Ethiopian TVET-System

INDUSTRIAL ELECTRICAL MACHIN DRIVE TECHNOLOGY

Level-II

Based on May 2011 Occupational Standards

October, 2019

Module Title: Maintaining and repairing industrial electrical machines and drives

TTLM Code: EELEMD2TTLM1019

This module includes the following Learning Guides

LG30: Plan, prepare and coordinate maintenance works

LG Code: EEL EMD2 M08LO1 –LG 30

LG31: Maintain electrical system or equipment

LG Code: E EEL EMD2 M08LO2 –LG31

LG32: Troubleshoot faults in an Electrical System or equipment

LG Code: EEL EMD2 M08LO3-LG32

LG33: Notify completion of work

LG Code: EEL EMD2 M08LO4-LG33

LG34: clean- up

LG Code: E EEL EMD2 M08LO5-LG 34

Instruction Sheet	LG30: Plan, prepare and coordinate maintenance works

This learning guide is developed to provide you the necessary information regarding the following learning outcome and content coverage

- Secure Safety permit/Hot work permit
    - Identify potential hazards
    - Electromagnetic principles
    - Preparing Maintenance work schedule
    - Identify and request/obtain Materials, tools, equipment, testing devices and PPE
    - Preparing Work instructions according to machine's manual
    - Informing the schedule of work for concerned department/personnel

This guide will also assist you to attain the learning outcome and contents stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Secure Safety permit/Hot work permit
    - Identify potential hazards
    - Apply Electromagnetic principles
    - Prepare Maintenance work schedule
    - Identify and request/obtain Materials, tools, equipment, testing devices
    - Prepare Work instructions according to machine's manual
    - Inform the schedule of work for concerned department/personnel

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the "Information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6 and Sheet 7" in page 3, 5,9,14,18,79 and 82 respectively".
4. Accomplish the "Self-check 1, Self-check 2, Self-check 3 , Self-check 4 , Self-check 5 , Self-check 6 and Self-check 7" in page 4, 8,13,17,76,81and 83 respectively".
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1 and Operation Sheet 2" in page 84and 85 respectively.
6. Do the "LAP test" in page 86

Information Sheet :1	Secure Safety permit/Hot work permit

1.1. Introduction

Safety is the number one priority in any job. Every year, electrical accidents cause serious injury or death. Many of these casualties are young people just entering the workplace. They are involved in accidents that result from carelessness, from the pressures and distractions of a new job, or from a lack of understanding about electricity. This chapter is designed to develop an awareness of the dangers associated with electrical power and the potential dangers that can exist on the job or at a training facility.

1.2. Personal Protective Equipment (PPE)

Construction and manufacturing worksites, by nature, are potentially hazardous places. For this reason, safety has become an increasingly large factor in the working environment. The electrical industry, in particular, regards safety to be unquestionably the most single important priority because of the hazardous nature of the business. A safe operation depends largely upon all personnel being informed and aware of potential hazards. Safety signs and tags indicate areas or tasks that can pose a hazardto personnel and/or equipment. Signs and tags may provide warnings specific to the hazard, or they may provide safety instructions (Figure 1-2).To perform a job safely, the proper protective clothing must be used. Appropriate attire should be worn for each particular job site and work activity.

The following points should be observed:

i. Hard hats, safety shoes, and goggles must be worn in areas where they are specified. In addition, hard hats shall be approved for the purpose of the electrical work being performed but metal hats are not acceptable!

ii. Safety earmuffs or earplugs must be worn in noisy areas.

iii. Clothing should fit snugly to avoid the danger of becoming entangled in moving machinery. Avoid wearing synthetic-fiber clothing such as polyester material as these types of materials may melt or ignite when exposed to high temperatures and may hard hat Goggles Cotton only, no polyester Tight sleeves and trouser legs No rings on fingers Safety shoe.

Self-Check -1	Written Test

Directions: Choose the best answer.

1. Which one of the following safety equipment?
   A. Measuring instrument
   B. Hand tool
   C. Glave
   D. All of the above
2. _______ must be worn in noisy areas.
   A. Safety shoose
   B. Ear plag
   C. Hat
   D. All of the above

Note: **Satisfactory rating - 1 points** **Unsatisfactory - below 1 points**

Score = ___________

Rating: _____________

Name: _________________________ Date: _______________

Information Sheet :2	Identify potential hazards

2.1. Electrical Shock

The human body conducts electricity. Even low currents may cause severe health effects. Spasms, burns, muscle paralysis, or death can result, depending on the amount of the current flowing through the body, the route it takes, and the duration of exposure. The main factor for determining the severity of an electric shock is the amount of electric current that passes through the body. This current is dependent upon the voltage and the resistance of the path it follows through the body. Electrical resistance (R) is the opposition to the flow of current in a circuit and is measured in ohms (Ω).The lower the body resistance, the greater the current flow and potential electric shock hazard. Body resistance can be divided into external (skin resistance) and internal (body tissues and blood stream resistance). Dry skin is a good insulator; moisture lowers the resistance of skin, which explains why shock intensity is greater when the hands are wet. Internal resistance is low owing to the salt and moisture content of the blood. There is a wide degree of variation in body resistance. A shock that may be fatal to one person may cause only brief discomfort to another.

Typical body resistance values are:

Dry skin—100,000 to 600,000 Ω

• Wet skin—1,000 Ω

• Internal body (hand to foot)—400 to 600 Ω

• Ear to ear—100 Ω

Thin or wet skin is much less resistant than thickor dry skin. When skin resistance is low, the current may cause little or no skin damage but severely burn internal organs and tissues. Conversely, high skin resistance can produce severe skin burns but prevent the current from entering the body.

2.2. Rubber Protective Equipment

Rubber gloves are used to prevent the skin from coming into contact with energized circuits. A separate outer leather cover is used to protect the rubber glove from punctures and other damage. Rubber blankets are used to prevent contact with energized conductors or circuit parts when working near exposed energized circuits. All rubber protective equipment must be marked with the appropriate voltage rating and the last inspection date. It is important that the insulating value of both rubber gloves and blankets have a voltage rating that matches that of the circuit or equipment they are to be used with. Insulating gloves must be given an air test, along with inspection. Twirl the glove around quickly or roll it down to trap air inside. Squeeze the palm, fingers, and thumb to detect any escaping air. If the glove does not pass this inspection it must be disposed of.

2.3. Protection Apparel

Special protective equipment available for high-voltage applications include highvoltage sleeves, high-voltage boots, nonconductive protective helmets, nonconductive eyewear and face protection, switchboard blankets, and flash suits.

2.4. Hot Sticks

hot sticks are insulated tools designed for the manual operation of high-voltage disconnecting switches, high-voltage fuse removal and insertion, as well as the connection and removal of temporary grounds on high-voltage circuits. A hot stick is made up of two parts, the head, or hood, and the insulating rod. The head can be made of metal or hardened plastic, while the insulating section may be wood, plastic, or other effective insulating materials.

2.5. Shorting Probes

Shorting probes are used on de energized circuits to discharge any charged capacitors or built-up static charges that may be present when power to the circuit is disconnected. Also, when working on or near any high-voltage circuits, shorting probes should be connected and left attached as an extra safety precaution in the event of any accidental application of voltage to the circuit. When installing a shorting probe, first connect the test clip to a good ground contact. Next, hold the shorting probe by the handle and hook the probe end over the part or terminal to be grounded. Never touch any metal part of the shorting probe while grounding circuits or components.

2.6. Face Shields

listed face shields should be worn during all switching operations where there is a possibility of injury to the eyes or face from electrical arcs or flashes, or from flying or falling objects that may result from an electrical explosion. With proper precautions, there is no reason for you to ever receive a serious electrical shock. Receiving an electrical shock is a clear warning that proper safety measures have not been followed. To maintain a high level of electrical safety while you work, there are a number of precautions you should follow. Your individual job will have its own unique safety requirements. However, the following are given as essential basics.

i. Do not close any switch unless you are familiar with the circuit that it controls and know the reason for its being open.
ii. When working on any circuit, take steps to ensure that the controlling switch is not operated in your absence. Switches should be padlocked open and warning notices should be displayed (**lockout/tag out**).
iii. Avoid working on "live" circuits as much as possible.
iv. When installing new machinery, ensure that the framework is efficiently and permanently grounded.
v. Always treat circuits as "live" until you have proven them to be "dead." Presumption at this point can kill you. It is a good practice to take a meter reading before starting work on a dead circuit.
vi. Avoid touching any grounded objects while working on electrical equipment.
vii. When working on live equipment containing voltages over approximately 30-V, work with only one hand. Keeping one hand out of the way greatly reduces the possibility of passing a current through the chest.
viii. Safely discharge capacitors before handling them. Capacitors connected in live motor control circuits can store a lethal charge for a considerable time after the voltage to the circuits has been switched off. Although Article 460 of the National Electric Code (NEC) requires an automatic discharge within 1 minute, never assume that the discharge is working! Always verify that there is no voltage present. Confined spaces can be found in almost any workplace

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Choose the best answer.

1. ______ are insulated tools designed for the manual operation of high-voltage disconnecting switches, high-voltage fuse removal and insertion.
   A. Hot Sticks
   B. Shorting probes
   C. face shields
   D. None of the above
3. ______ are used on de energized circuits to discharge any charged capacitors
   A. Hot Sticks
   B. Shorting probes
   C. face shields
   D. None of the above

***Note:* Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :3	Electromagnetic principles

3.1. Introduction

A magnetic field is a change in energy within a volume of space. The magnetic field surrounding a bar magnet can be seen in the magnetograph shown in fig 3.1. A magnetograph can be created by placing a piece of paper over a magnet and sprinklingt he paper with iron filings. The particles align themselves with the lines of magneticforce produced by the magnet. The magnetic lines of force show where the magneticfield exits the material at one pole and reenters the material at another pole along thelength of the magnet. It should be noted that the magnetic lines of force exist in three-dimensions but are only seen in two dimensions in the image.

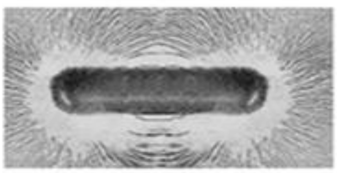


Fig.3.1. Horseshoe magnet

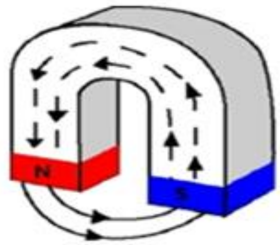


Fig3.2 the magnetic field surrounding a bar magnet

It can be seen in the magnetograph that there are poles all along the length of the magnet but that the poles are concentrated at the ends of the magnet. The area where the exit poles are concentrated is called the magnet's north pole and the area where the entrance poles are concentrated is called the magnet's south pol.Magnets come in a varity of shapes and one of then more common is the horseshoe (U) magnet. Then horse shoe magnet has north and south poles just like a barmagnet but the magnet is curved so the poles lie in the poles as shown in fig. (3.2). Same plane, the magnetic field is concentrated between the number of magnetic lines of force is known as magnetic flux. The flux has the weber (wb) as its unit, The number of magnetic lines of force cutting through a plane of a given area at a right angle is known as the magnetic flux density B. The flux density or magnetic induction has the tesla as its unit. One tesla is equal to one Newton/(A/m). From these units it can be flux density is a measure of the force applide to a particle by the magnetic field.

3.2. Types of magnets

There are two kinds of magnets permanent and temporary magnets.

- ✓ **Permanent magnet**

Permanent magnet will retain or keep their magnetic properties for a very long time. Permanen magnets are by placing pieces of iron cobalt, and nickel into strong magnetic fields. Permanent magnets are mixtures of iron , nickel, or cobalt with other elements. These are known as hard magnetic materials. The natural form of a magnet is called a load stone, it contains iron. When man mixed the pure metals together (ie. iron, nickel and cobalt) we created an even stronger magnet which a.e the ones we use most today

- ✓ **Temporary magnets**

Temporary magnets will loose all or most of their magnetic properties. Temporary magnets are made of shuch materials as iron and nickel. There are two essential methods for generating a magnetic field . Those two following methods

(a) Electromagnetic Fields

Magnets are not the only source of magnetic fields. In 1820, Hans Christian oersterd discovered that the current in the wire was generating a magnetic field. He found that the magneticfield existed in circular form around the wire and that the intensity of the field was directly proportional to the amount of current carried by the wire as shown in the fig.3.3.

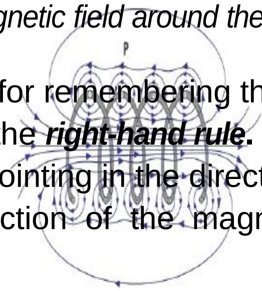


Fig.3.3: *Magnetic field around the wire carried current*

There is a simple rule for remembering the direction of the magnetic field around a conductor. It is called the ***right-hand rule.*** If a person grasps a conductor in ones right hand with the thumb pointing in the direction of the current, the fingers will circle the conductor in the direction of the magnetic field as shown in fig.3.4.

Figure 3.4 : Right-hand rule

(b) Magnetic Field Produced by a Coil

Themagnetic field is essentially uniform down the length of the coil when it is wound The strength of a coil's magnetic field increases not only with increasing current but also with each loop that is added to the coil. Coiling a current-carrying conductor around a core material that can be easily magnetized, such as iron, can form an electro magnetism. The magnetic field will be concentrated in the core. This arrangement is called a **solenoid.**

- ✓ **Induction**

Faraday noticed that the rate at which themagnetic field changed also had an ef fect on the amountof current or voltage that was induced. Faraday's Law for an uncoiled conductor state that the amount of induced voltage is proportional to the rate of change of flux lines cutting the conductor. Faraday's Law for a straight wire is shown below.

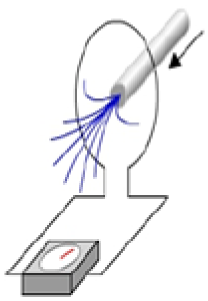
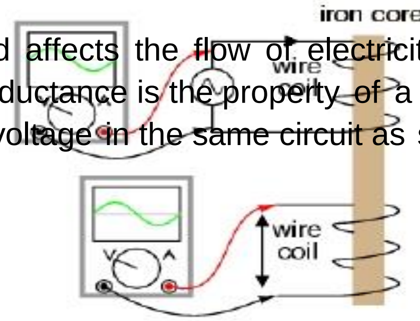


Figure 3.5. Induction in wire

Induction is measured in unit of Henries (H) which reflects this dependence on the rate of change of the magnetic field. One henry is the amount of inductance that is required to generate one volt of induced voltage when the current is changing at the rate of one ampere per second. Note that current is used in the definition rather than magnetic field

- **Self-inductance**

When induction occurs in an electrical circuit and affects the flow of electricity it is called inductance (L) Self-inductance, or simply inductance is the property of a circuit where by a change in current causes a change in voltage in the same circuit as shown in fig 3.6.



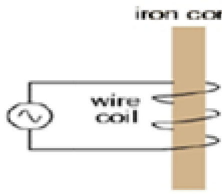


fig 3.6: Self inductance

The mmf required to produce the changing magnetic flux (Φ) must be supplid by a changing current through the coil. Magnetomotive force generated by an electromag oil is equal to the amount of current through that coil (in amps) multiplie by the number of turns of that coil around the core (the unit for mmf is the amp-turn). Because the mathematical relationship between magnetic flux and mmf is directly Proportional, and because the mathematical relationship between mmf and current is also directly proportional (no rates-of-change present in either equation), the current through the coil will be in-phase with the flux waveform as shown in fig 3.7:

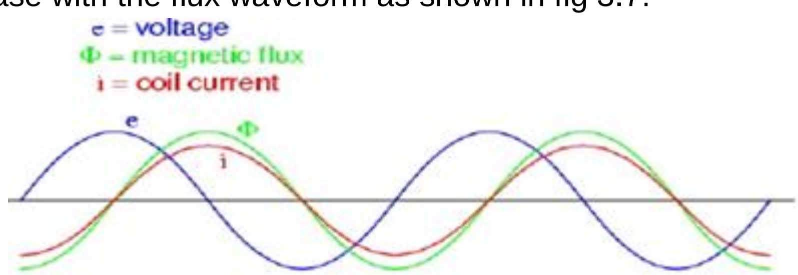


fig 3.7: Current, flux and voltage waveform

- **Mutual-inductance**

When one circuit induces current flow in a second nearby circuit, it is known as mutual-inductance. The image to the right shows an example of mutual-inductance as shown in fig 3.8. When an AC current is flowing through a piece of wire in a circuit, an electromagnetic field is produced that is constantly growing and shrinking and changing direction due to the constantly changing current in the wire. This changing magnetic field will induce electrical current in another wire or circuit that is brought close to the wire in the primary circuit. The current in the second wire will also be AC and in fact will

fig 3.8. Mutual inductance

Self-Check -3	Written Test

Directions: Choose the best answer.

- ✓ ______ is measured in units of henneries (H)
  - A. Magnetic field　　C. Iduction
  - B. Electromagnet　　D. A and B
- ✓ The SI unit of magnetic flux is _____?
  - A. Magnet　　C. Electromagnet
  - B. Weber　　D. None of the above
- ✓ ________ is a change in energy with in a volume of space
  - A. Permanent magnet　　C. Magnetic Filed
  - B. Temporary Magenet　　D. All
- ✓ Magnet will return or keep their magnetic properties for a very long time?
  - A. Permanent magnet　　C. Magnetic Filed
  - B. Temporary Magenet　　D. All
- ✓ The number of magnetic lines of forces cutting through a plane of a given area at a right angle is ________?
  - A. Flux　　C. magnetic filled
  - B. Magnetic flux density　　D. All

***Note:* Satisfactory rating - 3 and 5 points　　Unsatisfactory - below 3 and 5 points**

Score = ___________
Rating: ____________

Name: _________________________　　Date: _______________

Information Sheet :4	Preparing Maintenance work schedule and inform the schedule of work for concerned department/personnel

4.1. Types of Maintenance

4.1.1. Breakdown maintenance

Breakdown maintenance is basically the **"run it till it breaks"** type of maintenance mode. No actions or efforts are taken to maintain the equipment till its design life is reached. Advantages are, Low cost, less staff. Disadvantages are: Increased cost due to unplanned downtime of equipment. Increased labor cost, especially if overtime is needed. Cost involved in repair or replacement of equipment. Possible secondary equipment or process, damage from equipment failure, inefficient use of staff.

4.1.2. Preventive maintenance:

It is a daily maintenance procedure (cleaning, inspection, oiling and re-tightening), designed to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis by measuring deterioration. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance.

It is further divided into Periodic maintenance and Predictive maintenance.

a) Periodic maintenance (Time based maintenance - TBM):

Time based maintenance consists of periodically (at pre-determined intervals) inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

b) Predictive maintenance:

This is a method in which the service life of important part is predicted based on inspection or diagnosis, (for Ex., by testing the condition of the lubricating oil in a vehicle for its actual condition and lubrication properties in a good testing centre instead of changing every 5000kM), This type of maintenance allows us to use the parts/equipment to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. Basically, predictive maintenance differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some preset schedule. It is possible to schedule maintenance activities to minimize or delete overtime cost. Also, inventory and order parts can be minimized as required, well ahead of time to support the downstream maintenance needs. It helps to optimize the operation of the equipment, saving energy cost and increasing plant reliability.

4.1.3. Corrective maintenance:

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability

4.1.4. Maintenance prevention:

It indicates the design of a new equipment. Weakness of current machines are sufficiently studied (on site information leading to failure prevention, easier maintenance and prevents of defects, safety and ease of manufacturing) and are incorporated before commissioning a new equipment.

4.2. Preventive Maintenance of Electrical Equipments

Maintenance usually consists of regularly scheduled inspection, greasing, oiling and possibly Minor repairs. Most causes of failure of alternator and electrical equipment are poor maintenance procedure, which involves flushing out oil wells, greases cups, and checking of rotor and slip rings for concentricity. Shop overhaul is essential for all electrical equipment at least once in five years.

To avoid major repairs:

- Check all connections and wiring.
- Make sure that moisture does not penetrate the winding insulation. Presence of moisture lowers insulation resistance. Test insulation using a megger.
- Remove the moisture by heating the windings using hot bulbs or applying low voltage to winding to develop heat and dry. Do not allow the temperature to rise above 90^0C, which may damage the insulation.
- Dust in the machine should be removed by using a blower with low pressure of air.
- Remove grease and oil using carbon tetrachloride (CTC). While using CTC the area should be well ventilated to avoid fumes and toxics.

Check voltage of alternator at terminals and panel boards. If the generator is operating satisfactory, load the alternator gradually for 2 to 4 hours to evaporate remaining moisture. While testing it should be within 5% of rated voltage and 3 phases load should be well balanced.

- Always open bus bar switches and then stop the alternator. Be sure that all the switches are in ˈoff’ condition before working on the equipment.
- Reversed coil connections of pole windings can be detected by passing Direct current through winding and testing poles by soft iron strip or bar. If polarity is

correct soft iron piece will be held tightly. If not the bar will not be held in its place. Great care is to be taken if D.C. exciter is to be removed for check up of main alternator itself.

- Slip rings on rotor are made of Bronze or non ferrous metal which are polished by fine sand paper or polishing stone. If the rings are worn-out excessively, the rotor should be removed and the rings be reduced down in diameter on the lathe machine. Insulation resistance is then measured by Megger, ring to ring and ring to shaft. Accumulation of carbon or metal dust in the vicinity of rings should be cleaned thoroughly.
- Before starting the motor or alternator – clean the motor/alternator surrounding area to make sure that there is sufficient open space for air movement, also be sure of dry windings.

Make sure from name plate data that type, design of the motor for that work and load.

- Check that operating speed reaches in minimum time, if not there may be overload or centrifugal switch or starting coil is defective. If motor is running in improper direction check for the proper connections as per manufacturing data.
- Check for unusual noises. Poor alignment of end plates, which causes the rotor core to strike against the stator core. Bearing may be defective. If motor becomes overloaded and begins smoking, there may be over loading or defective starting winding or switch. Clean the commutator or reset brushes or adjust spring tension of brushes, if there is sparking at brushes.

Self-Check -4	Written Test

Directions: Answer all the questions listed below**. Choose the best answer**

1. The maintenance work carried out on the machine after it has failed to work is called

A) Breakdown maintenance B) Preventive maintenance

C) Periodic maintenance D) Predictive maintenance.

2. Moisture is the air is prevented from absorption in motor insulation by

A) laminating the windings B) applying varnish

C) Covering with plastic sheets D) vacuum sealing

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :5	Identify and request/obtain Materials, tools, equipment, testing devices and PPE

1. Introduction to Transformer

Transformer is a static device that transfers electrical energy from one electrical circuit to another electrical circuit through the medium of magnetic field and withouta change in the frequency. The electric circuit which receives energy from the supplymains is called ***primary winding*** and the other circuit which delivers electricalenerg y to the load is called ***secondary winding.***Actually the transformer is an electric energ y conversion device, since the energyreceived by the primary is converted to usef ul electrical energy in the other circuits(secondary winding circuit).If the secondary winding has more turns than the primary winding, then thesecondary voltag e is higher than the primary voltage and the transformer is called a ***step-up transformer***. When the secondary winding has less turns than the primary windings then the secondary voltage is lower than the primary voltage and the transformer is called ***step down transformer.***

The most important tasks performed by transformers are

i) Changing voltage and current levels in electrical power systems
ii) Matching source and load impedances for maximum powertransfer in electronic and control circuit an
iii) Electrical isolation (isolating one circuit from another

Transformers are used extensively in ac power systems. AC electrical power can be generated at one central location, its voltage stepped up for transmission very long distances at very low losses and its voltage stepped down again for final use.

