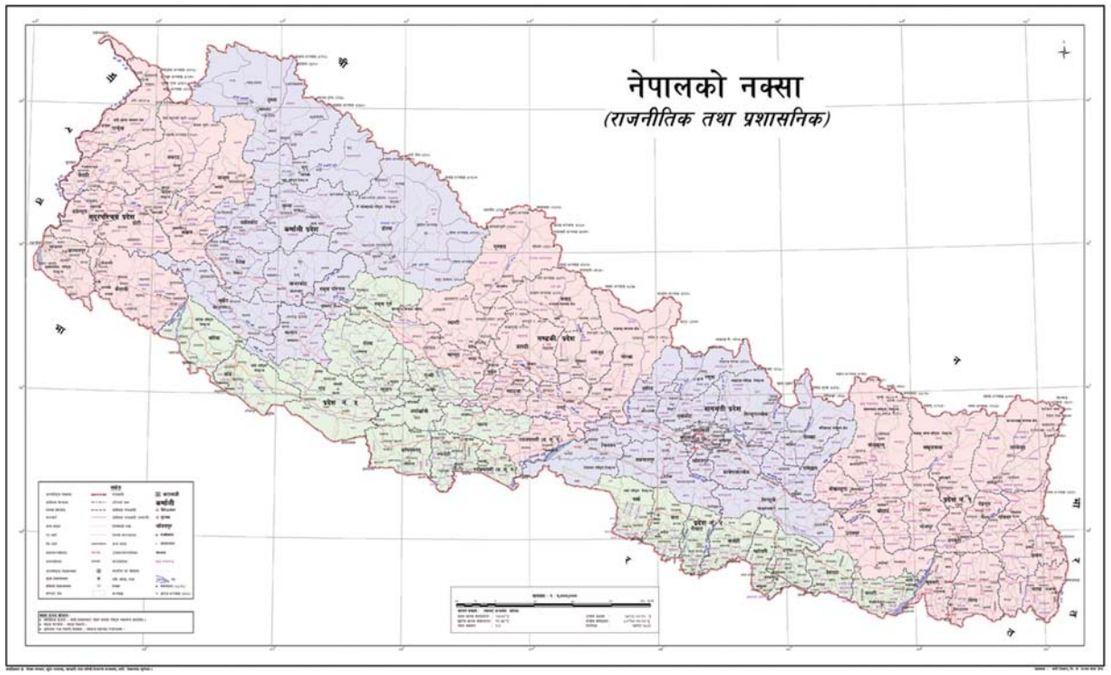

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Electrical Engineering

Industrial Installation and Maintenance

10

Feedback Copy

Technical and Vocational Stream
Learning Resource Material

Industrial Installation & Maintenance
(Grade 10)

Secondary Level
Electrical Engineering

Government of Nepal
Ministry of Education, Science and Technology
Curriculum Development Centre
Sanothimi, Bhaktapur

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Preface

The curriculum and curricular materials have been developed and revised on a regular basis with the aim of making education objective-oriented, practical, relevant and job oriented. It is necessary to instill the feelings of nationalism, national integrity and democratic spirit in students and equip them with morality, discipline and self-reliance, creativity and thoughtfulness. It is essential to develop in them the linguistic and mathematical skills, knowledge of science, information and communication technology, environment, health and population and life skills. it is also necessary to bring in them the feeling of preserving and promoting arts and aesthetics, humanistic norms, values and ideals. It has become the need of the present time to make them aware of respect for ethnicity, gender, disabilities, languages, religions, cultures, regional diversity, human rights and social values so as to make them capable of playing the role of responsible citizens with applied technical and vocational knowledge and skills. This Learning Resource Material for Electrical Engineering has been developed in line with the Secondary Level Electrical Engineering Curriculum with an aim to facilitate the students in their study and learning on the subject by incorporating the recommendations and feedback obtained from various schools, workshops and seminars, interaction programs attended by teachers, students and parents.

In bringing out the learning resource material in this form, the contribution of the Director General of CDC Dr. Lekhnath Poudel, Pro.Dr. Indraman Tamrakar, Dipak Shrestha, Akhileshwar Mishra, Shivaram Shrestha, Jagdishraj Ghimire, Harisharan Kafle, Nabin Adhikari is highly acknowledged. The book is written by Sanju Shrestha and the subject matter of the book was edited by Badrinath Timalsina and Khilanath Dhamala. CDC extends sincere thanks to all those who have contributed in developing this book in this form.

This book is a supplimentary learning resource material for students and teachrs. In addition they have to make use of other relevnt materials to ensure all the learning outcomes set in the curriculum. The teachers, students and all other stakeholders are expected to make constructive comments and suggestions to make it a more useful learning resource material.

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Table of Contents

UNIT - 1
Power Supply Unit

1. Objectives

This chapter mainly focuses on the constructional details, operating principle and applications of DC power supply unit. The main objectives of this unit are as follows:

- **To visualize each parts of a DC power supply unit**
- **To analyse the working of all types of rectifier**
- **To design and fabricate a DC power supply unit of required capacity**

2. Learning Materials

- **Electrical components like transformer, diodes, resistors, capacitors, zener diodes etc.**
- **A DC power supply**

3. Course Contents

Power Supply

Power supply is an electrical device that supplies electrical power to electrical load. All power supplies have a power input connection, which receives energy in the form of electric current from a source, and one or more power output connections that deliver current to the load. Power supply is broadly classified into two types:

a) DC Power Supply
b) AC Power Supply

a) DC Power Supply

A DC power supply is one that supplies a constant DC voltage to its load. Depending on its design, a DC power supply may be powered from a DC source or from an AC source.

b) AC Power Supply

An AC power supply is the one that takes supply from the AC source and steps up or steps down the voltage to the desired value.

Fig:-AC Power Supply **Fig:- DC Power Supply**

Simple DC Power Supply Unit

A DC Power Supply Unit deriving power from the AC mains (line) supply performs the following tasks:-

1. It changes (in most cases reduces) the level of supply to a value suitable for driving the load circuit.
2. It produces a DC supply from a pure AC wave.
3. It prevents any AC from appearing at the supply output.
4. It will ensure that the output voltage is kept at a constant level, independent of changes in:
   a. The AC supply voltage at the supply input.
   b. The Load current drawn from the supply output.
   c. Temperature.

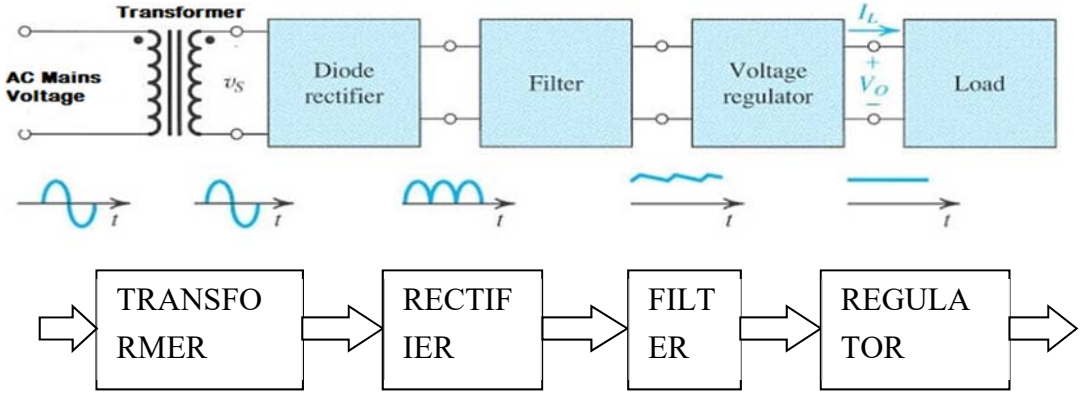

Fig:- Block diagram of a power supply

In order to achieve these functions, the main units of the DC Power Supply Unit are as follows:-

- **Transformer**

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. The transformer may be step up transformer or step down transformer. The step-down transformer reduces the AC voltage from high to low whereas the step-up transformer increases the AC voltage from low to high.

Fig:-230/12 Volts Transformer

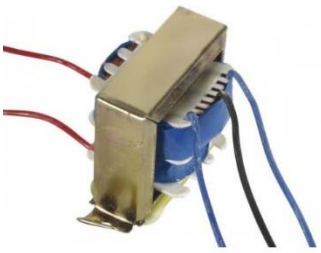

Fig:- Center tapped Transformer

- **Rectification unit**

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process of conversion from AC to DC is known as rectification. Diodes are involved in rectification unit.

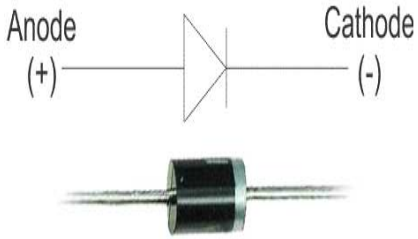

Fig:- Bridge type Rectifier

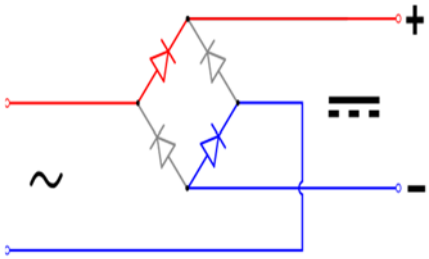

Fig:- PN Junction Diode

- **Filtering Unit**

The filter of filtering unit converts the pulsating direct current into pure direct current. The ripples from the output of a rectifier are removed with the help of a filter. A capacitor or an inductor is used as a filter to convert the pulsating DC to pure DC.

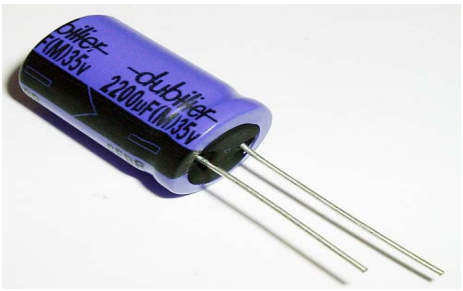

Fig:- Electrolytic capacitor

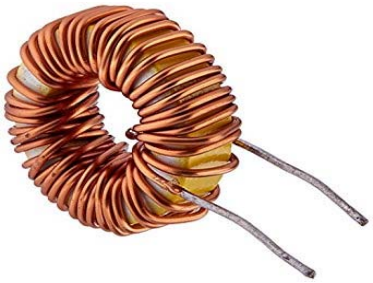

Fig:- Inductor

- **Regulation unit**

The regulator of regulation unit maintains constant DC voltage irrespective of the change in output current or input voltage. Zener diode is used as a regulator in DC power supply.

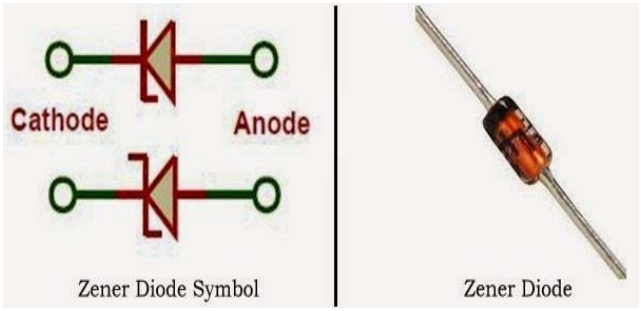

Fig:- Zener diode

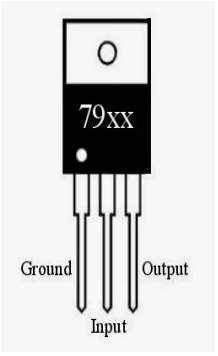

Fig:- Voltage Regulating IC

Rectification System

The rectification system can be done in two ways:-

- Half wave rectification
- Full wave rectification
- Half wave rectification

In half-wave rectification, either the positive or negative half of the AC wave is passed while the other half is blocked. Half-wave rectification requires a single diode in a single-phase supply. This action can be achieved by using a half wave rectifier.

The half wave rectifier is a type of rectifier which converts half of the AC input signal (positive half cycle) into pulsating DC output signal and the remaining half signal (negative half cycle) is blocked or lost.

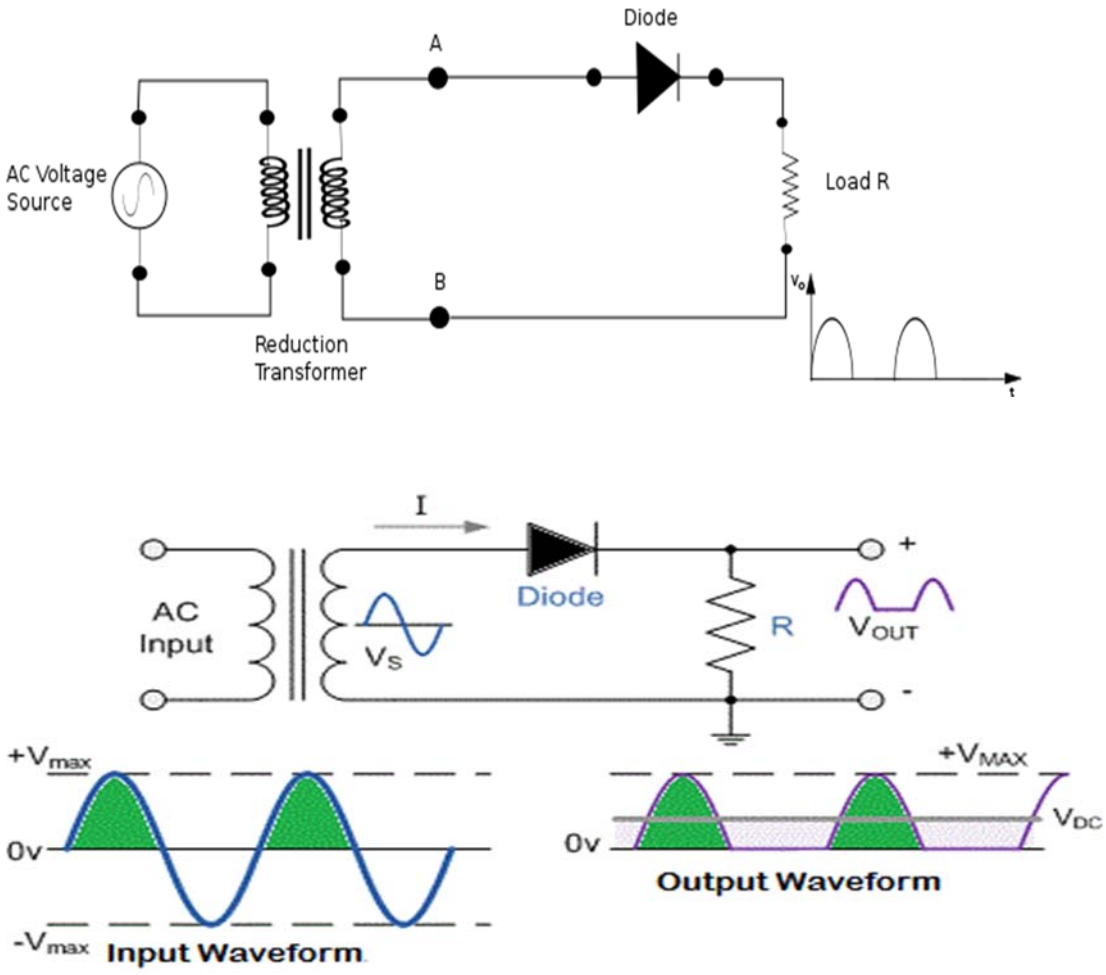

Fig: Half Wave Rectification

- **Full wave rectification**

Full-wave rectification converts both polarities(positive and negative) of the input waveform to pulsating DC (direct current). Two diodes and a center tapped transformer, or four diodes in a bridge configuration and any AC source (including a transformer without center tap), are needed for full wave rectification. This action can be achieved by using a full wave rectifier.

A full-wave bridge rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. It is a type of rectifier which converts the full AC input signal (positive half cycle and negative half cycle) to pulsating DC output signal. Unlike the half wave rectifier, the input signal is not wasted in full wave rectifier. There are two types of full wave rectifier:-

- Center tapped type full wave rectifier
- Bridge type Full wave rectifier

Center tapped type full wave rectifier

The center-tapped full-wave rectifier circuit uses two diodes D_1 and D_2 which are connected to the center-tapped secondary winding of the transformer. The center-tapped on the secondary is taken at zero voltage reference point. If the secondary voltage is V_2 then the voltage between one end of secondary and center tapped is equal to $V_2/2$.

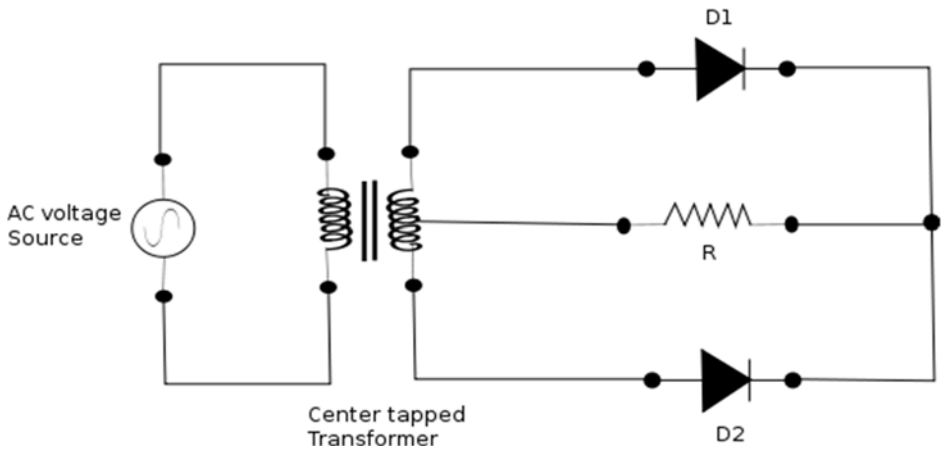

Fig:- Construction of a Center Tapped Full wave rectifier

Working:

During positive half cycle, diode D_1 is forward biased whereas diode D_2 is reverse biased. Hence, diode D_1 only conducts but diode D_2 does not for positive half cycle. Thus, current I flows through the load resister R.

