*

$\sqrt{3}$ Phase voltage (V_{ph}) = Line voltage (V_L)

∴ Potential difference across each phase winding

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

$$= \frac{433}{1.73} = 250 \text{ V}$$

Inductive reactance of the coil,

$$X_L = 2 \times \pi \times f \times L$$

$$= 2 \times \frac{22}{7} \times 50 \times 0.07 = 22\ \Omega$$

Impedance of each phase, $Z_{ph} = \sqrt{R^2 + X_L^2}$

$$= \sqrt{(11.88)^2 + (22)^2}$$

$$= \sqrt{141.1 + 484} = \sqrt{625.1}$$

$$= 25\ \Omega$$

∴ Current in each phase winding $= \frac{V_{ph}}{Z_{ph}}$

$$= \frac{250}{25} = 10 \text{ A}$$ **Ans.**

But in star connection

$$I_{ph} = I_L$$

∴ Line current due to star connection = 10 A **Ans.**

∴ Power factor, $\cos\theta = \frac{R}{Z} = \frac{12}{25} = 0.48$

∴ Power taken in star connection,

$$W = \sqrt{3}\, V_L \times I_L \times \cos\theta$$

$$= \frac{1.732 \times 433 \times 10 \times 0.48}{1000} = 3.6 \text{ kW}$$ **Ans.**

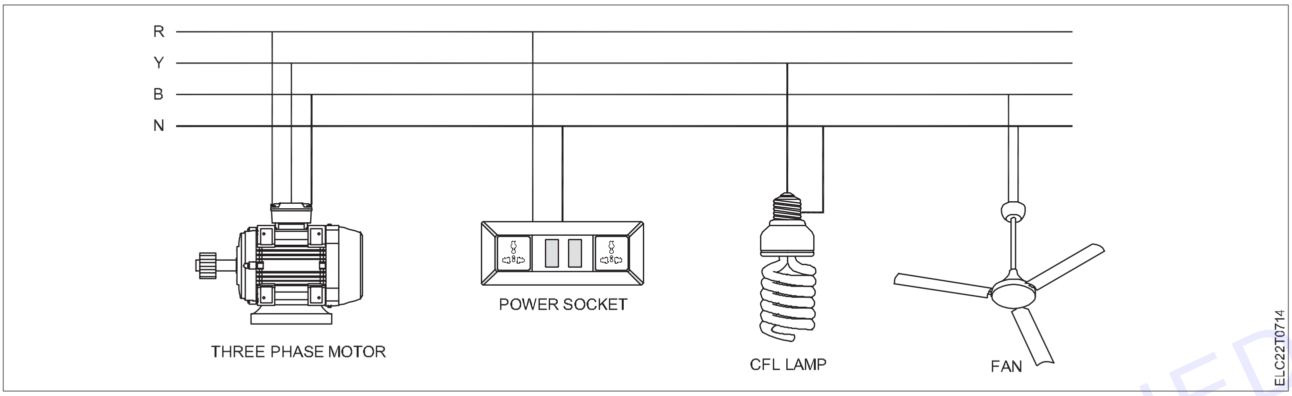
Measurement of three phase power

Power measurement in 3 phase system depends upon whether the load connected across it is balanced or unbalanced and whether it is in star or delta.Various methods are used for the measurement of power in three phase circuits. On the basis of number of wattmeter used, there are three methods

1 Three watt meters method

2 Two watt meters method

3 Single watt meter method.



Three watt meter method

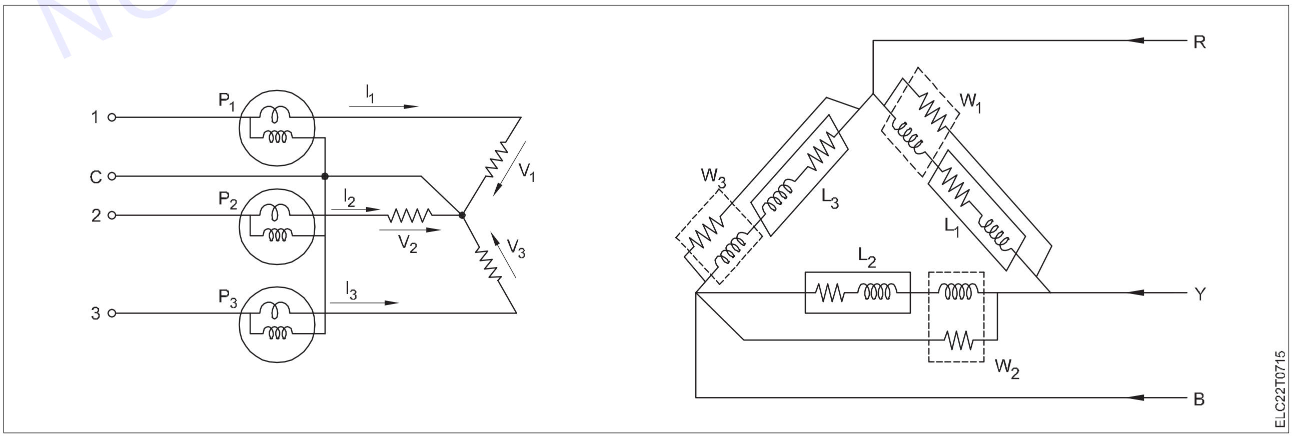
This method of power measurement can be used to measure the power in a three phase circuit for both balanced and unbalanced load. It is generally employed to measure power in a 3 phase, 4 wire system. The connections for measuring power of a star connected load by three wattmeter method is shown below.

The pressure coil of all the Three watt meters namely W_1, W_2 and W_3 are connected to a common terminal known as the neutral point. The product of the phase current and phase voltage represents as phase power and is recorded by individual wattmeter.

The total power in a Three wattmeter method of power measurement is given by the algebraic sum of the readings of Three watt meters. i.e.

Total Power P= $W_1+W_2+W_2$

However, this method can also be employed in a 3 phase, 3 wire delta connected load, where power consumed by each load is required to be determined separately.



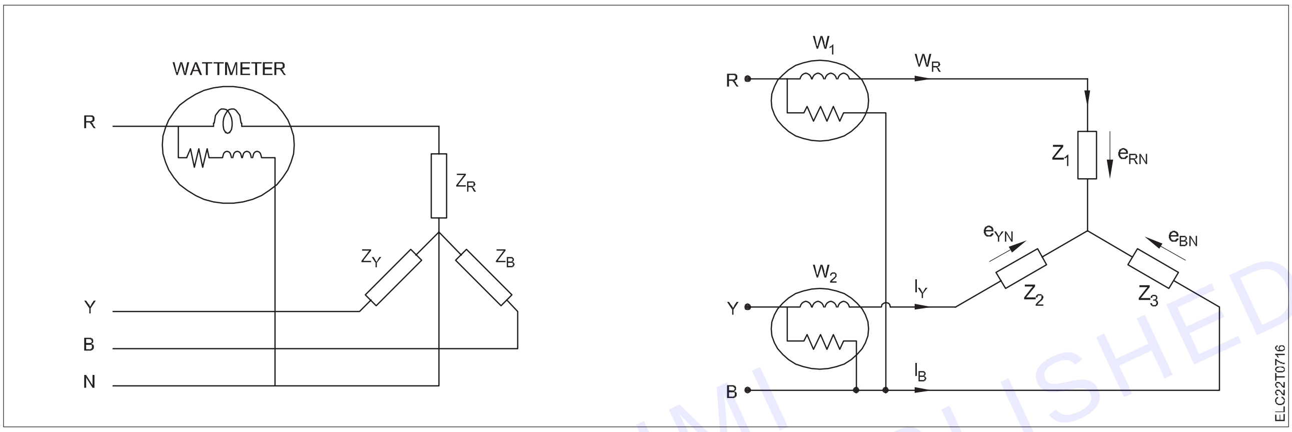
One watt meter method

This method is applicable only to a balanced load and when neutral is available. This method is generally used with three phase star connected load. In this method watt meter is connected in any of the phase i.e., current coil of the watt meter is connected in series to any of the phase and pressure coil connected across that phase and neutral. The power consumed in the three phase circuit is three times the reading of wattmeter.

Total power = 3 x Wattmeter Reading

If in this system, a neutral is not available, an artificial neutral point can be made by connecting the pressure coil of wattmeter with two resistances each with a value equal to pressure coil the wattmeter

Two wattmeter method



Considering the above figure in which Two Wattmeter W_1 and W_2 are connected, the instantaneous current through the current coil of Wattmeter,

W_1 is given by the equation shown below.

$W_1 - i_R$

Instantaneous potential difference across the potential coil of Wattmeter, W_1 is given as

$W_1 = e_{RN} - e_{BN}$

Instantaneous power measured by the Wattmeter, W_1 is

$W_1 = i_R \ (e_{RN} - e_{BN})$ ... ... (1)

The instantaneous current through the current coil of Wattmeter, W_2 is given by the equation

$W_2 = i_Y$

Instantaneous potential difference across the potential coil of Wattmeter, W_2 is given as

$W_2 = e_{YN} - e_{BN}$

Instantaneous power measured by the Wattmeter, W_2 is

$W_2 = i_Y \ (e_{YN} - e_{BN})$ ... ... (2)

Therefore, the Total Power Measured by the Two Wattmeter W_1 and W_2 will be obtained by adding the equation (1) and (2).

$$W_1 + W_2 = i_R (e_{RN} - e_{BN}) + i_Y (e_{YN} - e_{BN})$$

$$W_1 + W_2 = i_R e_{RN} + i_Y e_{YN} - e_{BN} (i_R + i_Y) \quad \text{or}$$

$$W_1 + W_2 = i_R e_{RN} + i_Y e_{YN} + i_B e_{BN} \quad (\text{i.e.}\, i_R + i_Y + i_B = 0)$$

$$W_1 + W_2 = P$$

It is used to measure the power in star or delta connected load in balanced or unbalanced condition

Current coil of two meters are connected in any two lines and the potential coil of each are connected to the third line. Pressure coils of all the three wattmeter are connected to common point at neutral line. The resultant sum of all the readings of wattmeter will give the total power of the circuit.

Total Power = P_1+P_2

Consider the instantaneous power in the system

Instantaneous current through W_1 =I 1_R

Instantaneous P.D across $W_1=E_{RB}=E_R-E_B$

Instantaneous Power read by $W_1=I_R(E_R-E_B)$

Instantaneous current through $W_2=I_Y$

Instantaneous P.D across $W_1= E_{YB} = E_Y-E_B$

Instantaneous Power read by $W_1 = I_Y(E_Y-E_B)$

$W_1+W_2 = I_R(E_R-E_B)+ I_Y(E_Y-E_B)$

= IRER-IREB+IYEY-IYEB

Rearrange the values then = IRER+IYEY-IREB-IYEB

= IRER+IYEY-EB(IR+IY)

Now IR+IY+IB = 0 (Acc. Kirchhoff's Point law)

IR+IY = -IB

= IRER+IYEY-EB(-IB)

= IRER+IYEY+IBEB

	0 Degree	0-59 Degree	60 Degree	60-90 Degree	90 Degree
PF	1	<1 but >0.5	0.5	<0.5 but >0	0
W1	+Ve	+Ve	+Ve	+Ve	+Ve
W2	+Ve	+Ve	0	-Ve	-Ve
	W1 &W2 are equal W1=W2	W1 &W2 are different	W1 only	W1 &W2 are different and opposite	W1 &W2 are equal but opposite W1=W2

Effect of load pf on wattmeter reading

Power factor from two wattmeter reading

tan¢=√3 (W1-W2)

(W1+W2)

¢=tan~√3 (W1-W2)

Phase-sequence indicator (Meter)

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

- describe the method of finding the phase sequence of a 3-phase supply using a phase-sequence indicator
- explain the methods of finding phase sequence using lamps.

Phase sequence

A three-phase alternator contains three sets of coils positioned 120° apart and its output is a three-phase voltage as shown in Fig 1. A three-phase voltage consists of three voltage waves, 120 electrical degrees apart.

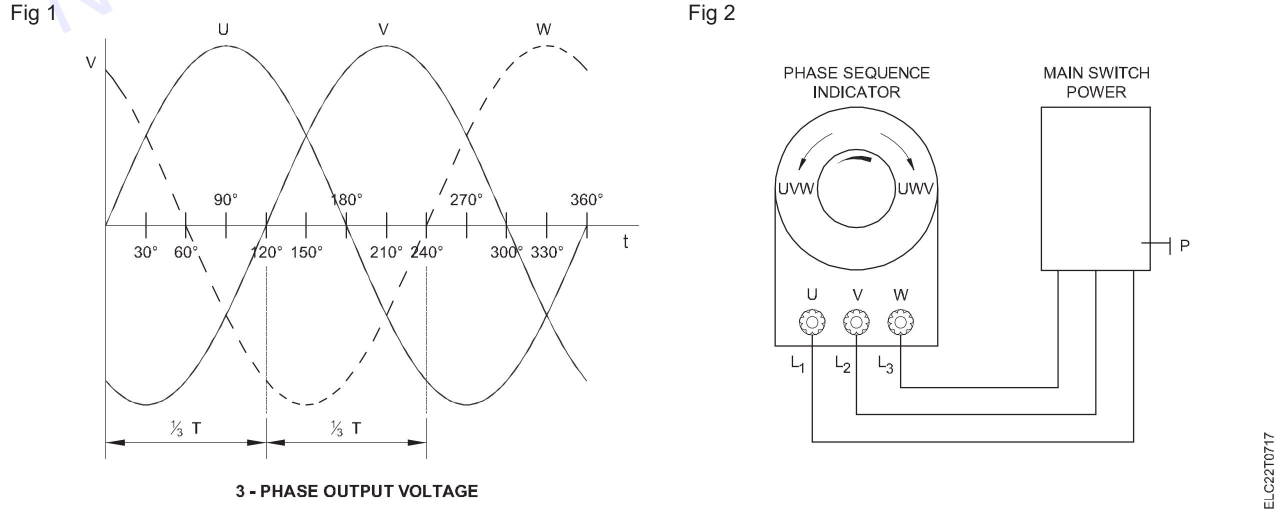
At a time 0, phase U is passing through zero volts with positively increasing voltage. (Fig 1) V follows with its zero crossing 1/3 of the period later and the same applies to W with respect to V. The order in which the three-phases attain their maximum or minimum values is called the phase sequence. In the illustration given here the phase sequence is U,V,W.

Importance of correct phase sequence: Correct phase sequence is important in the construction and connection of various three-phase systems. For example, correct phase sequence is important when the outputs of three-phase alternators must be paralleled into a common voltage system. The phase `U' of one alternator must be connected to phase `U' of another alternator. The phase `V' to phase `V' and phase `W' to phase `W' must be similarly connected to each other.

In the case of an induction motor, reversal of the sequence results in the reversal of the direction of motor rotation which will drive the machinery the wrong way.

Phase-sequence indicator(meter): A phase-sequence indicator (meter) provides a means of ensuring the correct phase-sequence of a three-phase system. The phase-sequence indicator consists of 3 terminals `UVW' to which three-phases of the supply are connected. When the supply is fed to the indicator a disc in the indicator moves either in the clockwise direction or in the anticlockwise direction. The direction of the disc movement is marked with an arrowhead on the indicator. Below the arrowhead the correct sequence is marked. (Fig 2)

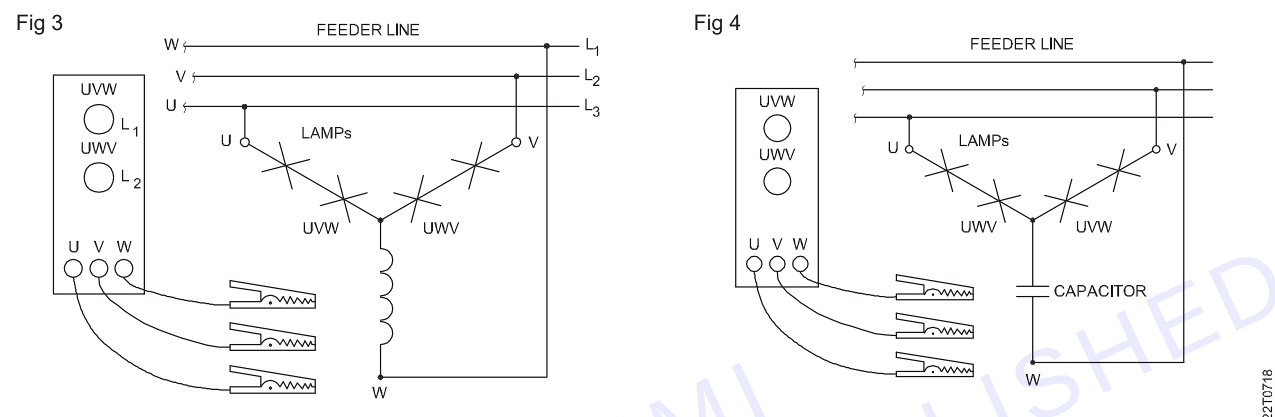
Fig 1 Fig 2



The phase sequence of the three-phase system may be reversed by interchanging the connections of any two of the three phases.

Phase-sequence indicator using choke and lamps: The phase-sequence indicator consists of four lamps and an inductor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One lamp is labelled U-V-W, and the other is labelled U-W-V. When the three leads are connected to a three-phase line, the brighter lamp indicates the phase sequence. (Fig 3)

Phase-sequence indicator using capacitor & lamps: The phase-sequence indicator consists of four lamps and a capacitor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One pair of lamps are labelled U-V-W,and the other pair are labelled U-W-V. When the three leads are connected to a 3-phase line, the brighter lamp indicates the phase sequence. (Fig 4)



PHASE SEQUENCE INDICATOR USING CHOKE & LAMPS

PHASE SEQUENCE INDICATOR USING CAPACITOR & LAMPS

MODULE 6 : DC Generator and DC Motor

LESSON 30-37 : DC Generator Principle - parts - types - function e.m.f equations, charactrics of D.C

Objectives

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

- state the principle of the D.C. generator
- expain the faraday's of laws of electromagnetic induction
- describe the parts of a DC generator & their function
- classity & identify the different type of generator
- drive the e.m.f equations, charactrics of D.C generator
- explain the operation of parallel of D.C generator

Principle of dc generator operation

Faradays laws of electromagnetic induction

First law:

Whenever the magnetic flux linked with a circuit changes, an e.m.f. is always induced in it.

Whenever a conductor cuts magnetic flux, an e.m.f. is induced in that conductor.

Second law:

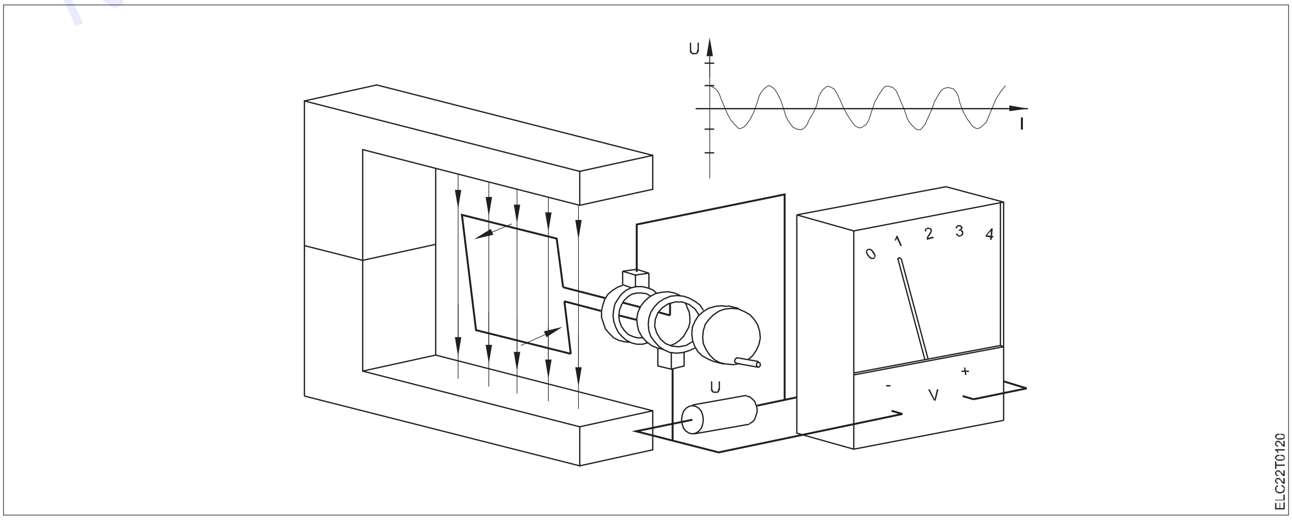
The magnitude of the induced e.m.f. is equal to the rate of change of flux linkages.

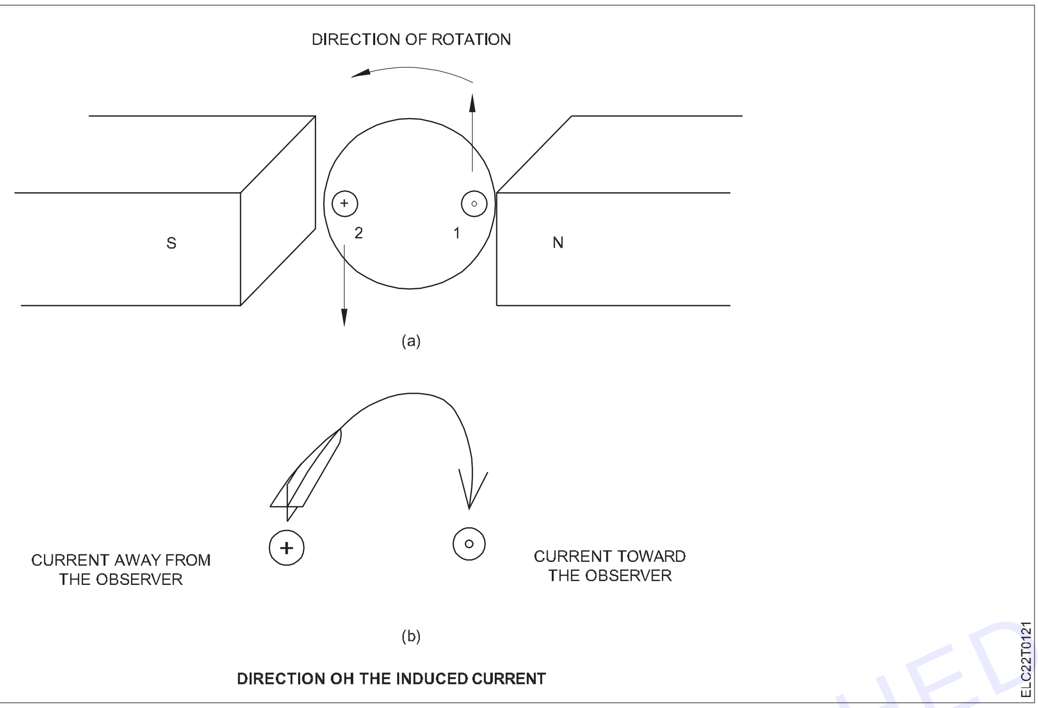
Requirements for dc generator

- Magnetic field
- A conductor
- A mechanical driving force as prime mover

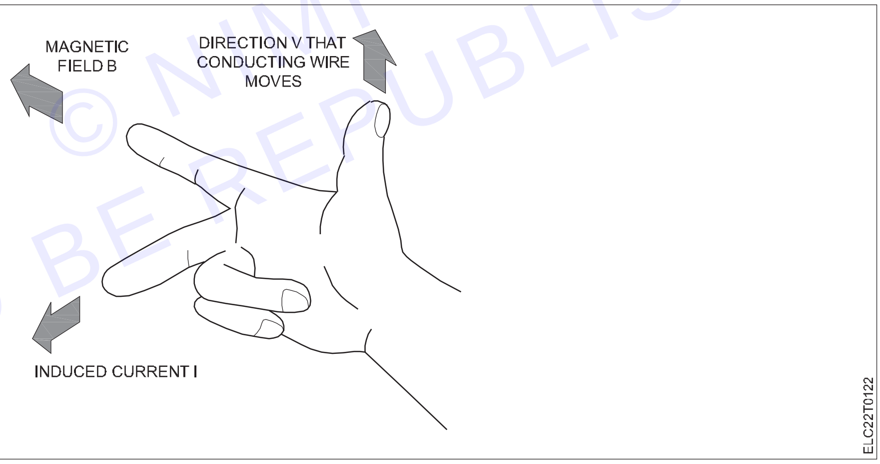
Generation of AC

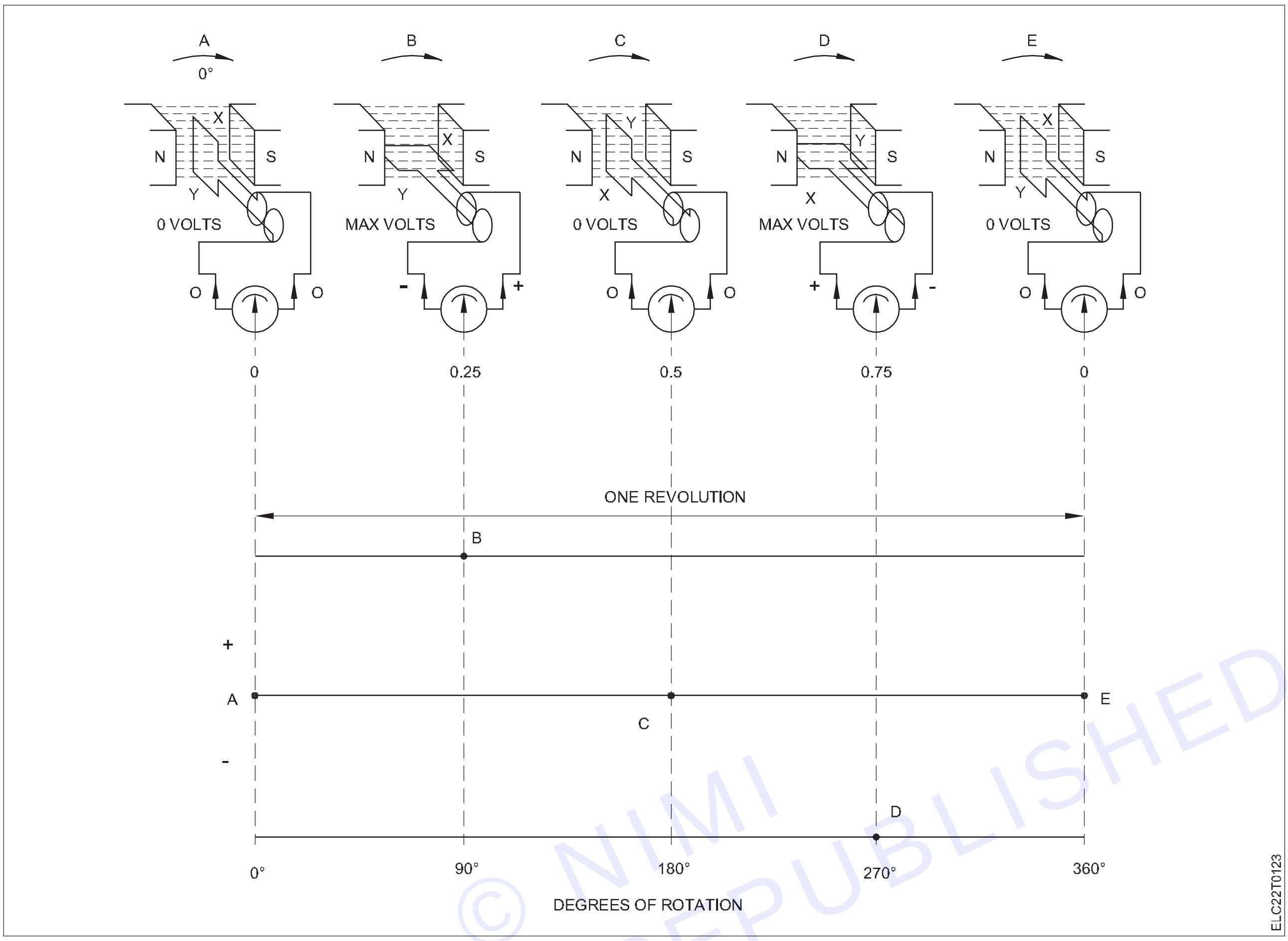
1 A coil moves in a magnetic field
2 Coil is connected to slip rings
3 Brushes connect the load R to the slip ring
   A The maximum emf is induced when the coil is perpendicular to the magnetic field.
   B The minimum emf is induced when the coil is parallel to the magnetic field



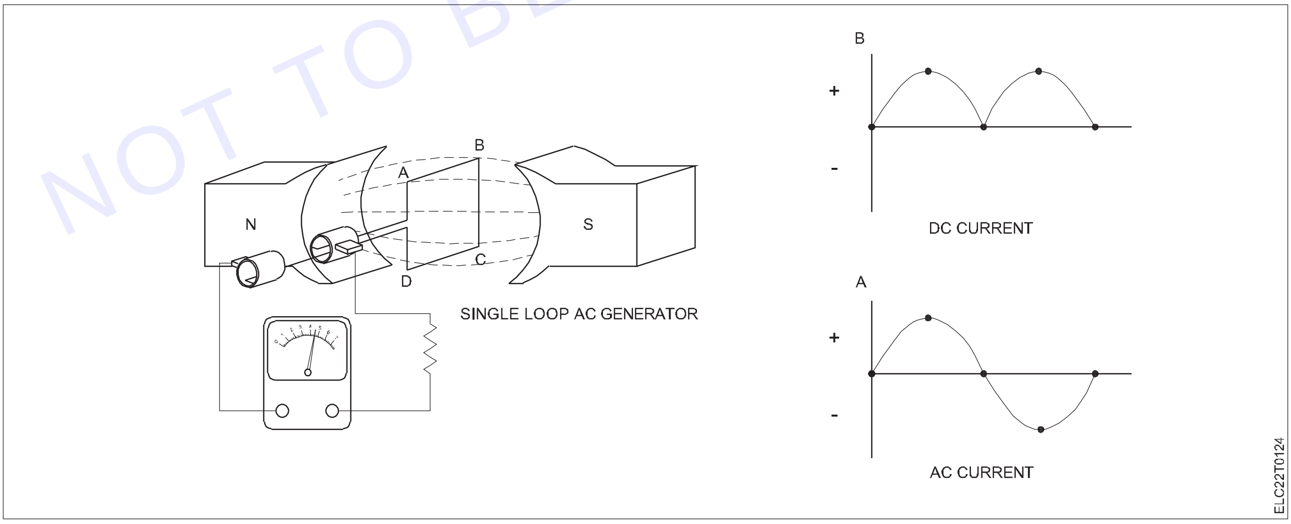


DIRECTION OH THE INDUCED CURRENT



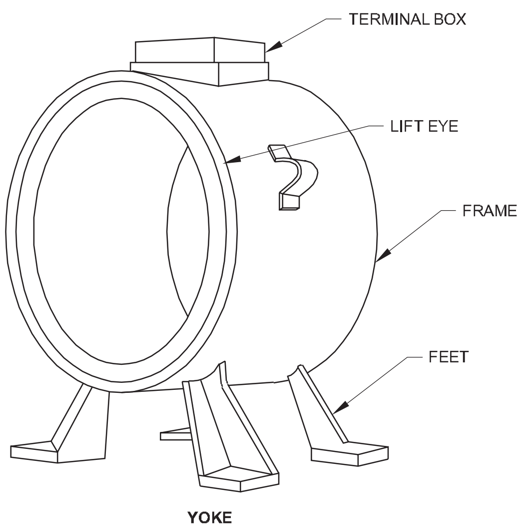


Split rings to convert ac to dc



Construction of DC machines

- The same DC Machine can be used as generator or Motor



Slip rings

Copper / Brass /phosphorous bronze slip rings

Yoke

small dc generator - cast iron – cheap

big dc generator of cast steel / rolled steel – high permeability

Pole core& pole shoe

small dc generator - solid pole core and laminated pole shoe

big dc generator – both are laminated

Armature core

Cylindrical – laminations of approx. 0.5mm, with keyway and airducts.

Types of dc generators

Permanent magnet dc generators

Applications

Dynamos

Meggar

Advantages

Simple to build and requires very less maintenance

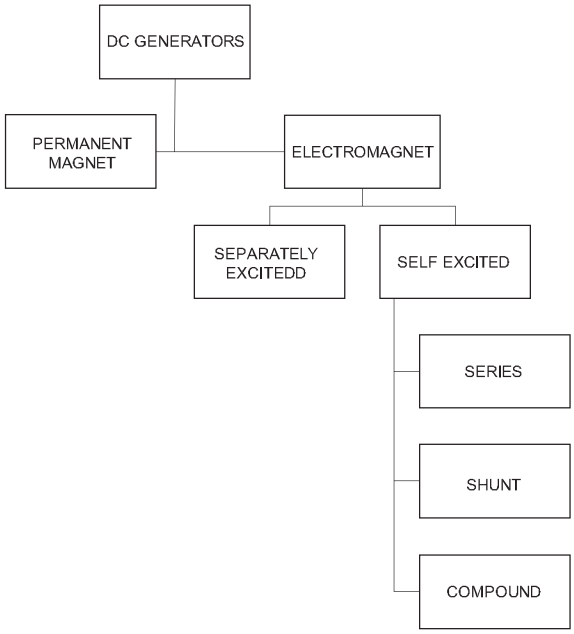
Disadvantages

As the field strength is fixed, voltage variation is not possible by flux control

Difficult to regulate.

Separately excited dc generators

Electromagnet is used as field. Separate source of power needed to excite. Excitation is independent of load. Wide voltage variations are attainable.



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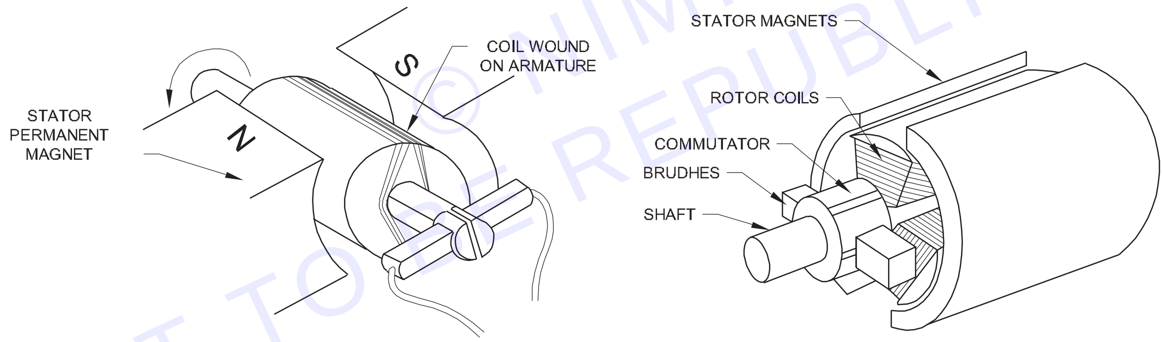

PERMANENT MAGNET DC GENERATOR

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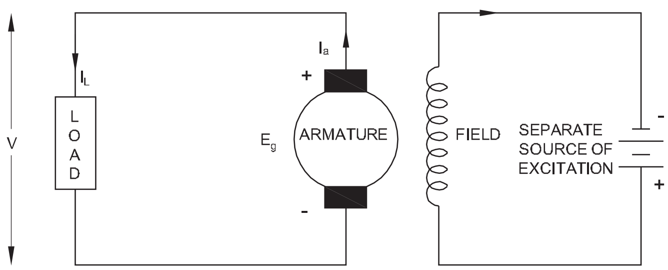


SEPARATELY EXCITED DC GENERATORS

ELC22T0128

Self excited dc generators

Windings – Armature and field

Field windings --Series and Shunt

Series field winding arein series with armature and have large cross section and few turns.

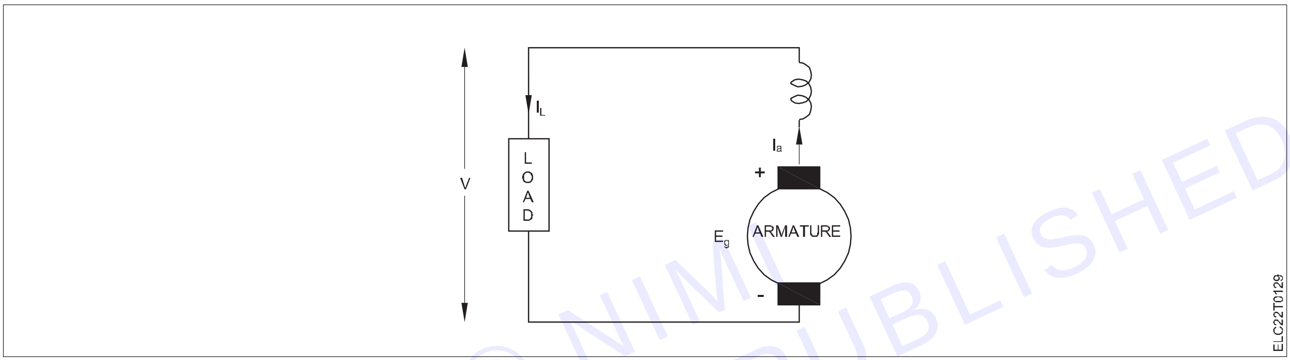
Resistance of series field winding is small.

Shunt field winding in parallel with armature having small cross section and large number of turns, resistance is more.

Se lf excited dc series generator

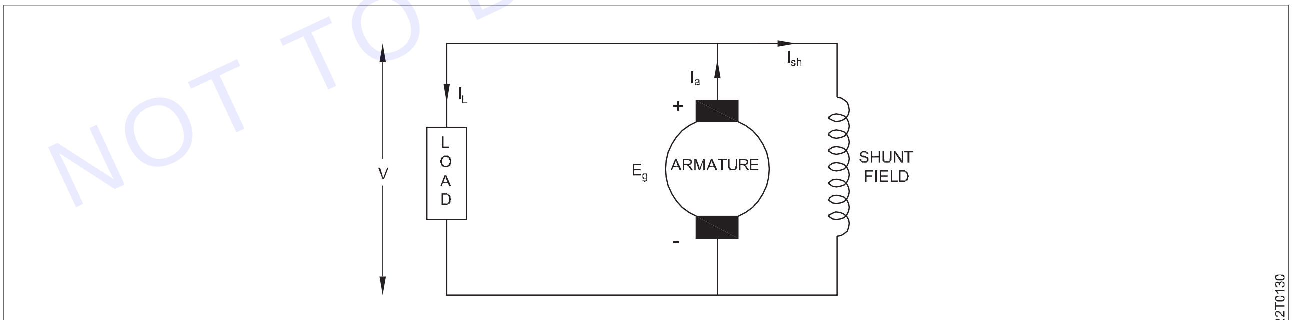
Series field winding are in series with armature and have large cross section and few turns.

Resistance of series field winding is small. It has 4 terminals, 2of armature and 2of series field.



DC shunt generator

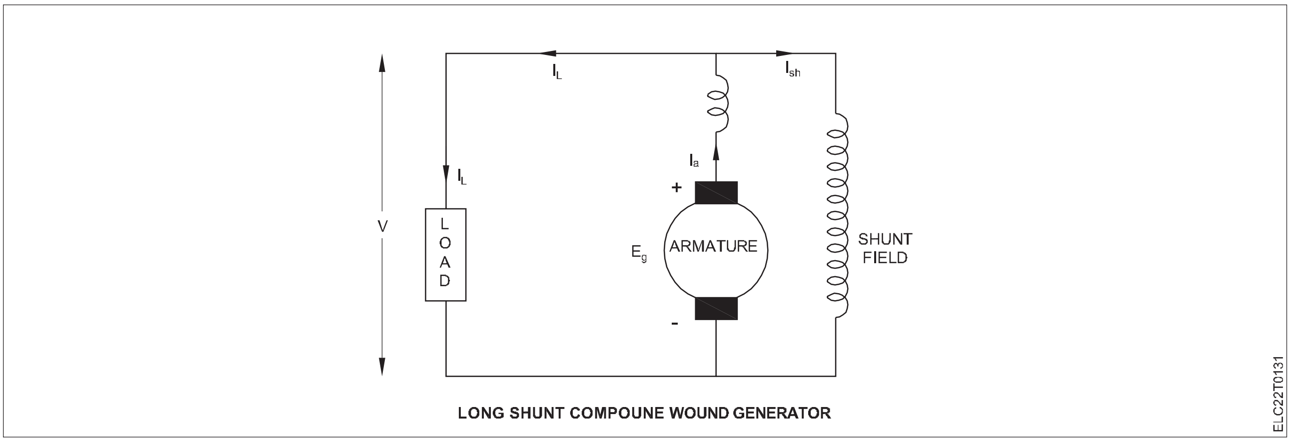
Shunt field winding in parallel with armature. Shunt field windings small crosssection,largeturns,moreresistance. It has4 terminals, 2of armature and 2of shunt field.



DC SHUNT GENERATORS

DC compound generator

- Armature winding
- Series field winding and
- Shunt field winding
- 6 terminals,
- 2of armature, 2of series field and 2of shunt field



LONG SHUNT COMPOUNE WOUND GENERATOR

Types of dc compound generators

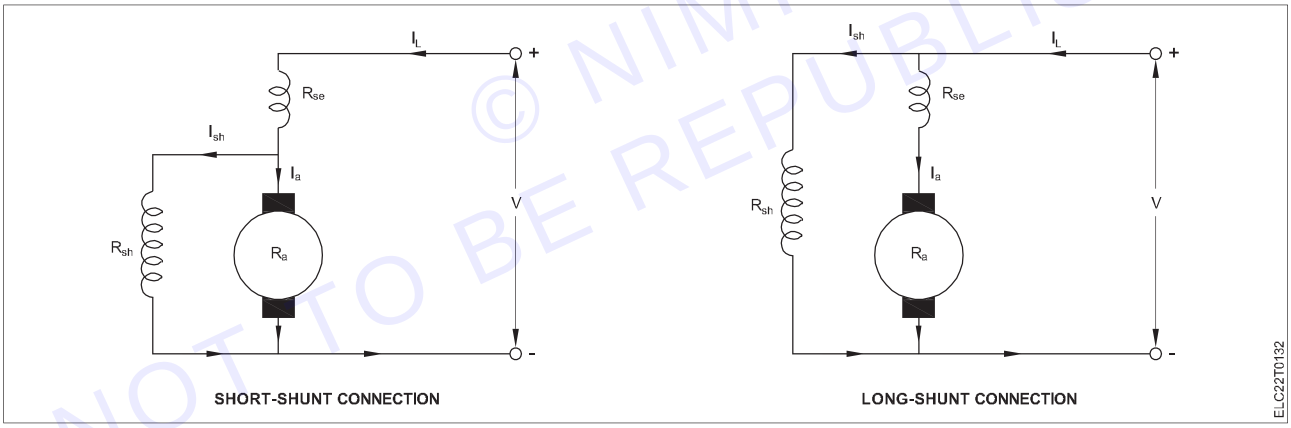
Based on physical connections;

Long shunt and short shunt compound generators

Types of dc compound generators

Based on physical connections;

Long shunt and short shunt compound generators



SHORT-SHUNT CONNECTION LONG-SHUNT CONNECTION

EMF EQUATION OF DC GENERATOR

φ = Flux per pole in web

Z = No. of conductors or coil sides

= 2T [where T= No. of coils or turns]

N = Rotor Speed in r.p.m or $\frac{N}{60}$ r.p.s

i.e. Time for 1 Revolution

$$\frac{60}{N} \frac{\text{Second}}{\text{Revolution}}$$

= 60/N Second/Revolution

P = No. of poles;

A = No. of Parallel paths.

In one revolution of the rotor each conductor

is cut by a flux of ϕ P , $\frac{60}{N}$

Time for 1 revolution = $\frac{60}{N}$ Second

Average emf induced per

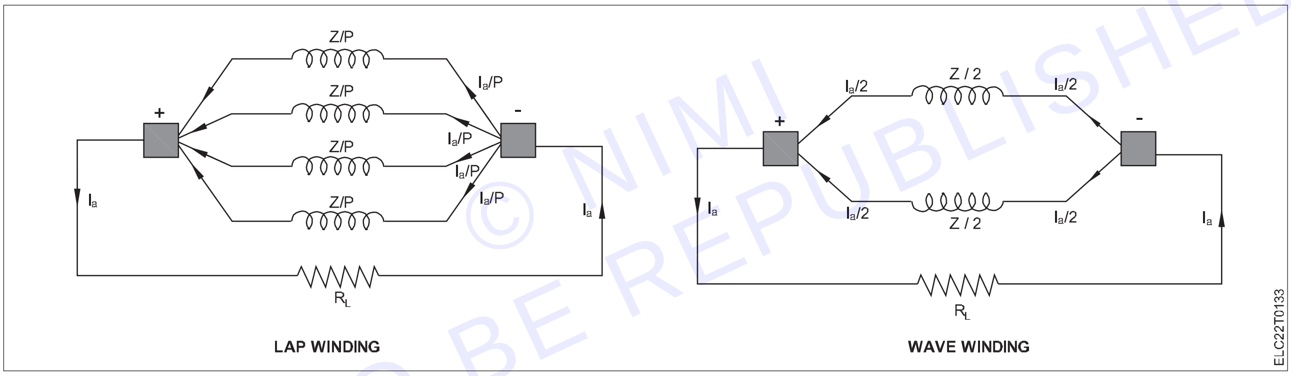
conductor /revolution = $\frac{\varphi P}{\frac{60}{N}} = \frac{\varphi PN}{60}$

No.of conductors = Z

No of parallel paths = a

Equation for induced emf = $\frac{\varphi PN}{60} \times \frac{Z}{a}$ or $E_R = \frac{\varphi ZN}{60} \times \frac{P}{a}$

where a =P for lap and 2 for wave



Characteristics of dc generators

- Open Circuit Characteristics (OCC) / Magnetization Characteristics
- Plot between Eg / If
- Internal Characteristic Curve (ICC)/Total Characteristic
- Plot between Eg / Ia
- External Characteristics Curve (ECC) / Load Characteristics
- Plot between V_T / I_L

Permanent magnet dc generator

Eg = VT + IaRa

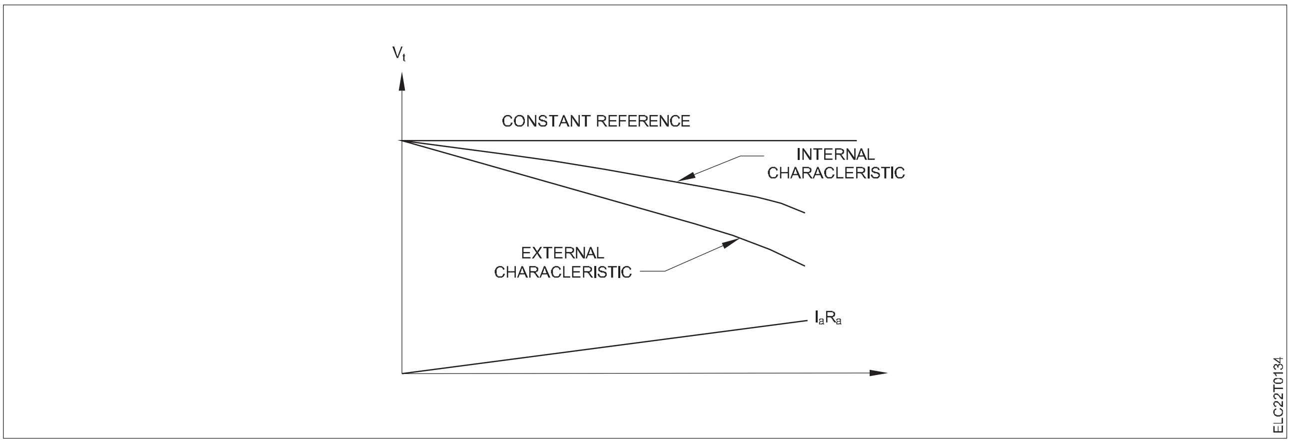
The voltage can not changed,Difficult to have strong magnetic field,Magnetic power reduces wrt time.

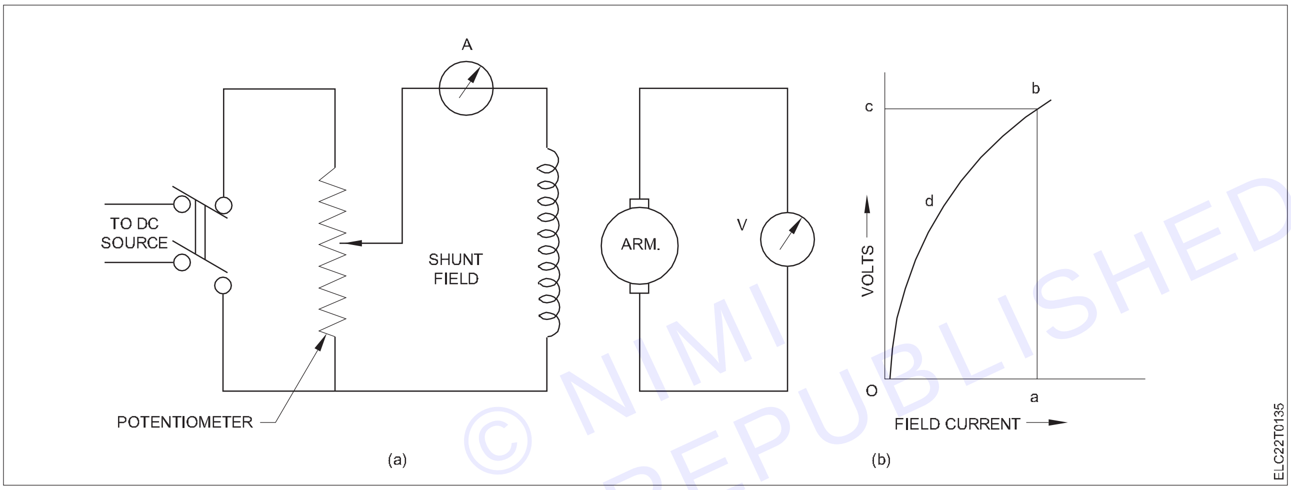
Separately excited generator

Open Circuit Characteristics (OCC) / MagnetizationCharacteristics Plot between Eg / If

ICC and LCC are similar.

Requires a separate DC Source and hence rarelyused. Used for wide voltage variation as the field is separately excited.





Separately excited.

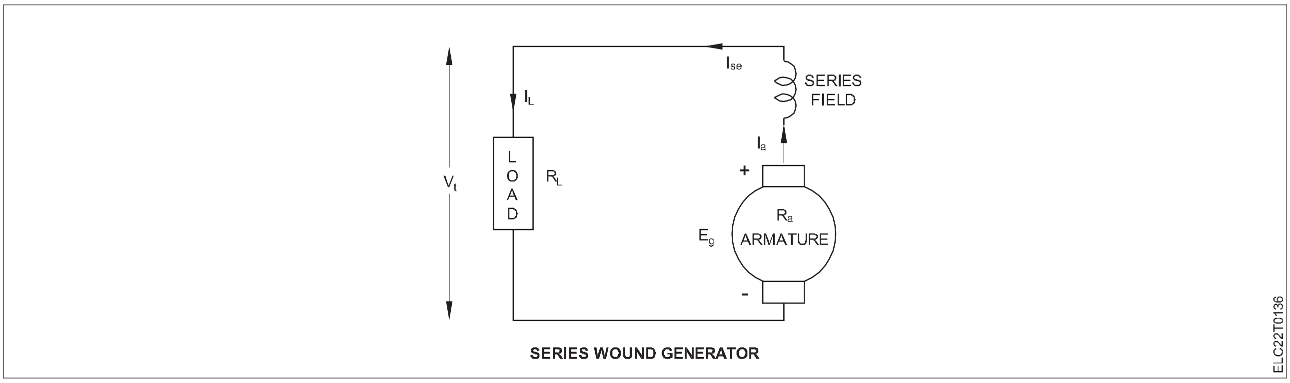
DC series generator

$Ia = If = I_L$

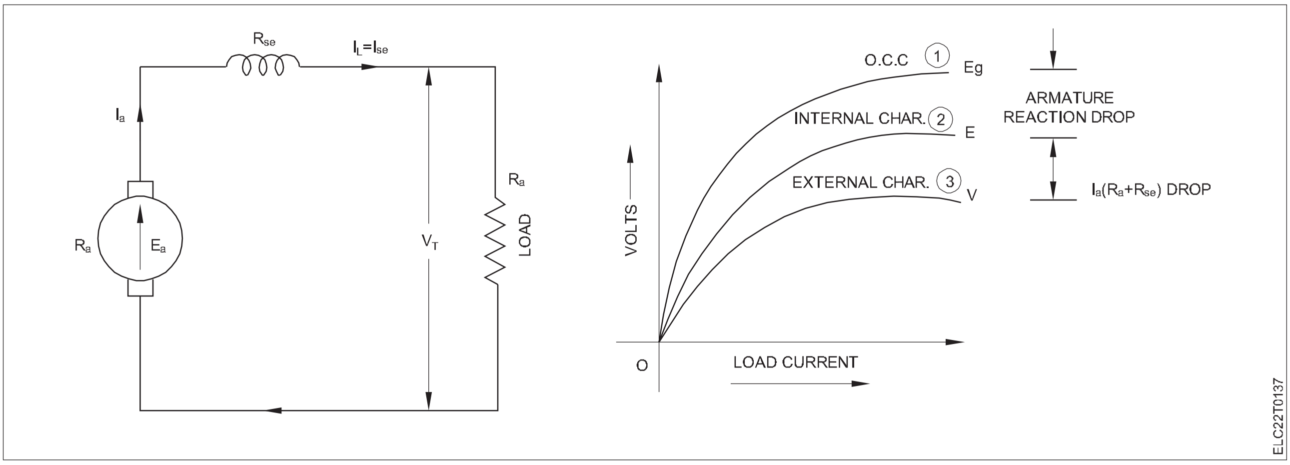
Rf ,Rse, RL

$$I = \frac{Eg}{Rf + Ra + RL}$$

I x RL = Vt = Eg – I (Ra +Rf



OCC/ICC/ECC of DC Series Generator



Applications of dc series generators

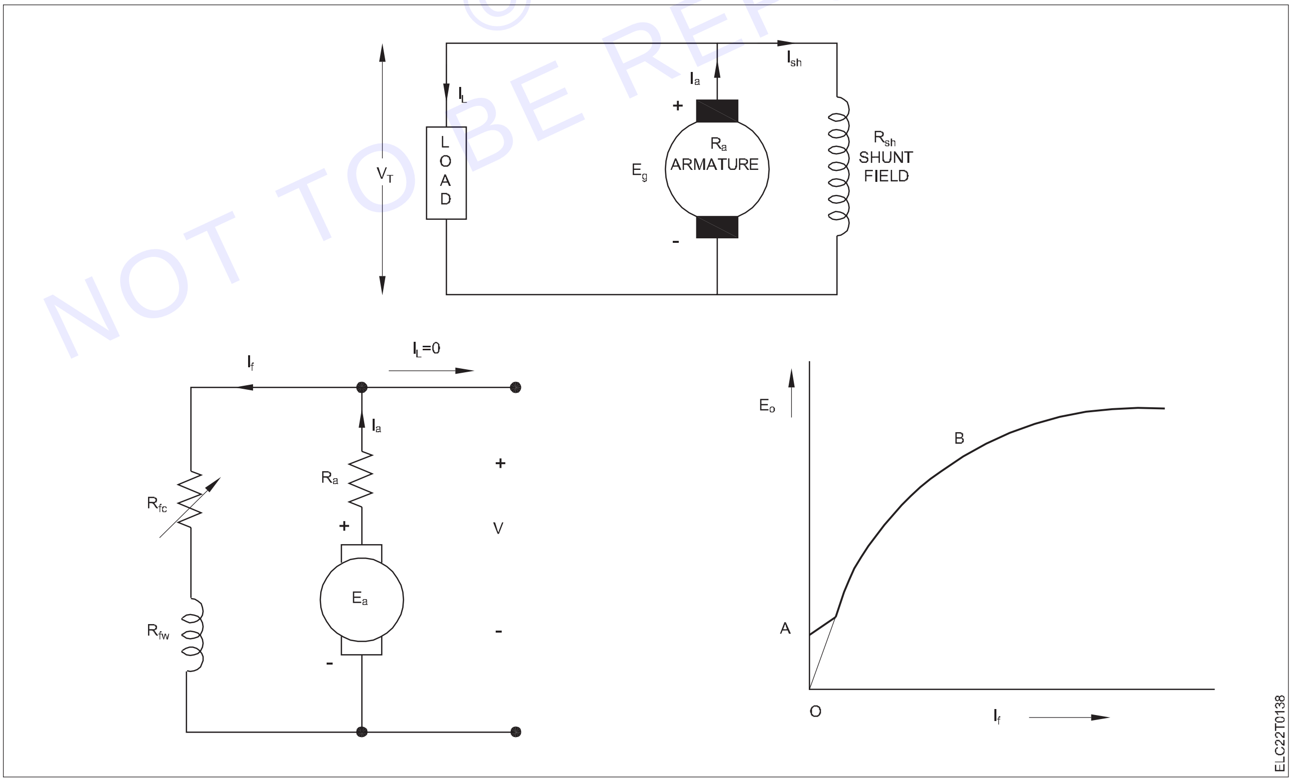
- Terminal voltage varies with load
- Used as line boosters in DC Distribution &long transmission lines

DC SHUNT GENERATOR

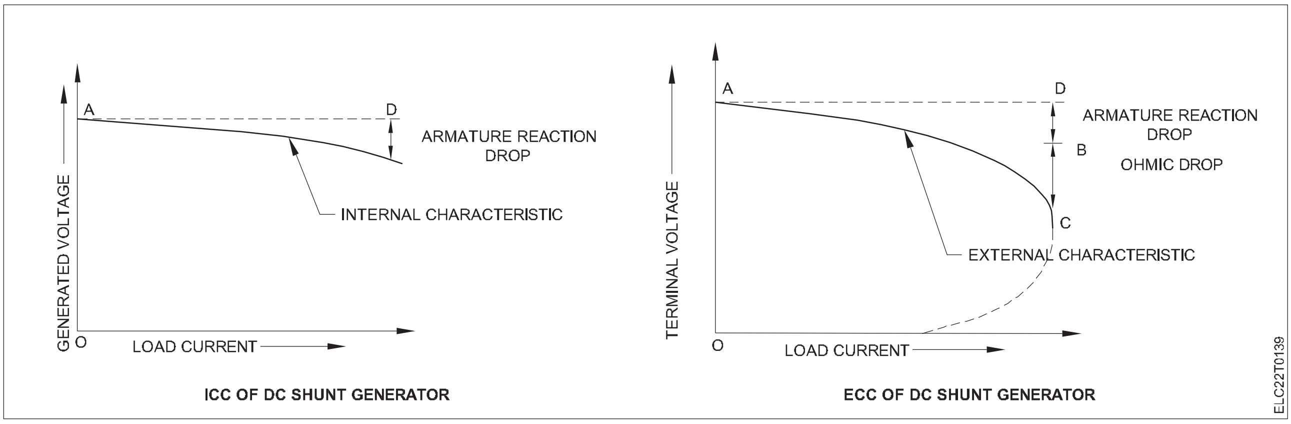
V_T=I x R

V= $E_g - I_a R_a$

I_a= I_a + I



Applications of dc shunt generators



- Constant voltage applications
- Battery charging
- Electroplating
- Welding purposes.

Conditions of build up of voltage

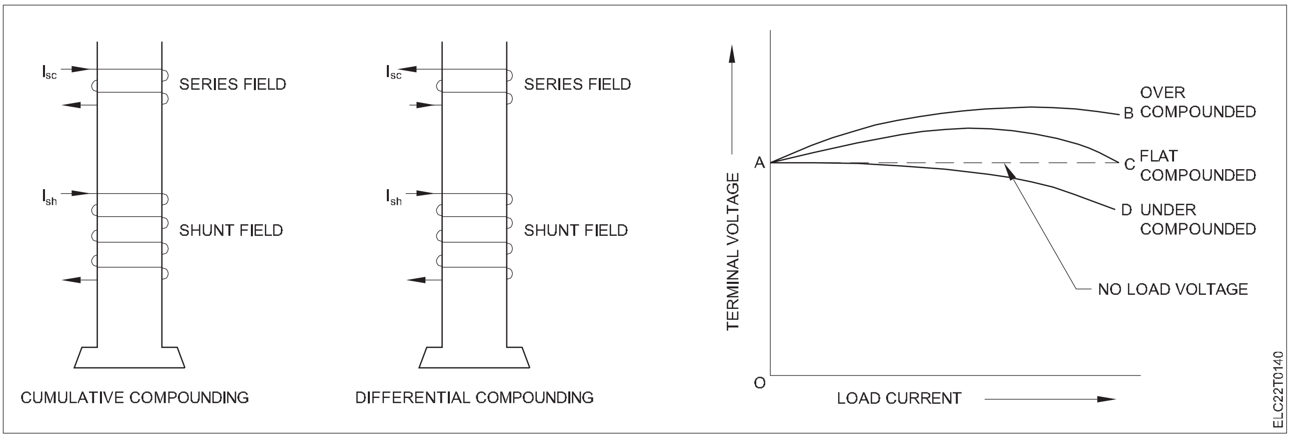
- Common conditions – Series and Shunt
- Residual magnetism
- Proper polarity of field winding to armature
- To aid increase in flux
- Proper Direction of Rotation
- Use flashing to get residual magnetism or
- Run the machine as DC Motor

Build up of voltage in shunt generator

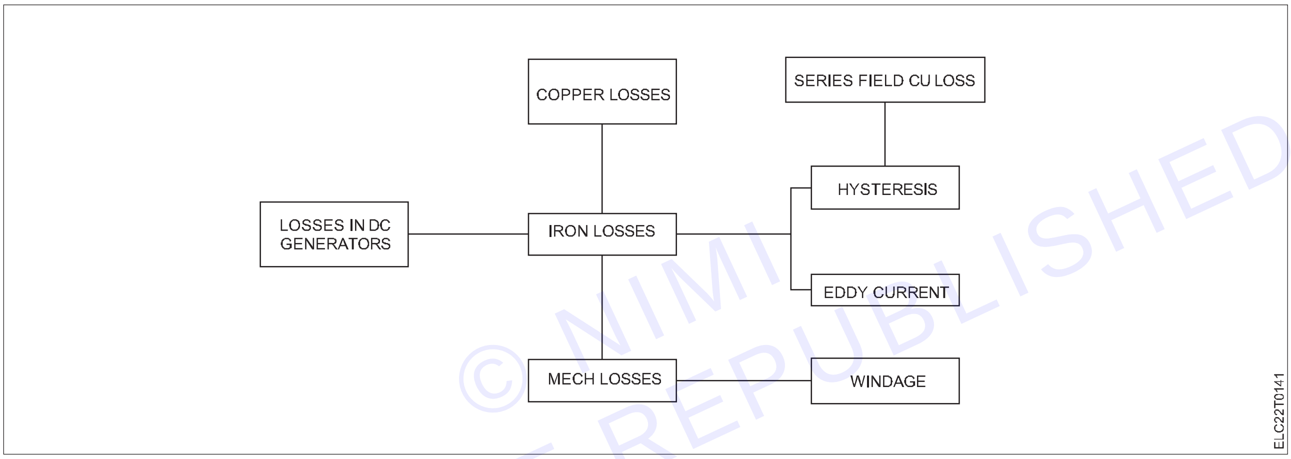
- Start without load or light load
- High load at start will cause less field current and fail in build up
- Shunt field be less than "Critical Resistance"
- Load critical resistance.
- Resistance of shunt field beyond which shunt generator will fail to excite
- Critical speed- the minimum speed below which the shunt generator will fail to excite

Build up of voltage in series generator

- Compound have series and shunt field
- Long shunt or short shunt
- When series field aid shunt field flux – Cumulatively compounded
- When series field OPPOSE shunt field flux – Differentially compounded



DC generators- power stage



Losses in a dc generator

- Losses in dc machines appear as heat.
- They raise the temperature of the machine.
- Losses also lower the efficiency of the machine.
- Losses include:

 1 Copper losses.

 2 Iron losses.

 3 Mechanical losses

COPPER LOSSES

- Occur due to currents in the various windings.
- Armature copper loss = Ia^2 Ra
- Field copper loss = $I^2_{sh}R_f$ or V I_{sh}
- Also P = Series field copper loss = I^2 se R se

Magnetic loss or core loss

- Occur in the armature core of a dc machine.
- Types: Hysteresis & Eddy current loss.

Hysteresis loss

- Occurs in the armature of the dc machine
- magnetic field reversals as it passes under successive poles.
- Small amount of power wasted in reversal of magnetism is called hysteresis loss.
- In other words, due to magnetization & de-magnetization of core.
- $P_h = K_h f V B^{1.6}$ max Watts

V- volume of armature in m^3.

Eddy current loss

- emf induces in armature conductors
- in addition, small amount of voltage is also induced in the armature core
- this cause the circulating current in the armature core, called eddy current.
- Power loss due to this current is called eddy current loss.
- Eddy current can be reduced by making the core resistance high.
- Core resistance can be increased by making the core of thin, round iron sheets called laminations.
- Laminations are separated by varnish which has high resistance to avoid the flow of current from one lamination to the other.
- Pe = B^2max f^2 t^2 v Watts

Mechanical losses

- Friction loss e.g., bearing friction, brushes friction etc.
- Windage loss e.g., air friction of rotating parts.