1.1. Principles of transformer

Faraday summed up the results of the experiments in the form of following two laws, *known as Faraday's laws of electromagnetic induction.* Faraday's first law states that whenever the magnetic flux associated or linked with a closed circuit is changed, or alternatively, when a conductor cuts or is cut by the magnetic flux, an emf is induced in the circuit resulting in an induced current. This emf is induced so long as the magnetic flux changes.

Faraday's second law states that the magnitude of the induced emf generated in a coil is directly proportional to the rate of change of magnetic flux. These two basic laws discovered by Faraday changed the course of electrical engineering and led to the development of generators, transformers, etc. The change of flux as discussed in the

Faraday's laws can be produced in two different ways:

(i) by the motion of the conductor or the coil in a magnetic field, i.e. the magnetic field is stationary and the moving conductors cut across it. The emf generated in this way is normally called dynamically induced emf;
(ii) by changing the current (either increasing or decreasing) in a circuit. There by changing the flux linked with stationary conductors, i.e. the conductors or coils remain stationary and the flux linking these conductors is changed. The emf is termed statically induced emf. *Statically induced* emf can be further subdivided into:

(a) Self-induced emf and

(b) Mutually induced emf.

The concept of dynamically induced emf gave rise to the development of generators, whereas statically induced emf was helpful in developing transformers.

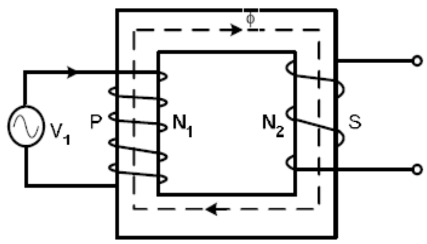


Figure 5.1.. Schematic diagram of a two-winding transformer

The primary winding P is connected to an alternating voltage source, therefore, an alternating current I_m starts flowing through N_1 turns. The alternating mmf N_1I_m sets up an alternating flux ϕ which is confined to the high permeability iron path as indicated in Figure 5.1. The alternating flux induces voltage E1 in the primary (P) and E2 in secondary (S). If a load is connected across the secondary, load current starts flowing.

1.2. Ideal Two-Winding Transformer

For a transformer to be an ideal one, the various assumptions are as follows

1. Winding resistances are negligible.
2. All the flux set up by the primary links the secondary windings i.e. all of the flux is confined to the magnetic core.
3. The core losses (hysteresis and eddy current losses) are negligible. Therefore, volt-amperes input to the primary are equal to the output volt-amperes i.e.

$$V_1I_1 = V_2I_2$$

Input VA= Output VA

4. The core has constant permeability, i.e. the magnetization curve for the core is linear.

1.2.1. Voltage Transformation Ratio

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = k \qquad \frac{I_1}{I_2} = \frac{V_2}{V_1} = \frac{1}{k}$$

Where : - E_1 & I_1 – for primery voltage & current respectively

N_1 - for primery turn

E_2 - for secondery voltage

N_2 - for secondery turn

K – transformer ratio

Hence, the currents are in the inverse ratio of the (voltage) transformation ratio.

The ratio is known as voltage transformation ratio.

i) If N2 > N1 i.e., K<1, then the transformer is called a ***step-up transformer.***

ii) If N2 < N1 i.e., K>1, then the transformer is known as a ***step-down transformer***.

1.2.2. Type of transformer

Depending upon the manner in which the primary and secondary are wound on the core, transformers are of two types viz., (i) core-type transformer and (ii) shell-type transformer.

(i) Core-type transformer.

In a core-type transformer, half of the primary winding and half of the secondary winding are placed round each limb as shown in Fig. 5.2.This reduces the leakage flux. It is a usual practice to place the low-voltage winding below the high-voltage winding for mechanical considerations.

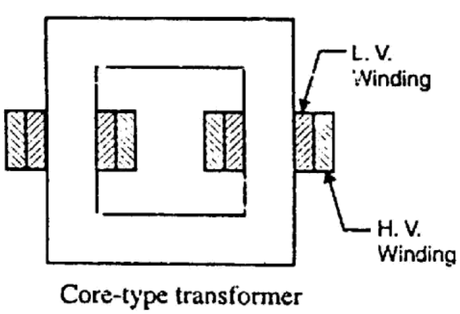


Fig .5.2. Core-type transformer

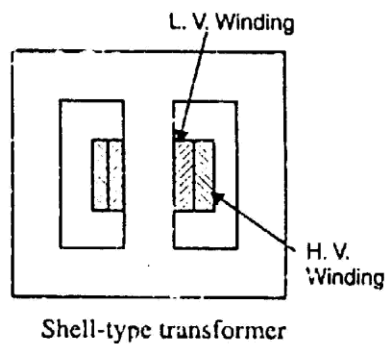


Fig .5.3. Shell-type transformer

(iii) Shell-type transformer.

This method of construction involves the use of a double magnetic circuit. Both the windings are placed round the central limb (See Fig. 5.3), the other two limbs acting simply as a low-reluctance flux path.

The choice of type (whether core or shell) will not greatly affect the efficiency of the transformer. The core type is generally more suitable for high voltage and small output while the shell-type is generally more suitable for low voltage and high output.

1.3. Autotransformer

An autotransformer has a single winding on an iron core and a part of winding is common to both the primary and secondary circuits. Fig.(Fig.5.4 (i)) shows the connections of a step-down autotransformer whereas Fig. (Fig.5.4 (ii)) shows the connections of a step-up autotransformer. In either case, the winding ab having N_1 turns is the primary winding and winding be having N_2 turns is the secondary winding. Note that the primary and secondary windings are connected electrically as well as magnetically. Therefore, power from the primary is transferred to the secondary conductively as well as inductively (transformer action).

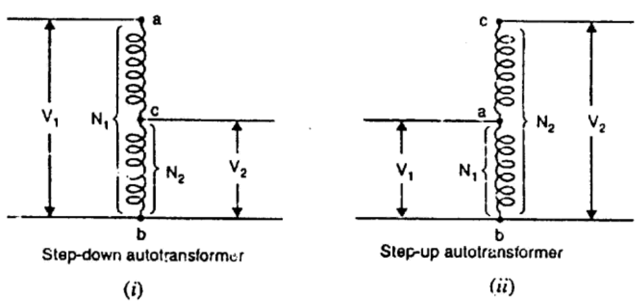


Fig. 5.4. Autotransformer

1.3.1. Welding Machine

Welding is a fabrication process that joins materials usually metals or thermoplastics, by causing coalescence. Generally, most of the weldable common steels are preferred to be join by welding method. The most popular of the welding machines uses the arc welding methods, which include the (i) SMAW – The stick welding or shielded metal arc welding (ii) GMAM – The tig welding gas metal arc welding (iii) GTAM – The tig welding or gas tungsten arc welding. Others are brazing, soldering and oxyacetylene welding. In the automobile industry the resistance spot welding (RSM) is one of the most efficient material-joining processes, it utilizes currents in the range of 1 – 200KA with durations ranging from a few cycles to one second to generate joule heating. RSM transformers operates within a middle frequency range of around 1kHz.

The welding system constructed uses low frequency transformer that operate at the utility mains frequency of 50 or 60 Hz with variable current selectors to avoid power quality problem. Power quality problem refers to voltage current and frequency deviation from nominal value in electrical distribution and utilization system.

Any significant deviation in the waveform magnitude, frequency or purity is a potential power quality problem which may result in failure or malfunctioning of equipment. The current selector introduced in this transformer help to maximize the power quality problem association with a.c electric power systems, that operates at a sinusoidal waveform of 50 or 60 Hz and rated voltage magnitude. The deviations depends on the duration and magnitude which help to categorize the voltage deviation as voltage sags, interruption, over voltage, under voltage, transients, voltage imbalance and voltage

In many electric welding systems, a potential difference of 50-70 volts is required to strike an electric arc. After the arc is struck, an essentially constant current supply is desired .The welding transformer converts the high voltage and low current from the utility mains into low voltage and high current, usually in the range of 55 –590 amperes. In this transformer the variable current selector help to maintain the constant current supply desired.

1.3.2. Construction

The a.c welding machine design is a two pole circuit, with the first pole been the primary circuit and the second pole is the secondary circuit.

i. The Primary Circuit (pole 1)

The primary circuit was design to vary in current selection without tempering with the coil itself; it has a four step coil with three looping for the selection of current capacity.

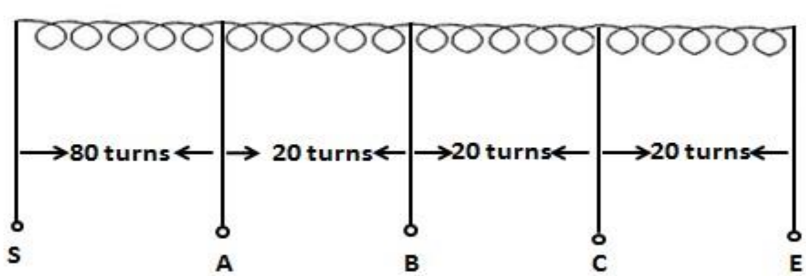


Fig 5.5: A circuit showing the four step circuit and the looping for the current selection

In the primary circuit the winding begins at the start point S and was given 80 turns with a copper wire of size gauge 13. The first looping was introduced after the first winding and was labeled A, the winding continues with same size gauge for another 20 turns before the second looping labeled B. The third looping C and the last winding labeled E was given 20 turns each with same size wire gauge 13. The beginning of the wire marks the starting point „ S" and the end of the wire marks the ending point „ E", both point are use for connection purposes.

ii. The Secondary Circuit (Pole 2)

The second circuit was design to consist of two coils over lapping each other. The first coil is the primary coil wound with 114 turn's size wire gauge 13 while the secondary coil was 40 turn of tick size wire gauge 8 as shown in figure 5.6.The starting point and ending point of the secondary coil serve as the welding terminals.

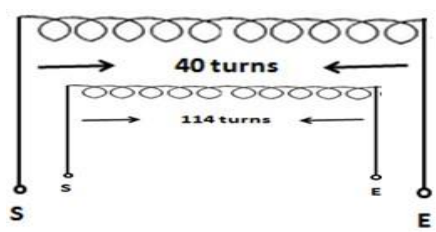


Fig 5.6: A circuit showing the secondary circuit with the over lapped primary circuit

The core is made of laminations assembled to provide a continuous magnetic path with a minimum of air gap included. The lamination steel help to minimize eddy current loss and the thickness of the lamination varies from 0.35mm for a frequency of 50Hz 0.5mm for a frequency of 25Hz. The cores are cut in the form of long strips. L"s, E"s and I" shapes as shown below.

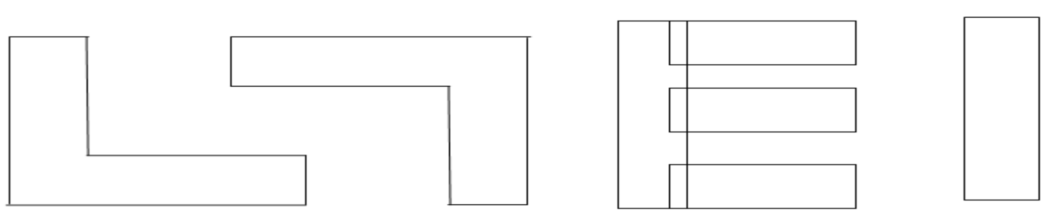


Fig. 5.7: Diagrams showing the shapes of lamination

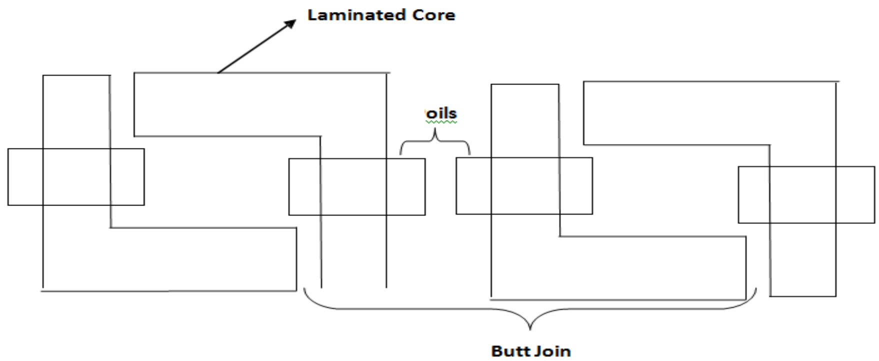


Fig. 5.8: Diagrams showing the arrangement of a laminated core on the coil

In other to avoid reluctance at the joins where the laminated cores are butted against each other, the alternate layers are stacked differently with the shape I to eliminated joins as shown below.

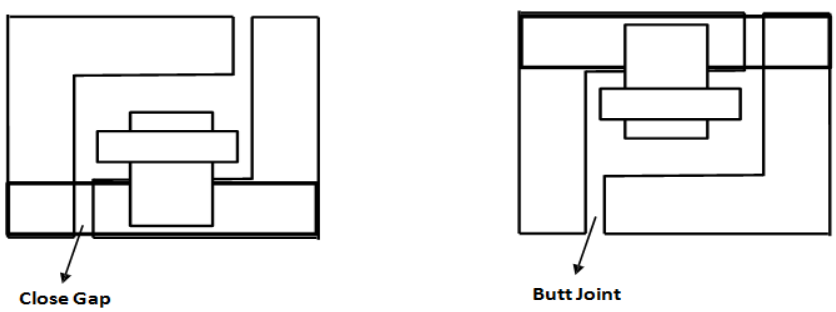


Fig 5.9: Diagrams showing the arrangement of the I lamination covering the butted joint.

✓ **Copper as my coil**

Copper wire is of more advantage in winding process than that of aluminum. Copper wire has more capacity and strong enough to resist the function of any kind of winding for a longer time. It has different type of gauge and is coated with insulator to prevent contact of wires when winding.

For the aluminum wire its very effective when used than the copper wire, it produces stronger magnetic flux which makes the machine more powerful. The disadvantage of an aluminum wire is that they are not insulated thereby need proper insulation before it can be used for winding.

✓ **Insulators**

Insulators are materials that do not conduct electricity in any form. They are used to separate two wires to avoid partial contact of any form.

✓ **Connection**

The major kinds of connections that can be given to this construction include:

a) Star-delta connection or End to start connection
b) Star – star connection or start to start connection
c) Delta-Delta connection or End to End connection

The type of connection use in this work is the start to start connection; it involves the starting wire hand of the primary circuit connected to the secondary circuit as shown in figure below.

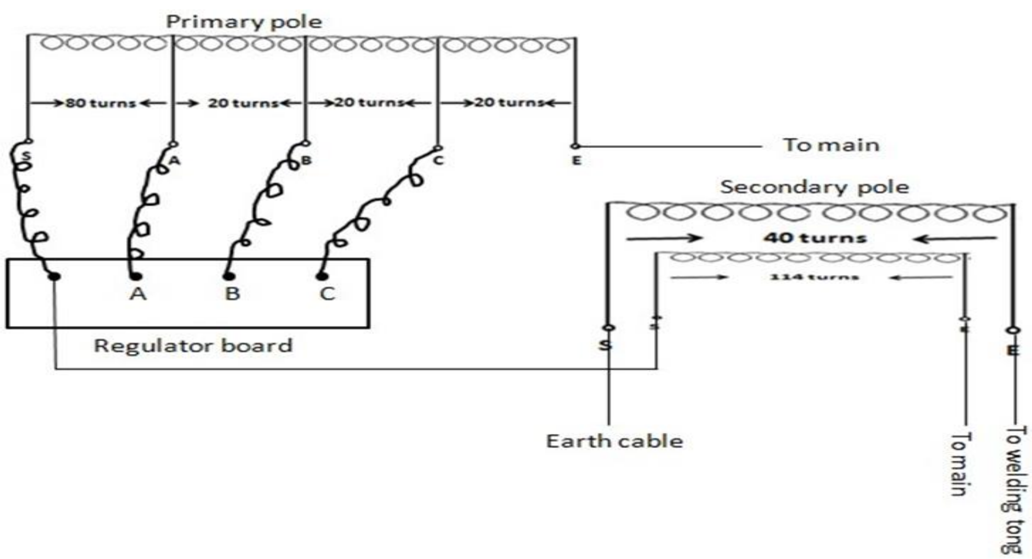


Fig 5.10: The detail connection of the primary circuit diagram

Owing to the connection between the primary pole and the secondary pole, the primary turns will toggle with respect to the variation of the current thus, 254 turns from S to A, 174 turn from A to B, 154 turns from B to C and 114 turns from C to E. At the secondary circuit, the starting hand is connected to the earth of the welding side and the end hand connected to the tong bearing the electrode.

✓ **Testing**

The testing of the machine confirmed the success of the design, construction and connection of the work, as there was no spark or shock from the laminated core and when connected to the welding apparatus, it was used for joning metals without any problem. In the testing, the voltages at zero load and when in operation was measured and recorded as shown in the result below.

1.3.3. Three-phase transformer

A three-phase system in used to generate and transmit electric power. Three- phase voltages are raised or lowered by means of three-phase transformers. A three-phase transformer can be built in two ways viz. (i) by suitably connecting a bank of three single-phase transformers or (ii) by constructing a three-phase transformer on a common magnetic structure. In either case, the windings may be connected in Y-Y, ∆-∆ , Y-∆ or ∆-Y.

(i) Bank of three single-phase transformers

Three similar single-phase transformers can be connected to form a three-phase transformer. The primary and secondary windings may be connected in star (Y) or delta (∆) arrangement. Fig. (5.11.(ii)) shows a Y – ∆ connection of a three-phase transformer.

The primary windings are connected in star and the secondary windings are connected in delta. A more convenient way of showing this connection is illustrated in Fig. (5.11.(i)). The primary and secondary windings shown parallel to each other belong to the same single-phase transformer. The ratio of secondary phase voltage to primary phase voltage is the phase transformation ratio K.

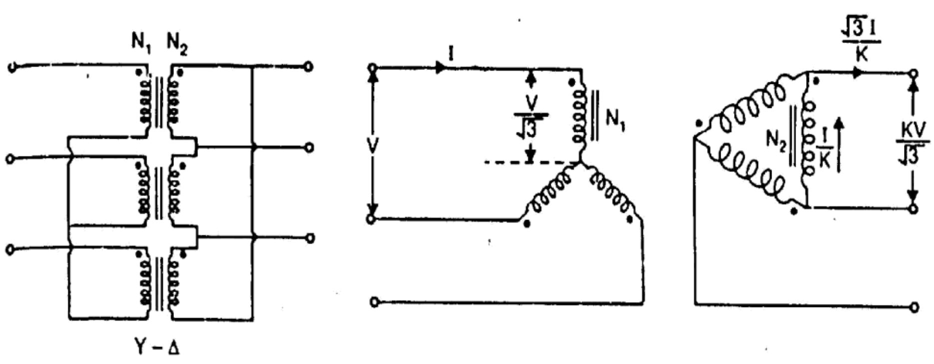


Fig. 5.11: connection of a three-phase transformer.

(ii) Three-phase transformer

A three-phase transformer can be constructed by having three primary and three secondary windings on a common magnetic circuit. The basic principle of a 3- phase transformer is illustrated in Fig. (5.12.(i)).The three single-phase core- type transformers, each with windings (primary and secondary) on only one leg have their unwound legs combined to provide a path for the returning flux. The primaries as well as secondaries may be connected in star or delta. If the primary is energized from a 3-phase supply, the central limb (i.e., unwound limb) carries the fluxes produced by the 3-phase primary windings. Since the phasor sum of three primary currents at any instant is zero, the sum of three fluxes passing through the central limb must be zero. Hence no flux exists in the central limb and it may, therefore, be eliminated. This modification gives a three leg core- type 3-phase transformer. In this case, any two legs will act as a return path for the flux in the third leg. For example, if flux is   in one leg at some instant, then flux is /2 in the opposite direction through the other two legs at the same instant. All the connections of a 3-phase transformer are made inside the case and for delta-connected winding three leads are brought out while for star- connected winding four leads are brought out.

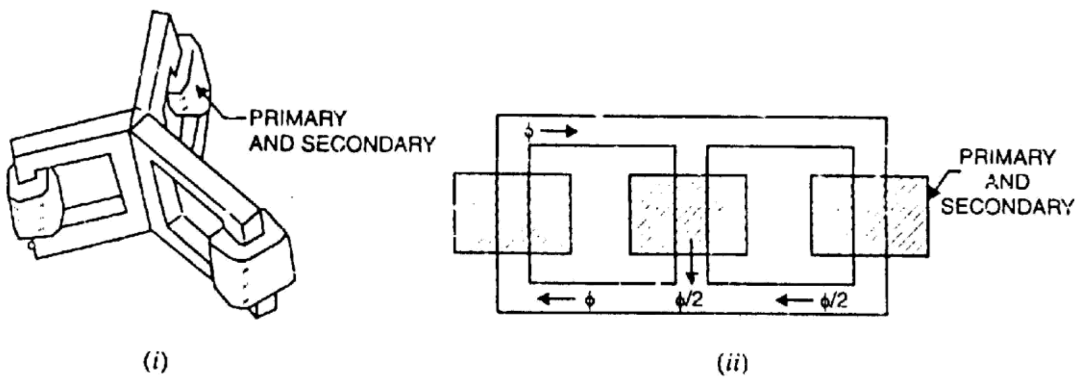


Fig.(5.12) construction of three phase transformer

For the same capacity, a 3-phase transformer weighs less, occupies less space and costs about 20% less than a bank of three single-phase transformers. Because of these advantages, 3-phase transformers are in common use, especially for large power transformations.

A disadvantage of the three-phase transformer lies in the fact that when one phase becomes defective, the entire three-phase unit must be removed from service. When one transformer in a bank of three single-phase transformers becomes defective, it may be removed from service and the other two transformers may be reconnected to supply service on an emergency basis until repairs can be made.

1.3.4. Three-Phase Transformer Connections

A three-phase transformer can be built by suitably connecting a bank of three single-phase transformers or by one three-phase transformer. The primary or secondary windings may be connected in either star (Y) or delta (∆) arrangement. The four most common connections are (i) Y-Y (ii) ∆-∆ (iii) Y- ∆ and (iv) ∆ -Y. These four connections are shown in Fig. (5.13).In this figure, the windings at the left are the primaries and those at the right are the secondary's. The primary and secondary voltages and currents are also shown. The primary line voltage is V and the primary line current is I. The phase transformation ratio K is given by;

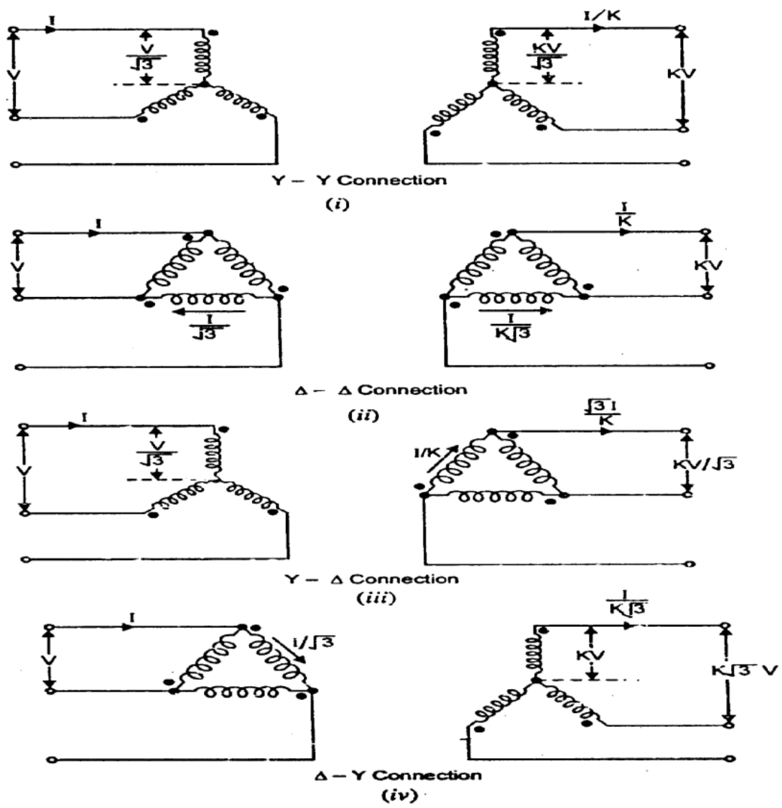


Fig.(5.13) three-phase transformer connection

$$K = \frac{\text{Secondary phase voltage}}{\text{Primary phase voltage}} = \frac{N_2}{N_1}$$

(i) **Y-Y Connection**. In the Y-Y connection shown in Fig. (5.13 (i)), 57.7% (or $1/\sqrt{3}$) of the line voltage is impressed upon each winding but full line current flows in each winding. Power circuits supplied from a Y-Y bank often create serious disturbances in communication circuits in their immediate vicinity. Because of this and other disadvantages, the Y-Y connection is seldom used.