During negative half cycle, diode D_2 is forward biased whereas diode D_1 is reverse biased. Hence diode D_2 only conducts but diode D_1 does not for negative half cycle. Thus, current I flows through the load resistor R in the direction same as above.

It is clear that one diode conducts for positive half cycle and another diode conducts for negative half cycle. Hence, an unidirectional current flows continuously in a full wave rectifier.

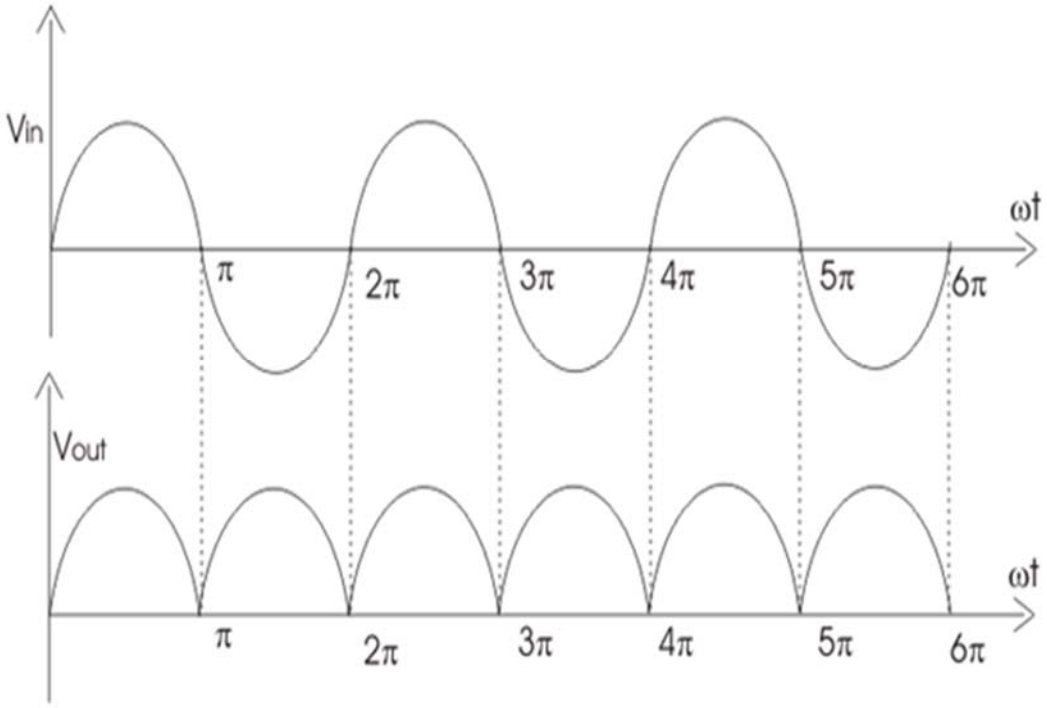

Fig: Input and output waveforms of a center tapped full wave rectifier

Bridge type Full wave rectifier

The full wave bridge rectifier uses four diodes arranged in a bridge circuit which are connected across the secondary of a transformer. This circuit gives full wave rectification without the need of a centre-tapped transformer.

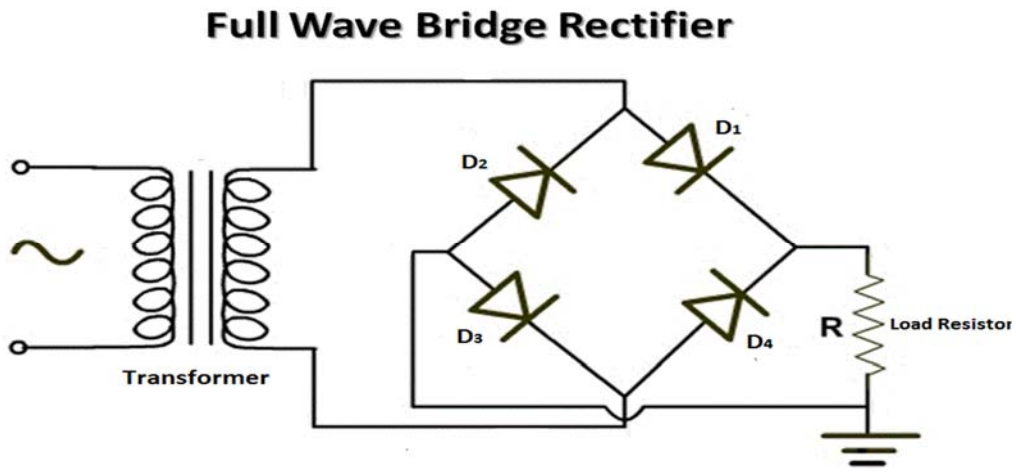

Fig:- Construction of a bridge type full wave rectifier

Working:-

During positive half cycle, the diodes D_1 and D_3 are forward biased whereas diodes D_2 and D_4 are reverse biased. Hence diodes D_1 and D_3 only conduct but diodes D_2 and D_4 do not. Thus, the current will flow through diode D_1, load resistor R and diode D_3.

During negative half cycle, the diodes D_2 and D_4 are forward biased whereas diodes D_1 and D_3 are reverse biased. Hence diodes D_2 and D_4 only conduct but diodes D_1 and D_3 do not. Thus, the current will flow through diode D_4, load resistor R and diode D_2.

It is clear that the output voltage is unidirectional across the load continuously in a bridge type full wave rectifier. The input and output voltage waveform for a bridge type full wave rectifier is shown below:-

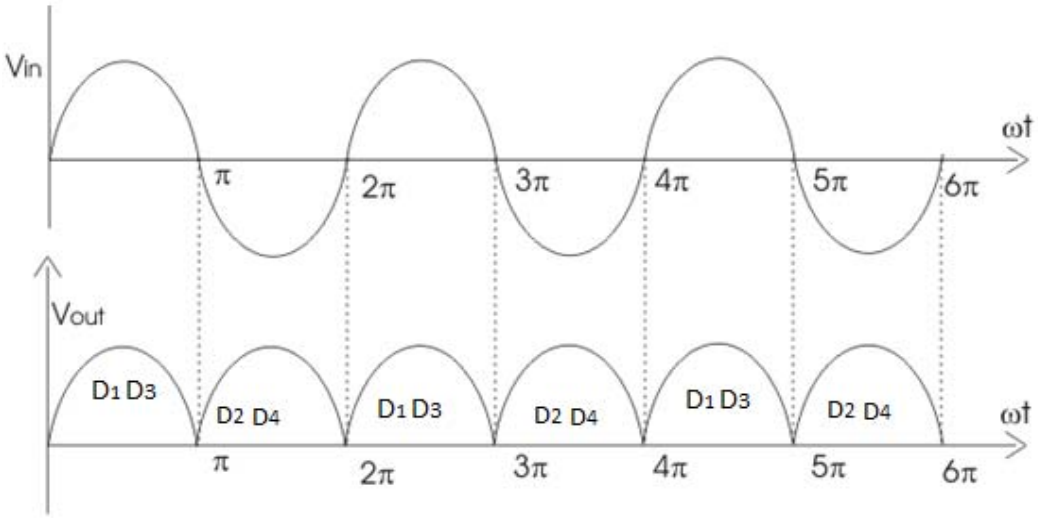

Fig: Input and Output Waveforms of Bridge Type full wave Rectifier

4. Assessment

Very Short Answer Questions

1) What do you mean by power supply?
2) What are the main components of a power supply?
3) Which component is used in rectification?
4) Which component is used as filter?
5) How many diode/s are there in half wave rectifier?
6) What do you mean by center tapped transformer?

Short Answer Questions

1) What do you understand by half wave rectification?
2) What is a rectifier? Which component is used to convert AC into DC?
3) Draw the output waveform of full wave rectifier with proper labelling when pure sine wave is given input.
4) Define voltage regulation. Why filter is necessary in a power supply?

Long Answer Questions

1) List out the main parts of a DC power supply unit. Explain each of them in detail.
2) Explain the construction and working of a half wave rectifier.

3) Explain the construction and working of a center tapped full wave rectifier.
4) Explain the construction and working of a bridge type full wave rectifier.

Glossary

Fabricate: put together/ construct

Tapping: Tapping of a transformer means the connection point along the transformer winding to select the suitable number of turns.

Waveform: A graphical representation which shows the changes in amplitude over a certain amount of time.

AC Mains: Alternating Current power supply delivered to homes and offices for general purpose

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UNIT - 2
Inspection and Testing of Installations

1. Objectives:

The main objectives of this unit are as follows:-

- To explain the concept of inspection and testing of new or existing wiring installation
- To differentiate the different methods of testing of wiring installations
- To use the different types of instruments required for wiring installations
- To be able to perform testing using the required electrical instrument

2. Learning Materials:

- Hand driven or battery operated Megger
- Earth Resistance Tester
- Neon Tube Tester
- Lamp Tester
- Phase Tester

3. Course Contents

Inspection of Installations

Inspection should be carried out by competent personnel at new installations. General workmanship, finishing, neatness, tightness of terminations, settings of protective devices etc should be checked/ inspected. The lighting circuits shall be checked whether:

- proper connectors and junction boxes are used wherever joints are to be made in conductors or crossovers of conductors take place
- The polarity is checked and all fuses and single pole switches are connected on the phase conductor only
- spare knockouts provided in distribution boards
- proper terminal connectors are used for termination of wires(conductors and earth leads) and all strands are inserted in the terminals

- a separate earth wire run in the lighting installation to provide earthing for fixtures, equipments and plug points
- The fittings and fixtures used for outdoor use are all of weather proof construction.

Internal wiring should be inspected annually. The following points should checked while carrying out inspection of the wiring installation:

1. Service Connections (In case of Overhead line)

- The SP MCB or fuse wire of correct rating is provided on the phase line
- The lead in wires are of sufficient size to carry the full load current
- The lead in pipe is properly earthed

2. Main Switch Board

- The voltage available is correct (i.e. within permissible limits of declared voltage).
- The main switch is provided close to the point of incoming supply.
- The fuse of correct size is provided on the live pole.
- The main switch is easily accessible so that in case of emergency, the entire supply to the building can be switched off at once.
- The phase and neutral wires are clearly marked for identification.

Testing of Wiring Installations

The tests to be performed before a new installation or an additional installation are as follows:-

- Insulation Resistance Test between conductors
- Insulation Resistance Test between the Wiring and Earth
- Polarity test of switches
- Earth Continuity Test

Insulation Resistance Test between the Wiring and Earth

The test performed to know whether the cables or wires used in the wiring system are sufficiently insulated to avoid leakage of current is called Insulation Resistance Test between the Wiring and Earth. The values of insulation resistance are measured in terms of Mega ohms(MΩ).

Insulation Resistance Tester, also known as Megger, having working voltage of not more than 500V DC is used to test the insulation resistance. Before making an insulation test, following things should be taken into consideration:-

i. Main switch is in OFF position.
ii. Main fuse has to be taken out or main MCB has to be made in OFF position.
iii. All other fuses are in position.
iv. All the switches are in ON position.
v. All the lamps are in their positions or the lamp holders are short circuited
vi. Line and neutral terminals are shorted on the installation side.

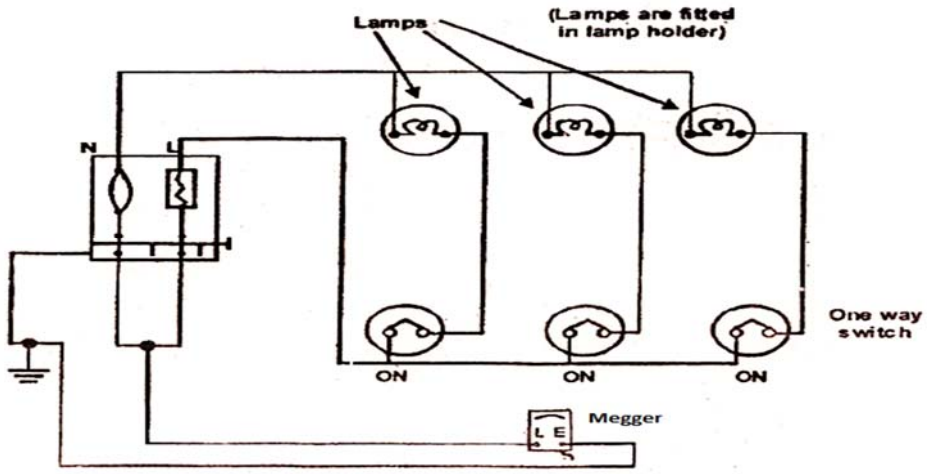


Fig:- Insulation Test between Conductor and Earth

Procedure:-

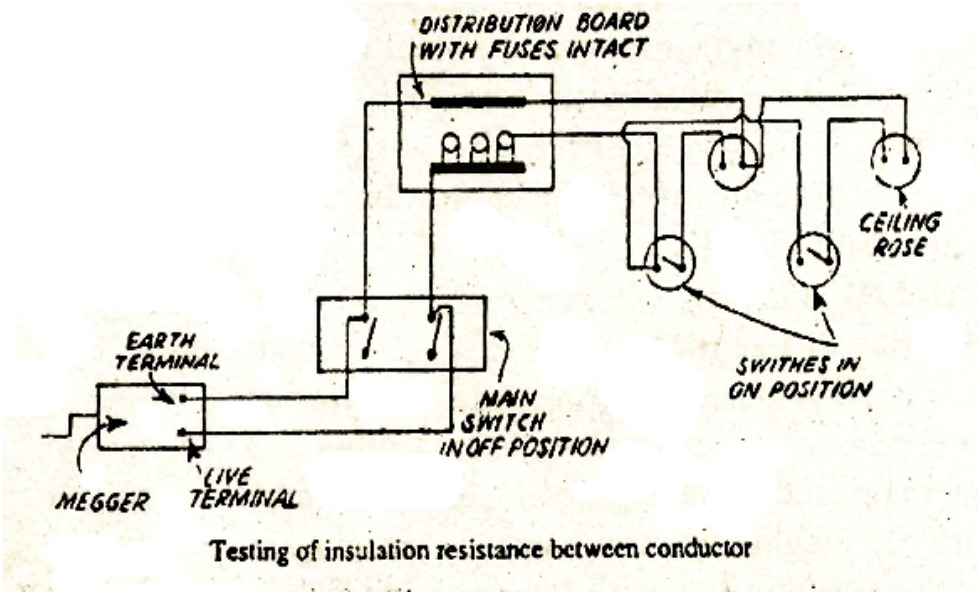
The line terminal of the megger is connected to the point where the conductors have been shorted at the main switch and the earth terminal is connected to the earth. The handle of the megger is then rotated if it is analog hand driven megger. Then the readings are noted. The measured insulation resistance should not be less than 50 MegaOhms(MΩ) divided by the number of outlets. If the ration is 1MΩ is more than unity, insulation resistance is considered sufficient but the insulation resistance should not be less than 0.5 MΩ. If the reading is zero, it means that there is short circuit in wiring which should be removed.

Insulation Resistance Test between the conductors

This test is conducted to ensure that the insulation between the conductors is sound so that there may not be appreciable leakage between them. In this test, megger is used to find out the insulation resistance between the conductors.

Before making an insulation test, following things should be taken into consideration:-

i. Main switch is in OFF position.
ii. Main fuse has to be taken out or main MCB has to be made in OFF position.
iii. All other fuses are in position.
iv. All the switches are in ON position.
v. All the lamps and all metallic connections between the two wires of the installation are removed from the lamp holders.
vi. In this case, all the things to be considered are same as above except the loop at the main switch is removed and the all the lamps and all metallic connections are removed from the lamp holders.



Testing of insulation resistance between conductor

Procedure:-

The terminals of the megger are connected to the two poles or lines of the installation and insulation resistance is measured between two conductors(i.e phase and neutral). The insulation resistance so measured should not be less than 0.5 MΩ and need not be more than 1MΩ.

Polarity test of single pole switches

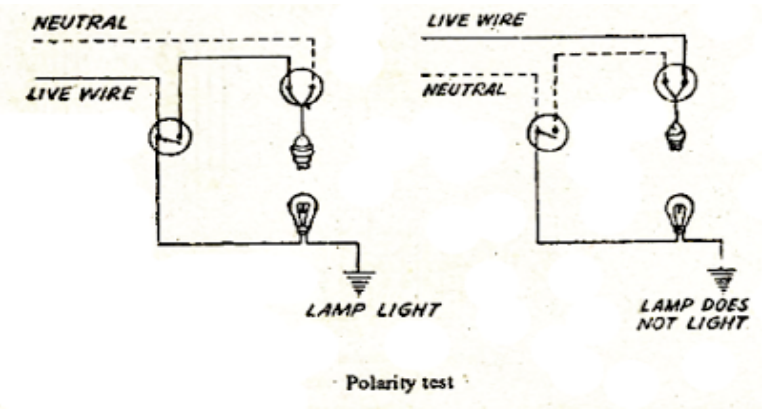
This test is performed to ensure that all the switches are placed in phase or live conductors and not in neutral conductor. It is necessary that single pole switches are placed in live wire so that the lamp can be made quite dead when switched off. If switch is provided on neutral wire, the wiring will remain alive even when the single pole switch is turned off. The person who is working with this circuit might get injured when replacing the lamps if s/he comes in contact with the line terminal of the lamp holder. Hence single pole switches should be kept in live wire, never in neutral wire.