Constant losses

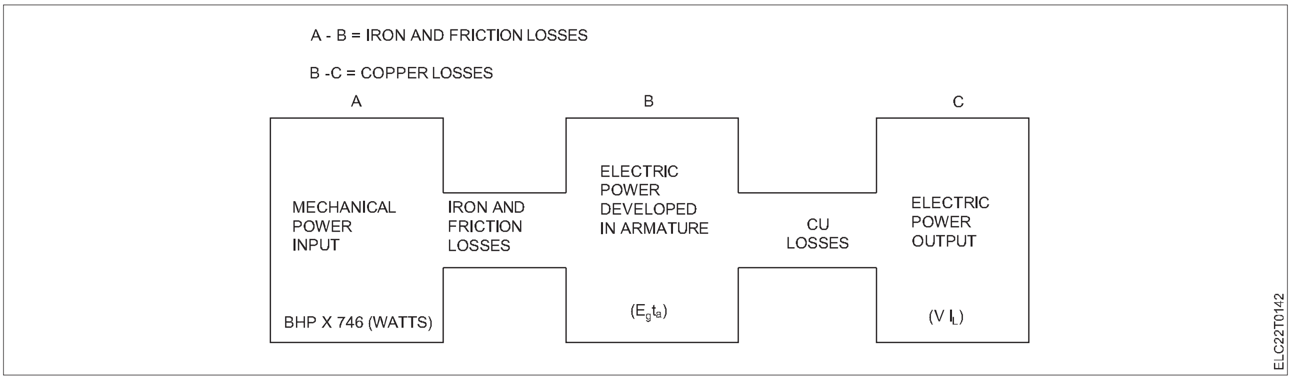
- (1) Iron losses
- (2) Mechanical losses
- (3) Shunt field losses.

Variable losses

- Armature copper loss ($I_a^2 R_a$)
- Series field copper loss ($I_{se}^2 R_{se}$).

Power stages of a dc generator

Power stages of a dc generator tell us how much mechanical power is converted into electrical power and into losses.



Efficiency of dc generator

η = Output / Input

$$\text{Mechanical Efficiency} = \frac{\text{Power developed in the armature}}{\text{Mechanical power input}} = \frac{B}{A} = \frac{EgIa}{BHP \times 746}$$

$$\text{Electrical Efficiency} = \frac{\text{General electrical power input}}{\text{Power developed in armature}}$$

$$= \frac{C}{B} = \frac{VI}{EgIa}$$

$$\text{Overall Efficiency} = \frac{\text{General electrical power input}}{\text{Mechanical power input}}$$

$$= \frac{C}{A} = \frac{VI}{BHP \times 746}$$

Condition for maximum efficiency

$$\text{Generator output} = V I_L$$
$$\text{Generator input} = \text{Output} + \text{Losses}$$
$$= V I_L + \text{Variable losses} + \text{Constant losses}$$
$$= VI_L + I_a^2 R_a + W_C$$
$$= VI_L + (I_L + I_{sh})^2 R_a + W_C \qquad [\because I_a = I_L + I_{sh}]$$

As $I_{SH} <<< I_L$, so neglect shunt current.

Therefore

Generator Input = $V I_L + I_L^2 R_a + W_c$

η = Output / Input

= $V I_L / V I_L + I_L^2 R_a + Wc$

= $V / [V + I_L Ra + Wc / I_L]$

For maximum efficiency, denominator should be minimum. Take the derivative of denominator with respect to IL (variable parameter) and equate to zero.

$d / d I_L [V + I_L Ra + Wc / I_L] = 0$

$[0 + Ra + (-W_c / I_L^2) = 0$

$I_L^2 Ra = Wc$

Variable losses = Constant losses

VOLTAGE REGULATION (VR)

Change voltage from no-load voltage to full-load voltage, expressed as percentage of no-load voltage, at constant speed

$$\% \text{ Voltage regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

Lower the regulation, better the output.

Problem # 1

A 20 KW dc shunt generator has the following losses at full-load:

Mechanical losses = 300 W; Iron losses = 400 W; Shunt Cu. loss = 120 W, Armature copper loss = 600 W

Calculate the efficiency at (i) No-load (ii) 25 % load.

Solution

Efficiency at no-load?

Stray losses = mechanical losses + iron losses = 700 W

Total constant losses at no-load=$P_{stray} + P_{Sh, Cu}$ = 820 W

Efficiency at no-load will be zero.

Efficiency at 25 % Full - load?

Constant losses = 820 W

Arm. Cu. loss at 25 % of full-load = $(25/100)^2$ x 600 = 37.5 W

Total losses = constant losses + armature copper loss = 857.5 W

Output at 25 % of full-load = 25 % of 20 KW = 5 KW

Total input = Output + total Losses = 5 KW + 857.5 W = 5857.5 W

Efficiency = output x 100 / input = 5000 x 100 / 5857.5 = 85.4 %

Problem # 2

A shunt generator delivers 195 A at terminal voltage of 200 V. The armature resistance and shunt field resistance are 0.03 ohms and 40 ohms respectively. The iron and friction losses (stray losses) are equal to 900 watts. Calculate the following:

- EMF generated?
- Copper losses?
- Output of the prime mover?
- Commercial efficiency?
- Mechanical efficiency?
- Electrical efficiency?
- EMF generated?

I SH = V / R f = 200 / 40 = 5 A

I a = Load current + field current

= 195 A + 5 A = 200 A

Armature voltage drop = I a Ra = 200 x 0.03 = 6 V

EMF generated = V + Ia Ra = 200 + 6 = 206 V

- Copper loss?

Armature copper losses = I^2aR a

= 200 x 200 x 0.03 = 1200 W

Shunt copper loss = P SH = V I SH = 200 x 5 = 1000 W

{P SH = I^2_{SH} R_{SH}= 1000 W}

Total copper loss = 1200 + 1000 = 2200 W

- Output of the prime mover?

Total losses = Total copper losses + stray losses

= 2200 W + 900 W

= 3100 W

Load Output = V I_L = 200 x 195

= 39000 W

Output of P/mover = Input of the generator

= generator output + losses

= 39000 W + 3100 W

= 42.1 KW

- Mechanical efficiency?

$$\text{Mech. Efficiency} = \frac{\text{E. power developed in armature}}{\text{Mechanical power input}}$$

Power developed in arm. = Gen-input – Stray losses

= 42.1 KW – 900 W

= 41.2 KW{Egla = 41.2 KW}

Generator input = output of prime mover

= 42.1 KW

Mech. Efficiency = 41.2 KW x 100 / 42.1 KW Electrical efficiency?

Elect. Efficiency = V I_L /Egla

= V I_L / (Gen-input – Stray losses)

= V I_L /Egla

= 39000 x 100 / 41200

= 94.66 %

Commercial efficiency = Elect. power output

Mech. power input

= V I_L / Mech-IP

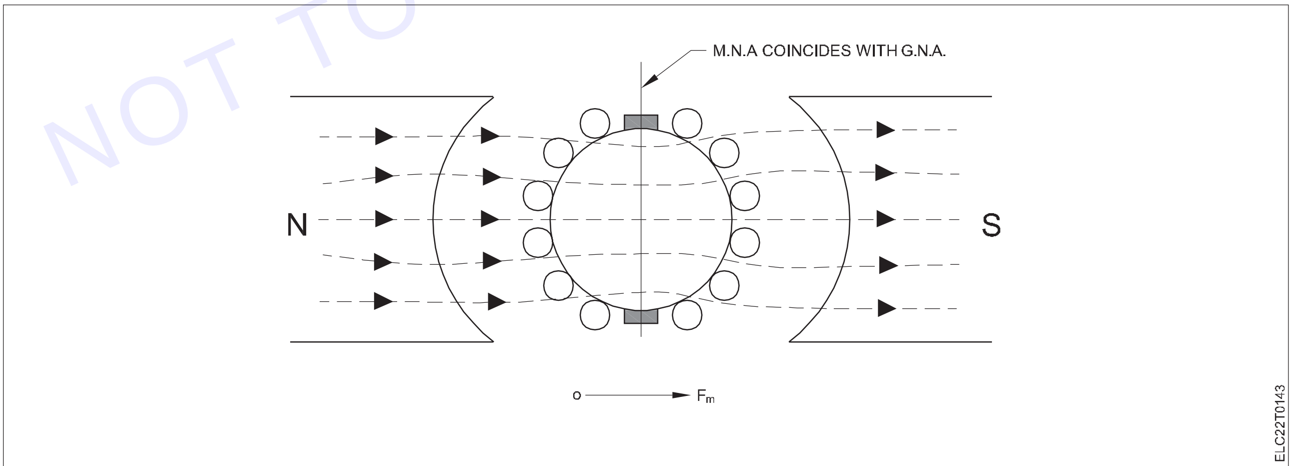
= 39000 x100 /42100

= 92.64 %

Armature reaction

Few terms first;

GNA- Midway b/w opposite adjacent poles and right angle to center line of poles



MNA-Perpendicular to lines of force

Brush placing axis -Least spark

LPT -End of pole tip which first contact armature in DOR

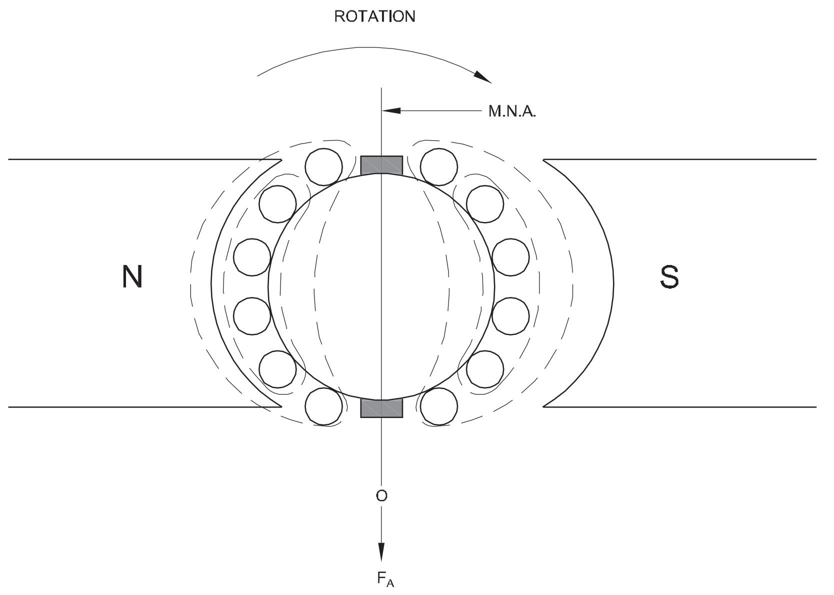
TPT -End of pole tip which comes in contact later with armature in DOR

LPT

- End of pole tip which first contact armature in DOR

TPT

- End of pole tip which comes in contact later with armature in DOR



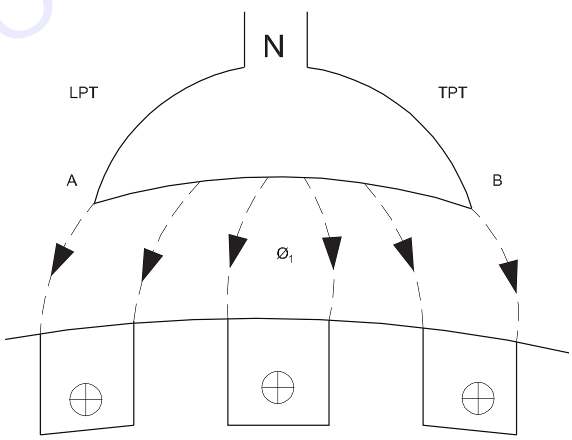
What is armature reaction ?

The effect of armature flux produced by the armature current on the main flux or field flux.

- Effects…The armature reaction produces the following two undesirable effects:

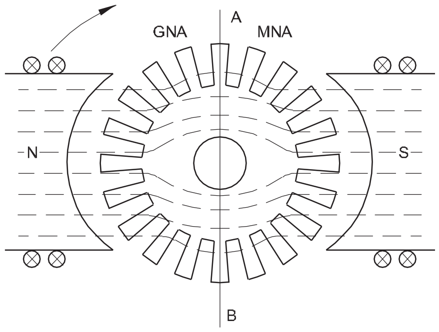
1 It demagnetizes or weakens the main flux.

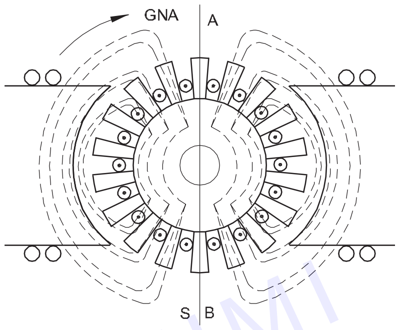
2 It cross-magnetizes or distorts the main flux



Explanation

- Consider main field flux only
- Consider armature flux only





Effects of armature reaction

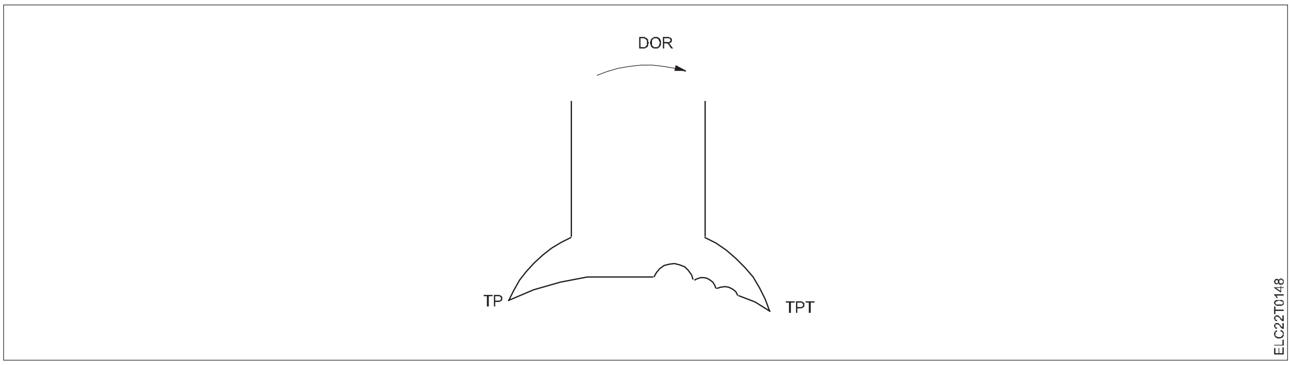
- MNA is shifted
- The path of the magnetic field is distorted
- The flux concentrates on trailing pole tip
- Effectively the field is demagnetised as the leading pole tip is weakened

Problems due to armature reaction

- Causes sparking as MNA is shifted
- EMF generated is reduced as field is weakened
- Causes more wear and tear of brushes.
- Efficiency is reduced
- Reduced capacity
- Remedy for armature reaction Making slots in TPT
- Rarely used as only one DOR can be use

Remedy for armature reaction

- Staggering



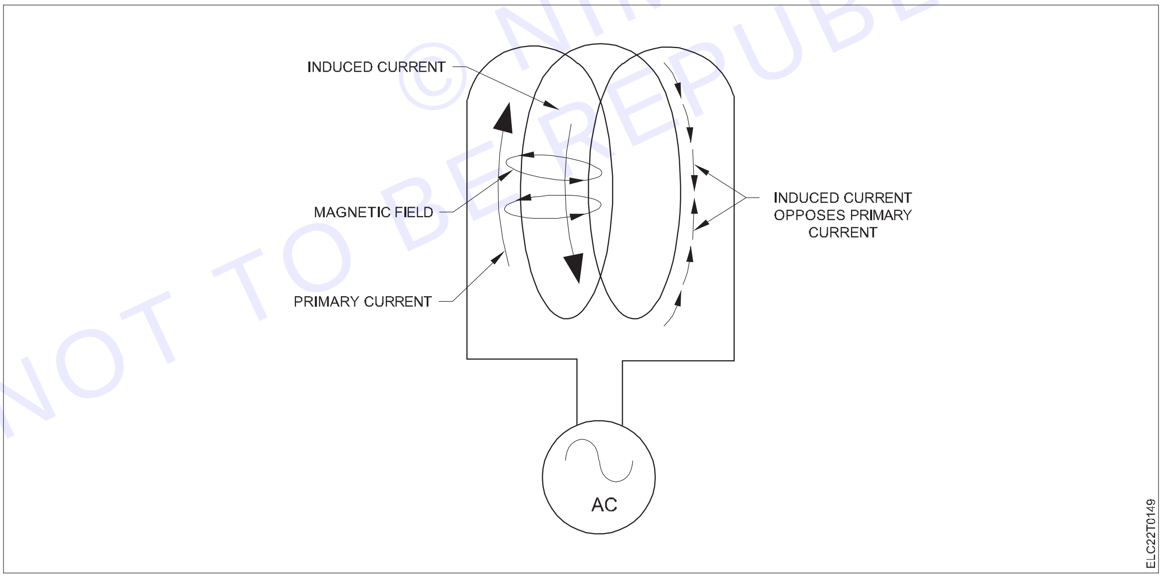
Remedy for armature reaction

- Compensating winding embedded the face in the pole shoe in series with armature current is in opposite direction to armature conductors directly below the pole shoes.
- compensating windings produce magnetic field, which varies directly with armature current.
- compensating winding field oppose the magnetic field of the armature,
- they tend to cancel the effects of the armature magnetic field causing armature reaction

Commutation

Self-induced voltage in coil

Reactance voltage



The changes in the direction of current in a coil after the period of short circuiting the coil is called commutation.

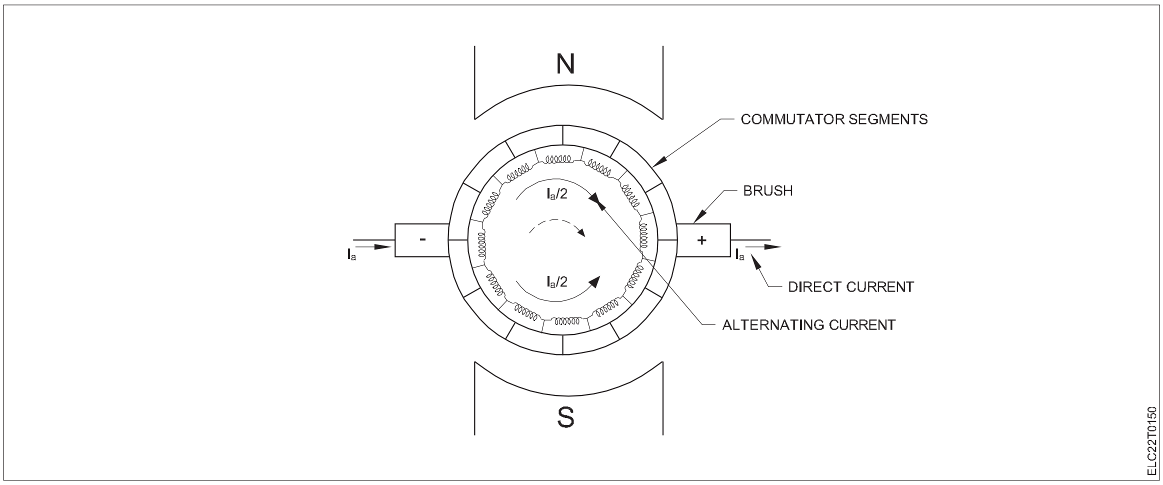
Effects of poor commutation

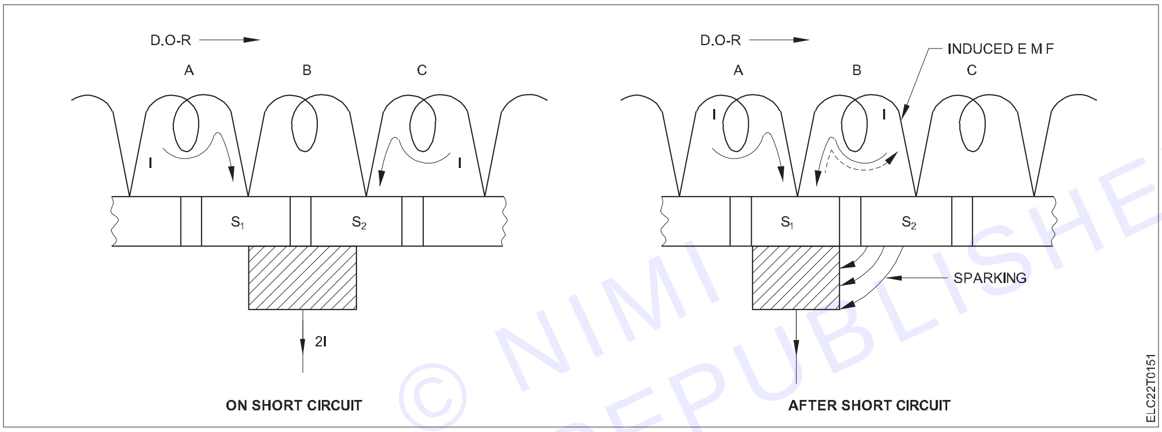
Sparking

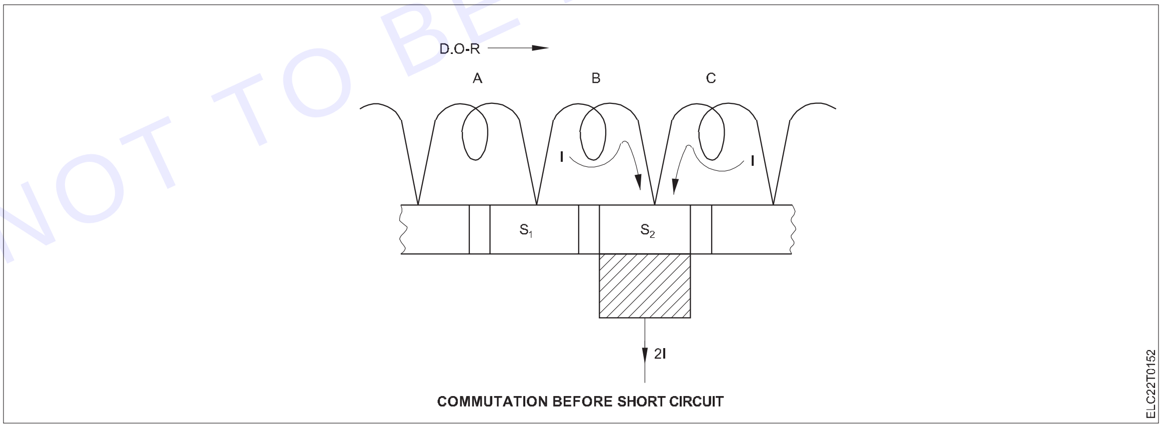
- Commutator Surface carbonization & short circuit
- Damage to commutator
- Increased spark
- Excess heat may result loose connection in riser

Remedy / improving commutation

- Resistance Commutation
- EMF commutation

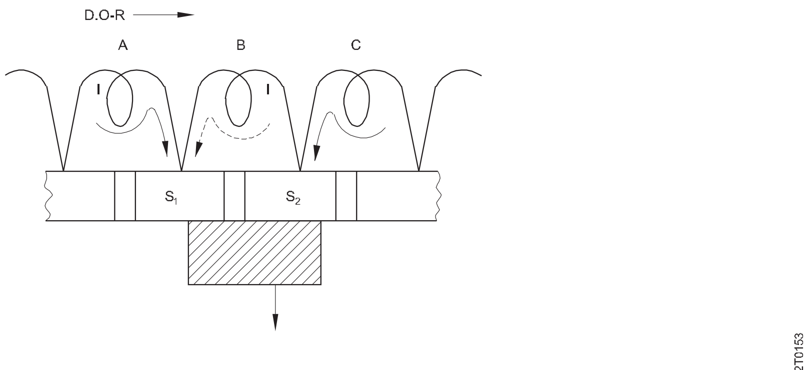






1 Resistance commutation

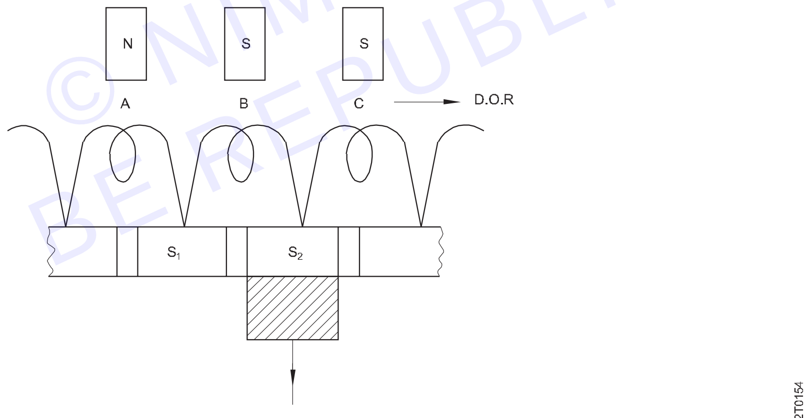
- Reactance voltage in the short circuited coil creates commutation problem
- Change in direction of current before and after short circuit creates reactance voltage.
- Increased brush resistance in resistance commutationslow down the change in direction of current
- Reduces the reactance voltage
- Reduces commutation problem



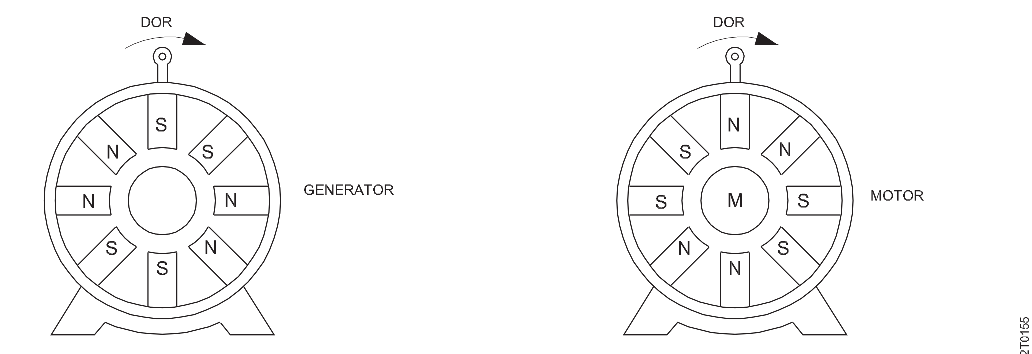
REMEDY OF COMMUTATION BY RESISTANCE COMMUTATION METHOD

EMF commutation

- Interpoles / compoles /auxiliary poles are small poles
- Equal in number of main poles
- connected in series with armature
- Reactance voltage in short circuited coil is neutralized by the interpole magnetic field



REMEDY OF COMMUTATION BY EMF COMMUTATION METHOD



POLARITY OF POLE IN CASE OF GENERATOR

POLARITY OF POLE IN CASE OF MOTOR

- EMF commutation to some extent armature reaction
- Interpoles are provided only for improving commutation
- The LPT is strengthened by Interpole TPT
- Machine with Interpole has 25% more capacity

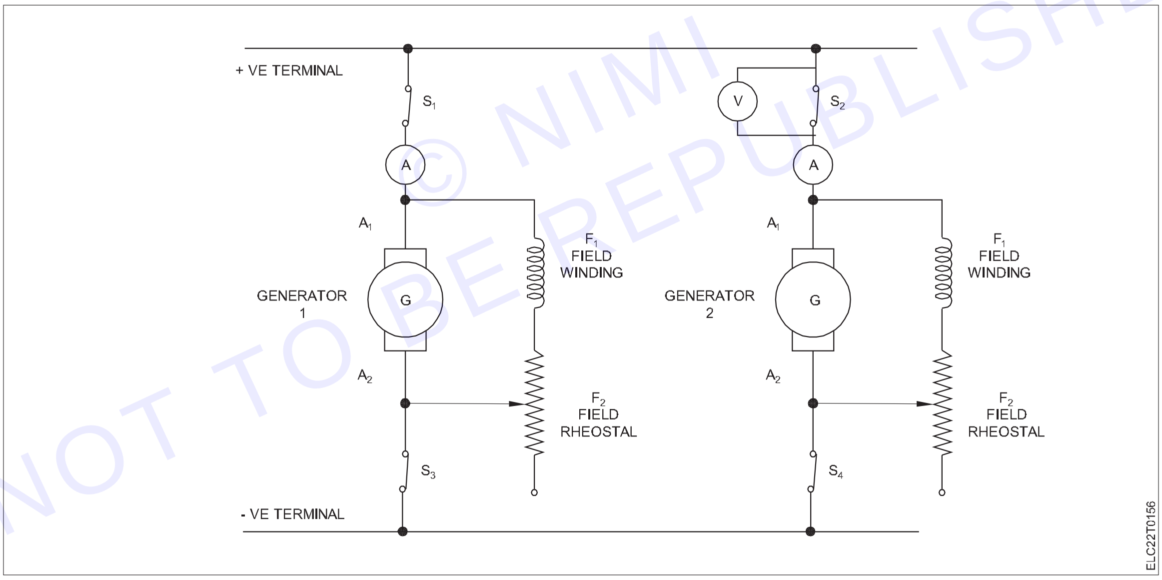
Parallel operation of dc generators

Advantages of parallel operation

- Continuity of service
- Efficiency
- Maintenance and repair
- Increasing plant capacity
- Non-availability of single large unit

Conditions of parallel operation

- Same voltage
- Same polarity
- Power rating need NOT be the same



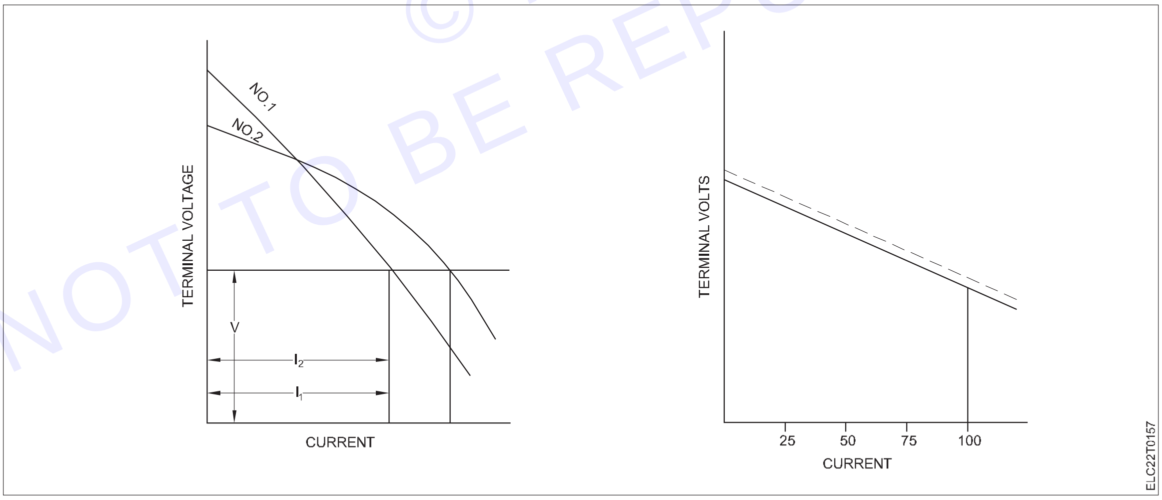
Parallel operation of dc shunt generator

- generator 1 is connected &supplying to the load.
- Now generator 2 is to be connected in parallel.
- Start the prime mover of the generator 2
- Adjusted its speed is to the rated value.
- Close the switch S4 .
- The voltmeter connected across S2 measures voltage
- Adjust excitation of the generator 2 till the voltmeter reads zero.
- The zero on the voltmeter ensures that the voltage of incoming generator 2 is same as that of generator 1 or the bus bar voltage.
- closed the switch S2which connects the incoming generator 2 in parallel with the system.

- Under these conditions, the generator 2 will not take any load as its induced e.m.f. is same as bus bar voltage and there will not be any flow of current between two points at same potential.
- This generator is thus said to be floating on bus bars.
- In order that the generator 2 should supply current, it is necessary that its induced e.m.f. should be more than the bus bar voltage.
- field of gen2 is strengthened till it takes proper share of load.
- field of generator 1 is weakened to maintain the bus bar voltage constant.

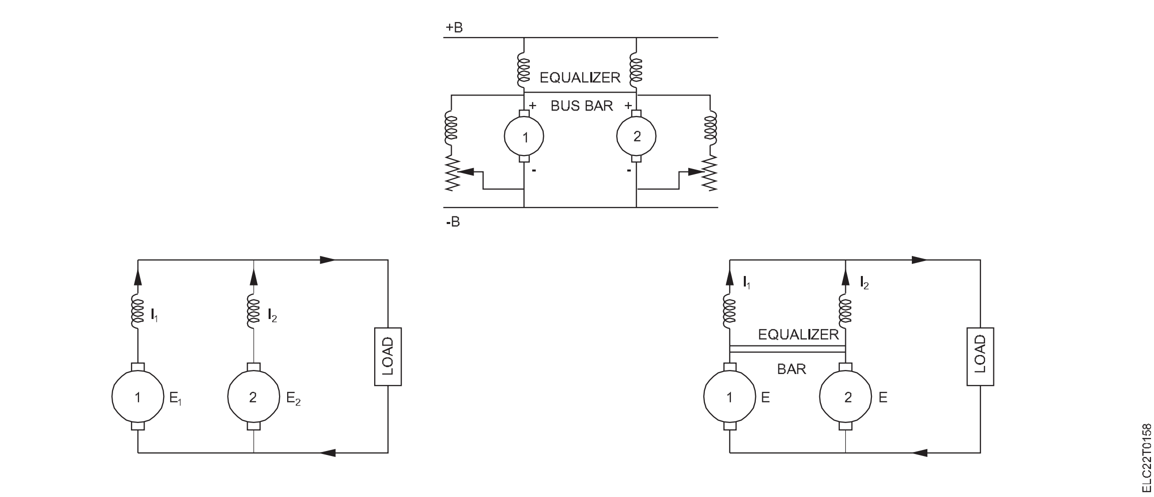
Load sharing of dc generators

- To take a generator out of service, its field is weakened until the ammeter of the generator to be cleared reads zero.
- This method helps in avoiding any shock or sudden disruption to the prime-mover or to the system itself.
- Shunt Generator has slightly drooping voltage characteristics,
- most suited for stable parallel operation.
- Therefore, once paralleled, they're automatically command in parallel.
- Two parallel shunt generators having equal no-load voltages share the load in such a ratio that the load current of each machine produces the same drop in each generator.
- In the case of two parallel generators having unequal no-load voltages, the load currents produce sufficient voltage drops in each so as to keep their terminal voltage the same.
- The generator with the least drop assumes greater share of the change in bus load.
- Paralleled generators with different power ratings but the same voltage regulation will divide any oncoming bus load in direct proportion to their respective power ratings.



Parallel operation of dc compound generators

- Rising characteristics of the usual compounded generators
- the parallel operation of such generators is unstable
- Let each generator is taking its proper share of load.
- Let us now assume that for some reason, generator No.1 takes a slightly increased load.
- In that case, the current passing through its series winding increases;
- further strengthens its field and so raises its generated e.m.f. thus causing it to take still more load.



- Since the system load is assumed to be constant, generator No. 2 will drop some of its load
- thereby weakening its series field which will result in its further dropping off its load.
- This effect is cumulative.
- Generator No. 1 will, therefore, tend to take the entire load and finally drive generator No. 2 as a motor. For making the parallel operation of over-compound and level-compound generators stable, they are always used with an equalizer bar connected to the armature ends of the series coils of the generators.
- The equalizer bar is a conductor of low resistance.
- Suppose that generator No. 1 starts taking more than its proper share of load.
- Its series field current is increased.
- But now this increased current passes partly through the series field coil of generator No. 1 and partly it flows via the equalizer bar through the series field winding of generator No. 2.
- Hence, the generators are affected in a similar manner with the result the generator No. 1 cannot take the entire load.

Troubleshooting in DC machines

At the end of this exercise you shall be able to

- use the trouble shooting chart to rectify defects in i) DC machines in general ii) DC motors iii) DC generators.

DC machines have Power problems which are not normally found in AC machines. DC motors and generators have commutators and brushes, which cause special problems. If the commutator is properly maintained, it will give many years of useful service.

Chart 1 deals with DC motors and Chart 2 is for DC generator.

Chart 1

Troubleshooting chart for DC motors

Symptoms	Cause	Remedies
Motor will not start	a) Open circuit in starter. b) Low or no terminal voltage. c) Bearing frozen. d) Overload. e) Excessive friction.	a) Check for open starting resistor, b) Check the incoming voltage with name-plate rating and correct the supply voltage. c) Recondition the shaft and replace the bearing. d) Reduce the load. e) Check the bearing lubrication to make sure that the oil is sufficient quantity and of good quality. Disconnect motor from driven machine and turn motor by hand to see if trouble is in motor. Strip and reassemble motor; then check part by part for proper location and fit. Straighten or replace bent Shaft.
Motor stops after running short time	a) Motor is not getting power. b) Motor is started with weak or no c) Motor torque insufficient to drive	a) Check voltage in the motor terminals: also fuses and overload relay. Rectify the defect. b) If adjustable-speed motor, check field.the rheostat for correct If correct, check the condition of rheostat. Check the field coils for open winding. Check the wiring for loose or broken condition c) Check the line voltage with name load. plate rating. Use larger motor or one with suitable characteristic to match the load.
Motor runs too slow under load.	a) Line voltage too low. b) Brushes ahead of neutral plane. c) Overload.	a) Rectify the supply voltage or under load check and remove any excess resistance in supply line, connections or controller. b) Set brushes on neutral plane. c) Check to see that load does not exceed allowable load on motor.
Motor runs too fast under load.	a) Weak field. b) Line voltage too high. c) Brushes are out of neutral plane.	a) Check for resistance in shunt-under load field circuits. Check for grounds. b) Correct high voltage condition. c) Set brushes on neutral plane.

Chart 2

Troubleshooting chart for DC Generators

Symptoms	Cause	Remedies
Generator fails to build up voltage	a) The direction of rotation must have been reversed.	a) Change the direction of rotation
	b) Brushes not resting on the commutator.	b) Brushes to be set over the commutator in correct position.
	c) Residual magnetism is completely lost.	c) Run the generator as a DC motor or sometime (few seconds) or connect the field circuit to a battery or DC voltage to reestablish the residual magnetism.
	d) Generator speed is too low.	d) Generator speed should be restored to normal speed by increasing the prime mover speed.
	e) Short circuit in the armature.	e) Rectify the short circuit in the armature.
	f) Open circuit in the armature.	f) Test and rectify the open circuit.
	g) Short circuit in the field circuit.	g) Test and rectify the short circuit which may be in the coil. Faulty coil will show much less resistance than a good coil.
	h) Open circuit in field winding.	h) Check the continuity of the circuit and rectify the defect.

Maintenance procedure for DC machines

At the end of this exercise you shall be able to

- state what is meant by preventive maintenance and its importance
- describe the recommended maintenance schedule for DC motors
- explain how to maintain the maintenance record.

Preventive maintenance: Preventive maintenance of Power machines consists of routinely scheduled periodical inspections, tests, planned minor maintenance repairs and a system of maintaining inspection records for future reference. Preventive maintenance is a combination of routine and planned operations.

Routine operations: Routine operations are those which follow fixed schedules to maintain Power motors at daily, weekly or at other fixed intervals.

Planned operation: By contrast, planned operation consists of additional work which is performed at irregular frequencies, and is determined by inspection and previous operating experience or the details of defects found in the maintenance records.

Necessity of preventive maintenance: By carrying out an effective preventive maintenance programme on Power machines, we can eliminate major failures of the machines, accidents, heavy repair costs and loss of production time. Proper preventive maintenance will lead to economy of operation, less down-time, dependable machine operation, longer machine life and lower overall cost of maintenance and repair.

Scheduling of preventive maintenance: Routine periodical inspection and tests may be scheduled to be carried out daily, weekly, monthly, half-yearly and annually depending upon the following factors.

- The importance of the motor/generator in the production
- The duty cycle of the machineator.
- The age of the machine
- The earlier history of the machine
- The environment in which the machine operates
- The recommendations of the manufacturer.

Recommended maintenance schedule for machines: While carrying out routine periodical maintenance, an electrician will make full use of his senses to diagnose and locate problems in Power machines. The sense of smell directs attention to burning insulation: the sense of feel detects excessive heating in winding or bearing; the sense of hearing detects excessive noise, speed or vibration and the sense of sight detects excessive sparking and many other mechanical faults.

Sensory impressions must also be supplemented by various testing procedures to localize the trouble. A thorough understanding of Power principles and the efficient use of test equipment are important to an electrician during this phase of operation.

The following maintenance schedule is recommended for DC machines.

1 Daily maintenance

- Examine visually earth connections and machine leads.
- Check the sparking at the commutator.
- Check the motor windings for overheating. (The permissible maximum temperature is near about that which can be comfortably felt by hand.)
- Examine the control equipment.
- In the case of oil-ring lubricated machines
  a) examine the bearings to see that the oil rings are working
  b) note the temperature of the bearings
  c) add oil, if necessary
  d) check end play.
- Check for unusual noise at the machine while running.

2 Weekly maintenance

- Examine the commutator and brushes.
- Check belt tension. In cases where this is excessive it should immediately be reduced. In the case of sleeve-bearing machines, the air gap between the rotor and stator should be checked.
- Blow out air through the windings of protected type machines situated in dusty locations.
- Examine the starting equipment for burnt contacts where machine is started and stopped frequently.
- Examine oil in the case of oil-ring lubricated bearings for contamination by dust, grit, etc.(This can be roughly judged from the colour of the oil.)
- Check foundation bolts and other fasteners.

3 Monthly maintenance

- Overhaul controllers.
- Inspect and clean the oil circuit breakers.
- Renew the oil in high- speed bearings which are in damp and dusty locations.
- Wipe the brush-holders and check the bedding of brushes of DC machines.
- Test the insulation of windings.

4 Half-yearly maintenance

- Check the brushes and replace, if necessary.
- Check the windings of machines subjected to corrosive and other elements. If necessary, bake the windings and varnish.
- Check the brush tension and adjust, if necessary.
- Check the grease in the ball and roller bearings, and make it up, where necessary, taking care to avoid overfilling.
- Check the current input to the motor or the output of the generator and compare it with normal values.
- Drain all the oil bearings, wash with petrol to which a few drops of oil have been added; flush with lubricating oil and refill with clean oil.

5 Annual maintenance

- Check all the high speed bearings, and renew, if necessary.
- Blow out all the machine winding thoroughly with clean dry air. Make sure that the pressure is not that high as to damage the insulation.
- Clean and varnish the oily windings.
- Overhaul the motors which have been subjected to severe operating conditions.
- Renew the switch and fuse contacts, if damaged.
- Check the oil in the starter and the grease/oil in the bearings.
- Renew the oil in the starters subjected to damp or corrosive elements.
- Check the switch conditions, resistance to earth between motor/generator windings, control gear and wiring.
- Check the resistance of earth connections.
- Check the air gaps in between the armature and field.
- Test the insulation of windings before and after overhauling the motors/generators.

6 Records

- Maintain a register giving one or more pages for each machine, and record therein all important inspections and maintenance works carried out from time to time. These records should show past performance, normal insulation level, air gap measurements, nature of repairs and interval between previous repairs and other important information which would be of help for good performance and maintenance.

While routine maintenance could be done either during the working of the machine or during short interval `down' periods, the planned maintenance requires to be done during holidays or by taking shut-downs of small duration.

Planned maintenance schedule needs to be decided, based on the routine maintenance reports entered in the maintenance card.

Initial test results	Page 1
Resistance value of shunt winding ____________	
Resistance value of series winding ____________	
Resistance value of armature ____________	
Insulation resistance value between	
armature and shunt field ____________	
armature and series field ____________	
series field and shunt field____________	
armature and frame____________	
shunt field and frame____________	
series field and frame____________	
The 2^{nd} page gives the record of maintenance carried out, and, in particular the defects noted therein.	

Maintenance record

Maintaining a system of inspection records is a must in preventive maintenance schedule. This system uses a register as stated above or cards as shown below which are kept in the master file. By referring to these maintenance cards, the foreman can schedule the planned maintenance.

Maintenance card: The 1st page gives initial test results etc pertaining to the machine.

A careful study of the maintenance card helps the foreman to plan the shut-down date to facilitate early overhauling or planned maintenance schedule to prevent a major breakdown.

Method of maintenance: During the routine maintenance inspection, the investigations and adjustment to be carried out for the parts and accessories of the motors/generators are given below to improve the efficiency of preventive maintenance.

- Clean daily the motor/generator, switch gear and associated cables free from dirt, dust and grease. Use dry compressed air to drive away the dust from the machines.
- Check the bearing daily for excessive noise and temperature. If required, re-grease or re-oil the bearing with the same grade of grease/oil as in original. Do not mix different grades of grease together as it may result in forming sludge or acids, and spoil the bearings.
- Check the machine daily against strains of water or oil or grease which may leak from the surroundings. Take the necessary protective steps to prevent the leakage.
- Check daily the belts, gears and coupling for looseness, vibration and noise. Adjust/replace the parts, if found defective.
- Check weekly the brushes and the commutator for sparking and wear.
- Check weekly the bearing for proper lubrication.
- Check weekly the terminals and switch contacts.
- Inspect the brushes and the commutator once in a month for excessive wear, chatter and sparking. Worn-out brushes need to be replaced with the same grade brushes. Check spring tension on the brushes, and adjust, if necessary. Badly worn-out commutators need to be turned in a lathe or be replaced.
- Check monthly the brushes for proper seating. If necessary, reshape the brushes to proper curvature to suit the commutator surface.
- Check monthly the end plates and the shaft for excessive end play.
- Check monthly the main and auxiliary contact points of the switch gear for wear, pitting and burns. Badly worn out contact point needs replacement. Check the connection terminals for loose connection and scales or burning. Rectify the defects.
- Test monthly once the field windings and armature for insulation and ground faults. Low reading of insulation below 1 megohm indicates weak insulation. Dry out the winding, and re-varnish, if necessary.
- Check monthly once the foundation bolt and other fasteners for tightness.
- Once a year undercut the mica in between the commutator bars. Test the commutator and armature for shorts, open and ground faults.

Maintenance card

Report on routine maintenance **Page 2**

Date of maintenance	Scheduled maintenance carried out	Defects noted	Attended by (Signature)	Reported to (Signature)	Remarks

The 3rd page gives the details of the test carried out in the motor at intervals with corresponding readings

Maintenance card

Report on test details **Page 3**

Date of Test	Schedule	Test particulars	Test results	Tested by (Signature)	Reported to (Signature)	Remarks

From the above it is clear that atleast once in a year, the motor/generator needs a thorough overhauling in addition to frequent routine maintenance.

The 4th page gives the details of the defects, causes and repair carried out

Motor service card **Page 4**

Date of repair	Repair and parts replaced	Cause	Repaired by (Signature)	Supervised by (Signature)	Remarks

DC Motor principle and types

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

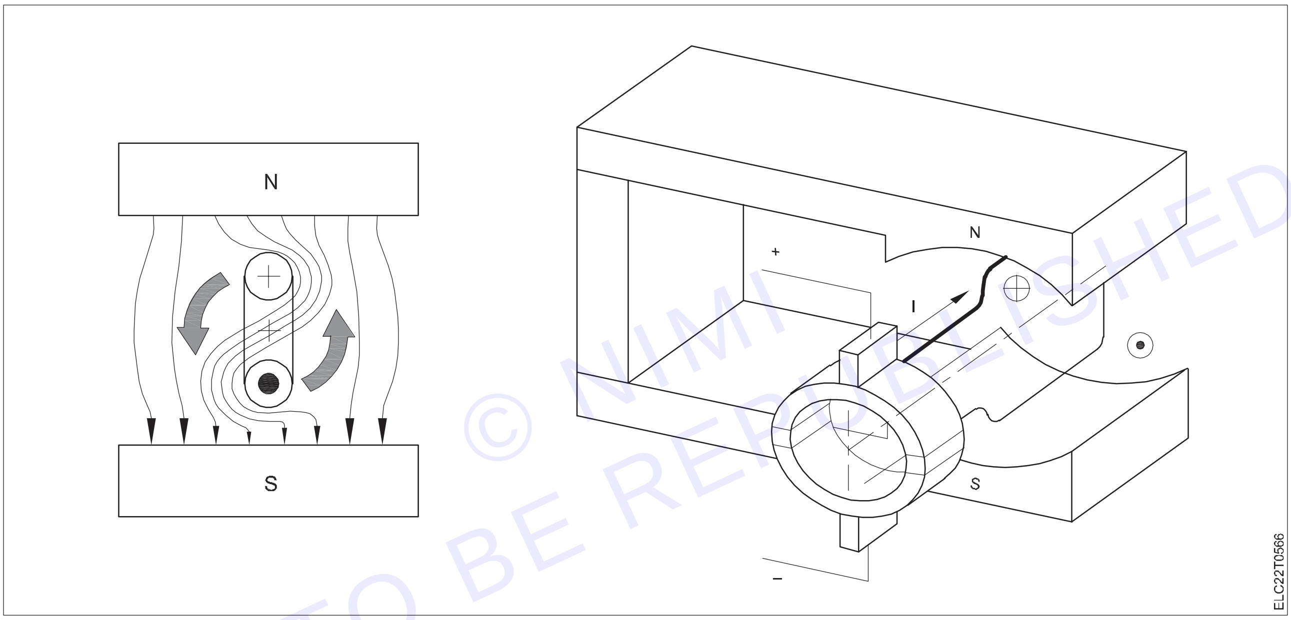
- explain the working principle of a DC motor
- state the different types of DC motor construction, working principle of 2 point 3 point and 4 point starts
- state the necessosty of series shunt is compound motor its application
- explain speed control methods of a DC motor.

Basics of dc motors

A DC moor is a machine which converts DC electrical energy in to mechanical energy

Working principle

Whenever a current carrying conductor is kept in a uniform magnetic field, a force will be setup on the conductor so as to move it at right angle to the magnetic field.



Significance of the back E.M.F.

Back emf Eb = (ΦZN/60) x (P/A)

Voltage equation:

V = Eb + IaRa

Power equation

V Ia = EbIa + Ia2Ra

EbIa = Electrical equivalent of mechanical power Pm developed in the armature

Ia2Ra = Copper loss in the armature.

TORQUE

The turning twisting moment of force about an axis

Let Force is F Newton

r = Radius of shaft in meters

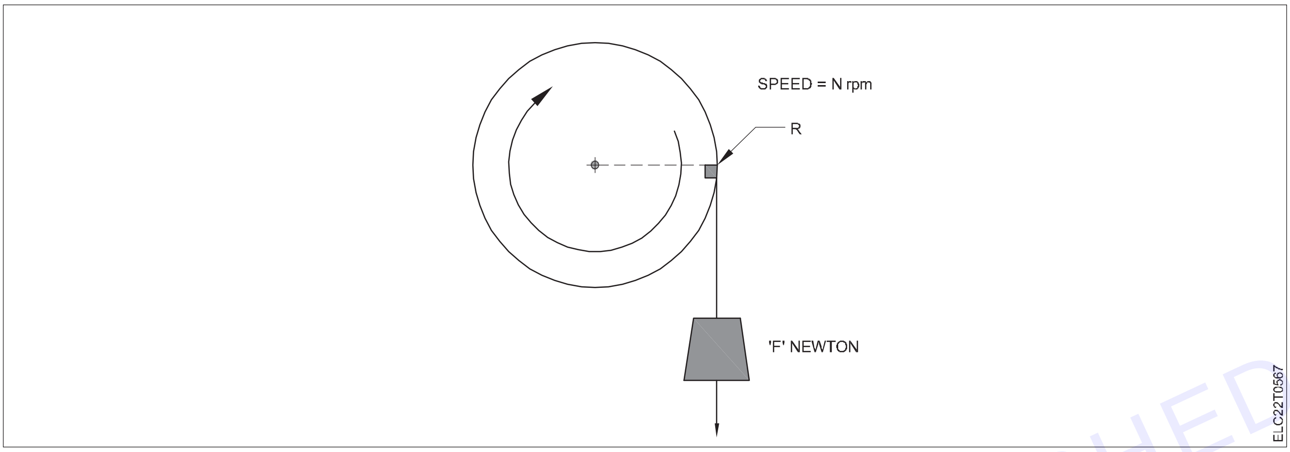
Then Torque T = F x r (Nm)

Power developed by shaft

Work done = Force x distance

Distance travelled by the shaft in 1 revolution = perimeter = 2 x πxr

Work done by shaft in 1 rev = F x 2 x π x r



As F x r = T,

Work done = F x2π x r = 2 πT

Speed = N rpm $\frac{N}{60}$ or rps. Or $\frac{60}{N}$ second for 1 revolution 60 N

N Power developed by shaft in 1 second $= 2\pi T \times \frac{N}{60}$ J/S or Watts

Horse power developed $= \frac{2\pi .NT}{60 \times 746}$ HP

Torques in dc motors

- Gross torque / armature torque
- Shaft torque
- Lost torque
- Power equation of a shaft $= \frac{2\pi N.T}{60}$ J/S or watts
- Power equation of a shaft $= \frac{2\pi .N.T}{60 \times 746}$ HP

Armature torque(ta) / gross torque

Power equation of a shaft $= \frac{2\pi N.T}{60}$ J/S or watts

- Power developed in armature $= Eb\,Ia = \frac{2\pi .NT_a}{60}$

Armature Torque $Ta = \frac{Eb\,Ia \times 60}{2\pi N}$

$$= \frac{9.55\,Eb\,Ia}{N} N-m$$

Shaft torque(tsh) / output torque

- Power equation of a shaft $= \frac{2\pi .NT}{60x746} BHP$

$$BHP = \frac{2\pi .NT_{sh}}{60 \times 746}$$

- Shaft torque $T_{sh} = \frac{BHP \times 60 \times 746}{2\pi N}$
- $T_a = \frac{E_b I_a \times 60}{2\pi N}$

$$E_b = \frac{\Phi ZN \times P}{60 \times a}$$

$$T_a = \frac{\Phi ZN \times P}{60 \times a} \times \frac{I_a \times 60}{2\pi N}$$

- Ta = K. Φ Ia or
- Tα α Φ Iα

$$E_b = \frac{\Phi ZN \times P}{60 \times a}$$

$$E_b = K \times \Phi N$$

$$\frac{E_b}{\Phi} = K \times N \quad \text{or}$$

$$N \alpha \frac{E_b}{\Phi}$$

Speed,back emf and fluxes

$$N1 = \frac{k\, E_{b1}}{\Phi_1} ----$$

$$N2 = \frac{k\, E_{b2}}{\Phi_2} ----$$

$$\frac{N1}{N2} = \frac{E_{b1}}{\Phi_1} \times \frac{\Phi_2}{E_{b2}}$$

$$\frac{N1}{N2} = \frac{E_{b1}}{E_{b2}} \times \frac{\Phi_2}{\Phi_1}$$

Flux and torques

$$\frac{T_{a1}}{T_{a2}} = \frac{I_{a1}}{I_{a2}} \times \frac{\Phi_1}{\Phi_2}$$

Characteristics of dc motors

The important characteristics of dc motor are:

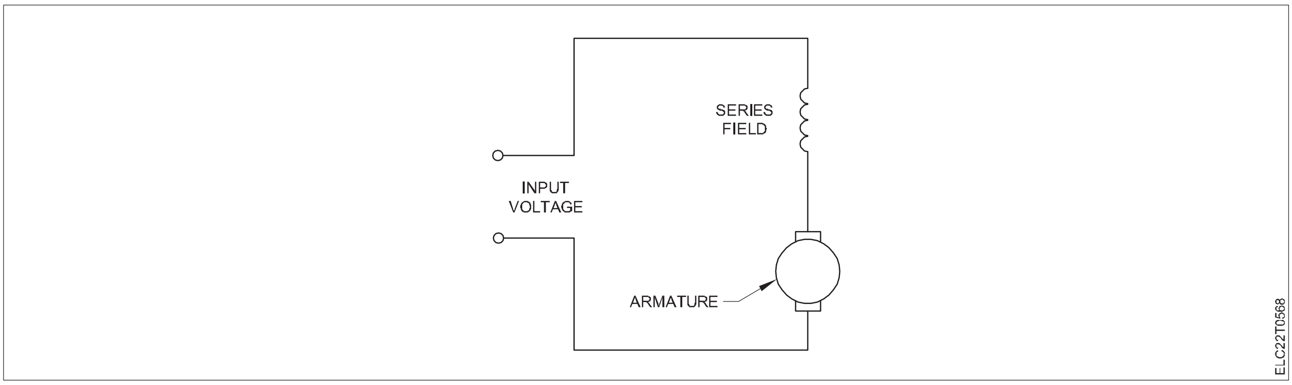
1 Torque/ Armature current(T / Ia)

2 Speed / Armature current (N / Ia)

3 Speed /Torque (N /T)

Dc series motor

IN series motor, speed decreases as load increases. At heavy load, torque is high and speed become low. When load is removed completely / lightly loaded the speed of the motor becomes dangerously high. So DC Series motor is not used in places where load may be removed. A DC series motor can never be started without load / light load. It is a variable speed motor;self-adjust as per load.



Characteristics of dc series motor

- In series motor
- T αØI_a
- Ø αI_a
- T α Ia^2.

After saturation, flux is constant

so T αIa

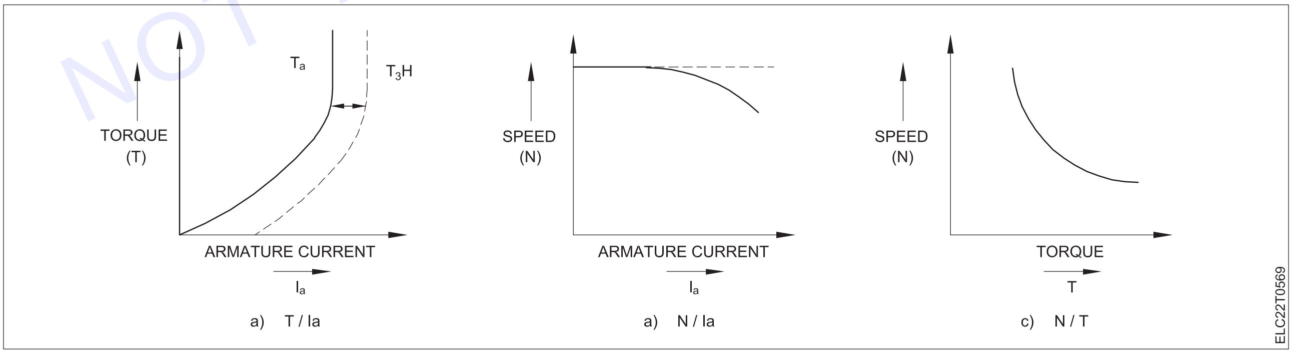
T / Ia Characteristics

Here from the equation at first curve is parabolaand then it is straight line.

N / Ia Characteristics

Speed torque characteristics

(N/T) In DC series motor, at constant load, Eb is constant.



Characteristics of dc shunt motor

In DC shunt motor the field is connected in parallel with armature. Field current is almost constant. Sofield flux almost remains constant.

Torque / armature current characteristics

General Torque equation

Ta α Φ Ia

For Shunt motor, Ta α Ia

In this characteristic torque is directlyproportional to the armature current.

T α Φ Ia,

where, Φ is constant, so,

T α Ia

whichgivesstraight line in practically.

Speed / armature current characteristics

$$N \alpha \frac{E.b}{\Phi}$$

For shunt motor, Φ is alomst constant

"Eb" is approximately constant

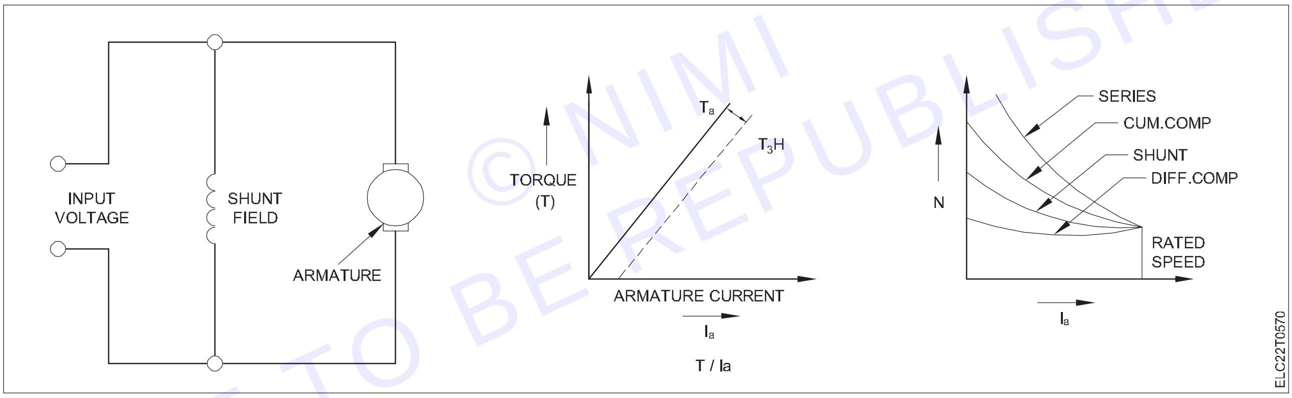
Constant speed motor

when loaded;

Practically "Eb" and "Φ" decrease,

"Eb" decreases a little more

Hence speed decreases with increase in load



Speed / torque characteristics

In a DC shunt motor, when load is increased, speed reduces slightly. Eb reduces due to that.

So I_a is increased. Torque increases within capacity of motor.

Characteristics of dccompound motors

Compound motor have combine characteristics of both series and shunt motors. It can be started with load. Load can be thrown suddenly. Effectively, is used in intermittent loads

Cumulatively compounded

Generally compounded motors are connected cumulatively

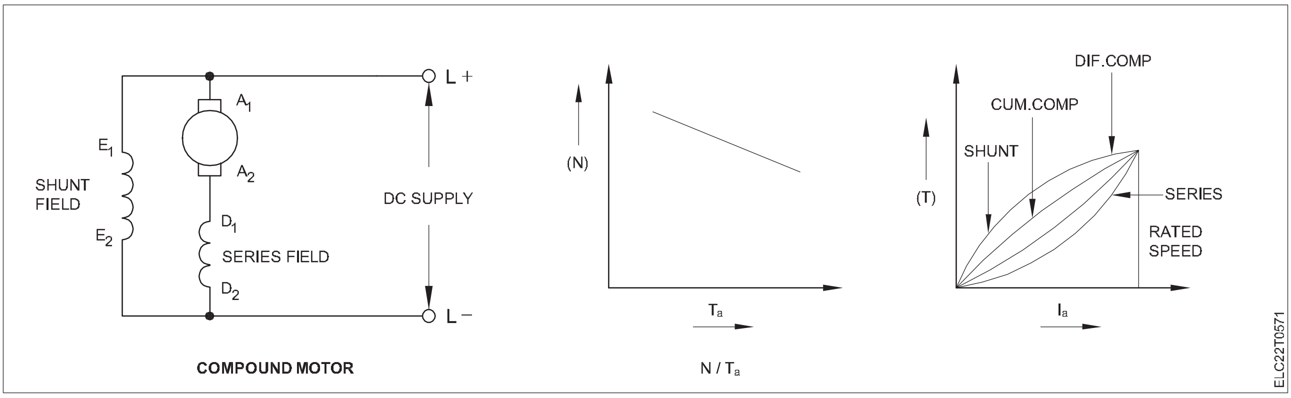
Application

Rolling mills, heavy tool machines, shears, conveyors

Differential compound

If heavy load is suddenly given; Series filed current increases and its flux. Total flux reduces, Attains a dangerously high speed

Not used where load may be removed



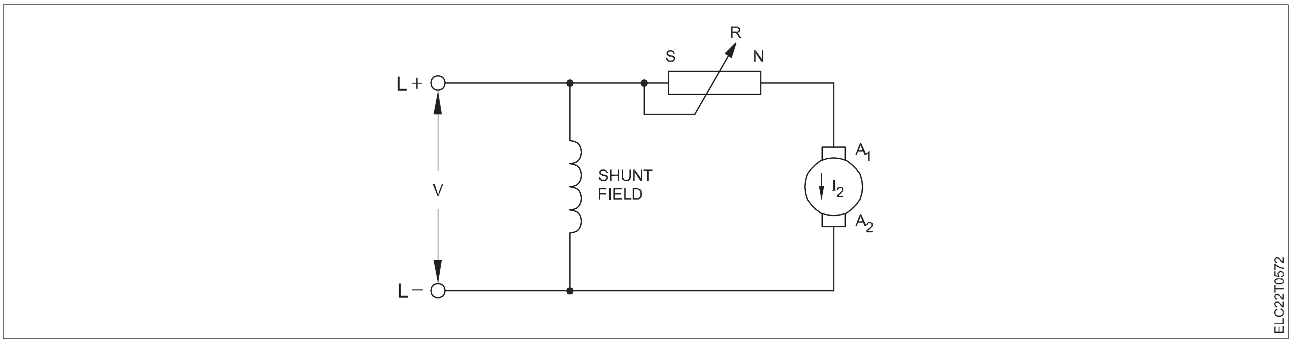
Type of motor	Characteristics	Applications
Shunt	Approximately constant speed Adjustable speed Medium starting torque (Up to 1.5 F.L. torque)	For driving constant speed line shafting Lathes Centrifugal pumps Machine tools Blowers and fans Reciprocating pumps
Series	Variable speed Adjustable variying speed High Starting torque	For traction work i.e. Electric locomotives Rapid transit systems. Trolley, cars etc. Cranes and hoists Conveyors
Comulative Compound	Variable speed Adjustable varying speed High starting torque	For intermittent high torque loads For shears and punches Elevators Conveyors Heavy planers Heavy planers Rolling mills; Ice machines; Printing presses; Air compressors

DC motor starters

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

- state the necessity of starter for a DC motor
- state the different types of starters - construction and working principle of 2-point, 3-point and 4-point starters.