(ii) Δ-Δ **Connection**. The - connection shown in Fig. (5.13 (ii)) is often used for moderate voltages. An advantage of this connection is that if one transformer gets damaged or is removed from service, the remaining two can be operated in what is known as the open-delta or V-V connection. By being operated in this way, the bank still delivers three-phase currents and voltages in their correct phase relationships but the capacity of the bank is reduced to 57.7% of what it was with all three transformers in service.

(iii) **Y-** Δ **Connection**. The Y- Δ connection shown in Fig. (5.13 (iii)) is suitable for stepping down a high voltage. In this case, the primaries are designed for 57.7% of the high-tension line voltages.

(iv) Δ **-Y Connection**. The Δ –Y connection shown in Fig. (5.13(iv)) is commonly used for stepping up to a high voltage

1.3.5. Applications of Transformers

There are four principal applications of transformers viz.

(i) power transformers (ii) distribution transformers

(iii) autotransformers (iv) instrument transformers

(i) **Power Transformers**. They are designed to operate with an almost constant load which is equal to their rating. The maximum efficiency is designed to be at full-load. This means that full-load winding copper losses must be equal to the core losses.

(ii) **Distribution Transformers**. These transformers have variable load which is usually considerably less than the full-load rating. Therefore, these are designed to have their maximum efficiency at between 1/2 and 3/4 of full- load.

(iii) **Autotransformers**. An autotransformer has only one winding and is used in cases where the ratio of transformation (K), either step-up or step down, differs little from 1. For the same output and voltage ratio, an autotransformer requires less copper than an ordinary 2-winding transformer. Autotransformers are used for starting induction motors (reducing applied voltage during starting) and in boosters for raising the voltage of feeders.

(iv) **Instrument transformers**. Current and voltage transformers are used to extend the range of a.c. instruments.

(a) Current transformer

A current transformer is a device that is used to measure high alternating current in a conductor. Fig. (5.14.) illustrates the principle of a current transformer. The conductor carrying large current passes through a circular laminated iron core. The conductor constitutes a one-turn primary winding. The secondary winding consists of a large number of turns of much fine wire wrapped around the core as shown. Due to transformer action, the secondary current is transformed to a low value which can be measured by ordinary meters.

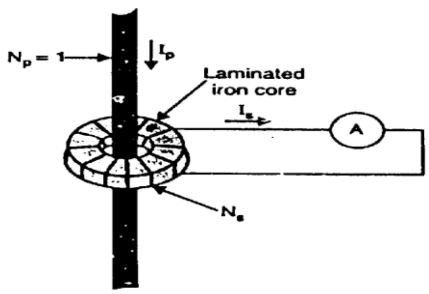


Fig. (5.14): current transformer

(b) Voltage transformer

It is a device that is used to measure high alternating voltage. It is essentially a step-down transformer having small number of secondary turns as shown in Fig. (5.15).The high alternating voltage to be measured is connected directly across the primary. The low voltage winding (secondary winding) is connected to the voltmeter. The power rating of a potential transformer is small (seldom exceeds 300W) since voltmeter is the only load on the transformer.

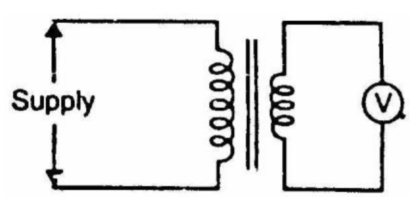


Fig.(5.15): Voltage Transformer

1.3.6. Testing of transformer

(a) open-circuit and short-circuit tests

These two tests on a transformer help to determine

(i) The parameters of the equivalent circuit

(ii) The voltage regulation and

(iii) Efficiency

The equivalent circuit parameters can also be obtained from the physical dimensions of the transformer core and its winding details. Complete analysis of the transformer can be carried out, once its equivalent circuit parameters are known. The power required during these two tests is equal to the appropriate power loss occurring in the transformer.

(b) Open Circuit (or No-Load) Test

The circuit diagram for performing open circuit test on a single phase transformer is given in Figure 5.16 (a).In this diagram, a voltmeter, wattmeter and an ammeter are shown connected on the low voltage side of the transformer. The high voltage side is left open circuited. The rated frequency voltage applied to the primary, i.e. low voltage side, is varied with the help of a variable ratio auto-transformer. When the voltmeter reading is equal to the rated voltage of the L.V. winding, all three instrument readings are recorded.

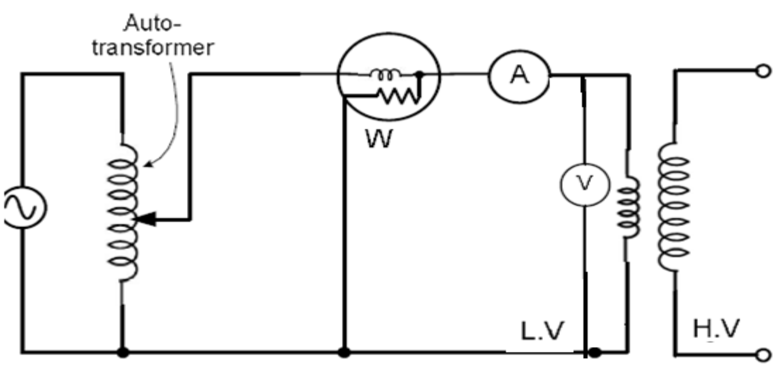


Fig: 5.16: open circuit test

The-ammeter records the no-load current or exciting current Ie. Since Ie is quite small (2 to 6%) of rated current), the primary leakage impedance drop is almost negligible, and for all practical purposes, the applied voltage V1 is equal to the induced emf E1.

(c) Short-Circuit Test

The low voltage-side of the transformer is short-circuited and the instruments are placed on the high voltage side, as illustrated in Figure .

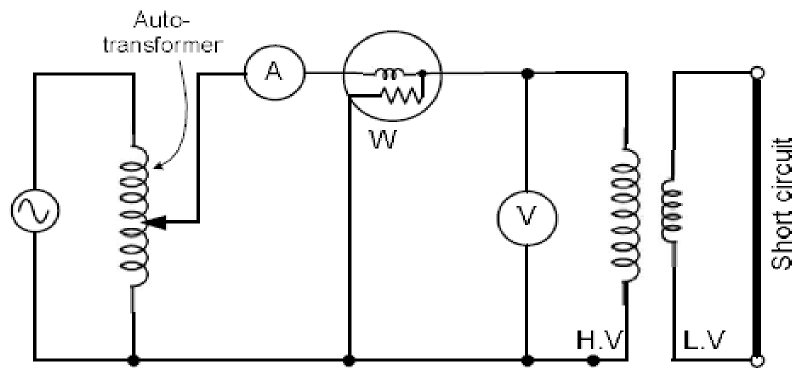


Fig: 5.17: short circuit test

The-ammeter records the no-load current or exciting current Ie. Since Ie is quite small (2 to 6%) of rated current), the primary leakage impedance drop is almost negligible, and for all practical purposes, the applied voltage V1 is equal to the induced emf E1.

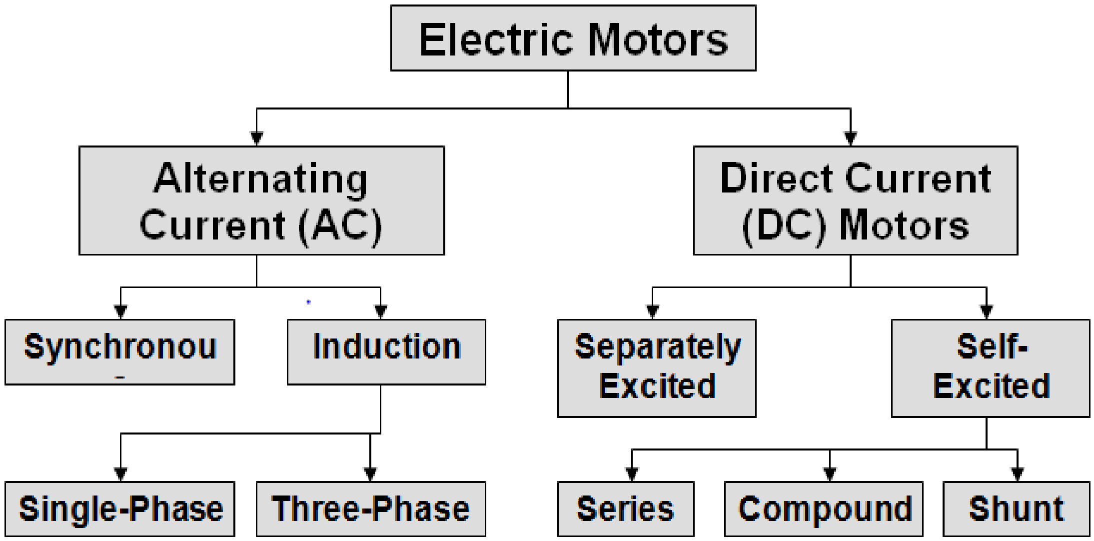
The applied voltage is adjusted by auto-transformer, to circulate rated current in the high voltage side. In a transformer, the primary m.m.f. is almost equal to the secondary m.m.f., therefore, a rated current in the H.V. winding causes rated current to flow in the L.V. winding

1.4. Types and operation of DC Machine

1.4.1. Introduction

Electric motors and generators are referred to as electric machines. Electricians are most frequently concerned with electric motors; due to their extensive application.The electric motor must be one of man's most useful inventions. In the manufacturing industries they are used in large numbers, to drive lathes, drilling and milling machines, augers, conveyors, cranes, hoists, lifts, fans and steel rolling equipment. In the process industries they are used to pump liquids and gases. They are used in transport to start engines,

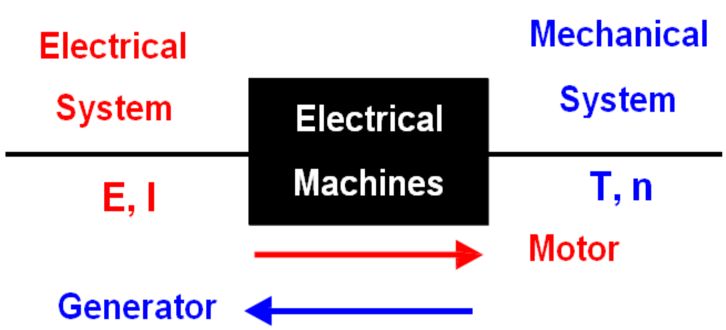
operate windscreen wipers, open and close windows and power electric vehicles. In domestic situations they are used in washing machines, clothes dryers, cookers, fridges, freezers, vacuum cleaners, food mixers, audio / video equipment, cameras, clocks etc.Electric motors are popular because they are compact, reliable, and cheap, need little attention, and are convenient to use. They can be provided in a wide range of sizes and can be designed to have different characteristics for various applications. Also, there is a readily available supply of electricity.



In these machines, conversion of energy results from the following two electromagnetic phenomena:

i. When a conductor moves in a magnetic field voltage is induced in the conductor (generator action)

ii. When a current –carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force (Motor action)



Note that the two systems in fig.above, electrical and mechanical, are different in nature.

- ✓ In electrical system the primary quantities involved are voltage & current
- ✓ While in mechanical system, the analogous quantities are torque & speed.

The coupling medium between these different systems is the magnetic field.The dc machines are versatile and extensively used in industry. A wide variety of volt-ampere or torque-speed characteristics can be obtained from various connections of the field winding. Dc machines can work as generators, motors & brakes.

- ✓ In the generator mode the machine is driven by a prime mover (such as a steam turbine or a diesel engine) with the mechanical power converted into electrical power.
- ✓ While in the motor mode, the machine drives a mechanical load with the electrical power supplied converted into mechanical power.
- ✓ In the brake mode, the machine decelerates on account of the power supplied or dissipated by it and, therefore, produces a mechanical braking action.

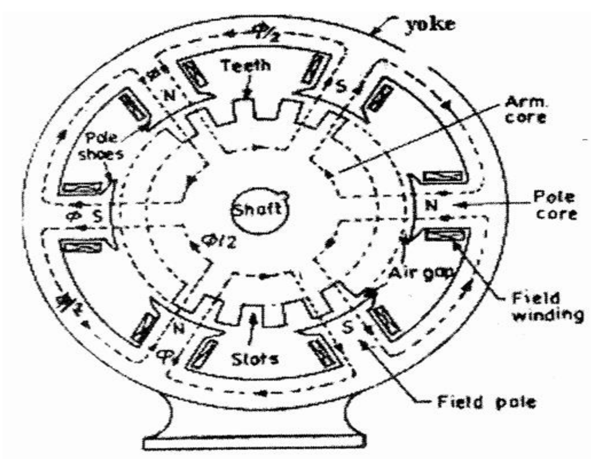
1.4.2. Construction

The dc machines used for industrial applications have essentially three major parts:

a) Field system (Stator)

b) Armature (Rotor) and

c) Commutator



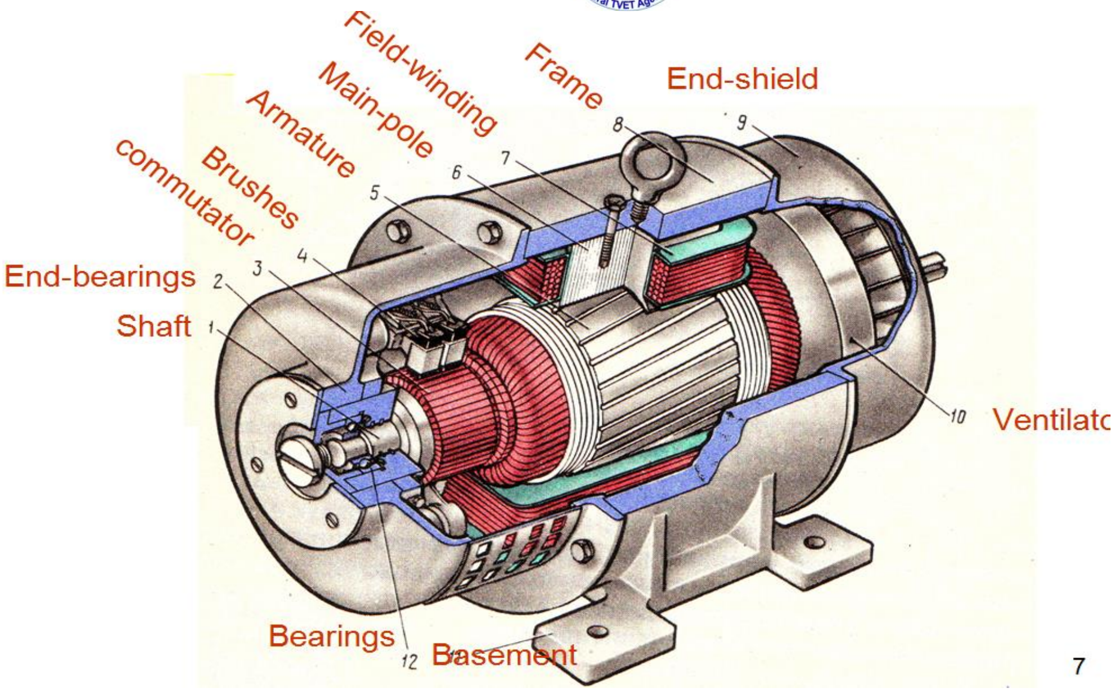


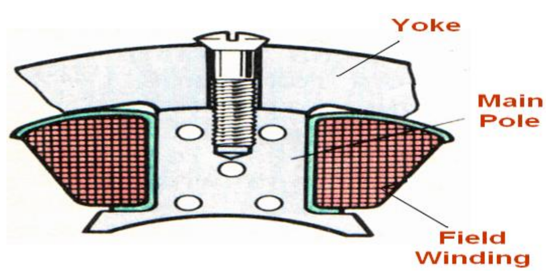
Fig.5.2. Cutaway view of DC Machines away view of DC Machines

a) Filled system

The field system is located on the stationary part of the machine called stator. The field system is designated for producing magnetic flux and, therefore, provides the necessary excitation for operation of machine.

The stator of dc machines comprises of

i. Frame(yoke)
ii. Main poles
iii. Inter-poles



- **Stator**

The stator of a dc machines consists of a frame or yoke, and poles, which support the field windings.

- The frame or yoke in addition to being a part of a magnetic circuit serves as mechanical support for entire assembly.

i. Yoke

Earlier, cast iron was used for the construction of yoke but it has been replaced by cast steel.

- This is because cast iron has saturation density of 0.8 Wb/m^2 while saturation occurs in cast steel at density of approximately 1.5 Wb/m^2.
- Thus, the cross section of the cast steel frame or yoke is half that of iron cast and hence cast steel is used in case it is desired to reduce the weight of machine.
- Fabricated steel yokes are commonly used, as they are economical and have consistent magnetic & mechanical properties used.

ii. Main poles

- Poles are made of sheet steel laminations of 1,0 to 1,2mm thickness (nowadays the thickness becomes 0.4-0.5mm)
- The pole shoes support the field coils placed on the pole body and also spread the total flux over a greater area, thereby reduce the air gap reluctance and giving the desired flux distribution to limit saturation in the teeth of the armature.
- The poles are secured to the yoke by means of bolts. In small machines the pole are built of steel forgings, bolted directly to the yoke.
- In case of machines having compensating windings, the pole face is slotted to accommodate the windings.

iii. Interpole

- In addition to the main poles, modern direct current machines are also provided with interlopes with windings on them in order to improve commutation under loaded conditions.
- They are arranged midway between the mains poles and are bolted to the yolk.
- Laminated interlopes are used in machine with sever commutator problems.
- For small and medium size machines they could be solid

b) Armature

- The armature is the rotating part (rotor) of the dc machine where the process of electromechanical energy conversion takes pace.
- The armature is a cylindrical body, which rotates between the magnetic poles.
- The armature and the field system are separated from each other by an air gap.

The armature consists of:

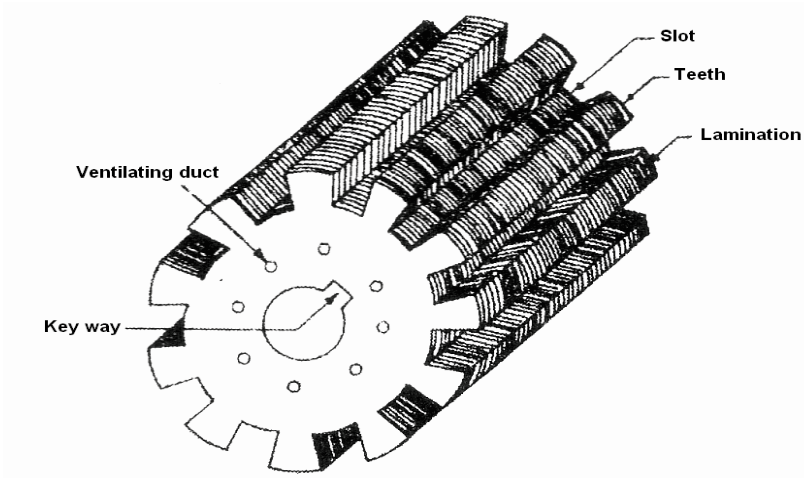
- ✓ Armature core with slots and
- ✓ Armature winding accommodated in slots

- ✓ The armature of the dc machines is a cylindrical shape, consists of slots, teeth, winding and the core.
- ✓ The purpose of the armature is to rotate the conductors in the uniform magnetic field and to induce an alternating emf in its winding.
- ✓ The armature core is normally made from high permeability silicon- steel laminations of 0.4-0.5mm thickness, which are insulated from one another by varnish or ceramic insulation.

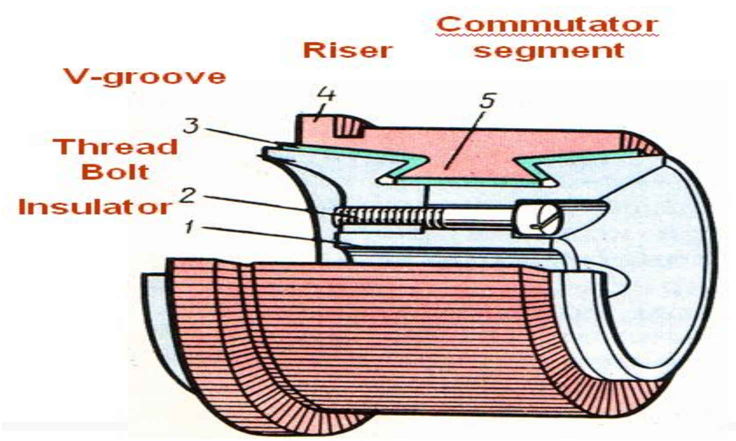
The use of high grade steel is made:

- ✓ To keep hysteresis loss low, which is due to cyclic change of magnetization caused by rotation of the core in the magnetic field and
- ✓ To reduce the eddy current in the core which are induced by the rotation of the core in the magnetic field
- ✓ In order to dissipate the heat produced by hysteresis and eddy current losses etc, ventilating ducts are provided.

By the fanning action of the armature, air is drawn in through these ducts, thus producing efficient ventilation.



- The commutator is mounte on the rotor of a dc machine and it performs with help of brushes a mechanical rectification of power from
  - ✓ ac to dc in case of generators and
  - ✓ dc to ac in case of motors.

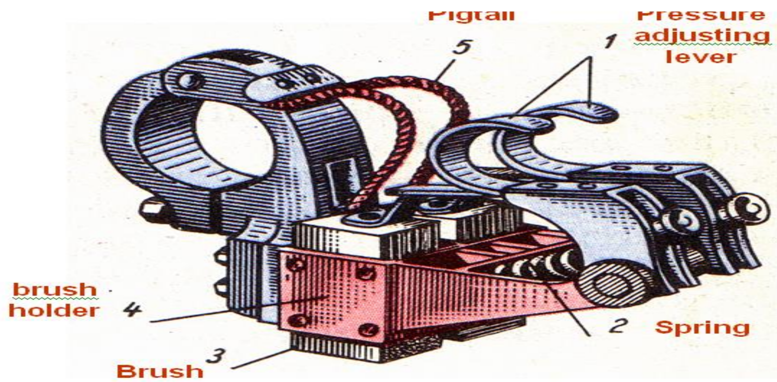


- **Brushes And Brush Holder**

✓ Brushes are needed to collect the current from the rotating commutator or to lead the current to it.

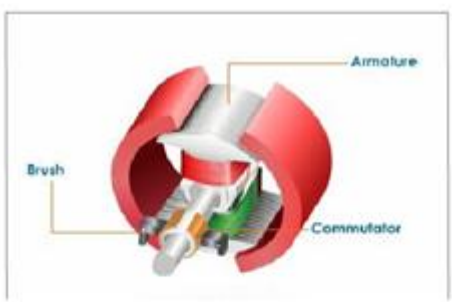
✓ Normally brushes are made up of carbon and graphite, so that while in contact with the commutator, the commutator surface is not spoiled.