There are two methods of testing of polarity of single pole switches which are as follows:-

- Using test lamp
- Using neon tube tester

Using Test Lamp

In this method, all the lamps are removed, main switch is put in ON position and main fuse is inserted. Then, one end of test lamp is connected to Earth and the other end is tapped to each contact of each switch in turn. If the test lamp lights on one of the two contacts, it indicates that switch is on the live wire. If the test lamp doesn't give light on either contact of the switch, it indicates that the switch is on neutral wire.



Polarity test

Using neon tube tester

While performing polarity test by means of neon tube tester, one terminal of it is held in the hand and the other against the feed terminal of the switch. If the switch is in live wire, the neon lamp will glow otherwise not.

Earth Continuity Test

This test is carried out to check that the resistance of the earth continuity conductor between its connection to the earth electrode and any other metal pieces in the installations does not exceed 1Ω. In a properly designed wiring system, there are number of earth points located different positions throughout the wiring. For example each plug socket will have a third earthing point. The metallic body of each electrical appliance is connected to the earth through an earth points. This test ensures the continuity between an earth point and the actual earth.

In this test, main switch should be opened, main fuse withdrawn, all other switches in ON position and lamps in their respective holders. One terminal of Earth Resistance tester is connected to the earth point whose continuity is to be checked and other terminal of the tester is connected to the main earthing system of the building. The pointer of earth continuity tester will give the resistive value between the said earth point and actual earth. In any case, the value must not be greater than 1 ohm. If it is greater than 1 ohm, then the earthing connection should be physically rechecked and properly rectified to achieve desired minimum earth resistance.

Earth Resistance Test

This test is carried out to check that the earth resistance is within permissible limits. The permissible earth resistance of domestic purpose is 5Ω. Earth resistance is checked by using an instrument called Earth Resistance Tester.

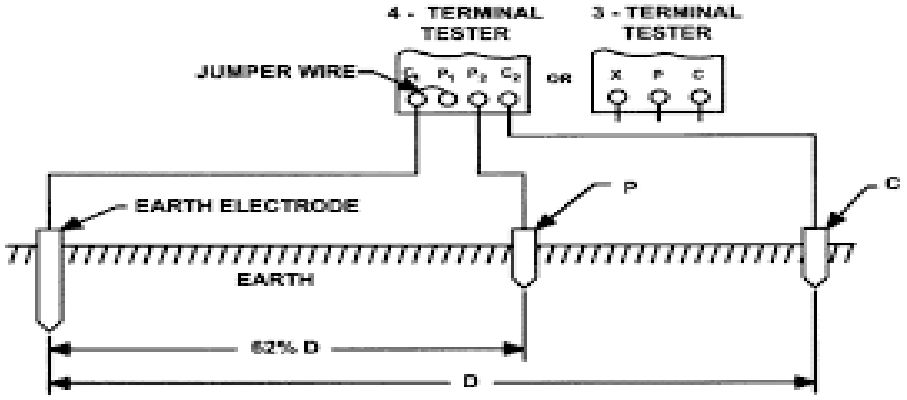


Fig:- Measurement of Earth Resistance by using Earth Tester

4. Assessment

Very Short Answer Questions

1) Define insulation resistance tester or megger.
2) Which instrument is used to measure high resistance?
3) Why insulation test is conducted?
4) What does the reading of megger while conducting test being zero indicate?
5) What is polarity test?
6) Why is insulation test between conductor and earth conducted?

Short Answer Questions

1. Write any four points of main switch board that should be checked in wiring installation.
2. How is polarity test of single pole switch in wiring installation conducted?
3. How can we perform test between conductors using megger?
4. What does the reading of megger zero and infinity represent?

Long Answer Questions

1) Explain the different tests to be performed before a new or an additional wiring installations.
2) Explain in detail about insulation test between conductors.
3) Explain in detail about insulation test between conductor and earth.

Glossary

Inspection: A formal or official examination

Competent: Qualified or skilled

Personnel: Staff

Workmanship: Skilled in a particular occupation

Terminations: The end points of a wire/conductor

Spare: Extra; keeping something in reserve etc.

References

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UNIT - 3
Earthing

1. Objectives

The main objectives of this unit are as follows:-

- To understand the concept of Earthing
- To differentiate different methods of earthing
- To understand the construction and working of an Earth Tester
- To have the basic concept of substation earthing

2. Learning Materials

1) Copper and GI Earth Electrodes (Plate, Pipe, Rod, Strip etc)
2) Earth Resistance Tester

3. Course Contents

Concept of Earthing

Earthing or Grounding is the term used for electrical connection to general mass of the earth. It can be defined as the connection of the non current carrying parts of the electrical equipments or the neutral point of the supply system to the general mass of the earth. In earthing, the metallic parts of an electrical installation such as metallic casing, stay wire, end terminals of cable armour etc. that do not carry current are connected to an earth electrode or conductor buried in moist earth using a thick metal conductor of low resistance for safety.

Earthing is provided with the following objectives:-

- For the safety of the personnel from electric shock
- For the safety of equipment and personnel from against lighting and voltage surges
- For providing the ground connection for grounded neutral systems

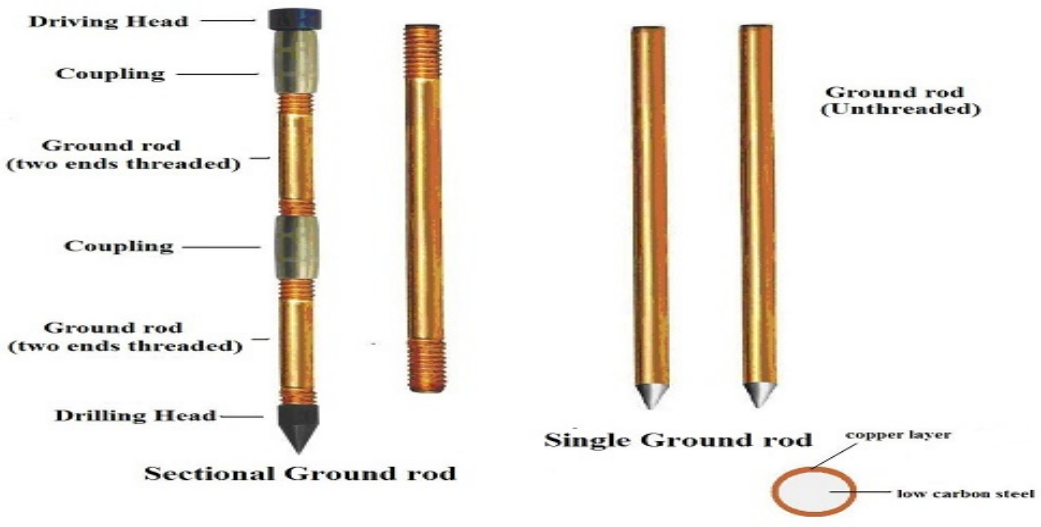
The earthing can be divided into neutral (system) and equipment earthing. Neutral earthing deals with earthing of the system neutral to ensure system security and protection. In neutral earthing, the neutral points of star connected 3-phase windings

of power transformers, generators, motors, etc are connected to low resistance earth. Equipment earthing deals with earthing of non-current carrying parts of the equipment to ensure safety of personnel and protection against lighting.

The conductor (or conductive plate) buried in the earth for electrical earthing system is known as Earth Electrode. Earth electrodes are in different shapes like, conductive plate, conductive rod, metal water pipe or any other conductor with low resistance. On the basis of use of earth electrode, methods of earthing can be classified into the following types:-

- Rod earthing
- Pipe earthing
- Plate earthing

Rod Earthing: - In this system of earthing, 12.5 mm diameter solid rod of copper or 16 mm diameter solid rod of galvanized iron or steel; or hollow section 25 mm GI pipes of length not less than 2.5 meters are driven vertically into the earth. In order to increase the length of electrodes under the ground, which is sometimes necessary to reduce the earth resistance to desired value, more than one rod sections are hammered on above the other. This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap as no excavation work is involved.



Pipe earthing:- In this system of earthing, a galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil. The size of pipe to use depends on the magnitude of current and the type of soil. The dimension of the pipe is usually 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil.

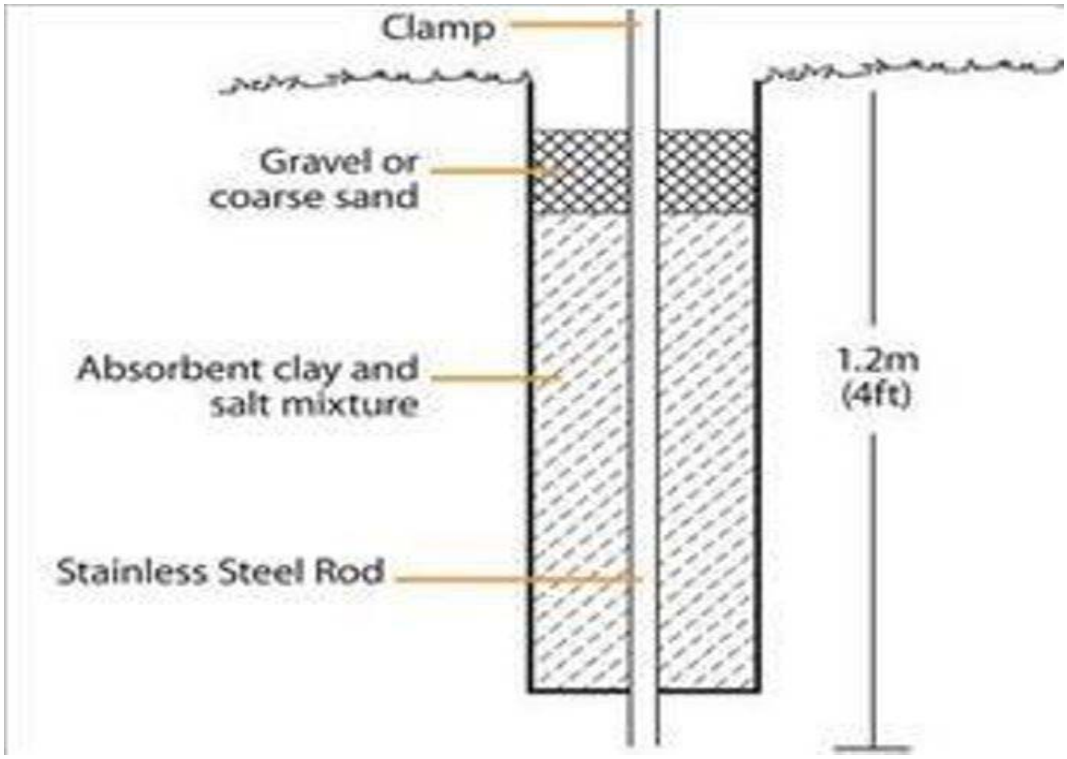


Fig: Pipe Earthing

Plate Earthing:- In this method of earthing, plate electrodes made of either copper or Galvanized Iron(GI) or steel is used. The plate made up of either copper with dimensions 60cm x 60cm x 3.18mm (i.e. 2ft x 2ft x 1/8 in) or GI or steel of dimensions 60cm x 60cm x 6.35 mm (2ft x 2ft x ¼ in) is buried vertical in the earth (earth pit) which should not be less than 3m (10ft) from the ground level. The moisture condition around the earth electrode or earth plate is to be maintained properly in order to reduce the earth resistance. Hence the earth plate is embedded in alternate layers of charcoal and salt for a minimum thickness of 15 cm. The earth wire (G I wire for G I plate

earthing and copper wire for copper plate earthing) is securely bolted to an earth plate with the help of a bolt, nut and washer made of material of that of earth plate (made of copper in case of copper plate earthing and of galvanized iron in case of G I plate earthing).

If the resistance of one plate electrode is not satisfactory, two or more plates may be used in parallel with a minimum distance of 8 meters between the two plates.

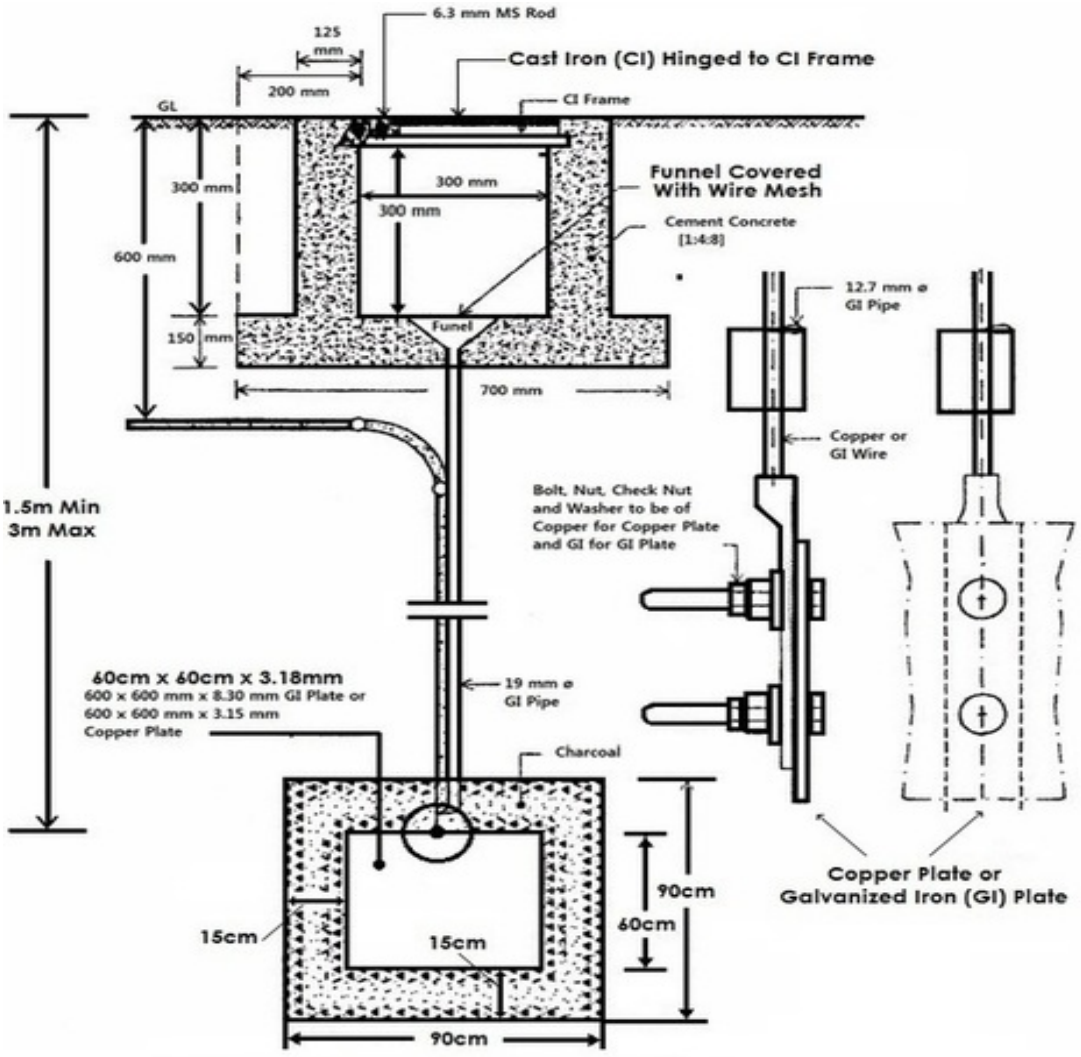


Plate Earthing

Earthing materials

1. Conventional Earthing Materials include:

- Earth Electrode(Copper Plates or G.I. Plates, Copper Strips or G.I. Strips, Copper Rod or G.I. Rod)
- Earth Lead
- Earth Continuity Conductor
- Salt, Charcoal etc.

2. Modern Earthing materials include:

- Gel Earthing Electrodes, Copper Bonded Earthing Electrodes etc.
- Auxiliary materials:- Funnel, Lighting Arrestor, GI Pipe, Nut Bolts etc.

Earth Electrode: The conductor (or conductive plate) buried in the earth for electrical earthing system is called earth electrode. Earth electrodes are in different shapes like, conductive plate, conductive rod, metal pipe or any other conductor with low resistance.

Earth Lead: The conductor wire or conductive strip connected between Earth electrode and Electrical installation system and devices is called Earth lead. The material of earth lead shall be same as that of earth electrode.

Earth Continuity Conductor: The conductor wire, which is connected among different electrical devices and appliances like distribution board , different plugs and appliances etc. in other words, the wire between earth lead and electrical device or appliance is called earth continuity conductor. It may be in the shape of metal pipe (fully or partial), or cable metallic sheath or flexible wire.

Testing procedure of Earthing

The earthing system should be checked before the installation is brought into use. Also it should be checked once a year on a dry day during dry season. During such tests, following checks should be done:-

1. Earth resistance should be within the prescribed limits
2. Earth conductor should have its cross sectional area as large as possible.(not less than minimum limit specified)

Earth resistance tester megger is used for measuring the earth resistance.

Analog Hand Driven Earth Resistance Tester

Earth resistance is defined as the resistance between actual earth and the earthed body of the installation. This is the resistance of the path connecting the body of the installation to the actual earth. This resistance should be low enough to carry sufficient current to the earth to ensure proper operation of protective relays or blowing of fuses associated to the installation. The earth path consists not only the earth continuity conductor but also it includes soil in between the end of the earth continuity conductor inside the ground and actual earth. Maximum allowable earth resistance for residential areas is less than 5 ohm. The resistance between any point on the earthed body and the earth pit should be less than 1 ohm.

The determination of resistance between the earthing electrode and the surrounding ground in distribution system is made by using earth resistance tester.