Necessity of starters: Since the armature is stationary before starting, the back emf which is proportional to speed is zero. As the armature resistance is very small, if the rated voltage is applied to the armature, it will draw many times the full load current, and thereby, there is every possibility of damaging the armature due to heavy starting current. Therefore, the starting current should be limited to a safe value. This is done by inserting a resistance in series with the armature at the time of starting for a period of 5 to 10 seconds. As the motor gains in speed, back emf is built up, and then the starting resistance could be gradually cut off. Fig 1 shows such an arrangement. Resistance R is fully included in the armature circuit by keeping the moving arm in position `S' at the time of starting, and then it is moved towards position `N' to exclude the resistance `R' when the motor has picked up its speed. But such an arrangement will be purely manual and needs constant monitoring. For example, if the motor is running, the resistance `R' will be excluded, and the moving arm position will be at position `N'. In case the supply fails, the motor will stop but the moving arm will still be in position `N'. When the supply returns, as there is no resistance included in the armature circuit through `R', the armature may draw heavy current and may get damaged. To prevent such a happening a device called starter is used in motor circuits.



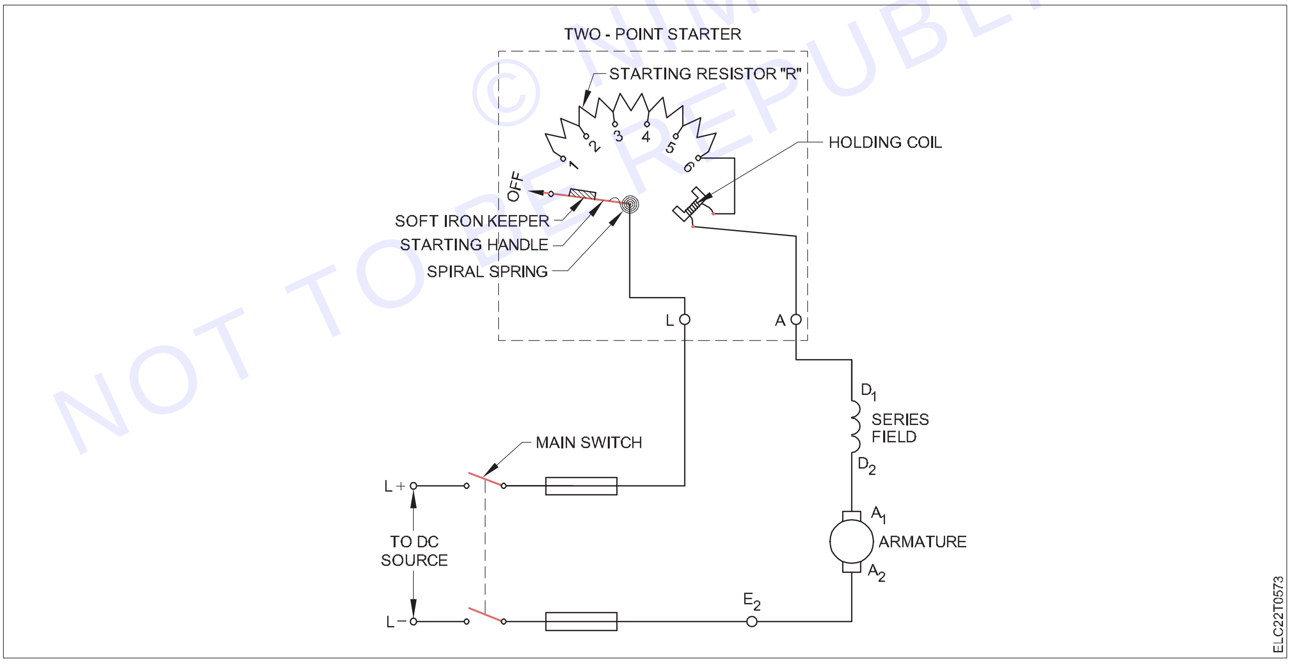
Types of starters: Starters used to start the DC motors are generally of three types.

- Two-point starter
- Three-point starter
- Four-point starter

Two-point starter: This contains the following components.

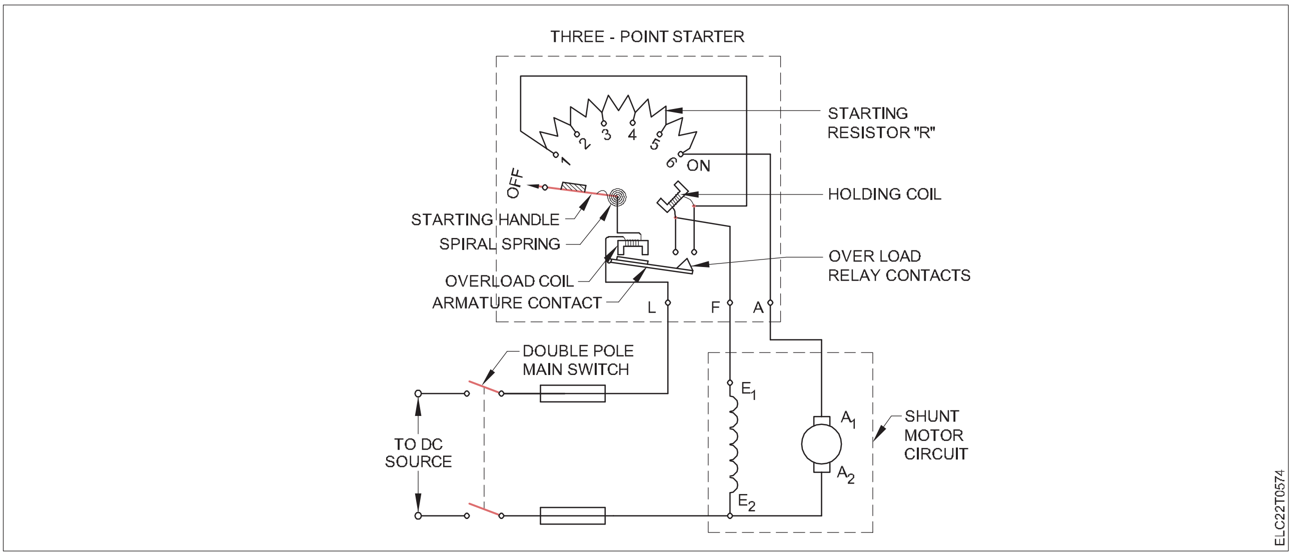
- The series resistor required for starting a motor.
- The contacts (brass studs) and switching arm required to include or exclude the resistor in the armature circuit.
- A spring on the handle to bring the handle to the `OFF' position when supply fails.
- An electromagnet to hold the handle in the `ON' position.

The two-point starter is frequently used with a DC series motor. The starting resistance, electromagnet armature and the series field are all connected in series as shown in Fig 2.



When the arm is moved to the first contact point, the circuit is completed, and the armature begins to rotate. As the armature speed increases, the arm is slowly moved towards the right side electromagnet, thereby the starter resistance is reduced. When the arm is against the electromagnet, complete starter resistance is cut off from the circuit.

Three-point starter: Fig 3 shows the internal diagram of a three(terminal) point starter connected to a DC shunt motor. The direct current supply is connected to the starter, the motor circuit through a double pole switch and suitable fuses. The starter has an insulated handle or knob for the operator's use. By moving the starter handle from the `off' position to the first brass contact (1) of the starter, the armature is connected across the line through the starting resistance. Note that the armature is in series with the total starting resistance. The shunt field, in series with the holding coil, is also connected across the line. In this mode of operation, the rush of the initial current to the armature is limited by the resistance. At the same time, the field current is at the maximum value to provide a good starting torque.

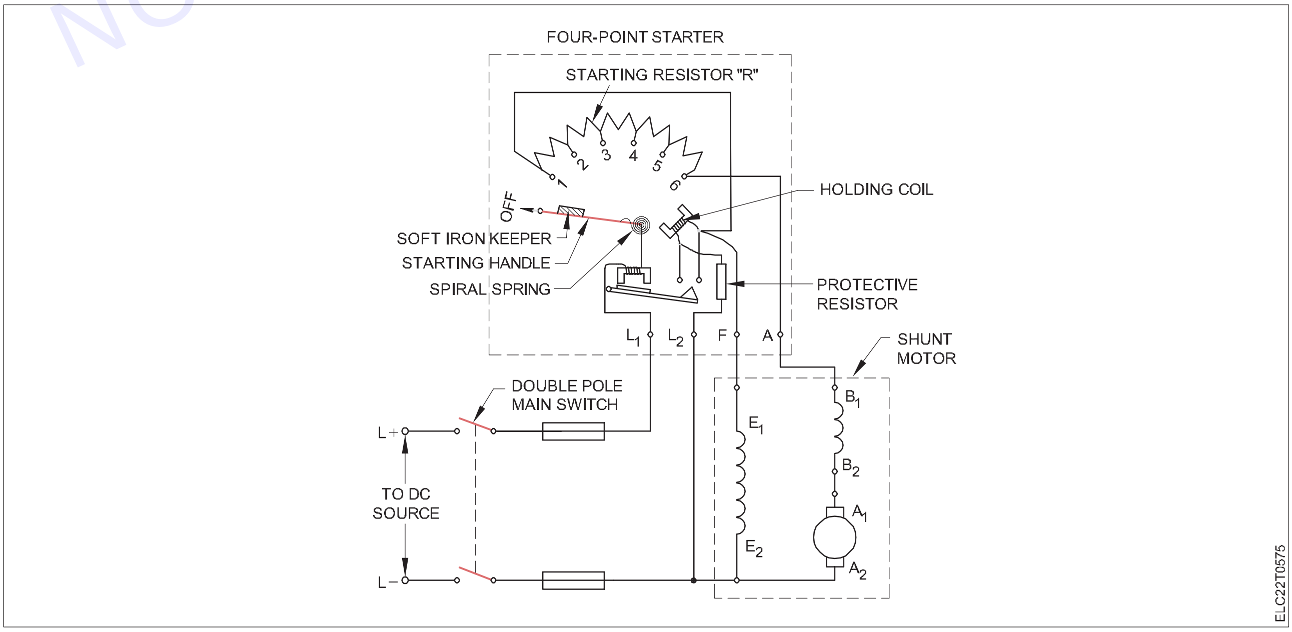


As the handle arm is moved to the right, the starting resistance is reduced and the motor gradually accelerates. When the last contact is reached, the armature is connected directly across the supply; thus, the motor is at full speed.

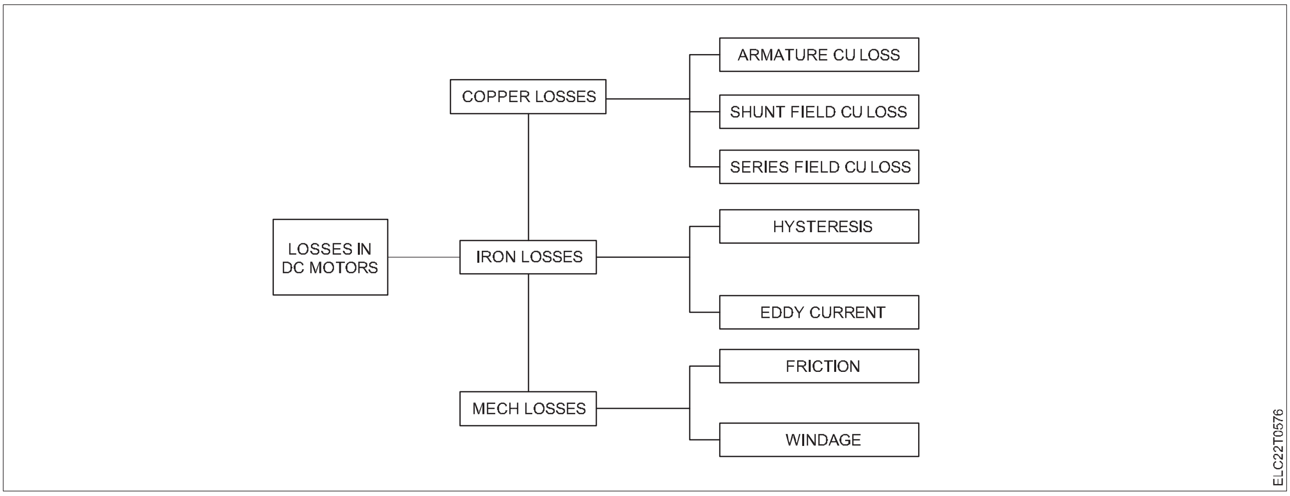
An overload coil is provided to prevent damage to the motor from overload. Under normal load condition, the flux produced by the over load coil will not be in a position to attract the armature contact. When the load current increases beyond a certain specified value, the flux of the over load coil will attract the armature. The contact points of the armature then short-circuit the holding coil and demagnetize it. This enables the handle to come to the `OFF' position due to the tension of the spiral spring.

This type of starter can be used to start both shunt and compound motors.

Four-point starter: In applications where many motor speeds are to be increased beyond their rated value, a four-terminal, face plate starter is used with the motor. The four(terminal) point starter, shown in Fig 4, differs from the three-point starter in that the holding coil is not connected in series with the shunt field. Instead, it is connected across the supply in series with a resistor. This resistor limits the current in the holding coil to the desired value. The holding coil serves as a no-voltage release rather than as a no-field release. If the line voltage drops below the desired value, the magnetic attraction of the holding coil is decreased, and then the spring pulls the starter handle back to the `off' position.



DC Motors- power stages



Losses in a dc motor

Losses in dc machines appear as heat.They raise the temperature of the machine. Losses also lower the efficiency of the machine.

Losses include:

1 Copper losses.

2 Iron losses.

3 Mechanical losses

Copper losses

- Occur due to currents in the various windings.
- Armature copper loss = Ia^2 Ra
- Field copper loss = I^2shRf / VI_{sh}
- Also P = Series field copper loss = I^2 se R se

Magnetic loss or core loss

- Occur in the armature core of a dc machine.
- Types: Hysteresis & Eddy current loss.

Hysteresis loss

Hysteresis Loss occurs in the armature of the dc machine. Magnetic field reversals occur as it passes under successive poles. Small amount of power wasted in reversal of magnetism is called hysteresis loss. In other words, due to magnetization & de-magnetization of core.

- $P_h = K_h$ f V $B^{1.6}$ max W/m^3

Eddy current loss

An emfis induced in armature conductors due to the rotation of armature. In addition, small amount of voltage is also induced in the armature core. Thiscause the circulating current in the armature core, called eddy current. Power loss due to this current is called eddy current loss. Eddy current can be reduced by making the core resistance high. Core resistance can be increased by making the core of thin, round iron sheets called laminations. Laminations are separated by varnish which has high resistance to avoid the flow of current from one lamination to the other.

Pe = B^2max f^2 t^2 Watts

Mechanical losses

Friction loss e.g., bearing friction, brushes friction etc. Windage loss e.g., air friction of rotating parts.

Constant losses

(1) Iron losses

(2) Mechanical losses

(3) Shunt field losses.

Variable losses

Armature copper loss (I^2 a Ra)

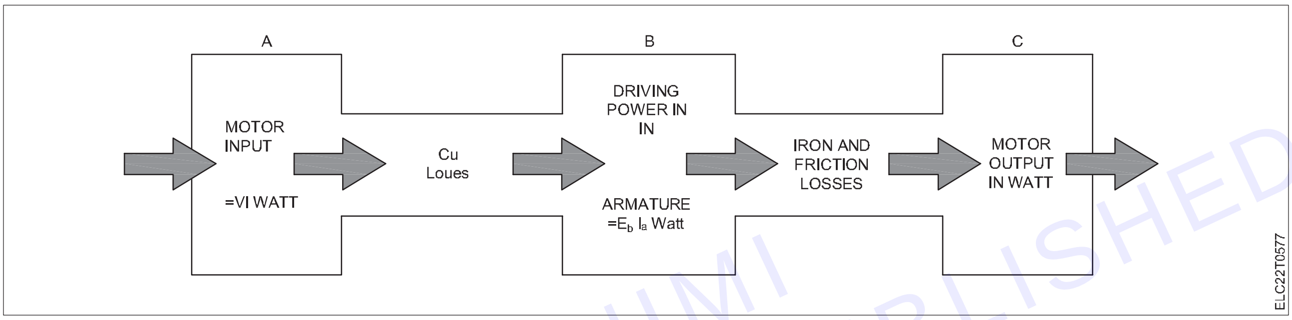
Series field copper loss (I^2 se R se).

Power stages of a dc motor

- Power stages of a dc motor tell us how much electrical power is converted into mechanical power and into losses.

  A- B = Copper losses

  B – C = Iron and friction losses



Electric braking: A motor may be brought to rest quickly

i Friction Braking or ii Electric Braking.

mechanical brake has drawback

Not a smooth stop. It depends on the condition of the braking surface. It is well as on the skill of the operator.

Electric braking

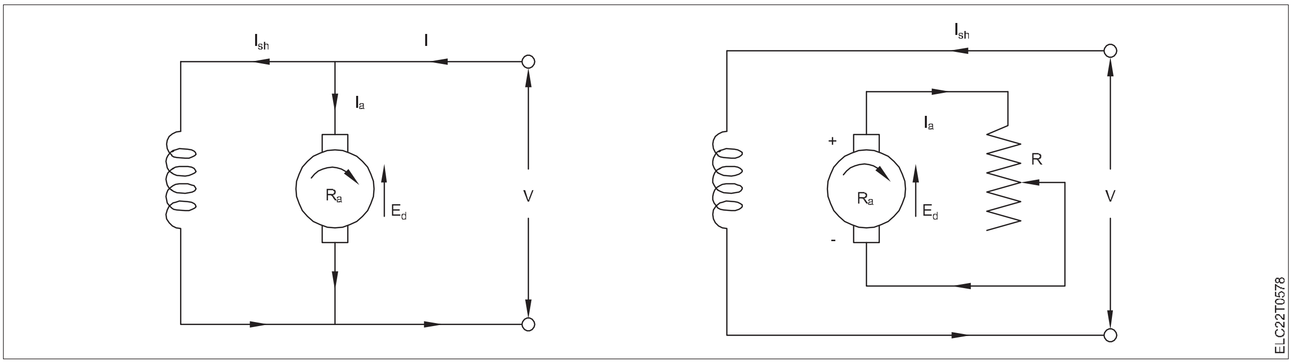
No brake lining levers and other mechanical gadgets. Efficient and smooth. Still a mechanical brake needed for standstill

1 Rheostatic or Dynamic braking

2 Plugging or Braking Reverse Current

3 Regenerative Braking

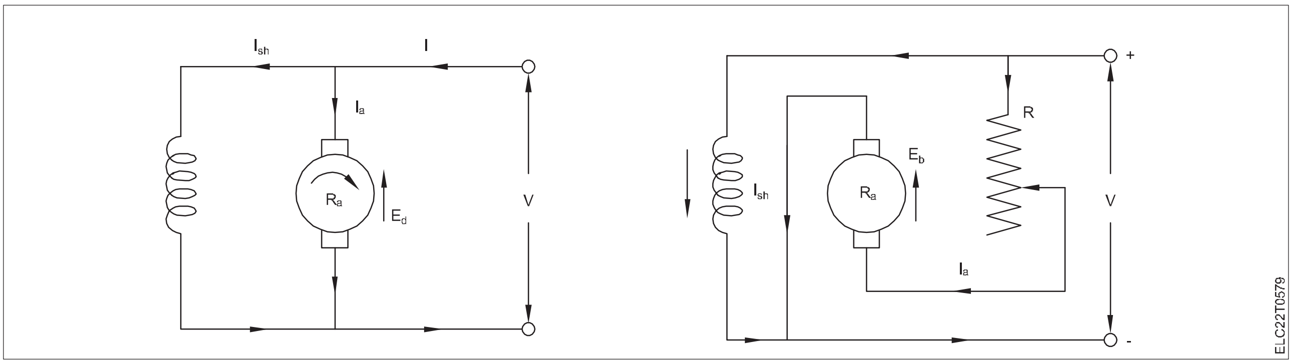
Rheostatic or dynamic braking - dc shunt



Disconnect armature from the supply. Then connected across a variable resistance.The field winding is still connected across the supply undisturbed. This method makes use of generator action in a motor to bring it to rest. The braking effect is controlled by varying the series resistance R. TBdecreases as motor slows down .TBbecome 0 altogether when it comes to a stop.

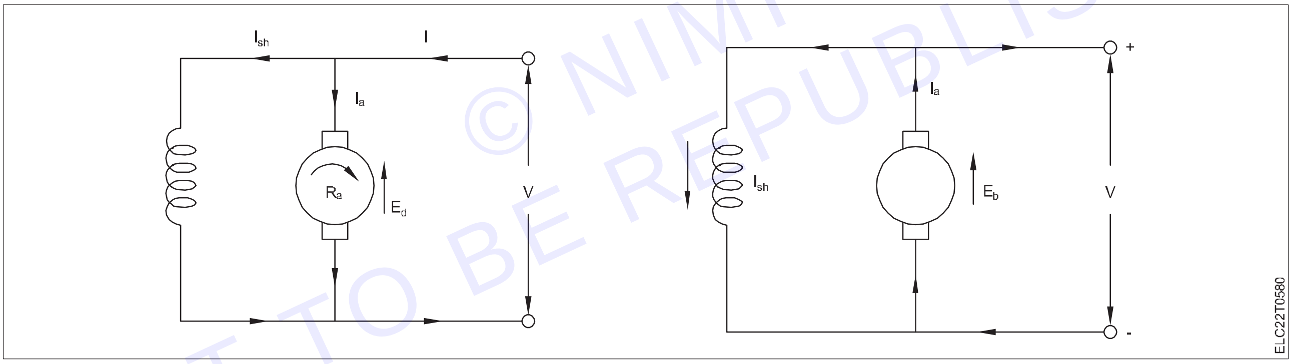
Plugging or reverse current braking - dc shunt

Armature terminals are reversed so that motor tends to run in the opposite direction. V and Ebstart acting in the same direction, due to the reversal of armature connections.To limit the armature current to a reasonable value a resistor inserted in the circuit while reversing armature connections.commonly used in controlling elevators, rolling mills, printing presses and machine tools etc.Plugging gives greater braking torque than rheostaticbraking. Power is drawn from the supply and is dissipated by R in the form of heat.even when motor is reaching zero speed, there is some braking torque TB

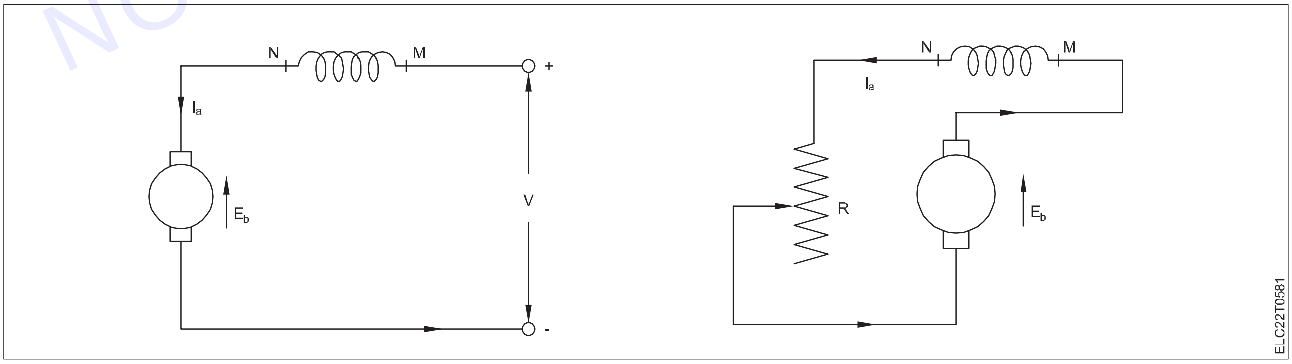


Regenerative braking – DC shunt

When the overhauling load acts as a prime mover and so drives the machines as a generator.Regeneration takes place when Ebbecomes greater than V. Direction of Iaand hence of armature torque is reversed and speed falls until Ebbecomes lower than V. For protective purposes, mechanical brake in order tohold the load in the event of a power failure.



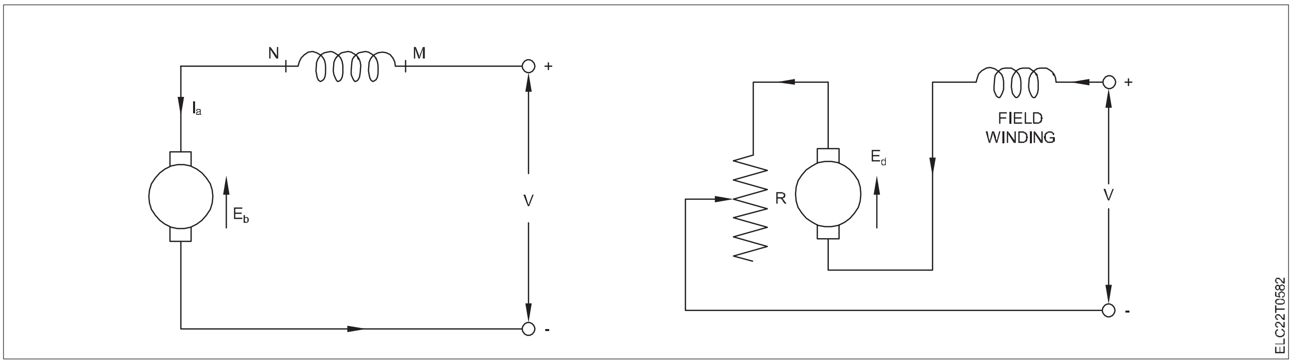
Rheostatic (or dynamic) braking – dc series



The motor is disconnected from the supply, the field connections are reversedandthe motor is connected in series with a variable resistance R . Obviously, now, the machine is running as a generator.The field connections are reversed to make sure that current through field winding flows in the same direction as before (i.e., from M to N) in order to assist residual magnetism.

Plugging or reverse current braking – dc series

Connections of the armature are reversed. Supply is NOT disconnected. variable resistance R is put in series with the armature



Regenerative braking – dc series

In shunt, used for overhauling loads- motor becomes generator. It is not possible in DC series motor without modification, reversal of Iawould also mean reversal of the field and hence of Eb.However, this method is sometimes used with traction motors, with special arrangements.

Speed control of dc motors

The governing equation

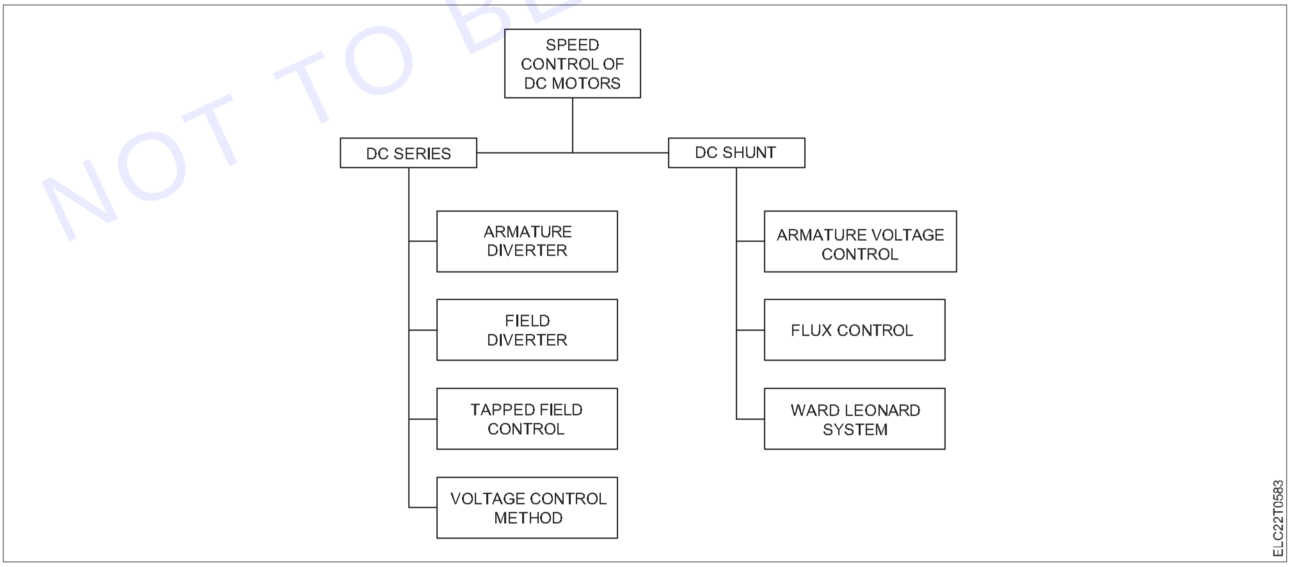
$$N \alpha \frac{Eb}{\Phi}$$

$$Eb = V - Ia\,Ra$$

$$N \alpha \frac{V - Ia\,Ra}{\Phi}$$

Methods of speed control

- Armature circuit resistance control
- Flux control by variable resistance in field circuit
- Applied voltage control

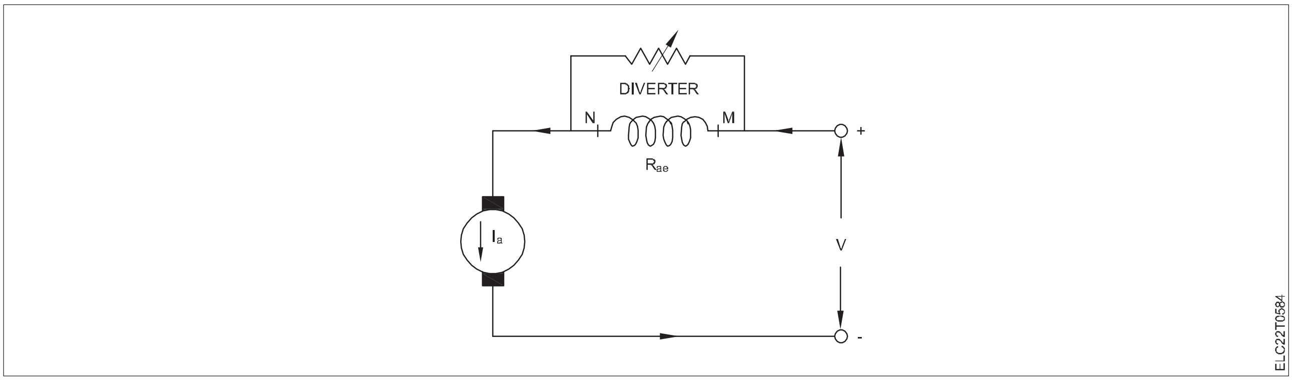


DC Series motor - armature diverter

DC Series motor speed control - field diverter

- Field diverter
- For speeds higher than normal
- Resistance in parallel to series field

- Ise is bypassed / reduced
- Field current and flux decrease
- Speed increases $N \alpha \frac{1}{\Phi}$

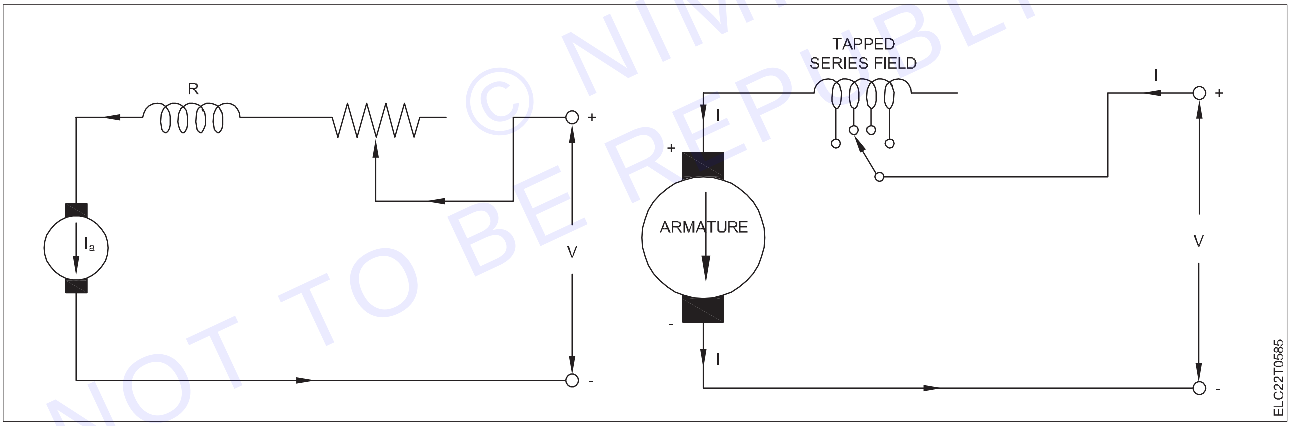


DC Series motor - voltage control method

In voltage control method, speeds lesser than normal is obtained. For this a resistance is connected in series to motor. Hence the supply voltage to motor is reduced, field current and flux decrease. So speed decreases. This method requires high power resistance. Solosses increase

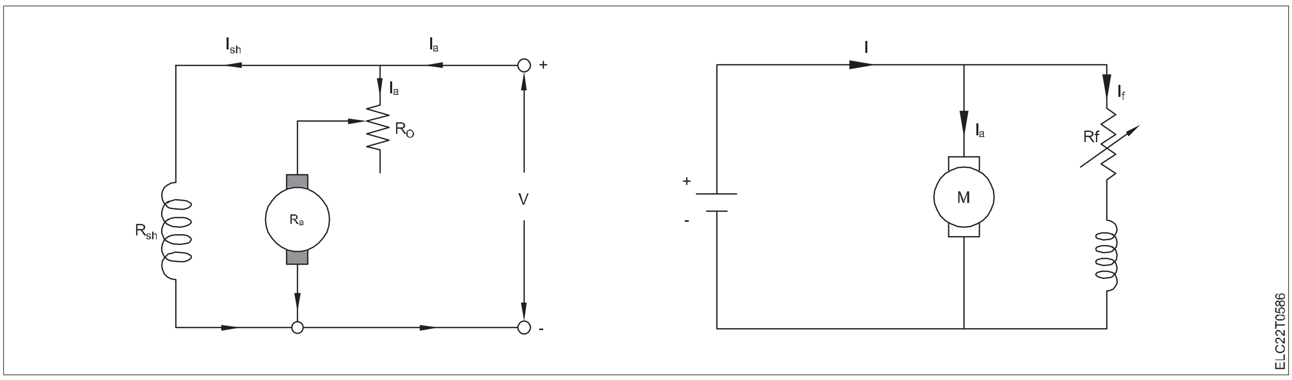
Tapped field control

In this method field turns are tapped. Field flux decrease when tapped. When flux decreased speed increases. This method is used in traction



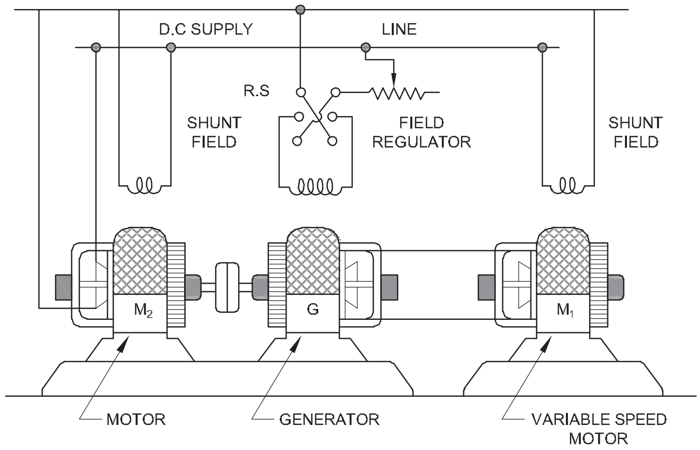
DC Shunt motor- flux control method

DC Shunt motor- flux control method

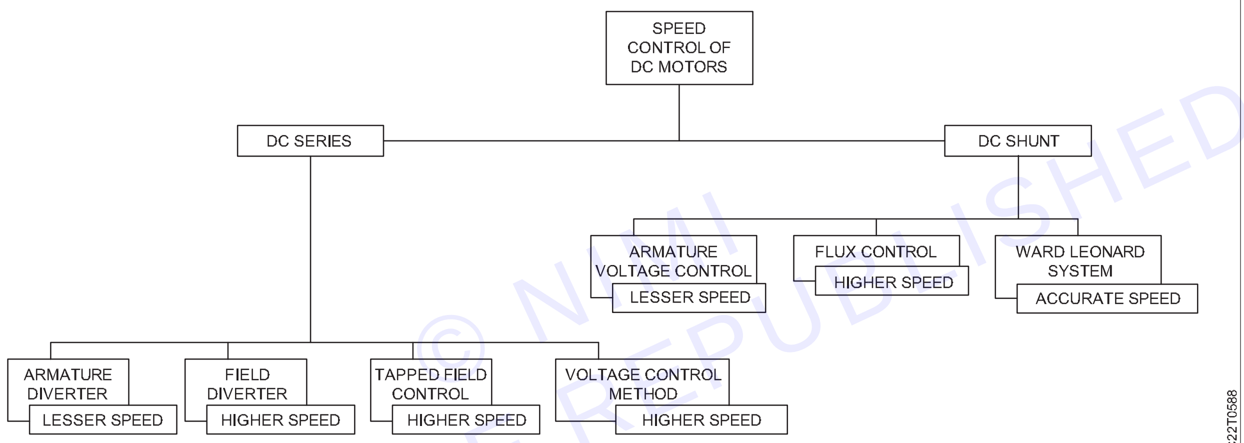


Ward leonard system

In this system a variable voltage is applied across armature. Separately excited Generator supplies variable voltage.This generator is driven by a motor.Field regulator of generator controls the voltage and polarity of the supply to motor under speed control. M-G set runs at constant speed in one direction



WARD LEONARD SYSTEM OF SPEED CONTROL



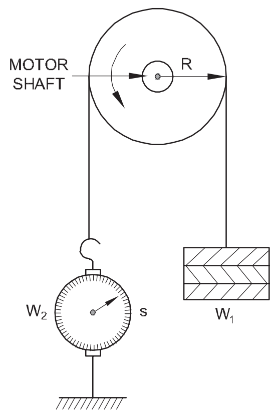
Change direction of rotation of dc motors

To change the direction of rotation, the direction of current either in armature or field circuit is to be changed. In compound machines,if field currents are changed, change both series and shunt field currents, unless it will inverse between cumulative or differential.

Tests on dc motors

Brake test – direct loading test

This method is used only for small motors with simple brake. It gives almost accurate results. In large motors, it is difficult to dissipate the large heat at the brake. Lot of power is wasted.



Predetermination of efficiency

- Swinburne's Test
- No-load Test
- Losses Method
- Only for machine with constant flux
- shunt and compound

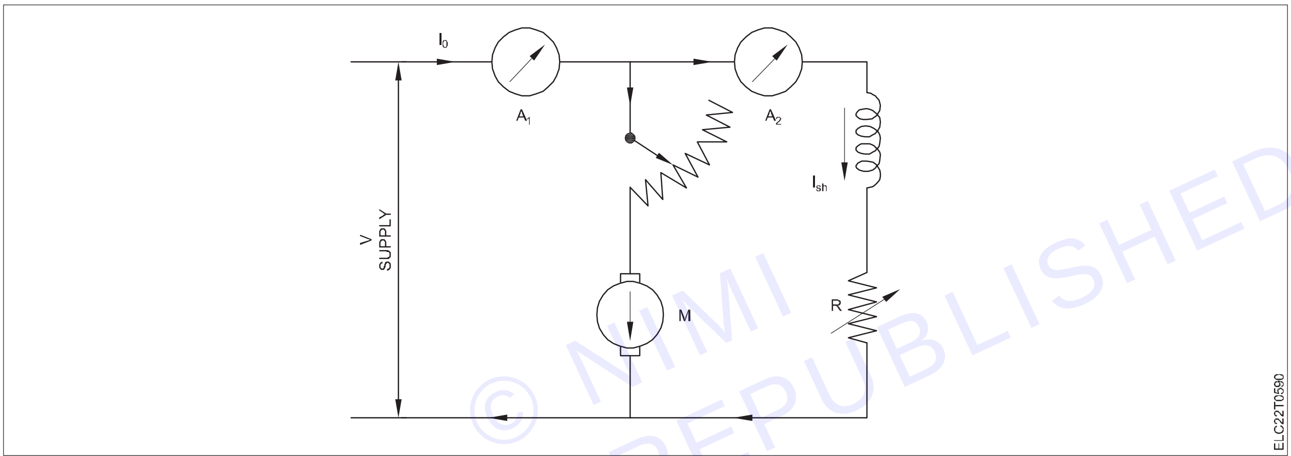
No load test

Run machine as a motor on no-load at

rated voltage and rated speed

Note down I_0 and I_{sh}

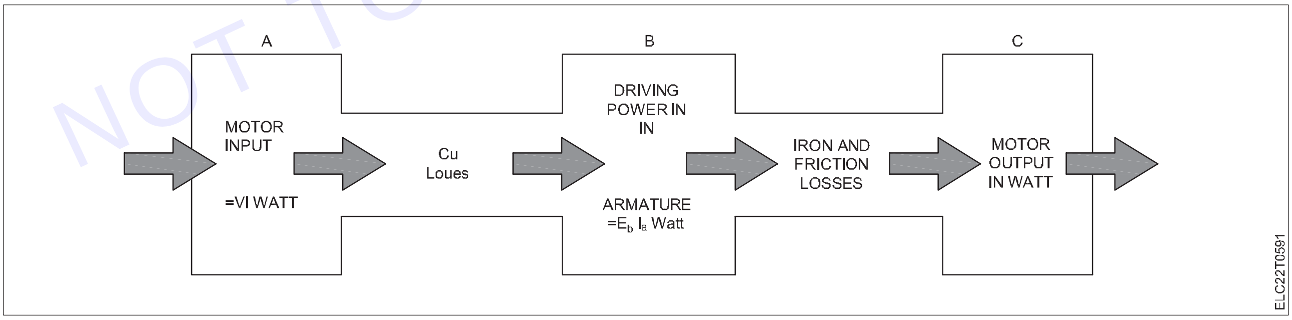
$I_{a0} = I_0 - I_{sh}$



Measurement of armature resistance

VI method

Calculate the 'hot' resistance, 1.2 R



Supply voltage = V

No load current = I_o

No load input = VI_0 watt

Power input to armature = $V (I_0 - I_{sh})$;

Power input to shunt = $V\ I_{sh}$

No-load power input to armature supplies the following:

(i) Iron losses in core (ii) friction loss (iii) Windage loss and

(iv) armature Cu loss, $(I_0 - I_{sh})^2Ra$ or $Ia0_2Ra$

FINDING CONSTANT LOSSES(WC)

Subtract no-load armature Cu loss from the total input,then we get constant losses. Constant losses Wc= total input - no-load armature Cu loss = VI0 − $(I_0 - I_{sh})^2$Ra

From the constant losses of the machine, its efficiency at any other load can be determined

Let / = load current at which efficiency is required.

Then, armature current is Ia = I - Ish...if machine is motoring

= I + Ish ...if machine is generating

Efficiency when running as a motor

Input = VI, Armature Cu loss = Ia²Ra = (1 - Ish)²Ra

Constant losses = W_c

Total losses = (1 - Ish)²Ra + W_c

$$\text{Efficiency} = \frac{\text{output}}{\text{Input}} = \frac{\text{Input} - \text{Losses}}{\text{Input}}$$

$$= \frac{VI - [(I - Ish)^2 Ra + Wc]}{VI}$$

Efficiency when running as a generator

Let / = load current at which efficiency is required.

Then, armature current is Ia = I - Ish ...if machine is motoring

= I + Ish ...if machine is generating

Output = VI, Armature Cu loss = Ia²Ra = (1 + Ish)²Ra

Constant losses = W_c

Total losses = [(1 + Ish)²Ra + Wc]

$$\text{Efficiency} = \frac{\text{Output}}{\text{Output} + \text{Losses}}$$

$$\frac{VI}{VI + [(1 + I_{sh})^2 R_a + W_c}$$

Advantages of swinburne's test

- Convenient and economical
- Power required to test a large machine only the no-load input power.
- The efficiency can be predetermined at any load because constant-losses are known.

Disadvantages of swinburne's test

- Armature reaction causes flux distortion
- In some cases, by as much as 50%.
- This is not taken care by Swinburne's test
- Impossible to know whether full-load commutation would be satisfactory
- Temperature rise properties at full load not k

MODULE 7 : Electrical Power, Power Factor & Electrical Energy

LESSON 38-40 : Work, power, energy & power factor

Objectives

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

- define active, reactive power,
- simple calculation on A.C. circuit work, power energy
- define power factor explain the causes of low power factor
- list out advantages of higher power factor in a circuit
- explain the methods to improve the power factor in an A.C. circuit.

Type of power in ac circuits

Active power [True power]

Reactive power

Apparent power

The active power to be measured is the product of voltage , current and power factor

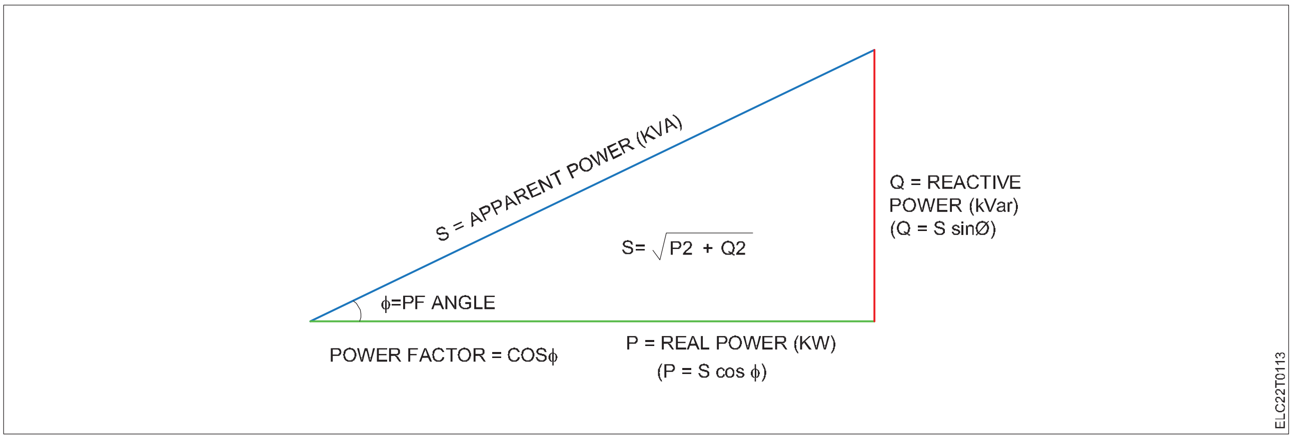
The active power indicates that with a load which is not purely resistive and where the current and voltage are not in phase , only that part of the voltage will produce power P = in phase , current which is in phase with the only that part of the V x I x cos Ø

Units of Active power is Watts/ kilowatts and is measured by using Wattmeter

Reactive power only that part of current which is 900 out of phase with the voltage is used in this case. Capacitors, inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt ampere reactivePr =V x I sin ø

Apparent power

- It is the simply the product of the total applied voltage and the total circuit current and its unit is volt-ampere [VA], Pa = V x I



Power triangle

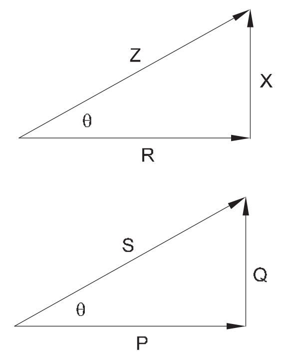
A power triangle identifies three different types of power in AC circuitsTrue power in watts[P] Reactive power in vars [Pq]Apparent power in VA[Pa]$Pa^2 = P^2 + Pq^2$

The power triangle graphically shows the relationship between real (P), reactive (Q) and apparent power (S).

$$S = \sqrt{P^2 + Q^2}$$

$$S = P + JQ_L$$

$$S = S<\theta$$



The power triangle also shows that we can find real (P) and reactive (Q) power.

S = IV	(VA)
P = Scosθ	(W)
Q=S sinθ	(VAR)

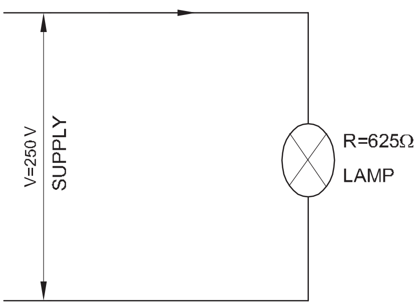
Related problem

Calculate the power taken by an incandescent lamp rated 250v when it carries a current of 0.4A if the resistance is 625 ohms

P= VR x IR =250 x 0.4 = 100Watts

P = I2xR =0.4 x 0.4 x 625 =100 Watts

P = E2 / R =2502 /625 = 100Watts



AC power to a resistive load

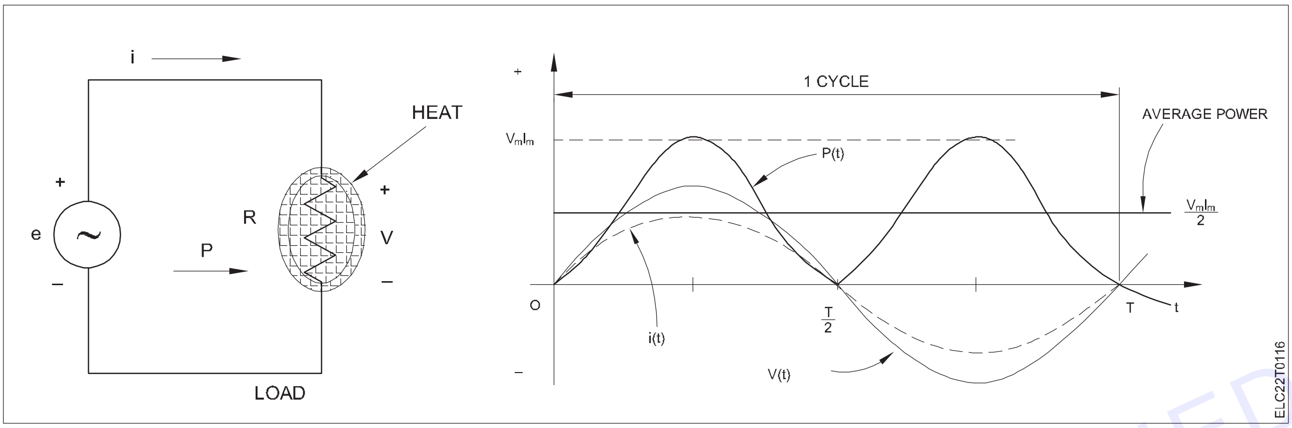
In ac circuits, voltage and current are functions of time.

Power at a particular instant in time is given

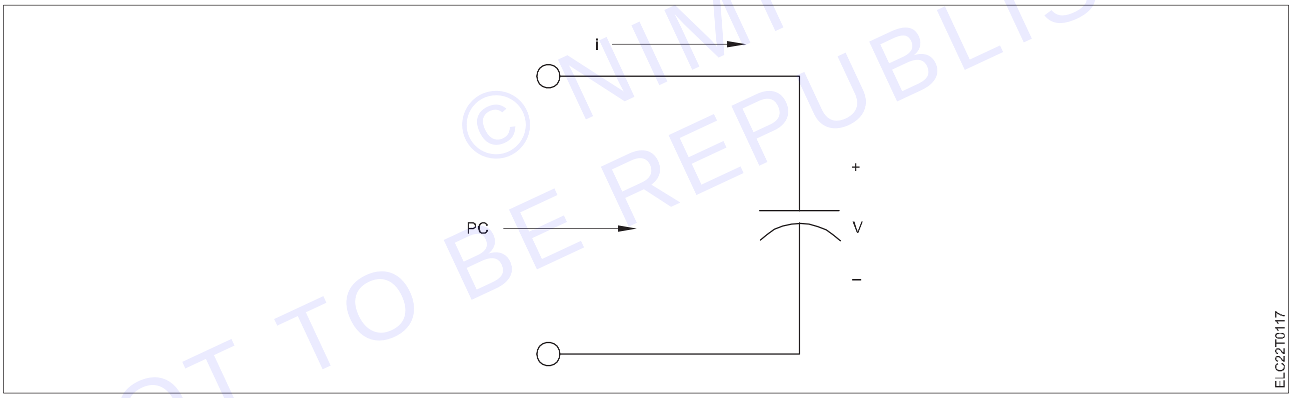
P = vi= (Vmsinωt)(Imsinωt)

= VmImsin2ωt

=VmIm(1-cos2 ωt)



Power to capacitive



$i=I_m$ sinατ

$v=V_m\sin(\alpha\tau-90)$

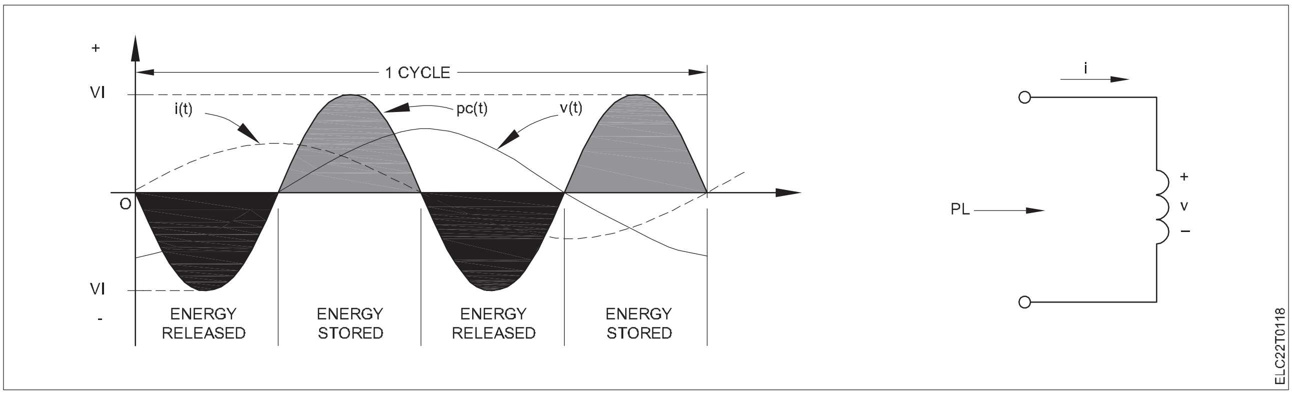
$p=vi=(V_m\ \text{sinct}-90°)(I_m\sin\ \text{at})=-V_mI_m\cos\alpha\tau\sin\alpha\tau$

$$=\frac{V_mI_m}{2}(\text{Sin}2\omega S=\left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)\text{Sin}2\omega=-V_{RMS}I_{RMS}\text{Sin}2\omega$$

Load

Average power to a resistive load

Active power is the average value of instantaneous power



$$V_{RMS} = \frac{V_m}{\sqrt{2}} \quad \text{rms value of voltage}$$

$$I_{RMS} = \frac{I_m}{\sqrt{2}} \quad \text{rms value of current}$$

$$P = \frac{V_m I_m}{2} = \left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right) = V_{RMS} I_{RMS} \quad \text{(watts)}$$

Power to an inductive load

Consider the following circuit where

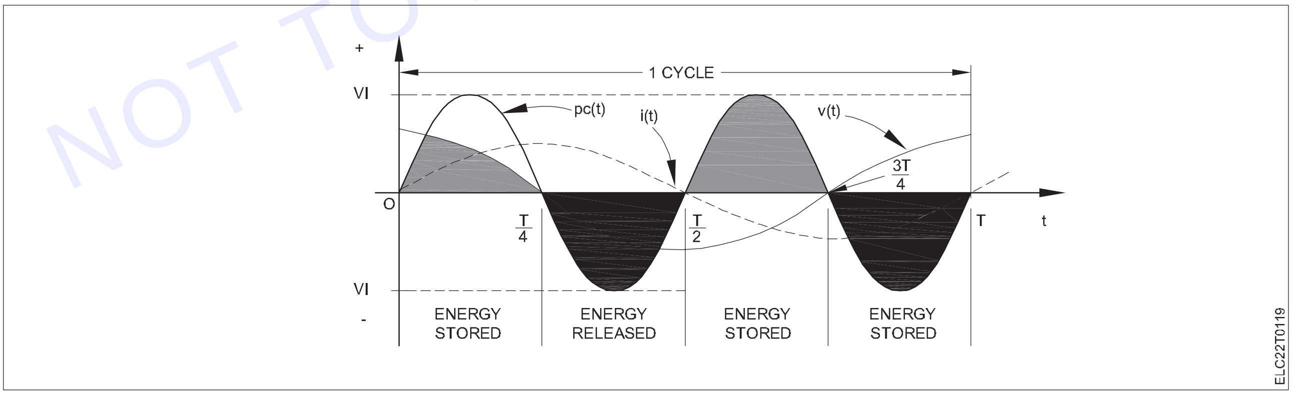
i = $I_m$sin ατ

$$i = I_m \sin\omega t$$

$$v = V_m \sin(\omega t + 90)$$

$$p = vi = (V_m \sin\omega t + 90^\circ)(I_m \sin\omega t) = V_m I_m \cos\omega t \sin\omega t$$

$$= \frac{V_m I_m}{2}(\sin 2\omega t) = \left(\frac{V_m}{\sqrt{2}}\right)\left(\frac{I_m}{\sqrt{2}}\right)\sin 2\omega t = V_{RMS} I_{RMS} \sin 2\omega t$$



Work – The work is said to be done when a force acting on a body causes it to move. The work done can be calculated by the product of force and the displacement of the point of application in the direction of force.

So work done = force x distance

The unit of work in M.K.S. system is joule

Power – The rate of doing work is called power.

Work done

Time

The unit of power is joule/second or watt in M.K.S. or S.I. system of unit.

Energy – The energy is as the capacity for doing work.

The unit in M.K.S. system is joule or watt/second and KWHr.

Power factor

In an alternating current (AC) electrical supply, a mysterious thing called "Power Factor" comes into play.

- Power Factor is simply the measure of the efficiency of the power being used,
- so, a power factor of 1 would mean 100% of the supply is being used efficiently.
- A power factor of 0.5 means the use of the power is very inefficient or wasteful

It is defined as the

1 Cosine of the angle Ø of current lag or lead from the applied voltage ,i.e. cos Ø

2 It is the ratio of Resistance and impedance of the AC circuit, cos Ø=R/Z

3 And it is the ratio of True power and apparent power. Cos Ø = KW/KVA

  - Ideal power factor is unity
  - It is the measure how efficiently the electrical power is converted into useful work.

Let us consider a 230V,50Hz, 1Hp motor. Let us assume that it is 100% efficient so that it draws a true power of 746W. Such a motor has a typical power factor of 0.75 lagging.

- To deliver 746W from 230V at a power factor of 0.75 requires a current of
- I=P/V X cosØA , 746W/230V X 0.75=4.33A
- Let us assume that we can modify the motor in some way to make the power factor unity. The current now required is

I=P/V*cosØ

- 746W/230V*1 =3.24A
- It requires a higher current to deliver a given quantity of true power if the power factor of the load is less than unity.

This higher current means that more energy is wasted in the feeder wires serving the motor. In fact if an industrial installation has a power factor less than 85%, a power factor penalty is assessed by the electric utility company. It is the reason for power factor correction.

Sources of reactive power

Transformer, Induction motor, Alternator, Discharge lighting etc

Causes and effects of lowe power factor

i In industrial and domestic fields, the induction motors are widely used. The induction motors are always taking lagging current which constitute or results low power factor.

ii The industrial furnaces have low power factor.

iii The transformers at substations have lagging power factor because of load and magnetising currents.

iv Because of inductive load in houses like tubes, traction h.p. motors etc.

Effect of low power factor

i For the same power to be transmitted over a distance, it will have to carry more current at low power factor. As a result the area of cross-section of the conductors is more, causing more cost, labour cost, line losses, line drops and lowering the efficiency of transmission lines.

ii The transformer, switch and switch gears, generators has to carry more current to meet the same power with low power factor. It will again effect the size, cost, efficiency and life of the machine and apparatus.

iii The prime mover capacity will also be effected with low power factor, as the alternator has to induce more power to meet the demand at low power factor.

iv Low power factor will effect the voltage regulation of generator, transformer, transmission line side.

Advantages of power factor improvement

i The output capacity of the prime mover is better utilized.

ii The output of alternator is increased.

iii The kW output of transformer and line are increased.

iv Efficiency of plant is increased.

v The voltage regulation is also improved.

vi The machines generator, transformer, line etc. Will carry less cross-sectional area for the same power to be transmitted and utilized for improved power factor than low power factor.

Power factor improvement methods

- For Power factor improvement purpose, Static capacitors are connected in parallel with those devices which work on low power factor.
- These static capacitors provides leading current which neutralize (totally or approximately) the lagging inductive component of load current (i.e. leading component neutralize or eliminate the lagging component of load current) thus power factor of the load circuit is improved.

Synchronous Condenser

- When a Synchronous motor operates at No-Load and over-exited then it's called a synchronous Condenser. Whenever a Synchronous motor is over-exited then it provides leading current and works like a capacitor.
- When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component and this way, power factor is improved. Generally, synchronous condenser is Used To Improve The Power Factor In Large Industries

Phase Advancer

- Phase advancer is a simple AC exciter which is connected on the main shaft of the motor and operates with the motor's rotor circuit for power factor improvement. Phase advancer is used to improve the power factor of induction motor in industries.

Advantages of power factor correction

- Increases equipment life.
- Save on utility cost.
- Enhance equipment operation by improving voltage.
- Improve energy efficiency.
- Power Factor Penalty Is Reduced

Single phase power measurement

Single phase power refers to the distribution of alternating current electric power using a system in which all the voltages of the supply vary in corresponding exactly.

Single phase distribution is used when loads are mostly lighting and heating ,with few large electric motors

A single phase supply connected to an alternating current electric motor does not produce a revolving magnetic field, single phase motors need additional circuitsforstarting and such motors are uncommon above 10 or 20KW

MODULE 8 :Transformer Connection and Testing

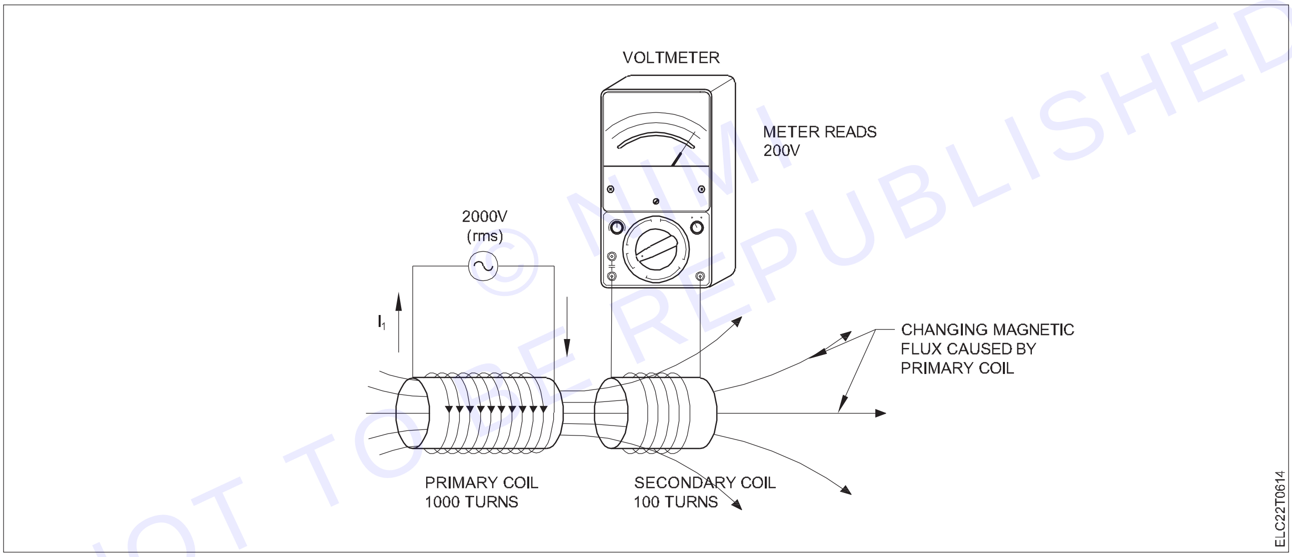
LESSON 41-49 : Transformer - principle - classfication - EMF equation

Objectives

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

- explain the principle construction and EMF equation of transformer
- explain transformer parts and their functions cooling methods
- state the princple construction of auto- transformer
- explain current and potentional transformer
- explain voltage regulation.