- ✓ The brush is accommodated in the brush holder where a spring presses ita gains the commutator with pressure of 1,5 to 2,0 Ncm^2
- ✓ A twisted flexible copper conductor called pigtail securely fixed in to the brush is used to make the connection between the brush and its brush holder.
- ✓ Normally brush holders used in dc machines are of box type.
- ✓ The numbers of brush holders usually equal to the number of main poles in dc machines.



1.4.3. Dc Motor Principle

As showed in the illustration below the stator consists of a permanent magnet, a DC voltage is applied to the brushes, a current flows into the rotor coil. The excitation field applies a force to the rotor coil and a torque is exerted, the rotor starts rotating. When passing the horizontal position, the commutator reverses the polarity of the current, but since position of the rotor is also reversed the current flows in the same direction, exerting the torque in the same direction.



Machine that converts dc power into mechanical energy is known as dc motor. Its operation is based on the principle that when a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force. The direction of the force is given by Fleming 's left hand rule.

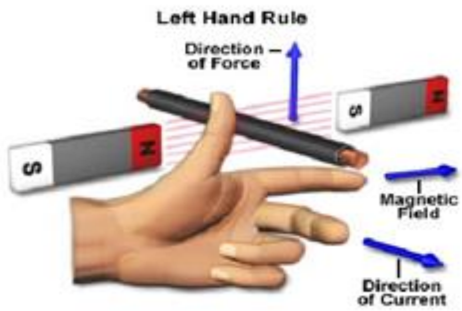
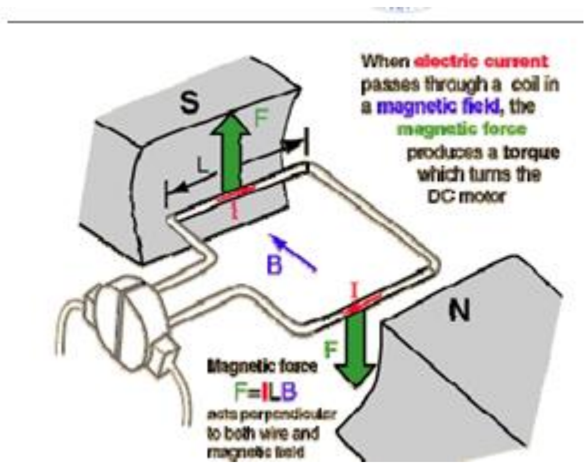


Fig. 5.2.2 Fleming Left Hand Rule



1.4.4. Working of D.C. Motor

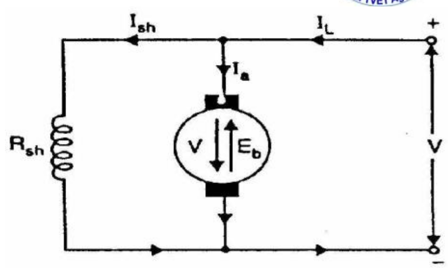
When the terminals of the motor are connected to an external source of d.c. supply:

(i) The field magnets are excited developing alternate N and S poles;
(ii) The armature conductors carry ^currents.

All conductors under N-pole carry currents in one direction while all the conductors under S-pole carry currents in the opposite direction. Suppose the conductors under N-pole carry currents into the plane of the paper and those under S-pole carry currents out of the plane of the paper

1.4.5. Back or Counter E.M.F.

When the armature of a D.C. motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and hence e.m.f. is induced in them as in a generator. The induced e.m.f. acts in opposite direction to the applied voltage Consider a shunt wound motor shown in.

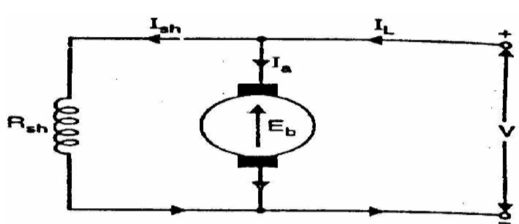


When d.c. voltage V is applied across the motor terminals, the field magnets are excited and armature conductors are supplied with current. Therefore, driving torque acts on the armature which begins to rotate. As the armature rotates, back e.m.f. Eb is induced which opposes the applied voltage V. The applied voltage V has to force current through the armature against the back e.m.f. Eb. The electric work done in overcoming and causing the current to flow against Eb is converted into mechanical energy developed in the armature. It follows, therefore, that energy conversion in a d.c. motor is only possible due to the production of back e.m.f. Eb.
Net voltage across armature circuit = V - Eb
If Ra is the armature circuit resistance, then Ia =V –Eb/Ra
Since V and Ra are usually fixed, the value of Eb will determine the current drawn by the motor. If the speed of the motor is high, then back e.m.f.

- **Significance of Back E.M.F.**

The presence of back e.m.f. makes the d.c. motor a self-regulating machine i.e.,it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the la. Armature current Ia=V-Ea/Ra

Voltage Equation of D.C. Motor



- Let in a d.c. motor
- V = applied voltage
- Eb = back e.m.f.
- Ra = armature resistance
- Ia = armature current

- Since back e.m.f. Eb acts in opposition to the
- Applied voltage V, the net voltage across the armature circuit is V- Eb. The
- armature current Ia is given by
- V-Ea/Ra
- V=Ea+IaRa

1.4.6. Types of D.C. Motors Shunt

i. Shunt Wound Motor

In shunt wound motor the field winding is connected in parallel with the armature. The current through the shunt field winding is not the same as the armature current. Shunt field windings are designed to produce the necessary m.m.f. by means of a relatively large number of turns of wire having high resistance. Therefore, shunt field current is relatively small compared with the armature current. Application of d,c shunt motor fans, blowers, centrifugal pumps, machine tools

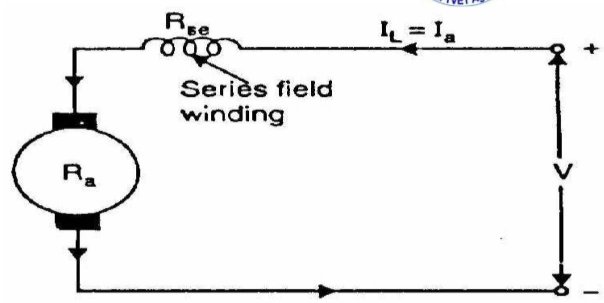
✓ Characteristics of Shunt Motors

Shows the connections of a D.C. shunt motor. The field current Ish is constant since the field winding is directly connected to the supply voltage V which is assumed to be constant. Hence, the flux in a shunt motor is approximately constant.00 for short periods125% to 200% full load torque starting torque

ii. Series Wound Motor

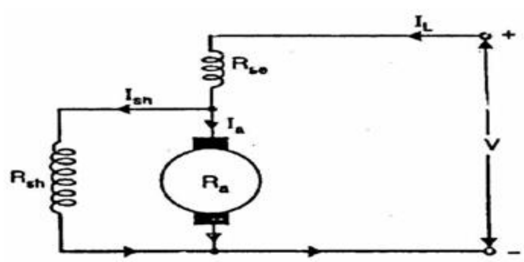
In series wound motor the field winding is connected in series with the armature [See Fig.below]. Therefore, series field winding carries the armature current. Since the current passing through a series field winding is the same as the armature current, series field

windings must be designed with much fewer turns than shunt field windings for the same m.m.f.Therefore, a series field winding has a relatively small number of turns of thick wire and, therefore, will possess a low resistance.

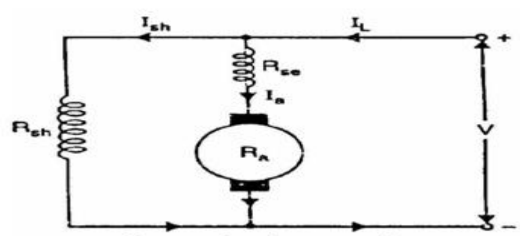


iii. Compound Wound Motor

Compound wound motor has two field windings; one connected in parallel with the armature and the other in series with it. There are two types of compound motor connections (like generators). When the shunt field winding is directly connected across the armature terminals it is called short-shunt connection. When the shunt winding is so connected that it shunts the series combination of armature and series field it is called long-shunt connection.



Short-shunt connection



Long-shunt connection

- Performance is roughly between series-wound and shunt-wound
- Moderately high starting torque
- Moderate speed control
- Inherently controlled no-load speed
  - safer than a series motor where load may be disconnected
    e.g. cranes

1.4.7. Starting Methods of DC Motor

If we apply full voltage to a stationary DC motor, the starting current in thearmature will be very high and we run the risk of

- Burning out the armature;
- Damaging the commutator and brushes, due to heavy sparking;
- Overloading the feeder;

– Snapping off the shaft due to mechanical shock;
– Damaging the driven equipment because of the sudden mechanical hammer blow.

All dc motors must, therefore, be provided with a means to limit the starting current to reasonable values, usually between 1.5 and twice full-load current. One solution is to connect a rheostat in series with the armature. The resistance is gradually reduced as the motor accelerates and is eventually eliminated entirely.

1.5. Dc Generator

An electric generator is a machine that converts mechanical energy into electrical energy. An electric generator is based on the principle that whenever flux is cut by a conductor, an e.m.f. is induced which will cause a current to flow if the conductor circuit is closed. The direction of induced e.m.f. (and hence current) is given by Fleming's right hand rule. Therefore, the essential components of a generator are:

(a) a magnetic field
(b) conductor or a group of conductors
(c) Motion of conductor w.r.t. magnetic field

1.5.1. Construction of d.c. Generator

The d.c. generators and d.c. motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a d.c. generator or motor. Any d.c. generator can be run as a d.c. motor and vice-versa. All d.c. machines have five principal components viz. (i) field system (ii) armature core (iii) armature winding (iv) commutator (v)brushes.

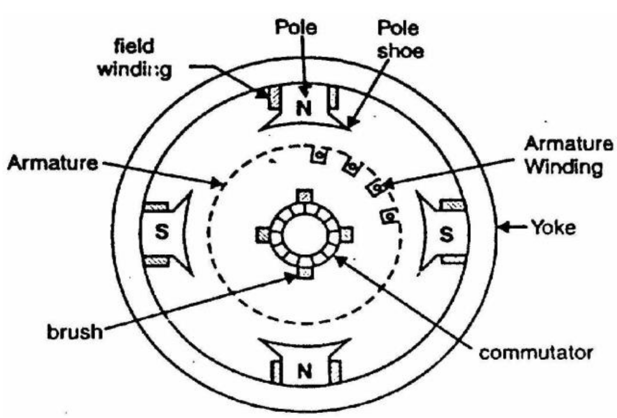


Fig. 5.3.1 d.c. generators

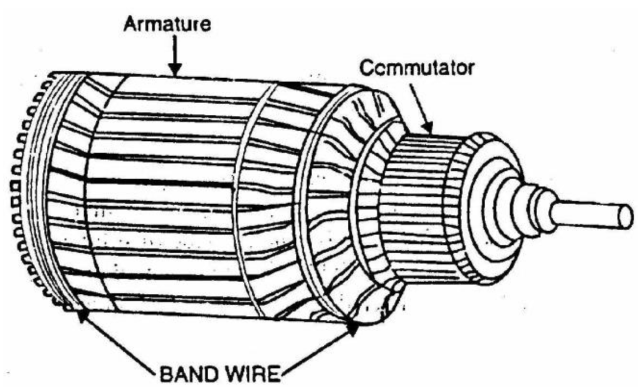
✓ **Field system**

The function of the field system is to produce uniform magnetic field within which the armature rotates. It consists of a number of salient poles (of course, even number) bolted to the inside of circular frame (generally called yoke). The m.m.f. developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame.

Practical d.c. machines have air gaps ranging from 0.5 mm to 1.5 mm. Since armature and field systems are composed of materials that have high permeability, most of the m.m.f. of field coils is required to set up flux in the air gap. By reducing the length of air gap, we can reduce the size of field coils (i.e. number of turns).

✓ **Armature core**

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of slotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in Fig below. The laminations (See Fig. below) are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature "teeth".



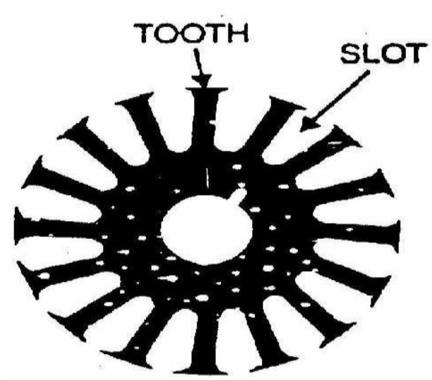


Fig. 5.3.2. Armature Core

1.5.2. Armature winding

The slots of the armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding. This is the winding in which “working” e.m.f. is induced. The armature conductors are connected in series-parallel; the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current. The armature winding of a d.c. machine is a closed-circuit winding; the conductors being connected in a symmetrical manner forming a closed loop or series of closed loops.

1.5.3. Commutator

A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes. The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine. The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding. Depending upon the manner in which the armature conductors are connected to the commutator segments, there are two types of armature winding in a d.c. machine viz., (a) lap winding (b) wave winding

1.5.4. Brushes

The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator. The brush pressure is adjusted by means of adjustable springs (See Fig. 5.4.3). If the brush pressure is very large, the friction produces heating of the commutator and the brushes. On the other hand, if it is too weak, the imperfect contact with the commutator may produce sparking.

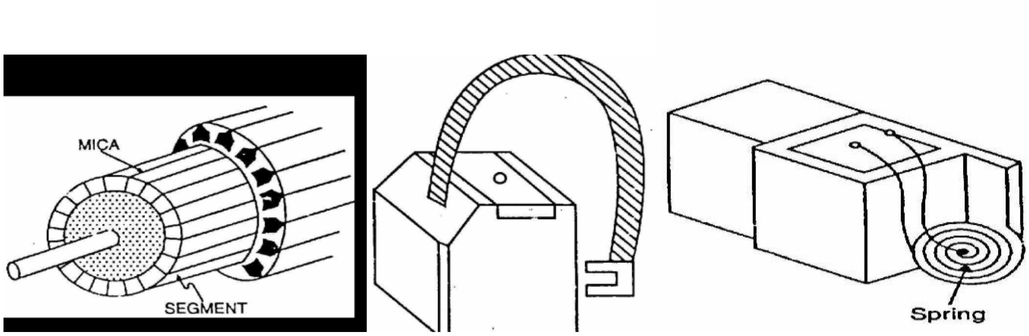


Fig. 5.4.3.

Multi pole machines have as many brushes as they have poles. For example, a 4-pole machine has 4 brushes. As we go round the commutator, the successive brushes have positive and negative polarities. Brushes having the same polarity are connected together so that we have two terminals viz., the +ve terminal and the -ve terminal.

1.6. Types and operation of AC Machines

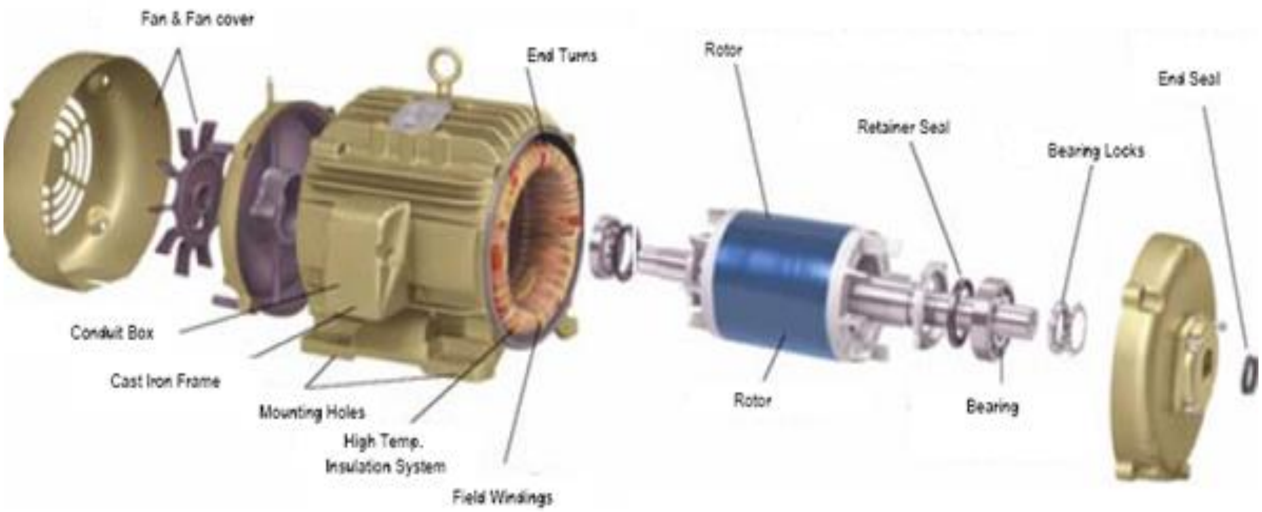
1.6.1. Introduction

Ac machine are motor that convert a.c electrical energy to mechanical energy and generator that convert mechanical energy to a.c electrical energy. A set of three phase a.c voltage is induced in to the stator armature winding of an a.c machine by the rotor field winding (generator action). AC machines, also known as induction machines, use ac (alternating current i.e. sinusoidal) voltages and currents to establish the required magnetic fields, and utilize ac values at its terminals .Induction machines are the most widely used type of electric machine, and can range in size from small sub one-horsepower machines to large many thousands of horsepower machines. The larger ac machines use what is known as three phase power and will be the type of machine we will focus on.

When a single-phase supply is connected to a single stator winding it provides an alternating rather than a rotating magnetic field and the rotor will not turn. However, single-phase motors will run successfully provided that an initial start is given to the rotor. They will run in either direction depending on the direction of the initial start. This initial start is produced by providing an artificial phase, which simulates a two-phase supply. In order to create this artificial phase, single-phase induction motors are manufactured with two separate windings. These windings are connected in parallel with each other during starting. One winding is called the Main Winding (or Run Winding),while the other winding is called the Auxiliary Winding (or Start Winding). The main winding is always left in circuit, but the auxiliary winding may be disconnected once the motor has started.

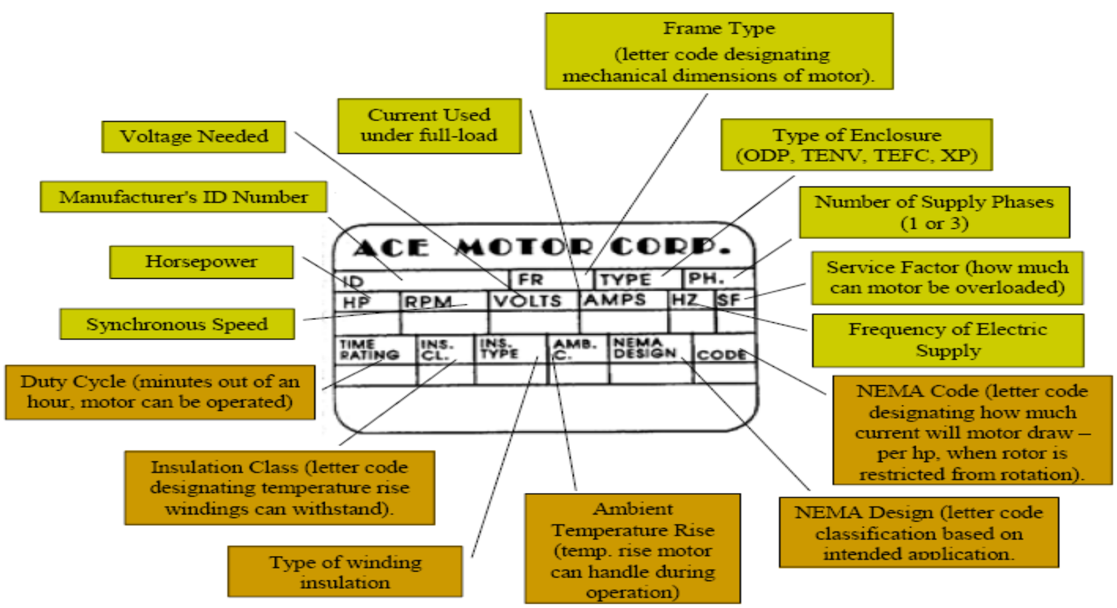
They are in common use, particularly in domestic, agricultural and commercial spheres. Single-phase induction motors cannot compete with the performance or efficiency of three-phase induction motors. They are more troublesome, mainly on account of the ancillary starting equipment required. They are also physically larger than equally rated three-phase motors.

1.6.2. Parts of Ac Motor



1.6.3. AC Motor Data Plate

Each motor has a plate mounted on its frame, with electrical and mechanical information.



1.6.4. Types of AC Motors

1.6.4.1. Single-phase Induction Motor

single phase a.c motors as the name suggests, these motors are used on single-phase supply. Single phase motors are the most familiar of all electric motors because they are extensively used in home appliances, shops, offices etc. It is true that single phase motors are less efficient substitute for 3-phase motors but 3-phase power is normally not available except in large commercial and industrial establishments. Since electric power was originally generated and distributed for lighting only, millions of homes were given single-phase supply. This led to the development of single-phase motors. Even where 3-phase mains are present, the single-phase supply may be obtained by using one of the three lines and the neutral. In this chapter, we shall focus our attention on the construction, working and characteristics of commonly used single-phase motors

- **Construction single phase induction motor**

A single phase induction motor is very similar to a 3-phase squirrel cage induction motor. It has (i) a squirrel-cage rotor identical to a 3-phase motor and (ii) a single-phase winding on the stator. Unlike a 3-phase induction motor, a single-phase induction motor is not self-starting but requires some starting means. The single-phase stator winding produces a magnetic field that pulsates in strength in a sinusoidal manner. The field polarity reverses after each half cycle but the field does not rotate. Consequently, the alternating flux cannot produce rotation in a stationary squirrel-cage rotor. However, if the rotor of a single-phase motor is rotated in one direction by some mechanical means, it will continue to run in the direction of rotation. As a matter of fact, the rotor quickly accelerates until it reaches a speed slightly below the synchronous speed. Once the motor is running at this speed, it will continue to rotate even though single-phase current is flowing through the stator winding. This method of starting is generally not convenient for large motors. Nor can it be employed fur a motor located at some inaccessible spot.

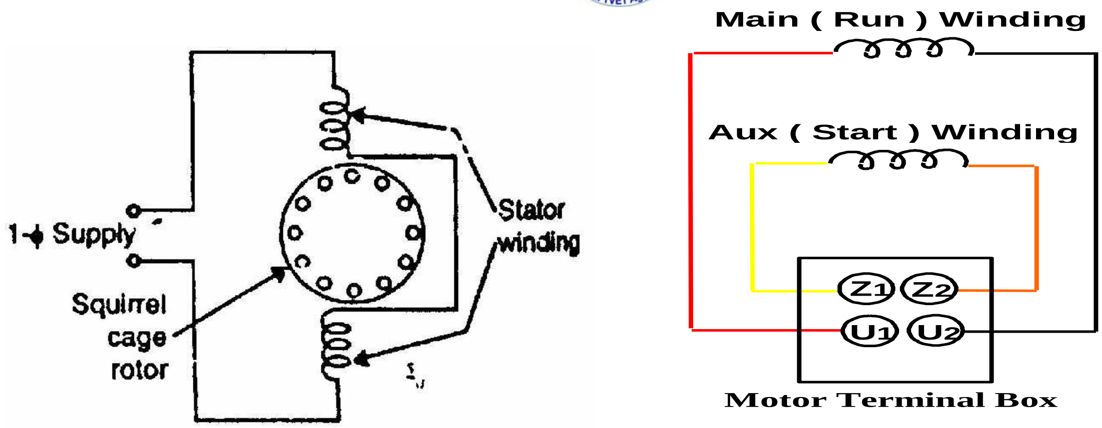


Fig 5.4.1. Single-phase induction motor

Having a squirrel cage rotor and a single phase distributed stator winding. Such a motor inherently docs not develop any starting torque and, therefore, will not start to rotate if the stator winding is connected to single-phase a.c. supply. However, if the rotor is started by auxiliary means, the motor will quickly attain me final speed.