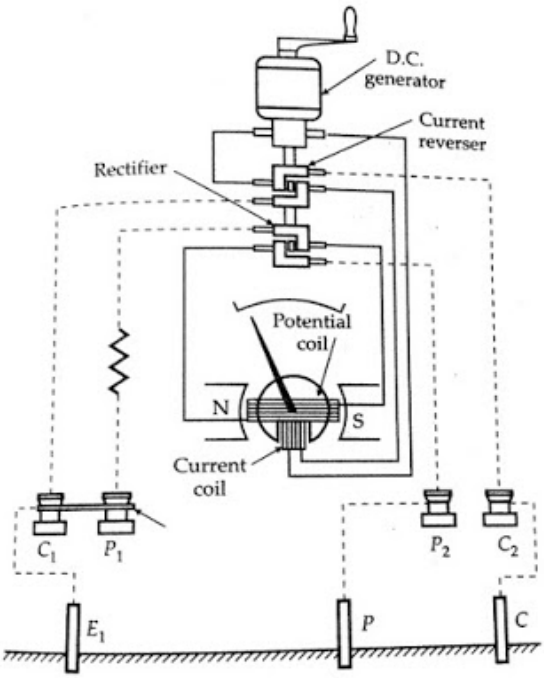


Fig:- Construction of an analog hand driven earth resistance tester

Fig: Analog Hand driven Earth Tester

Analog Earth testing megger consists of a hand driven magneto type D.C. Generator, a current reverser, a rotary rectifier and an ohm meter. The current reverser and rotary rectifier are driven along with D.C. Generator by a driving system which incorporate a clutch mechanism for unidirectional rotation and a governor for speed control. The function of current reverser is to change the direction of flow of current in the soil and that of rotary rectifier is to maintain unidirectional current in the potential coils of the ohm meter. The ohm meter consists of a current coil and a potential coil mounted on a common spindle and placed in the magnetic field of a permanent magnet. The current coils is connected in series with the earth electrodes and current electrodes. The potential coil is connected across the earth electrode and the potential electrode through the rotary rectifier.

While measuring the earth resistance the terminals C1, P1 are connected to the main earth electrode P2 to the potential electrode and C2 to the current electrode. The potential and current electrodes are temporary electrodes placed in the ground 50 to 75 feet apart and 50 to 75 feet & from the earth electrode. When the device is operated, an A/C current is produced in the coil. The voltage drop produced in the earth electrode is applied across the potential coil. The current coil produces a Torque in the clock wise direction, and the potential coil produces a Torque in anticlock wise direction.

The current applied to the current coil is inversely proportional to the earth resistance and the voltage drop applied across the potential coil is directly proportional to the earth resistance the Torque opposes each other and bring the moving system to rest when they are equal. The pointer indicates the earth resistance values on a calibrated scale. The potential electrode is shifted 10 inches close to the earth electrode and second reading is taken in a similar manner third reading also taken after shifting the potential electrode 10 inches closer to the current electrode. All the three readings should be equal.

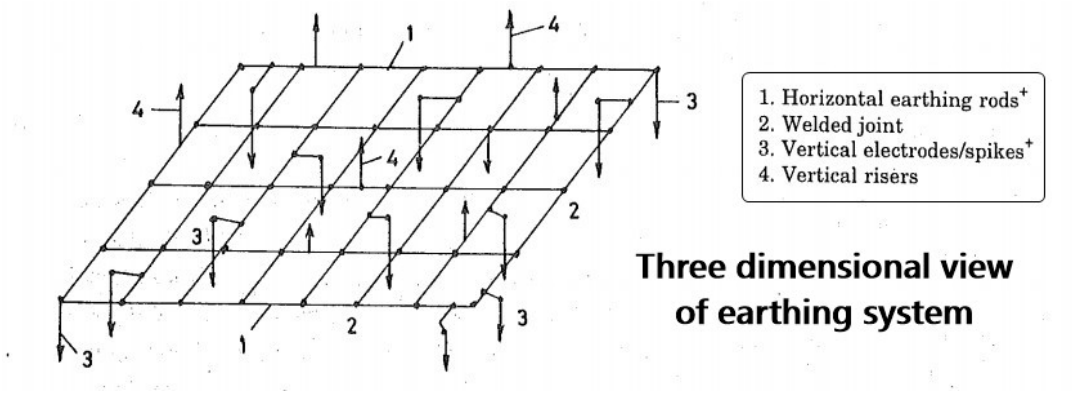
Installation of Earthing system

Following are some of the points which should be considered at the time of installation of earthing:-

- The size of earth continuity conductor should not be less than 14 SWG copper wire.
- The cross section of the earth wire should not be less than half of the cross section of the main wire of the conductor.
- The earth electrode and earth wire should be of same material either copper or GI and the electrode should always be buried in the vertical position.
- The earth resistance of any earthing should be between 0.5Ω to 2Ω for better performance.
- The distance of the earth electrode from the installation at the premises should not be more than 1.5m.

Earthing Mesh

In substation earthing, horizontal mesh of steel rods and vertical electrodes welded to the mesh is buried. These horizontal mesh of steel rods in which vertical electrodes (spikes) are welded to it is called earthing mesh. The vertical risers and the galvanized steel earthing strips or copper bars are connected between the earthing mesh and the points to be grounded.



Earthing and Grounding are the same terms used for earthing. Grounding is the commonly word used for earthing in the North American standards like IEEE, NEC,

ANSI and UL etc while, Earthing is used in European, Common wealth countries and Britain standards like IS and IEC etc.

4. Assessment

Very Short Answer Questions

1) What do you understand by earthing?
2) What should be the earth resistance of large power station?
3) List out the materials required for earthing.
4) What do you mean by earth resistance?

Short Answer Questions

1) Name the instrument that is used to measure earth resistance. Name its terminals as well.
2) Explain the types of earthing.
3) What do you understand by earthing mesh? Where is earthing mesh implemented?

Long Answer Questions

1) Classify different methods of earthing on basis of use of electrodes. Explain each of them in brief.
2) Explain in detail about plate earthing with neat sketches.
3) Explain the construction and working of an earth tester.

Glossary

Mesh: A network whose components are all connected directly to every other component

Galvanised: Coated with Zinc

Calibrated: Marked with

Torque: A rotational force

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UNIT - 4
Three Phase and Single Phase Distribution System

1. Objective

The main objectives of this unit are as follows:-

- To understand the concept of Distribution System
- To be able to differentiate three phase and single phase distribution system
- To be familiar with the components of 3 phase,4 wire supply system
- To make single line diagram(SLD) of different components of a power system

2. Learning Materials

- Different kinds of MCBs, cables, MCCB, busbar, etc.
- Single phase and three phase distribution board

3. Course Contents

Introduction of distribution system

Electric power, produced at the power stations, are located at distances far away from the consumers. It is then transmitted over large distances to load centers with the help of conductors known as transmission lines. Finally, it is distributed to a large number of small and big consumers through a distribution network. Distribution system can be broadly classified into:

(i) DC or AC system,

(ii) (ii) Overhead or Underground system.

AC distribution system is generally adopted in our country. Underground system is chosen over overhead system because of its cheapness.

Distribution system delivers power from power stations or substations to the various consumers. The voltages for primary distribution are 11 KV,6.6 KV or 3.3 KV depending upon the requirements of the bulk consumers and secondary distribution is 400/230V.

The secondary distribution system may be further divided into feeders, distributors and service mains

Feeder

The conductor which connect the stations (may be generating station in some cases) to the areas to be fed by those stations is called feeder. Generally, no tapping is taken to the consumers from feeders, therefore, current loading of a feeder remains the same along its length.

Distributor

The conductor from which numerous tappings for the supply to the consumers is taken is called distributor. The current loading of a distributor varies along its length.

Service Mains

The conductor which connects the consumer's terminal to the distributor is called service mains.

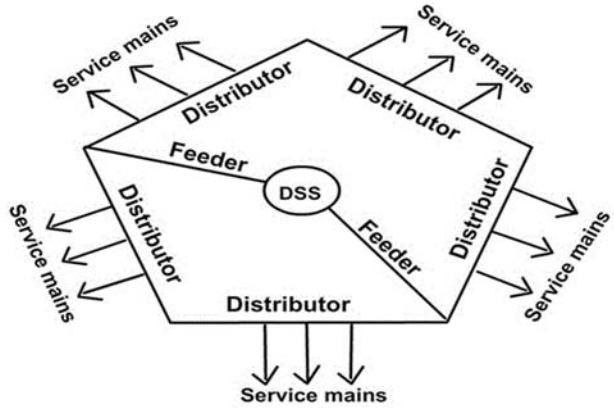


Fig:- Secondary Distribution System

Advantages of three phase over single phase distribution system

When electrical power is distributed to its point of utilization, it is normally either in the form of single-phase or three-phase alternating current (AC) voltage. Single-phase distribution is used when loads are mostly lighting and heating, with few large electric motors. Single-phase systems can be of two major types-single-phase two wire systems or single-phase three-wire systems.

Three-phase electric power is a common method of alternating current electric power generation, transmission, and distribution. It is a type of polyphase system and is the most common method used by electrical grids worldwide to transfer power. It is also used to power large motors and other heavy loads.

The main advantages of three phase system over single phase distribution system are as follows:-

i. A three-wire three-phase circuit is usually more economical than an equivalent two-wire single-phase circuit at the same line to ground voltage because it uses less conductor material to transmit a given amount of electrical power.
ii. As compared to a single-phase AC power supply that uses two conductors (phase and neutral), a three-phase supply with no neutral and the same phase-to-ground voltage and current capacity per phase can transmit three times as much power using just 1.5 times as many wires (i.e., three instead of two).
iii. Three-phase systems may also have a fourth wire, particularly in low-voltage distribution. This is the neutral wire. The neutral allows three separate single-phase supplies to be provided at a constant voltage and is commonly used for supplying groups of domestic properties which are each single-phase loads.
iv. The phase currents tend to cancel out one another, summing to zero in the case of a linear balanced load. This makes it possible to reduce the size of the neutral conductor because it carries little or no current. With a balanced load, all the phase conductors carry the same current and so can be the same size.

Differences between 3 phase and 1 phase distribution system

The electrical energy produced at the power station is transmitted at very high voltages by 3 phase, 3 wire system to step-down substations for distribution. The distribution system consists of two parts viz. primary distribution and secondary distribution. The primary distribution system operates at voltages somewhat higher than general utilization and handles large blocks of energy than the average low voltage consumer uses. The primary distribution circuit is normally 3 phase, 3 wire and operates at voltages(3.3 or 6.6. or 11kV). It delivers power to the secondary distribution circuit through distribution transformers. Second distribution system includes the range of voltages at which the ultimate consumer utilizes the electrical energy delivered. Each

distribution transformer steps down the voltage to 400 V and power is distributed to consumers by 3 phase, 4 wire. The voltage between any two phases is 400V and between any phase and neutral is 230V.

- Three phase distribution system comprises of three or four wires(three live wires and one neutral) whereas 1 phase distribution system comprises of only two wires(live and neutral).
- Three phase distribution system is mostly supplied to commercial and industrial buildings whereas 1 phase distribution system is supplied to residential buildings.
- The single phase system has only one phase wire, and if the fault occurs on the network, then the power supply completely fails. But in three phase system the network has three phases, and if the fault occurs on any one of the phases, the other two will continuously supply the power.
- The maximum power is transferred through three phases as compared to single phase supply.
- Three phase system is more efficient to operate motors of large sizes where single phase system is more efficient to operate small sized motors.

3 phase 4 wire supply system

The 3-phase, 4 wire system is widely used for the distribution of electric power in commercial and industrial buildings. The single phase load is connected between any line and neutral wire while a 3 phase load is connected across the three lines. The current in the neutral wire will be the phasor sum of three line currents.

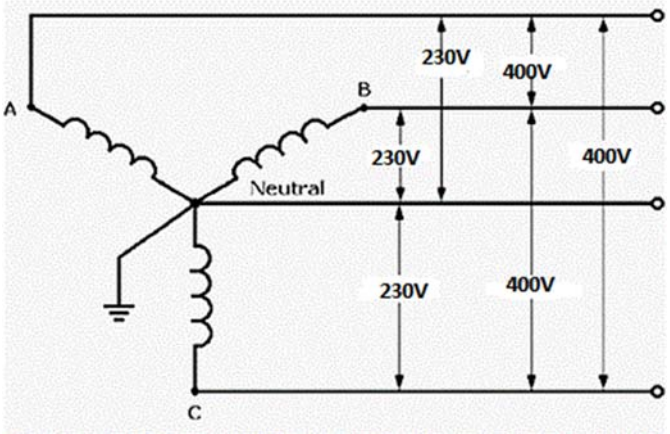
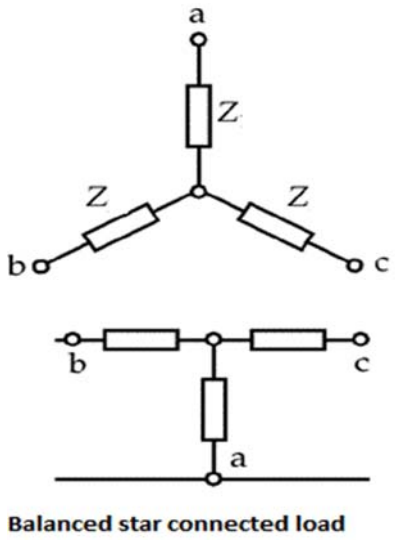


Fig: Three phase 4 wire supply system

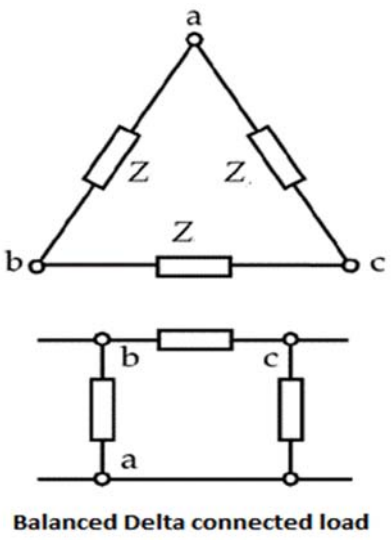
Some Terminologies:-

1. **Three phase Balanced loads**:- The three phase loads that have same impedance and power factor in each phase are called balanced loads. In this case, current and power in each phase will be same. Following are the types of balanced load:-

- Balanced delta connected load
- Balanced star connected load



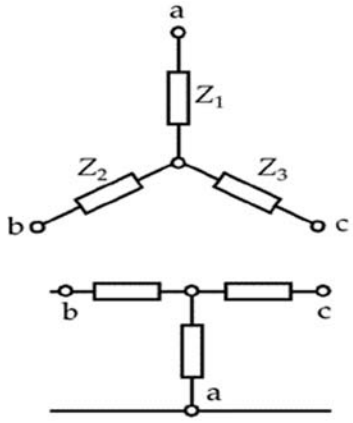
Balanced star connected load



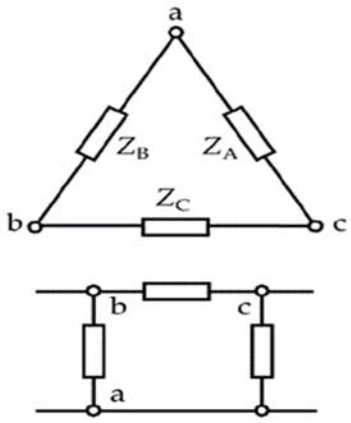
Balanced Delta connected load

2. **Three phase Unbalanced loads**:- The three phase loads that have different impedance and power factor in each phase are called unbalanced loads. In this case, current and power in each phase will be different. Following are the types of unbalanced load:-

- Unbalanced delta connected load
- Unbalanced 3 wire, star connected load
- Four wire star connected unbalanced load



Unbalanced star connected load



Unbalanced Delta connected load

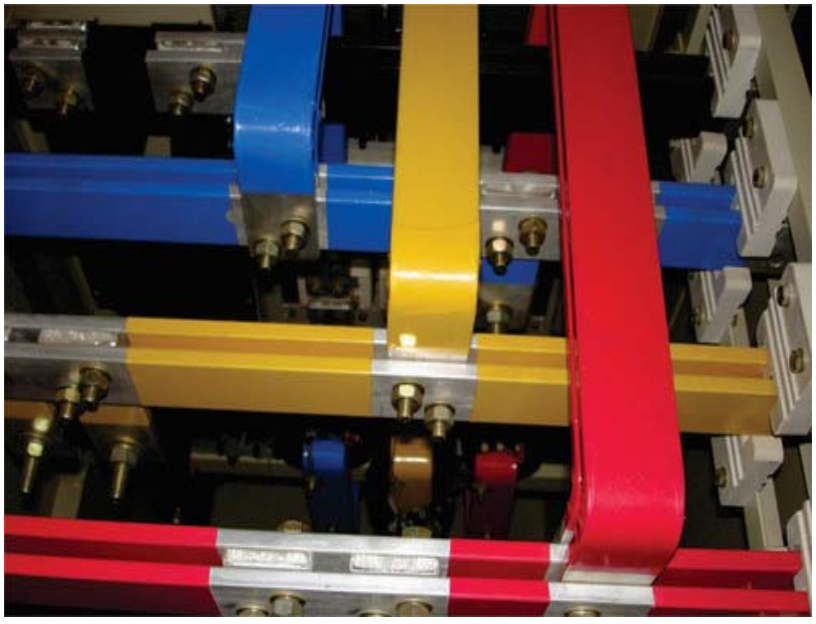
3. **Phase Voltage**:- The voltage between one of the phase or line and neutral is known as phase voltage. It is represented by Vph.
4. **Line Voltage**:- The voltage between any two phases or lines is called the line voltage. It is represented by V_L.
5. **Phase Current**:- The current flowing through any one of the phase winding is known as phase current. It is represented by Iph.
6. **Line Current**:- The current flowing between any two phase of the winding is termed as line current. It is denoted by I_L.
7. **Phase Power**:- The power measured between a phase and a neutral point is known as phase power.
8. **Total Three Phase Power**:- The total power measured in a phase circuit is called total three phase power. Since the phase impedances of a balanced star- or delta-connected load contain equal currents, the total power is three times the phase power. In case of unbalanced load, three phase power is equal to the sum of power in each phases.