Static electrical deviceTransfers electric power from one circuit to another. It does so without a change of frequency. It accomplishes this by electromagnetic induction. Transformer can change the voltage levels of the circuits. There are two or more electric circuits coupled magnetically.

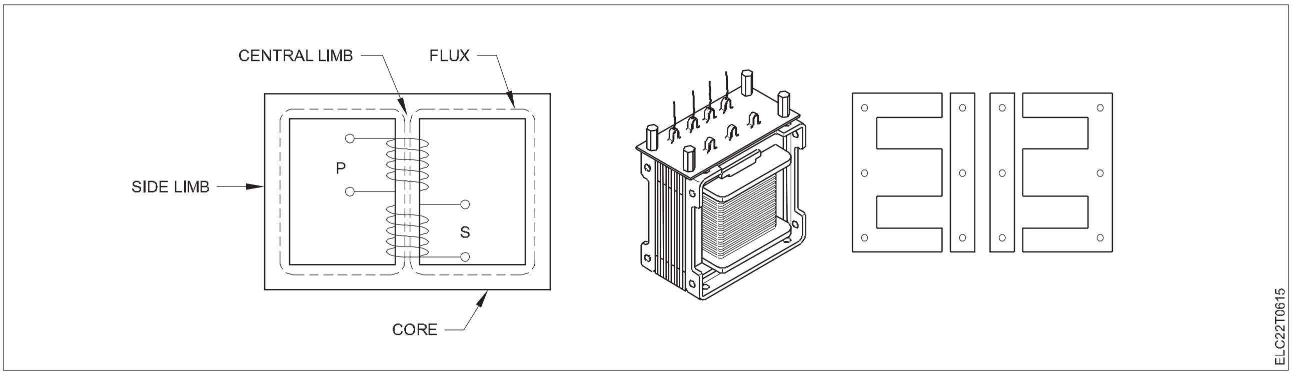


Principile Of Operation

It is based on principle of MUTUAL INDUCTION.

An e.m.f. is induced in a coil whenan when neighbouring coil changes

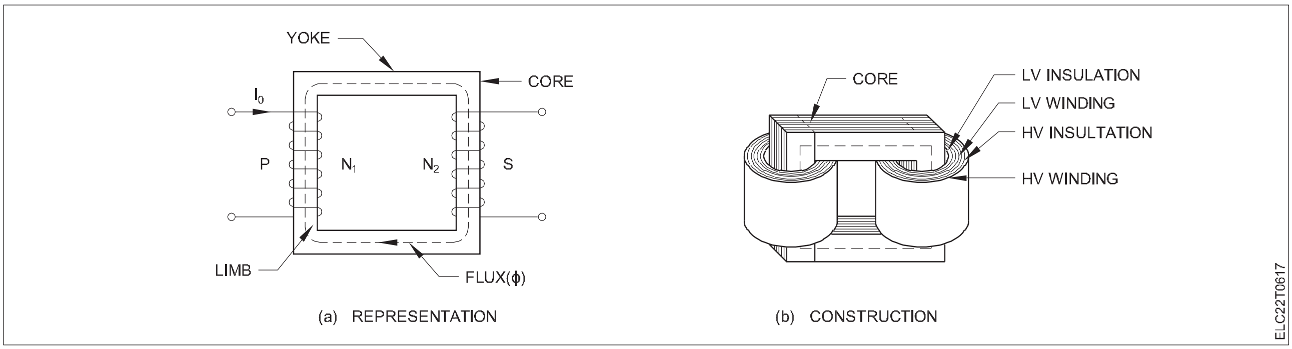
Construction Details



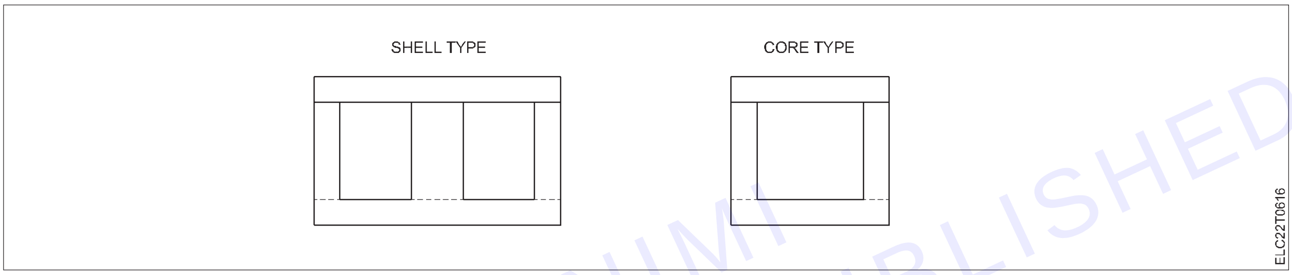
Windings are wrapped around the center leg of a laminated core. Generally used in single phase transformers

Core Type

Windings are wrapped around two sides of a laminated square coreUsed in high output transformers



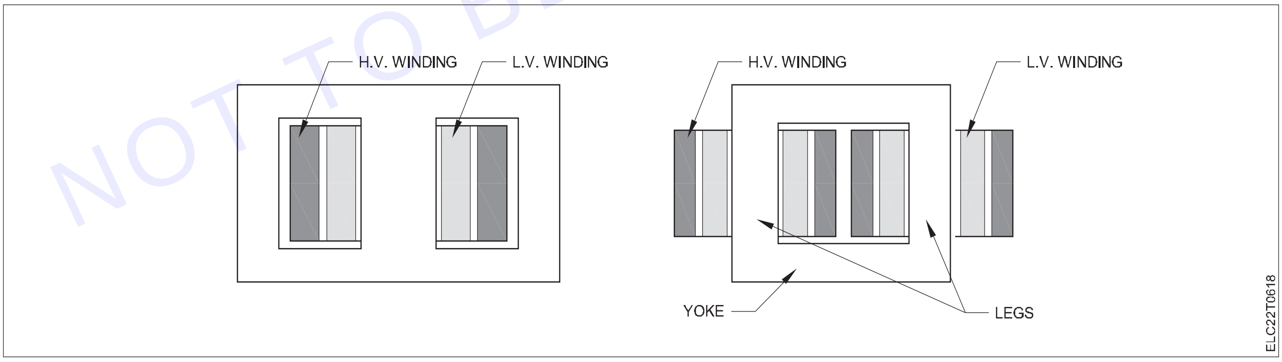
Construction of transformer from stampmpings



Sectional View Of Transformer

Inter leaving of LV and HV windings for better magnetic coupling

High voltage conductors are smaller cross section conductors than the low voltage coil(LV) winding is easiest to insulate, it is placed nearest to the core.



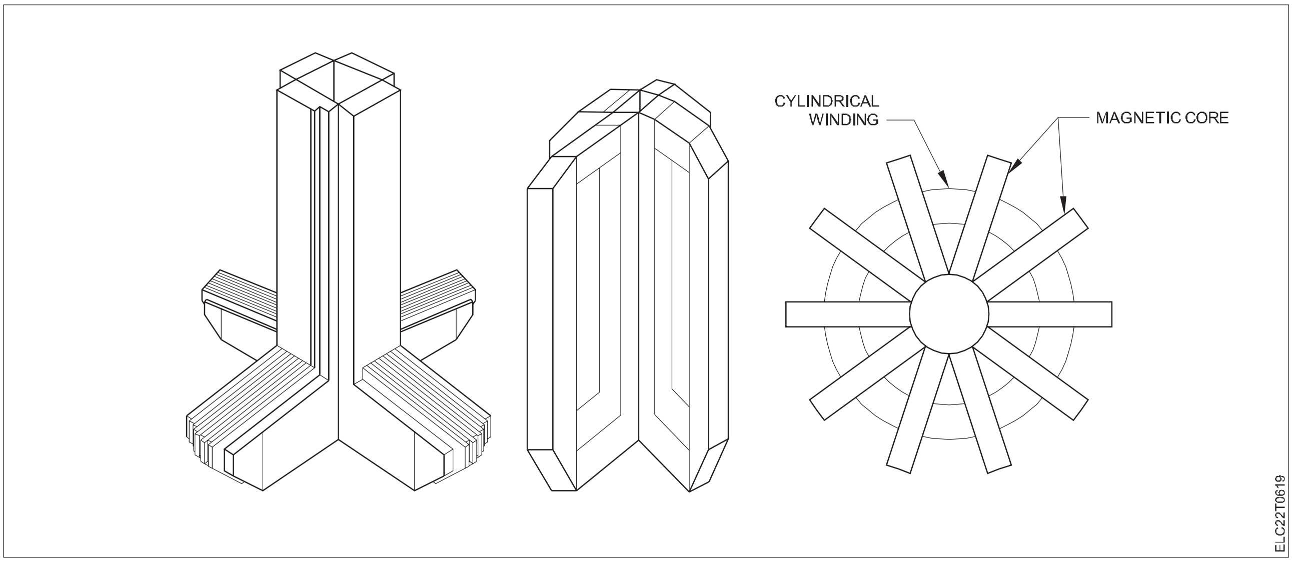
Berry type transformer

More parallel paths for flux. Cylindrical windings are used.

Advantages Of Transformer

Voltage can be easily changed,it is a Static device, no wear and tear

Most efficient electrical machine, very less maintenance required



Transformer Classification

Terms of number of windings

Conventional transformer: two windings

Autotransformer: one winding

Others: more than two windings

In terms of number of phase

Single-phase transformer

Three-phase transformer

Depending on the voltage level at which the winding is operated

Step-up transformer: primary winding is a low voltage (LV) winding

Step-down transformer: primary winding is a high voltage (HV) winding

In terms of power rating and application

- Distribution transformer
- Power transformer
- Instrument transformers

Parts Of Transformer

1 Pressure release Device

2 Buchholz relay

3 Oil inlet valve

4 Breather

5 Silica Gel

6 Explosion vent

7 Conservator

8 Diaphragm

9 Oil level indicator

10 HT Terminal

11 Temperature gauge

12 Tap changer manually operated

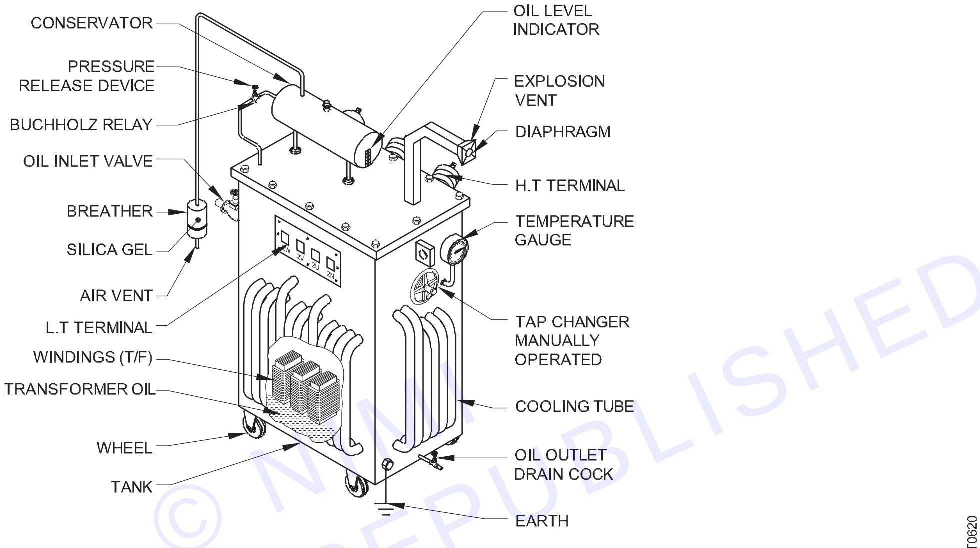
13 Cooling tubes.

14 Tank

15 Wheel

16 Oil out drain box

17 Earth



PARTS OF A 50KVA,6600/400V,OIL COOLED TRANSFORMER

Pressure Release Device

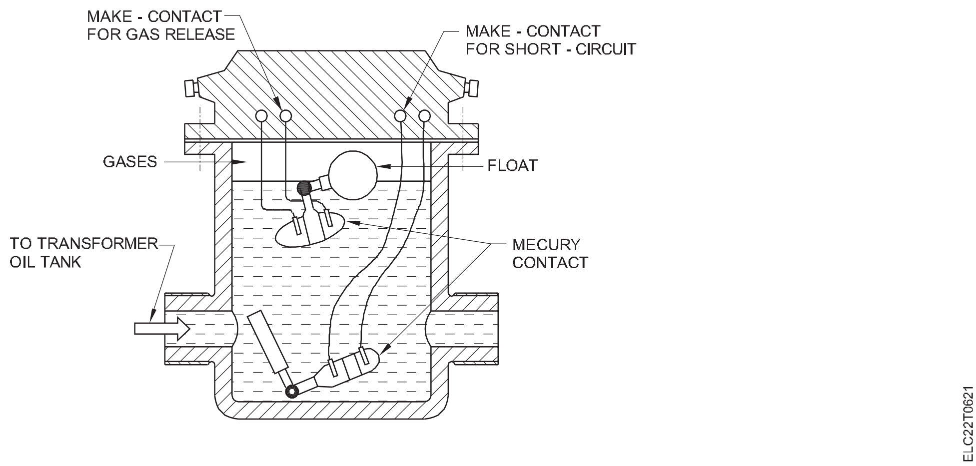
- Uncontrolled increases in pressure may create the danger of explosion with all the possible harm and damages.
- Control pressures inside tanks.
- Designed to discharge the pressure increases in a very short time period (a few thousandths of a second).
- They are widely used in the metal tanks of oil-cooled electric transformers.
- One or more pressure relief device with discharge sizes proportional to the volume of oil contained in the transformer
- Sudden and violent short circuits inside tanks, instantly generate an enormous amount of gas with a great increase in interior pressures.

Buch Holz Relay

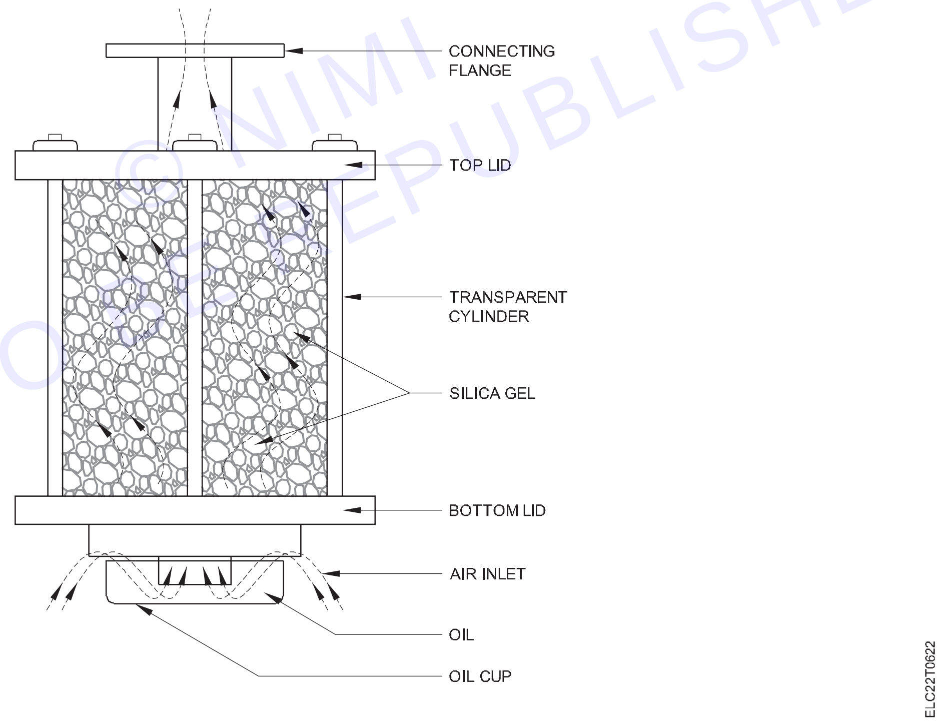
It is a sort of automatic circuit breaker which trips off the transformer in the case of transformer fault, due to insulation failure or short circuit. It consists of twomercury float switchesonefor alarm contact, it enables when excess gas pressure building inside main tank and the other for trip circuit which operates when the temperature of oil increased further.

Breather

- Silica gel is used in breather
- capacity of absorbing moisture.
- When air passes through these crystals in the breather; the moisture of the air is absorbed by them.



- The dust particles in the air get trapped by the oil in the oil seal cup.
- The color of silica gel crystal is dark blue when it absorbs moisture; it becomes pink.
- Transformer breathes out when heat increases.

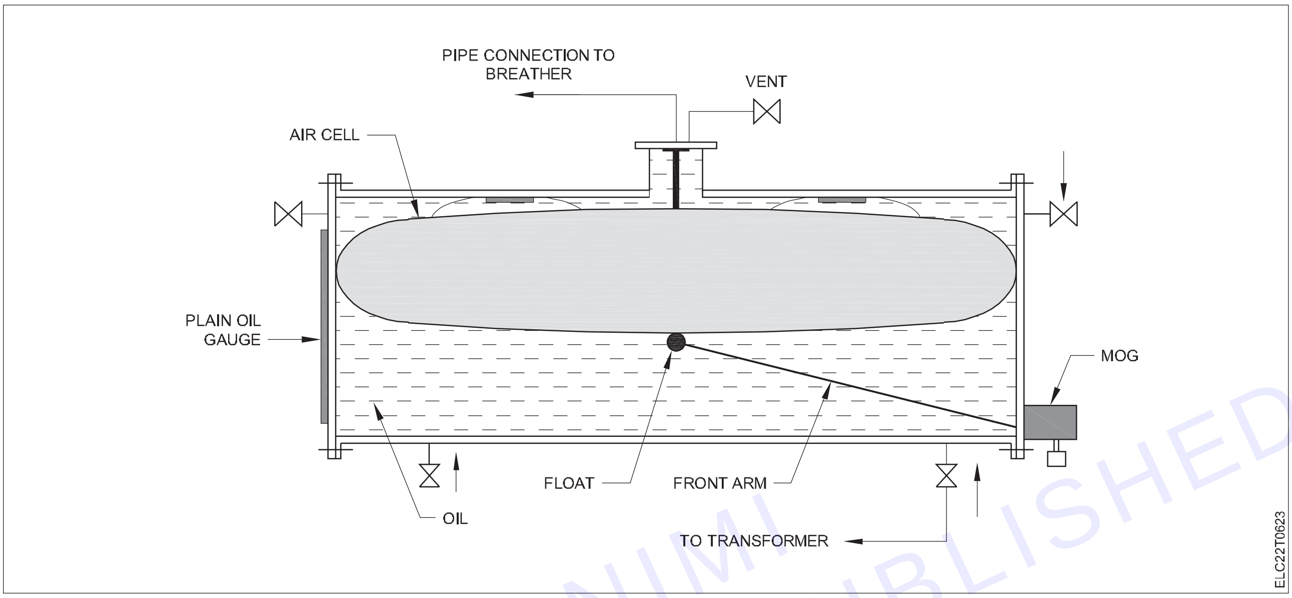


Explosion Vent

- prevent damage of the transformer tank be releasing any excessive pressure generated inside the transformer.
- bent pipe with thin aluminum diaphragms at both ends.
- A wire mesh is provided at lower end of the explosion vent to prevent the pieces of diaphragm from entering the tank.
- A wire mesh is also provided at upper end of vent pipe to protect mechanical damages of upper diaphragm.

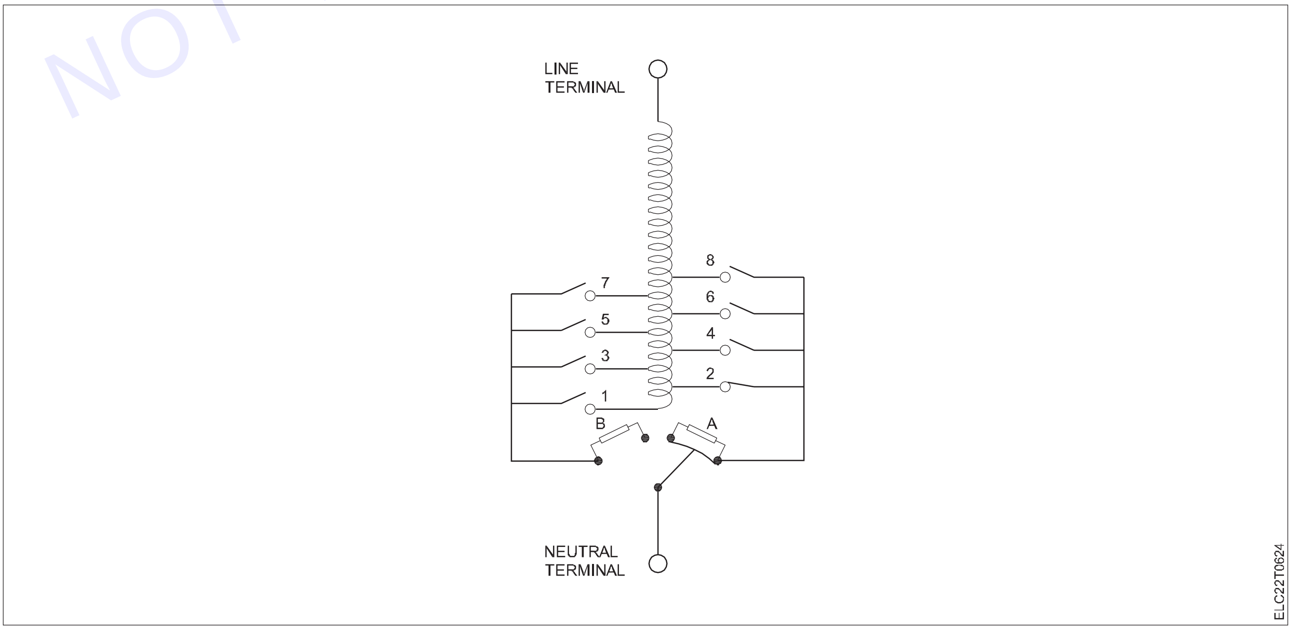
Conservator

- Cylindrical tank mounted on supporting structure on the roof the transformer main tank.
- When transformer is loaded and when ambient temperature rises, the volume of oil inside transformer increases.
- Provide adequate space for expansion of oil inside the transformer.
- Also acts as a reservoir for transformer insulating oil.



Tap Changer

- Used for voltage correction by tap changing.
- It may be manual automatic.
- OFF LOAD or
- ON LOAD TAP CHANGER(OLTC)
- Generally provided in HV side to operate with less current



Transformer Insulating Oils

It serves twofunctions:

- Provide Cooling
- Provide insulation

Mineral oils generally used,but high flammabilitysynthetic esters are used as alternate.

Earlier used Polychlorinated biphenyls (PCBs) like askarels, now banned.

Flash point is the lowest temperature at which vapours of material will ignite, when given an ignition source.

The pour point of a liquid is the temperature at which it becomes semi solid and loses its flow characteristics.

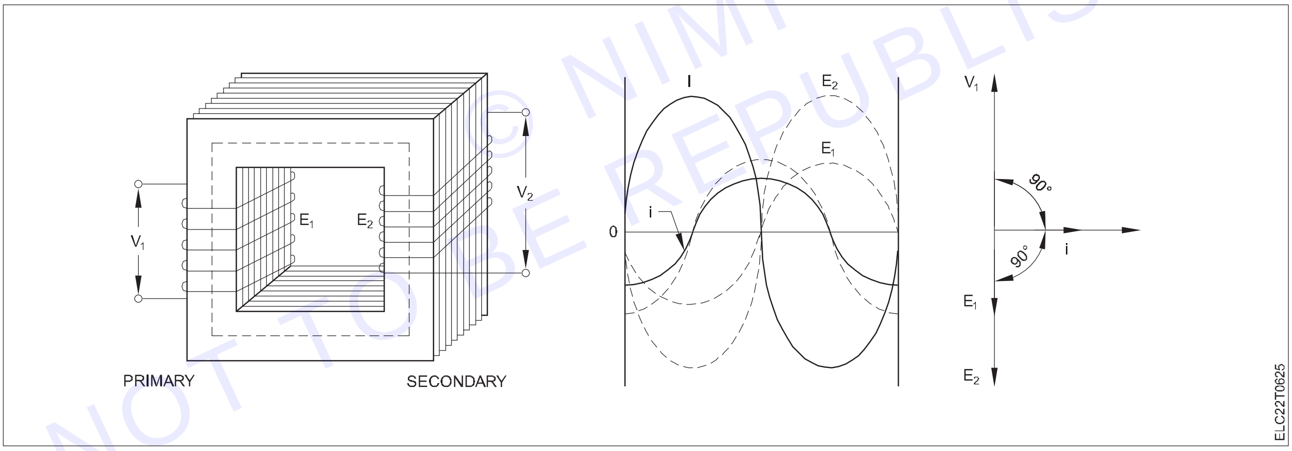
transformer on load

Ideal Transformer

An ideal transformer is a lossless device with an input winding and an output winding. It has the following properties:

- No iron and copper losses
- No leakage fluxes
- A core of infinite magnetic permeability and of infinite electrical resistivity
- Flux is passing fully through the core
- winding having no resistance.

Ideal tx. two purely inductive coils wound on a loss-free core



Emf Equation Of Transformer

N1=No.of turns in primary

N2=No.of turns in secondary

ϕ m=Maximum flux in core in webers = Bm A

f=Frequency of a.c.input inHZ

we know,Time period T= $\frac{1}{f}$

Time for flux to increase from its zero value to

maximum value = One quarter of the cycle ($\frac{1}{4f}$ second.)

Average rate of change of flux = $\frac{\phi m}{\frac{1}{4f}}$ = 4f ϕm

Now, rate of change of flux per turn means induced e.m.f. in volts. Average e.m.f./turn = $4f\phi_m$ volt

Now, form factor for sine wave = $\frac{\text{rms value}}{\text{Average Value}} = 1.11$

Therefore rms value = 1.11 x Average Value

r.m.s. value of e.m.f./turn = $1.11 \times 4\ \phi_m\ f = 4.44\ \phi_m\ f$ volt

r.m.s. value of the induced e.m.f. in the whole of primary winding = (induced e.m.f/turn) x No. of primary turns

$E1 = 4.44\ \phi_m\ f\ N1$ Volts

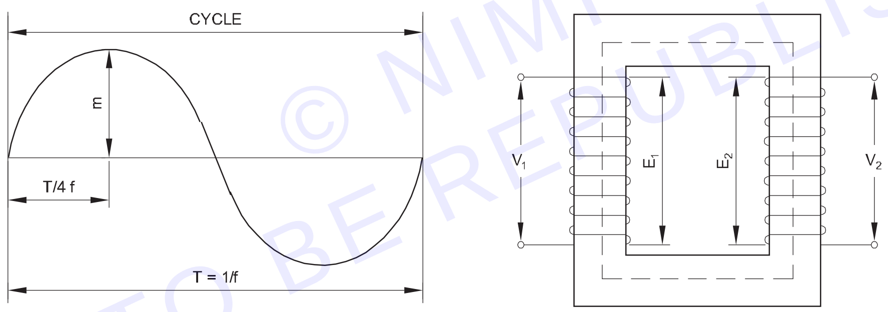
$E2 = 4.44\ \phi_m\ f\ N_2$ Volts

$E1 = 4.44\ \phi_m\ f\ N_1$ Volts

$$\frac{E2}{E1} = \frac{N2}{N1} = \frac{V2}{V1} = K$$

$V_1I_1 = V_2I_2$

$$\frac{V1}{V2} = \frac{I2}{I1} = \frac{1}{K} \quad \text{or} \quad \frac{I1}{I2} = K$$



Magnetization current

When an ac power source is connected to a transformer, a current flow in its primary circuit, even when the secondary circuit is open circuited. This current is the current required to produce flux in the ferromagnetic core and is called excitation current. It consists of two components:

- The magnetization currentIm, which is the current required to produce the flux in the transformer core
- The core-loss currentIh+e, which is the current required to make up for hysteresis and eddy current losses

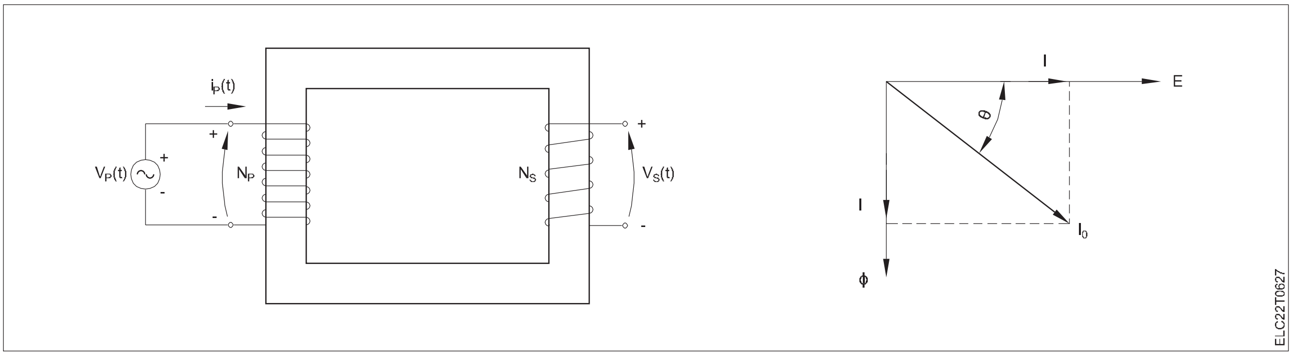
The magnetization current in a real transformer

When an ac power source is connected to the primary of a transformer, a current flow in its primary circuit, even when there is no current in the secondary. The transformer is said to be on no-load. If the secondary current is zero, the primary current should be zero too. However, when the transformer is on no-load, excitation current flows in the primary because of the core losses and the finite permeability of the core.

Excitation current, I_o

I_M is proportional to the flux f

$I_c = I_{h+e}$ = Core loss/E_1



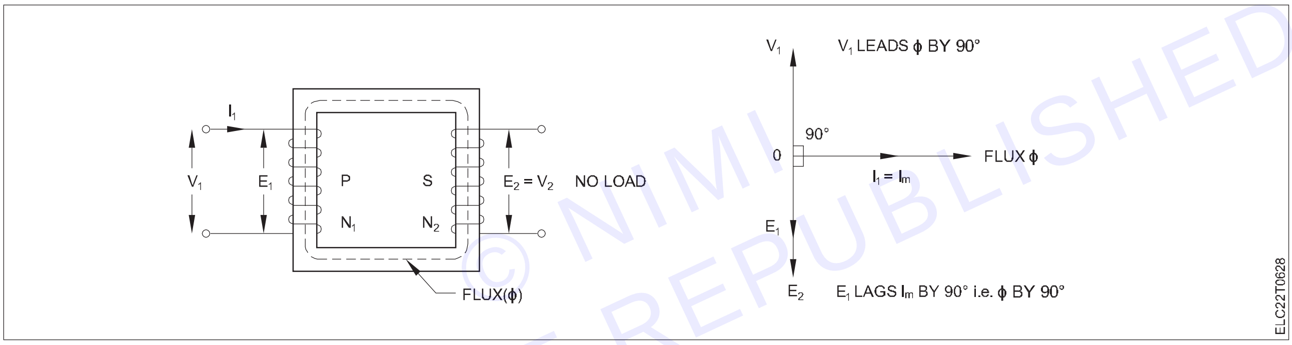
Ideal transformer

V_1 - supply voltage ; I_1 - noload input current ;

V_2 - output voltgae; I_2 - output current

I_m - magnetising current;

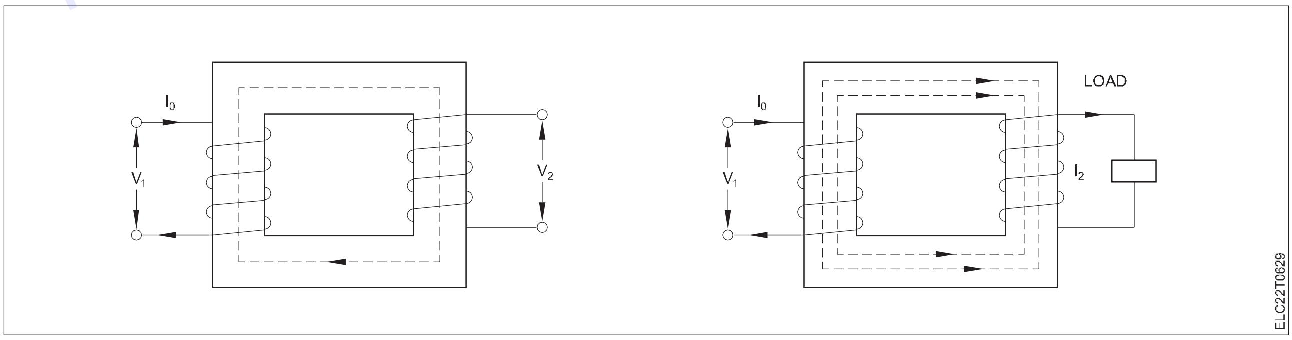
E_1 - self induced emf; E_2 - mutually induced emf



Transformer on load

secondary is loaded, current I_2 is set up.

- magnitude and phase of I_2 with V_2 is determined by the characteristics of the load.
- Current I_2 is; in phase with V_2 if load is non-inductive,
- lags if load is inductive & leads if load is capacitive



- I_2 has own m.m.f. (=N_2I_2)
- known as demagnetizing amp-turns.
- flux $_2$ is in opposition to the main primary flux due to I_0.
- The opposing secondary flux $_2$ weakens the primary flux momentarily,
- primary back e.m.f. E_1 reduce for a moment
- V $_1$ gains the upper hand over E_1 and causes more current to flow in primary.
- additional primary current is I_2' .
- I_2' is known as load component of primary current.
- I_2' is antiphase with additional primary m.m.f. N_1 I_2' sets up its own flux $_2$'
- which is in opposition to $_2$
- and equal to it in magnitude.
- Hence, the two cancel each other out.
- So, magnetic effects of secondary current I_2 are immediately neutralized by
- the additional primary current I_2'
- Hence, whatever the load conditions, the net flux passing through the core is approximately the same as at no-load.

due to the constant core flux at all loads, the core loss is also practically the same under all load conditions

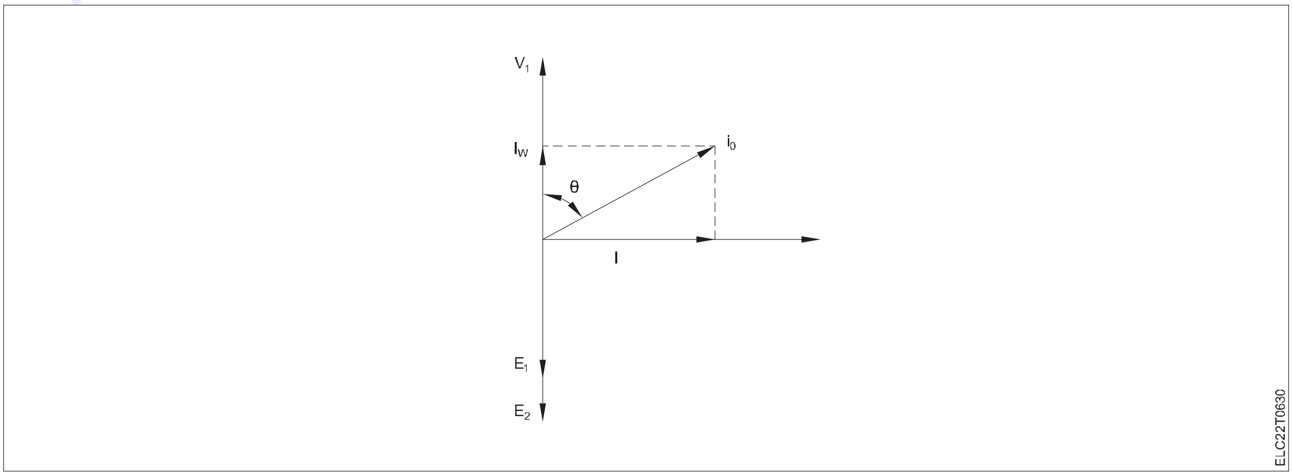
Transformer on NO Load

- On no-load, the primary input current is not wholly reactive.
- The primary input current under no-load conditions has to supply

  i Iron losses in the core i.e. hysteresis loss and eddy current loss and

  ii A very small amount of copper loss in primary

- Hence, the no-load primary input current I_0 is not at 90° behind V_1 but lags it by an angle 0 <90°.
- The no-load primary current I_0 is very small as compared to the full-load primary current.
- It is about 1 per cent of the full-load current.
- The no-load primary Cu loss is negligibly small
- No-load primary input is practically equal to the iron loss f



No - load input power_W0 = V1 $I_0 \cos \phi_0$

I_o has two components ;

i One in phase with V_1.

active or working component Iw

supplies small quantity of primary Cu loss.

$I_w = I_0 \cos \phi_0$

ii other component is in quadrature with V1 and is known as magnetising component Iμ

its function is to sustain the alternating flux in the core.

It is wattless. $I\mu = I_0 \sin \phi_0$

- $I_O = \sqrt{(OI\mu^2 + Iw^2)}$.

Cooling of transformers

Types of transformer cooling systems

- AN – Air Natural
- ONAN – Oil Natural Air Natural
- ONAF – Oil Natural Air Forced
- OFAF – Oil Forced Air Forced
- OFWF – Oil Forced Water Forced
- OD Applications - Oil Directed -are always forced oil flow that is directed through predetermined paths in the transformer winding.

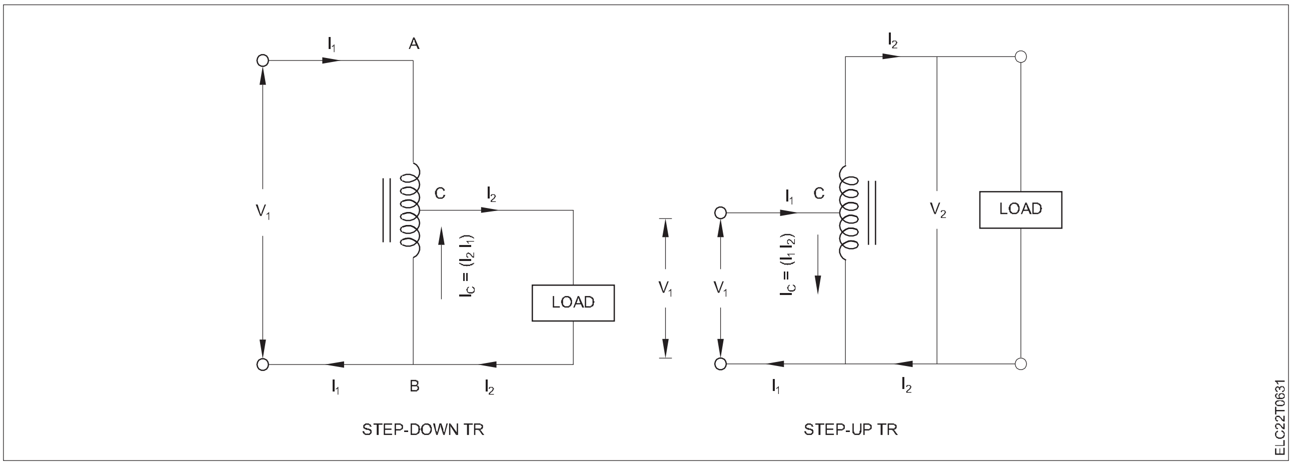
ONAN - Transformer Cooling Systems

- ONAN – Formerly known as OA.
- Natural convection flow of hot oil is utilized to dissipate heat.
- Radiator or tube applications are predominately used.
- Least expensive form of cooling if application and cooling levels are met.

ONAF - Transformer Cooling Systems

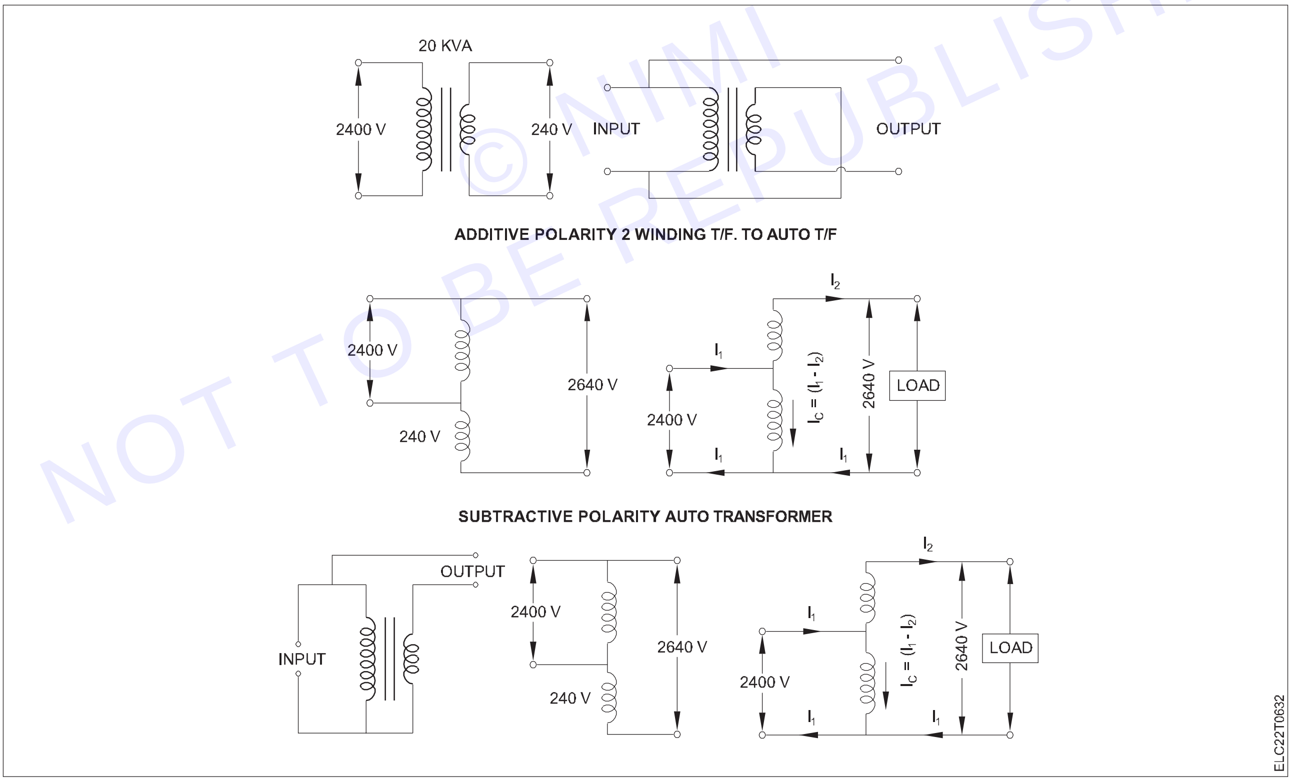
- ONAF – Formerly known as FA.
- Natural convection flow of hot oil is utilized in conjunction with cooling fans.
- Heat dissipation is increased across cooling surfaces by air movement.
- Most common application in the field.
- Offers dual ratings as an ONAN/ONAF system.
- ONAF – Formerly known as FA.
- Natural convection flow of hot oil is utilized in conjunction with cooling fans.
- Heat dissipation is increased across cooling surfaces by air movement.
- Most common application in the field.
- Offers dual ratings as an ONAN/ONAF system.

Auto transformer: An auto transformer works on the principle of self-induction. It has onlyone winding, part of this being common to both primary and secondary. Primary and secondary are not electrically isolated. Theory and operation is similar to two-winding transformer. This type of T/F uses less copper and hence is cheaper. They areused where transformation ratio differs little from unity. Their voltage regulation is superior



The current in section CB is;

- Vector difference of I_2 and I_1.
- I_2 and I_1 arepractically in phase opposition
- $I_2 > I_1$,
- resultant current is $I_2 - I_1$,



Parallel operation of two single phase transformers

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

- state the necessity of parallel operation of transformers
- state the conditions to be full filled for the parallel operation of transformers
- explain how to determine the polarity terminals of transformer.

Necessity of parallel operation of transformers

1 When the power demand of the load increases, two or more transformer may be operated in parallel.

2 When the power demand decreases, only required numbers of transformer may be operated with their full load capacity. Where as the remaining transformers may be switched "OFF" and taken for general maintenance/ service.

3 Thus the efficiencies and life of the transformers increases and the losses are reduced.

4 It provides more reliability of power i.e., even one transformer fails or become out of service, other transformers will supply to the certain amount of load.

5 It is not economical to manufacture a single very large capacity transformer. Thus operationg two or more numbers of optimal capacity transformers in parallel is more economical.

6 It is easy to plan the maintenance schedule of the transforemers, hence the cost of maintenance and spares are reduced.

Conditions

1 the same voltage ratio

2 Input voltage must be same

3 the same per unit (or percentage) impedance

4 the same polarity

5 the same phase sequence and zero relative phase displacement, for 3 phase transformers.

Of these (4) and (5) are absolutely essential (1) and (2) must be satisfied to a close degree.

There is more allowance for a wide extent with (3), but the more nearly it is true, the better will be the load division between several transformers.

Parallel operation

Fig 1 shows two single phase transformers connected in parallel with their primary windings connected to the same supply and their secondary windings supplying a common load.

When operating two or more transformers in parallel, to have satisfactory performance the following conditions should be met

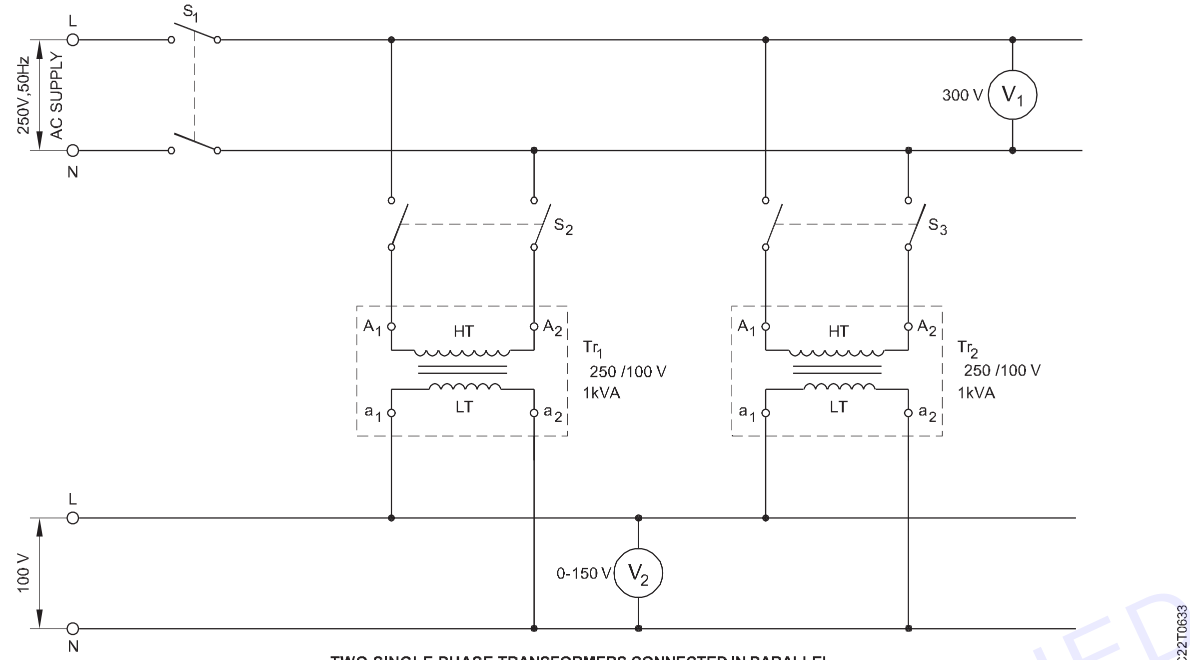
Voltage ratio: If voltage readings on the open secondaries of various transformers, to be run in parallel, do not show identical values, there will be circulating currents between the secondaries (and therefore between primaries also) when the secondary terminals are connected in parallel. The impedances of transformers is small, so that a small percentage voltage difference may be sufficient to circulate considerable current and cause additional I_2R loss.

When secondaries are loaded, the circulating current will tend to produce unequal loading conditions. Thus it may be impossible to take the full load output from the parallel connected group without one of the transformers becoming excessively heated.

Impedance: The currents carried by the two transformers are proportional to their ratings:

- if their numerical or ohmic impedances are inversely proportional to those ratings, and
- their per unit impedances are identical.

Fig 1



TWO SINGLE PHASE TRANSFORMERS CONNECTED IN PARALLEL

A difference in the quality factor (i.e the ratio of reactance to resistance) of the per unit impedance results in a divergence of the phase angle of the currents, so that one transformer will be working with a higher and the other with a lower power factor than that of the combined output.

Verification of terminals or Polarity: When two or more transformers are to be connected in parallel on their primary and secondary sides, the terminals of the same polarity only can be connected together, otherwise a heavy circulating current will be produced between the windings.

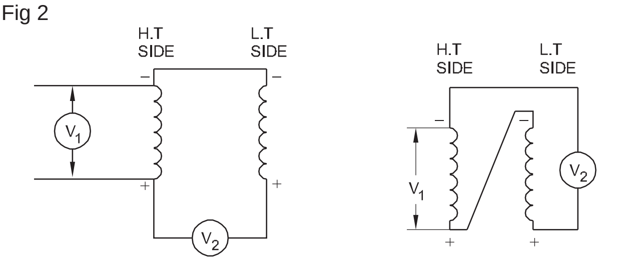
Standard procedure to determine the polarity is explained below:-

- Connect one end of the high voltage winding to one end of the low voltage winding as shown in Fig 2a.
- Connect a voltmeter between the two open ends.
- Apply a voltage not greater than the rated voltage of the winding to either high or low voltage winding.

If V2 reads less than V1 (Fig 2a) the primary and secondary emfs are in opposition. The marking on primary will be A1 for +ve side and A2 for –ve side and a1 for +ve side of secondary and a2 for –ve side. If the connections are made (Fig 2b) the voltmeter V2 will read more than V1. Thereby it is ascertained opposite ends are connected.

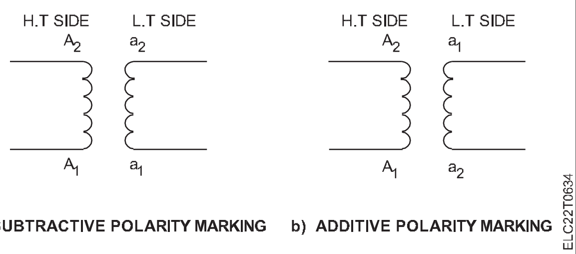
If in transformer has similar ends in one side (Fig 3a) the polarity marking is said to be subtractive polarity marking on the other hand if the opposite ends are in one side (Fig 3b) the polarity marking is called as additive polarity marking.

Fig 2



a) V_2 IS LESS THAN V_1 $(V_P - V_S)$VOLTS b) V_2 IS MORE THAN V_1 $(V_P + V_S)$VOLTS

Fig 3



a) SUBTRACTIVE POLARITY MARKING b) ADDITIVE POLARITY MARKING

Series (Secondary only) operation of transformers

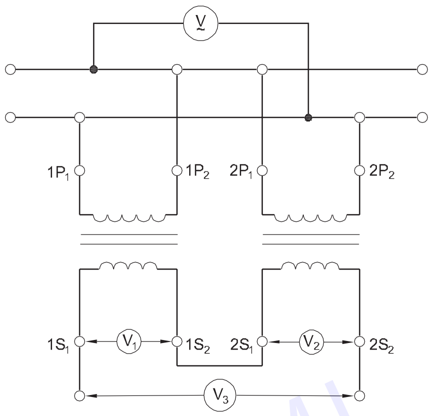
Objectives: At the end of this lesson you shall be able to:

- state the necessity of series operations
- state the conditions to be fulfilled for series operation.

Series operation:

The connection diagram for series operation (secondary only) of two identical transformers is given below (Fig 1)

Fig 1



SERIES OPERATION OF TRANSFORMERS (SECONDARY ONLY)

Necessity for series operations:

In general, the transformers are available with some standard input (primary) and output (secondary) voltages. In order to get some intermediate voltage for example ,

36V, 48 V for special purpose, the series operation of transformers (secondary only) are necessary.

In series operation, individual secondary voltages of both transformers are added if they are connected with proper polarity, but the current ratings are remains same.

Condition for series operation:

Both transformers should be identical i.e,

a Voltage ratio/turns ratio must be same

b Polarities must be same

c Type of core of both transformers (core or shell type) must be same.

d Input voltages of both transformers must be same.

e KVA ratings of both transformers must be same.

f Percentage impedance or per unit impedance of both the transfers must be same.

Precautions:

- **The polarities of secondary of both transformers should be connected in proper way, same as series connection, to get the voltage added, otherwise the output voltage will be zero.**
- **As the output voltage is double that the individual secondary voltages, care to be given to ascertain the insulation level of the secondary windings.**

Three single phase transformers for three phase operation

Objectives: At the end of this lesson you shall be able to:
- list and interpret the four types of connections of primary and secondary windings
- state the phase and line values of current and voltage.

There are various methods available for transforming 3-phase voltages, that is for handling a considerable amount of power. There are four possible ways in which the primary and secondary windings of a group of three transformers may be connected together to transfer energy from one 3-phase circuit to another. They are:

Primaries in U, Secondaries in U

Primaries in U, Secondaries in D

Primaries in D, Secondaries in D

Primaries in D, Secondaries in U.

Star/Star or U/U connection: Fig 1 shows the connection of a bank of 3 trans-formers in a star-star. This connection is most economical for small, high voltage transformers because the number of turns per phase and the amount of insulation required is minimum. This connection works satisfactorily only if the load is balanced. For a given voltage V between lines, the voltage across the terminals of a U connected transformer is ; the coil current is equal to the line current I.

of a Y connected transformer is $V/\sqrt{3}$; the coil current is equal to the line current I.

Star - Delta or U/D connection: In primary side 3 transformers are connected in star and the secondary consist of their secondary connected in delta as shown in Fig 2. The ratio between the secondary and primary line voltage is 1/ times the transformation ratio of each transformer. There is a 30o shift between the primary and secondary line voltages. The main use of this connection is at the substation end of the transmission line.

Fig 1

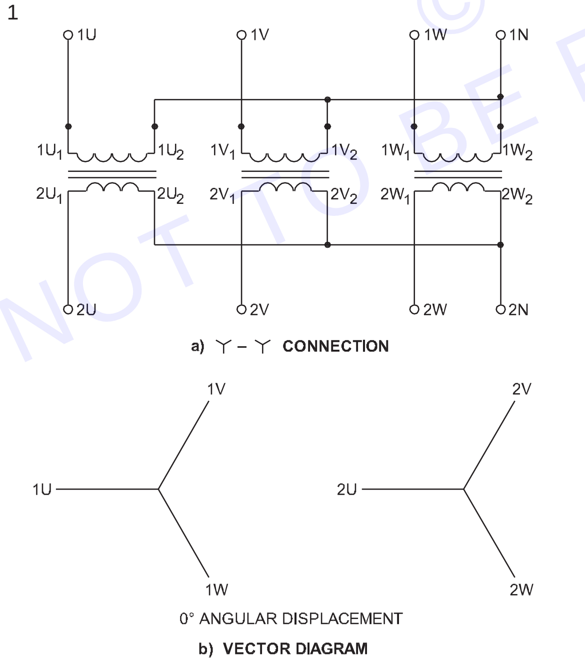
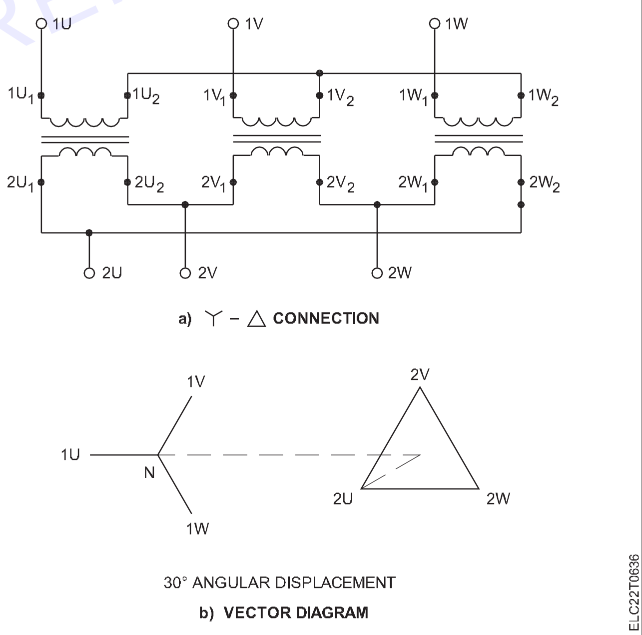


Fig 2



Delta - Delta or D/D connection: Fig 3 shows three transformers, connected in D on both primary and secondary sides. There is no angular displacement between the primary and secondary line voltages. An added advantage of this connection is that if one transformer becomes disabled, the system can continue to operate in open-delta or in V-V. In V-V it can be operated with a reduced capacity of 58% and not 66.6% of the normal value.

Delta - Star or D/U connection: (Fig 4) This connection is generally employed where it is necessary to step up the voltage, as for example, at the beginning of high tension transmission system.

The primary and secondary line voltages and line currents are out of phase with each other by 30o. The ratio of secondary to primary voltage $\sqrt{3}$ is times the transformation ratio of each transformer.

Fig 3

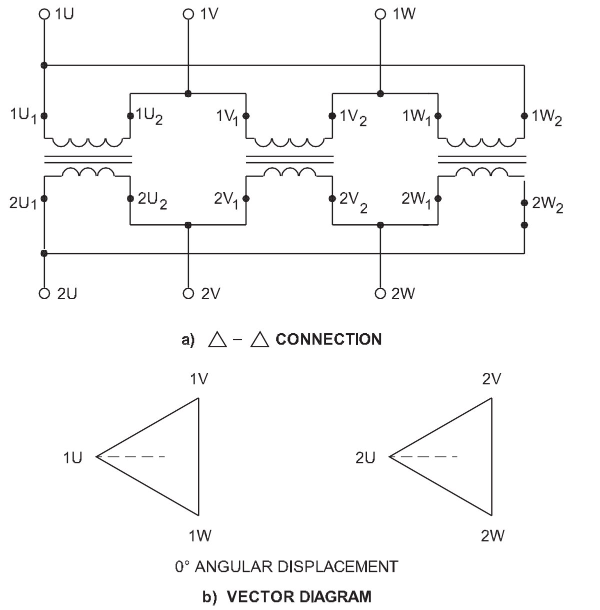
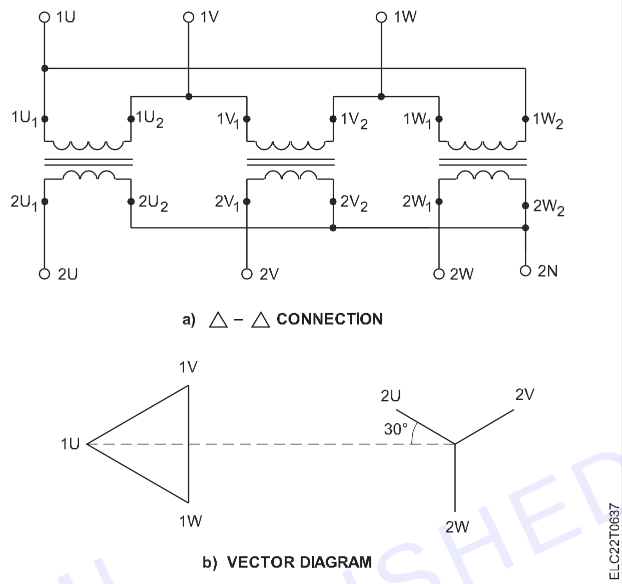


Fig 4



Parallel operation of 3-phase transformer

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

- explain parallel opration
- states the conditions for parallel operation of 3 phase transformer
- states the necessity of parallel opertion.

Parallel operation

Operating two or more transformers by connecting their primaries in parallel to a common supply line and connecting their respective secondaries in parallel with a common load-busbars is called as parallel operaion of transformers.

Conditions for pararllel opertion of transformers:

When operating two or more transformer in parallel, the following conditions have to be satisfied for the best performance of the transformer.

1 The voltage ratio must be same.

2 The per unit impedance or percentage impedance should be same i.e., the ratio between the equivalent leakage reactance and the equivalent resistance(X/R)should be same.

3 The polarities must be same.

4 For three phase transformers

   i The phase sequence must be same

   ii The vector group must be same (i.e., The relative phase displacement between the secondary line voltages must be zero)

Parallel operation of 3-phase transformer:

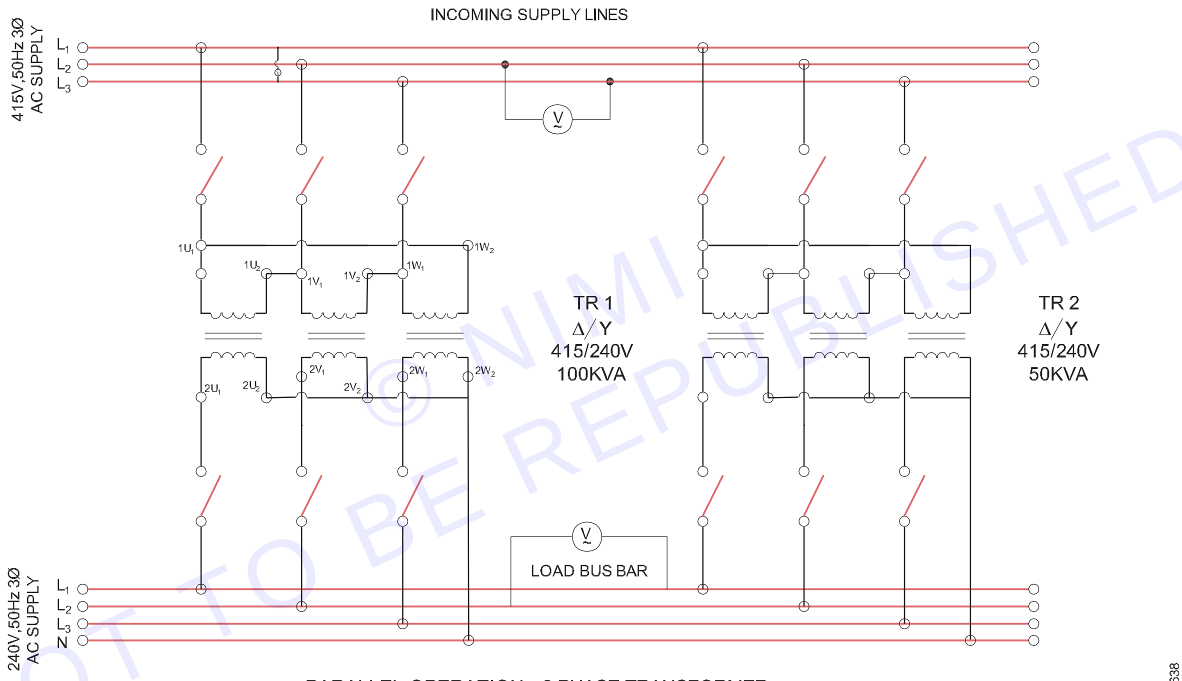
Fig 1 shows the connection diagram for parallel operation of two numbers of 3-phase transformers. In this case, the connection of both of transformer 1 and 2 are (delta - star)same.

However to operate the 2 transformers of having Y/D and connection, their primary and secondary line voltage D/Y must be same. In this case,the turns ratio may not be equal, but the voltage ratio between the terminal voltage of primary and secondary must be same.

If two transformers having different ratings, are connected in parallel the their percentage impedance must be same, where as the numerical impedance of transformer 1 will have half the impedance of transformer 2. In this case both the transformers will share the common load in propertional to their KVA ratings.(Fig 1)

For best performance of the parallel operation, the regulation of both the transformers must be same . If the percentage impedance of both the transformers are different. Than one transformer will be operating at a higer power factor and other will be operating at a lower power factor.

Fig 1



PARALLEL OPERATION - 3 PHASE TRANSFORMER - CONNECTION DIAGRAM

Cooling of transformer - Transformer oil and testing

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

- explain the necessity of cooling
- state the methods of cooling.

Necessity of cooling

Transformer is heated up when current flows through its, winding. This causes the liberation of heat. In large size transformer, where power rating is high, large amount of heat is liberated. This will affect the insulation of the windings as well as reduction of transformer efficiency. This heat should be transformed from transformer winding and dissipated in the atmosphere .

Methods for cooling transformers: Following are the methods of cooling employed in transformers. Any one or more methods could be adopted depending upon the size, application and location of the transformer.