- **Types of Single-Phase Motors**

Single-phase motors are generally built in the fractional-horsepower range and may be classified into the following four basic types:

(a) Single-phase induction motors
  (i) Split-phase type
  (ii) Capacitor type
  (iii) Shaded-pole type
(b) A.C. series motor or universal motor
(c) Repulsion motors
  (i) Repulsion-start induction-run motor
  (ii) Repulsion-induction motor

(a) Single-phase induction motors

i. split-phase induction motor

The stator of a split-phase induction motor is provided with an auxiliary or starting winding S in addition to the main or running winding M. The starting winding is located 90° electrical from the main winding and operates only during the brief period when the motor starts up. The two windings are so resigned that the starting winding S has a high resistance and relatively small reactance while the main winding M has relatively low resistance and large reactance consequently, the currents flowing in the two windings have reasonable phase difference c (25° to 30°)

ii. capacitor-start motor

The capacitor-start motor is identical to a split-phase motor except that the starting winding has as many turns as the main winding. Moreover, a capacitor C is connected in series with the starting winding .The value of capacitor is so chosen that Is leads Induction motor by about 80° (i.e., 75~ 80°)which is considerably greater than 25° found in split-phase motor . Consequently, starting torque (Ts = k Im Is sin &) is much more than that of a split-phase motor Again, the starting winding is opened by the centrifugal switch when the motor attains about 75% of synchronous speed. The motor then operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed

- **Characteristics of single phase capacitor-start motor**

Although starting characteristics of a capacitor-start motor are better than those of a split-phase motor, both machines possess the same running characteristics because the main windings are identical. The phase angle between the two currents is about 80° compared to about25° in a split-phase motor. Consequently, for the same starting torque, the current in the starting winding is only about half that in a split-phase motor. Therefore, the starting winding of a capacitor start motor heats up less quickly and is well suited to applications involving either frequent or prolonged starting periods.

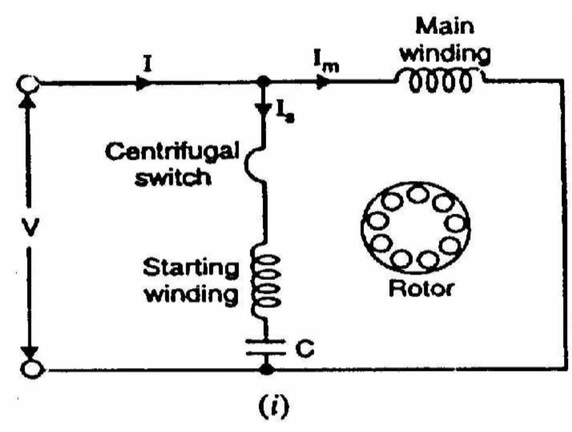


Fig 5.4.2. Capacitor-start motors

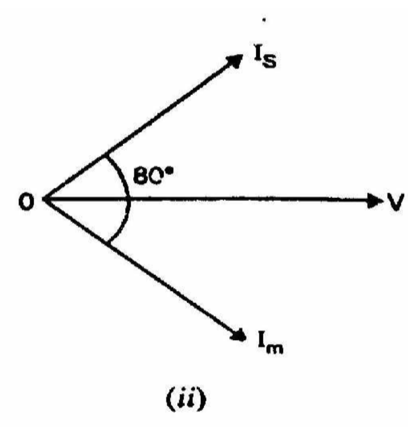


Fig 5.4.2. phaser diagram

Capacitor-start motors are used where high starting torque is required andwhere the starting period may be long e.g., to drive:

- compressors
- large fans
- Pumps
- high inertia loads

The power rating of such motors lies between 120 W and 7-5 kW.

iii. capacitor-start capacitor - run motor

This motor is identical to a capacitor-start motor except that starting winding is not opened after starting so that both the windings remain connected to the supply when running as well as at starting. Two designs are generally used. (i) In one design, a single

capacitor C is used for both starting and running as shown in Fig.(5.4.3. (i)). This design eliminates the need of a centrifugal switch and at the same time improve the power factor and efficiency of the motor.

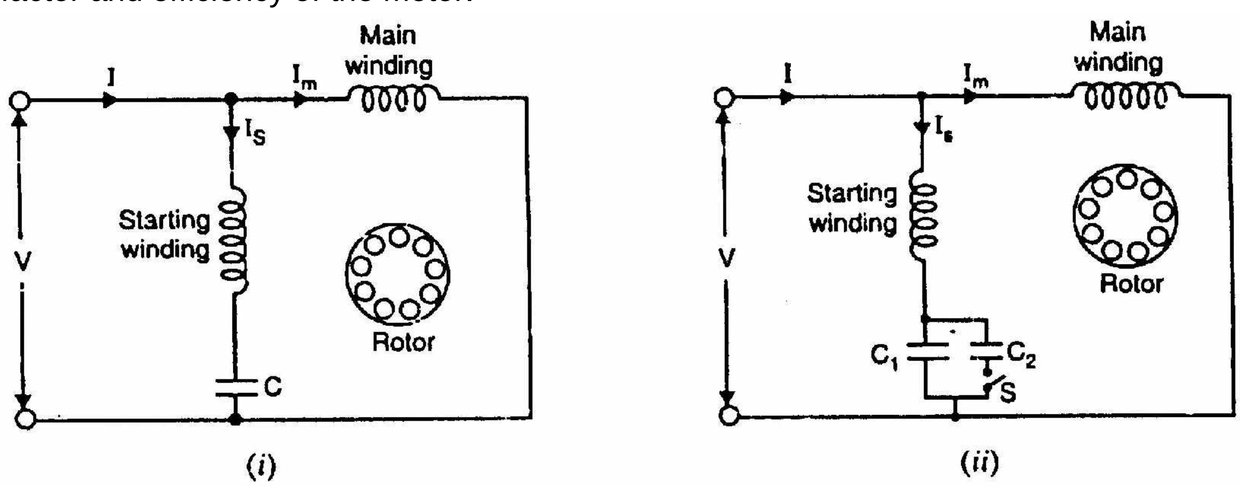
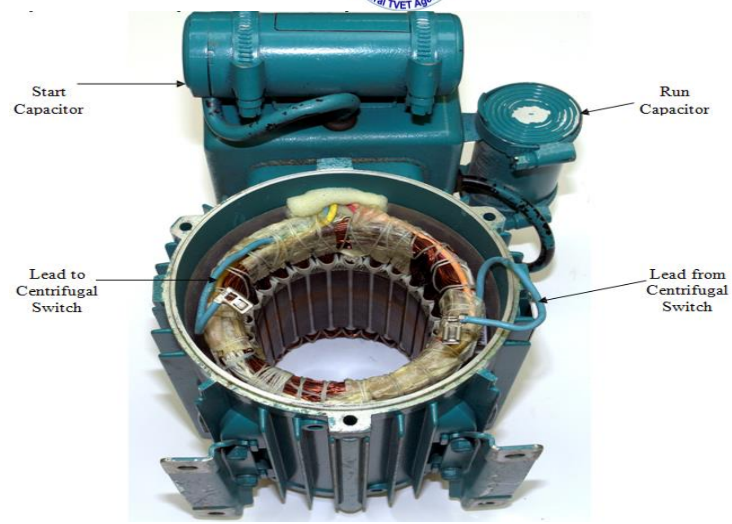


Fig 5.4.3. Capacitor-start capacitor - run motor



In the other design, two capacitors C1 and C2 are used in the starting winding as shown in Fig. 5.4.3. (ii)). The smaller capacitor C1 required for optimum running conditions is permanently connected in series with the starting winding. The much larger capacitor C2 is connected in parallel withC1 for optimum starting and remains in the circuit during starting. The starting capacitor C1 is disconnected when the motor approaches about 75%of synchronous speed. The motor then runs as a single-phase induction motor

iv. shaded-pole motor

The shaded-pole motor is very popular for ratings below 0.05 H.P.(~ 40 W) because of its extremely simple construction. It has salient poles on the stator excited by single-phase supply and a squirrel cage rotor as shown in Figure 5.2.4. A portion of each pole is surrounded by a short-circuitedturn of copper strip called shading

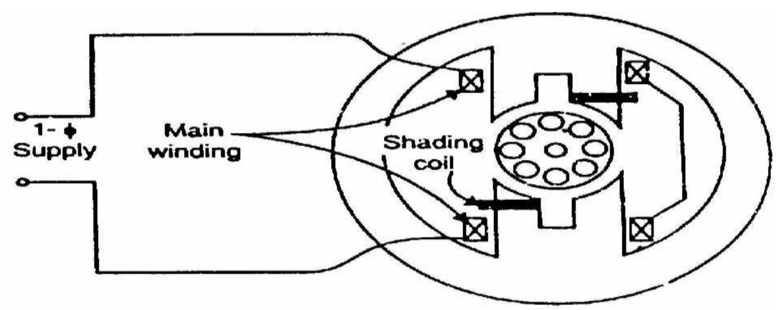


Figure 5.4.4. Shaded-pole motor

- **Characteristics shaded-pole motor**

✓ The salient features of this motor are extremely simple construction and absence of centrifugal switch.

✓ Since starting torque, efficiency and power factor are very low, these motors are only suitable for low power applications e.g., to drive:
  - small fans
  - toys
  - hair driers
  - desk fans etc.

The power rating of such motors is up to about 30 W.

(b) A.c series motor or universal motor

A d.c. series motor will rotate in the same direction regardless of the polarity of the supply. One can expect that a d.c. series motor would also operate on a single-phase supply. It is then called an a.c. series motor. However, some changes must be made in a d.c. motor that is to operate satisfactorily on a.c. supply.

- **Operation of universal motor**

When the motor is connected to an a.c. Supply, the same alternating current flows through the field and armature windings. The field winding produces an alternating flux that reacts with the current flowing in the armature to produce a torque. Since both armature current and flux reverse simultaneously, the torque always acts in the same direction. It may be noted that no rotating flux is produced in this type of machines; the principle of operation is the same as that of a d.c. series motor.

- **Characteristics of universal motor**

The operating characteristics of an a.c. series motor are similar to those of a d.c. series motor.

- The speed increases to a high value with a decrease in load. In very small series motors, the losses are usually large enough at no load that limits the speed to a definite value (1500 - 15,000 r.p.m.).
- The motor torque is high for large armature currents, thus giving a high starting torque.
- At full-load, the power factor is about 90%. However, at starting or when carrying an overload, the power factor is lower

- **Applications of universal motor**

The fractional horsepower a.c. series motors have high-speed (and corresponding small size) and large starting torque. They can, therefore, be used to drive:

- high-speed vacuum cleaners
- sewing machines
- electric shavers
- drills
- machine tools etc

c) Single-Phase Repulsion Motor

A repulsion motor is similar to an a.c. series motor except that brushes are not connected to supply but are short-circuited [See Fig.5.2.5). Consequently, currents are induced in the armature conductors by transformer action. the field structure has non-salient pole construction. By adjusting the position of short-circuited brushes on the commutator, the starting torque can be developed in the motor.

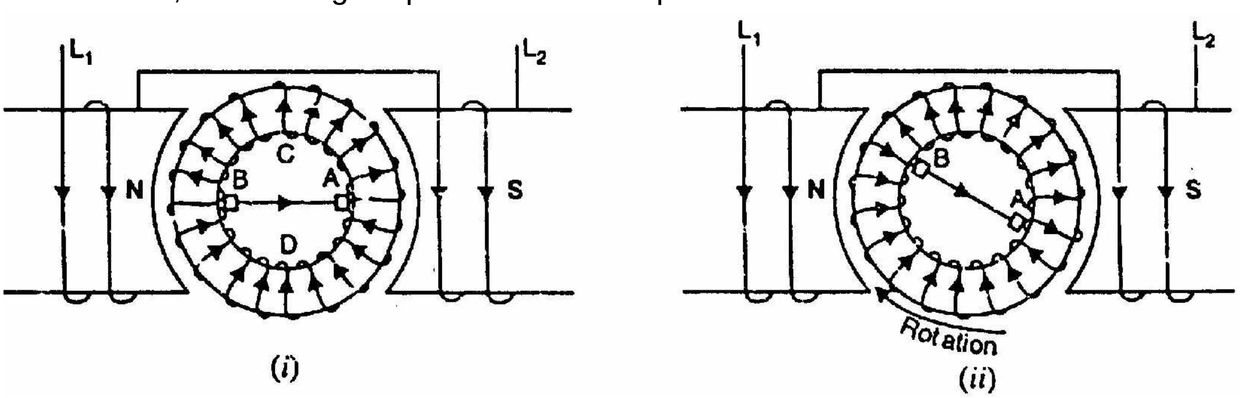


Fig. 5.4.5. repulsion motor

- **Construction Single-Phase Repulsion Motor**

The field of stator winding is wound like the main winding of a split-phase motor and is connected directly to a single-phase source. The armature or rotor is similar to a d.c. motor armature with drum type winding connected to a commutator (not shown in the figure). However, the brushes are not connected to supply but are connected to each other or short-circuited. Short-circuiting the brushes effectively makes the rotor into a type of squirrel cage. The major difficulty with an ordinary single-phase induction motor is the low starting torque. By using a commutator motor with brushes short-circuited, it is possible to vary the starting torque by changing the brush axis. It has also better power factor than the conventional single-phase motor.

- **Characteristics of single phase repulsion motor**

- ✓ The repulsion motor has characteristics very similar to those of an a.c. series motor i.e., it has a high starting torque and a high speed at no load.
- ✓ The speed which the repulsion motor develops for any given load will depend upon the position of the brushes.
- ✓ In comparison with other single-phase motors, the repulsion motor has a high starring torque and relatively low starting current.

1.6.4.2. The three-phase induction motors

- **Introduction**

The three-phase induction motors are the most widely used electric motors in industry. They run at essentially constant speed from no-load to full-load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. We usually prefer d.c. motors when large speed variations are required. Nevertheless, the 3-phase induction motors are simple, rugged, low-priced, easy to maintain and can be manufactured with characteristics to suit most industrial requirements. In this chapter, we shall focus our attention on the general principles of 3-phase induction motors.

Like any electric motor, a 3-phase induction motor has a stator and a rotor. The stator carries a 3-phase winding (called stator winding) while the rotor carries a short-circuited winding (called rotor winding). Only the stator winding is fed from 3-phase supply. The rotor winding derives its voltage and power from the externally energized stator winding through electromagnetic induction and hence the name. The induction motor may be considered to be a transformer with a rotating secondary and it can, therefore, be described as a “transformer type” a.c. machine in which electrical energy is converted into mechanical energy.

- **Advantages 3-phase induction motor**

  - ✓ It has simple and rugged, almost un breakable construction.
  - ✓ It is relatively cheap.
  - ✓ It requires little maintenance.
  - ✓ It has high efficiency and reasonably good power factor.
  - ✓ It has self starting torque

- **Disadvantages**

  - ✓ It is essentially a constant speed motor and its speed cannot be changed easily.
  - ✓ Its starting torque is inferior to d.c. shunt motor.

- **Construction of A 3-phase induction motor**

A 3-phase induction motor has two main parts (i) stator and (ii) rotor. The rotor is separated from the stator by a small air-gap which ranges from 0.4mm to 4mm, depending on the power of the motor.

✓ **Stator**

It consists of a steel frame which encloses a hollow, cylindrical core made up of thin laminations of silicon steel to reduce hysteresis and eddy current losses. A number of evenly spaced slots are provided on the near periphery of the lamination A 3-phase induction motor. The insulated connected to form a balanced 3-phase star or delta connected circuit. The 3-phase stator winding is wound for a definite number of poles as per requirement of speed. Greater the number of poles, lesser is the speed of the motor and vice-versa. When 3-phase supply is given to the stator winding, a rotating magnetic field of constant magnitude is produced. This rotating field induces currents in the rotor by electromagnetic induction.

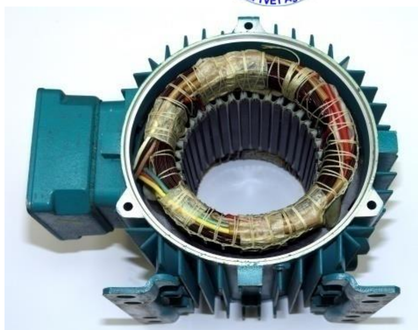


Fig.5.2.6. stator winding

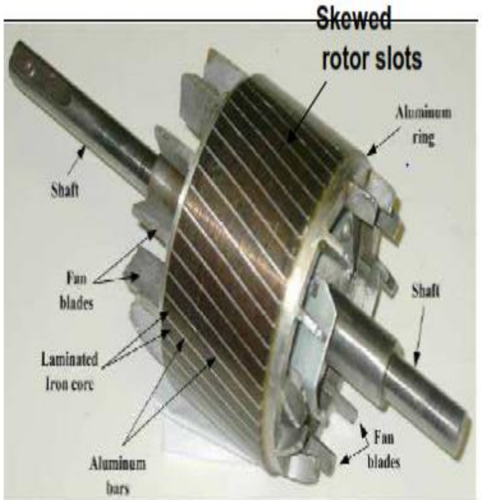
✓ **Rotor**

The rotor, mounted on a shaft, is a hollow laminated core having slots on its outer periphery. The winding placed in these slots (called rotor winding) may be one of the following two types:

(i) Squirrel cage rotor
(ii) Wound rotor

i. Squirrel cage rotor.

It consists of a laminated cylindrical core having parallel slots on its outer periphery. One copper or aluminum bar is placed in each slot. All these bars are joined at each end by metal rings called end rings. This forms a permanently short-circuited winding which is indestructible. The entire construction (bars and end rings) resembles a squirrel cage and hence the name. The rotor is not connected electrically to the supply but has current induced in it by transformer action from the stator. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors. Most of 3-phase induction motors use squirrel cage rotor as it has a remarkably simple and robust construction enabling it to operate in the most adverse circumstances. However, it suffers from the disadvantage of a low starting torque. It is because the rotor bars are permanently short-circuited and it is not possible to add any external resistance to the rotor circuit to have a large starting torque.



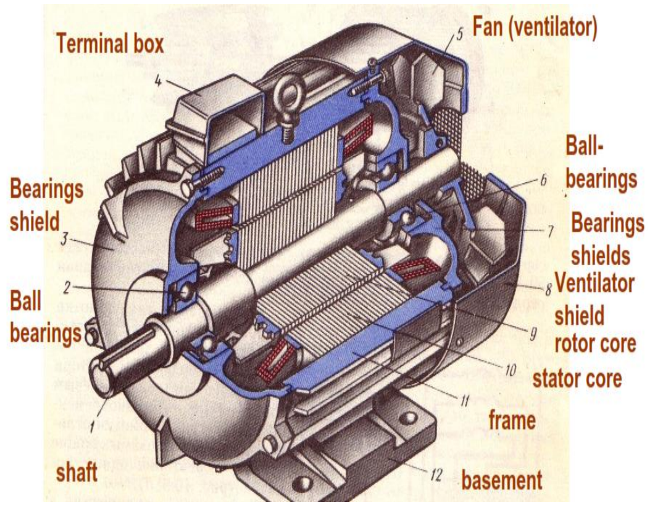


Fig. 5.4.7. squirrel cage rotor

ii. Wound rotor.

It consists of a laminated cylindrical core and carries a 3-phase winding, similar to the one on the stator. The rotor winding is uniformly distributed in the slots and is usually star-connected. The open ends of the rotor winding are brought out and joined to three insulated slip rings mounted on the rotor shaft with one brush resting on each slip ring. The three brushes are connected to a 3-phase star-connected rheostat. At starting, the external resistances are included in the rotor circuit to give a large starting torque. These resistances are gradually reduced to zero as the motor runs up to speed. The external resistances are used during starting period only. When the motor attains normal speed, the three brushes are short-circuited so that the wound rotor runs like a squirrel cage rotor.

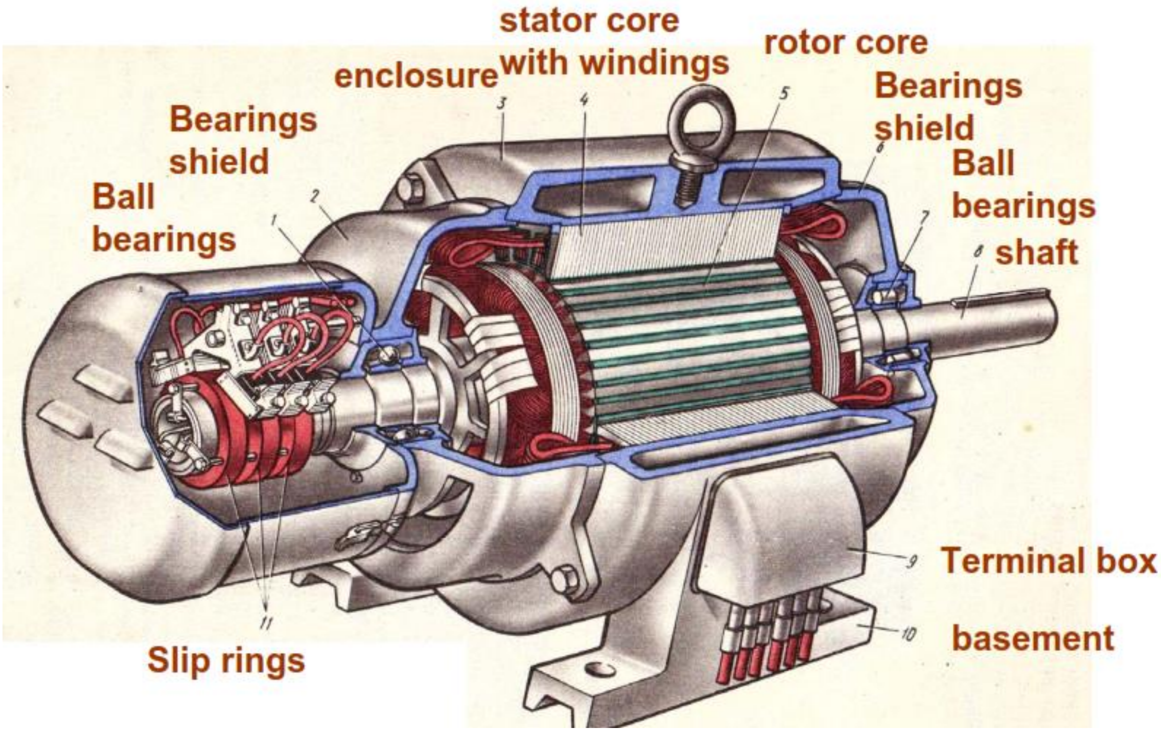


Fig. 5.4.8. wound rotor motor

- **Principle of Operation**

When a 3-phase winding is energized from a 3-phase supply, a rotating magnetic field is produced. This field is such that its poles do no remain in a fixed position on the stator but go on shifting their positions around the stator. For this reason, it is called a rotating Held. It can be shown that magnitude of this rotating field is constant and is equal to 1.5 m where □m is the maximum flux due to any phase .To see how rotating field is produced, consider a 2-pole,phase winding a The three phases X, Y and Z are energized from a 3-phase source and currents in these phases are indicated as Ix, Iy and Iz the fluxes produced by these currents are given by Here □m is the maximum flux due to any phase. Fig.5.2.9. shows the phasor

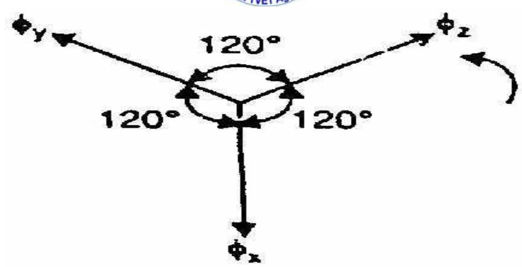


Fig 5.4.9 the phasor diagram

Consider a portion of 3-phase induction motor. The operation of the motor can be explained as when 3-phase stator winding is energized from a 3-phase supply, a rotating magnetic field is set up which rotates round the stator at synchronous speed Ns (= 120 f/P).The rotating field passes through the air gap and cuts the rotor conductors, which as yet, are stationary. Due to the relative speed between the rotating flux and the stationary rotor, e.m.f.s are induced in the rotor conductors. Since the rotor circuit is short-circuited, currents start flowing in the rotor conductors. The current-carrying rotor conductors are placed in the magnetic field produced by the stator. Consequently, mechanical force acts on the rotor conductors. The sum of the mechanical forces on all the rotor conductors produces a torque which tends to move the rotor in the same direction as the rotating field. The fact that rotor is urged to follow the stator field (i.e., rotor moves in the direction of stator field) can be explained by Lenz's law. According to this law, the direction of rotor currents will be such that they tend to oppose the cause producing them. Now, the cause producing the rotor currents is the relative speed between the rotating field and the stationary rotor conductors. Hence to reduce this relative speed, the rotor starts running in the same direction as that of stator field and tries to catch it.