Main components of 3 phase, 4 wire supply system

The main components of 3 phase, 4 wire distribution system are:- Protective devices (TPMCB, MCCB, SPMCB), Busbar and cables. The explanation of each are as follows:-

1. **Protective devices**:- Protective devices are used for protection against over-current resulting from both short circuit and overload. MCB is used as a protective device upto 100 A. It automatically switches off the electrical circuit during abnormal condition of the network i.e., in over load condition as well as faulty condition.

   Molded Case Circuit Breakers (MCCB) is a bit heavier-duty than MCBs which can withstand amperage levels of up to 2,500 amperes. It is also used for overload and fault protection. The trip settings are also typically adjustable. The adjustability of MCCBs make them particularly useful in main electric feeders as more circuits may eventually be added to the system and thus, will possibly require a change in the overall trip settings. Motor protection is also a common application for MCCBs.
2. **Bus bar**:- An electrical bus bar is defined as a conductor or a group of conductors used for collecting electrical energy from the incoming feeders and distributes them to the outgoing feeders. It is also a point where different equipments can be connected. Bus bar may be of copper, aluminium or steel.



3. **Core**:- Single conductor of a cable with its insulation but without any mechanical protective covering is called core of a cable.
4. **Cable:-** A length of one or more than one insulated conductors which are laid up together to carry electric current is called cable. Cable may be single core, twin core or three core cables according to the number of conductors.

Fig:- 3 cored cables

Fig:- Four cored cable

Main component of 3 phase 4 wire supply system for single phase and 3 phase load distribution board

Distribution board is an assembly of parts, including one or more fuses or circuit breakers, arranged for the distribution of electrical energy to various circuits or other distribution boards. These other distribution boards which gets electrical energy from the main distribution board are called sub main distribution boards. For any distribution board, the protection system must be used in the incomer. The protective devices provides protection against short circuit and overloads. For a three phase distribution panel either TP or TPN or 4P can be used as the incoming protection. For single phase loads, SP or DP MCBs can be used as protective devices.

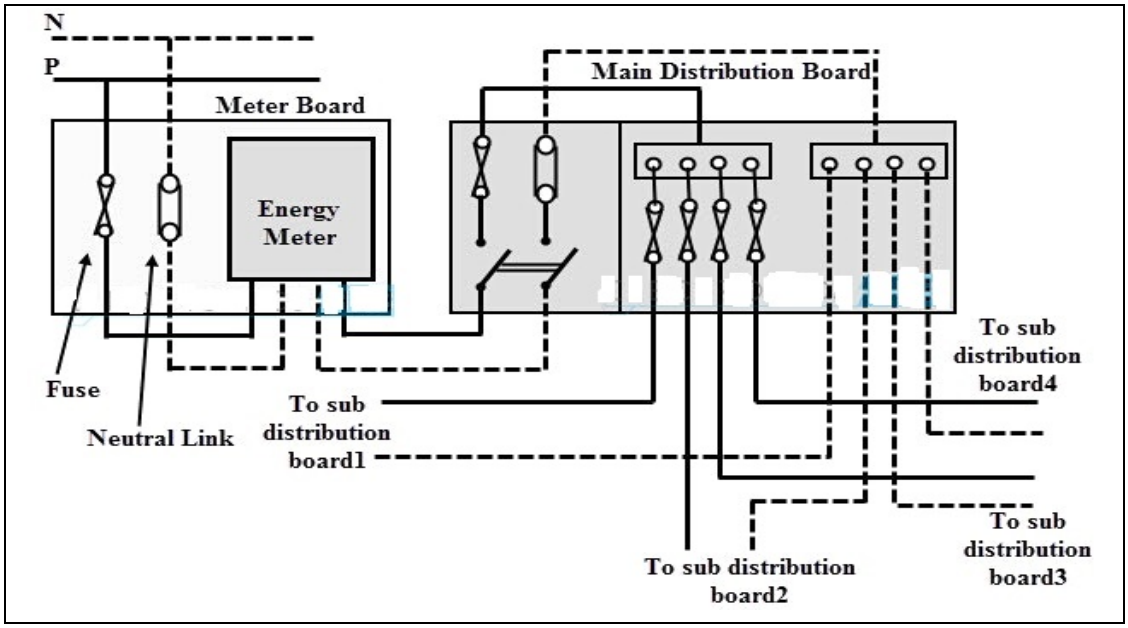


Fig:- Single phase distribution board with fuse

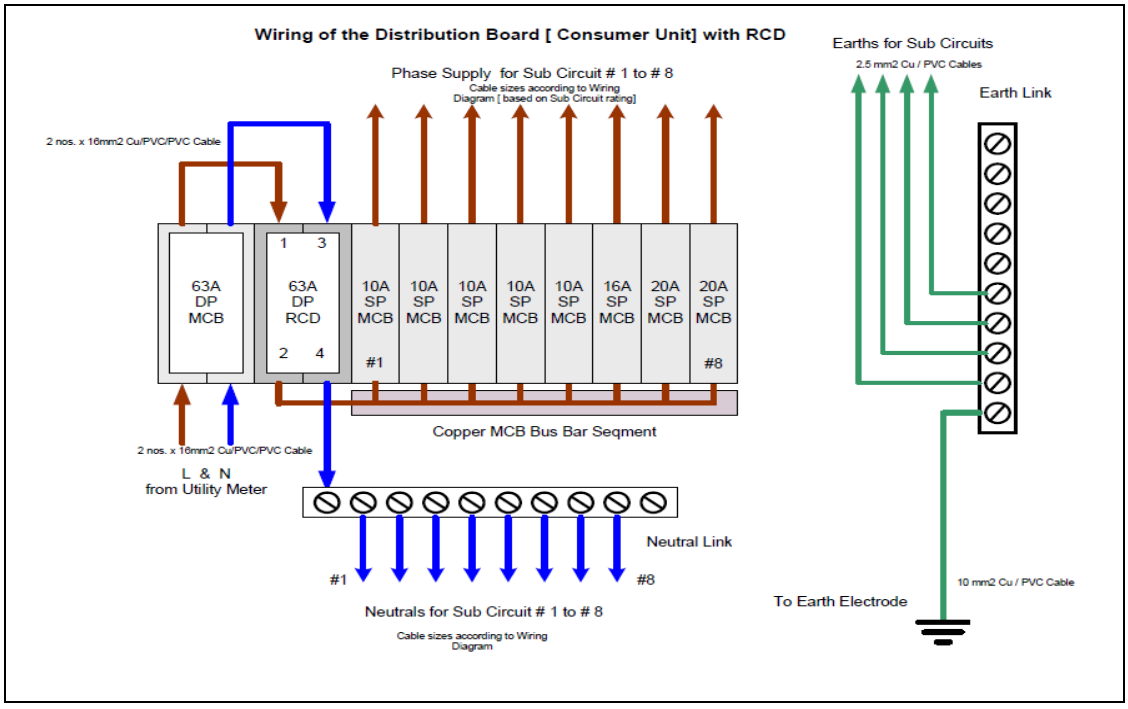


Fig: Single phase load distribution board with MCB

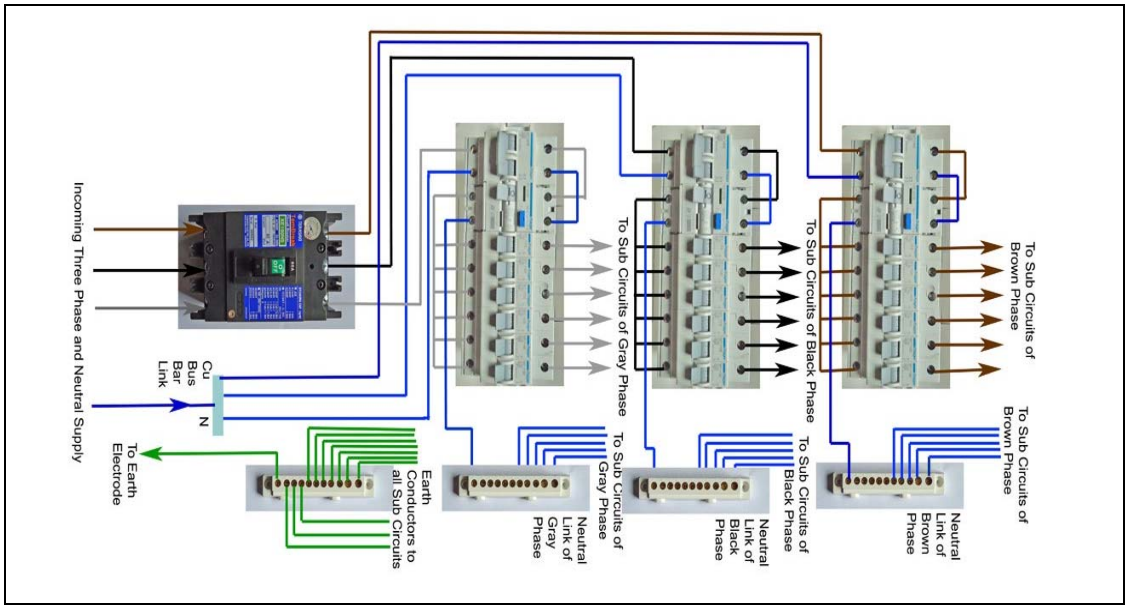


Fig: Three phase four wire load Distribution Board

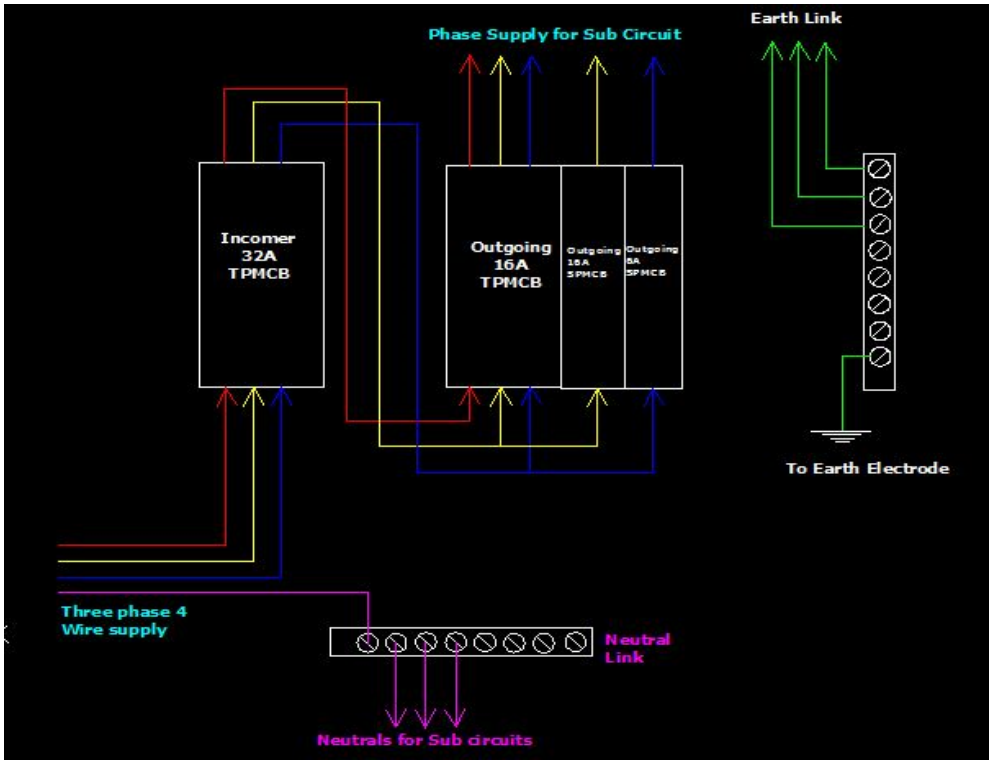
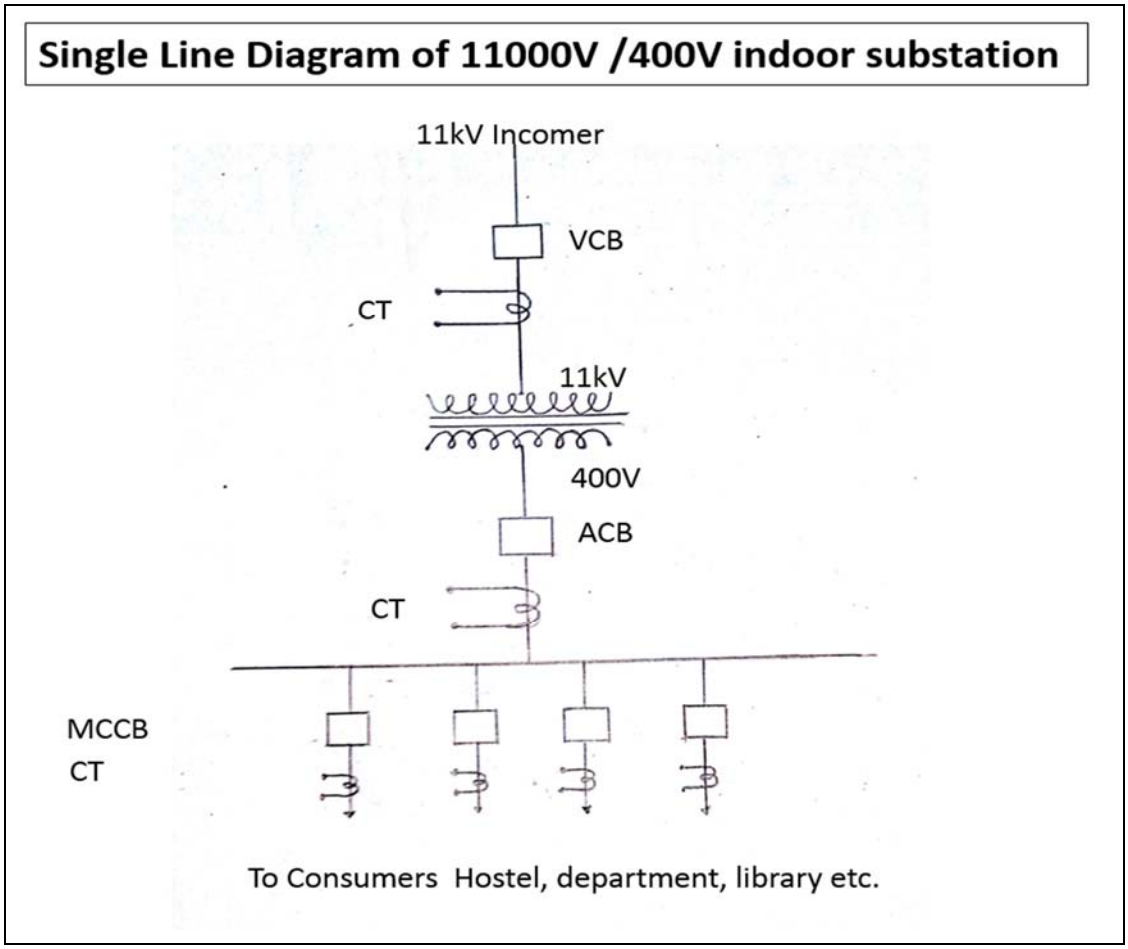
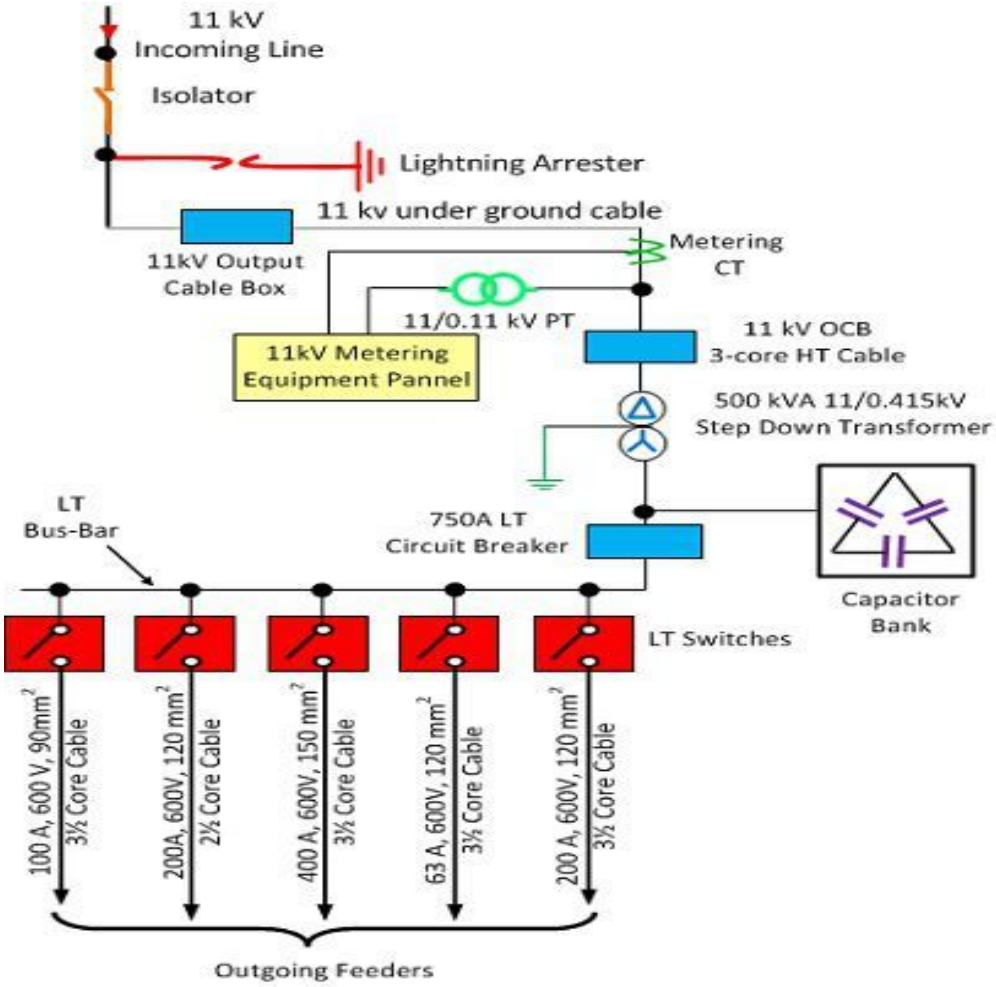


Fig: Distribution board of Three phase 4 wire supply (Drawn in AUTOCAD)

Single Line Diagram(SLD)

It is a simplified notation for representing a power system by means of simple symbols for each component. In a single line diagram, the system components are usually drawn in the form of their symbols.