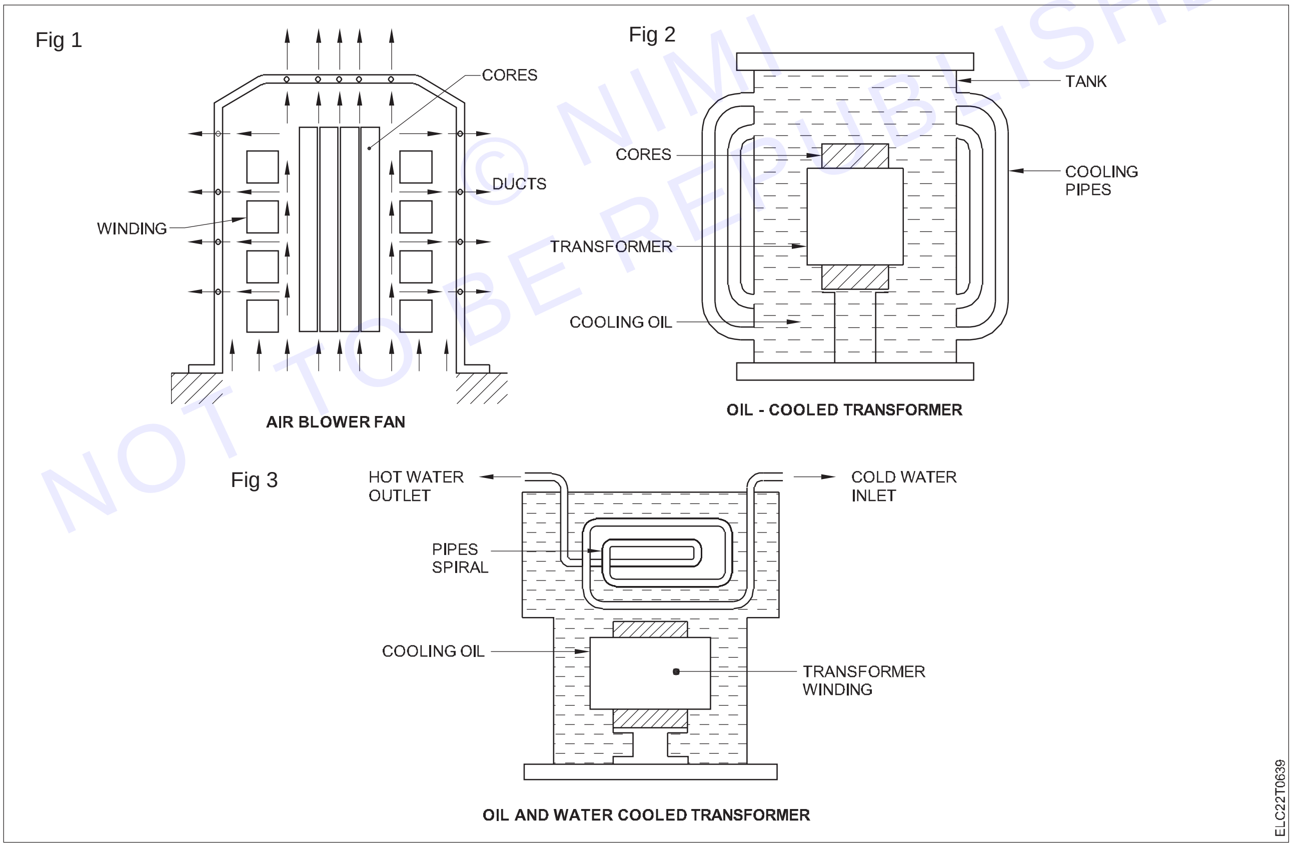
- Natural air method
- Air blast method (Fig 1)
- Natural oil cooled method (Fig 2)
- Oil blast method
- Forced circulation of oil
- Oil and water cooled (Fig 3) and
- Forced oil and water cooled

Natural air cooling method is generally adopted for low capacity distribution transformer upto 100KVA. The natural circulation of the surrounding air is used to carry away the heat from the transformer winding.

In air blast method, the fans are used to blow the air on the surface of the transformer thereby the heat generated is carried away by the air blast.

Transformer of 200KVA above capacity are cooled by using an insulating oil. The winding and core are immersed in oil. The area of the tank is increased by using cooling tubes. (Radiator tubes)

In oil and water cooled system, the low pressure water tubes through the heated oil used to remove the heat from the transformer.



Testing of transformer oil

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

- explain the transformer oil
- name three insulating oils used in transformer
- list the important properties of a transformers oil
- state the necessity of transformer oil
- state the causes for deterioration of oil
- explain the methods of testings the oil for its parameter.

Transformer oil

It is an insulating liquid, used to cool and insulate the transformer windigs and core.A cooling liquid is also considered as a part of the transformer.

Three kinds of cooling oils/liquids are used in transformers today.

- Mineral oil (inflammable)
- Silicon liquids(low flammable) and
- Hydrocarbon liquids (non-flammable)

The common transformer oil is a mineral oil obtained by refining crude petroleum. Clean and dry mineral oil is an excellent insulator. Its loss by evaporation is small. But it is an inflammable liquid and readily absorbs moisture from the air. Great care should be taken to keep the oil away from flame and moisture.

Synthetic liquids do not catch fire easily. Synthetic liquids are therefore replace mineral transformer oils of those transformers used in

- underground mines
- refineries and hazardous location
- tunnels
- workshop and plants of metal processing theatres and cinemas etc.

Transformer oil consists of organic compounds, namely paraffin, naphthalene and aromatics. All these are hydro carbons, hence insulating oil/transformer oil/ synthetic transformer oil known as ASKARELS and PYROCLORE are also in use.

Properties of transformer oil

A good transformer oil should have the following properties.

1 High specific resistance so that high insulation resistance

2 Better heat conductivity, (i.e) higher specific heat.

3 High firing point, so that not to catch fire at low temperature.

4 Do not absorb moisture easily, when exposed to air.

5 Low viscosity

Necessity of transformer oil: Large capacity distribution transformers produces more heat due to losses like core losses and copper losses, on load. It is necessary to stablize the heat within temperature class by providing suitable insulating materials.

Transformer oil acts as a good electrical insulating material. Thus it reduces electrical break down. Transformer oil will also act as cooling agent. Thus it brings thermal stability to all the internal parts of transformer.

Causes for deterioration of transformer oil: When the oil cooled transformers are in use, the oils of the transformers are subjected to normal deterioration due to the conditions of the use.

For example

1 The oil may come in contact with the air, there by presence of moisture and dust in the oil. The presence of moisture is harmful and affects the electrical characteristics of oil and will accelerate deterioration of insulating materials.

2 Sediment and precipitable sludge may be formed on the winding and core surfaces. It will reduce the cooling rate and hence it may lead to deterioration of the insulating materials.

3 The presence of certain solid iron, copper and dissolved metallic compounds will increase the acidity. In such cases, the resistivity decreases, and electrical strength also decreases, and it is also the causes for deterioration of transformer oil.

Testing of transformer oil: For reliable use and maintenance of oil cooled transformer, the transformer oil shall be tested before initial filling of the oil as well as during service of the transformers. As per the test result it may be required to filter the transformer oil or in some cases, new oil may be recommended for safe and better maintenance of oil cooled transformers.

The following tests are conducted periodically to decide the performance of the transformer oil.

1 Field test of insulation oil

2 Crackle test of insulating oil

3 Dielectric test of insulating oil

4 Acidity test.

1 Field test of insulating oil

A drop of transformer oil, when placed slowly from a pipette on the still surface of a distilled water contained in heater should retain its shape when the oil is new.

In the case of used cyclo-octane oils (or) paraffin oils (even though unused) the drop usually flattened. If this flattened drop occupies an area of diameter less than 15 to 18 mm, the oil may be used. Otherwise, it has to be reconditioned. Oils with the longer spreads are unsuitable.

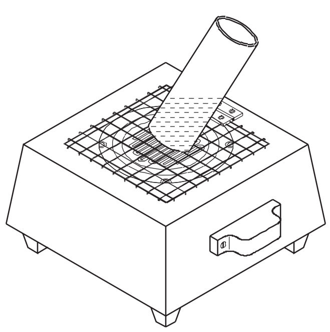
2 Crackle test of transformer oil (Fig 1)

A rough test may be made, by closing one end of steel tube, and heating the closed end to just dull red hot. (Fig 1) When the oil sample is plunging into the tube, a sharp Crackle sound will be heard, if the oil contains much moisture. Dry oil will only sizzle.

3 Dielectric test of transformer oil

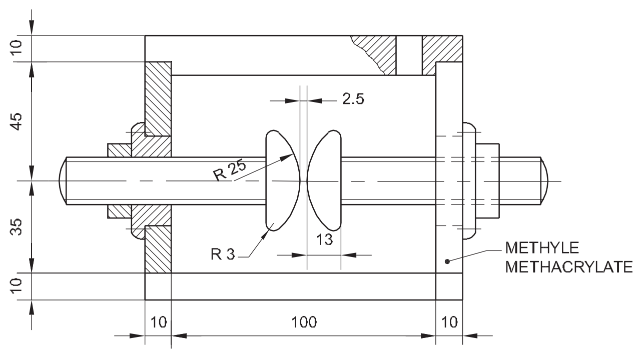
This test is preferably conducted using standard oil test set. The oil test set consists of a container/cell made up of glass or plastic.(Fig 2)

Fig 1



CRACKLE TEST

Fig 2



OIL TEST CONTAINER/CELL

The cell shall have an effective volume between 300 to 500 ml. It should be preferably closed. Section view of container. (Fig 3)

Two numbers of the copper, brass, bronze or stainless steel in the shape of sphere of diameter 12.5 to 13 mm elliptical are mounted on a horizontal axis at 2.5 mm apart, is used as electrodes, for oil test of 11KV transformer.

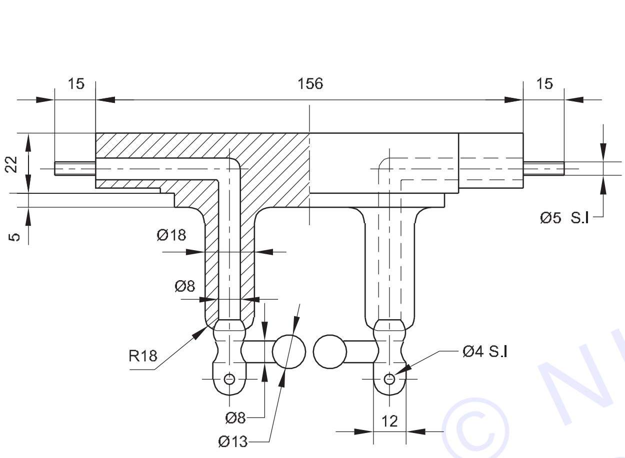
The cell is mounted on a test set. HT connection to the electrodes, is made by the point contact arrangements.

The test set is also provided into step up transformer where the voltage can be varied from zero to 60KV. In some designs, the voltage is varied by electric motor, with the operation of push button switch.

Electrical circuit diagram of dielectric test unit (Fig 4)

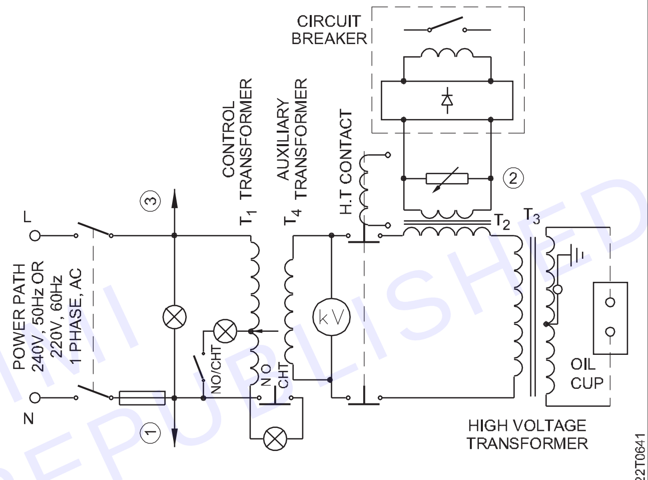
For conducting dielectric test on transformer oil, the oil is to be gently agitated and turned over several times so that homogeneous distribution of the impurities contained in the oil is spread all over.

Fig 3



DIELECTRIC TEST

Fig 4



CIRCUIT DIAGRAM OF DIELECTRIC TEST

Immediately after this, the oil is poured down into the test cell slowly in order to avoid air bubbles. The operation is carried out in a dry place free from dust. The oil temperature at the time of test shall be same as that of ambient.

After fulfilling the above conditions the cover of the cell is placed in position. The cell is placed in the test unit and power is switched "ON".

The AC voltage across the electrode of frequency 40 to 60Hz is increased uniformly at the rate of 2KV RMS starting from 'O' up to the value of producing break down. The break down voltage is the voltage reached during the test at the time the first spark occurs between electrodes.

The circuit is opened automatically if an arc is established between electrodes. The break down voltage is recorded and the reading is interpreted according to the standard ratings. The requirements as per IS-335-1983 is: Electrical Strength (break down voltage)

1 New unfiltered transformer oil - 30KV (RMS)

2 After filtration transformer oil - 50KV (RMS)

It is recommended to filter the transformer oil if the break down voltage does not attain 30KV (RMS).

The test shall be carried out 6 times on the same cell filling. The electric strength shall be the arithmetic mean of the 6 results which have been obtained.

4 Acidity test

The acid products are formed by the oxidation of the oil. This oxidation will deteriorate the insulating materials like insulating paper and press boards used in transformer windings. It is therefore essential to detect and monitor the acidity formation.

To conduct this test portable test kit is available consisting of:

1 Two polythene bottles containing 100ml each of ethyl alcohol and sodium carbonate solution of 0.0085N concentration.

2 An indicator bottle containing universal indicator.

3 Four clean glass test tube.

4 Three graduated droppers, which serves as pipettes.

5 Colour chart with acidity range.

6 Instruction booklet.

PROCEDURE

The test is conducted by taking 1.1 ml of insulating oil (to be tested) in test tube, 8 ml oil 1 ml of rectified spirit is added and mixture is to be gently shakened. Further 1 ml of solution of 0.008 5 N sodium carbonate added. After shaking the test tube once again 5 drops of universal indicator is added. The resulting mixture develops a colour depending on the acidity value of the mixture.

The approximate colour range will be as follows:

Total acidity value in No.	Colour
0.00	Black
0.2	Green
0.5	Yellow
1.0	Orange

Any how the colour chart will be provided with the test kit to indicate exact value.

Three phase transformer

Uses of three phase transformers

- Power generated about 11kV
- Transmission voltages of 110, 132, 275, 400 and 750 kV
- Step up and step down by three phase transformers
- Previously interconnection of 3 single phase transformers used
- Single unit 3ϕtx. Costs 15% less and need less space

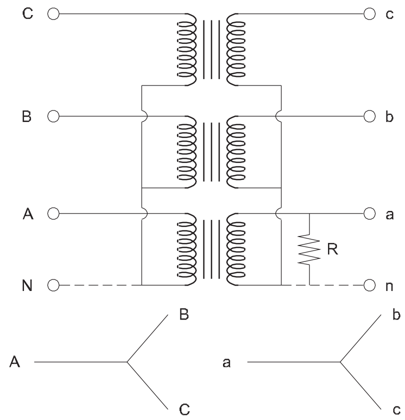
Star star (YY) connection (Fig 5)

This connection is most economical for small, high-voltage transformers.Numberof turns/phase and the amount of insulation required is minimum (as phase voltage is only 1/3 of line voltage. Phase shift of 30° between the phase voltages and line voltages both on the primary and secondary sides.Line voltages on both sides as well as primary voltages are respectively in phase with each other. Works satisfactorily only if the load is balanced.

Delta delta (ΔΔ) connection (Fig 6)

This type connection is economical for large, low-voltage. No internal phase shift between phase and line voltages on either side as was the case in Y Y.This connection can be used for unbalanced load. Better sinusoidal voltage output. If one transformer becomes disabled, the system can continue to operate in open-delta or in V V although with reduced available capacity. The reduced capacity is 58% and not 66.7% of the normal value

Fig 5

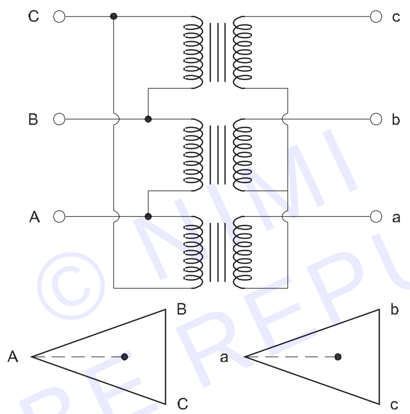


0° ANGULAR DISPLACEMENT

STAR STAR (YY) CONNECTION

ELC22T0642

Fig 6



0° ANGULAR DISPLACEMENT

DELTA DELTA (ΔΔ) CONNECTION

ELC22T0643

Star delta (Y Δ) connection (Fig 7)

This connection is used at the end of the transmission linewhere the voltage is to be stepped down. The primary winding is Y-connected with grounded neutral. The ratio between the secondary and primary line voltage is 1/3 times the transformation ratio of each transformer. There is a 30° shift between the primary and secondary line voltages .A Y Δ transformer bank cannot be paralleled with either a Y Y bank. Also, third harmonic currents flows in the Δ to provide a sinusoidal flux.

Delta star (Δ Y) connection (Fig 8)

At the beginning of high transmission system.

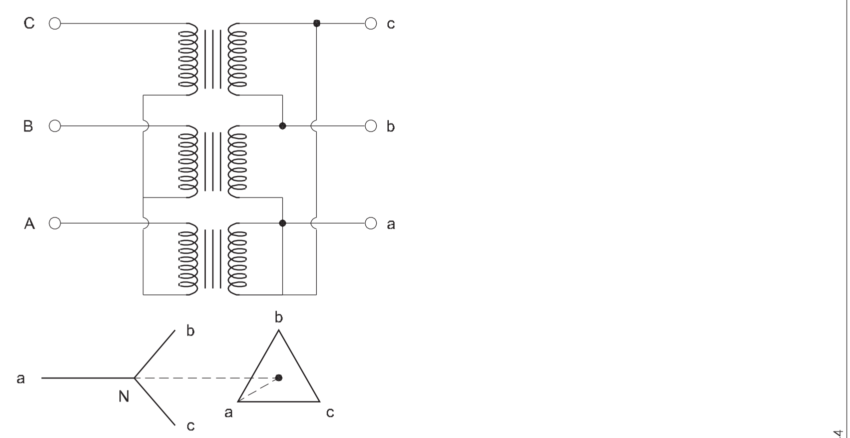
The neutral of the secondary is grounded for providing 3-phase 4-wire service.

Can be used to serve both the 3-phase power equipment and single-phase lighting circuits.

Primary and secondary line voltages and line currents are out of phase with each other by 30°.

Impossible to parallel such a bank with ΔΔ or Y Y bank of transformers even though the voltage ratios are correctly adjusted.

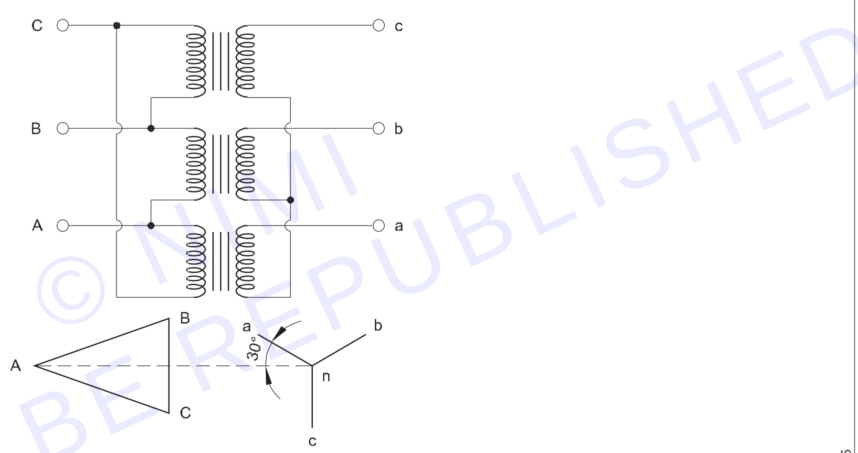
Fig 7



30° ANGULAR DISPLACEMENT

STAR DELTA (YΔ) CONNECTION

Fig 8



30° ANGULAR DISPLACEMENT

DELTA STAR (ΔY) CONNECTION

Open delta - VV connection (Fig 9)

- Used when load is less or future expansion expected
- When a 1ϕ transformer need repairs
- The total load that can be carried by a VV bank is not two-third of the capacity of a bank but it is only 57.7% of it.
- one of the transformers of a 3ϕ is removed and 3-phase supply is connected to the primaries

Instrument transformers

The transformer which is required to facilitate measurement of high voltage and current are known as instrument transformers. They are of two types

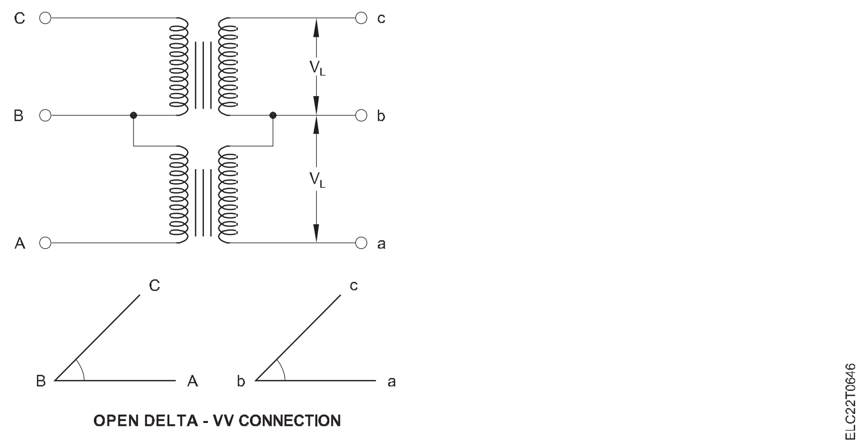
1 Current transformer

2 Potential transformer

Current transformer (CT)

Used with low-range ammeters to measure currents in high-voltage alternating-current circuits, where it is not practicable to connect instruments and meters directly to the lines. They step down the current in a known ratio.

Fig 9



The current transformer has a primary coil of one or more turns of thick wire connected in series, with the line whose current is to be measured. The secondary consists of a large number of turns of fine wire and is connected across the ammeter terminals (usually of 5 - ampere or 1 - ampere range). (Fig 10&11)

Fig 10

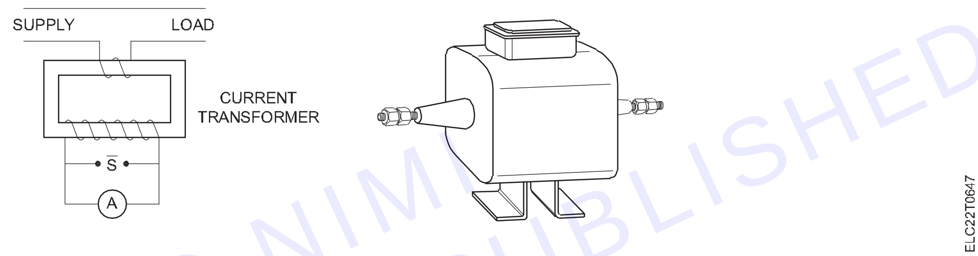
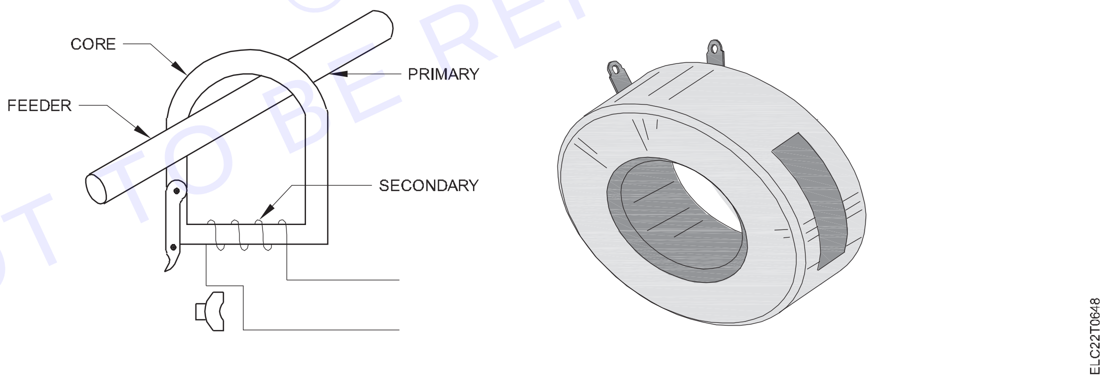


Fig 11



Voltage is stepped up and current stepped down. If the CT Ratio (I_1/I_2) and reading of the a.c. ammeter is known, the line current can be calculated.

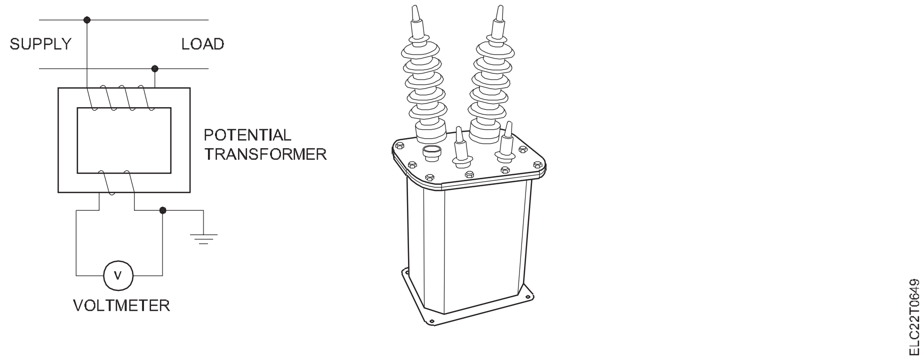
Most commonly used current transformer is the one known as clamp-on or clip-on type. It has a laminated core with a hinged section to press. When the core is thus opened, it permits the admission of very heavy current carrying bus bars and the core is tightly closed by a spring. The current carrying conductor or feeder acts as a single-turn primary whereas the secondary is connected across the standard ammeter. It should be noted that, since the ammeter resistance is very low, the current transformer normally works short circuited.The current transformer normally works secondary short circuited.

Ammeter in secondary is having negligible resistance. As secondary is short circuited, net flux and voltage is very less in secondary. Current in primary of CT is the load current. If ammeter is taken out for any reason;secondary must be short-circuited with the help of short-circulating switch. If secondary of current transformer is not short circuited;absence of counter amp-turns (mmf) of the secondary, the unopposed primary m.m.f. will set up an abnormally high flux in the core. Excessive core loss with subsequent heating and a high voltage across the secondary terminals. If unprotected, CT may get damaged.

The secondary of a current transformer should never be left open under any circumstances.

Potential transformers (Fig 12)

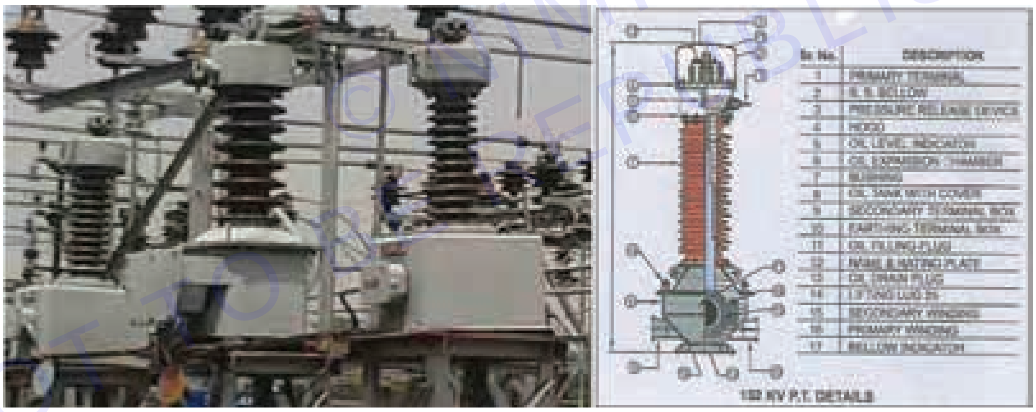
Fig 12



PT are used to measure HV in combination with low voltage voltmeters. They are accurate-ratio step-down transformers. When divided by voltage transformation ratio, gives the true voltage on the high voltage side. Shell-type ordinary two-winding transformers discussed. Power rating is extremely small. Upto voltages of 5,000 usually of the dry type 5,000 to 13,800 volts, either dry type or oil immersed type.

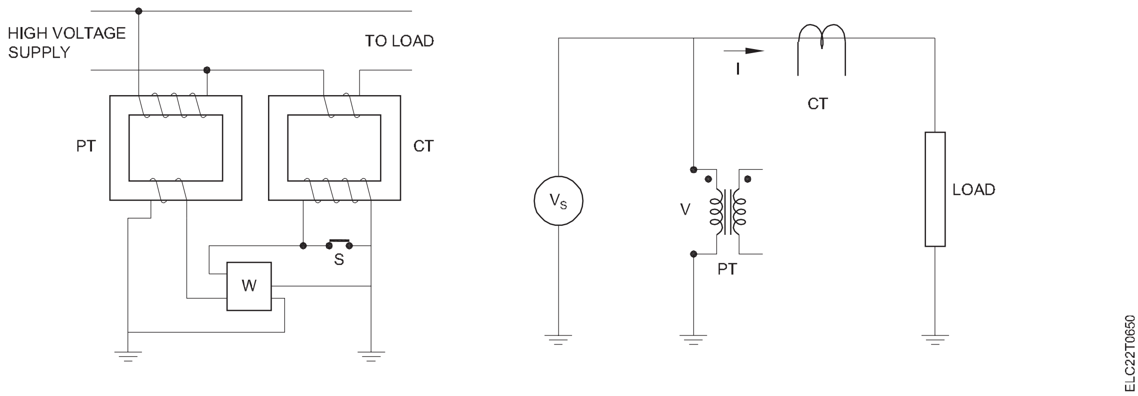
Voltages above 13,800 always oil immersed type.Operate instruments or relays or pilot lights, their ratings are usually of 40 to 100 W. For safety, the secondary should be completely insulated from the high-voltage primary and grounded. (Fig 13)

Fig 13



Power measurement (Fig 14)

Fig 14



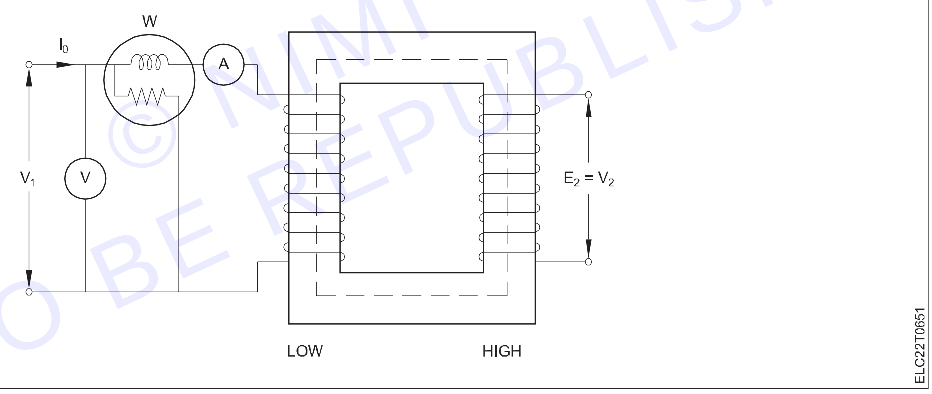
Testing of transformer (Fig 15)

Open circuit or no load test

Open circuit or No load test is conducted to find no load losses or core losses. The following steps are used to conduct this test.

- Find I_0 and find R_0 and X_0
- HV kept open
- Easy to provide supply to LV
- Low range measuring instruments only needed
- Rated voltage is fed
- No load current is measured I_0
- No load loss/ Core loss shown by wattmeter
- OC Test
- The no load current in LV is only 2 - 10% of full load current
- HV side is open
- Copper loss in LV is negligible and nil in HV
- Hence the entire loss shown read in wattmeter is taken as CORE Loss

Fig 15

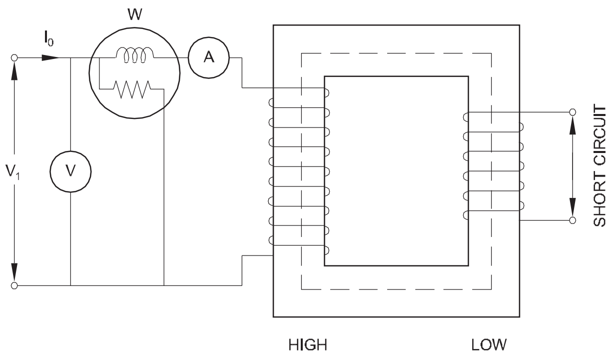


Short circuit test or impedance test (Fig 16)

The following steps are used to conduct the Short circuit test.

- LV side is short circuited
- Rated current is passed in HV side
- The voltage at HV side is only 5-10% of rated voltage.
- Flux is proportional to the voltage
- Voltage is very low, and hence flux too
- Core loss is dependent on flux setting loss
- Core loss value is negligibly small
- Wattmeter in SC test is considered as Copper loss only

Fig 16



To find the copper losses

Calculations from SC test data

Calculations from SC test data

$$\text{Let } k = \frac{V_2}{V_1}$$

$$I_2 Z_{02} = V_{sc}$$

$$Z_{02} = \frac{V_{sc}}{I_2}$$

$$Z_{01} = \frac{Z_{02}}{K^2} \text{ also,}$$

$$I_2^2 R_{02} = W_{sc},\ R_{02} = \frac{W_{sc}}{I_2^2}$$

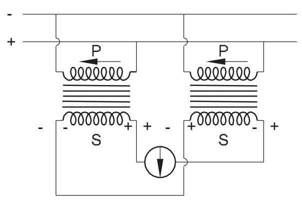
$$R_{01} = \frac{R_{02}}{K^2},$$

$$X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$$

Polarity test on transformer (Fig 17)

- If voltmeter indicates zero, transformers polarities are same
- If voltmeter indicates twice the rated voltage, transformers polarities are different

Fig 17



Transformer rating

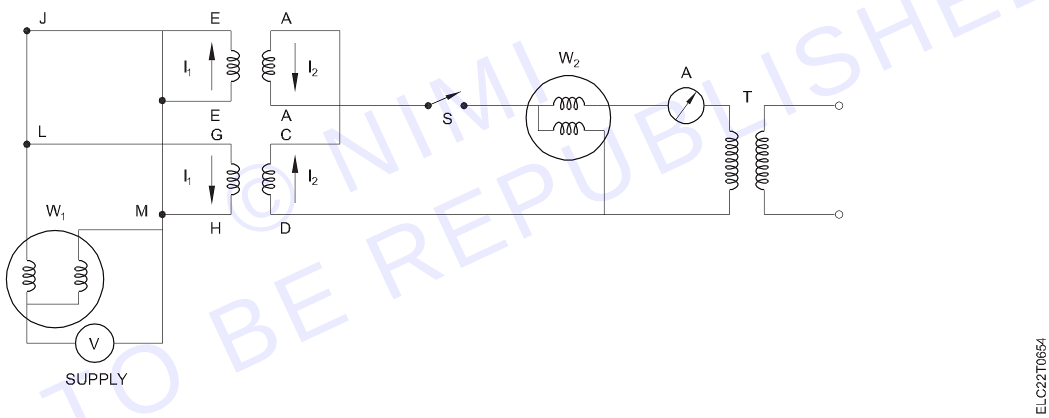
- Transformer is rated in kVA and not KW
- iron loss of a transformer depends on voltage.
- Copper loss of a transformer depends on current
- Total transformer loss depends on volt-ampere (VA) and not on phase angle between voltage and current
- Transformer loss is independent of load power factor.
- Hence rating of transformers is in kVA and not in kW.

Voltage regulation

- $\% \text{ regulation "down"} = \dfrac{\text{No load voltage - Full load voltage}}{\text{Full load voltage}}$
- unless stated otherwise, regulation is to be taken as regulation "down"
- $\% \text{ regulation "up"} = \dfrac{\text{No load voltage - Full load voltage}}{\text{No load voltage}}$

Sumpner back to back test (Fig 18)

Fig 18



- Find efficiency, regulation and heating under load conditions
- Can be done if 2 similar tx. Are available
- Power drawn is only for meeting losses
- Primaries of tx. Are paralleled
- If switch s1 open, W1 indicates core loss of 2 transformers
- Secondary potentials are in opposition
- $V_{AB} = V_{CD}$
- A is connected to C and B to D
- No secondary current due to potentials are in opposition
- T is auxiliary transformer
- Through T, rated I2 is passed in secondary's by closing switch S1
- I_2 flows from D to C and then from A to B.
- Flow of I_1 is through the loop FEJLGHMF
- I_2 does not pass through W_1

- W_1 read only the core loss
- W_2 read the copper loss only at the current set from T.
- $W_1 + W_2$ is twice the loss of a single transformer
- Power taken from source is only $W_1 + W_2$
- Continuous losses create heat in transformer
- Temperature rise characteristics data can be found out by using thermocouples
- No full loading is needed to get temperature rise data.

Core loss is practically constant in all load conditions

Full load copper loss = X watts

$\frac{1}{2}$ load copper loss = $(\frac{1}{2})^2$. X watts = $\frac{X}{4}$

$\frac{1}{4}$ load copper loss = $(\frac{1}{4})^2$.X watts = $\frac{X}{16}$

kW = kVA cos ϕ

Condition for maximum efficiency

- Cu loss = Iron loss
- Given iron and full load cu loss,
- Then the load at which two losses would be equal (i.e. corresponding to maximum efficiency)

$$= \text{Full load x} \sqrt{\frac{\text{Iron loss}}{\text{Full load copper loss}}}$$

Efficiencies of transformer

- Ordinary efficiency

$$\text{Ordinary efficiency} = \frac{\text{Output in watts}}{\text{Input in watts}}$$

- All day efficiency

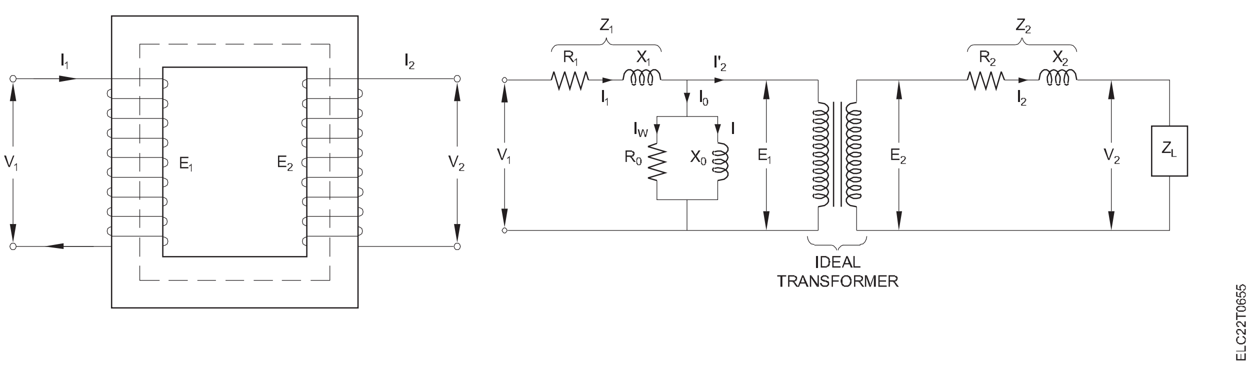
$$\text{All day efficiency} = \frac{\text{Output in kilo - watts hours}}{\text{Input in kilo - watts hours}} \text{(24 hours)}$$

- Ordinary efficiency > All day efficiency

Transformer equivalent circuit

Transformer circuit (Fig 19)

Fig 19



- To transfer X_2 from secondary to primary, $X_2 = \frac{X_2}{K^2}$
- To transfer X_1 from primary to secondary $X_1 = X_1 k_2$
- Impedance of transformer referred to primary

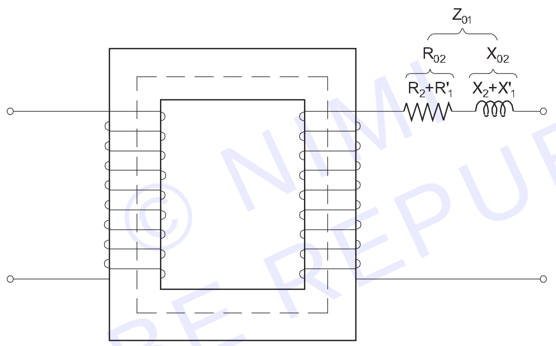
  $Z_{01} = \sqrt{R_{01}^2 + X_{01}^2}$

Transferring data from one side to other

Parameter	Secondary to primary	Primary to secondary
Resistance	R_2/K^2	R_1K^2
Reactance	X_2/K^2	X_1K^2
Impedance	Z_2/K^2	Z_1K^2
Voltage	V_2/K	V_1K
Current	I_2K	I_1/K

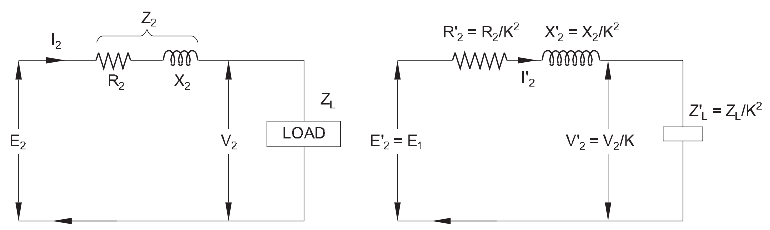
Impedance of transformer referred to secondary $Z_{02} = \sqrt{R_{02}^2 + X_{02}^2}$ (Fig 20)

Fig 20



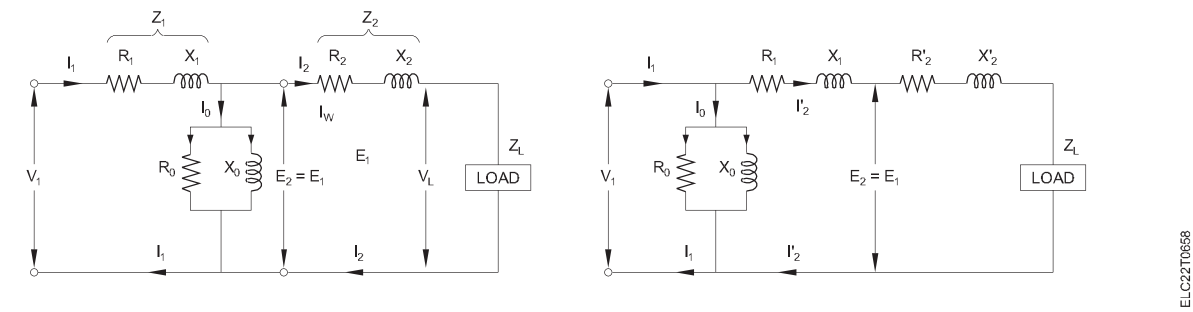
Secondary circuit (Fig 21)

Fig 21



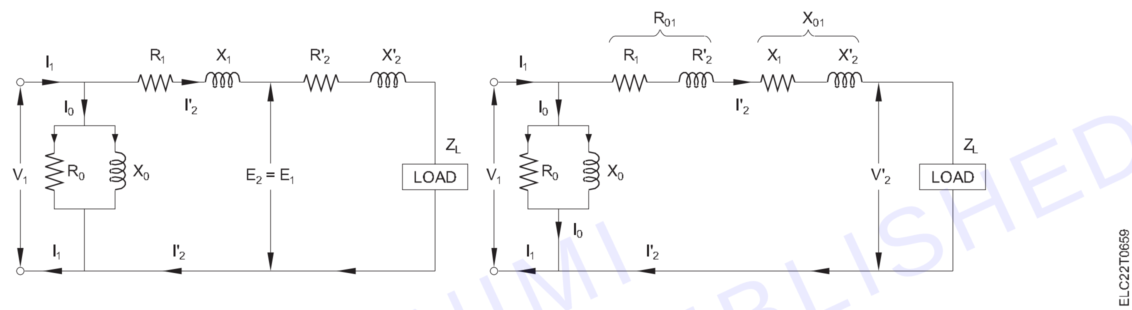
Equivalent circuit referred to primary (Fig 22)

Fig 22



Equivalent circuit referred to primary (Fig 23)

Fig 23



MODULE 9 : Electrical Meters and Calibration

LESSON 50-53 : Instruments - scales - classification - PMMC and MI meters

Objectives

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

- state the instrument, classification of instruments
- classify electrical instruments
- explain the type forces required for the proper functioning of an electrical instruments
- state the prinicple and construction of PMMC, MI type instruments
- state the prinicple & construction of meggar, earth testa
- state the digital ammeter voltmeter, frequently meter, energy meter calibration of meter.

Measuring instrument

The device or instrument used for measuring an unknown quantity is called measuring instrument. These devices compare the unknown quantity to be measured with the unit of measurement or standard quantity.

Examples are voltmeter, ammeter, measuring tape etc

The instrument which are used for measuring electrical quantities like voltage, current etc are called electrical measuring instrument

Classification of measuring instrument

Electrical instruments may be divided into two categories, that are;

Primary instrument or Absolute instruments,

Secondary instruments.

Primary instrument

Primary or Absolute instruments gives the quantity to be measured in term of instrument constant & its deflection.

Example: Tangent Galvanometer

It gives the value of current to be measured in terms of the tangent of deflection produced by current and meter constant (the radius and number of turns wire used and the horizontal component of earth's field)

Secondary instrument

These instruments give the magnitude of electrical quantity to be measured directly. These instruments are required to be calibrated by comparing with another standard instrument before putting into use.

Example: Voltmeter, Ammeter etc

Electrical measuring instruments may also be classified according to the kind of quantity, kind of current, principle of operation of moving system.

According to principle of operation

According to the principle of operation of the moving system, electrical measuring instruments are also be classified into;

Magnetic effect	Ammeter and Voltmeter
Electrodynamic effect	Ammeter, Voltmeter and wattmeter
Electromagnetic effect	Ammeter and Voltmeter, wattmeter and watthour meter
Thermal effect	Ammeter and Voltmeter
Chemical effect	dc ampere hour meter
Magnetic effect	Voltmeter

According to the kind of current

According to the type of current of the quantity to be measured; electrical measuring instruments are also be classified into;

- AC Meter
- DC Meter
- AC & DC Meter

Electrical measuring instruments are also be classified into three;

1 Indicating Instrument

2 Recordings Instrument

3 Integrating Instrument

Indicating intrument

It indicate the magnitude of an electrical quantity at the time when it is being measured. The indications are given by a pointer moving over a graduated dial.

Example: voltmeter, ammeter etc

Recording instrument

The instruments which keep a continuous record of the variations of the magnitude of an electrical quantity to be observed over a defined period of time.

Example: ECG, Temperature recorder

Integrating instrument : The instruments which measure the total amount of either quantity of electricity or electrical energy supplied over a period of time.

Example: energy meters

Indicating intrument

Essentials of indicating instruments

As defined above, indicating instruments are those which indicate the value of quantity that is being measured at the time at which it is measured. Indicating instruments consist essentially of a pointer which moves over a calibrated scale and which is attached to a moving system pivoted in jewelled bearings. In an indicating instrument, it is essential that the moving system is acted upon by three torque for satisfactory working. The moving system is subjected to the following 3 torques:

1 Deflecting torque or operating torque
2 Controlling torque or restoring torque
3 Damping torque

Deflecting torque

The deflecting or operating torque (Td) is produced by utilizing one or other effects, e.g., magnetic, electrostatic, electrodynamic, thermal or inductive. The method of torque production depends on the type of instrument. The deflecting torque causes the moving system (and hence the pointer attached to it) to move from its zero position.

Controlling torque

Controlling torque or restoring or balancing torque is the torque which controls the movement of the pointer on a particular scale. Controlling torque is acted opposite to the deflection torque. Important of controlling torque are;

The magnitude of the moving system would be somewhat indefinite under the influence of deflecting torque, unless the controlling torque existed to oppose the deflecting torque.

It increases with increase in deflection of moving system.

Without controlling torque the pointer will swing at its maximum position & will not return to zero after removing the source.

It is obtained by two methods which are discussed below

i Spring control

In the spring control method, a hair spring usually of phosphor bronze, attached to the moving system is used. Two springs are arranged, one at the bottom and other at the top of the pointer, and are twisted in the opposite direction. With the deflection of the pointer, one of the spring is twisted and other unwind. This twist in the spring produces restoring torque which is directly proportional to the angle of deflection of the moving system. The pointer comes to a position of rest (or equilibrium) when the deflecting torque (T_d) and the controlling torque (T_c) are equal.

$T_d \alpha I$

$T_c \alpha \Theta$

At final position, $T_c = T_d$

$\Theta \alpha I$

Since deflection Θ is directly proportional to current I, the spring-controlled instrument have a uniform or equally-spaced scales over the whole of their range.

ii Gravity controll

Gravity control is obtained by attaching a small adjustable weight to some part of the moving system such that, the deflecting torque produced by the instrument has to act against the action of gravity. Thus a controlling torque is obtained. This weight is called the control weight. Another adjustable weight is also attached is the moving system for zero adjustment and balancing purpose. This weight is called Balance weight. The degree of control is adjusted by screwing the weight up or down the carrying system

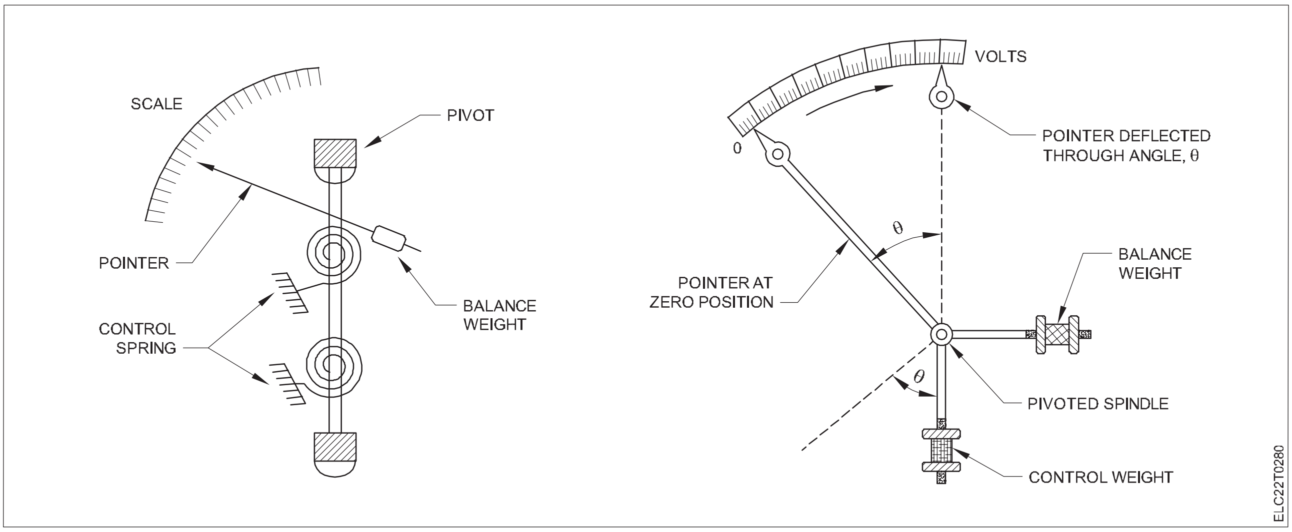
As shown in the figure, the controlling or restoring torque is proportional to the sine of the angle of deflection, i.e

$T_c \alpha \sin \Theta$

$T_d \alpha I$

At final position, $T_c = T_d$

$\sin \Theta \alpha I$



Hence in gravity control instruments, the scales are not uniform but are cramped or crowded at their lower ends.

Comoparison between spring control and gravity control

Spring control	**Gravity control**
Instruments have uniformly or equally spaced scale	Instrument have unequal scale (cramped or crowded at lower end)
Costly	It is cheap compared to spring control
Instrument can mounted in any way	Mounted only in vertical position

Damping torque

Damping torque is one which acts on the moving system of the instrument only when it is moving and always opposes its motion. Such damping force is necessary to bring the pointer to rest quickly, otherwise due to inertia of the moving system, the pointer will oscillate about its final deflected position for quite some time before coming to rest in the steady position. The degree of damping should be adjusted to a value which is sufficient to enable the pointer to rise quickly to its deflected position without over-shooting. According to the degree of damping, damping is of three types as graphically represented below

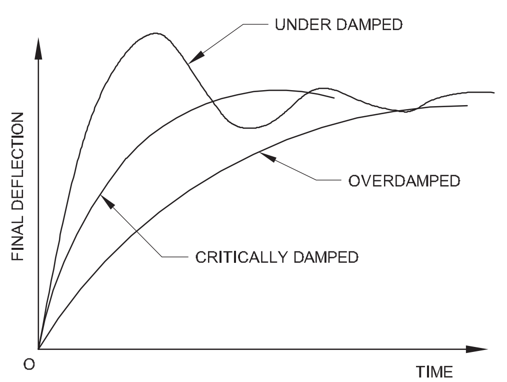
1 Under damped condition:

The response is oscillatoryie the pointer make oscillation at its final position.

2 Over damped condition:

The pointer rises very slowly from its zero position to final position.

3 Critically damped condition:

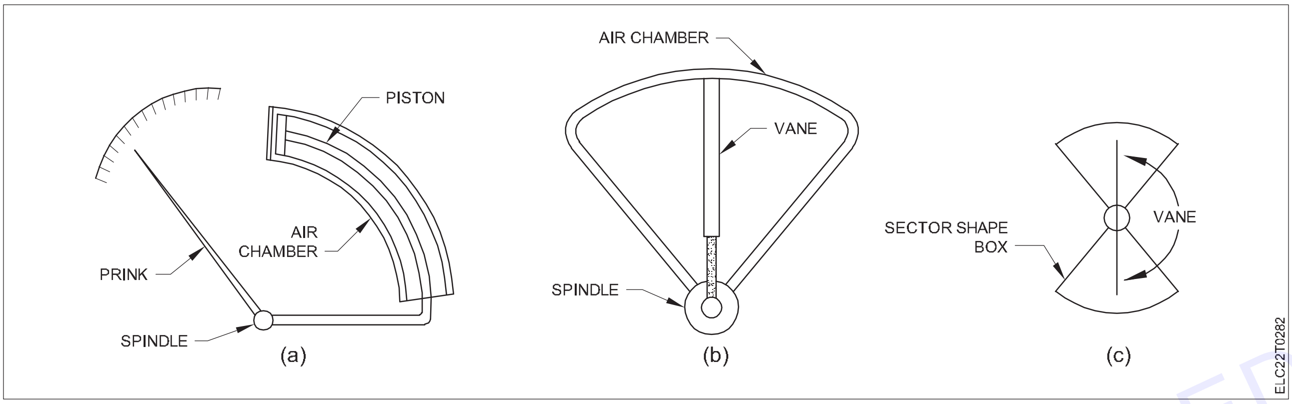


When the response settles quickly without any oscillation, the system is said to be critically damped.

The damping force can be produced by i) air friction, ii) fluid friction and iii) eddy currents.

i Air friction damping

The light aluminium piston attached to the moving system of the instrument is arranged to travel with a very small clearance in a fixed chamber closed at one end. The cross-section of the chamber is either circular or rectangular. Damping of the system is affected by the compression and suction actions of the piston on the air enclosed in the chamber. In another method, light aluminium vane is mounted on the spindle of the moving system which moves in air or in a closed sector-shaped box.

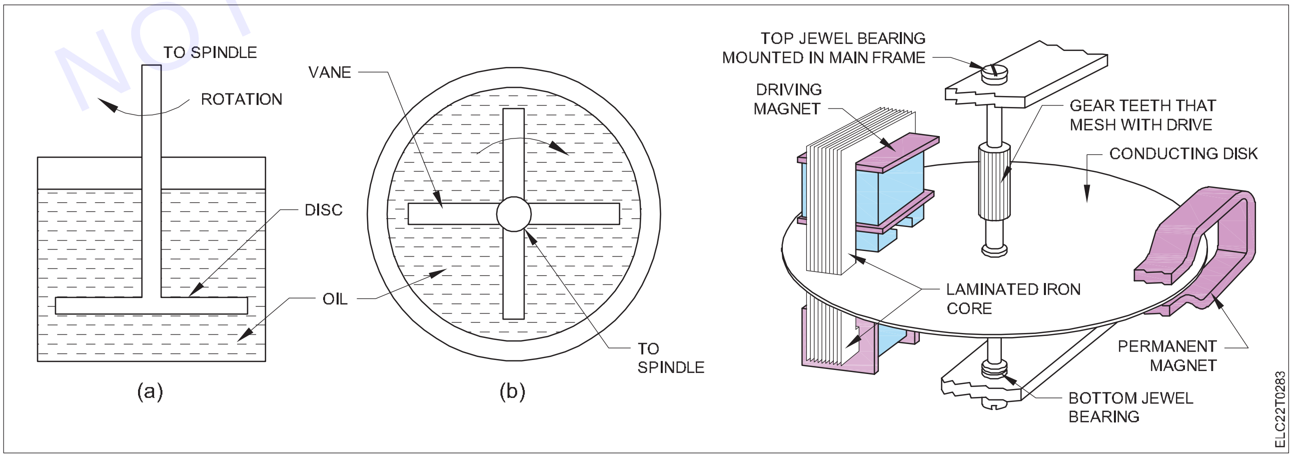


ii Fluid friction daming

Fluid-friction is similar is action to the air-friction. In this type a high viscosity oil is used. Due to greater viscosity of the oil, the damping is more effective. However, oil damping is not much used because of several disadvantages such as objectionable creeping of oil, the necessity of using the instrument always in vertical position and its obvious unsuitability for use in portable instruments.

iii Eddy current damping

Eddy current damping is the most efficient type of damping A thin disc of a conducting but non-magnetic material like copper or aluminium is mounted on the spindle. The disc is so positioned that its edges, when in rotation, cut the magnetic flux between the poles of a permanent magnet. Hence eddy currents are produced in the disc which flow and so produce a damping force in such a direction as to oppose the very cause producing them (Lenz's law). Since the cause producing them, is the rotation of the disc, these eddy currents retard the motion of the disc and moving system as a whole



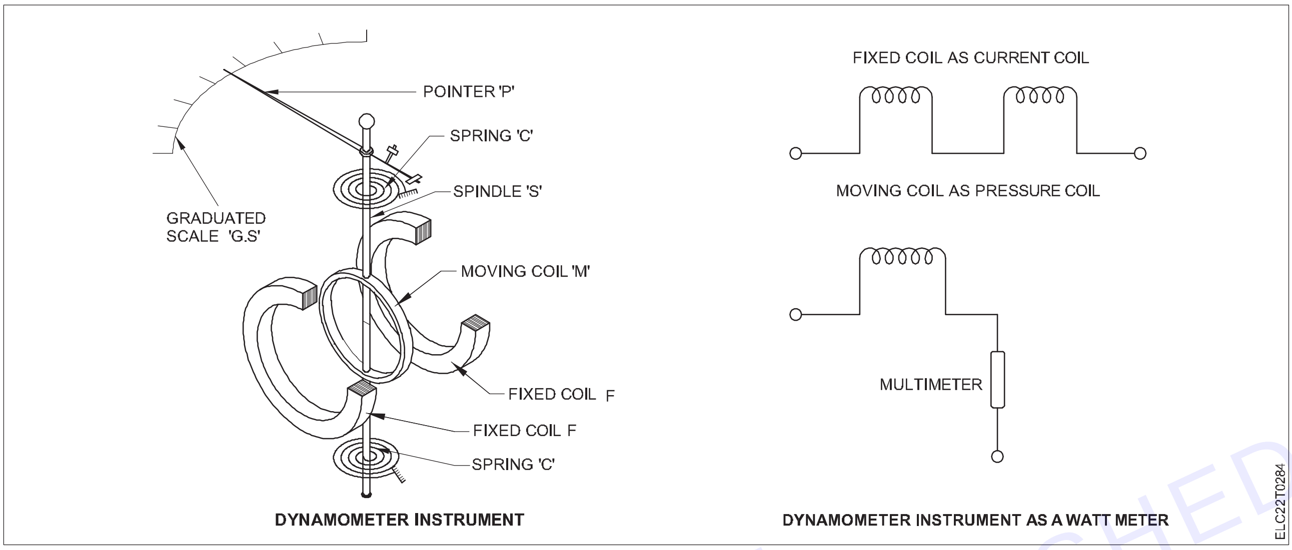
Wattmeter

Dynamometer type

Dynamo-meter type wattmeter is used to measure power in both AC and DC circuit. Dynamo-meter type instrument works on the principle of DC motor.ie. whenever a current carrying conductor is kept in a magnetic field, a force is created and it tends to move the conductor away from the magnetic field.

Operation of this instrument in both AC and DC is possible due to the fact that whenever the current reverses in AC , the direction of flux in the fixed coil as well as the direction of flux produced by moving coil reverses at the same time resulting in the same direction of torque

In this type of instrument, the main magnetic field is produced by an electro magnet named as fixed coil. The fixed coil is treated as current coil and the moving coil is made as pressure coil with necessary multiplier resistance. The deflection torque is proportional to the load current. This type of watt meter have uniform scale



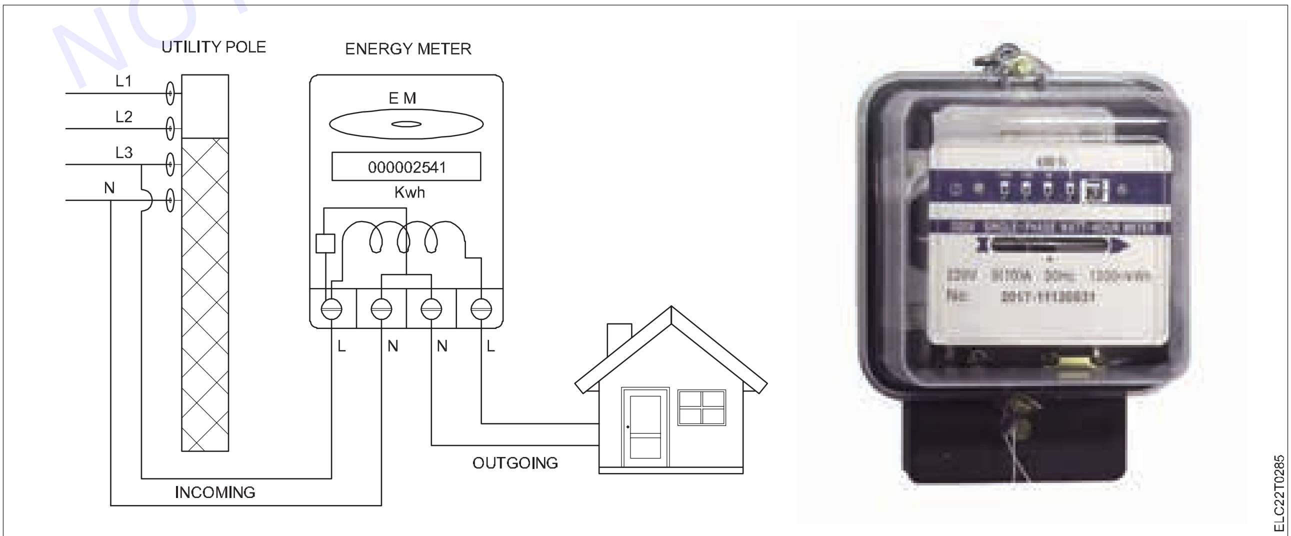
Advantage

- This instrument can be used both in AC and DC.
- As this is an air cored instrument, the hysteresis and eddy current losses are eliminated.
- When used as wattmeter, the scale is uniform.

Disadvantage

- It is more expensive than PMMC instruments.
- It consumes more power than PMMC meters.
- Sensitive for over loads and mechanical impact. Hence careful handling is necessary.

Energy meter



Necessity

The electrical energy supplied by the EB should be billed, based on the actual amount of energy consumed. Electrical energy is measured in KWH in practice. The meter used for this purpose is known as energy meter

In AC induction type energy meter is universally used in domestic as well as industrial uses.