- **Direction of rotating magnetic field**

The phase sequence of the three-phase voltage applied to the stator winding is X-Y-Z. If this sequence is changed to X-Z-Y, it is observed that direction of rotation of the field is reversed i.e., the field rotates counterclockwise rather than clockwise. However, the number of poles and the speed at which the magnetic field rotates remain unchanged. Thus it is necessary only to change the phase sequence in order to change the direction of rotation of the magnetic field. For a three-phase supply, this can be done by interchanging any two of the three lines. As we shall see, the rotor in a 3-phase induction motor runs in the same direction as the rotating magnetic field. Therefore, the direction of rotation of a 3-phase induction motor can be reversed by interchanging any two of the three motor supply lines.

- **Slip**

We have seen above that rotor rapidly accelerates in the direction of rotating field. In practice, the rotor can never reach the speed of stator flux. If it did, there would be no relative speed between the stator field and rotor conductors, no induced rotor currents and, therefore, no torque to drive the rotor. The friction and windage would immediately cause the rotor to slow down. Hence, the rotor speed (N) is always less than the suitor field speed (Ns). This difference in speed depends upon load on the motor. The difference between the synchronous speed Ns of the rotating stator field and the actual rotor speed N is called slip. It is usually expressed as a percentage of synchronous speed.

i.e. % age slip, s=Ns-N/Nsx100

i. The quantity Ns □□N is sometimes called slip speed.
ii. When the rotor is stationary (i.e., N = 0), slip, s = 1 or 100 %.
iii. In an induction motor, the change in slip from no-load to full-load is hardly 0.1% to 3% so that it is essentially a constant-speed motor

- **Rotor Current Frequency**

The frequency of a voltage or current induced due to the relative speed between a vending and a magnetic field is given by the general formula
Frequency=NP/120

where N = Relative speed between magnetic field and the winding
P = Number of poles

For a rotor speed N, the relative speed between the rotating flux and the rotor is Ns =N. Consequently, the rotor current frequency f' is given by; f'=(Ns-N)/120
S=Nsp/120=Sf
S=Ns-N/Ns

f=Nsp/120

- **Squirrel cage motors**

The speed of a squirrel cage motor is changed by changing the number of stator poles. Only two or four speeds are possible by this method. Two-speed motor has one stator winding that may be switched through suitable control equipment to provide two speeds, one of which is half of the other. For instance, the winding may be connected for either 4 or 8 poles, giving synchronous speeds of 1500 and 750 r.p.m. Four-speed motors are equipped with two separate stator windings each of which provides two speeds. The disadvantages of this method are:

i. It is not possible to obtain gradual continuous speed control.
ii. Because of the complications in the design and switching of the interconnections of the stator winding, this method can provide amaximum of four different synchronous speeds for any one motor

- **Wound rotor motors**

The speed of wound rotor motors is changed by changing the motor slip. This can be achieved by;

i. varying the stator line voltage
ii. varying the resistance of the rotor circuit
iii. inserting and varying a foreign voltage in the rotor circuit

- **Power Stages in an Induction Motor**

The input electric power fed to the stator of the motor is converted into mechanical power at the shaft of the motor. The various losses during the energy conversion are:

✓ **Fixed losses**

i. Stator iron loss
ii. Friction and windage loss

The rotor iron loss is negligible because the frequency of rotor currents under normal running condition is small.

✓ **Variable losses**

i. Stator copper loss
ii. Rotor copper loss

Electric power fed to the stator of an induction motor suffers losses and finally converted into mechanical power. The following points may be noted from the above diagram:

(a) Stator input, Pi = Stator output + Stator losses

= Stator output + Stator Iron loss + Stator Cu loss

(b) input, Pr = Stator output

It is because stator output is entirely transferred to the rotor through airgap by electromagnetic induction.

(c) Mechanical power available, Pm = Pr□□Rotor Cu loss

This mechanical power available is the gross rotor output and will produce a gross torque Tg.

(d) Mechanical power at shaft, Pout = Pin Friction and windage loss

Mechanical power available at the shaft produces a shaft torque Tsh. Clearly, $P_m - P_{out}$ = Friction and windage loss

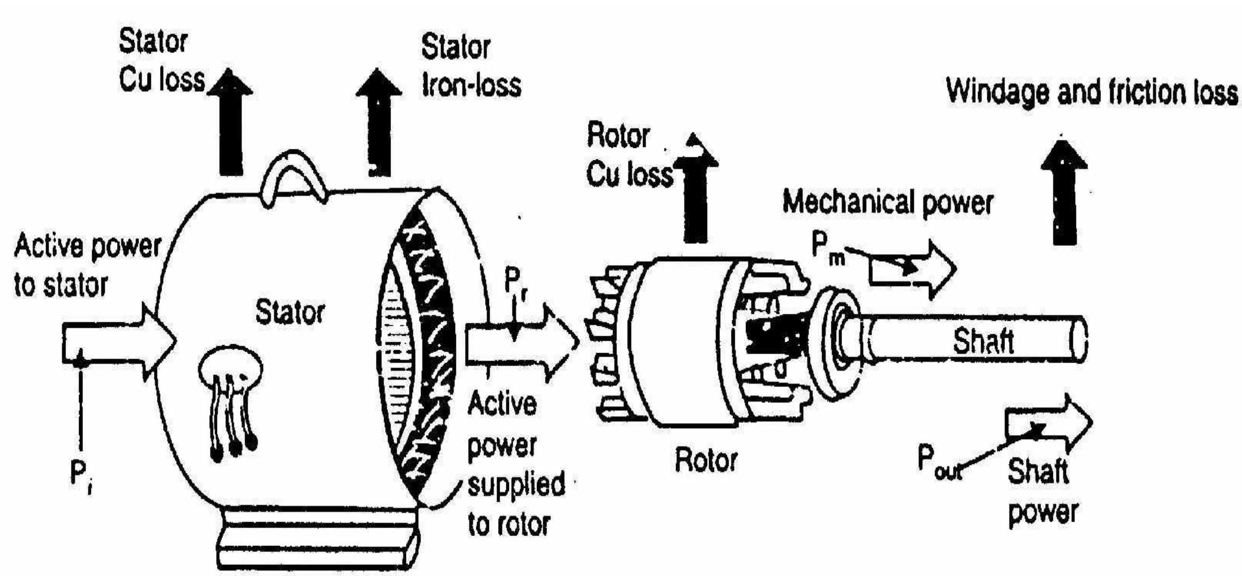


Fig. 5.4.10. stator and rotor loss

1.6.5. Ac generator

An electrical generator that converts mechanical energy to electrical energy in the form of alternating current. For reasons of cost and simplicity, most alternators use a rotating magnetic field with a stationary armature. Occasionally, a linear alternator or a rotating armature with a stationary magnetic field is used. In principle, any *AC electrical generator* can be called an alternator, but usually the term refers to small rotating machines driven by *automotive* and other *internal combustion engines.* An alternator that uses a permanent magnet for its magnetic field is called a magneto. Alternators in power stations driven by steam turbines are called turbo-alternators. Large 50 or 60 Hz three phase alternators in power plants generate most of the world's electric power, which is distributed by electric power**.** all electrical generators, whether dc or ac, depend upon the principle of magnetic induction. An emf is induced in a coil as a result of

- ✓ a coil cutting through a magnetic field, or
- ✓ a magnetic field cutting through a coil. As long as there is relative motion between a conductor and a magnetic field, a voltage will be induced in the conductor.

That part of a generator that produces the magnetic field is called the field. That part in which the voltage is induced is called the armature. For relative motion to take place between the conductor and the magnetic field, all generators must have two mechanical parts a rotor and a stator. The Rotor is the part that Rotates; the Stator is the part that remains Stationary. In a dc generator, the armature is always the rotor. In alternators, the armature may be either the rotor or stator.

1.6.5.1. Types of ac generators

Various types of alternating current generators are utilized today ,whoever they all perform the same basic function .the types discussed in the following paragraphs are typical of the more predominant ones in use .

i. Rotating armature alternator

In the rotating armature AC generator as illustrated in Fig 5.4.11, the stator provides a stationary electromagnetic field. The rotor, acting as the armature, rotates in the field, cutting the lines of force and producing the desired output voltage. The output voltage is taken from the rotor by the slip rings and brushes. One slip ring is attached to each end of the rotating loop.

The brushes make sliding electrical contact with the slip rings. The generator's AC output voltage can be transferred from the slip rings through the brushes to an external circuit.

Rotating armature alternator is essentially a loop rotating through a stationary magnetic fealties cutting action of the loop through the magnetic field generates ac in the loop. This ac is removed from the loop by means of slip rings and applied to an external load.

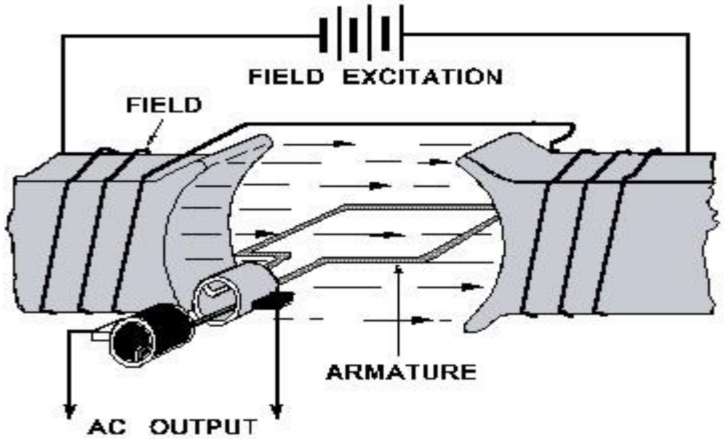


Fig 5.4.11 Rotating armature alternator

Rotating armature AC generators are typically used i n applications involving small amounts of power. With larger amounts of power, a great deal more current flow occurs through the slip rings and brushes. It is difficult and expensive to build slip rings and brushes to carry large amounts of current. Therefore, most large AC generators are rotating field generators.

ii. Rotating Field Generator

The rotating field AC generator as illustrated in Fig 5.4.12. is by far the most widely used generator. In this type of generator, direct current from a separate source is passed through wiendings on the rotor by means of slip rings and brushes.

This maintain ns a rotating electromagnetic field of fi xed polarity (similar to a rotating bar magnet). The rotating magnetic field of the rotor extends outward and cuts through the armature windings embedded in the surrounding stator. As the rotor turns, alternating voltages are induced in the windings because magnetic fields of first one polarity and then the other cut through them. Because the output power is take n from stationary windings, the output may be connected through fixed terminals. The advantage i n this type of construction is that larger amounts of currents can be handled because there are no sliding contacts and the whole output circuit is continuouslyinsulated.

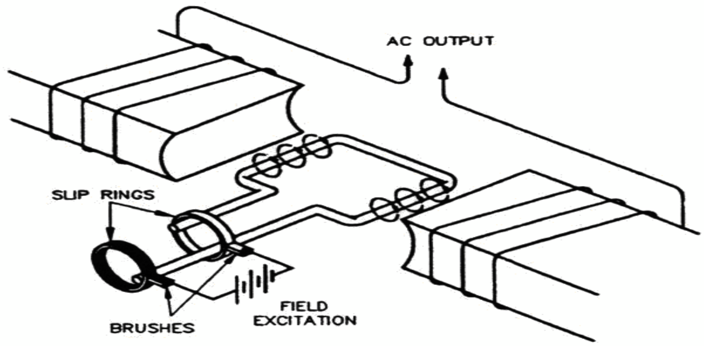


Figure 5.4.12. Rotating Field Generator

Slip rings and brushes are adequate for the DC field supply because the current level in the is much smaller than in than in the armature circuit.

The rotating-field alternator has a stationary armature winding and a rotating-field winding, view B The advantage of having a stationary armature winding is that the generated voltage can be connected directly to the load. A rotating armature requires slip rings and brushes to conduct the current from the armature to the load. The armature, brushes, and slip rings are difficult to insulate, and arc-overs and short circuits can result at high voltages. For this reason, high-voltage alternators are usually of the rotating-field type. Since the voltage applied to the rotating field is low voltage dc, the problem of high voltage arc-over at the slip rings does not exist. The stationary armature, or stator, of this type of alternator holds the windings that are cut by the rotating magnetic field. The voltage generated in the armature as a result of this cutting action is the ac power that

will be applied to the load. The stators of all rotating-field alternators are about the same. The stator consists of a laminated iron core with the armature windings embedded in this core as shown in figure 5.4.12.The core is secured to the stator frame.

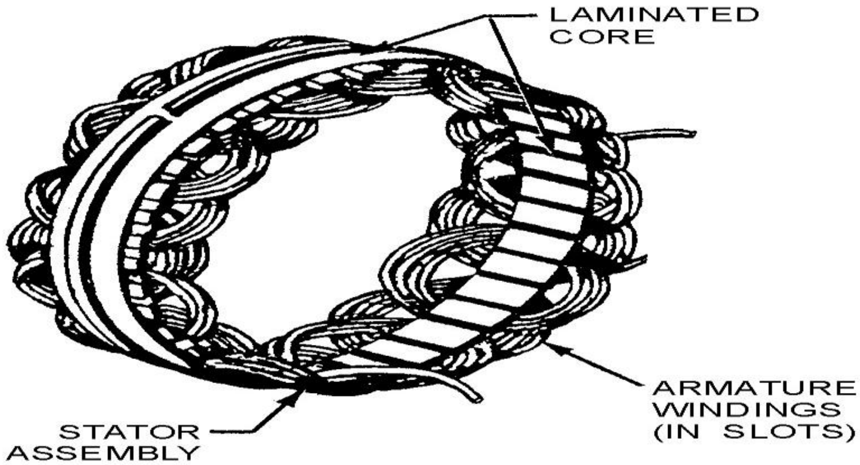


Fig. 5.4.12. stator frame

1.6.5.2. SINGLE-PHASE ALTERNATORS

A generator that produces a single, continuously alternating voltage is known as a SINGLE-PHASE alternator. All of the alternators that have been discussed so far fit this definition. The stator (armature) windings are connected in series. The individual voltages, therefore, add to produce a single-phase ac voltage. Fig.5.3.3. shows a basic alternator with its single-phase output voltage.

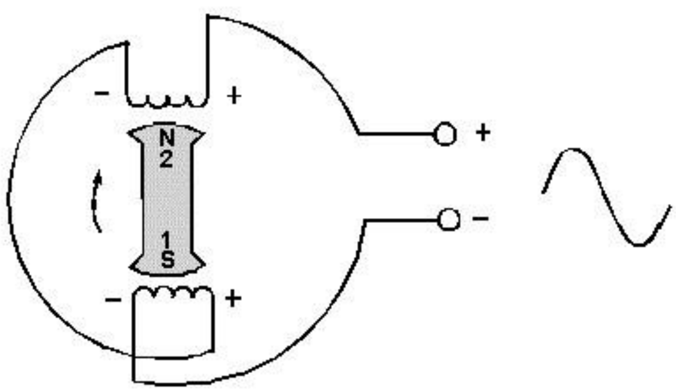


Figure 5.4.13. Single-phase alternator.

Now, it may be easier to think of the word *phase* as meaning voltage as in single voltage. The need for a modified definition of phase in this usage will be easier to see as we go along.

Single-phase alternators are found in many applications. They are most often used when the loads being driven are relatively light. The reason for this will be more apparent as we get into multiphase alternators (also called polyphase).

Power that is used in homes, shops, and ships to operate portable tools and small appliances is single-phase power. Single-phase power alternators always generate single-phase power. However, all single-phase power does not come from single-phase alternators. This will sound more reasonable to you as we get into the next subjects.

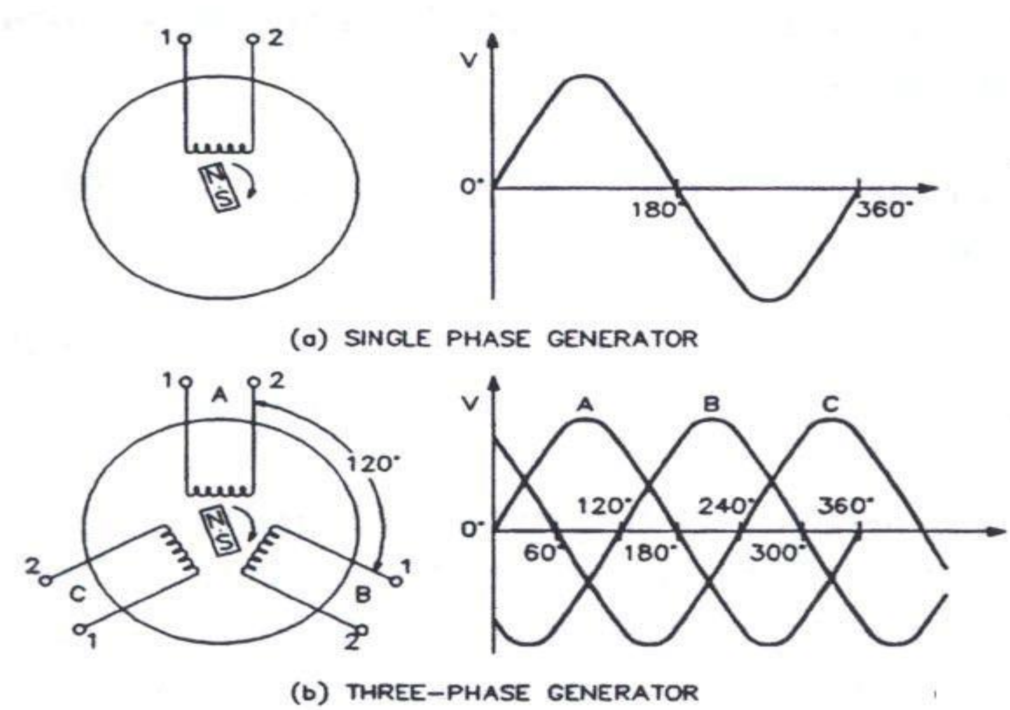


Figure 5.4.15. Voltage Output of a Three-Phase Generator

6. Insulation Resistance Testor (Megger)

If the motor is not put into operation immediately upon arrival, it is important **to protect it against external factors** like moisture, high temperature and impurities in order to avoid damage to the insulation. Before the motor is put into operation after a long period of storage, you have to measure the winding insulation resistance.

If the motor is kept in a place with high humidity, **a periodical inspection is necessary**. It is practically impossible to determine rules for the actual minimum insulation resistance value of a motor because resistance varies according to method of construction, condition of insulation material used, rated voltage, size and type. In fact, it takes many years of experience to determine whether a motor is ready for operation or not.

A general rule-of-thumb is 10 Megohm or more.

Insulation resistance value	Insulation level
2 Meg ohm or less	Bad
2-5 Meg ohm	Critical
5-10 Meg ohm	Abnormal
10-50 Meg ohm	Good
50-100 Meg ohm	Very good
100 Meg ohm or more	Excellent

The measurement of insulation resistance is carried out by means of a meg ohmmeter – high resistance range ohmmeter. This is how the test works: **DC voltage of 500 or 1000 V** is applied between the windings and the ground of the motor.

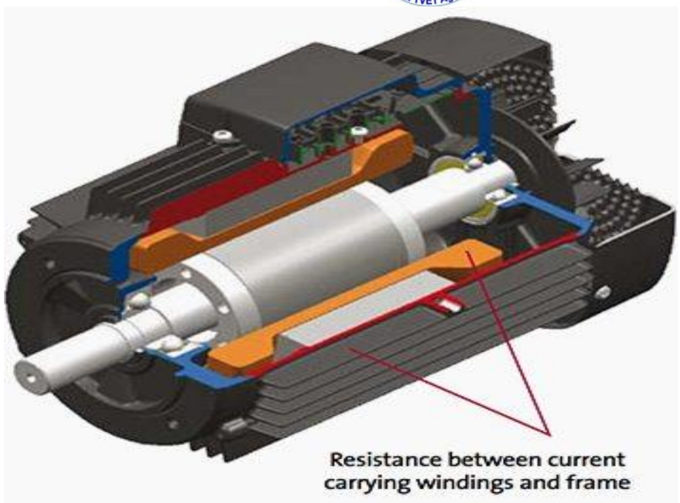


Figure 5.4.16: Ground insulation test of a motor

During the measurement and immediately afterwards, some of the terminals carry dangerous voltages and ***MUST NOT BE TOUCHED***.

Now, three points are worth mentioning in this connection: Insulation resistance, Measurement and Checking.

i. **Insulation resistance**

4. The minimum insulation resistance of new, cleaned or repaired windings with respect to ground is **10 Meg ohm or more**.
5. The minimum insulation resistance, **R**, is calculated by multiplying the **rated voltage U_n**, with the **constant factor 0.5 Meg ohm/kV**.

   For example: If the rated voltage is 690 V = 0.69 kV, the minimum insulation resistance is: 0.69 kV x 0.5 Meg ohm/kV = **0.35 Meg ohm**

ii. **Measurement**

- Minimum insulation resistance of the winding to ground is measured with **500 V DC**. The winding temperature should be **25°C ± 15°C**.
- Maximum insulation resistance should be measured with 500 V DC with the windings at a operating temperature of **80 – 120°C** depending on the motor type and efficiency.

iii. **Checking**

- If the insulation resistance of a new, cleaned or repaired motor that has been stored for some time is less then **10 Mohm**, the reason might be that the windings are humid and need to be dried.
- If the motor has been operating for a long period of time, the minimum insulation resistance **may drop to a critical level**. As long as the measured value does not fall below the calculated value of minimum insulation resistance, the motor can continue to run However, if it drops below this limit, **the motor has to be stopped immediately**, in order to avoid that people get hurt due to the high leakage voltage.

Self-Check -5	**Written Test**

Directions: Choose the best answer.