Main Components of 11kV Substation

The working of the electrical equipment used in the substation is explained below:-

1) **Isolator** – The isolator connects or disconnects the incoming circuit when the supply is already interrupted. The isolator is placed on the supply side of the circuit breaker so that the circuit breaker can be isolated from the live parts of the maintenance.
2) **Lightning Arrester** – The lightning arrester is a protective device which protects the system from lightning effects. It has two terminals one is high voltage and the other is the ground voltage. The high voltage terminal is connected to the transmission line and the ground terminal passes the high voltage surges to earth.

3) **CT Metering** – The metering current transformer(CT) measures and records the current when their secondary terminal is connected to the metering equipment panel.
4) **Step-down Transformer** – The step-down transformer converts the high voltage current into the low voltage current.
5) **Capacitor Bank** – The capacitor bank consists series or parallel connection of the capacitor. The main function of the capacitor bank is to improve the power factor of the line
6) **Circuit Breaker** – The circuit breaker interrupts the abnormal or faults current flowing through the line. It is a kind of electrical switch with arc interrupting device which open or closes the contacts when the fault occurs in the system.

The outgoing feeder supplies the input power to the consumer end.

4. Assessment

Very Short Answer Questions

1) What do you mean by distribution system?
2) Name the different connection in three phase system.
3) How many wires are used in three phase circuits?
4) Define phase voltage.
5) Name the two wires of single phase system.
6) List out the different kinds of MCB.
7) Which protective devices are used in three phase circuits?
8) What do you mean by balanced load?
9) What is a feeder?

Short Answer Questions

1) Define feeder and service mains.
2) What do you understand by MCB? List out the types of MCB on the basis of number of poles.
3) Differentiate SP MCB and TP MCB.
4) Differentiate star connection and delta connection.
5) Define single line diagram. Draw a single line diagram of 11KV to end user.

Long Answer Questions

1. Define distribution system. List out its types and explain each of them in detail.
2. Explain in detail about 3 phase,4 wire supply system.
3. What do you mean by distribution board? Explain in detail about the components used in distribution board.
4. Differentiate single phase and three phase system.
5. Draw a single line diagram of 11KV to end user and explain each of the components.

Glossary

surges: a sudden or abrupt increase

metering: measuring

References

1) A course in Electrical Installation Estimating and Costing, J.B Gupta
2) A course in Power System, J.B. Gupta
3) Power System Analysis and Design, Dr. B.R Gupta
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6) http://www.wikipedia.com/

UNIT - 5
Three Phase Induction Motor

1. Objectives:

- To be familiar with the parts of a three phase induction motor
- To understand the concept of starting method by star delta converter
- To be familiar with the different types of drum switch
- To understand the construction and application of different components of a control panel board
- To be able to design and fabricate control panel as per requirement

2. Learning Materials:

- Three phase induction motor
- Drum switch-ON/OFF, Reverse/Forward, Star/Delta
- Panel board, TPMCB, Contactors, OLR, Start-stop push button switches, cables, cable shoe plier, cable shoe etc.

3. Course Contents

Induction motor and its main parts

Induction motor is an electric motor which operates from AC voltage source and operates under the principle of electromagnetic induction. It is the most widely used motor because of its low cost, simple and rugged construction, absence of commutator, good operating characteristics etc. It is also known as asynchronous motor. The main parts of an induction motor are as follows:-

i. **Stator :-** It is the stationary part of motor which consists of steel frame that encloses a hollow, cylindrical core made up of thin laminations of silicon steel. A number of evenly spaced slots are provided on the inner periphery of the laminations. The insulated conductors(windings) are placed in the stator slots. When supply is given to the stator winding, a magnetic field is produced.

ii. **Rotor:-** It is the central rotating part of the motor which is a laminated core having slots in its outer periphery. It is mounted on a shaft in such a way that it rotates

freely keeping an air gap of about 1 to 4 mm with the stator. There are two types of rotor:- (a) Squirrel Cage Rotor and (b) Phase Wound(Slip Ring) Rotor

a. Squirrel Cage Rotor:- This type of rotor consists of a cylindrical core having parallel slots on its outer periphery. These parallel slot carry rotor conductors and the ends of these conductors are short circuited by metal rings called end rings. The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator.
b. Phase Wound(Slip Ring) type:- This type of rotor also consists of laminated cylindrical core but it has open slots along the outer circumference on which windings are provided.
c. The rotor windings are connected to separate slip rings and the slip rings are shorted with or without external resistance. The slip rings are electrically isolated from the shaft.

Application of forward/reverse switch

In single phase induction motor, the direction can be reversed by changing the direction of the rotating magnetic field produced by the main and starter windings. And this can be accomplished by reversing the polarity of the starter winding.

In three phase induction motor, the direction of rotation can be reversed by interchanging any two leads of the three phase lines. This action can be achieved by manually i.e. by using forward/reverse changeover drum switch or automatically i.e. by using contactors and push button switches.

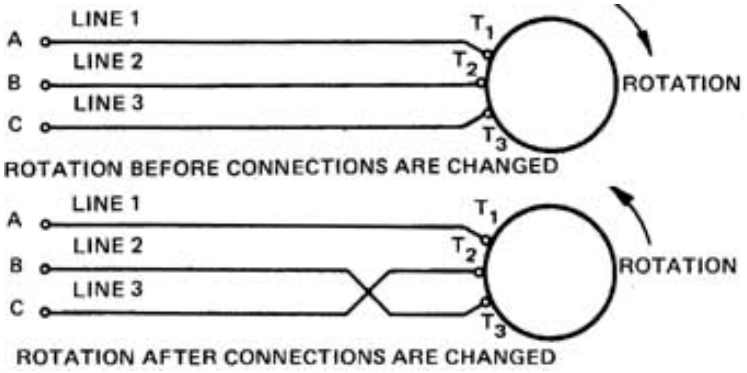


Fig: Rotation of three phase Induction Motor

The forward/reverse changeover switch is a manual switch that lets one manually reverse the direction in which a motor is turning. The switch contacts are opened and closed manually by moving the drum switch from the off position to the forward or reverse position.

Application of star delta switch

Three phase squirrel cage induction motors of higher ratings draw very high starting current. In order to reduce starting current, the motor winding has to be in star connection during starting and in delta connection during running. The six terminals of the motor winding are connected first in star, and when the motor has picked up speed, the connections are changed over to delta. Since the starting voltage is $1/\sqrt{3}$ times the normal voltage in star connection, the starting torque and line current are reduced to one third of the full voltage values. The changeover from star to delta can be manual with the help of drum switch or automatic with the help of contactors.

In changeover drum switch, the motor runs in star connection when the knob is in star and the motor runs in delta connection when the knob is in delta. In automatic star delta starter, three contactors have to be used in which one contactor is in star connection, the next in delta connection and the other as main contactor.

Drum type switch

A switch in which the electrical contacts are made on pins, segments, or surfaces on the periphery of a

rotating cylinder is called drum type switch. This switch has stationary contacts called finger contacts and a rotating drum which carries copper contacts in the form of segments . The crank type operating handle is moved in 'steps' by a star wheel and a pivoted arm. It is a manual switch that lets one manually change the function.

Types of Drum type Switch

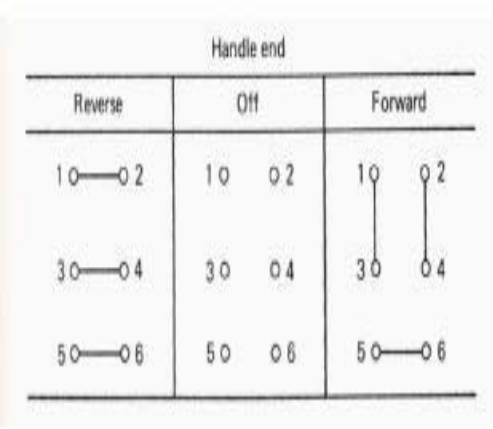
- • ON/OFF Drum type Switch
- • Forward/Reverse Drum type Switch
- • Star/Delta Drum type Switch

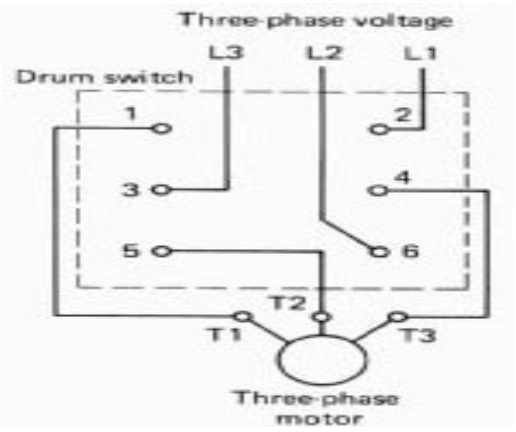
ON/OFF Drum type Switch

This switch helps to turn ON and OFF simply by rotating the handle. It helps in starting up three phase induction motor in which stator windings of the motor are connected directly to the main supply.

Forward/Reverse Drum type Switch

This switch helps the three phase induction motor to rotate in either forward direction or in reverse direction. When the handle of the switch is turned in the forward direction, motor terminals A,B,C are connected to L1, L2,L3 respectively at one step. Again, when the handle is turned in the reverse direction, the motor terminals A,B,C are connected to L2,L1,L3 respectively thus reversing the direction of motor.





Star/Delta Drum type Switch

This switch is used for starting motors of higher ratings (normally greater than 5HP). The motor can be started with star connection and can be manually changed into delta connection once it attains full speed.

When starting up large AC motors directly on the grid, a high starting current is temporarily generated for the relevant systems. This can cause fuses to trip and thus lead to unwanted production downtime. In order to avoid this, star/delta changeover switches are used.

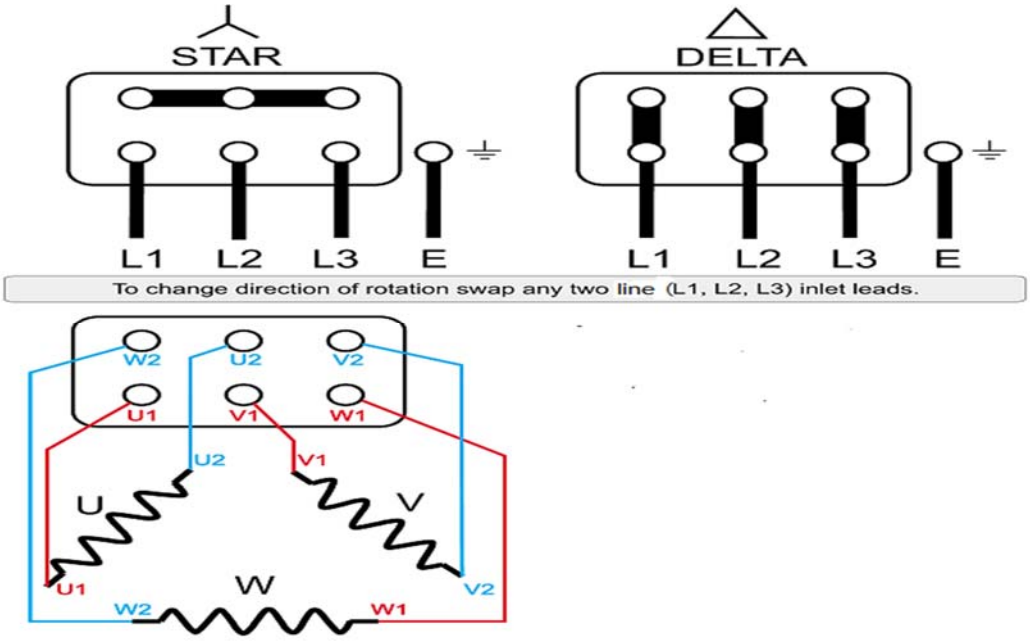


Fig: Star Delta Connection in a three phase induction motor

Fig:-Star Delta Drum type Switch

Functions and applications of TPMCB, contactor, OLR and push button switch

Magnetic contactors can be utilized in starting of inductive and resistive loads. Automatic control of magnetic contactors can be achieved by using OLR or push

button switches. The components required for control circuit of contactor are as follows:-

Triple Pole Miniature Circuit Breaker(TPMCB)

This circuit breaker protects three phase circuits against short circuit and overloading. This is also the main incoming terminal of the supply.

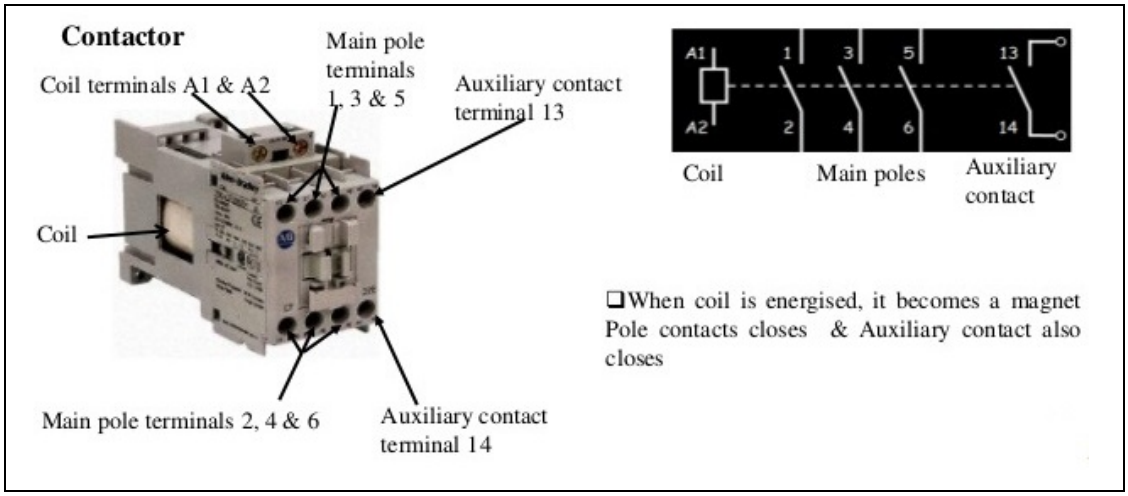
Applications of TPMCB

- It is used in protection of three phase loads.
- It is used in protection of commercial and industrial lighting and power circuits.
- It is used as the incoming terminal of three phase circuits.
- It is used for switching three phase circuits.

Contactor

It is a device operated by an electromagnet for repeatedly establishing and interrupting an electric circuit. Contactors are like normal switches but the only difference is that the contactors have an electromagnet that holds the contacts when energized whereas switches do not have it.

Contactor consists of main contacts and auxiliary contacts. Auxiliary contacts may be Normally Open(NO) or Normally Closed(NC) contacts. A normally open contact closes when the contactor closes or when the contactor coil is energized. A normally closed contact opens when the contactor closes or when the contactor coil is de-energized. There are two circuits associated with an electromagnet; the main circuit and the control circuit.



Applications of AC Contactors

- Switching of resistance or inductive loads
- Switching of induction motors
- Switching of capacitor banks
- Switching of commercial, industrial and street lighting

Over Load Relay(OLR)

A relay is a device which senses first and then controls the circuit. OLR is used to protect the motor from overload or over-current. It senses the over-current and opens the trip contact which finally disconnects the motor from the supply source.