It is an example of integrating instrument. These types of instruments keep a record of the total quantity of energy consumed from the time they are connected to the supply, to the time of reading. Energy meter (watt-hour meter) measure the quantity of electricity in kwh

Parts and function of energy meter

Iron core-is specially shaped to direct the magnetic field in the desired path

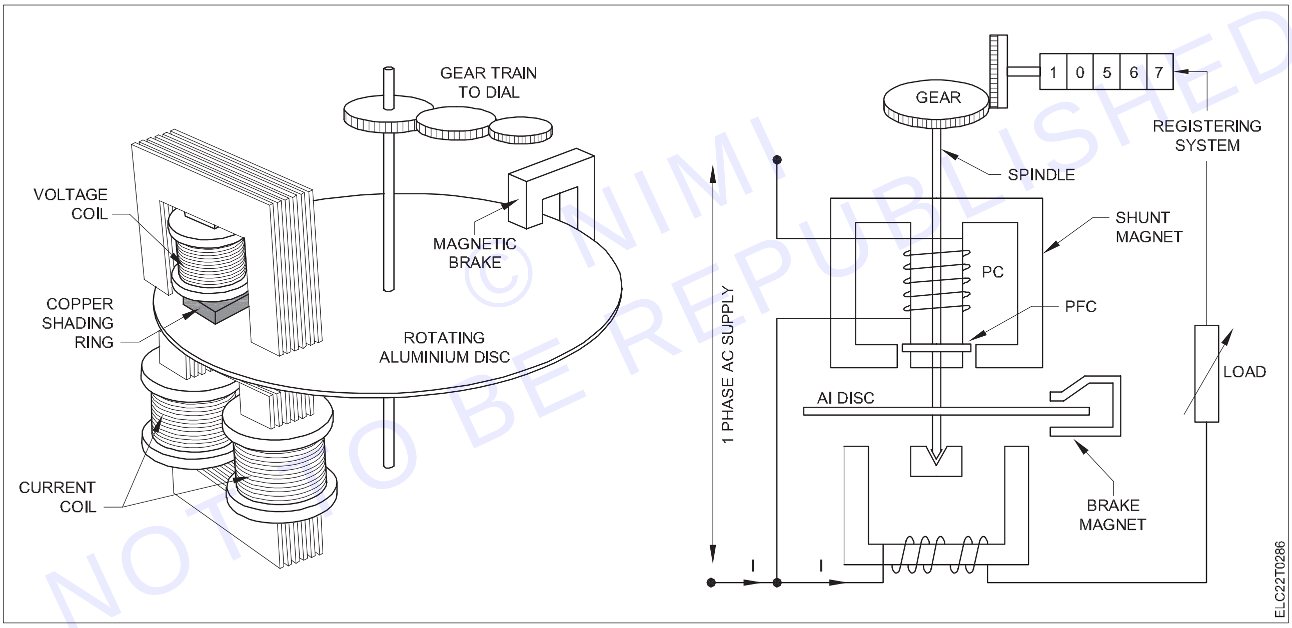
Pressure coil (P.C)-is connected across the supply carry current proportional to the supply voltage (coil have many turns of thin wire).

Current coil (C.C) - is connected series with the supply and carry full load current (coil have few turns of thick wire).

Disc- is the rotating element in the meter. The disc is made of aluminum and is positioned between the air gap between the two coils (PC & CC)

Spindle- the disc is mounted on a vertical spindle whose ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of spindle. As the gear turns the dial they indicate the amount of energy passes through the meter.

Break magnet-as the name implies it produce necessary controlling torque on disc.



Working

When energy meter connected to supply,

- Two fluxes produced by C.C & P.C act on 'Al' disc
- The changing flux induces eddy currents in the disc which intern produce rotating torque on the disc
- Hence the disc rotates due to the interaction of the two fluxes
- The speed of the disc is proportional to the product of voltage, current and time i.e. the energy consumed by the load
- The no. of revolution completed by the disc for 1kwh is called meter constant
- Energy consumed $= \dfrac{\text{Rev. travelled by the disc}}{\text{Meter constant}}$

Calculate the no. of revolutions, which would be completed by the disc of 1 ϕ E/M in 15 minute when the load on it is 250W.Meter constant, is 3600 revolution /kWh

ANS - We know that

$$kWh = \frac{\text{rev. travelled by the disc}}{\text{Meter constant}}$$

$$\frac{(250*15)}{(1000*60} = \frac{\text{rev. travelled by the disc}}{3600}$$

Revolution travelled by the disc=225 rev.

Three phase energy meter

We can use three separate 1ф energy meter for the measurement of 3ф power or a single 3ф energy meter for the measurement of three phase installation.

3ф energy meter are of two types

1 Three phase three wires E/M

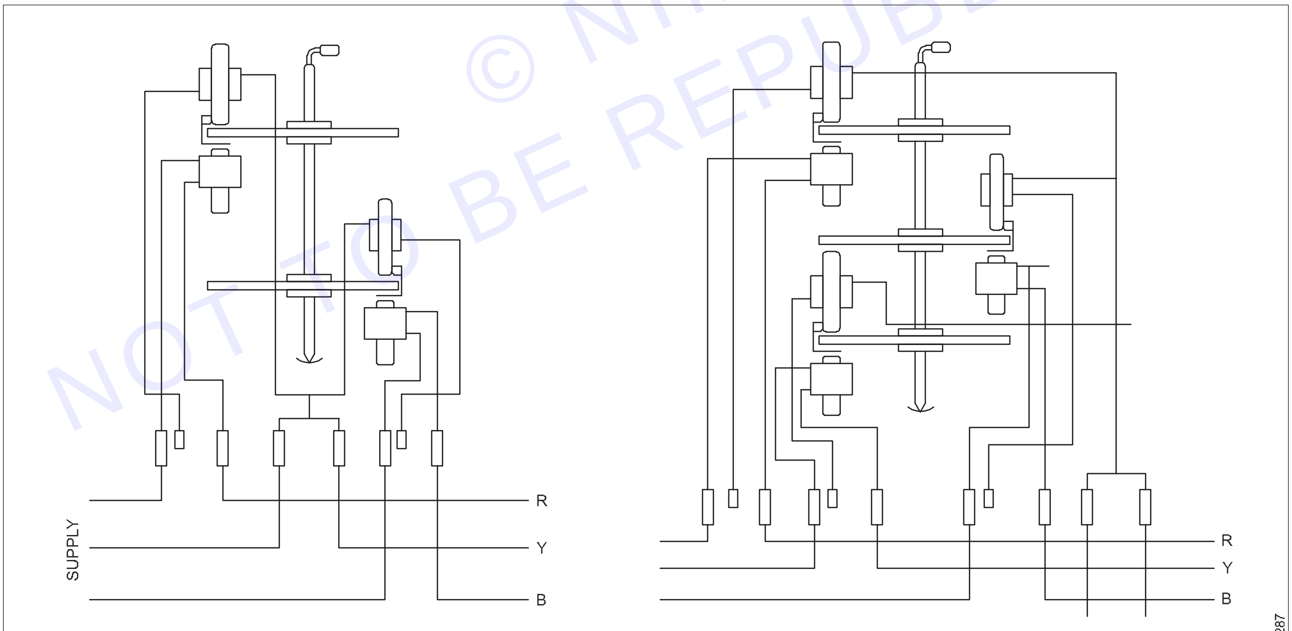
2 Three phase four wires E/M

Three phase three wires e/m

It is a combination of two single phase E/M. The meter is used for three phase balanced load. The deflecting torque is produced by the resultant reaction between the fluxes of pressure and current coil connected to two phases.Counting mechanism mounted on the spindle gives the kWh reading. The overall working is identical to that of a single phase E/M - three element E/M

Three phase four wires e/m

It is a combination of 3 single phase E/M.The meter is capable of measuring energy of 3 phase unbalanced load. It consist of 3 P.C., 3C.Cand 3 Al discs. All 'Al' discs are mounted on same spindle. The counting mechanism mounted on the spindle gives the kWh reading.



(a) INTERNAL ARRANGEMENT OF TWO ELEMENT

(b) INTERNAL ARRANGEMENT & CONNECTION DIAGRAM OF THREE - ELEMENT METER.

Errors in induction type energy meter

1 Creeping error

The slow but continuous rotation of the disc in energy meter is known as creeping

Causes of creeping

1 When there is no current flow through C.C. i.e. when the P.C. is energized

2 Major cause of creeping is over-compensation of friction.

3 Excess voltage across P.C.

4 Vibration

5 Stray magnetic field

Adjustment

In order to prevent error due to creeping, two diametrically opposite holes are drilled in the disc. This cause sufficient distortion of the field. The result is that the disc tends to remain stationary when one of the holes comes under one of the shunt magnet.

Phase error

It is necessary that the E/M should give correct reading on all power factors, which is only possible when the field set up by the shunt magnet lags behind the applied voltage by 90˚.

Adjustment -by changing the position of shading band (shading ring or power factor compensator) placed on the central limp of shunt magnet we can correct the phase error.

Speed error

Sometimes the speed of the meter is either fast or slow, resulting in wrong recording of energy consumption.

Adjustment -Error can be correctly adjusted by adjusting the position of the break magnet. Moment of break magnet in the direction of the spindle will reduce the breaking torque and vice-versa.

Insulation tester(megohmmeter)

Insulation resistance is measured in mega ohms. The instrument used to measure insulation resistance is known as megger.

There are two types of megger

1 Magneto generator type

2 Transistorised type (Electronic insulation tester)

Magneto generator type megger

In this tester the testing voltage is produced by a magneto generator when the handle is cranked at 160 rpm . The testing voltage is in the order of 500 V or high as 1 Mega volt. V DC is produced by internal circuitry.

It consists of three main parts .

1 Hand driven DC generator

2 A cranking system

3 A meter calibrated to measure high resistance.

The current supplied by the megger is in the order of 5 to10- mA. The meter scale is calibrated in Meg ohms

Transistorised type (electronic insulation tester)

This type of megger consists of

1 Power source

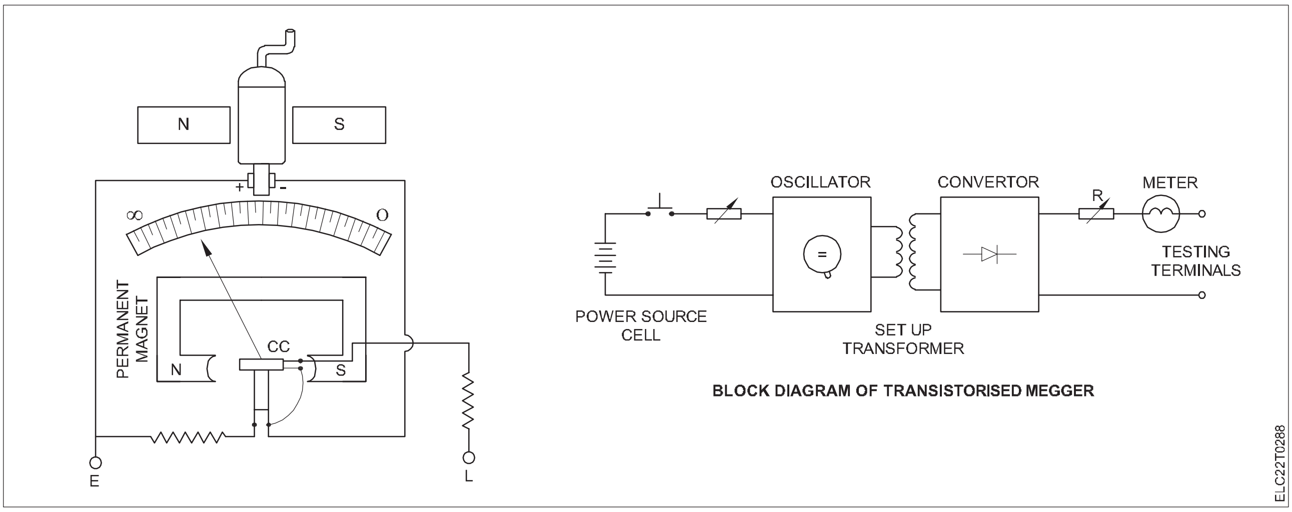
2 An oscillator

3 Step up transformer

4 Converter

5 A moving coil meter

The voltage coils are connected across the generator terminal. The current coil is connected in series with the resistance to be measured. The unknown resistance is connected in between terminals L and E . The rated resistance in meg ohms and the rated voltage of the insulation resistance tester having the following ranges are recommended by IS 2992 of 1980



Rated DC Voltage	Rated Resistance
250 V	20 megohms 50megohms
500 V	20 megohms 100 megohms 1000 megohms
1000 V	200 megohms 2000 megohms 20000 megohms
2500 V	5000 megohms 50000 megohms
5000 V	100000 megohms

Precautions

- A meg ohmmeter should not be used on a live system.
- The handle of the meg ohmmeter should be rotated only in clock wise direction.
- Do not touch the terminals of a meg ohmmeter while conducting a test.
- Support the instrument firmly while operating.
- Rotate the handle at slip speed.

Uses of megger: To check the insulation resistance and to check the continuity.

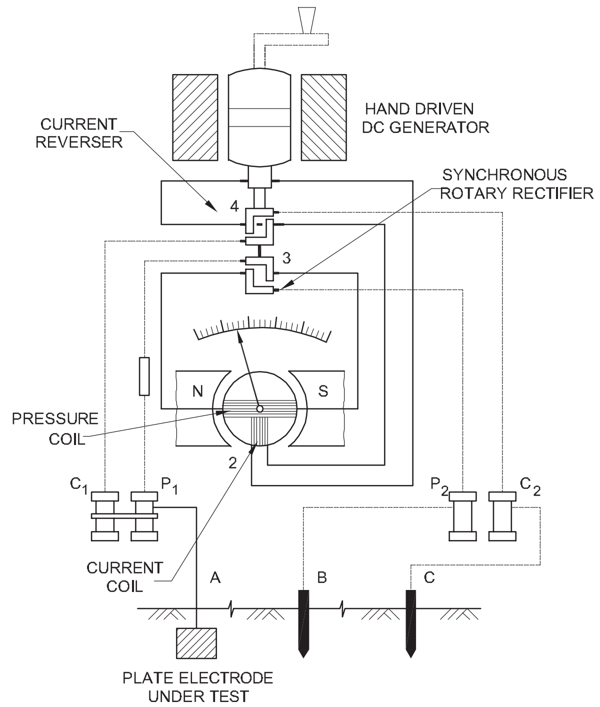
Earth resistance tester(earth megger)

Earth megger consists of

1 A hand driven generator
2 Current reverser
3 Synchronous rotary rectifier
4 An ohm meter

Functions

1 Hand driven generator



EARTH TESTER

The generator develops supply voltage to the electrodes and ohmmeter.

2 Current reverser

Dc produced by the generator is changed to ac through a current reverser.

3 Sychronous rotary rectifier

The ohmmeter requires dc supply for working, for this synchronous rotary rectifier is used.

4 Ohmmeter

Ohmmeter consists of two coils namely current coil and potential coil. The two coils are kept at 90o to each other and mounted on the same spindle. A pointer is attached to this spindle. The current coil carries a current proportional to the current in the test circuit. The pressure coil carries a current proportional to the potential across the resistance under test. The deflection of ohmmeter reading is proportional to the current in the two coils.

Hot wire instrument

The working parts of the instruments as shown in below figure. It is based on the heating effect of current. It consists of a platinum – iridium (it can withstand oxidation at high temperatures) wire AB stretched screw at A. When current is passed through AB, it expands according to I2R formula. Due to heating AB expands of sag. This sag in AB produces a slack in phosphor- bronze tension wire CD attached to the center of AB. This slack in CD is taken up by silk fiber which after passing round the pulley W is attached to a spring S. As the silk thread is pulled by S, pulley rotates, there by deflecting the pointer. It would be noted that even a small sag in AB is magnified very much and is conveyed to the pointer. Expansion of AB is magnified by CD which is further magnified by silk thread.

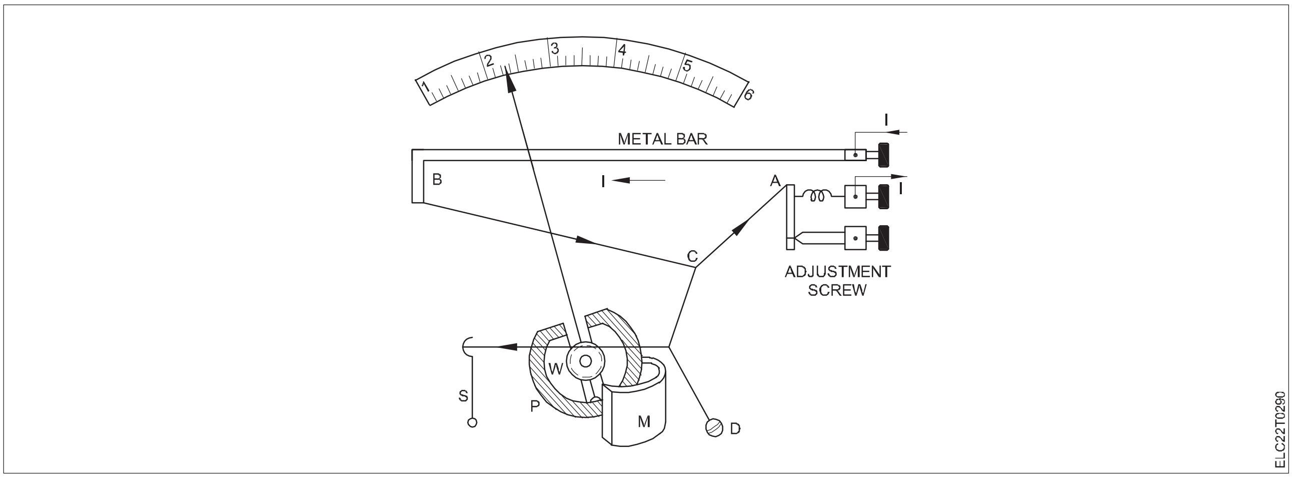
It will be seen that the deflection of pointer is proportional to I2.Hencedeflection is proportional to I2.If spring control is used then Tc α ϴ .

Hence ϴαI2.

So these instruments have a square law type scale They read the rms value of current and are independent of its wave form and frequency.

Damping

A thin light aluminum disc P is attached to the pulley such that its edge moves between the poles of a permanent magnet M .Eddy current produced in this disc give the necessary damping



Advantages

- As their deflection depend on the rms value of the alternating current, they can be used on direct current also.
- Their readings are independent of wave form and frequency.
- Their calibration is the same both for AC as well as DC measurements.
- They are unaffected by stray fields.

Disadvantages

- They are unable to withstand over load without burning out.
- They have a cramped scale
- They have high power consumption as compared to moving coil instruments.Current consumption is about 200 Ma AT full load.
- Their zero position need frequent adjustment.

Thermocouple

There may be cases when the transduction element performs the action of both transduction and sensing. The best example of such a transducer is a thermocouple.

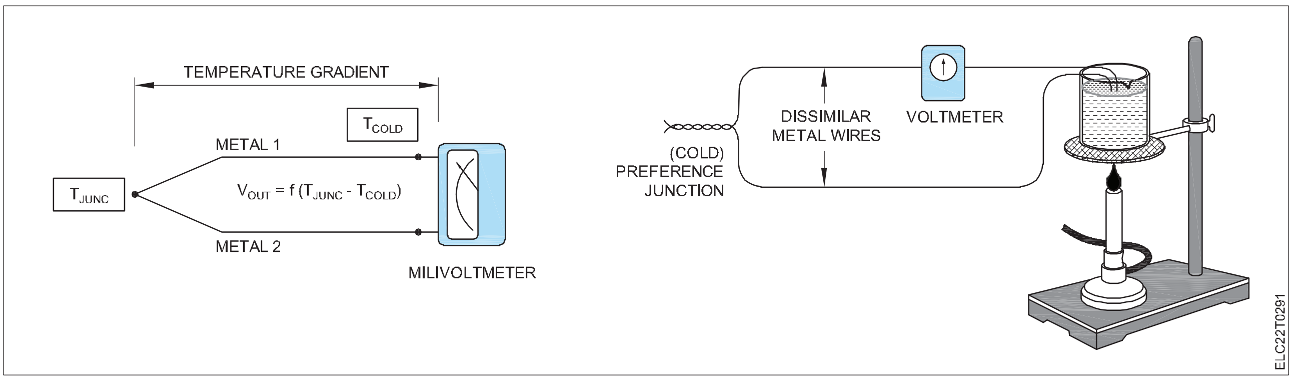
Thermoelectric Sensors

The junction of two dissimilar metals forms a thermocouple. As shown fig.

When the two junctions are at different temperatures, a voltage is developed across the junction.

By measuring the voltage difference between the two junctions, the difference in temperature between the two can be calculated.

- The thermoelectric effect: when one junction has a different temperature than the other, an electromotive force is produced in the circuit and current flows.
- The magnitude of the force or potential depends on the temperature difference between the two junctions.



There are three main effects related to thermoelectricity

1 The see beck effect

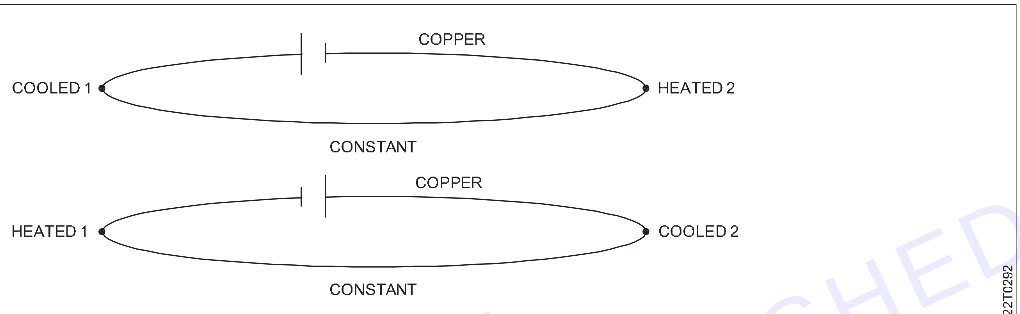
The See beck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or Semiconductors produces a voltage difference between the two substances.

2 The thomson effect

Thomson effect, the evolution or absorption of heat when electric current passes through a circuit composed of a single material that has a temperature difference along its length.

3 The peltier effect

Peltier effect, the cooling of one junction and the heating of the other when electric current is maintained in a circuit of material consisting of two dissimilar conductors; the effect is even stronger in circuits containing dissimilar semiconductors.



PELTIER EFFECT FOR COPPER - CONSTANT THERMOCOUPLE

The above figure shows the copper-constantan thermocouple. a battery is inserted in the circuit. It is found that the heat is absorbed at one junction (junction gets cooled) and liberated at the other junction (it gets heated).

Thermocouples Common thermocouple types

Metal	**Type**
T	Copper and constantan
J	Iron and constantan
E	Nickel (10% chromium and constantan
K	Nickel and Nickel (5% aluminum/silicon

Advantages

- Extremely strong and robust
- Shock and vibration resistant
- Offers wide temperature range
- Easy to manufacture
- No power supply required for excitation
- No self-heating involved
- Available in small sizes also
- High degree of versatility and flexibility

Disadvantages

- Thermocouples generate a quite low level output signal. Besides, the resulting output tends to be non-linear due to which a sensitive and stable device is needed for temperature measurement.
- Installation of a thermocouple also necessitates tremendous care so that the possible noise sources could be diminished.
- Moreover, the hardware employed for measurement should also offer excellent noise rejection capability.

Electro static voltmeter

Force of attraction between electric charges on neighbouring plates between which a p.d is maintained

These force gives a deflecting torque

Used for the measurement of high very high voltages

Used as laboratory type rather than industrial type

Types of electro static voltmeter

Quadrant type –used up to 20 kv

The attracted disc type –used up to 500 kv

1 Attracted disc type voltmeter

It consists of 2 parallel plates C & D

D is fixed and earthed

C is connected to positive end of supply and suspended by coach spring which carries a micro meter head for adjustment

When pd is applied between plates C is attracted towards D and returned to its original shape by micro meter head

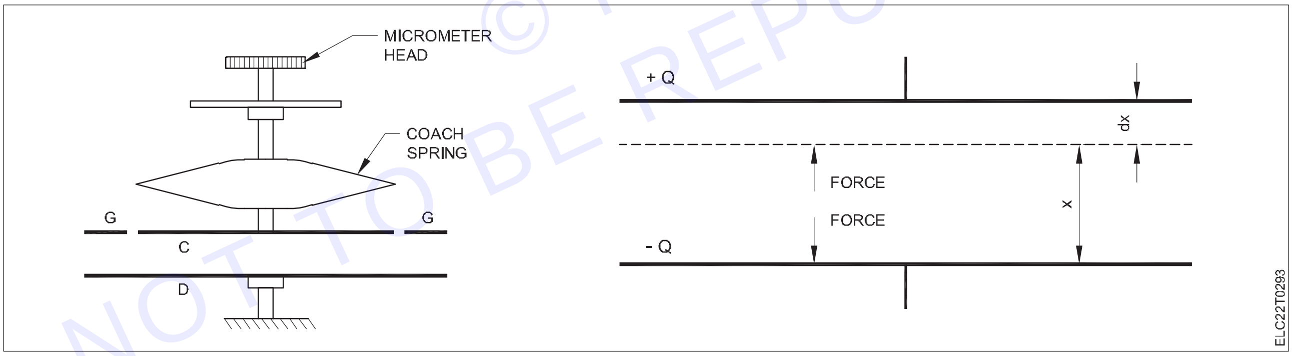
The movement of these head indicate the force F with which C is pulled downwards

Movement of plate C is balanced by control device which actuates a pointer attached to it that sweeps over a calibrated scale

Theory

Before the movement capacitance of capacitor is C farad then initial energy = (1/2) Q 2/C

By the movement of plates capacitance changes to c+dc.so final energy stored = (1/2) Q2/C+ dc =(Q2/2C) (1-dc/C)



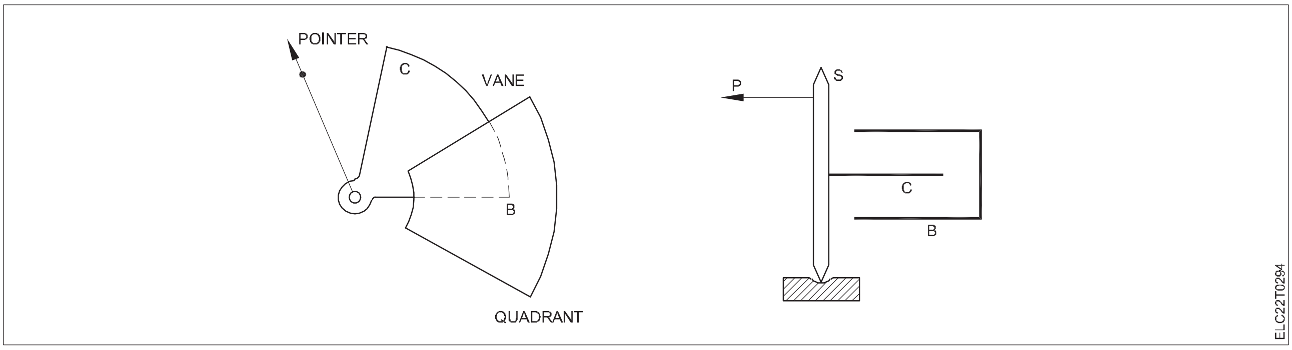
Change in stored energy=Q2dC/2 CC

F x dx =Q2dC/2 C C

F= V2 Dc /2 dx

Force is directly proportional to squire of the applied voltage to be measured

2 Quadrant type voltmeter



A light aluminium vane C is mounted on spindle S is situated partially with in a hollow metal quadrant B

Alternatively, vane may be suspended in the quadrant

Vane and quadrant are oppositely charged by the voltage under measurement the vane is attracted inwards into the quadrant causing the spindle and hence the pointer to rotate

The deflection torque Is proportional to square of the voltage so an uneven scale damping is by vane immersed in oil in case of suspended type or by air friction in case of pivoted type instruments

T is proportional to square of the voltage to be measured whether the voltage is alternating or direct. the alternating circuits the scale will read rms value

Advantages of electrolytic voltmeter

First grade accuracy

Give correct readings both in ac and dc

Ac circuits scale will read rms values whatever the waveforms

No iron is used in these instruments so free from hysteresis and eddy current loss and temperature errors

Their power loss is small

Unaffected by stray magnetic field

Limitations of electrolytic voltmeter

They are expensive and cannot be made robust

Torque is proportional to square of the voltage so scale is not uniform.

Types of measuring instruments

Ammeter and voltmeter

1 Moving coil type
   - a Permanent magnet(for DC only)
   - b Electro dynamic or Dynamo meter type(for DC/AC)

2 Moving iron type(both for DC/AC)
   - a Attraction type
   - b Repulsion type

3 Hot wire type(for DC/AC)

4 Induction type(for AC only)
   - a Split phase type
   - b Shaded pole type

5 Electrostatic type for voltmeter only (for DC/AC)

Watt meters

6 Dynamo meter type(for DC/AC)

7 Induction type(for AC only)

Energy meters

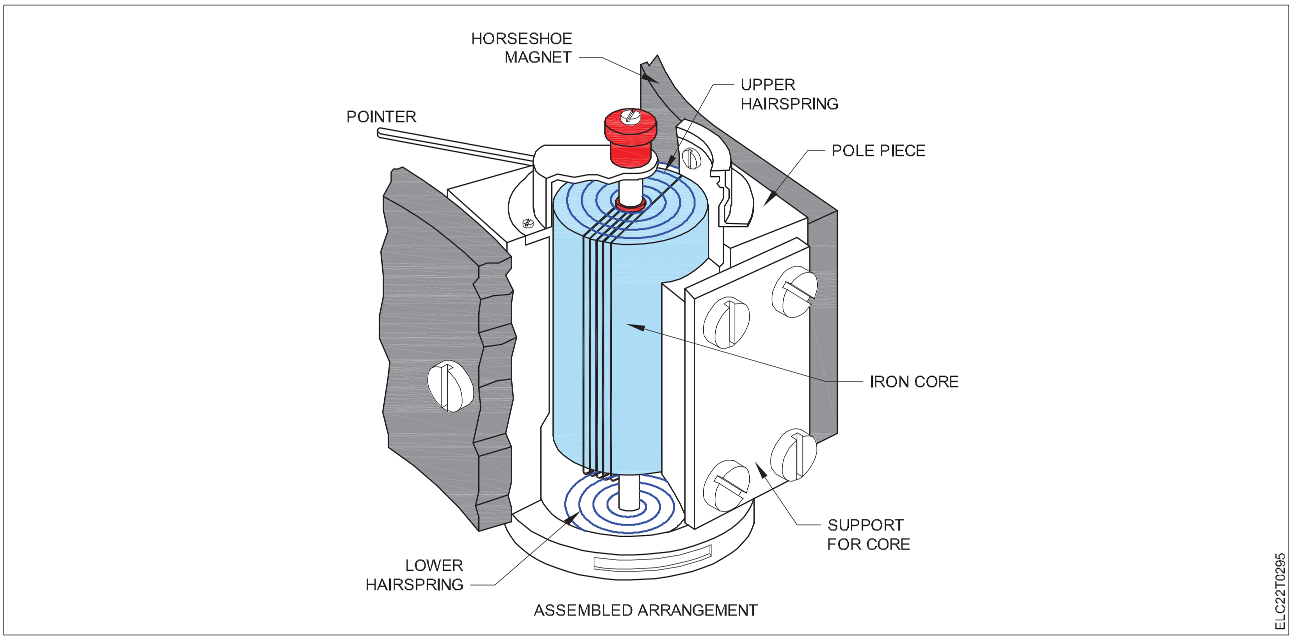
8 Electrolytic type(for DC only)

9 Motor meters
   - a Mercury motor meter(for DC only)
   - b Induction type (for AC only)

Permanent magnet moving coil instrument (pmmc)

Principle of operation:

When a current carrying conductor. Is placed in a magnetic field, it experiences a force and tends to move in the direction as per fleming's left hand rule.



ASSEMBLED ARRANGEMENT

Consists of permanent magnet and rectangular coil wound with very fine insulated copper wire of many turns .Coil is wound on an aluminium bobbin which is free to rotate by about 90◦.Coil and former are attached with spindle can move on a calibrated scale.

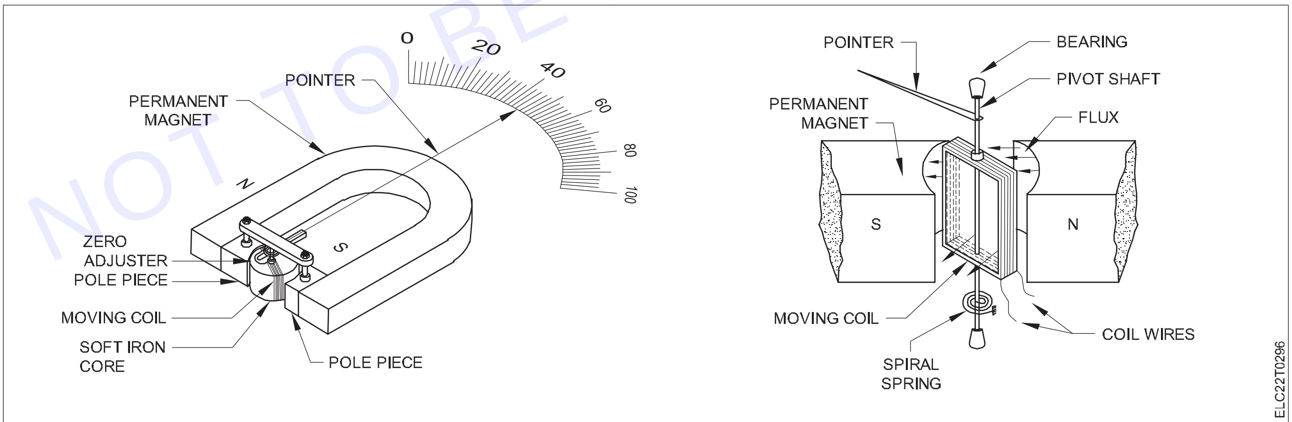
Two springs one at top and other at bottom were attached to the assembly and serves two purposes

One is to provide path for current to the coil and other for providing controlling torque.

Horse shoe shaped Permanent magnet is used.Core is made of soft iron, Magnetic poles& iron core are cylindrical in shape. This has two advantages

Firstly, the length of the air gap is reduced (flux leakage=0)

Secondly, it ensures uniform magnetic field in the air gap



Working

When a current is passed through a coil in a magnetic field, the coil experiences a force proportional to the current. The deflecting torque is produced by the electromagnetic action of the current in the coil and the magnetic field.

How the deflection torque is produced

Force F=BILN Newton , B is the flux density in the air gap, I is the current ,L is the length of one conductor in air gap and N is the number of turns

Net deflecting torque=force x perpendicular distance between the centre of the conductor to the centre of the spindle

T = Fr Newton meter

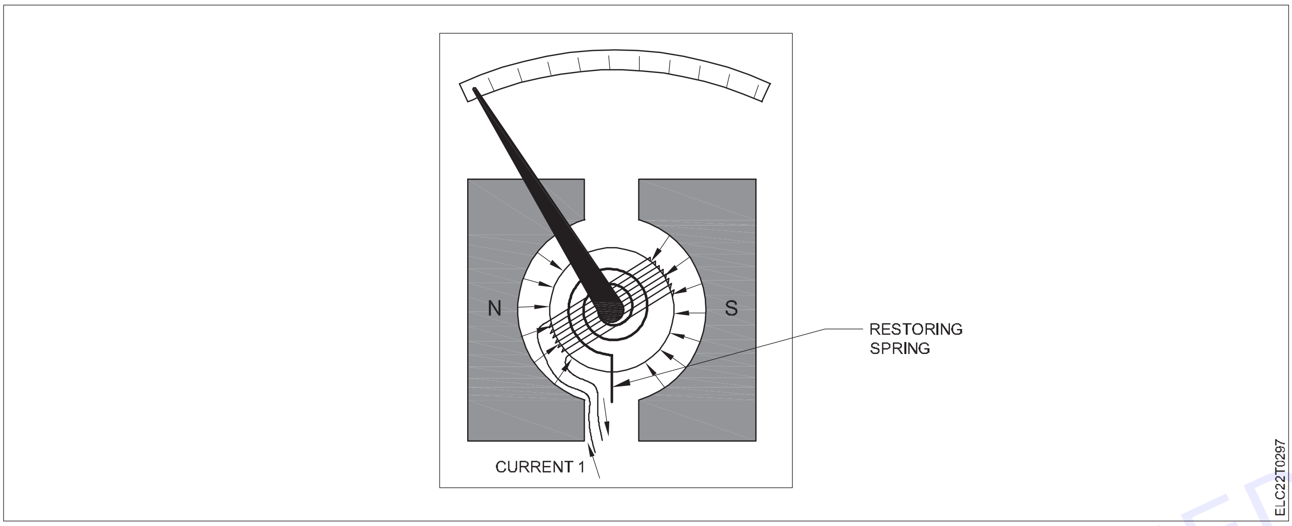
T = BILNr

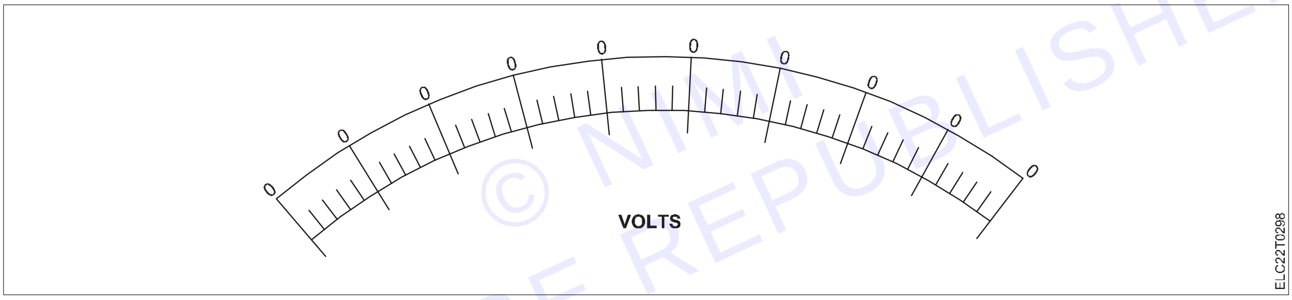
Here B,L,N,r are constant and denoted K

Torque = kI

The deflection is proportional to the current and hence the scale is uniformly divided

Uniform scale





The controlling torque

It is provided by two phosphor bronze springs. These springs serve as a flexible connection to the coil conductors.

Springs are spiralled in the opposite direction in order to neutralize the effect of temperature changes

Damping Torque

Itis caused by the eddy current set up in the aluminum former which prevents the oscillation of the pointer.

Advantages

1 The PMMC consumes less power and has great accuracy.

2 It has uniformly divided scale

3 The PMMC has a high torque to weight ratio.

4 It can be modified as ammeter or voltmeter with suitable resistance.

5 It has efficient damping characteristics and is not affected by stray magnetic field.

6 It produces no losses due to hysteresis

Disadvantage

1 The moving coil instrument can only be used on D.C supply as the reversal of current produces reversal of torque on the coil.

2 It is costly as compared to moving coil iron instruments.

3 It may show error due to loss of magnetism of permanent magnet.

Moving iron instrument

The deflecting torque in any moving-iron instrument is due to forces on a small piece of magnetically 'soft' iron that magnetized by a coil carrying the operating current.

Moving iron type(both for DC/AC)

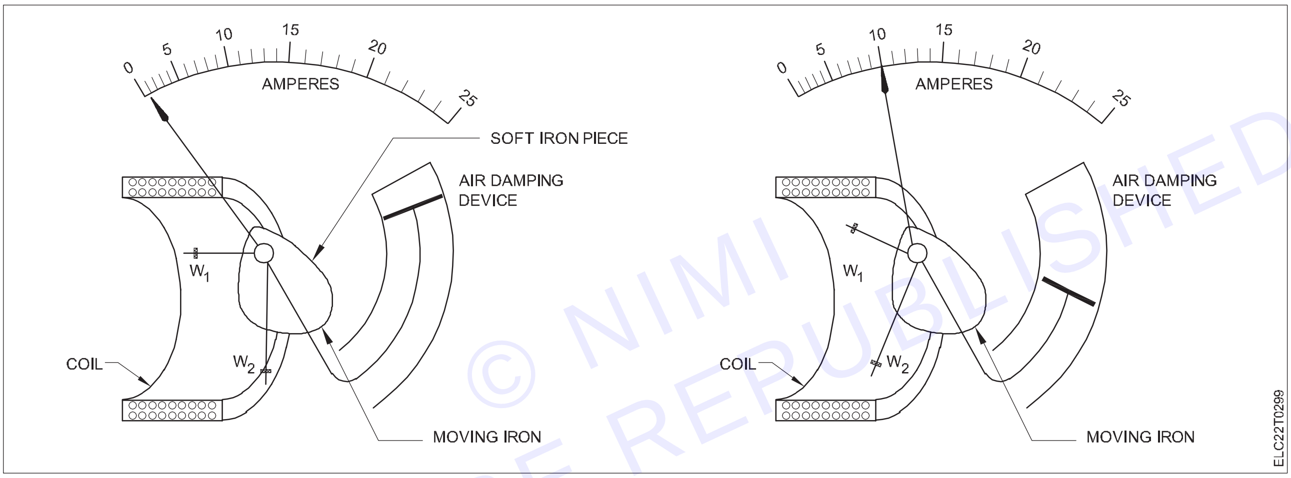
a Attraction type

b Repulsion type

Parts and essential t orques of moving iron

- **Moving element:** a small piece of soft iron in the form of a vane or rod.
- **Coil:** to produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.
- **In attraction type,** a vane of soft iron piece is attached to the spindle
- **In repulsion type,** a fixed and movable vane is also used and magnetized with the same polarity.

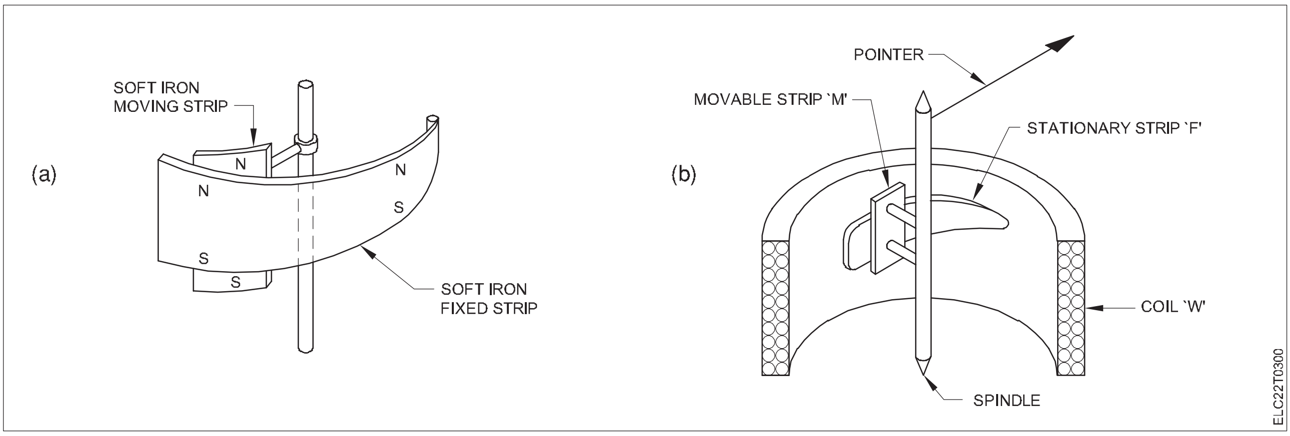
Attraction type



Working

- It consists of an electromagnetic coil with air core
- When coil is connected to the supply,magnetic field is produced and it attracts the iron piece.
- It's turn moves the pointer to deflect
- Attraction of soft iron piece independent on the current direction and can be used in Ac and DC

Repulsion type



Construction

- It consists of coil wound on brass bobbin, inside which two strips of soft iron vanes set axially

- One is fixed and other is movable
- Movable strip is attached to the spindle, which also carries the pointer

Working

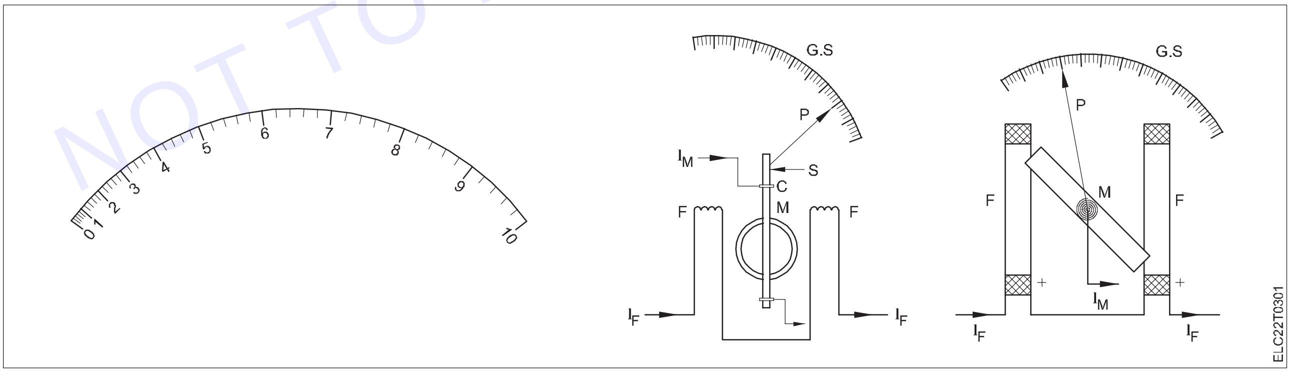
- When the meter connected to the supply, coil produces a magnetic field
- Both vanes to become magnetized and same poles are created
- They repel each other
- Repulsion between the similarly magnetized vanes produces a proportional rotation

Parts and essential torques of moving iron

- Control torque is provided by spring or weight (gravity).
- Damping torque is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.
- Deflecting torque produces a movement on an aluminum pointer over a graduated scale.
- The deflecting torque is proportional to the square of the current in the coil
- Moving iron instruments having scales that are nonlinear
- It is crowded in the beginning and open at the end

Dynamometer type instruments

- These instruments are similar to the permanent magnet type instruments, except that the permanent magnet is replaced by a fixed coil.
- The coil is divided into two halves, connected in series or parallel with the moving coil.
- Moving coil mechanism to be placed between the fixed coil
- The two halves of the coil are placed close together and parallel to each other to provide uniform field within the range of the movement of moving coil.
- Moving coil is mounted on spindle and is free to move in air
- Controlling torque provided by two spring and it also allows the flow of current to the moving coil



- It can work in both AC and DC
- Because when the current is reversed in AC, the direction of flux produced in fixed and moving coil is also reversed
- So the direction of torque is same
- It can be used as Voltmeter or Ammeter
- Best suits as a power meter

Working

- When the current is pass through the two coils,the magnetic field is produced.
- The field strength is proportional to the field current

- Deflecting torque is produced due to the interaction of fields produced by fixed and moving coil field
- Deflecting torque is proportional to square of the current.

When it is used as volt meter or ammeter, its scale will be non

Dynamo meter instrument as an ammeter

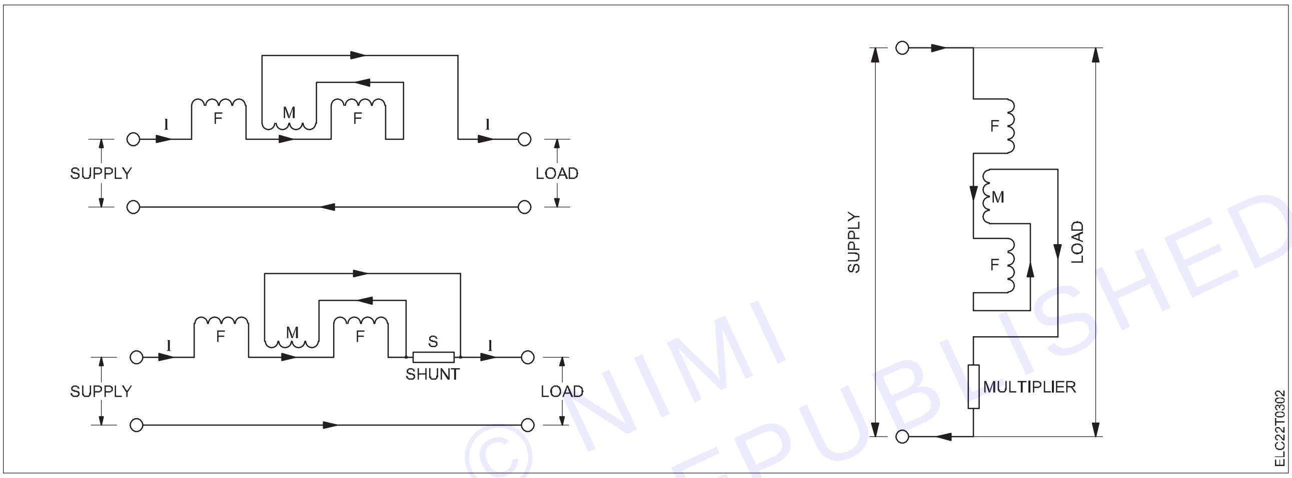
This instrument could be used as milli or micro ammeter by connecting the fixed and moving coil in series

Dynamo meter instrument as an ammeter

For measuring large current, a moving coil is connected across a shunt

Dynamo meter instrument as a volt meter

The instrument is used as a volt meter,the fixed and moving coils are joined in series along with a high value resistance (multiplier)



Digital Ammeter

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

- state the features of digital ammeter
- state the movements, special operation and standard.

Digital Ammeter

Digital Ammeters are instruments that measure the current in ampere and display it in digital. These instruments provide information about current drawn and current continuty to help users troubleshoot electric loads.

They have both positive and negative leads and low internal resistance. Digital ammeters are connected in series with a circuit so that current flow passes through the meter.

It can be used to measure the A.C and D.C. Many digital ammeters include a current sensor built in the meter.

Features:

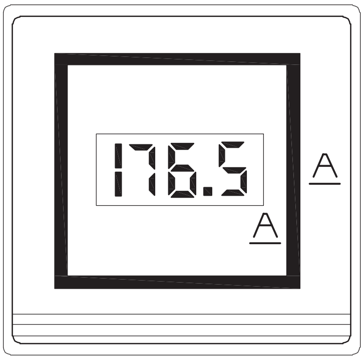
Different types of digital ammeters can measure different ranges of A.C current and D.C current and also A.C frequency.

Batteries are provided in it to operate without plug-in-power and suitable for cutdoor use Fig 1 shows a typical digital ammeter.

Standards :

Digital ammeters must have a certain standards and specifications to ensure proper design and functionality refer IEC 600 51 - 2.

Fig 1



TYPICAL DIGITAL AMMETER

ELC22T0303

Digital Volt Meter (DVM)

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

- distinguish between analogue and digital voltmeter
- list out the advantage of DVM
- explain the working principle of DVM.

Digital Volt Meter (DVM) :

The Digital Volt Meter(DVM) is an electrical measureing instrument which is used to measure line potential difference (P.D) between two points. The voltage to be measured may be AC or DC.

Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

Advantages of Digital Voltmeters:

- Read out of DVMs is easy as it eliminates observational errors in measurement
- Parallax error is eliminated
- Reading can be taken very fast
- Output can be fed to memory devices for storage and future computations
- More versatile and accurate
- Compact portable and cheap
- Requires low power

Working Principle of Digital Voltmeter:

The block diagram of a simple digital voltmeter is shown in the Fig 1 It consists the following blocks

1 Input signal
2 Pulse generator
3 AND gate:
4 Decimal Display

Working (Fig 2)

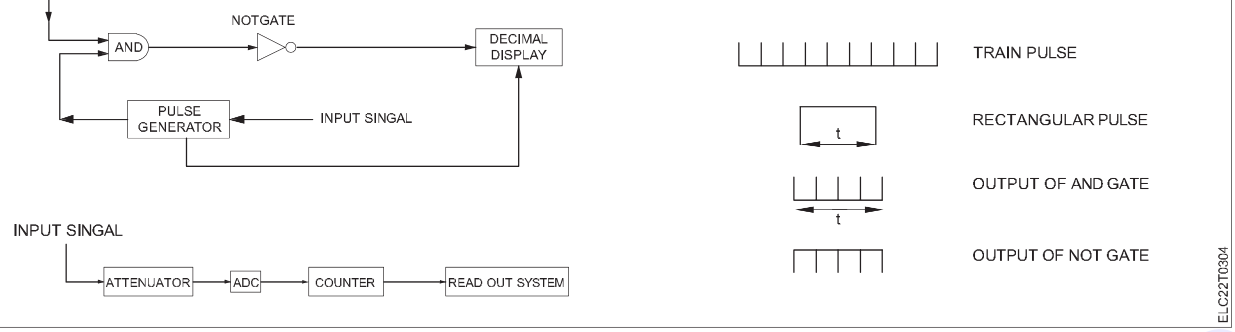
- Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
- Output of pulse generator is fed to one leg of the AND gate.
- The input signal to the other leg of the AND gate is a train of pulses.
- Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.

- This postitive triggered train is fed to the inverter which converts it into a negative triggered train.
- Output of the inverter is fed to a counter which counts the number of triggers in the duration which is proportional to the input signal i.e. voltage under measurement

This counter can be calibrated to indicate voltage in volts converts an analog signal into a train of pulses, the number is proportional to the input signal. So a digital voltmeter can be made by using any one of the A/D conversion methods (Fig 3)

Now-a- days digital voltmeters are also replaced by digital multi meters due to its multitasking feature.

Figs 1 - 3



Wattmeters

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

- state the advantages of measuring power directly
- explain the construction and working of the induction type single phase wattmeter.

Advantages of measuring power supply

Power in a single phase AC circuit can be calculated by using an ammeter, a voltmeter and a power factor meter with the help of the formula

Power in a single phase circuit = EI Cos ø watts.

To get an on the spot true power reading, a wattmeter is used. The power dissipated in the circuit can be read directly from the scale of the meter. The wattmeter takes the power factor of the circuit into account and always indicates the true power.

Types of wattmeters

There are three types of wattmeters in use as stated below.

- Dynamometer wattmeter
- Induction wattmeter
- Electrostatic wattmeter

Among the three, the electrostatic type is very rarely used. Information given here is for the other two types only.

Dynamometer type, single phase wattmeter: This type is commonly used as a wattmeter.

Dynanometer used as a Wattmeter: The dynamometer is commonly used as a wattmeter to measure power in both AC and DC circuits and will have uniform scale.

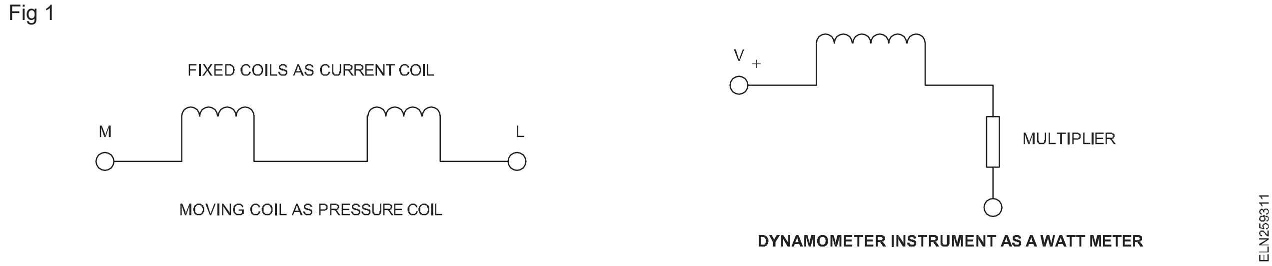
When this instrument is used as a wattmeter, the fixed coils are treated as current coil, and the moving coil is made as pressure coil with necessary multiplier resistance (Fig 1).

Advantages

- This instrument can be used both in AC and DC.
- As this is an air cored instrument, the hysteresis and eddy current losses are eliminated.

- This instrument has better accuracy.
- When used as wattmeter, the scale is uniform.

Fig 1



Disadvantages

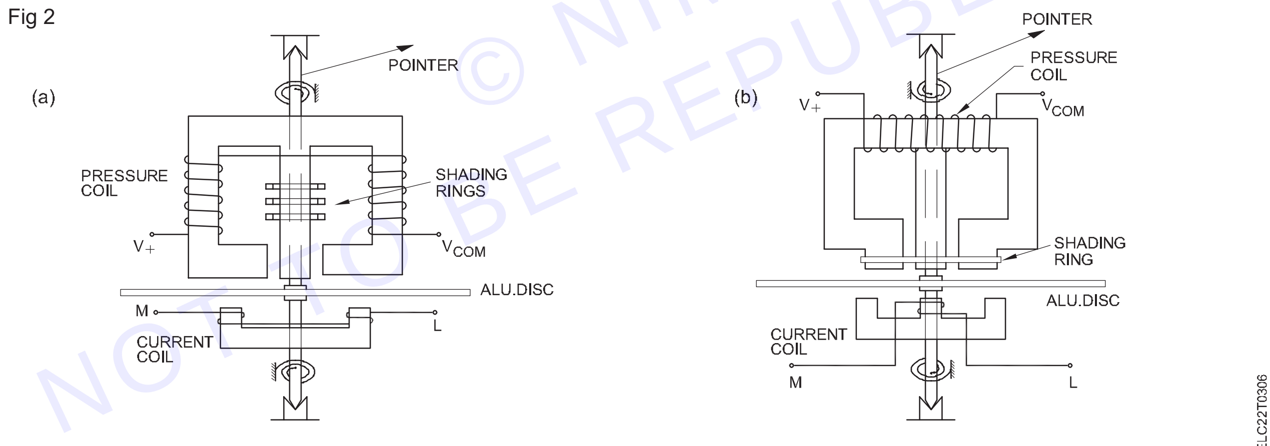
- It is more expensive than PMMC and moving iron instruments.
- When used as voltmeter or ammeter the scale will not be uniform.
- It has a low torque/weight ratio-as such has low sensitivity.
- Sensitive for over loads and mechanical impact. Hence careful handling is necessary.
- It consumes more power than PMMC meters.

Induction type single phase wattmeter: This type of wattmeters could be used only in AC circuits whereas a dynamometer type wattmeter could be used in both AC and DC circuits.

Induction type wattmeters are useful only when the supply voltage and frequency are almost constant.

Construction: Induction wattmeters having two different types of magnetic cores (Figs 2a and 2b).

Fig 2



Both the types have one pressure coil magnet and one current coil magnet. The pressure coil carries a current proportional to the voltage whereas the current coil carries the load current.

A thin aluminium disc is mounted on a spindle in between the space of the magnets and its movement is controlled by springs. The spindle carries a weightless pointer at one end.

Working: The alternating magnetic fluxes produced by the pressure and current coils cut the aluminium disc and produce eddy currents in the disc. Due to the interaction between the fluxes and the eddy currents a deflecting torque is produced in the disc and the disc tries to move. Control springs attached to the two ends of the spindle control the deflection and the pointer shows the power in watts on a graduated scale.

Shaded rings provided in the pressure coil (shunt) magnet could be adjusted in order to cause the resultant flux in the magnet to lag in phase by exactly 90o behind the applied voltage.

Method of connecting wattmeter in single phase circuits - pressure coil connection to reduce erroneous measurement.

There are two ways of connecting the pressure coil of the wattmeter (Fig 3).

Both the methods shown in Figs 3a & b need correction in power measurement due to the reasons stated below.

In the method of connection shown in Fig 3a, the pressure coil is connected on the 'supply' side of the current coil, and hence, the error in power measurement is due to the fact that the voltage applied to the voltage coil is higher than that of the load on account of the voltage drop in the current coil. As such the wattmeter measures the load power in addition to the power lost in the current coil.

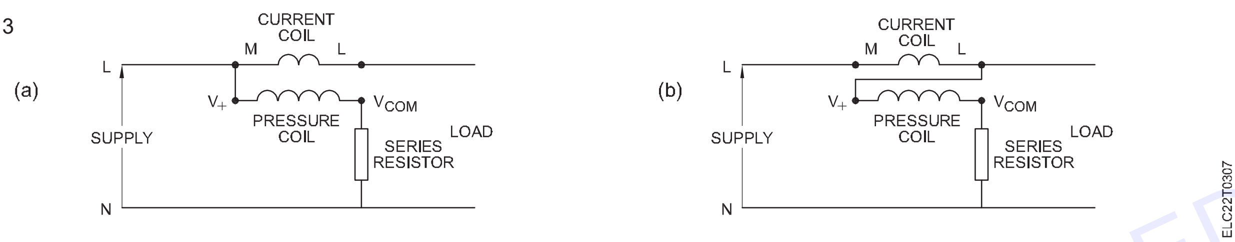
On the other hand, in the method of connection shown in Fig 3b, the current coil carries the small current taken by the voltage coil, in addition to the load current, thereby introducing errors in power measurement. As such the wattmeter measures the load power in addition to the power lost in the pressure coil.

If the load current is small, the voltage drops in the current coill will be small, so that the method of connection, shown in Fig 3a, introduces a very small error and, hence, preferable.

On the other hand, if the load current is large the power lost in the pressure coil will be negligible when compared to the load power in the method of connection shown in

Fig 3b, and, hence, a very small error is introduced resulting in the preference of this connection.

Fig 3



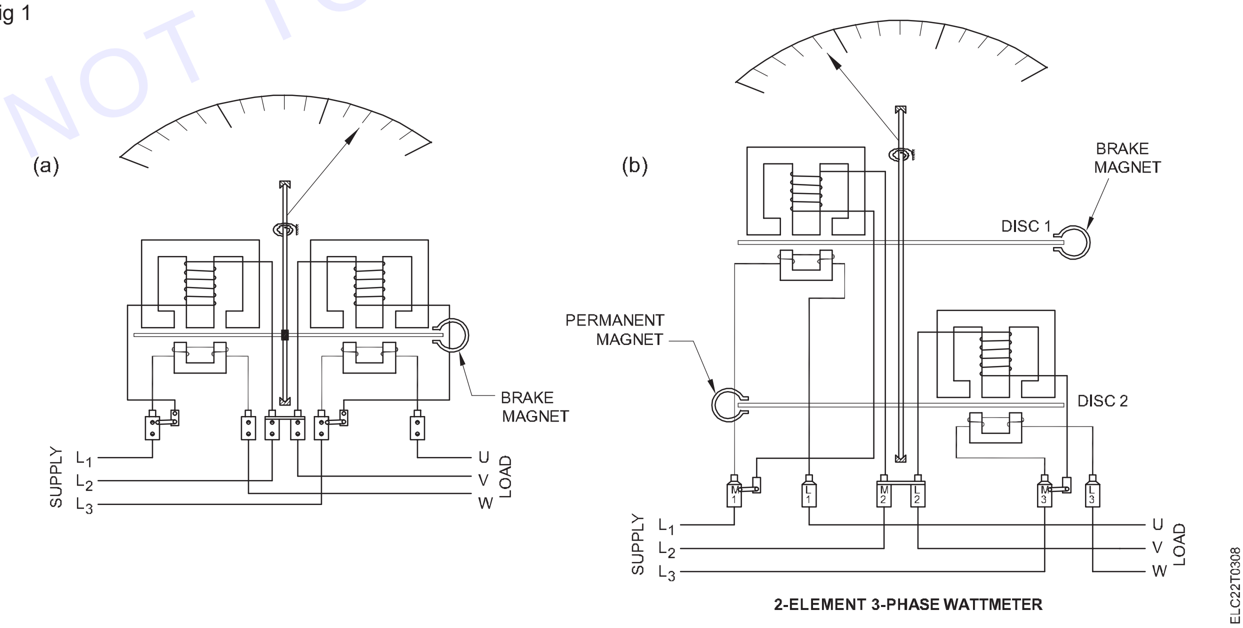
3-Phase Wattmeter

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

- describe the various types of 3-phase wattmeters, their connections
- state how to connect different types of 3 phase watt meter.

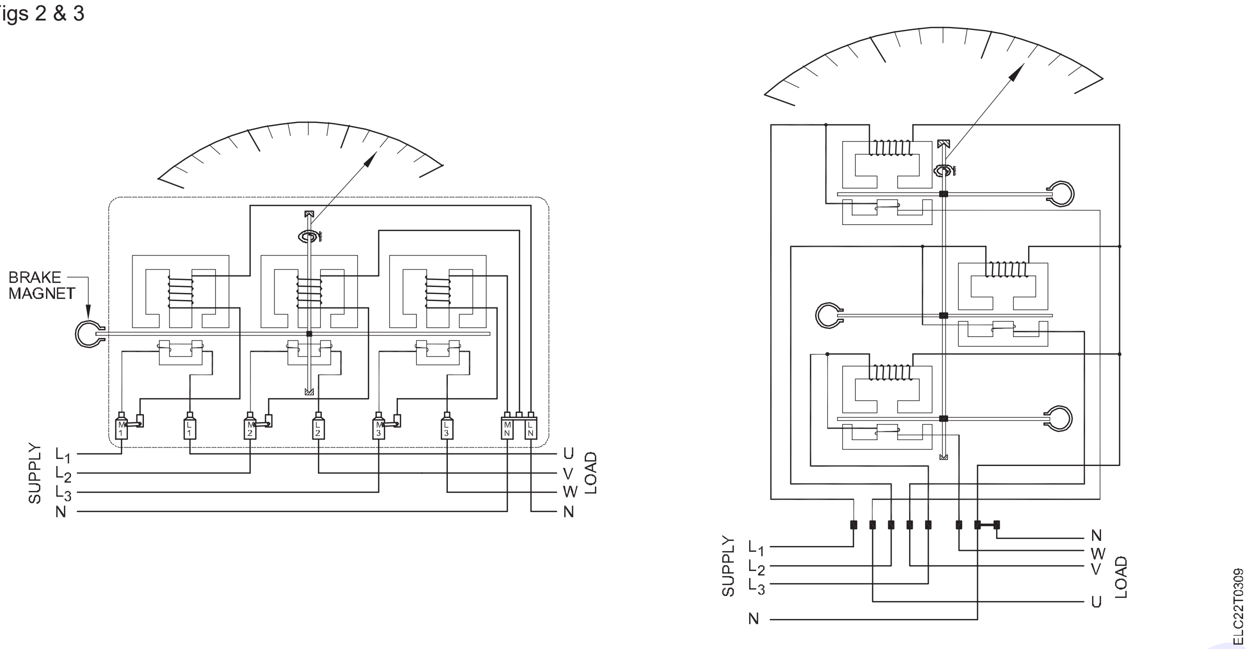
In single-phase wattmeters there will be one set of pressure and current coils driving a single aluminium disc, whereas in 2-element, three phase wattmeters there will be two sets of pressure and current coils driving a single aluminium disc (Fig 1a) or driving two aluminium discs mounted on the same shaft (Fig 1b) thereby providing a torque proportional to the 3-phase power.