1. Which of the following is type of special transformer that is used only for motor control system to reduce the starting current of big motor?
   A. Auto transformer
   B. Welding transformer
   C. Power transformer
   D. All of the above
2. From the given alternative one is not included in instrumentation transformer
   A. Current transformer
   B. Voltage transformer
   C. Auto transformer
   D. All of the above
3. A type of three phase transformer which is commonly used for stepping up to a high voltage.
   A. Δ –Y connection
   B. Y – Δ connection
   C. Δ – Δ connection
   D. All of the above
4. The primery and secondary voltage is 220v and 110v respectively, Calculate the secondary number of turn if the primery turn is 100 turns.
   A. 200 turns
   B. 100 turns
   C. 60 turns
   D. 50 turns
5. If N2 < N1 then the transformer is known as
   A. step-up transformer
   B. step-down transformer
   C. A and B
   D. None of the above
6. _______ convert a.c electrical energy to mechanical energy?
   A. Single phase motor
   B. Three phase motor
   C. Dc motor
   D. A and B
7. _______ is the advantage of a three phase induction motor?
   A. It has self starting torque
   B. Little maintenance
   C. It is relatively cheep
   D. All
8. One is not a type of single phase motor?

A. Shaded pole motor
B. Capacitor start motor
C. Universal motor
D. Squiral cage rotor motor

9. From the given alternative one is not self starting motor?

   A. Shaded pole motor
   B. Squirrel cage rotor motor
   C. Wound rotor motor
   D. B and C

10. The difference between synchronous speed and rotor speed is______?

    A. Centrifugal switch
    B. Voltage regulator
    C. slip
    D. All of the above

11. Machine that converts dc power into mechanical energy is known as

    A. dc motor
    B. ac generator
    C. ac motor
    D. dc generator

12. In ________ motor the field winding is connected in series with the armature

    A. Shunt wound
    B. Series wound
    C. Compound wound
    D. All of the above

13. An electric machine that converts mechanical energy into electrical energy

    A. Generator
    B. Motor
    C. Transformer
    D. None of the above

14. A D.C. generator whose field magnet winding is supplied from an independent external D.C. source.

    A. Self excited generator
    B. Separately excited generator
    C. A and B
    D. None of the above

I. Mach column A with column B.

Column A	Column B
1. Motor	A. Convertion from mechanical to electrical.
2. Dc machines	B. The rotating part of DC machine.
3. Generator	C. Convertion from electrical to mechanical
4. Rotor	D. if the electrical system is DC

Note: **Satisfactory rating - 10points** **Unsatisfactory - below 10 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :6	Prepare Work instructions according to machine's manual

6.1. Introduction to work instructions

- More than nine out of 10 workplace accidents are due to human error. These result in serious injuries and cost industry billions of dollars every year. Yet much of this could be avoided with better, clearer work instructions. This guide will show you how to write work instructions – or Standard Operating Procedures.

- Knowing how to write work instructions, or SOPs (Standard Operating Procedures), clearly and concisely for your colleagues ensures they know exactly how their various tasks should be performed. It reduces risk because the likelihood of things going wrong is lessened. It also improves efficiency; work instructions ensure the very best way of doing a job is clear and known to the people doing it.
- Work instructions are also called work guides, Standard Operating Procedures (SOPs), job aids or user manuals, depending on the situation. In any case, the purpose of work instructions is to clearly explain how a particular work task is performed. They're like the step-by-step instructions we receive when we learn to drive a car: check gear stick is in neutral, start ignition, press clutch, change to first gear and so forth.
- What's important is that work instructions should not be confused with processes or process maps. Let's quickly look at where work instructions fit into our overall process documentation levels:

6.2. Important of work instructions

- They reduce the impact when key people leave

Work instructions, or SOPs, build and preserve the knowledge inside a company. When "how things are done" are passed on verbally, there is room for interpretation and human error. And knowledge about how to most efficiently perform a task is lost when said employee leaves the company and takes the knowledge with them. Good work instructions avoid all this.

- Work instructions reduce risk

They reduce risk because the safest way of doing a job is clear and known by the people that matter.

- Avoid errors and "the blame game"

Clarity avoid errors. Crucially, this avoids the blame game. When things go wrong the tendency is to blame or hold people responsible, which is natural. But if this happens often it can have an impact on staff morale. Having clear work instructions minimises this problem.

- Save time

The chart below shows Glue's own research on the Return on Investment when writing work instructions. The point is that your initial investment in time is paid back once your work instruction has been used just three times. This only refers to time-saving – we haven't even mentioned the value of avoiding errors and rework. This is also referred to as "Standard Work" within Lean:

6.3. How to write the work instruction

Next, the method of filling in the work instruction will be explained.

(1) Part number/part name

(2) Required amount/Classification number

(3) Affiliation/name

(4) Operation details

(5) Quality

(a) Checks - write the frequency by which the quality of assembled parts is checked, how often do we check an item (or perform one check).
Examples: (This is in the normal operation details)

- 1/1 – The check is performed every cycle.
- 1/10 – One item of every ten items is checked.
- 1/H – One item is checked every hour.
- 2/Shift – Two checks per shift.
- 1/D – One check per day.

(b) Gauges - write the type of measuring instruments (gauges) should be used to check the part.
(6) Key Points - Write the key points required (Corresponding to the work instructions).

Self-Check -6	Written Test

Directions: Choose the best answer

Directions: say true or false

1. More than nine out of 10 workplace accidents are due to human error

2. Work instructions are also called work guides

3. Gauges - write the type of measuring instruments (gauges) should be used to check the part.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _____________

Information Sheet :7	Inform the schedule of work for concerned department/personnel

7.1.Report Writing

7.1.1. Formal Reports

A formal report contains the following:

- **Title Page:** includes the title of the project/report, to whom the report is submitted, b y whom it isprepared, the date it is written (*not* the date the report is due!),

- **Abstract:** *a short* paragraph indicating what the project was and what solution was found
- **Table of Contents:** contains page numbers of the titles and subtitles of different sections of the report.
- **Introduction:** a brief description of the problem, how it was approached, and what procedure wasused to solve it. It may also give the reader some information on what was done in the sections followingthe introduction (for longer reports).
- **Development:** describes the details of the methods, procedures, techniques, etc., used in solving theproblem. This section usually has subsections such as model development, calculations, experimentalprocedure, applications, etc.
- **Discussion:** a discussion of the findings and any discrepancies.
- **Conclusion and Suggestions:** This section is a brief summary of what the findings were and what thesignificance of the work is. If it is a research project, it also contains suggestions about future researchareas.

7.1.2. Informal Reports

An informal report consists of a memo plus attachments and contains the following sections

- **Heading** (required)**:** To whom the report is submitted, who wrote it, when it was *written* (*not* the datethe report is due!), and what it is about. (An example of the first page of an informal report is included onthe following page.)
- **Summary** (required)**:** The summary is a brief (one or two paragraphs) description of the project andthe results, plus a brief mention of cost and schedule (so that managers don't have to read the entire reportto find this information). It should never extend onto the second page of the report and in most cases willnot contain figures, tables, or equations.
- **Design** (optional)**:** Describes how the circuit or system was designed.
- **Testing** (optional)**:** Describes how the circuit or system was constructed and teste
- **Results** or **Conclusion** (required): This section summarizes the results of the project, compares themeasured results to the design goals and numerical simulations, gives detailed breakdowns of costs andtime spent (if required), etc.

Self-Check -4	Written Test

Directions: say true or false

1. Conclusion and Suggestions:the section is a brief summary of what the findings were and what thesignificance of the work.
2. describes the details of the methods, procedures, techniques, etc., used in solving t heproblem.
3. The summary is a brief (one or two paragraphs) description of the project andthe re sults

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _____________

Operation Sheet :1	Assemble and Disassemble of Dc Motor

Procedures for Assemble and Disassemble of Dc Motor then identify each constructional parts

1. First unfasten (Unlock) all tighten screws by using Allen key, socket wrench or adjustable wrench.
2. Disassemble the end plate of the motor part at both sides.
3. Takeout the armature from the inside of stator.

4. Identify each part of series, shunt and compound wound Dc motors.
5. Assemble all constructional parts of DC motor, according to disassembling procedure or sequence.
6. Set (bring back) all tools and equipment from picked up store room at proper placement.

Operation Sheet :2	Assemble and Disassemble of Ac Motor

Procedures for Assemble and Disassemble of Ac Motor then identify each constructional parts

1. First lose all tighten bolts from their constructional body and carefully collect all bolts and set up in one place.
2. Marked all dismantle parts by marker with their corresponding part.
3. Take out the armature from the inside of stator.
4. Identify each part of squirrel cage and wound rotor Ac motors.

5. Assemble all constructional parts of AC motor, according to disassembling procedure or sequence.
6. Set (bring back) all tools and equipment from picked up store room at proper placement.
7. Assemble all parts from their exact place.
8. Set up (bring back) all tools and equipment from picked up store room at proper placement.

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: _________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 2hour.

Task 1. Assemble and disassemble Dc motor then identify each constructional parts.

Task 2. Assemble and disassemble Ac motor then identify each constructional parts.

Instruction Sheet :1	LG31: Maintain electrical system or equipment

This learning guide is developed to provide you the necessary information regarding the following learning outcome and content coverage

- Follow safety policies and procedures
- Test/ Clean/Lubricate electrical system or equipment parts
- Identify and replace worn-out/malfunctioning electrical system or equipment parts
- Check and identify readings of electrical measuring instruments
- Check and tight Connectors, bolts, nuts and screws
- Conduct regular routine/visual/sensory inspection

This guide will also assist you to attain the learning outcome and contents stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Follow safety policies and procedures
- Test/ Clean/Lubricate electrical system or equipment parts
- Identify and replace worn-out/malfunctioning electrical system or equipment parts

- Check and identify readings of electrical measuring instruments
- Check and tight Connectors, bolts, nuts and screws
- Conduct regular routine/visual/sensory inspection

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the "Information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5 and Sheet 6" in page 3,6,10,43,51 and 56 respectively".
4. Accomplish the "Self-check 1, Self-check 2, Self-check 3, Self-check 4 , Self-check 5 and Self-check 6" in page 5,9,42,50,55 and 57 respectively".
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1 and Operation Sheet 2" in page 58 and 59 respectively.
6. Do the "LAP test" in page 60

Information Sheet :1	Follow safety policies and procedures

1.1. OHS policies and procedures

Your Company Name is committed to the goal of providing and maintaining a healthy and safe working environment, with a view to continuous improvement. This goal is only achievable by adherence to established objectives striving to exceed all obligations under applicable legislation, and by fostering an enthusiastic commitment to health, safety and the environment within Your Company Name personnel, contractors and visitors.

In particular:

- Management, working in cooperation with the Joint Health and Safety Committee, will strive to take all reasonable steps to reduce workplace hazards to as low as reasonably achievable.
- Supervisors and managers are held accountable for the health and safety of all employees under their supervision. This includes responsibility for applicable

training and instruction, appropriate follow-up on reported health and safety concerns, and implementation of recommended corrective action. This accountability is integrated into the performance appraisal system.

- Supervisors, workers and visitors are expected to perform their duties and responsibilities in a safe and healthful manner, and are accountable for the Health and Safety of themselves and others.
- Your Company Name is committed to providing all necessary training and instruction to ensure that appropriate work practices are followed on the job, and to promote their use off the job.
- If necessary, Your Company Name will take disciplinary action where individuals fail to work in a healthy and safe manner, or do not comply with applicable legislation or corporate policies and procedures.

1.2. Electrical hazards prevention

Employees can prevent shocks and injuries/electrocution from electrical hazards by:

- Following safe work practices
- Understanding electric shock and electro caution
- Recognizing potential hazards around work involving electricity
- Following OHS requirements
- Maintaining clearances around panels
- Using proper protective devices
- Eliminating access to exposed energized parts Using proper PPE
- Using proper lockout/tag out procedures
- Maintaining proper clearance from overhead lines
- Following proper procedures for confined space/enclosed space/underground electrical work
- Following manufacturer's instructions

When you have to do maintenance work on a machine, take these four steps to protect yourself and your coworkers from injury:

- De-energize the machine. Positively disconnect it from the power source. If there is more than one source of power, disconnect them all.
- Lock out the disconnect switches. You must be given a lock and key for each disconnect before you begin working on the machine
- Tag the disconnect switches. Get tags or accident prevention signs from your supervisor.
- Test the machine to make sure it won't start
- Keep the key with you

Each worker who works on the machine must lock out and tag the power disconnect. Never assume that the machine you are working on has been disconnected and locked out unless you have done it yourself. Also remember that the current ratings off use and circuit breakers are at 15 to 30amperes for most residences. These safeguards cannot protect you against shocks. High voltage transmission and distribution lines carry a lot of electricity and if accidently touched it can be fatal. Since farm and construction workers use equipment that can reach high, these employees must be trained on the hazard supposed by high voltage overhead lines. Each year, workers who accidentally make contact with high voltage power lines are either killed or become permanently disabled. Electrically powered equipment is used daily by most workers. Power tools, metal and woodworking machines, restaurant equipment, computers and many other types of electrical equipment are found in the workplace. Failure to use the equipment correctly can create hazards to employees. Generally, there are instructions from the manufacturers on the use and maintenance of each piece of equipment. Workers need to follow the instructions while using and

- Replace broken 3-prong plugs and make sure the third prong is properly grounded.
- Never use extension cords as permanent wiring.
- Do not plug several power cords into one outlet.
- Do not disconnect power supplies by pulling or jerking the cords from the outlets.
- Always use the correct size fuse or breaker.
- Be aware that unusually warm or hot outlets may be a sign that unsafe wiring conditions exists.
- Use proper PPE for the electrical job.
- Always use ladders made of wood or other non-conductive materials when working with or near electricity or power lines.

Self-Check -1	Written Test

Directions: Choose the best answer

6. Which one of the following safety equipment?
   E. Measuring instrument
   F. Hand tool
   G. Glave
   H. All of the above
7. Which one of the following is not included in preventing shocks and injuries/electrocution from electrical hazards?
   A. Following safe work practices
   B. Understanding electric shock and electro caution
   C. Recognizing potential hazards around work involving electricity
   D. None of the above
8. Which one of the following is not included in PPE?
   A. Goggle
   B. Glave
   C. Safety shoes
   D. None of the above

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Information Sheet – 2	Test/ Clean/Lubricate electrical system or equipment parts

2.1. Introduction

The key to minimizing motor problems is scheduled routine inspection and maintenance. The frequency of routine maintenance varies widely between applications. Including the motors in the maintenance schedule for the driven machine or general plant equipment is usually sufficient. A motor may require additional or more frequent attention if a breakdown would cause health or safety problems, severe loss of production, damage to expensive equipment or other serious losses.

Written records indicating date, items inspected, service performed and motor condition are important to an effective routine maintenance program. From such records, specific problems in each application can be identified and solved routinely to avoid breakdowns and production losses. The routine inspection and servicing can generally be done without disconnecting or disassembling the motor.

All types of rotating machinery require regular inspections so to maintain their integrity and availability. The maintenance becomes simple and effective with the use of minor and major inspections categorized into levels representing the life of the product, be it running hours or years of installation. For each level, a defined number of inspection points are determined which can be undertaken within a specified time. The aim is not to lengthen the outages but to provide an effective solution that can be accommodated within planned maintenance periods and provide expert support when returning the equipment back on line.

2.2. Maintenance of Bearings

Keep the bearings dirt-free, moisture free, and lubricated. Water will rust the bearings and dirt will destroy the smoothness of the super finish on the bearing races, increasing friction. Clean the bearings when they become dirty or noisy with the most environmentally friendly cleaner that is suitable for dissolving oil, grease, and removing dirt from the steel, plastic and rubber surfaces. To obtain a long service life of bearings, they must be relubricated periodically. Used grease together with wear debris and any contamination should be removed from the contact zone and be replaced by fresh grease.

For most types, the sources of bearing failures are:

- Insufficient oil or grease.
- Too much grease causing churning and overheating.
- Worn bearings (i.e., broken balls or rough races, etc.)
- Hot motor or external environment.

Long service lives are possible when the following republication conditions are observed:

- the same grease is used as originally applied;
- the republication should be carried out at the operating temperature;
- the bearing should be re lubricated before a long interruption in operation occurs

Lubrication system	Inspection interval	
	Normal operating conditions	Severe operating conditions
Disk lubrication method	One year	6 months
Oil bath or splash lubrication	6 months	3 months
Circulating lubrication	9 months	1 to 3 months

Fig 2.1. Frequency of Lubricating Oil Analysis

2.3. Brush and Commutator Maintenance

The brushes and commutator are integral to the normal operation of a D.C. motor. The brushes ride or slide on the rotating commutator of the armature; there should be little brush noise, chatter or sparking when the motor is powered up. Excessive brush wear or chipping are signs that the motor is not commutating properly, which can be caused by a variety of factors. While de-energized, rotate the armature by hand to see if the brushes are free to ride on the commutator and there's adequate spring tension to keep them hugging the commutator. A good brush should have a polished surface which indicates that it has been seated properly. Check the brush connections to ensure they are tight and clean. Determine if the brushes are aligned properly. Misalignment from neutral can cause sparking (armature reaction). The brushes should have equidistant spacing around the commutator and parallel to the bars. Clean any debris around the brushes. Compare the brushes to a new set of brushes to gauge the amount of wear. If excessive or, if you don't think they will last until the next maintenance time, replace them.

The commutator should have a smooth, polished, brown appearance. There should be no grooves, scratches or scores. If there is any blackened, rough areas on the commutator, it's probably caused by brush sparking. If a commutator has a brassy appearance, there's excessive wear that could be caused by the wrong type of brush or the wrong spring tension. Check the manufacturer's technical documentation to verify the correct brushes are installed. Carbon dust and debris from the brushes can cause sparking and damage the commutator. If the commutator is rough and the bars are uneven, it will need to be turned on a lathe to restore its roundness. To clean the commutator, use a commutator cleaning brush (fiberglass) and some electric motor cleaner. Never use emery paper because it has metal particles in it that if rubbed off could cause electrical shorts. Remove the brush springs, slide the brush across the commutator hood and spray. When done, blow out the motor so it is dry and clean.

The usual defects in brushes and brush gear areas are as follows:

- ✓ Incorrect grade of brush and improper brush tension
- ✓ Improper bedding of brushes.
- ✓ Carbon brush chattering due to:
    - **(a)** Excessive clearance between carbon brush and its holder.

Fit up correct size brush. It should be good slide fit in its holder. Clearance should not be more than 2 mils.

(b) Excessive overhang of brush

Normally, the clearance between the bottom edge of brush holder and the commutator should only be 1.5mm (1/16 In.) or less. The brush holders should be properly reset and secured in position so that the clearance is correct.

- ✓ Carbon brush too tight in holder

This is generally due to accumulation of carbon dust. All carbon brushes should be removed entirely out of the holders once a month at least. Accumulated carbon dust should be blown off by compressed air and both the brush and the holder cleaned thoroughly with dry cloth. Carbon brushes must slide freely inside the holder.

- ✓ Brush tail connections

They should be secured properly. If the tail connection improperly secured strands are damaged, new brushes should be fitted.

- ✓ Excessive wear of brush

Normally, carbon brushes should last for several months. Excessive wear is definite sign of poor commutation, it requires detailed investigation. If the worn-out brush is not replaced quickly, the metallic pig tail connection imbedded inside the carbon brush may damage the commutator badly.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Say True / False.

1. Insufficient oil or grease is one of the sources of bearing failure.
2. Hot motor or external environment is not the sources of bearing failure.
3. Bearing should be re lubricated before a long interruption in operation occurs

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet – 3	Identify and replace worn-out/malfunctioning electrical system or equipment parts

3.1. Maintenance of A.C. Motors

A.C. Motors are run for extremely long periods without repairs. If the bearings are properly lubricated and air passages are kept clear, then most of the A.C. Motors do not have failure problems, as the motors have no commutators which cause motor failure. There are few motors which have commutators, such as universal motor, repulsion motors in single phase system.

- **Single Phase Motors:**

Centrifugal (CF) switch is one of the main cause of troubles in single phase motors. If the springs of centrifugal switch become weak, the C.F. switch will operate before reaching the full speed, which will cause motor to run at sub normal speed and stop. If the switch sticks closed, the starting winding will remain in the circuit, overheat and damage the starting winding. Commutator motors need almost same type of care and maintenance as in dc motors.

- **Squirrel Cage Induction Motor :**

Overheating and shock may damage the squirrel cage rotor, which may cause fractures in bars in the slots and end ring connections and joint in the rotor cage. Satisfactory operation of motor is difficult with fractured rotor cage and end rings. In large motors the bars are bolted or wedged in slots and can be tightened readily if these become loose. Loose coils can be detected with the help of growler. If it is not possible to disassemble the motor, connect an ammeter in in series with one phase and apply 25% of full voltage to one of the stator phase winding and turn the rotor slowly by hand. If the ammeter reading varies in excess of 3%, it can be assumed that there is loose bar in rotor.

- **Wound Rotor Motors:**

Working principle is same as 3 phase sq. cage rotor induction motor, having better torque and speed. Wound rotor may have low speed with starter resistance cut off from rotor circuit. If there are no openings in control and starter circuit, the rotor coils should be tested for continuity. Growler test may reveal open are short circuit in the coils. There is also possibility of brushes sticking in the holder or brushes may not have sufficient tension (sparking and overheating at contact area).

Growler is an electromagnet having 110 V /240 V supply voltage and suitably shaped for testing armature/ rotor, by placing the growler core (or rotary growler for testing stator winding)and slowly moving on/in it shorted or broken coils can be detected by noting the change in the humming noise of the growler.

- **General procedure for overhaul of motors:**
  - ✓ Disconnect the supply cables at the terminal box of the motor, uncouple the motor from the driven machine, unfasten the foundation bolts or nuts and remove the motor to the maintenance shop.
  - ✓ Remove the external fan covers, canopies, heat exchanger or other fitments.
  - ✓ Dismantle the motor without using the excessive force, and without the hammer blows. Care should be taken to see that the rotor does not touch the stator winding overhangs. If possible do not open cartridge bearing housings.
  - ✓ Clean dust, dirt, oil and grit from every part of the machine with the help of blower, compressed air hose, bellows or brushes and then wash with petrol to which a few drops of lubricating oil have been added. The windings may be cleaned by means of carbon tetra-chloride. Care being taken to avoid its application to slip rings and brushes.
  - ✓ Carry out visual inspection of all parts for wear or damage, replace worn out or damaged parts.
  - ✓ Measure insulation resistance. If low dry out the windings, until correct

values are obtained. If necessary re-enamel or re-varnish all the winding and internal parts except the stator bore and rotor iron. Dry rotor and stator winding thoroughly.

- ✓ Reassemble motor without using any excessive force. Make sure that machine leads are on the correct terminals and everything is well tightened.
- ✓ Check the concentricity of the air gap through the air gap holes. Ensure that rotor can rotate freely. Any difficulty in rotating the rotor or unusual noise should be taken as sign of interference between stationary and moving parts. Investigate this and eliminate the cause of the trouble.
- ✓ Check insulation resistance again.
- ✓ Recommission the motor.

3.2. Details of AC Winding

The windings used in rotating electrical machines can be classified as

- **Concentrated Windings**
  - ✓ All the winding turns are wound together in series to form one multi-turn coil.
  - ✓ All the turns have the same magnetic axis

Examples of concentrated winding are

- ✓ field windings for salient-pole synchronous machines
- ✓ D.C. machines
- ✓ Primary and secondary windings of a transformer

- **Distributed Windings**
  - ✓ All the winding turns are arranged in several full-pitch or fractional-pitch Coils.
  - ✓ These coils are then housed in the slots spread around the air-gap periphery to form phase or commutator winding

Examples of distributed winding are

- ✓ Stator and rotor of induction machines
- ✓ The armatures of both synchronous and D.C. machines

3.3. **Some of the terms common to motor windings are described below**

1. **Conductor.** A length of wire which takes active part in the energy-conversion process is a called a conductor.
2. **Turn.** One turn consists of two conductors.
3. **Coil.** One coil may consist of any number of turns.
4. **Coil –side.** One coil with any number of turns has two coil-sides.
5. ***Active side of a coil*****:** It is that part of the coil which lies in the slots of the stator and EMF is induced in this part. It is also known as an **inductor**.