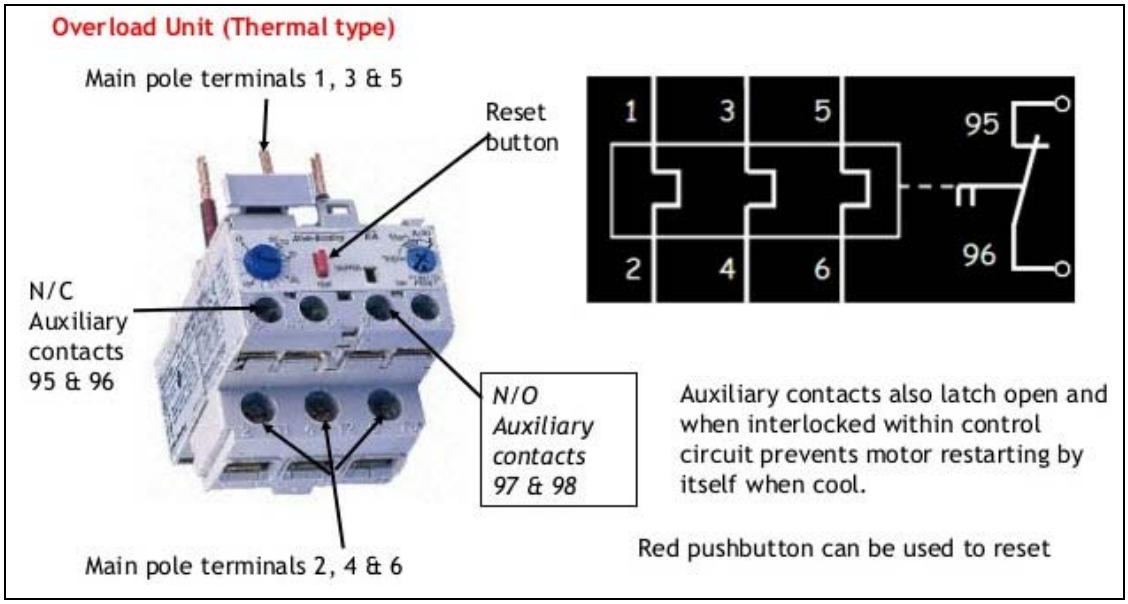
The overload relays are provided with heating elements inside of which bimetallic strips are arranged. When excessive current flows through the motor, overheating damages the motor winding. The overload coil becomes hot when the over current flows through the motor. This causes the bimetallic strip to expand and thereby opens the trip contact which finally disconnects the motor from the supply.

The setting of overload relay in respect of current and time lag is adjusted so as to maintain protection against sustained overload. When an overload relay operates, it has to be reset before the motor can re-start. The resetting may be manual or automatic. In the manual reset type, the relay has to be re-set with hand after giving enough time to the motor and the relay element to cool. If the time is not enough, the

relay will operate again . In automatic reset type, the relay re-sets itself after lapse of some time when the motor has cooled.

Applications of OLR

- Sensing the overload condition of induction motors
- Disconnects the motor from the supply when the motor is overloaded



Push Button Switch

The switch which provides control by pressing a button is called push button switch. Momentary type push button switches are of two types:- Start Push-button and Stop Push Button Switch.

Start Push-button is a spring loaded Normally open(NO) switch. When its button is pressed, the switch closes and the magnet coil gets energized. When the pressure is released, the push button contacts open and the magnet coil gets de-energized.

Stop Push Button Switch is a spring loaded Normally closed(NC) switch. When its button is pressed, the switch opens and the magnet coil gets de-energized. When the pressure is released, the push button contacts close and the magnet coil gets energized.

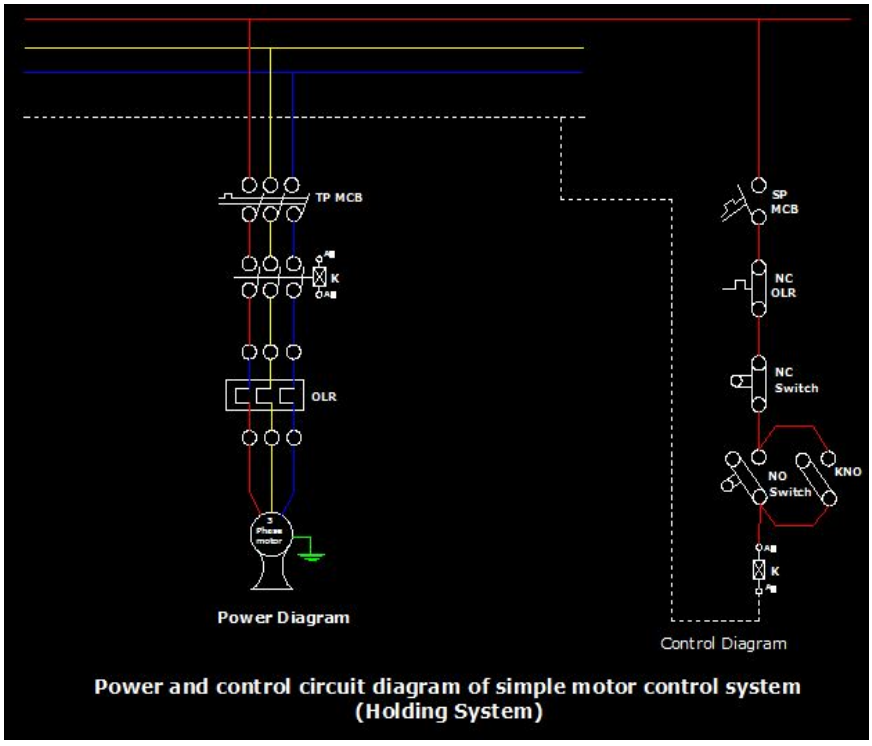
Fig:- Push button switches

Applications of push button switches

- It is used in control circuits of contactors.
- It is used in signalling circuits.
- It is used in remote operated circuits.

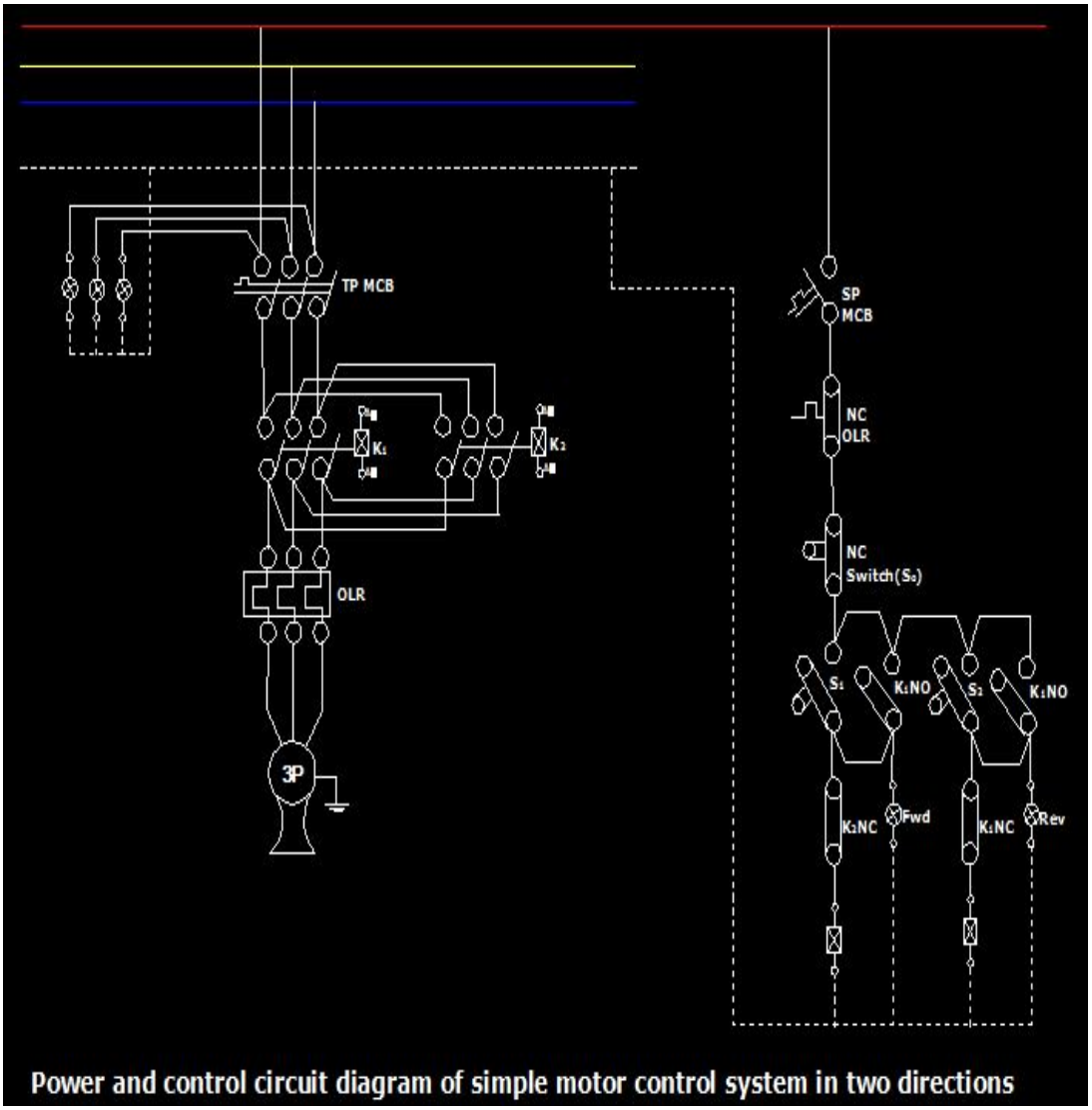
Some sample designs of motor control drawn in AutoCAD are as follows:-

1. Simple motor control using contactor, OLR and push button switches



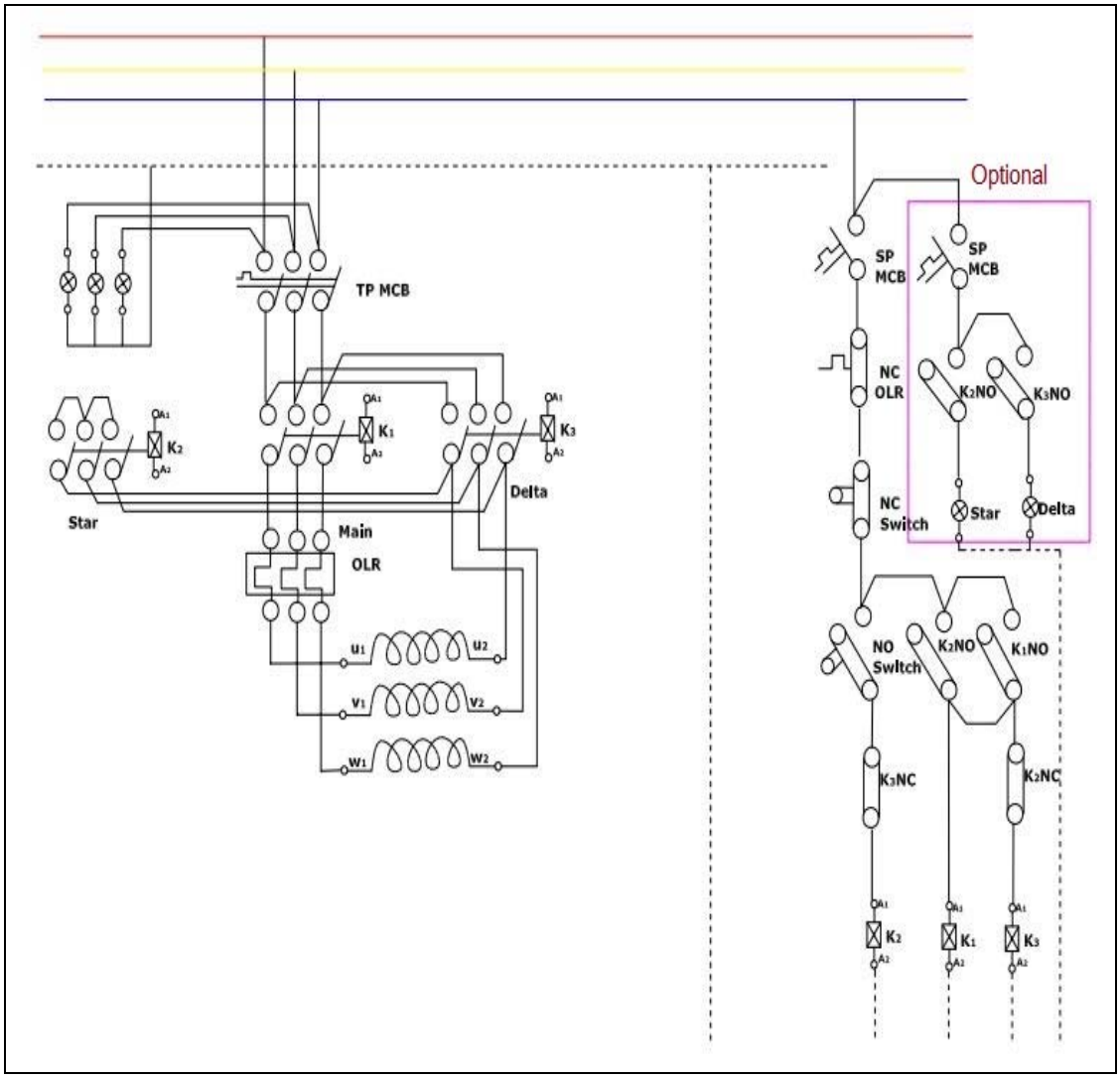
Power and control circuit diagram of simple motor control system (Holding System)

2. Three phase motor direction reverser using two contactors, OLR and push button switches

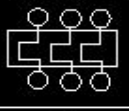
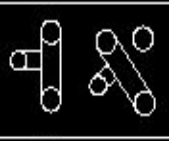


Power and control circuit diagram of simple motor control system in two directions

3. Three phase motor star delta starter using three contactors, OLR and push button switches



The description of each symbols is provided below:'-

INDEX	
Symbols	**Description**
	Triple Pole MCB
	Triple Pole Contactor
	Triple Pole OLR
	Contactor Coil
	Winding of a motor
	Single Pole MCB
	Normally Open(NO) contact of a relay
	Normally Closed(NC) contact of a relay
	NO and NC Switches
	Normally Open(NO) contact of a contactor
	Normally Closed(NC) contact of a contactor
	Indicator lamp
	Three phase squirrel cage induction motor

4. Assessment

Very Short Answer Questions

1) Which is the most commonly used induction motor?
2) What do you mean by rotor of an induction motor?
3) Which switch is used to change the direction of a three phase induction motor?
4) What is the function of star delta switch?
5) What do you mean by drum type switch?
6) Mention the types of push button switches.
7) What do you mean by contactor?
8) What is the function of Overload Relay?

Short Answer Questions

1) Explain the working of an induction motor.
2) What do you understand by star delta starting method? How can we achieve this starting method?
3) Draw an electrical connection of forward/reverse switch.
4) Mention the different applications of a contactor.
5) Define in short about overload relay.

Long Answer Questions

1) What do you mean by induction motor? Mention the different parts of an induction motor and explain them briefly.
2) Write the functions of the following components:
3) a. Air Break Contactor b. OLR c. Push button switch d. TP MCB
4) 3. Explain in detail about Forward/Reverse switch and Star/Delta switch.

Glossary

rugged: sturdy and strong in construction

commutator: Part of a DC motor which is like a switch for reversing the direction of an electric current

lamination: Bonding thin sheets of iron together

slot: A small slit for placing windings

lapse: Passage of given amount of time

CAD: Software used in engineering and manufacturing to assist in precision drawing

References

1) A course in Electrical Machines, J.B Gupta
2) Handbook of Electrical Engineering, S.L. Bhatia
3) Jain and Jain, " ABC of Electrical Engineering"
4) https://www.electronicshub.org
5) http://www.electricalclassroom.in/2016/04/contactors-construction-operating.html

UNIT - 6

ALTERNATOR

1. Objectives:

- To be familiar with the different parts of a synchronous machine
- To differentiate the types of rotor of synchronous machines
- To analyse the load and no load characteristics of synchronous machines

2. Learning Materials:

- Three phase alternator
- Videos and pictures of alternators

3. Course Contents Alternator

An alternator is an electrical generator that converts mechanical energy to electrical energy in the form of alternating current. Synchronous generator is normally called alternator. Based on the construction of machines, the synchronous machines may be classified as:- rotating armature type and rotating field type. Most of the alternators use rotating field and stationary armature.

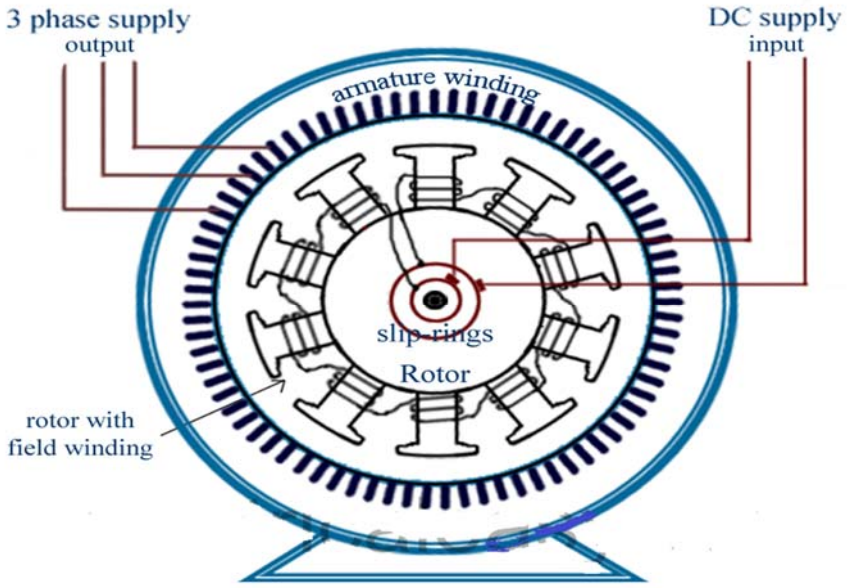


Fig: Structure of an Alternator

The main parts of an alternator are:- Armature(or Stator), Field(or rotor) and exciter.

1. **Armature (or Stator)**

   The stationary part of an alternator(stator) in which EMF is induced is called armature. The armature is an iron ring, made of laminations of magnetic iron or silicon steel, having slots on its periphery to accommodate armature conductors.