Fig 1



On the other hand a 3-element, 3-phase wattmeter will have three sets of pressure and current coils kept at 120° to each other but driving a single aluminium disc (Fig 2) or alternatively 3 sets of pressure and current coils driving three discs one over the other but mounted on the same single spindle (Fig 3).

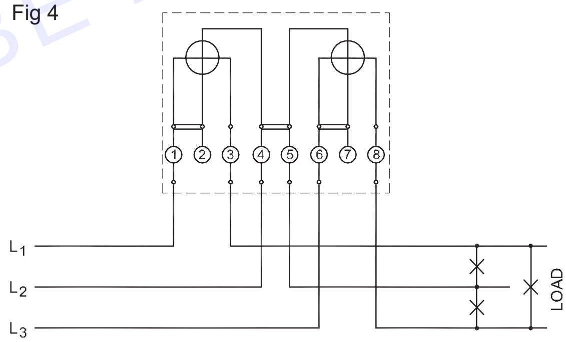
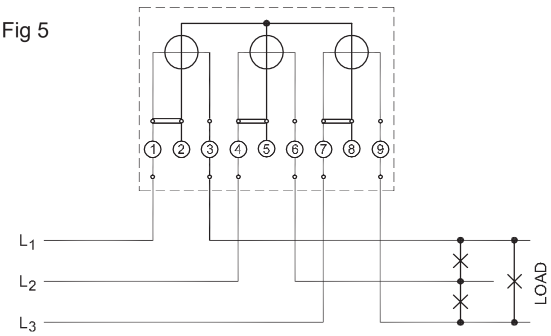
Figs 2 & 3

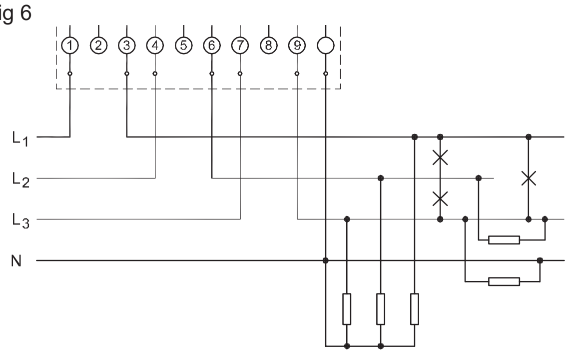


The principle and working of an induction type wattmeter are similar to the induction type energy meter. The only difference in construction between the energy meter and wattmeter is that the spindle of the wattmeter is spring-controlled, has a pointer but no train of gears.

However to summarise what has been learnt earlier the following table 1 is provided with connection diagram of 3- phase wattmeter Fig 4, Fig 5 & Fig 6

Table 1

Sl.No.	Types of 3-phase wattmeter	Circuit diagram	Application
1	2-element 3-wire type	Fig 4 	Balanced and unbalanced loads
2	3-element 3-wire type	Fig 5 	Balanced loads.

3	3-element 4-wire type	Fig 6 	Un balanced loads.

Digital Wattmeter

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

- describe the block diagram.

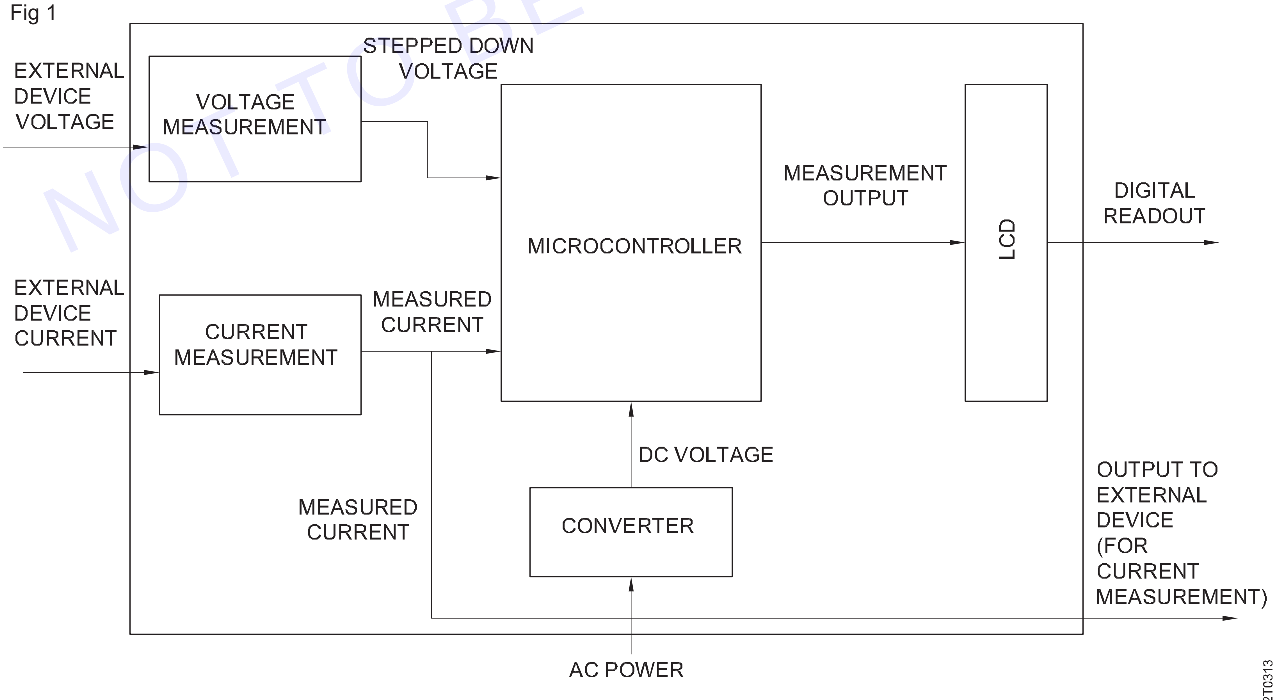
Digital wattmeter

The wattmeter is an instrument for measuring the electric power in watts of any given circuit. Electromagnetic wattmeters are used for measurment of utility frequency and audio frequency and audio frequency power; other types are required for radio frequency.

Fig 1 shows the block diagram of digital wattmeter.

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer microcontroller chip to determine watts. The computer can also perform statistics such as peak, average, low watts consumed. They can monitor the power line for voltage surges and outages. Digital electronic wattmeter, have become popular for conveniently measuring power consumption in household appliances with saving energy and money.

Fig 1



BLOCK DIAGRAM OF DIGITAL WATTMETER

Energy meter (analog)

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

- describe the construction and working principle of single phase energy meters
- state and explain creeping error in energy meter.

Necessity of energy meter: The electrical energy supplied by the Electricity board should be billed, based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

Principle of a single phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. (Fig 1) Torque is proportional to the power as in wattmeter.

The watt-hour meter must take both power and time into consideration. The instantaneous speed is proportional to the power passing through it.

The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are (Fig 1).

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc (Fig 2) is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

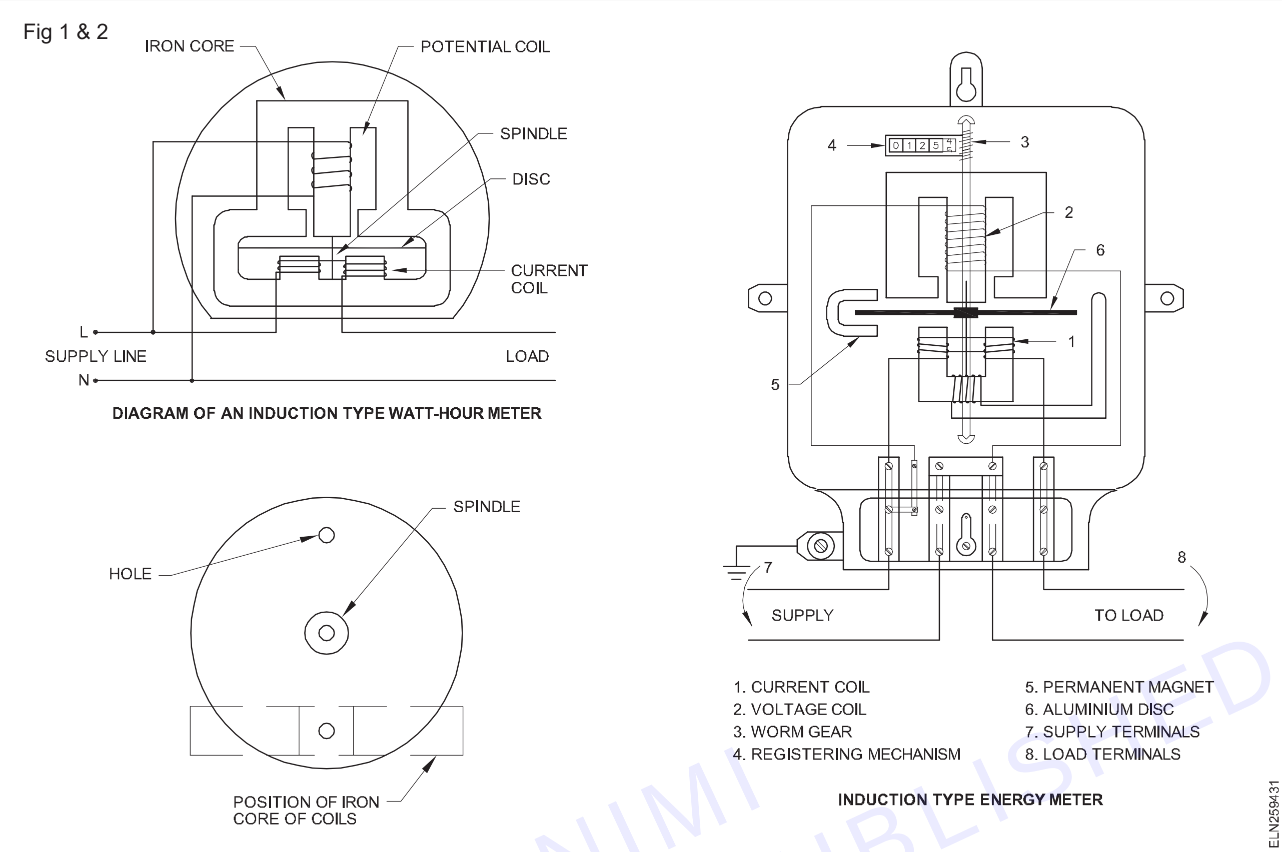
A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diameterically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 1 & 2



Digital Energy meters

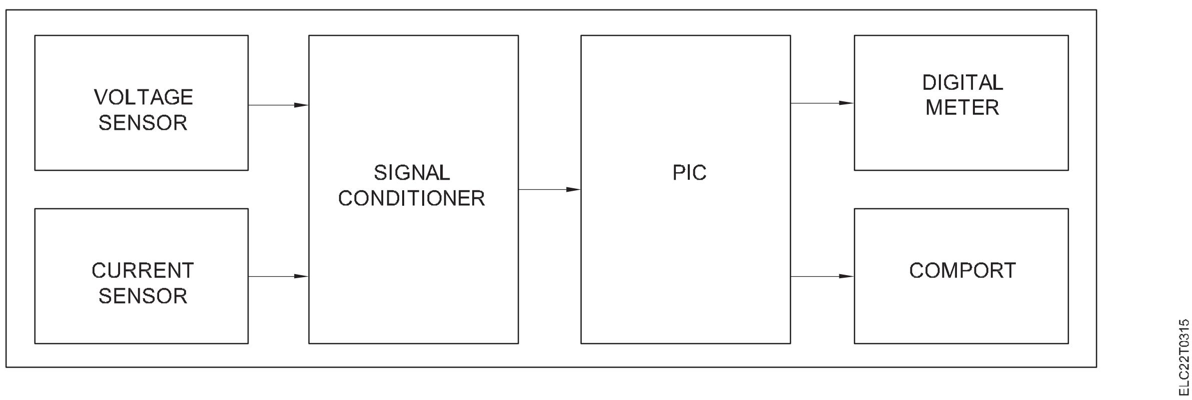
Objectives: At the end of this lesson you shall be able to:

- describe the functional operation of digital type energymeter from block diagram.

Electronic (Digital energy meter)

This meters measure the energy using highly integrated components and it digitizs the instantaneous voltage and current in a high-resolution sigma-delta analogue to digital converter (ADC), gives the instantaneous power in watts. Integration over time gives energy used, measured in kilo-Watt hour. The block diagram for a digital meter is shown in Fig 1. The two sensors, voltage and current sensors are employed.

Fig 1



The voltage sensor built around a step down element and potential divider network sensors both the phase voltage and load voltage.

The second sensor is a current sensor, which senses the current drawn by the load at any point in time .

It's inbuilt around a current transformer and other active devices (voltage comparator), which converts the sensed current to voltage for processing. The output from both sensors is then fed into a signal (voltage) conditioner which ensures matched voltage (or) signal level to the control circuit containing multiplexer. It enables sequential switching of both signal to the analogue input of the Peripheral Interface Controller (PIC).

The control circuit centred on a PIC integrated circuit. It contains ten bit analogue to digital converter (ADC), flexible to program and good for peripheral interfacing.

The ADC converts the analogue signals to its digital equivalent, both signals from the voltage and current sensors are then multiplied by the means of embedded software in the PIC.

The error correction is taken as the offset correction by determining the value of the input quality in the short circuited input and storing this value in the memory for use as the correction value device calibration.

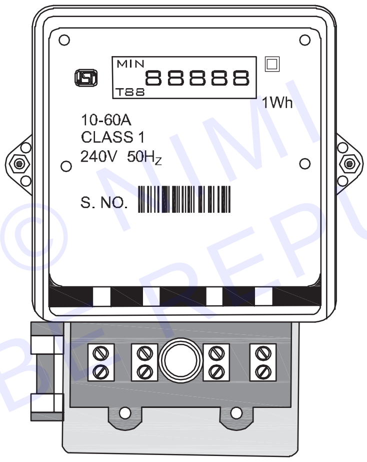
The PIC is programmed in 'C' language. It stimulates to use the received data to calculate power consumption per hour, as well as the expected charges. These are displayed on the liquid crystal display (LCD) attached to the circuit.

Fig 2 shows the image of a digital energy meter.

Advantages

DIGITAL electronic meters are much more accurate than electromechanical meters. There are no moving parts and, hence, mechanical defects like friction are absent

Fig 2



DIGITAL TYPE

3-phase energy meter

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

- list the various types of 3-phase energy meters
- describe the construction and working of a 3-phase 3-wire induction type energy meter
- describe the construction and working of a 3-phase 4-wire induction type energy meter
- state the application of a 3-phase 3-wire and 3-phase 4-wire energy meter.

3-phase energy meters: Even though different types of energy meters are available, the induction type energy meter is most commonly used because it is simple in construction, less in cost and requires less maintenance. The function of a 3-phase energy meter is similar to that of a single phase energy meter.

Types of 3-phase energy meters

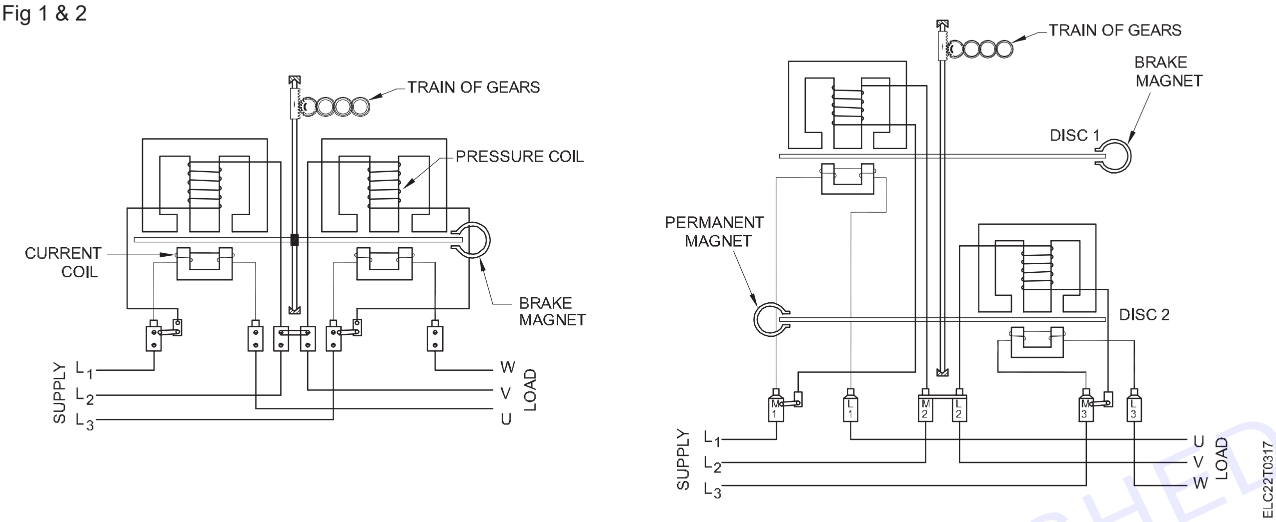
There are two types of 3-phase energy meters mainly.

- Three phase 3-wire energy meters (3-phase 2- element energy meter)
- Three phase 4-wire energy meters (3-phase 3- element energy meter)

Two element 3-phase energy meters: This energy meter works on the principle of measurement of power by the two wattmeter method. Two elements of a current coil and two elements of a potential coil are used in this energy meter. These assemblies can be arranged on the different sectors in a horizontal position (Fig 1) with a single aluminium disc which rotates between the poles of a single braking magnet.

The two elements can also have individual driving discs on a common spindle. In this case they will have individual braking magnets (Fig 2). The second type usually preferred by the manufacturers due to the construction simplicity.

Fig 1 & 2



In both the cases the driving torque produced by individual elements are summed up. The recording mechanism which is attached to the train of gears i.e., cyclometer or counter type dial shows the sum of the energies that has passed through the elements. The two element energy meter is only suitable for a 3-phase 3-wire system but can be used for both balanced and unbalanced loads.

3-element 3-phase energy meter: This works on the same principle as that of the 3 wattmeter method of power measurement with a 3-phase load. Here 3 units, each with a current coil and a potential coil, are used. The potential coils of the 3 elements are connected in star to the supply lines with their common point connected to the neutral line of power supply.

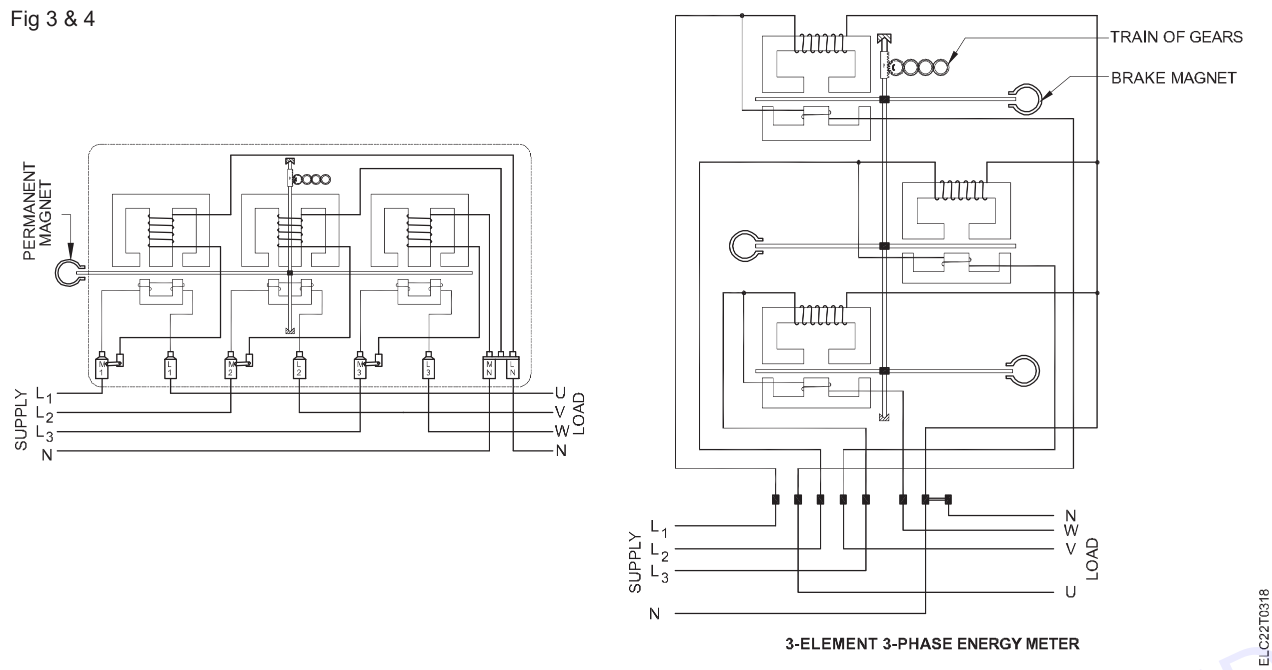
The current coils are connected in series to the individual lines. As is the case with the two element energy meter, these three elements can be arranged in the different sectors of a common single aluminium disc which serves as a rotating part connected to driving dial (Fig 3).

The three elements can also have a common spindle with three individual discs and braking magnets (Fig 4). Here also the 2nd type is usually preferred by manufacturers due to the easiness in construction. The driving torque produced by the three individual elements are summed up and the recording mechanism shows the sum of energies that has passed through the individual elements. This energy meter is suitable for the 3-phase 4-wire system.

Application of 3-phase energy meter: A two element 3-phase energy meter is used with three phase loads in which a neutral is not used such as for an industry or irrigation pumpset motors etc. having three phase loads only or with an 11kV 3-phase 3-wire supply to an industry.

A 3-phase 4-wire element energy meter is used with three phase load in which balanced or unbalanced loads are connected with individual phases and neutral such as for a large domestic consumer or for an industry having lighting loads also.

Fig 3 & 4



Errors and corrrection in energy meter measurement

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

- explain the errors caused by the driving system and the braking system in energy meters
- explain the different adjustments provided for correcting the errors in energy meters.

Errors caused by the driving system

Incorrect magnitude of fluxes: This may be due to abnormal values of current or voltage. The shunt magnet flux may be in error due to changes in resistance of coil or due to abnormal frequencies.

Incorrect phase angles: There may not be a proper relationship between the various phasors. This may be due to improper lag adjustment, abnormal frequencies, change in resistance with temperature etc.

Lack of symmetry in magnetic circuit: If the magnetic circuit is not symmetrical, a driving torque is produced which makes the meter creep.

Error caused by the braking system

They are:

- changes in the strength of the brake magnet
- changes in the disc resistance
- self-braking effect of series magnet flux
- abnormal friction of the moving parts.

Adjustments are provided for correcting the errors in the energy meters so that they read correctly and their errors are within acceptable limits.

Preliminary light load adjustment: The rated voltage is applied to the potential coil with no current through the current coil and the light load device is adjusted until the disc just fails to start. The electromagnet is slightly adjusted to make the holes in the disc to take a position in between the poles of the electromagnets.

Full load unity power factor adjustment: The pressure coil is connected across the rated supply voltage and the rated full load current at unity power factor is passed through the current coils. The position of the brake magnet is adjusted to vary the braking torque so that the meter revolves at the correct speed within the required limits of error.

LAG adjustments (Low power factor adjustments): The pressure coil is connected across the rated supply voltage and the rated full load current is passed through the current coil at 0.5 P.F. lagging. The lag device is adjusted till the meter runs at the correct speed.

Rated supply voltage: By adjusting the rated supply voltage, with the rated full load current and unity power factor, the speed of the meter is checked and the full load unity power factor and low power factor adjustments are repeated until the desired accuracy limits are reached for both the conditions.

Light load adjustment: The rated supply voltage is applied across the pressure coil and a very low current (about 5% of full load current) is passed through the meter at unity power factor. Light load adjustment is done so that the meter runs at the correct speed.

Full load unity power factor: Light load adjustments are again done until the speed is correct for both loads i.e. full load as well as light loads.

Creep adjustment: As a final check on the light load adjustment, the pressure coil is excited by 110 percent of the rated voltage with zero load current. If the light load adjustment is correct, the meter should not creep under these conditions.

Multimeters

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

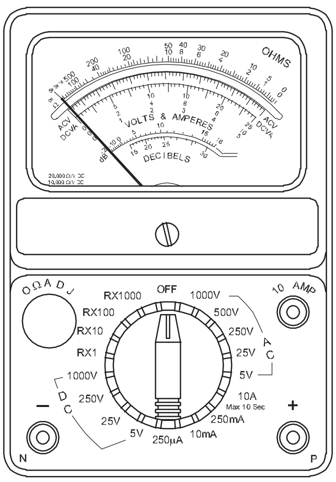
- explain the construction of multimeter
- explain the working priniciple of analog multimeter
- explain the method of measuring direct / alternating voltages and current with a multimeter
- explain the method of measuring resistance by a multimeter
- explain the precautions to be observed while measuring voltage, current and resistance in the circuit.

A single instrument used for measuring current voltage and resistance is known as a multimeter. It is a portable, multi range instrument.

It has a full scale deflection accuracy of ±1.5 %. The lowest sensitivity of multimeters for AC voltage range is 5 K ohms/volts and for the DC voltage range it is 20 K ohms/volts. The lowest range of DC is more sensitive than the other ranges.

Fig 1 show typical multimeters.

Fig 1



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Construction of a multimeter

A multimeter uses a single meter movement with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that function.

On some multimeters, two switches are used, one to select a function, and the other the range. Some multimeters do not have switches for this purpose; instead, they have separate jacks for each function and range.

Batteries/cells fixed inside the meter case provide the power supply for the resistance measurement.

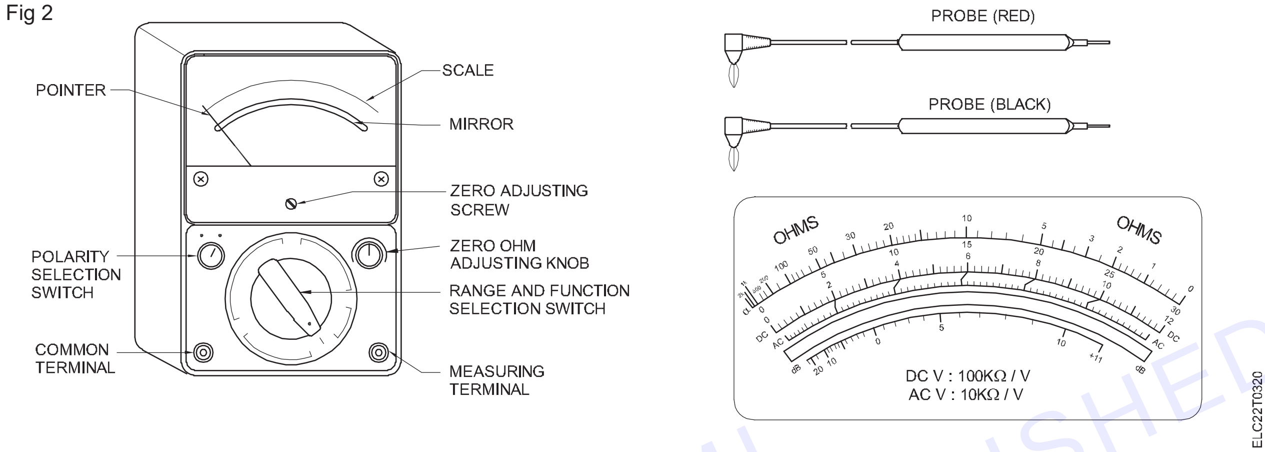
The meter movement is that of the moving coil system as used in DC ammeters and voltmeters.

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of the main parts and controls (Fig 2).

Fig 2

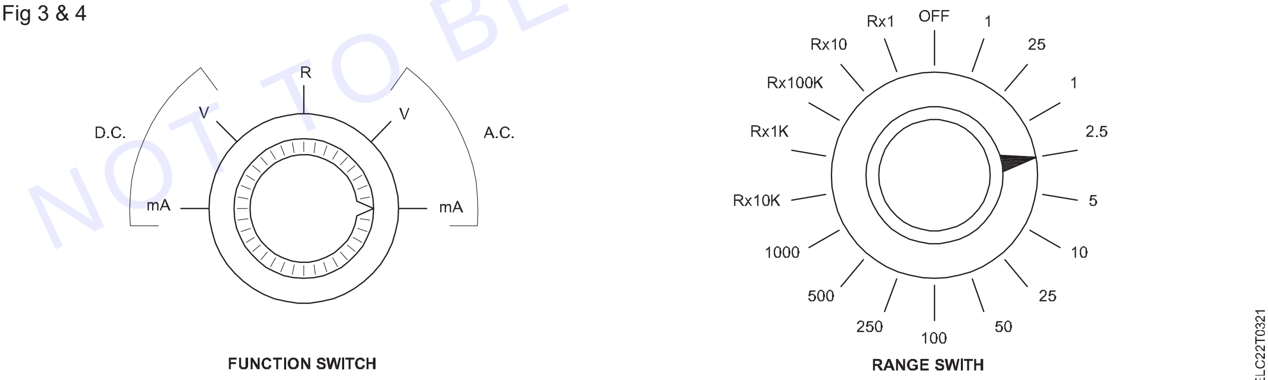


Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch. In the example given in Fig 3 the switch is set to mA, AC.

The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. In Fig 4, the switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

Fig 3 & 4



Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 5)

The scale of current and voltage is uniformly graduated.

The scale of the ohmmeter is non-linear.

The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter.(Fig 6)

Fig 5

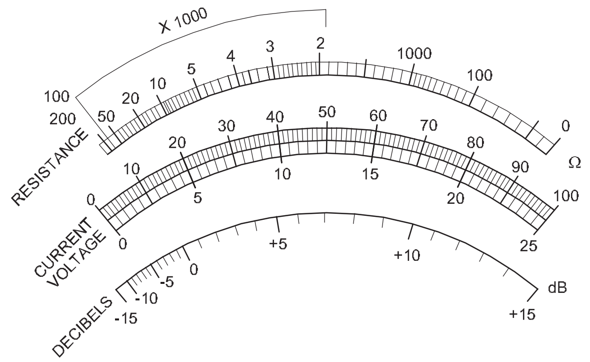
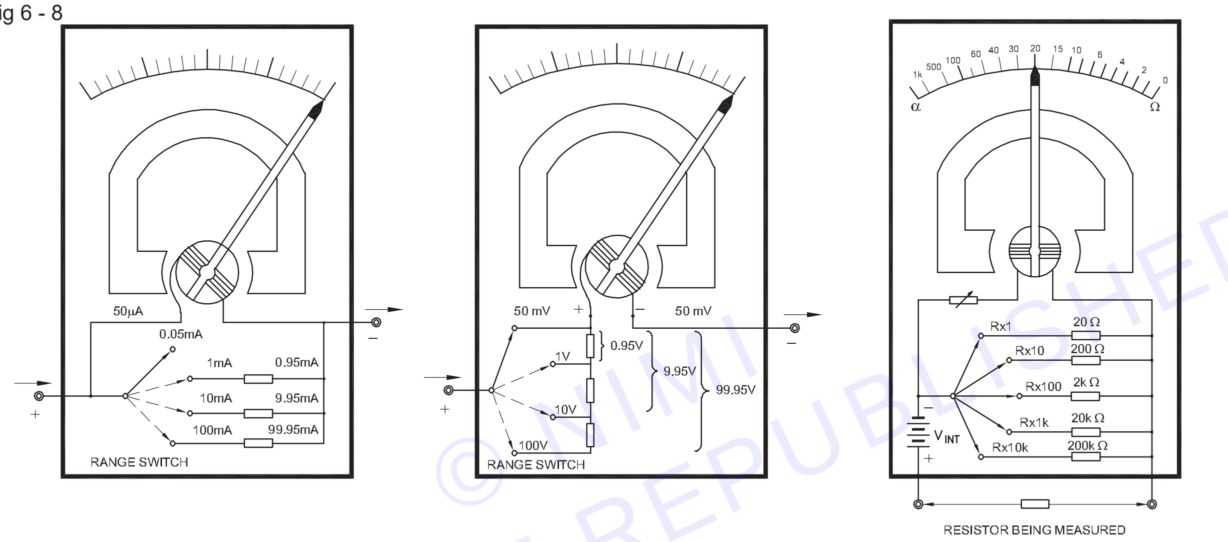


Fig 6 - 8



Shunt resistors across the meter movement bypass current in excess of 0.05 mA at fsd. A suitable value of shunt resistor is selected through the range switch for the required range of current measurement.

A circuitry when working as a voltmeter. (Fig 7)

The voltage drop across the meter coil is dependent on the current and the coil resistance. To indicate voltages greater than 50 mV at fsd as per the circuit, multiplier resistances of different values are connected in series with the meter movement through the range switch for the required range of measurement.

A circuitry when working as an ohmmeter. (Fig 8)

To measure resistance, the leads are connected across the external resistor to be measured (Fig 8). This connection completes the circuit, allowing the internal battery to produce current through the meter coil, causing deflection of the pointer, proportional to the value of the external resistance being measured.

Zero adjustment

When the ohmmeter leads are open, the pointer is at full left scale, indicating infinite (¥) resistance (open circuit). When the leads are shorted, the pointer is at full right scale, indicating zero resistance.

The purpose of the variable resistor is to adjust the current so that the pointer is at exactly zero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large ones. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

Remember, an ohmmeter must not be connected to a circuit when the circuit's power is on. Always turn the power off before connecting the ohmmeter.

Digital multimeters

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

- explain the method of measurement of voltage by using digital multimeter
- list and explain the types of digital multimeter
- state the application of digital multimeters.

Digital Multimeter

In a digital multimeter the meter movement is replaced by a digital read out (Fig 1 and 2). This readout is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital, integrated circuits. Like the analog-type multimeter, the digital multimeter has a front panel switching arrangement.

The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When DC quantities are measured the polarity is identified by '+ve' or '-ve' sign displayed to the left of the number indicating the probes are connected correctly by +ve sign and probes are reversely connected by -ve sign.

DMM functions: The basic functions found on most DMMs are the same as those on analouge multimeters. That is it can measure:-

- ohms
- DC voltage and current
- AC voltage and current

Some DMMs provide special functions such as transistor or diode test, power measurement, and decibel measurement for audio amplifier tests.

DMM displays: DMMs are available with either LCD (liquid -crystal display) or LED (light-emitting diode) read-outs. The LCD is the most commonly used read-out in battery-powered instruments due to the fact that it draws very small amount of current.

A typical battery-powered DMM with an LCD read-out operates on a 9V battery that will last from a few hundred hours to 2000 hours and more. The disadvantages of LCD read-outs are that (a) they are difficult or impossible to see in poor light conditions, and (b) they are relatively slow response to measurement changes.

LEDs, on the other hand, can be seen in the dark, and respond quickly to changes in measured values. LED displays require much more current than LCDs, and, therefore, battery life is shortened when they are used in portable equipment.

Both LCD and LED-DMM displays are in a seven segment format (Fig 3).

Multimeter: Safety precautions: The following safety precautions should always be taken.

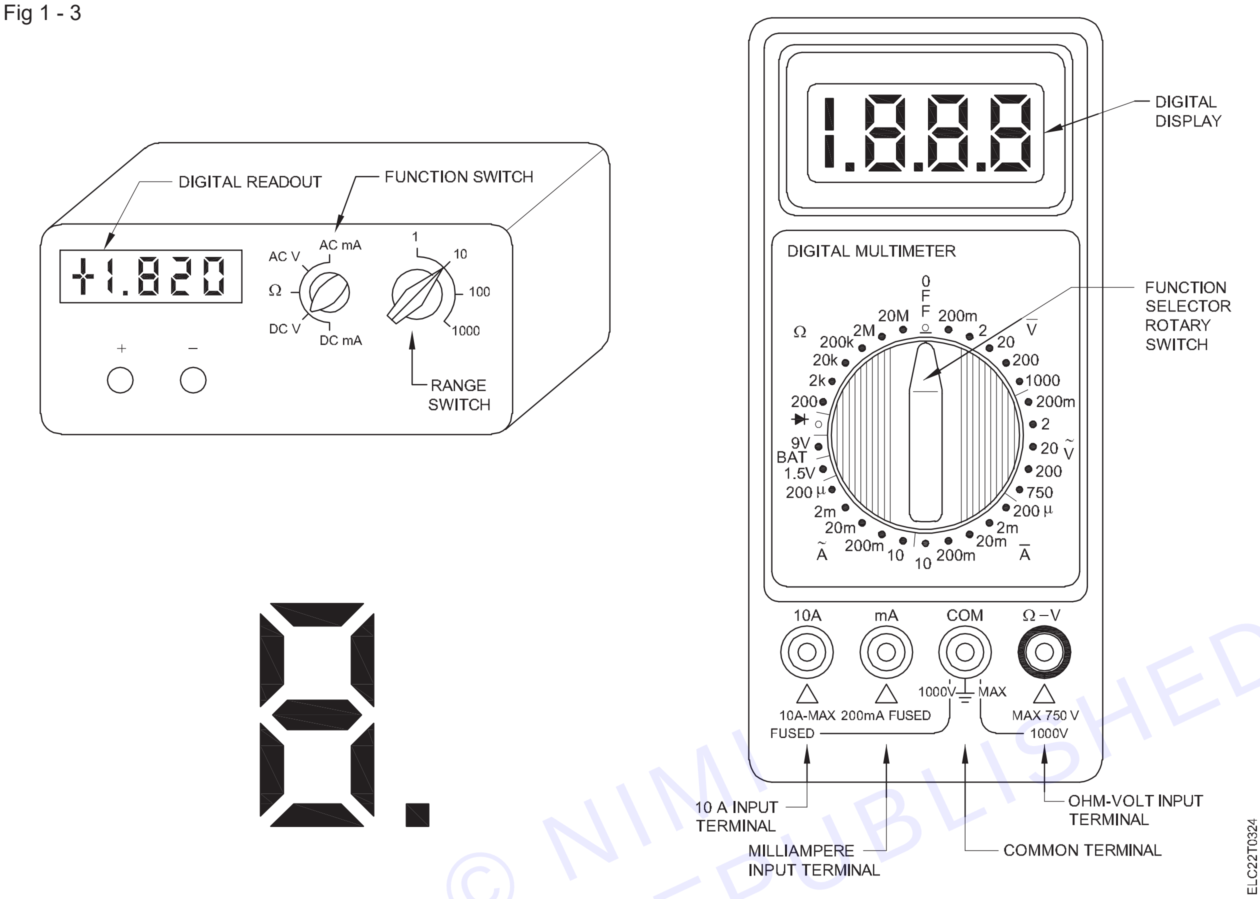
- Never use the ohmmeter section on a live circuit.
- Never connect the ammeter section in parallel with a voltage source.
- Never overload the ammeter or voltmeter sections by attempting to measure currents or voltages far in excess of the range switch setting.
- Check the meter test leads for frayed or broken insulation before working with them. If damaged insulation is found the test leads should be replaced.
- Avoid touching the bare metal clips or tips of the test probes.
- Whenever possible, remove the supply before connecting the meter test leads into the circuit.

Applications of Digital multimeter: A multimeter is used for testing and fault finding in electrical/electronic circuits, electrical appliances and machines. A multimeter is a portable handy instrument used for

- checking continuity of circuit, appliances and devices.
- measuring/checking the supply presence at the source
- for testing components like capacitors, diodes, and transistors for checking their condition.
- measuring the current drawn by the circuit.
- measuring resistance of the electrical appliances and devices.

Note: Some meters have provision also for temperature measurement with suitable sensing probes.

Fig 1 - 3



Frequency meter

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

- state the types of frequency meters
- describe the principle, construction and working of a mechanical resonance (vibrating reed) type frequency meter.

The following types of frequency meters are used for measuring power frequencies.

- Mechanical resonance type
- Electrical resonance type
- Electro-dynamic type
- Electro-dynamometer type
- Weston type
- Ratiometer type
- Saturable core type

The explanation given here is for mechanical resonance type frequency meter only as indicated below.

The trainees are advised to refer to books on electrical measuring instruments for learning about the other types of frequency meters.

Mechanical resonance type frequency meter (vibration reed type)

Principle: The vibration reed type frequency meter shown in Fig 1 works on the principle of natural frequency. Every object in the world has its natural frequency, depending upon its weight and dimensions. When an object is kept in a vibrating medium, it starts vibrating, if the frequency of the medium attains the natural frequency of the object.

If the vibrations are not controlled, the object may even get totally destroyed. A good example of this phenomenon is the shattering of window glass panes due to the vibration caused by low flying aircraft.

Construction: Mechanical resonance type frequency meters consist of an eletromagnet and a set of metallic reeds arranged in front of the electromagnet. The frequency meter is connected across the supply like a voltmeter, taking care about the voltage rating (Fig 2) .

Fig 1 & 2

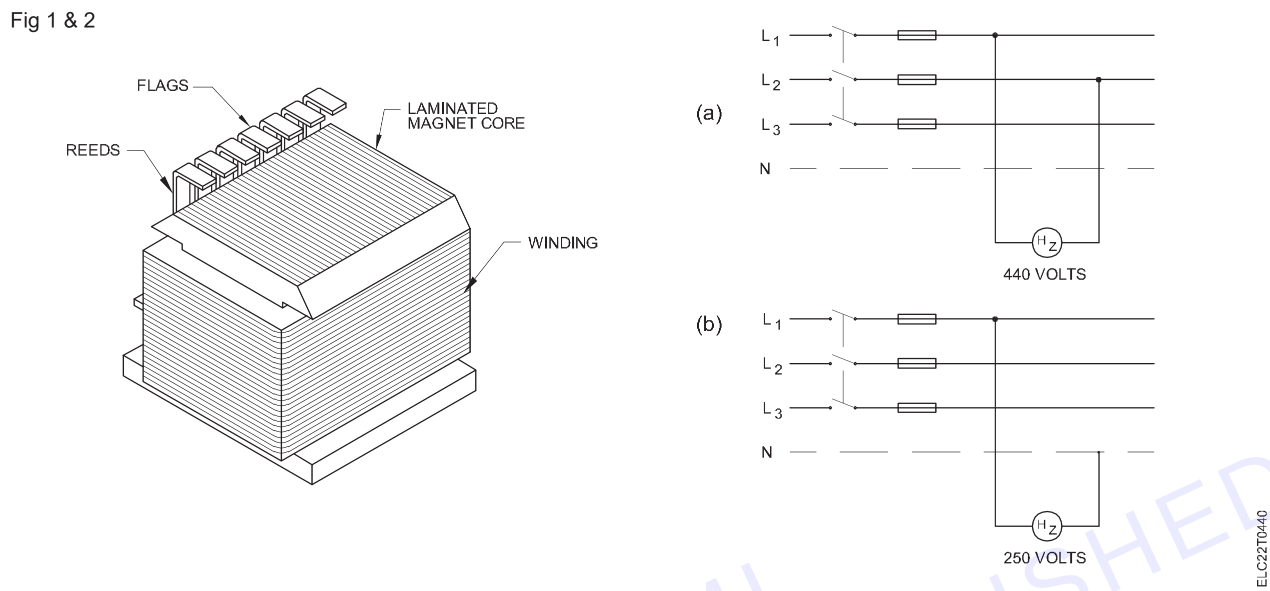


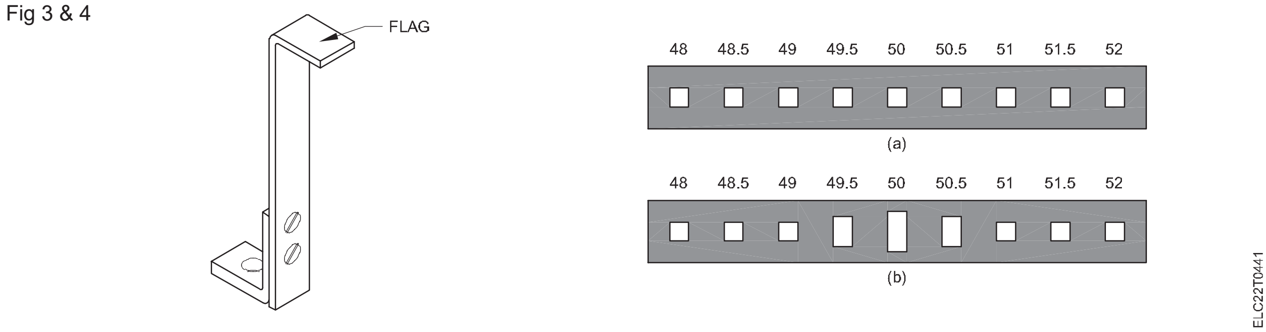
Fig 3 shows the shape of the reed and these reeds are of about 4mm wide and 0.5 mm thick. One end of the reed is fitted on a base, and the other overhanging end carries a white painted surface as the indicator and sometimes referred to as flag.

The reeds are arranged in a row and the natural frequency of the reeds differs by 1/2 cycle. This 1/2 cycle difference is possible between the reeds due to the difference in the weights of the reeds. The reeds are arranged in an ascending order (Fig 4a), and generally the natural frequency of the centre reed is the same as that of the supply frequency (50Hz).

Working: When the frequency meter is connected to the supply, the electromagnet produces a magnetic field which alternates at the rate of the supply frequency. The reed, which has its natural frequency coincident with that of the alternating magnetic field, vibrates more than the adjacent reeds Fig 4(b).

The flag of this vibrating reed makes it possible to note the frequency of the supply from the scale marking of the frequency meter. Though the other reeds also vibrate, Fig 4(b), their magnitude will be much less than the reed whose natural frequency is exactly in coincidence with the supply frequency.

Fig 3 & 4



Advantages and disadvantages

The reed type frequency meter has the following advantages.

The indications are independent of i) the wave form of the applied voltage and ii) magnitude of the applied voltage, provided that the voltage is not too low. At a low voltage the flag indication of the reed will not be reliable.

The disadvantages are the meter cannot read closer than half the cycle frequency difference between adjacent reeds and the accuracy greatly depends upon the proper tuning of the reeds.

Digital Frequency Meter

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

- state the function of digital frequency meter
- describe the block diagram of digital frequency meters.

A frequency counter is a digital instrument that can measure and display the frequency of any periodic waveform. It operates on the principle of gating the unknown input signal into the counter for a predetermined time.

If the unknown input signal were gated into the counter for exactly 1 second, the number of counts allowed into the counter would be the frequency of the input signal. The term gated comes from the fact that an AND or an OR gate is employed for allowing the unknown input signal into the counter to be accumulated. Fig 1

Discription of block diagram:

The simplified form of block diagram of frequency counter is in Fig 1. It consists of a counter with its associated display/decoder circuitry, clock oscillator, a divider and an AND gate. The counter is usually made up of cascaded Binary Coded Decimal(BCD) counters and the display/decoder unit converts the BCD outputs into a decimal display for easy monitoring.

A GATE ENABLE signal of known time period is generated with a clock oscillator and a divider circuit and is applied to one leg of an AND gate.

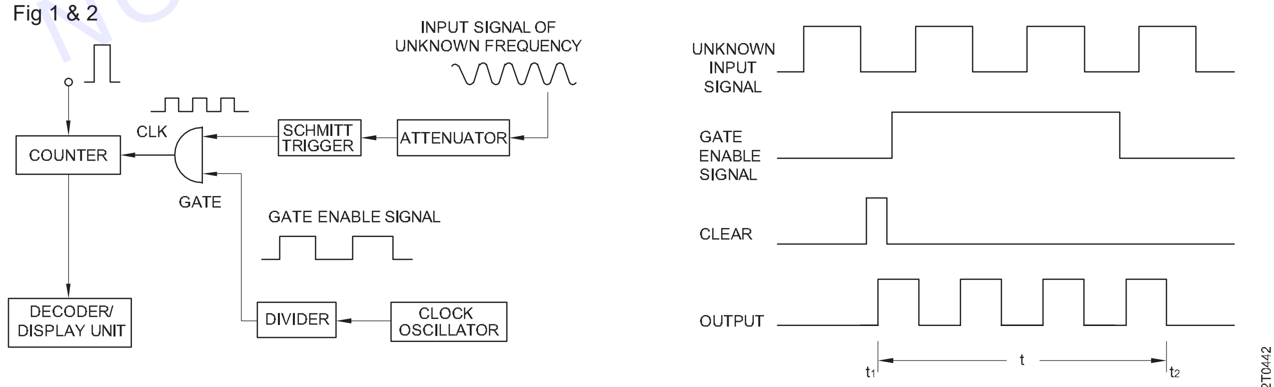
The unknown signal is applied to the other leg of the AND gate and acts as the clock for the counter. The counter advances one count for each transition of the unknown signal, and at the end of the known time interval, the contents of the counter will be equal to the number of periods of the unknown input signal that have occurred during time interval, t.In other words, the counter contents will be proportional to the frequency of the unknown input signal.

For instance if the gate signal is of a time of exactly 1 second and the unknown input signal is a 600-Hz square wave, at the end of 1 second the counter will counts up to 600, which is exactly the frequency of the unknown input signal

The wave form in Fig 2 shows that a clear pulse is applied to the counter at t0 to set the counter at zero. Prior to t1, the GATE ENABLE signal is LOW, and so the output of the AND gate will be LOW and the counter will not be counting. The GATE ENABLE goes HIGH from t1 t0 t2 and during this time interval t=(t2 - t1) the unknown input signal pulses will pass through the AND gate and will be counted by the counter

After t_2, the AND gate output will be again LOW and the counter will stop counting. Thus, the counter will have counted the number of pulses that occurred during the time interval, t of the GATE ENABLE SIGNAL, and the resulting contents of the counter are a direct measure of the frequency of the input signal.

Fig 1 & 2



BLOCK DIAGRAM OF FREQUENCY COUNTER

DIFFERENT WAVEFORMS IN A FREQUENCY COUNTER

Power factor meter

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

- explain the construction and connection of 3-phase dynamometer type power factor meter
- explain the construction, connection and operation of a 3-phase moving iron type power factor meter
- explain the construction, connection and operation of a single phase moving iron type power factor meter.

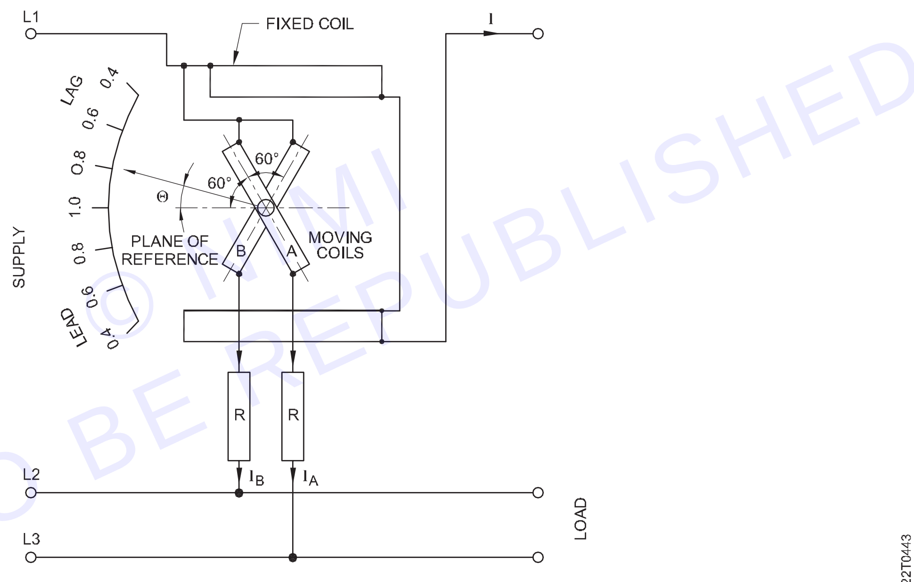
3-phase dynamometer type power factor meter for balanced load: Fig 1 shows the construction and connections of a 3-phase power factor meter used for balanced loads.

In this meter, the field coils are connected in series with the load along with one phase. The two moving coils are rigidly attached to each other at an angle of 120o. These coils are connected to two different phases. A resistance is connected in series with each coil.

Phase splitting through reactance is not necessary since the required phase displacement between currents in the two moving coils can be obtained by the supply itself.

Operation of the meter is in the same way as in a single phase meter. However this meter is suitable only for balanced loads.

Fig 1



DYNAMOMMETER TYPE THREE PHASE POWER FACTOR METER

Since the currents in the two moving coils are both affected in the same way by any change in frequency or wave-form, this meter is independent of frequency and wave-form.

Moving iron power factor meters: This type of power factor meter is more popular than the dynamometer type due to the following advantages.

- Torque-weight ratio (working forces) is large compared to the dynamometer type meter.
- As all the coils are fixed there is no ligament connection necessary.
- The scale can be extended to 360o.
- This meter is simple and robust in construction.
- Comparatively cheaper in cost.

Fig 2 shows the construction and connection of a moving iron type power factor meter used for balanced loads.

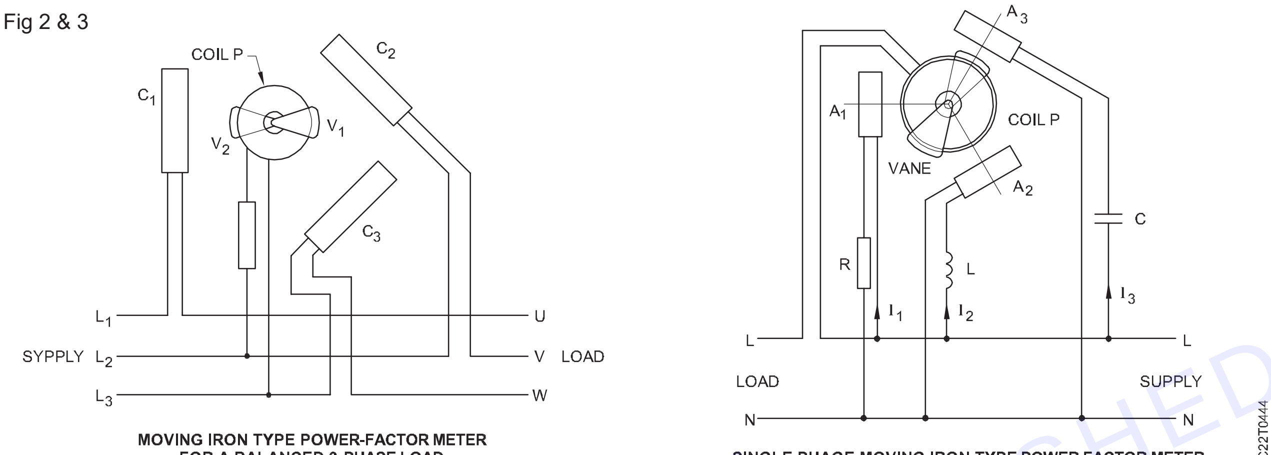
There are three similar coils at C1, C2 and C3 placed 120o degrees apart and connected to 3-phase supply directly (Fig 2) or through the secondary of the current transformers. Coil P is placed in the middle of the three coils C1, C2 and C3 and connected in series with a resistance across two lines of the supply. Inside the coil P there are are two vanes V1, and V2 mounted at the ends of a freely moving spindle but kept at 180o to each other. The spindle also has damping vanes and the pointer .

The rotating magnetic field produced by the three coils C_1, C_2 and C_3 interacts with the flux produced by the coil P. This causes the moving system to take up an angular position depending upon the phase angle of the current.

Single phase moving iron power factor meter: A single phase moving iron power factor meter (Fig 3) uses a phase splitting network comprising of a capacitor, an inductor and a resistor.

3-phase power factor meters for unbalanced load: For measurement of power factor in 3-phase unbalanced systems 2-element or 3-element power factor meters with each element with a current coil and pressure coil is used. The pressure coils are (moving coils) similar to that of single phase P.F. meters are mounted one below the other on a single spindle. The pointer shows the resultant power factor.

Fig 2 & 3



MOVING IRON TYPE POWER-FACTOR METER FOR A BALANCED 3-PHASE LOAD

SINGLE PHAGE MOVING IRON TYPE POWER FACTOR METER

Measurement of 3 phase power by single and two wattmeters

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

- explain the measurement 3 phase power using single wattmeter
- explain the measurement of 3 phase power using two wattmeters
- calculate the power factor by two wattmeter method power measurement.

The measurement of power: The number of wattmeters used to obtain power in a three-phase system depends on whether the load is balanced or not, and whether the neutral point, if there is one, is accessible

- Measurement of power in a star-connected balanced load with neutral point is possible by a single wattmeter
- Measurement of power in a star or delta-connected, balanced or unbalanced load (with or without neutral) is possible with two wattmeter method

Single wattmeter method: Fig 1 shows the circuit diagram to measure the three-phase power of a star-connected, balanced load with the neutral point accessible the current coil of the wattmeter being connected to one line, and the voltage coil between that line and neutral point. The wattmeter reading gives the power per phase. So the total is three times the wattmeter reading.

$P = 3E_P I_P$ χοσ= 3P = 3W

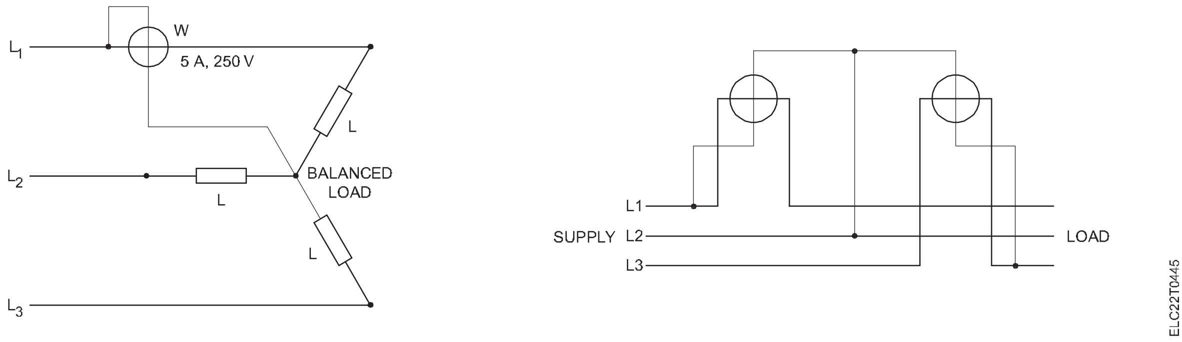
The two wattmeter method of measuring power

Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, if the load is unbalanced and the assumption that $I_U + I_V + I_W = 0$ will not be valid.

The two wattmeters are connected to the supply system (Fig 2). The current coils of the two wattmeters are connected in two of the lines, and the voltage coils are connected from the same two lines to the third line. The total power is then obtained by adding the two readings:

$P_T = P_1 + P_2$.

Fig 1& 2



Consider the total instantaneous power in the system $P_T= P_1+ P_2+ P_3$ where P_1, P_2 and P_3 are the instantaneous values of the power in each of the three phases.

$P_T = V_{UN}\ i_U+ V_{VN}\ i_V + V_{WN}\ I_W$

Since there is no fourth wire, $i_U+i_V+i_W= 0$; $i_V= (i_U+ i_W)$.

$PT = V_{UN}i_U\ V_{VN}(i_U+i_W) + V_{WN}\ i_W$

$= i_U(V_{UN}\ V_{VN}) + i_W(V_{WN}V_{UN})$

$= i_UV_{UV} + i_WV_{WV}$

Now i_UV_{UV} is the instantaneous power in the first wattmeter, and iWVWV is the instantaneous power in the second wattmeter. Therefore, the total mean power is the sum of the mean powers read by the two wattmeters.

It is possible that with the wattmeters connected correctly, one of them will attempt to read a negative value because of the large phase angle between the voltage and current for that instrument. The current coil or voltage coil must then be reversed and the reading given a negative sign when combined with the other wattmeter readings to obtain the total power.

At unity power factor, the readings of two wattmeter will be equal. total power = 2 x one wattmeter reading.

When the power factor = 0.5, one of the wattmeter's reading is zero and the other reads total power.

When the power factor is less than 0.5, one of the wattmeters will give negative indication. In order to read the wattmeter, reverse the pressure coil or current coil connection. The wattmeter will then give a positive reading but this must be taken as negative for calculating the total power.

When the power factor is zero, the readings of the two wattmeters are equal but of opposite signs.

Self-evaluation test

1 Draw a general wiring diagram for the two-wattmeter method of three-phase power measurement.

Power factor calculation in the two -wattmeter of measuring power

As you have learnt in the previous lesson, the total power $P_T= P_1 + P_2$ in the two-wattmeter method of measuring power in a 3-phase, 3-wire system.

From the readings obtained from the two wattmeters, the tan f can be calculated from the given formula

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}\,(W_1 - W_2)}{(W_1 + W_2)}$$

from which ϕ and power factor of the load may be found.

Example 1: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. Find the power factor of the circuit.

Solution

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$P_1= 4.5$ KW

$P_2= 3$ KW

$P_1 + P_2 = 4.5 + 3 = 7.5$ KW

$P_1\ P_2 = 4.5\ \ 3 = 1.5$ KW

$$\tan\phi = \frac{\sqrt{3} \times 1.5}{7.5} = \frac{\sqrt{3}}{5} = 0.3464$$

ϕ = tan1 0.3464 = 1906'

Power factor Cos 19°6' = 0.95

Example 2: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. The latter reading is obtained after reversing the connection of the voltage coil of that wattmeter. Find the power factor of the circuit.

Soultion

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$$= \frac{\sqrt{3}(4.5 - (-3))}{(4.5 + (-3))}$$

$$= \frac{\sqrt{3}(4.5 + 3)}{(4.5 - 3)}$$

$$= \frac{\sqrt{3} \times 7.5}{1.5} = \sqrt{3} \times 5$$

$$= 1.732 \times 5 = 8.66.$$

ϕ = tan—1 8.66 = 83°.27'

since power factor (Cos 83o 27') = 0.114.

Example 3: The reading on the two wattmeters connected to measure the power input to the three-phase, balanced load are 600W and 300W respectively.

Calculate the total power input and power factor of the load.

Solution

Total power = $P_T = P_1 + P_2$

P_1 = 600W.

P_2 = 300W.

P_T = 600 + 300 = 900

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(600 - 300)}{600 + 300} = \frac{\sqrt{3} \times 300}{900}$$

$$= \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} = 0.5774$$

ϕ = tan10.5774 = 30o

Power factor = Cos 30o = 0.866.

Assignment

Two wattmeters connected to measure the power input to a balanced, three-phase load indicate 25KW and 5KW respectively.

Find the power factor of the circuit when (i) both readings are positive and (ii) the latter reading is obtained after reversing the connections of the pressure coil of the wattmeter.

Tong - tester (clamp - on ammeter)

Objectives: At the end of this lesson you shall be able to:
- state the necessity of tong-testers
- state the construction and working of a tong-tester
- state the precautions to be observed while using a tong-tester.

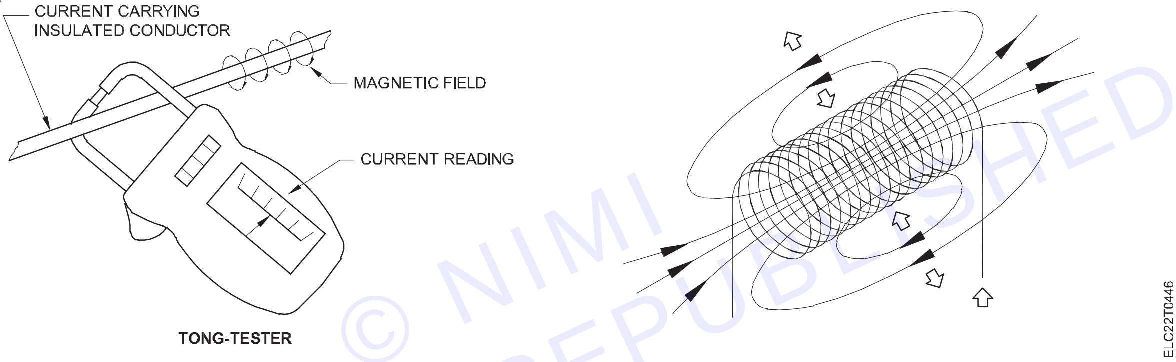
A tong-tester is an instrument devised for the measurement of A.C current, without interrupting the circuit. It is also called clip-on ammeter, or sometimes a clamp-on ammeter (Fig 1).

Working principle

The instrument can function only when current passes through its deflecting system. It works under the mutual induction principle.