2. **Field Magnet system(Rotor)**

   The magnetic field required for the generation of alternating voltage which is provided by field magnets is known as field magnet system. The field system of an alternator is rotated within the armature ring and is known as rotor. The exciting current is supplied to the rotor through two slip rings and brushes. The rotor are of two types:

   a) Salient pole rotor
   b) Cylindrical type rotor

a) Salient pole rotor

This type of rotor has got projected magnetic pole. The construction of this of rotor is easier and cheaper than cylindrical rotor. This type of rotor is generally used in the generators driven by low speed prime movers such as water turbine.

b) Cylindrical type rotor

This type of rotor has smooth magnetic poles in the form of closed cylinder. Construction of this type of rotor is more compact and robust with compare to salient pole rotor. This type of rotor is generally used in the generator driven by high speed prime movers like steam engine and gas turbine.

3. Excite

The DC generator(DC Shunt or DC compound generator) installed at one end of the shaft of the alternator is called exciter. The dc supply from the exciter is supplied to the field winding through two slip rings fixed on the shaft of the alternator.

Types of Alternators

Alternators are classified into following types:-

1. On the basis of construction

- Rotating Armature Type
- Rotating Field Type

2. On the basis of Rotor Design

- Salient pole type(Low and medium speed alternators)
- Cylindrical(Non-Salient) type (High speed alternators)

3. On the basis of number of phase

- Single phase alternator
- Polyphase alternator

4. On the basis of excitation

- Self excitation alternator
- Separately excited alternator

Load and no-load characteristics of Alternator

The terminal voltage of the alternator changes with the load current in the armature even though the exciting current and speed is kept constant. The relationship between the terminal voltage and load current of an alternator is known as load characteristics of alternator.

The output voltage of an alternator depends essentially upon the total flux in the air gap. At no load, this flux is established and determined exclusively by the dc field excitation. Under load, however, the air gap flux is determined by the ampere-turns of the rotor and the ampere-turns of the stator. The latter may aid or oppose the MMF (magneto motive force) of the rotor depending upon the power factor of the load. Leading power factors assist the rotor, and lagging power factors oppose it. Because the stator MMF has such an important effect upon the magnetic flux, the voltage regulation of alternators is quite poor, and the dc field current must continuously be adjusted to keep the voltage constant under variable load conditions.

The change in terminal voltage of an alternator with the change in load supplied by it is due to the following reasons:-

i. Voltage drop due to armature winding resistance
ii. Voltage drop due to armature leakage reactance
iii. Voltage drop due to armature reaction

Voltage Regulation

Voltage Regulation of an alternator is the change of voltage from full load to no load, expressed as a percentage of full load voltage, when the speed and field current are held constant.

$$\text{Percentage Regulation} = \frac{\text{ENL-EFL}}{\text{EFL}}$$

where, ENL is terminal voltage at no load

EFL is terminal voltage at full load

4. Assessment

Very Short Answer Questions

1) What do you mean by alternator?
2) Classify alternator on the basis of rotor design.
3) Define excitation of an alternator.

Short Answer Questions

1. Define Voltage Regulation.
2. Define stator of an alternator.

Long Answer Questions

1. Define Alternator. Explain the different parts of an alternator in detail.
2. Explain no-load characteristics of an alternator.

Glossary

armature: Coil in which EMF is induced by motion through a magnetic field
leakage: loss
reactance: Opposition to the flow of electric current resulting from inductance and capacitance

References

- S. Chand, "Principle of Electrical Machine"
- Handbook of Electrical Engineering, S.L Bhatia
- A course in Electrical Machines, J.B Gupta
- http://www.electricalbasicprojects.com
- http://www.electricaltechnology.org

UNIT - 7
Industrial Wiring

1. Objectives:

The main objectives of this unit are as follows:-

- To understand the concept of industrial wiring installation
- To understand the different types of Circuit Breakers
- To be able to differentiate underground and overhead distribution system

2. Learning Materials:

- Industrial Distribution Board
- Phase Tester
- Different kinds of circuit breakers
- Cables

3. Course Contents

The distribution board of industrial wiring consists of a set of insulated busbars, each incoming and outgoing circuit controlled by a suitable means and outgoing circuits (single three phase load or group of such loads). The outgoing circuits feed different sub distribution boards which distribute power to various machines/equipment. Circuits and sub-circuits to loads must be provided with protective devices.

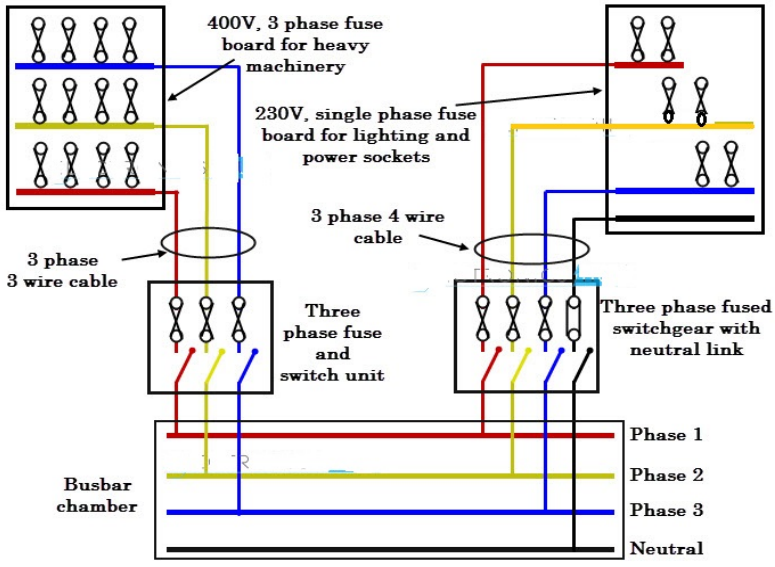


Fig:- Three phase Industrial wiring diagram inside a distribution board ***Picture taken from***

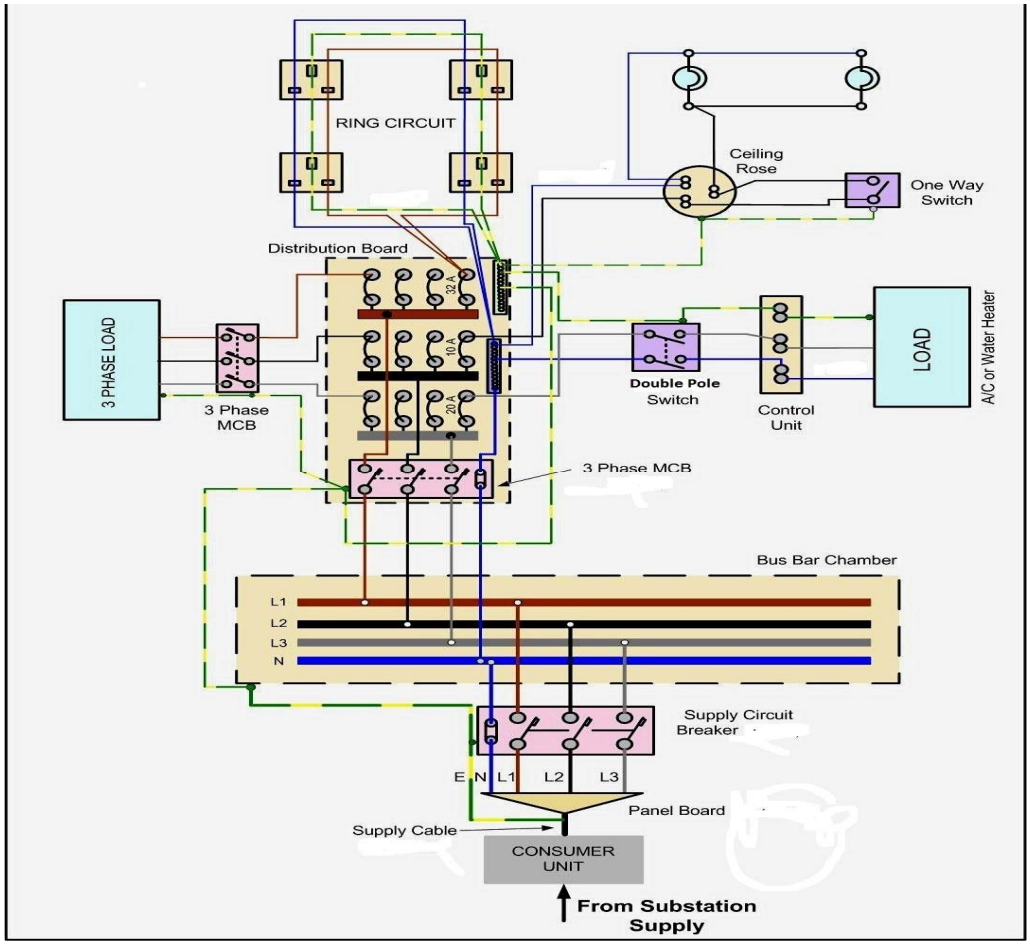


Fig: Components inside the board of three phase industrial wiring

Circuit breaker used in panel board

Circuit breaker is a mechanical device designed to open or close contact members under normal and abnormal conditions manually or automatically. It can also be said that circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current (typically resulting from an overload or short circuit). Its basic function is to interrupt current flow after a fault is detected.

Low-voltage (less than 1,000 V_{AC}) type circuit breakers are common in domestic, commercial and industrial application, and include:

- Miniature circuit breaker (MCB)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation.
- Molded Case Circuit Breaker (MCCB)—rated current up to 2,500 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.

Fig: DIN Rail mounted MCB

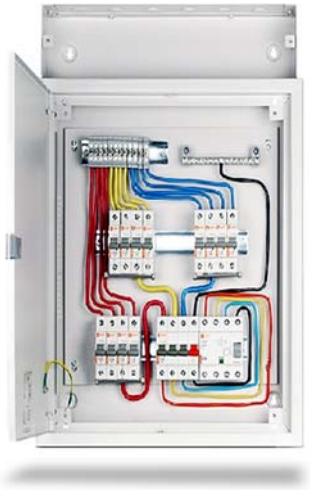


Fig:-MCBs in a panel board

These circuit breakers are often installed in draw-out enclosures that allow removal and interchange without dismantling the switchgear. Small circuit breakers are either installed directly in equipment, or are arranged in a breaker panel. The DIN rail-mounted thermal-magnetic miniature circuit breaker is the most common style in modern domestic consumer units and commercial electrical distribution boards. Low-voltage power circuit breakers can be mounted in multi-tiers in low-voltage switchboards or switchgear cabinets.

Types of circuit breaker

Following types of circuit breakers are used in industrial wiring:

- Oil Circuit Breaker (OCB)
  The circuit breaker in which the current carrying contacts operate in oil is called Oil Circuit Breaker. Oil is used as a medium of arc extinction.
- Air Circuit Breaker (ACB)
  The circuit breaker in which the current carrying contacts operate in air is called Air Circuit Breaker.
- Vacuum Circuit Breaker (VCB)
  The circuit breaker in which vacuum is used to extinct the arc is called Vacuum Circuit Breaker.
- Sulphur Hexafluoride Circuit Breaker (SF_6 CB)
  The circuit breaker in which the current carrying contacts operate in sulphur hexafluoride gas is called Sulphur Hexafluoride Circuit Breaker. SF_6 gas is used as an arc quenching medium.
- Miniature Circuit Breaker (MCB)
  MCB is an electromechanical switch which protects an electrical circuit from an overcurrent. The overcurrent, in an electrical circuit, may result from short circuit, overload or faulty design. It is generally used where normal current is less than 100 Amperes. Miniature Circuit Breakers are usually available in the range of 0.5A to 100A. It is suitable for low current circuits i.e. house wiring. An MCB is a better alternative to a fuse since it does not require replacement once an overload is detected. Unlike fuse, an MCB can be easily operated and thus offers improved operational safety and greater convenience without incurring large operating cost.

Based on number of poles, following types exist:

1) Single Pole (SP) MCB: A single pole MCB provides switching and protection only for single phase of a circuit.
2) Double Pole (DP) MCB: A two Pole MCB provides switching and protection both for a phase and the neutral.

3) Triple Pole (TP) MCB: A triple/three phase MCB provides switching and protection only to three phases of the circuit and not to the neutral.
4) 3 Pole with Neutral [TPN (3P+N) MCB]: A TPN MCB, has switching and protection to all three phases of circuit and additionally Neutral is also part of the MCB as a separate pole. However, Neutral pole is without any protection and can only be switched.
5) 4 Pole (4P) MCB: A 4 pole MCB is similar to TPN but additionally it also has protective release for the neutral pole. This MCB should be used in cases where there is possibility of high neutral current flow through the circuit as in cases of an unbalanced circuit.

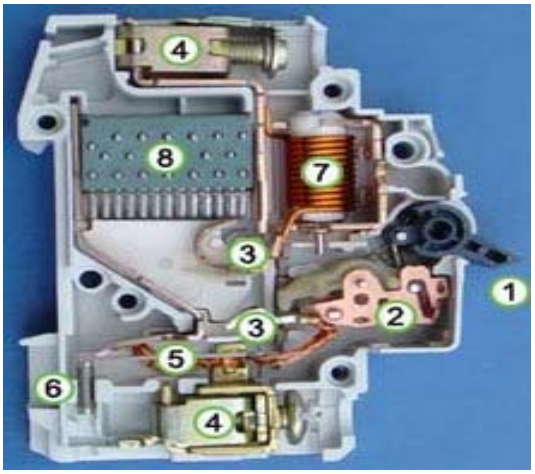


Fig: Inner view of a MCB

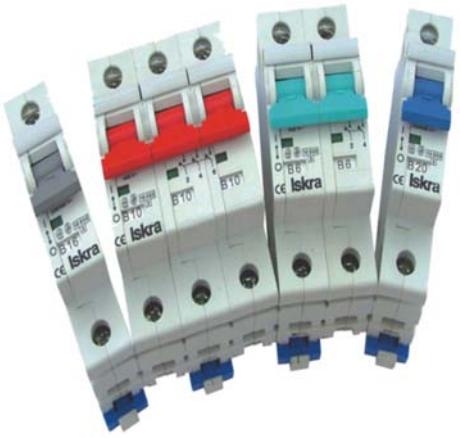


Fig:- Different types of MCB

Moulded Case Circuit Breaker (MCCB)

MCCB is also a protective used to protect electrical circuit from overcurrent. It is generally used where normal current is more than 100 Amperes. It is suitable for high power rating and high energy i.e. commercial and industrial use. It is an alternative to a fuse since it does not require replacement once an overload is detected. Unlike fuse, it can be easily reset after a fault and offers improved operational safety and convenience without incurring operating cost. In this device, trip current is adjustable in larger ratings.

Comparison of overhead and underground cable distribution system

The comparison between overhead and underground distribution system is given below:

i. The cost of installation of underground cables is much more costlier than that of overhead cables.
ii. Maintenance cost of underground system is very low in comparison with that of overhead system.
iii. Underground cables have much less danger of conductor theft, illegal connections, sabotage, and damage from armed conflict.
iv. There are fewer chances of power failures or faults in underground system as compared to overhead system.
v. Though there are rare chances of faults in underground system, but if occurs it is difficult to locate that fault and its repair is difficult and expensive.
vi. Underground system is more good looking than overhead system.
vii. Jointing of underground cables is difficult so tapping for loads and service mains is not conveniently possible in underground system.
viii. In underground system, there will be no interference with communication circuits.

Fig: Underground and overhead distribution cable

Characteristics of Circuit Breakers

The fundamental characteristics of a circuit breaker are as follows:-

i. Rated Voltage
ii. Rated current
iii. Breaking Capacity
iv. Short time Current rating

i. Rated Voltage

This is the voltage at which the circuit-breaker has been designed to operate in normal condition.

ii. Rated Current

This is the RMS value of the current which the circuit breaker shall be able to carry at rated frequency and at rated voltage continuously without temperature rise.

iii. Breaking Capacity

This is the highest rms value of short circuit current that the circuit breaker is capable of breaking. It is expressed in kA or MVA. The breaking capacity of a circuit breaker in MVA is given as √3 X rated voltage in kV X rated breaking current in kA.

iv. Short time Current rating

The short time rating of a circuit breaker is the rms value of current that a circuit breaker can carry in a fully closed position without damage for the specified time interval. It is normally expressed in terms of kA for a period of 1 second or 4 seconds. Low voltage breakers do not have such short time current rating.

Isolators

Isolators are mechanical switches which are employed only for isolating circuit when the current has already been interrupted. They are not equipped with arc quenching devices. They are capable of making and breaking circuits a t no load condition. They are extensively used for disconnecting feeders, circuit breakers, transformers, busbars, etc for regular maintenance and repair.

Fig:- Isolator

4. Assessment

Very Short Answer Questions

1) Write the full forms of SF_6 CB and ACB.
2) Which kind of protection does MCB do?
3) What do you mean by cable?
4) Which gas is used in SF6 CB?
5) What do you mean by rated current of a circuit breaker?
6) What do you mean by isolator?

Short Answer Questions

1) Differentiate MCB and MCCB.
2) Differentiate isolator and circuit breaker.
3) Write short note on breaking capacity of a circuit breaker.

Long Answer Questions

1) What do you mean by circuit breaker? Explain the different types of circuit breakers.
2) Compare overhead and underground cable distribution system.

Glossary

Short circuit- Accidental contact between two points in an electric circuit that have a potential difference

Pole: A contact on an electrical device at which electric current enters or leaves

Arc: Electrical conduction through a gas in an applied electric field

Quenching: act of extinguishing or causing to stop burning

Isolate: Set apart from others

RMS: Root Mean Square value

References

1) A course in Power System, J.B Gupta
2) Handbook of Electrical Engineering, S.L Bhatia
3) http://www.electricalbasicprojects.com
4) http://www.electricaltechnology.org
5) www.electronicshub.org