Electromagnetic induction: When a changing flux is linked with the coil, an emf is induced in the coil. The current in a coil so produced changes as that of the changing magnetic flux. If an alternating current is flowing through the coil, the magnetic flux produced is also alternative i.e. changing continuously.(Fig 2)

Fig 1 & 2

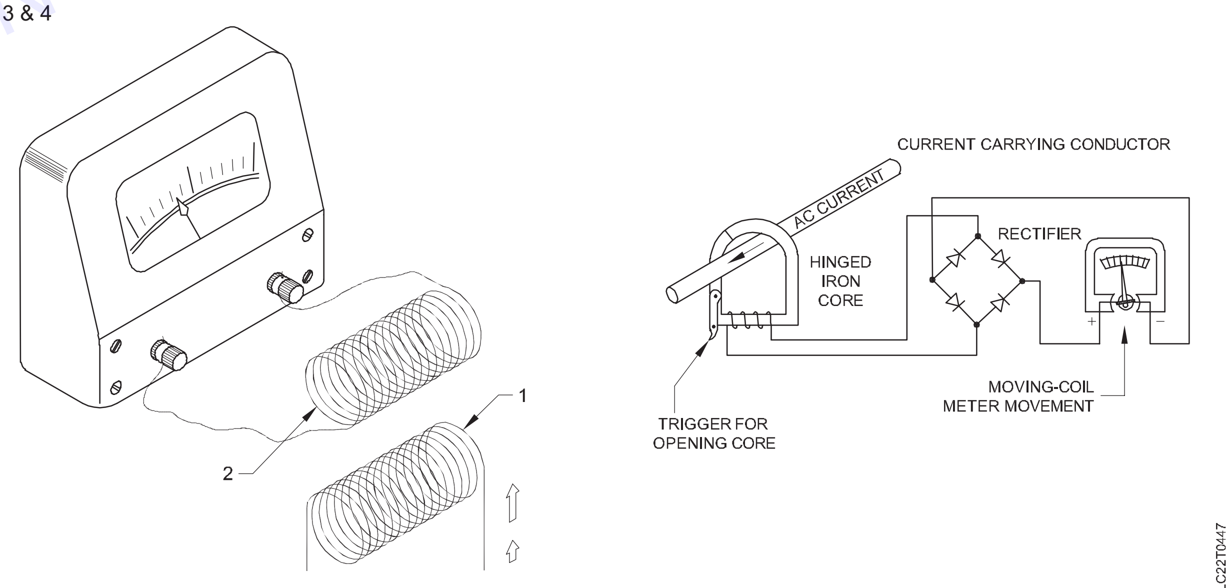


Placing another coil (2) in the changing flux of coil (1), an emf will be induced. (Fig 3)

This induced emf will send the current, causing deflection of the meter. Introduction of a magnetic core between the coils increases the induced emf. The coil (1) is called primary and the coil (2) is called secondary.

Construction: Fig 4 shows a tong-tester (the clamp-on ammeter) circuit. The split-core meter consists of a secondary coil with the split-core and a rectifier type instrument connected to the secondary. The current to be measured in the conductor serves as the primary of one turn coil. It induces a current in the secondary winding and this current causes the meter to deflect.

Fig 3 & 4



The core is so designed that there is only one break in the magnetic path. The hinge and the opening both fit tightly when the instrument closes around the conductor. The tight fit of the instrument ensures minimum variation in the response of the magnetic circuit.

To measure current with a clamp-on meter, open the jaws of the instrument and place them around the conductor in which you want to measure the current. Once the jaws are in place, allow them to close securely. Then, read the indicator position on the scale.

When the core is clamped around a current-carrying conductor, the alternating magnetic field induced in the core, produces a current in the secondary winding.

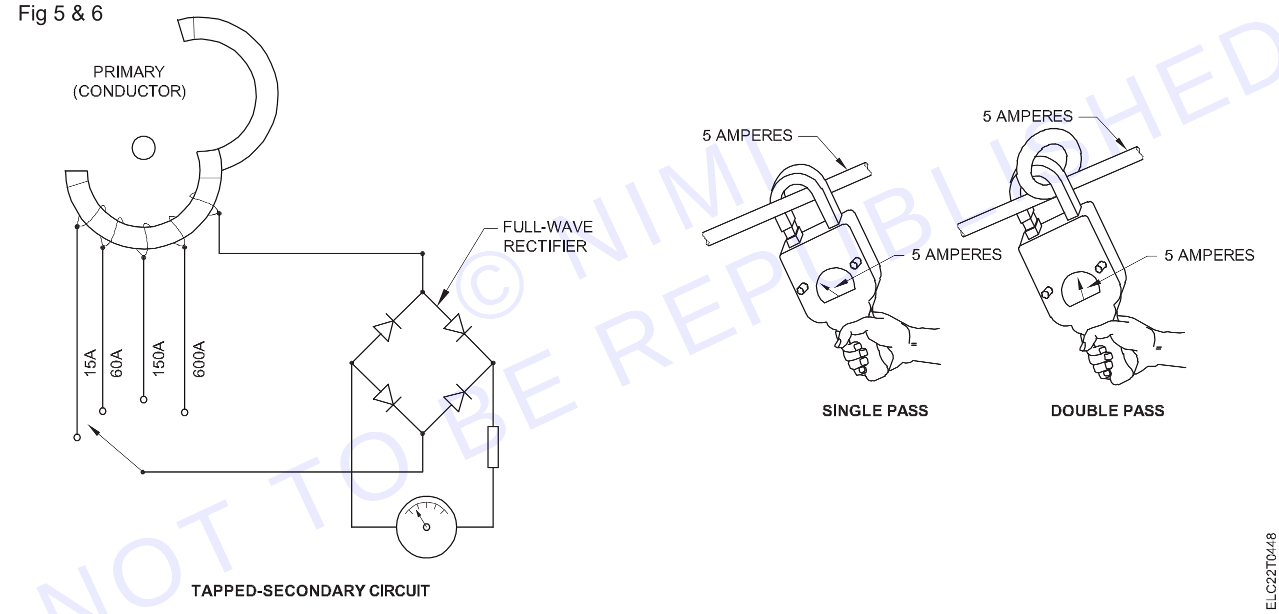
This current causes a deflection on the scale of the meter movement. The current range can be changed by means of a `range switch', which changes the taps on the transformer secondary (Fig 5).

Safety: The secondary winding of the current transformer should always be either shunted or connected to the ammeter; otherwise, dangerous potential differences may occur across the open secondary.

Before taking any measurement, make sure the indication is at zero on the scale. If it is not, reset by the zero-adjustment screw. It is usually located near the bottom of the meter.

Looping the conductor more than once through the core is another means of changing the range. If the current is far below the meter's maximum range, we can loop the conductor through the core two or more times (Fig 6).

Fig 5 & 6



Application

1 For measuring the incoming current in the main panel board.

2 Primary current of AC welding generators.

3 Secondary current of AC welding generators.

4 Newly rewinded AC motor phase current and line current.

5 Starting current of all AC machines.

6 Load current of all AC machines and cables.

7 For measuring the unbalanced or balanced loads.

8 For finding the faults in AC, 3-phase induction motors.

Precaution

1 Set the ampere range from higher to low if the measuring value is not known.

2 The ampere-range switch should not be changed when the clamp is closed.

3 Before taking any measurement make sure the indication is at zero on the scale.

4 Do not clamp on a bare conductor for current measurement.

5 Seating of the core should be perfect.

Calibration of MI Ammeter and Voltmeter

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

- define the term 'calibration'
- explain the calibration of voltmeter and ammeter.

Calibration

In many industrial operations, measurement instruments must be trusted to provide the accuracy stipulated by the original design to assure a satisfactory product. This confidence is provided by a periodic testing and adjustment of the instrument to verify the required performance. This type of maintenance is called calibration.

Standards

Before calibration can begin, you must have the accurately known values of the measured quantities against which to compare the measurements made by the instrument being calibrated. Thus, for an instrument that is supposed to measure current of 1 milli ampere, you must have, for comparison, a source of current that is known to within at least that range or better. Only then you can say whether the instrument performs satisfactorily.

A very accurately known quantity used for calibration of instruments is known as a standard.

Calibration standards

Quantity	Standard
Voltage	Standard cell, high precision source
Current	Voltage standard and standard resistance standard milli volt source, gas filled/ mercury filled thermometers.

Calibrating DC and AC meters (Ammeter & Voltmeter)

Both DC and AC meters are calibrated in essentially the same way. To calibrate a DC meter, a very accurate DC current source is connected to the meter. The output of the current source must be variable, and some means must be available to monitor the output current of the source. Many sources have built-in meter for this purpose.

The output of the current source is varied in very small steps, and at each step the scale of the meter being calibrated is marked to correspond to the reading on the monitoring device. This procedure is continued until the entire scale of the meter is calibrated.

Same procedure is used to calibrate an AC meter, except that a 50/60 cps sine wave is used mostly. Also, you know that an a-c meter reads the average value of a sine wave, but it is desirable for the meter to indicate rms values. Therefore the rms equivalent are calculated and marked on the scale.

Thermocouple meters are calibrated on the basis of a sine wave. But the calibration is made at the frequency at which the meter will be used. At the extremely high frequencies at which it is used, a phenomenon known as skin effect occurs.

At these frequencies, the current in a wire travels at the surface of the wire, the higher the frequency, the closer the current moves to the surface of the wire. This effect increases the resistance of the thermocouple heater wire because the diameter of the wire becomes, in effect, smaller.

Thus the resistance of the heater wire varies with frequency. Since the resistance of the heater wire varies with frequency, thermocouple meters must be calibrated at specific frequencies.

Precautions to be observed when using an ammeter in measurement work

1 Never connect an ammeter across a source of EMF. Because of its low resistance it would draw damaging high currents and damage the delicate movement. Always connect an ammeter in series with a load capable of limiting the current.

2 Observe the correct polarity. Reverse polarity causes the meter to deflect against the mechanical stop and this may damage the pointer.

METER ACCURACY

METER	TYPICAL ACCURACY
Moving coil	0.1 to 2%
Moving iron	5%
Rectifier type moving coil	5%
Thermocouple	1 to 3%

Loading effect of voltmeter and voltage drop effect of ammeter in circuits

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

- define the term 'multiplier'
- analyse the loading effect of the voltmeter
- analyse the effect of voltage drop across the ammeter in the resistance measurement.

Multipiler

In the case of P.M.M.C. instruments, we have seen that the moving coil consists of fine gauge copper wire. This copper wire can carry very low current in the order of milli or micro amperes only.

The acceptable current which enables the instrument to read full scale is called full scale deflection current or F.S.D. current. When such a P.M.M.C. instrument is to be converted as a voltmeter, the moving coil has to be connected with a high resistance in series so that the current could be restricted within the F.S.D. current value. This series resistance is called multiplier resistance.

Let us study how the voltmeter sensitivity causes loading effect in the circuit by the voltmeter.

Loading effect of a voltmeter: The sensitivity of a voltmeter is an important factor when selecting a meter for a certain voltage measurement. A low sensitivity voltmeter may give an almost correct reading when measuring voltages in low-resistance circuits, but it is certain to produce very high errors in high resistance circuits. It is due to the fact that the voltmeter, when connected across a high resistance circuit, acts as a shunt for that portion of the circuit, and, thereby, reduces the equivalent resistance in that portion of the circuit.

As such, the meter will then give a lower indication of the voltage drop than what actually existed before the meter was connected. This effect is called the loading effect of a voltmeter and it is caused principally by the low sensitivity of the voltmeter.

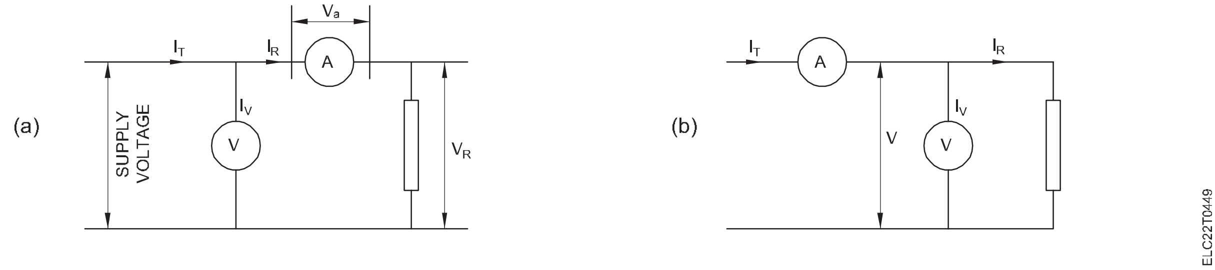
The meter with the higher sensitivity of ohms/volt rating gives the most reliable result. It is important to realize the factor of sensitivity, particularly when voltage measurements are made in high-resistance circuits. Hence the following points are required to be followed while using a voltmeter.

- When using a multi-range voltmeter, always use the highest voltage range, and then decrease the range until a good up-scale (above mid-scale) reading is obtained.
- Always be aware of the loading effect. This effect can be minimised by using a voltmeter of high sensitivity and highest range in voltmeter.
- Before reading the meter, try to select a range in the multi-scale instrument such that the reading obtained is above mid-scale. The precision of the measurement decreases if the indication is at the low end of the scale.

Effect of voltage drop across the ammeter in resistance measurement: The ammeter/voltmeter method of measuring resistance is very popular since the instrument required for this is usually available in the laboratory.

In this method, two types of connections of meters are possible (Figs 1a and b).

Fig 1



In both the cases, if readings of the ammeter and voltmeter are taken, then the measured value of resistance is given by

$$R_m \frac{\text{Voltmeter reading}}{\text{Ammeter reading}} = \frac{V}{I}$$

The measured value of resistance Rm, would be equal to the true value R, provided the ammeter resistance is zero and the voltmeter resistance is infinite, to make the circuit condition undisturbed.

However, in practice this is not possible, and hence, both the methods give inaccurate results. But the error in measurement could be reduced under different values of resistance to be measured as explained below.

Circuit (Fig 1a): In this circuit, the ammeter measures the true value of the current through the resistor. But the voltmeter does not read the true voltage across the resistance. On the other hand, the voltmeter measures the voltage drop across the resistance and also the ammeter.

Let R_a be the resistance of the ammeter.

Then the voltage drop across the ammeter $V_a = IR_a$

$$R_{mt} = \frac{V}{I} = \frac{V_R + V_a}{I_R} = \frac{IR + IR_a}{I_R}$$

$$= R + R_a \text{ ....Eqn.(1)}$$

true value of resistance $R = R_{m1}\ R_a$ ... Eqn.(2)

From equation 2, it is clear that the measured value of resistance is higher than the true value. It is also clear from the above equation, that the true value is equal to the measured value only if the ammeter resistance R_a is zero.

$$\text{Relavtive error } e_r = \frac{R_{m1} - R}{R}$$

$$e_r = \frac{R_{m1} - (R_{m1} - R_a)}{R}$$

$$= \frac{R_a}{R} \text{ ....Eqn.(3)}$$

Conclusion: From equation 3, it is clear that the error in measurement would be small if the value of resistance under measurement is large as compared to the internal resistance of the ammeter. Therefore, the circuit shown in Fig 1(a) is most suitable for measuring high resistance values only.

Circuit (Fig 1b): In this circuit the voltmeter measures the true value of the voltage across the resistance but the ammeter measures the sum of currents through the resistance and the voltmeter.

Let R_V be the resistance of the voltmeter. Then the current through the voltmeter

$$I_V = \frac{V}{R_V}$$

Measured value of the resistance

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_V}$$

$$R_{m2} = \frac{V}{\frac{V}{R} + \frac{V}{R_V}} \text{ .....Eqn.(4)}$$

By multiplying the denominator and numerator

by $\frac{R}{V}$, Eqn.(4) becomes

$$R_{m2} = \frac{R}{1 + \frac{R}{R_V}} \text{ .....Eqn.(4)}$$

From equation 4, it is clear that the true value of resistance is equal to the measured value only if

- the resistance of the voltmeter RV is infinite
- the resistance to be measured 'R' is very small when compared to the resistance of the voltmeter.

Relative error $e_r = \frac{R_{m2} - R}{R}$

By elimination process, we get

...Eqn.(5)

The value of R_{m2} is approximately equal to R.

Therefore er $e_r = \frac{-R}{R_V}$ .....Eqn.(6)

Conclusion: From equation (6), it is clear that the error in measurement would be small if the value of resistance under measurement is very small as compared to the resistance of the voltmeter. Hence the circuit shown in Fig 1(b) should be used when measuring resistances of a lower value.

MODULE 10 : IIllumination, Connection of Electrical Lights

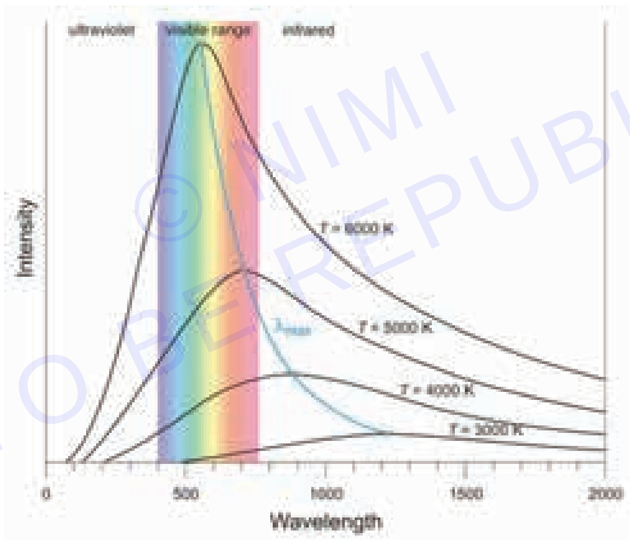
LESSON 54-59 : Illumination terms - law's

Objectives

At the end of this lesson you shall be able to:
- state and explain different terms used in illumination
- state and explain law's of illumination
- explain the different types of lamps
- explain the construction & working of incandescent lamp, flourescent lamp HPSV, HPMV lamp, CFL LED.

Light

Light is defined as that radiant energy which produce a sensation of vision upon the human eye.



Red 700 nm ⟶ violet 400 nm

Electrical lighting

Electrical lighting has following advantages:

1 Cleanliness

2 Easy to control

3 Economical

4 Easy to handle

5 Steady output

6 Better reliability

7 Suitable for almost all purposes etc.

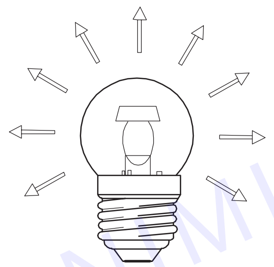
Terms used in illumination

1 Light
2 Luminous flux
3 Lumen
4 Plane angle
5 Solid angle
6 Steradian
7 Candle power

Luminous flux

The total quantity of radiant energy per second responsible for visual sensation from a luminous body is called luminous flux.

It is represented as f of ø and measured in lumens



LUMINOUS FLUX UNIT LUMEN (lm)

Lumen

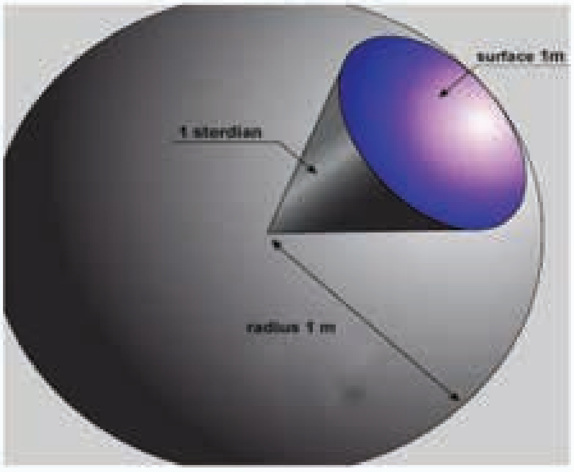
It is the unit of luminous flux. One lumen is defined as the luminous flux emitted per unit solid angle from a point source of one candle power.

Solid angle

The angle subtended by the partial surface area of a sphere at its centre is called as solid angle. It is measured in steradians and equal to the ratio of area of the surface to the square of radius of sphere,

ω = area of surface/ square of radius

= A/r^2 steradians

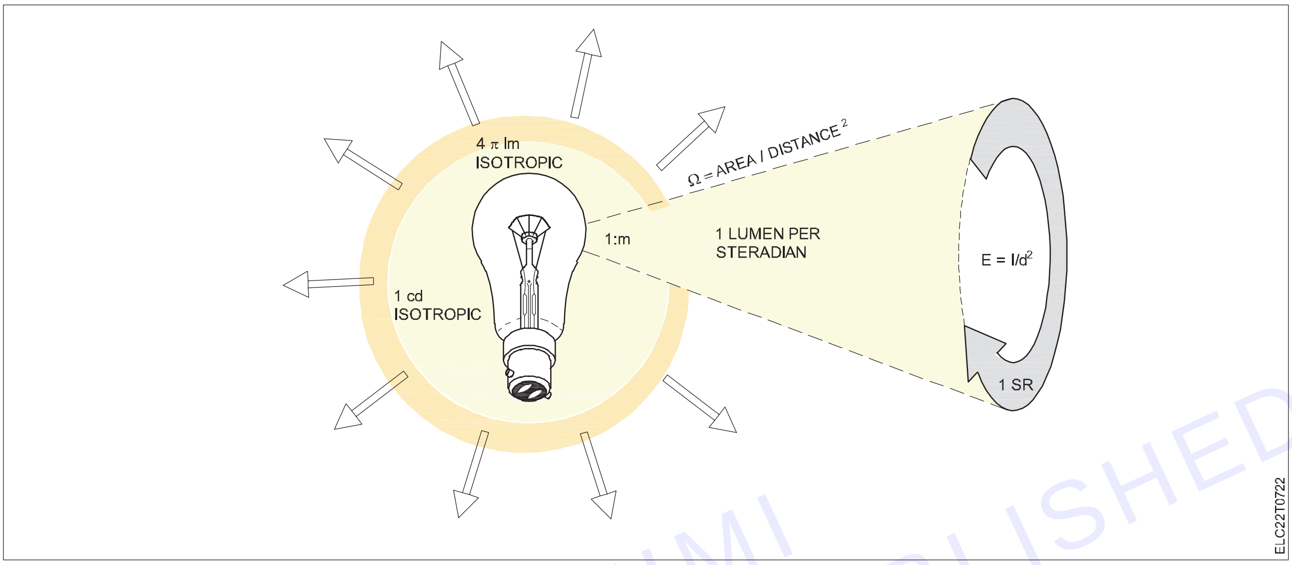


Steradian

Steradian is the unit of solid angle. One steradian is defined as the solid angle that is subtended at the centre of a sphere by its surface having area equal to radius square,

ω = area of surface/ square of radius

= A/r^2 steradians



Candale power

The light radiating capacity of a source is called its candle power. The number of lumens given out by a source per unit solid angle in a given direction is called its candle power. It is denoted by C.P.

Total flux emitted = CP x solid angle

= $1 \times 4\pi = 4\pi$ lumens

= 4π lumens

Luminious intensity

Luminous intensity in any particular direction is the luminous flux emitted by the source per unit solid angle in that direction. It is denoted by i and its unit is candela or candle power (CP) .Luminous intensity of source in a particular direction, $I = \varphi / \omega$

Illumination

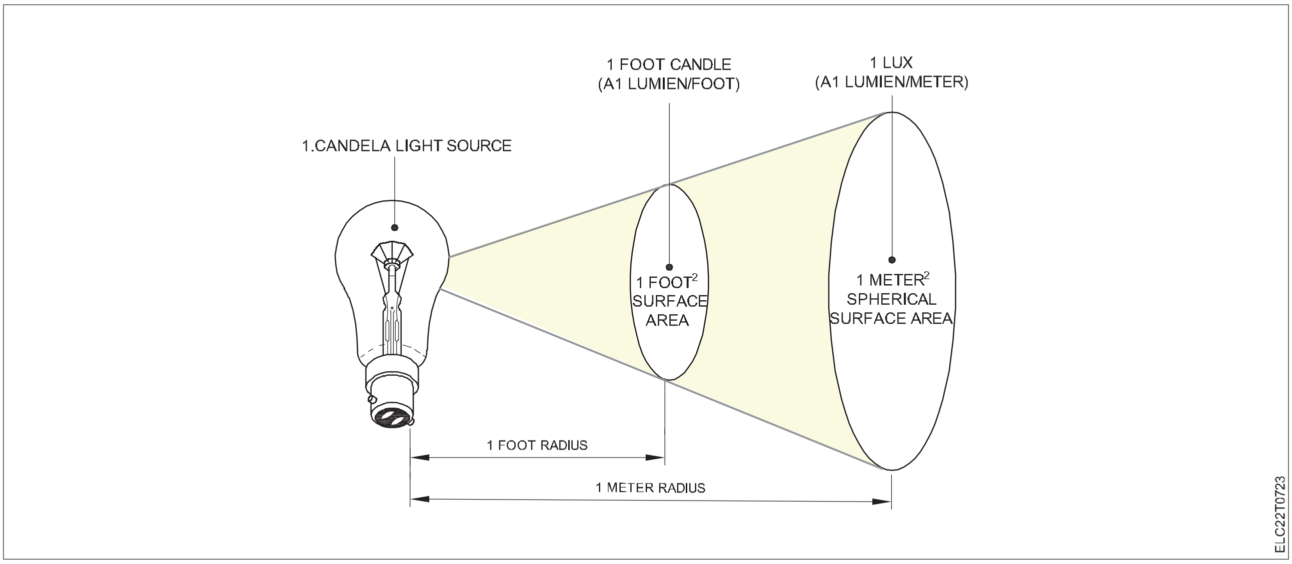
When light falls on a surface, it becomes visible, the phenomenon is called as illumination.

It is defined as luminous flux falling on a surface per unit area. It is denoted by E and measured in lumen per square meter or meter- candle .

$E = \Phi / A$ lux

LUX

One-meter candle or lux is defined as the illumination produced by a uniform source of one CP on the inner surface of a sphere of radius one meter.



Law of illumination

The illumination on a surface depends upon the luminous intensity, distance between the source and surface and the direction of rays of light. It is governed by following laws:

1 Inverse square law

2 Lambert's cosine law

Inverse Square Law

This law states that the Illumination (E) is directly proportional to the luminous intensity (I) of the source.

E α I

Illumination (E) is inversely proportional the square of the distance between the source and plane.

E α $1/d^2$

Illumination lumen/ sq.m.

Where,

I- luminous intensity in a given direction.

d- the distance.

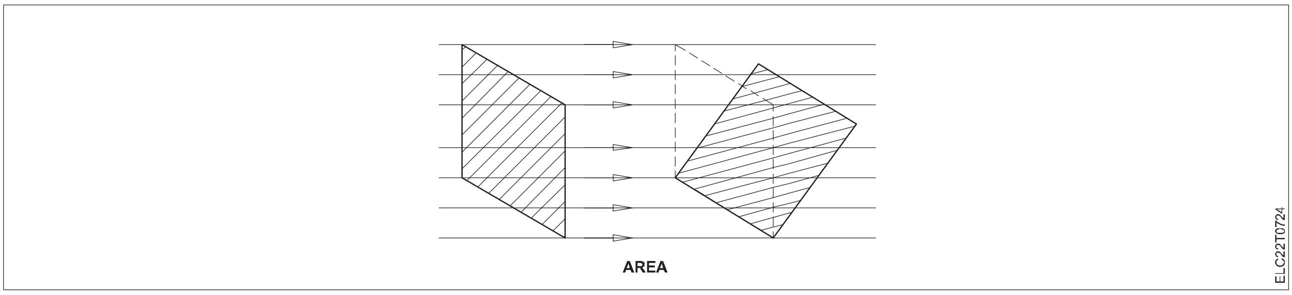
Lambert's cosine law

The law states that Illumination varies directly as the cosine of the angle between the direction of the incident light and the normal to the plane.

E α cosθ

combining two laws,

$E = I \cos\theta / d^2$



Types of lamp

1 Incandescent lamp (By passing a current through a filament).

2 Gas discharge lamp (By electric discharge through vapors or gases).

3 Arc lamps (By developing arc between two electrodes).

4 LED.

Filament or incandescent lamp

Working Principle:

As we know when a room heater is switched On, it gives out red light with heat at the working temperature of 750°C and at this temperature the radiations are mostly in infra-red regions. This working principle is used to develop the filament lamp.

Filament or Incandescent Lamp

When an electric current is passed through a fine metallic wire, it raises the temperature of wire. At low temperature only heat is produced but at higher temperature light radiations goes on increasing. As filament lamp consists of fine wire of high resistive material placed in an evacuated glass bulb. This type of lamps are operated at the temperature of 2500°C .

Properties of metal for filament

1 High melting point: so that it can be operated at high temperature.

2 High specific resistance: so that it produces more heat.

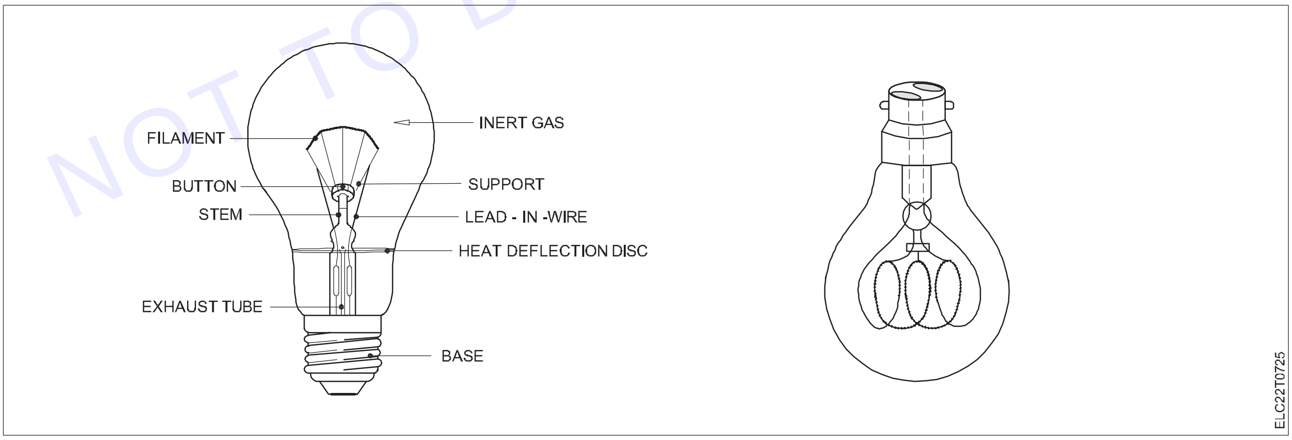
3 Low temperature coefficient: so that filament resistance may not change at operating temperature.

4 Low vapor pressure; so that it may not vaporize

5 High ductile: so that it may withstand mechanical vibrations

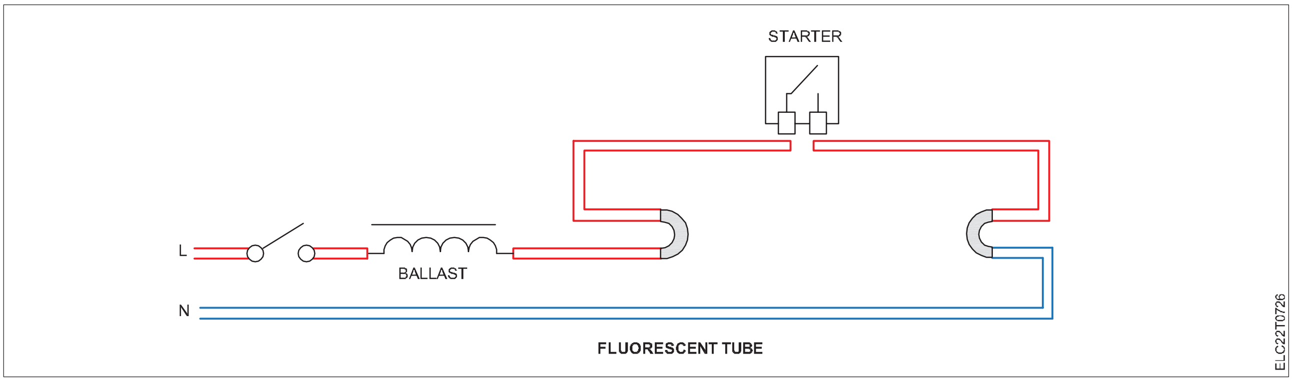
Carbon filament lamp

It is generally used for heating purpose. The filament is of carbon. Melting point of carbon is 3500 degreeCelsius. Working tem: is 1800.



Fluorescent tube

It is a low pressure mercury vapor lamp. It consists of a glass tube 25 mm in diameter and 0.6 m, 1.2 m and 1.5 m in length. The tube contains argon gas at low pressure about 2.5 mm of mercury. At the two ends, two electrodes coated with some electron emissive material are placed.



A choke is connected in series with the tube which act as a blast and provide a high voltage at starting glow in the tube. During running condition, the same choke absorbs some supply voltage and remain a voltage of 110 V across the tube. A capacitor is connected to improve the power factor.

Advantages of Fluorescent Tube

1 Voltage fluctuation has very small effect on light output.

2 The luminous efficiency is more as length of rod is more.

3 It gives light close to natural light.

4 Heat radiations are negligible.

Disadvantages of Fluorescent Tube

1 Its brightness is less.

2 Initial cost is more

3 Overall maintenance cost is high.

ARC LAMP

An arc lamp or arc light is a lamp that produces light by an electric arc.

CARBON ARC LAMP

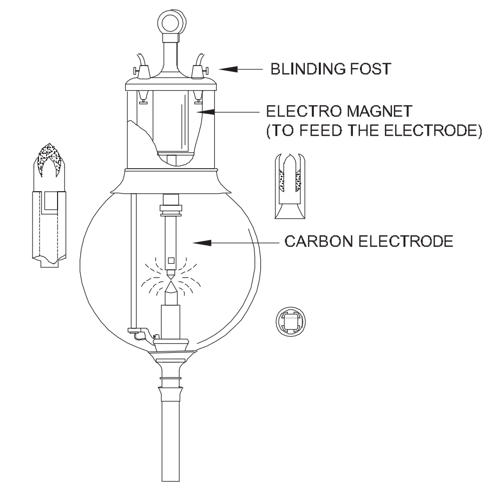
The carbon arc lamp which consist of an arc between carbon electrodes in air, invented by Humphry davy in 1800s. It was widely used for street light and large building lighting until it was superseded by incandescent light.

It continued in use in more specialized applications where high intensity point light was needed, such as search light and movie projectors.

Two carbon electrodes placed in contact end to end, in which a direct current is flowing and on separating by about 0.6 mm, apart gives out a luminous arc.

The arc gives path to the flow of current and the separated ends of carbon emits light rays. The major part of the light is due to the electrodes and only 5% is given out by arc. About 85% light is given out by positive electrode which has a temperature of 3500-4000 degcel

Only 10% light is emitted by negative electrode nearly at 2500 degcel.



Production of heat due to arc:

When carbon electrodes are separated, the electrons move from negative electrode to positive electrode through air and set the air in ionised condition.

The positive ions move towards the negative electrode and colliding with carbon thereby producing good amount of heat, similarly negative ions collides with positive carbon electrode and producing enough heat about 4000 degcel.

Due to higher operating temperature the rate of consumption of positive electrode is nearly double than the negative electrode. Due to this reason the positive electrode is made of twice the cross sectional area of negative electrode.

When using arc lamp on AC supply both electrodes burn away at equal rates therefore they are made of equal cross sectional area.

Efficiency is 20 lumen/watt

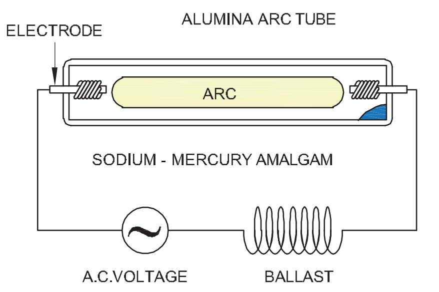
The negative electrode is generally fixed and positive electrode is placed in adjustable holder and the process is manual or automatic.

As the lamp needs frequent adjustment to maintain the constant gap between electrodes it is not used in general purpose. They are only used in cinema projectors, search lights

Gas discharge lamps

A gas discharge lamp is one in which some inert gas is filled in a glass tube having two electrodes sealed in to each end , which when heating allows the flow of electons through it.

To obtain continues flow of electrons gas is first charged but as the supply is disconnected from the bulb the gas is discharged.



Basic principle:

- Gases are poor conductors at normal &higher pressure.
- But application of high ignition voltage b/w two electrodes in a sealed envelope containing gas at low pressure ionises the gas and current pass through the gas medium.
- Once conduction starts due to ionisation the resistance in the circuit drops rapidly.
- To limit current due to low resistance a device must be provided.
- The current through the L.P gas is called discharge. This causes the gas/vapour to emit radiation in UV region. The UV radiation cannot be perceived by human eye.
- Certain phosphors emit light when exposed to UV rays and the same coated over the tube to emit light

Electric gas discharge lamp s are of two types:

1 Cold cathode lamp

2 Hot cathode lamp

In the first type no filament is used to heat the electrode for starting but in the second type filament is provided for heating the main electrode at the time of starting.

When a voltage is applied across two ends of filament contained in a gas filled glass tube electrons starts flowing from one electrode to other and current is passed through the gas then it emits light rays.

The following are the different types of gas discharge lamps.

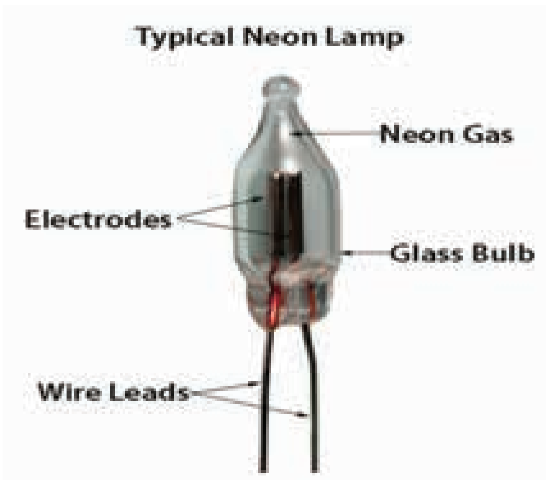
Cold cathode lamps

- Neon lamps
- Neon sign tubes
- Sodium vapour lamp

Hot cathode lamps

- Mercury vapour lamp
- Fluorescent tube

Neon lamp: A neon lamp (neon glow lamp) is a miniature gas discharge lamp. It is cold cathode lamp. The lamp typically consists of a small glass capsule that contains a mixture of neon and other gases at a low pressure and two flat or spiral electrodes (an anode and a cathode). When sufficient voltage is applied the gas become ionized ,and the lamp produces an orange glow discharge in ordinary neon lamp. The filled gas is generally a mixture, of 99.5% neon and 0.5% argon In comparison with incandescent light bulbs, neon lamps have much higher luminous efficiency.

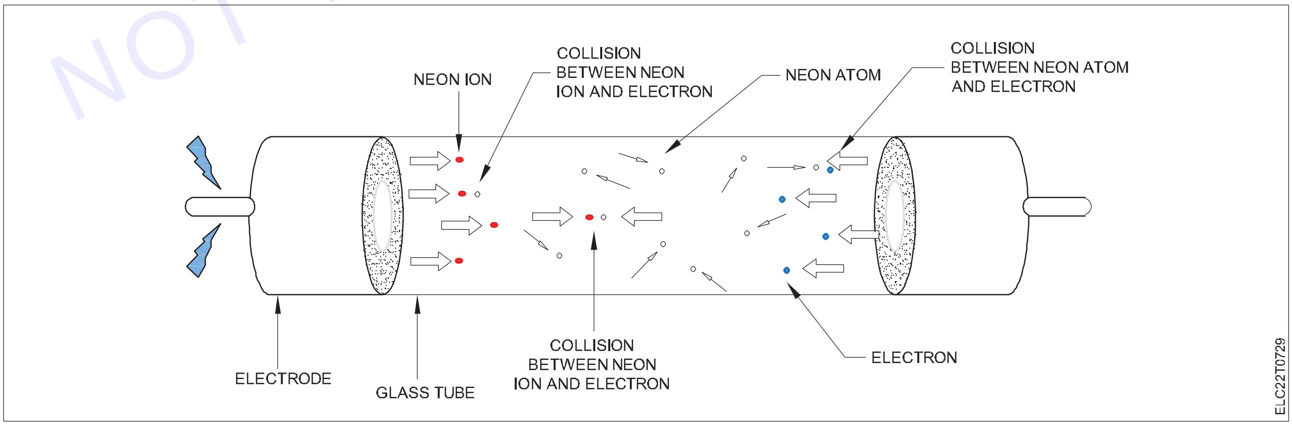


Small neon lamps are most widely used as indicators in electronic equipment and appliances, due to their low power consumption, long life, and ability to operate on mains power. It also can be used as night lamp. Neon indicator lamps are normally orange, and are frequently used with a colored filter over them to improve contrast and change their colour to red or a redder orange, or less often green

Neon sign tube

Neon sign tube is also a cold cathode light. It is a lighting display made of glass tubes that have been filled with different gases at low pressure. These glass tube can be bent into the shape of letters or decorative designs, and are mainly used for advertising and decorative purposes. Electrodes are made of iron or nickel, and arranged at the end of glass tube. The tubes are supplied electric current through a step up transformer. When a high-voltage is given to the tube, a discharge through the gas start, and the tubes emit light. For starting the discharge these tubes require 900 to 1200V /m. Applied voltage depends upon the length of tube. A choke may be connected in series with the primary winding which control the current after discharge takes place. A condenser is connected across the transformer to improve the power factor of the circuit. Different colours are obtained several other gases are also used by filling different gases, along with different tints and phosphorcoatings for the glass tubes.

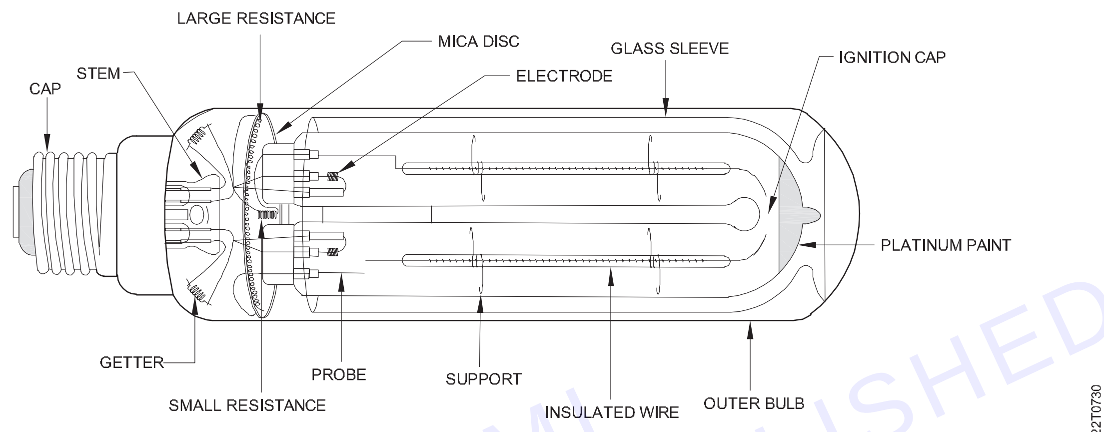
Gas filled	Colour of light
Neon	Red
Neon and argon	Reddish orange
Vapour of mercury	Blue
Neon and helium	Golden colour



Sodium vapour lamp

A sodium vapour lamp is a cold cathode lamp which gives higher luminous output than other lamps. The lamp consists of long glass tube, two oxide coated electrodes are fixed at the ends. This tube contains sodium and neon. To reduce the length of the lamp tube is made of 'U' shaped as shown in figure. This 'U' tube is arranged in double walled glass tube, and vacuum is created between the glass walls.

Initial time sodium is in solid state and hence the lamp cannot be started direct as sodium vapour lamp. When connected to supply it starts as a neon lamp giving reddish light. After 10-15 minutes' sodium turns into vapour and starts working as a sodium vapour lamp and giving yellow light. For starting discharge, high striking voltage is essential and is given by an ignitor.



SODIUM VAPOR LAMP

Mercury vapour lamps

It is a hot cathode discharge lamp. Luminous efficiency oflow Pressure mercury vapour lamp is low as Sodium vapour lamp.So to increase efficiency, medium pressure and high pressure hot cathode mercury vapour lamp are used

Types of high pressure mercury vapour lamp

1 MA Type (MV lamp with auxiliary electrode)

2 MAT type (MV lamp with tungsten filament)

3 MB Type (MV lamp with auxiliary electrode and Bayonet cap)

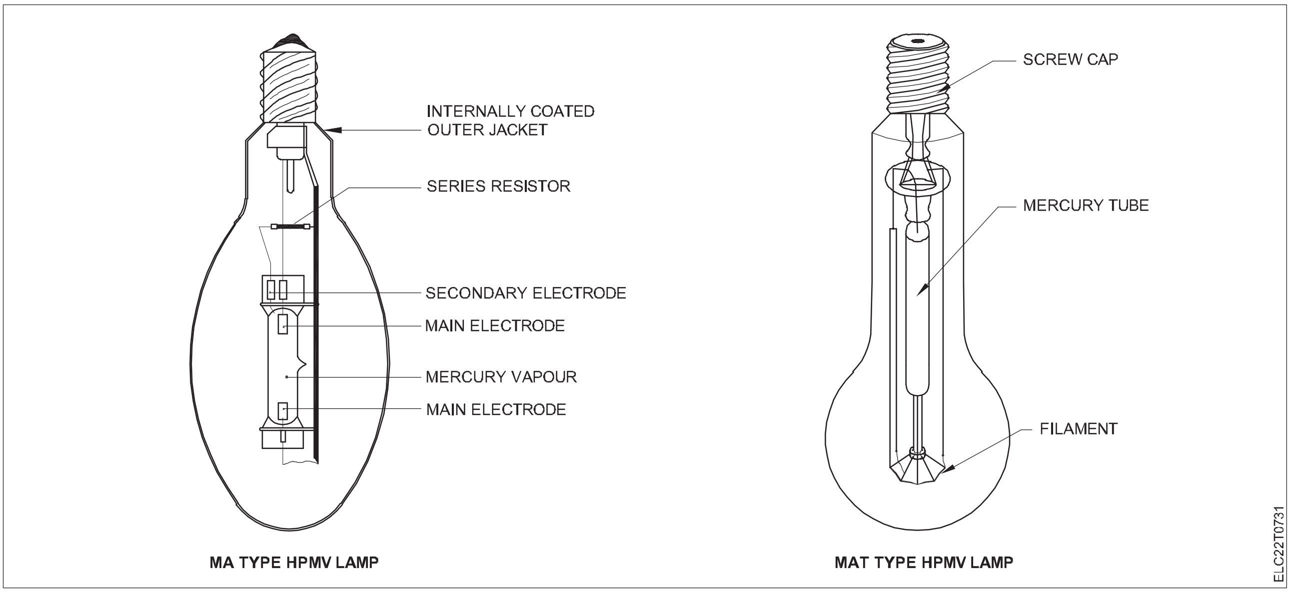
Ma type hpmv lamp

The two main electrodes are enclosed in discharge tube is made of borosilicate, contains mercury and small amount of argon.Argon assist in the starting of discharging.To start discharge, there is an auxiliary electrode is arranged close to the main electrode.The auxiliary electrode is connected to the lamp terminal through high resistor to limits the current.This quartz tube is enclosed in another ordinary glass bulb whose internal surface is coated with fluorescent powder.The space between tube and bulb is evacuated to reduce heat loss.The lamp operates at high pressure. It has a screw cap and is connected to the main through the choke.

When switched ON, normal mains voltage is not sufficient to start the discharge between the main electrode but it can start to flow between main and auxiliary electrode through argon gas. The argon discharge then warms up the tube and vaporise the mercury. The discharge then take place in the mercury vapour.

The lamp takes 5 minute to start giving full output. Once the lamp is switched OFF,will not start again until the pressure developed inside the tube falls back.It takes about 7 minutes to start again.The lamp should always be hung vertically,otherwise the inner tube will be damaged.

The efficiency is 45 lm/watt for 400watts lamp



Mat type HPMV lamp

This is similar to MA type, but outer glass envelope consists of tungsten filament.

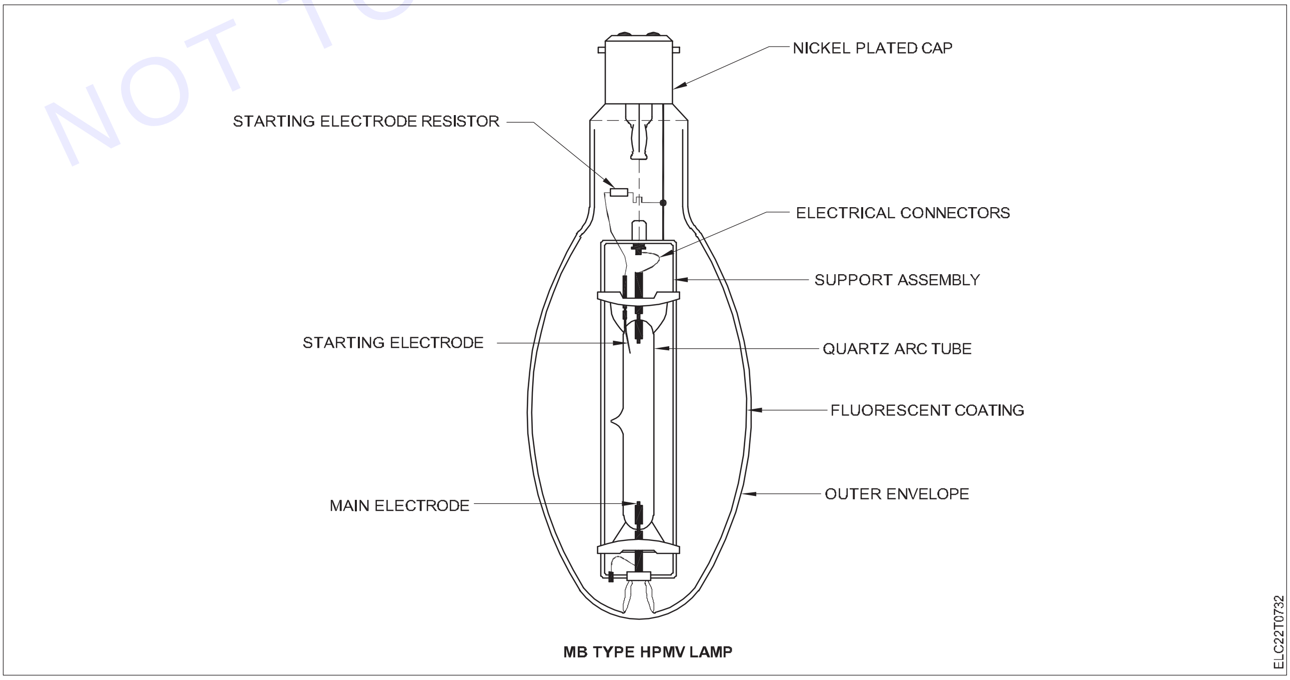
This filament is connected in series with discharge lamp.There no need of external choke and capacitor.

When the lamp is switched ON,it works as filament lamp and its full output is given by the outer tube.At the same time,the discharge tube starts warm up,when a particular temperature is attained,a thermal switch operates.The thermal switch cuts off a part of the filament so that the voltage across the discharge tube increases.

The light output is a mixture of light produced by filament lamp and discharge lamp

Mb type HPMV lamp: The discharge tube of this type is of quartz,about 5cm long and has three electrodes,two main and one auxiliary.This lamp has a 3-pin bayonet cap and it cannot be put in to an ordinary holder as it requires a choke and capacitor.The functioning of the tube is similar to that of a MA type lamp.Since a quartz tube can withstand high temperature,it can be used in any position

The wattage available are80W,125W,250W,400W,700W and 1000W.The efficiency is about 50lm/W



Lighting for decoration - Serial set design - Flasher

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

- state the methods used for decoration
- state the names of flasher and their function.

Use of decoration lights

Electric light decoration for special occasions like wedding parties, festivals and fairs is a common feature nowadays. Special electric light sign circuits add much colour, fun and pleasure on the occasion. Electric signs, particularly neon signs, are extensively used in advertisements which have tremendous eye catching effects. Decoration with electric signs improves the appearance of a building and makes the place more attractive.

Two methods are mainly used for decoration.

- Signs employing miniature low voltage incandescent lights which can be switched on and off in sequence to produce the desired effect.
- Neon signs employing tubes shaped to produce designs in various colours, the colour being determined by the type of gas used in the tube.

Miniature incandescent lamps: Miniature incandescent lamps are normally available with 6V, 9V, 12V & 16V ratings with different colours which may be grouped in series or series parallel combinations for operation in available 240V supply.

For getting different messages and decoration effects the following types of flasher signs are used.

Speller type flashers are used for spelling out signs letter by letter or word by word for building up or down, plain on-off flashing, with changing colour.

Speed type flashers are used for operating spectacular signs such as lighting waving-flags, - flame, revolving wheels etc.

Script type flashers as the name implies are used when the effect of handwriting in script letters is desired.

An example of a speed type flasher for revolving is shown in Fig 1. The speed of running light/ rotating light can be adjusted. In this three-point running light (the sign flasher) there are three groups of lamps, each group switched on and off, in sequence, for running effect (Fig 2) with the help of a small induction motor which is running on eddy current principle and is connected to 240V/115V 50 Hz. Cans or drums are mounted on a shaft which is rotated by the motor.

The circumference of the cans or the drums are so cut that the brushes will make contact only during the fixed portion of the revolution, thus completing the circuit. We can make three independent circuits by the 3-point sign flashers which are switched 'ON' and 'OFF' successively.

Fig 1

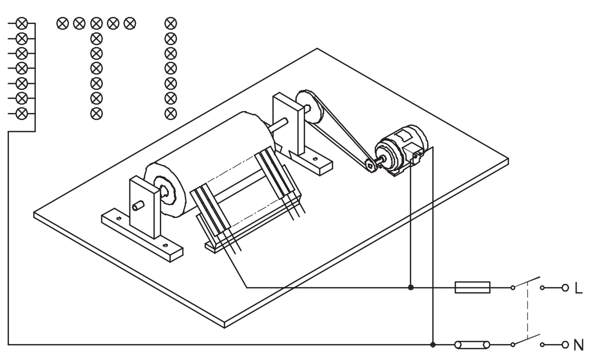
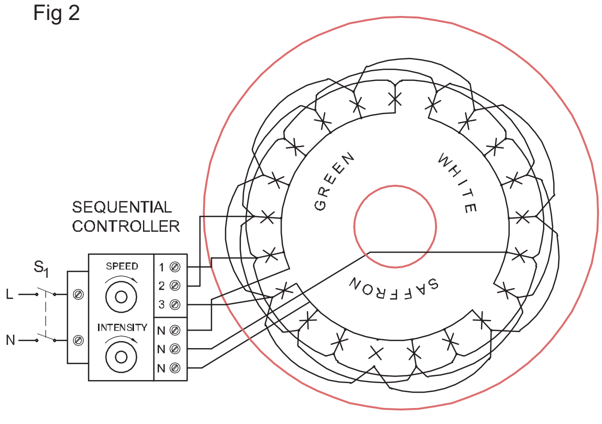


Fig 2



Designing a decorative serial lamp for a given supply voltage

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

- calculate the number of bulbs to be connected in series for a given supply voltage.

Serial set design

We have to design a row of 6 or 9 volts lamps. If these lamps are connected directly to the 240V supply, the lamps will get fused immediately. Therefore the lamps are to be connected in series. The calculation as shown will be -

1 For 6 volts lamps

$$\text{Total No. of lamps required} = \frac{240}{6} = 40 \text{ lamps.}$$

Taking 5% allowance for fluctuations in the supply voltage

$$\text{Total No. of lamps} = 40 + (5\% \text{ of } 40)$$

$$= 40 + 2 = 42 \text{ lamps.}$$

2 For 9 volts lamps

$$\text{Total No. of lamps required} = \frac{240}{6} = 26.6 \text{ or } 27 \text{ lmps.}$$

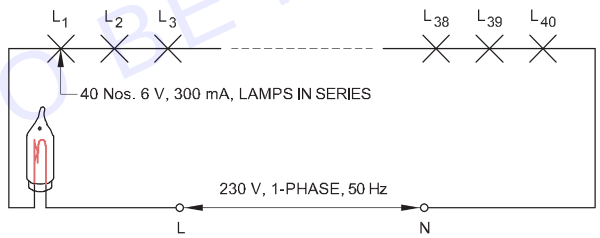
Taking 5% allowance for fluctuations in the supply voltage

$$\text{Total No. of lamps} = 27 + (5\% \text{ of } 27)$$

$$= 27 + 2 = 29 \text{ lamps.}$$

The circuit for a series lamp connection of 6V lamp and supply voltage 240V. (Fig 1)

Fig 1



Precautions

- Never connect the low volt lamps directly to the mains.
- Never touch the exposed wires.

In the above case we discussed for 6V and 9V lamps. In the market we get for 6 volts different current ratings viz. 100mA, 150mA, 300mA, 500mA. The shape of the lamp for the above current ratings however remains the same.

For the series lamps to work satisfactorily the current rating of all the lamps should be the same.

We can prepare serial lamps with different voltages but of the same current rating.

Example

You have 25 lamps of 6V, 300mA rating and 20 numbers of 9V,300mA lamps. How will you design a 'serial lamp' circuit for 240V supply mains

a using all the available 6V lamps and for the rest of 9V lamps.

b using all the available 9V lamps and for the remaining 6V lamps.

Flasher

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

- state the purpose of the flasher in the series lamp circuit.

Flasher: In the row of lamps of low voltage, a small lamp (flasher) of filament type is connected in series with the other lamps. This lamp (flasher) does not give light but acts as a switch for the other lamps. This lamp contains a bimetal strip, which is in contact with a fixed strip (Fig 1).

When the row of lamps is connected across the supply and switched ON, the bimetal strip gets heated up, this breaks the contacts and disconnects supply to the other lamps, making the lamps OFF.

After a few seconds, the bimetal strip cools down and makes contact. The supply to the other lamps is ON and the lamps light up. This is a twinkling type row of lamps used for decoration (Fig 2).

The rating of the flasher in each row of (small) low voltage lamps must be the same as that of the other lamps in that series circuit. If the lamps are of different ratings, then the flasher should be of the lowest current capacity in that circuit.

Though the flasher can be connected anywhere in the series circuit, it should be connected at the supply (phase) considering it as a switch.

The operating condition of the flasher can be decided by observation. If the bimetal strip is found welded to a fixed strip, then the flasher is not useful and if it is in an unserviceable condition. It can also be found out by connecting in circuit and tested for its condition, i.e. whether it is operating or not.

When a number of series lamp rows are connected in parallel the flasher should be connected at the input of supply as shown in Fig 2.

Fig 1

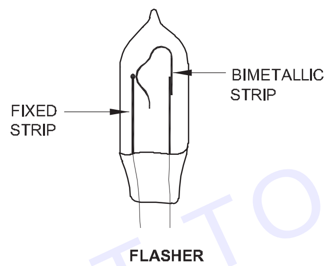
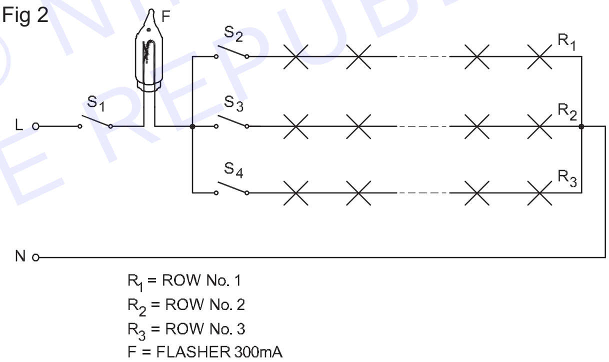


Fig 2



ELC22T0735

Show case lights and fittings - calculation of lumens efficiency

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

- state the types of bulbs for illumination
- explain direct and indirect lighting and showcase lighting
- explain the luminuous efficiency calculation.

Show case lighting: A number of commercial establishments use visual representation to their products, using a lighting system called show case lights. Some of them are discussed below.

Counters and dealing shelves: In bank cages and ticket offices supplementary trough lighting equipment is usually located at the top of the cages to produce a band of light lengthwise on the counter. Troughs may be covered with diffusing glass or fitted with longitudinal louvers to shield the lamps. Sixty watt lamps on 15 to 18 inch centres will generally be adequate. (Fig 1)

Small metal bracket type reflectors luminary or regular 25 or 40 watt tubular lamps effectively illuminate small vertical display racks, stands and cabinets. (Fig 2)

Fig 1

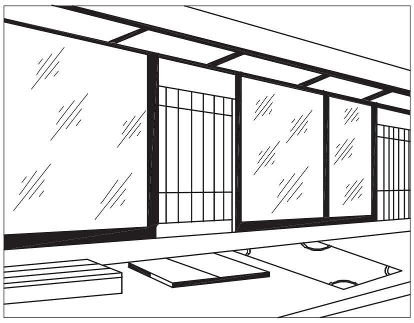


Fig 2

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Small compact lens posts available in both 250 and 400 watt size, mounted on columns or ceiling brackets, give sales emphasis to small counter or table displays. Adjustable in spot size for 12 to 48 inches diameter spot at 10 ft. a 250 watt unit at 10 ft. will deliver 200 to 250 feet candles, with a 12 to 15 inches spot size: the 400 watt unit will give 350 to 400 foot candles. (Fig 3)

For extended vertical surface displays - rungs, tapestries, draperies, paintings - a series of 150 or 200 watt lens plate units at the ceiling is suitable for fixed display locations. Bracket type parabolic, polished metal troughs produce equivalent results and have some advantage in greater mobility. (Fig 4)

Fig 3

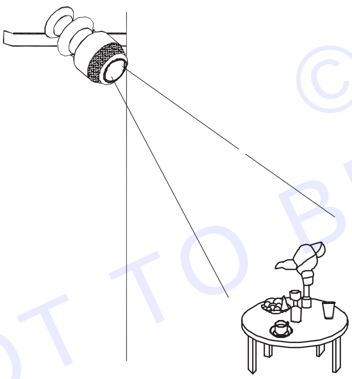
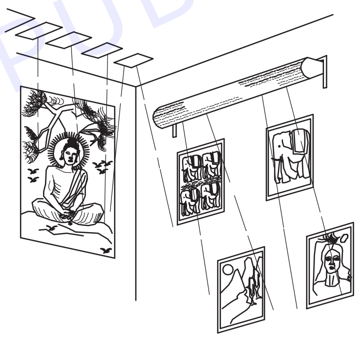


Fig 4



ELC22T0737

For necessity and impulse items such as groceries, where attention rather than critical seeing is the requirement, less engineering refinement is needed in shelf lighting equipment. Concentrating trough reflectors which incorporate luminous panels for changeable advertising copy are satisfactory. Sockets 30 cms apart may be fitted with 40 to 100 watt lamps, as conditions dictate. (Fig 5)

For lighting displays on columns or built-in shelving a metal nosing along the front edge of each shelf effectively conceals small 25 watt tubular lamps as shown in the sketch. Lamps should be spaced not more than 30 cms apart. Lumiline lamps are, of course, equally suitable in many cases.

Displays of glassware and bottled goods are highly attractive and colourful if lighted by transmitted light as shown in Fig 5. An opal glass panel, illuminated uniformly from behind the lamps spaced not more than 1½ times their distance at the back of the glass will provide a suitable luminous background.

Circline tubes used for window show case: For circline tubes the ballasts are specially designed and are easily adaptable to assembly on the stem of portable lamps and in shallow wall and ceiling fixtures, and in some designs they can be mounted within the circle of the tube.

Fig 5

ELC22T0738

Ballast equipments designed for use with the 8¼ inch 22 watt, 12-inch 32 watts. circle line include two single lamp ballasts, one with uncorrected power factor. The other with high power factor. Many of the portable lighting equipments - dressing table, desk lamp, vanity mirror, tie rack, display unit and boudoir lamps such as Fig 6 and 7 - in which the 8¼ inch circline will be used which have small thin bases and slender stems.

There are varieties of goods which are being displayed in showcases of different colours, size, shape, fineness etc. Hence Different shades and colour layers will be used to get the proper colour of goods or fineness of detail or both by proper illumination.

Precaution should be taken while putting the merchandise in showcases so that wiring will not be damaged. Also the wiring and merchandise should not get damaged due to the excessive heat of lamps.

Luminous Efficiency Calculation

Luminous Efficiency: Luminous efficiency is a measure of how will a light source produces a visible light. It is a quantity of measurement for light source and it is defined as the ratio of luminous flux to power of the lamp in watts. It's unit is lumen/watt in SI unit.

$$\text{Luminous efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

This is important, it describes how much light is being given compare to the amount of electricity is used.

Purpose of calculating luminous efficiency

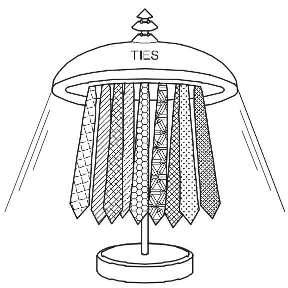
Typical house hold spends 30% of the electricity bill in lighting. Money can be saved by bringing the most cost efficient lighting option in home needs.

For example: A 60w light bulb usually produces 860 lumens. Calculate the luminous efficiency.

$$\text{So, efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

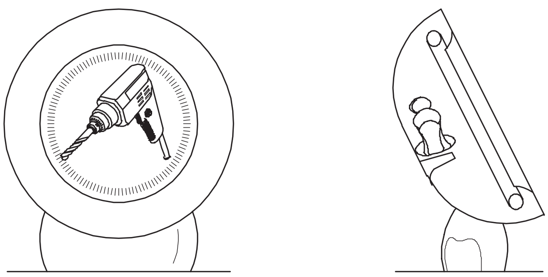
$$= \frac{860}{60} = 14.3 \text{ lumen/watt}$$

Fig 6



TIE RACK

Fig 7



DISPLAY UNIT

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