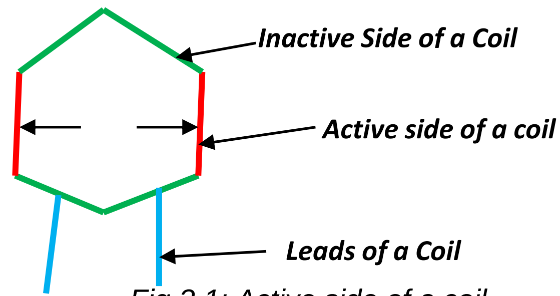
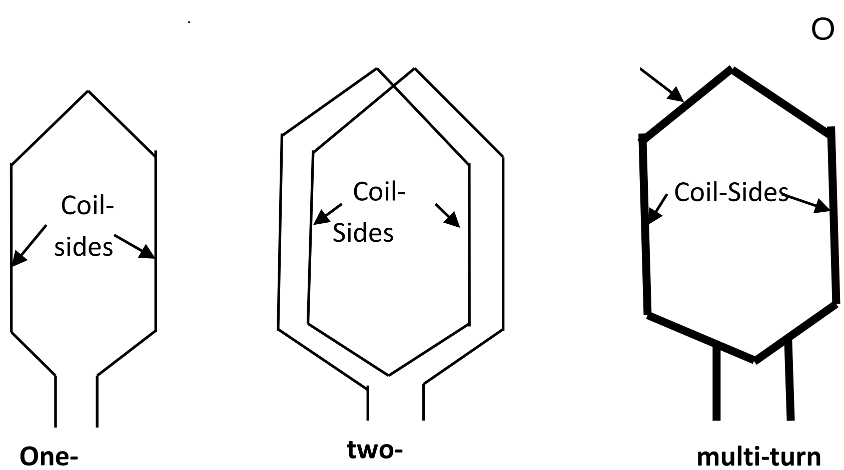


Fig 3.1: Active side of a coil

6. ***Inactive Side of a Coil or End Turn***: It is the portion of the conductor which joins the two inductors.
7. ***Leads of a Coil***: These are the starting and ending of a coil which are used for doing the connection.

The number of conductors ***(C)*** in any coil-side is **equal** to the number of turns ***(N)*** in that coil.



8. ***Coil Span or Winding Pitch*****:** The distance between the two active sides of a coil under the adjacent dissimilar poles. It is usually measured in terms of teeth, slots or electrical degrees.

If winding pitch is 6, then the coil throw is 1 to 7 and one side of the coil is put in slot no. 1 and the other side is inserted in slot no. 7. Then the winding pitch is 7-1 = 6.

Winding pitch may or may not be equal to pole pitch. While rewinding, it is always preferred not to change the winding pitch as it has been chosen by the designer after considering different factors leading to good performance of the machine. Any change in original winding pitch of a machine will affect the performance of that machine.

9. ***Coils per Pole***: The number of coils connected in series to produce a single pole when current pass through them.
10. **Coil Groups:** The total number of coil groups in a machine is called coil groups. It is the product of number of phases and number of poles in a machine, i.e.
    Coil groups = no. of phases **x** no. of poles
11. **Pole pitch:** The distance between the centers of two adjacent opposite poles. Pole pitch is measured in terms of slots. . Pole pitch is always equal to 180^{o}

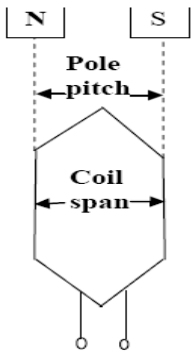
$$Pole\ pitch = \frac{No.of\ slots\ in\ a\ machine}{No.of\ Poles}$$

- if there are ***S*** slots and ***P*** poles, then pole pitch ***Q = S/P*** slots per pole.

12. **Pitch Factor**: Pitch factor is the ratio between the winding pitch and pole pitch.

$$Pitch\ factor = \frac{Winding\ pitch}{Pole\ Pitch}$$

13. **Full Pitch Winding**: In this winding, the winding pitch is equal to pole pitch. In other words, for a full pitch winding, the pitch factor is equal to unity and the winding is known as “Full Pitched Winding”.
14. **Chorded Winding:** In this winding, the winding pitch is not equal to pole pitch. Thus, the pitch factor is less than unity so the winding is named as ***short pitch or chorded winding***. If the pitch factor is more than unity, the winding is then termed as **long pitch winding**.
    - if coil-pitch ***Y = S/P*** , it results in ***full-pitch Winding.***
    - in case coil-pitch $Y < \frac{S}{P}$, it results in ***chorded***, ***short-pitched*** or ***fractional-pitch.***



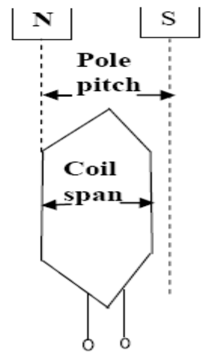


Fig 3.2: Full-pitch coil *Short-pitched or chorded coil*

15. ***Whole-Coil Winding***: A whole coil winding is one in which number of coils per phase is equal to the number of poles in the machine.
16. ***Half Coil Windings***: it is the winding in which number of coil per phase is equal to half of the number of poles in the machines. Half coil winding is generally done in the winding of ceiling fans, double speed motors etc
17. ***Balanced Winding***: When each pole of the same phase contains equal number of coils, then the winding is termed as balanced or even group winding.
18. ***Unbalanced winding***: If each pole of the same phase has unequal number of coils, then the winding is termed as unbalanced or odd group winding. It is important to note that there must be equal number of coils in each phase whether the winding is balanced or unbalanced.
19. **Number of slots per pole per phase (q)**: An important point in winding design is the selection of number of slots per pole per.

$$q = \frac{S}{Pm}$$

Where: S = no of slots

P = no of poles

m = no of phases

20. **Phase spread or phase apart**: - The requirement of a-c winding is that it must produce a symmetrical 3-phase of e.m.f.'s of identical magnitude, frequency and wave form of displaced in time by 120 electrical degrees for 3-phase system. This is secured by the following alternative methods.

i) Total electrical degrees = 360^0 X pole-pairs

ii) $\alpha slot^{0} = \frac{Total\ Elect.degrees}{total\ No.of\ Slots}$, in degrees

iii) Phase spread (phase displacement) $= \frac{120^{0}}{\alpha slot^{0}}$, in slots

Or, $Phase\ spread = \frac{120^{0}\ elect.}{180^{0}\ elect.}\ x \frac{S}{P}$

$= \frac{2}{3} \times \frac{S}{P}$, in slots

21. **Phase sequence**; means the order in which the three voltages become successively positive.

22. Relations for drawing winding diagram

$$n_s = \frac{120xf}{P}$$

$$q = \frac{Z}{Pxm}$$

$$Y_z \leq \frac{Z}{P}$$

$$\acute{\alpha}_{slot} = \frac{\frac{P}{2}x360^{0}}{Z}$$

$$Z_{phase} = \frac{120^{0}}{\acute{\alpha}_{slot}}$$

3.4. Rewinding stator coils of single phase AC motor

3.4.1. AC Lap Winding

Example: Develop a single phase, single layer AC lap winding for a 4 pole AC machine having 24 slots.

Solution: In single layer winding, the number of coil is equal to half the number of slots on the stator, so that each slots contains only one coil side. Therefore, number of coils, C = 12

pole pitch $= \frac{Number\ of\ slots}{Number\ of\ Poles} = \frac{24}{4} = 6$; and slots per pole

per phase, m = 24/4x1 = 6

Slots 1 to 6 and 13 to 18 lie under North pole regions N1 and N2 respectively. Similarly slots 7 to 12 and 19 to 24 lie under South pole regions S1 and S2 respectively. In other words, the first pole pair covers slots 1 to 12 and the second pole pair covers slots from 13 to 24. For full pitch winding, angle between the two sides of the same coil is 1800ed. 1800ed corresponds to 6 slots. Number of coils (or slots) per pole= 6.The coil in slot no. 1 is to be connected to coil in slot no. (1 + slots per pole = 1 + 6 =) 7 or back pitch, Yb = 7, ie., if slot no. 1 is at the beginning of the first North Pole, N1, the slot no. 7 will be at the beginning of the first South Pole, S1.The winding pitch, Y = +2 (progressive winding) Therefore, the front pitch, Yf =Yb – Y = 5. Table 4.1 gives the complete winding table for 4 pole, 24 slot ac machine. When the winding for one pole pair is completed then last coil side of this pair is connected to the first coil side of the next pole pair, ie., coil in slot no. 12 is connected in series with the coil in slot no.13. Similarly, the winding for the second pole pair is completed

S.No.	$-Y_f$	$+Y_b$
1	1	7
2	2	8
3	3	9
4	4	10
5	5	11
6	6	12
7	13	19
8	14	20
9	15	21
10	16	22
11	17	23
12	18	24

Table 3.1. Single Phase AC Lap Winding Table

To draw the main winding diagram, solid lines of equal length and equal distance equal to number of slots is drawn. Connect the coils as per the Winding Table 3.1.

Arbitrarily assume a particular current direction to the coil sides under the pole pairs. For the coil sides under North Pole regions, assume downward current direction and vice versa for the South Pole regions, as shown in Fig. 3.4.

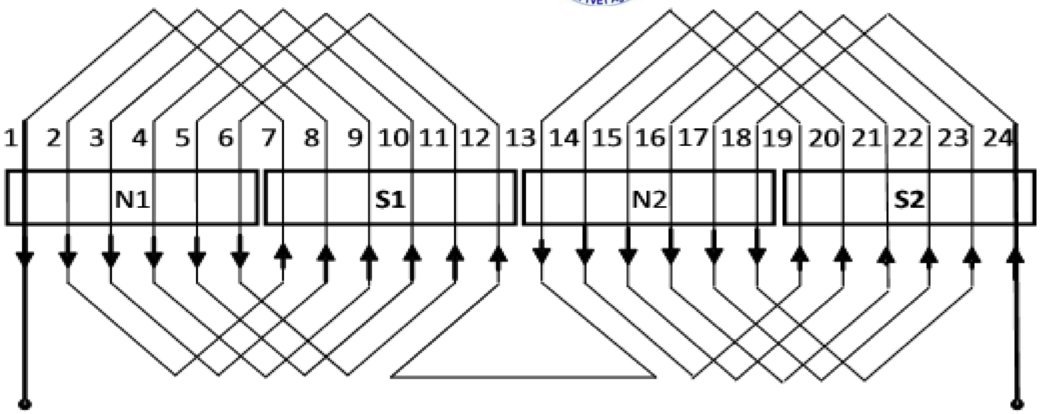


Fig.3.4: Single Phase AC Lap Main Winding Diagram

3.4.2. Wave Winding

Example: Develop a single phase, single layer wave winding for a 4 pole, 24 slot ac machine.

Solution: Number of coils, C = 12

Solution : Number of coils, C = 12

From equation 3.5, the pole pitch = $\frac{Number\ of\ slots}{Number\ of\ Poles} = \frac{24}{4}$ = 6; and slots per pole per phase, $m = \frac{6}{1} = 6$

Slots 1 to 6 and 13 to 18 lie under North pole regions N1 and N2 respectively. Similarly slots 7 to 12 and 19 to 24 lie under South pole regions S1 and S2 respectively. In other words, the first pole pair covers slots 1 to 12 and the second pole pair covers slots from 13 to 24.For full pitch winding, angle between the two sides of the same coil is 1800ed. 1800ed corresponds to 6 slots. For ac wave winding, back pitch, Yb = number of coils(or slots) per pole= 6 = front pitch, Yf. If one side of the coil is placed in slot no. 1, the other side of the coil should be placed in slot no. (1 + slots per pole = 1 + 6 =) 7. The finishing end of the coil side at slot no. 7 is connected to the starting end of the coil side at slot no. (7 + 6 =) 13. Now the other side of the coil side at slot no. 13 is placed at slot no. (13 + 6 =) 19. Adding 6 to slot no. 19 gives 25, which is slot no. 1, ie., 25 – 24 = 1. But a coil side is already placed at slot no. 1. So add 1 and place the coil side at slot no. 2. Similarly, add turn by turn back pitch and front pitch and at the end of each round add Yb + 1. Table 3.2 gives the complete winding table for a 4 pole 24 slot ac wave wound machine.

S.No.	Y_f	Y_b
1	1	7
2	13	19
3	2	8
4	14	20
5	3	9
6	15	21
7	4	10
8	16	22
9	5	11
10	17	23
11	6	12
12	18	24

Table 3.2. Single Phase AC Wave Winding Table

To draw the main winding diagram, solid lines of equal length and equal distance equal to number of slots is drawn. Connect the coils as per the Winding Table 3.2.

Arbitrarily assume a particular current direction to the coil sides under the pole pairs. For the coil sides under North Pole regions, assume downward current direction and vice versa for the South Pole regions, as shown in Fig. 3.5.

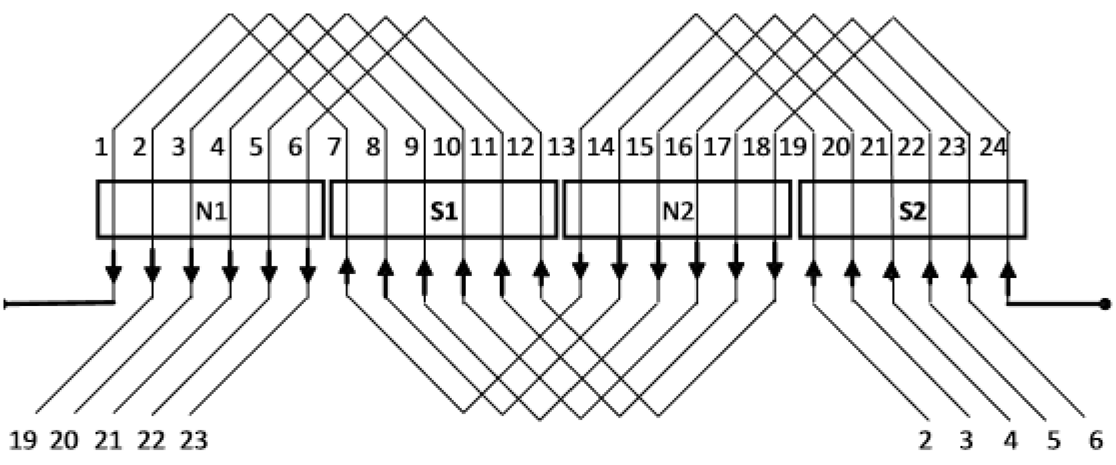


Fig. 3.5 Single phase AC Wave Main Winding Diagram

Spiral or Concentric Winding: Develop a single phase single layer concentric winding for a 4 pole AC Machine having 24 slots.

Solution : From equation 3.5, pole pitch = $\frac{slots}{Poles} = \frac{24}{4} = 6$

The pitch for larger coil = 6 – 1 = 5

The pitch for smallest coil = 1

Based on the rules, the winding is started from the starting end of the middle coil in the first North Pole, ie., coil side 4. The back end of the coil side 4 is connected to the back end of the coil side 9, ie., pitch for larger coil is added to coil side 4. The front end of the coil side 9 is connected to front side of coil side 5 to form concentric winding. Following the above procedure, Table 3.3 gives the complete winding table for 4 pole 24 slot AC Machine.

Draw 24 solid lines of equal length at equal distance. This represents the number of slots. This also represents the number of coils, as this is a single layer winding. Then assign numbers to the top side of the coils, as shown in Fig. 3.5. With reference to Table 3.2.3, complete the winding diagram

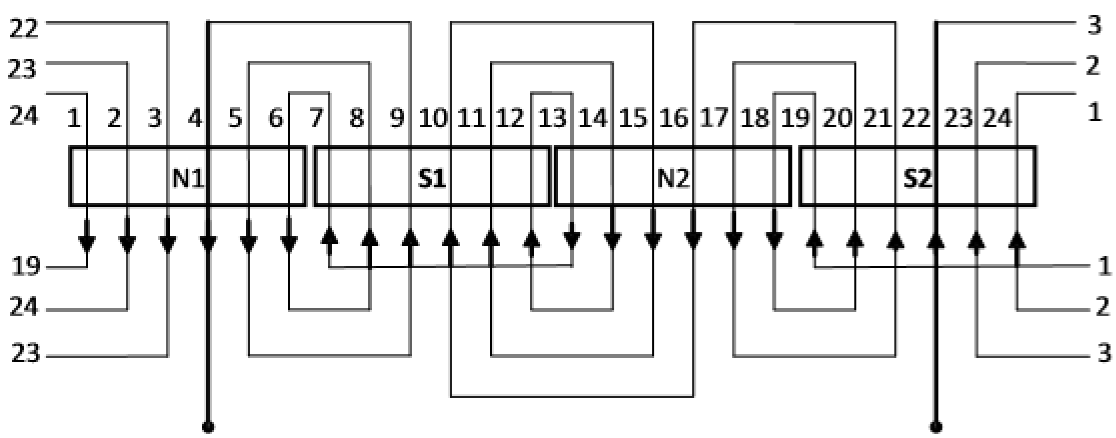


Fig.3.5 - Single Phase AC Concentric Main Winding Diagram

3.5. Types of Three-phase Windings

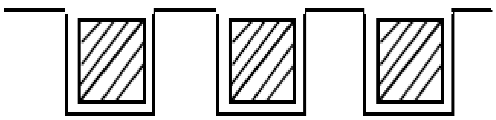
According to the number of layers per slot, three-phase a-c windings are divided in to two main groups:

- **Single –layer windings**

In single – layer windings, there is only one coil- side per slot. Therefore, number of coils in single- layer windings is half of the number of slots i.e

$$C = \frac{1}{2}S$$

Where : C = number of total coils , S = number of stator slots



one coil-side per slot

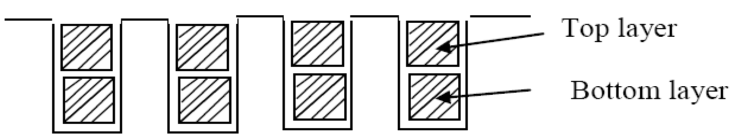
• One coil-side occupies the total slot area
• Used only in small ac machines

Examples of single- layer winding,

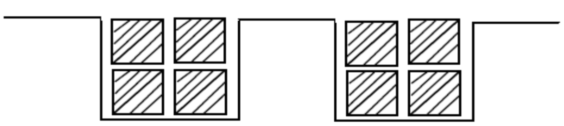
- ✓ Concentric windings
- ✓ Chain windings
- ✓ Mush(basket) windings (with mush over -hang)
- ✓ Chain winding with diamond over-hang(end connection)

- **Double- layer windings**

In double-layer windings, Slot contains even number (may be 2,4,6 etc.) of coil-sides in two layers.



Two coil –sides per slot



4-coil-sides per slot

Fig 3.6: coil side per slot

• Double-layer winding is more common above about 5kW machines

- In double layer windings, total number of coils is equal to the number of slots, i.e.

C = S

Examples of double- layer windings,

a) Integral slot winding
b) Fractional slot winding

The advantages of double-layer winding over single layer winding are as follows:

- ✓ Easier to manufacture and lower cost of the coils
- ✓ Fractional-slot winding can be used
- ✓ Chorded-winding is possible
- ✓ Lower-leakage reactance and therefore , better performance of the machine
- ✓ Better emf waveform in case of generators

In ***AC armature windings***, the separate coils may be connected in several different manners, but the two most common methods are ***lap*** and ***wave***

In polyphase windings it is essential that

- ✓ The generated ***emfs*** of all the phases are of ***equal magnitude***
- ✓ The ***waveforms*** of the ***phase emfs*** are ***identical***
- ✓ The ***frequency*** of the ***phase emfs*** are ***equal***

The ***phase emfs*** have mutual time-phase displacement of $\beta = \frac{2\pi}{m}$ electrical radians. Here ***m*** is the number of phases of the a.c. machine.

3.5.1. Types of *Single-layer windings*

- One coil side occupies one slot completely, in view of this, number of coils ***C*** is equal to half the number of slots ***S***, $C = \frac{1}{2}S$
- The 3-phase single –layer windings are of two types
  - ✓ Concentric windings
  - ✓ Mush windings

3.5.1.1. Concentric windings

- The coils under one pole pair are wound in such a manner as if these have one center
- the concentric winding can further be sub-divided into
  - ✓ half coil winding or unbifurcated winding
  - ✓ Whole coil winding or bifurcated winding

In concentric windings the coil pitch of the individual coil is different, the coil pitch of the outer coil is more than the pole pitch, while the coil-pitch of the inner coil is less than the pole-pitch.

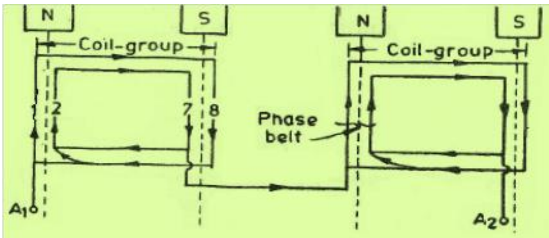


*Fig 3.7: Half coil winding, for phase **A** only*

- The half coil winding arrangement with 2-slots per pole per phase and for $\sigma=60^0$
- coil group may be defined as the group of coils having the same center
- The number of coils in each coil group = the number of coil sides in each phase belt (phase group)
- The carry current in the same direction in all the coil groups

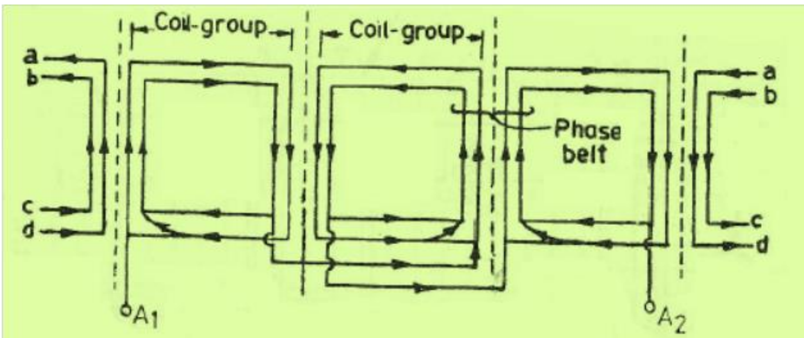


Fig 3.8: whole coil winding, For phase A only

- The whole coil winding arrangement with 2-slots per pole per phase
- The number of coil sides in each phase belt (here 4) are double the number of coils (here 2) in each coil group
- There are ***P*** coil groups and the adjacent coil groups carry currents in opposite directions

Example 1

Develop the single layer concentric winding diagram of a 3-phase, 24-slots, 4-poles stator of an induction motor.

Given:- S = 24 , P = 4 , m = 3

Type of winding: single-layer concentric

Phase connection: star connected,

Solution

1) $C = \frac{1}{2}S = \frac{1}{2} \times 24 = 12$

2) Total coil groups $= m \times \frac{P}{2} = 3 \times 2 = 6$

3) $Y_p = \frac{S}{P} = \frac{24}{4} = 6$

4) $q = \frac{S}{mp} = \frac{24}{3\times4} = 2$

5) Phase spread $= \frac{2}{3} \times \frac{S}{P} = \frac{2}{3} \times \frac{24}{4} = 4$

6) $Y_L = Y_p|a| + q = 6 + 2 = 8$

Therefore, coil throws will be:

Phase A =	1 – 8	Phase B=	5 – 12	Phase C =	9 - 16
	2 – 7		6 = 11		10 – 15
	13 – 20		17 – 24		21 - 4
	14 - 19		18 – 23		22 - 3

7) Phase sequence A C' B A' C B' A C' B A' C B'

2 2 2 2 2 2 2 2 2 2 2 2 = 24

No.of slots 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

phase seq. A A C' C' B B A' A' C C B' B' A A C' C' B B A' A' C C B' B'

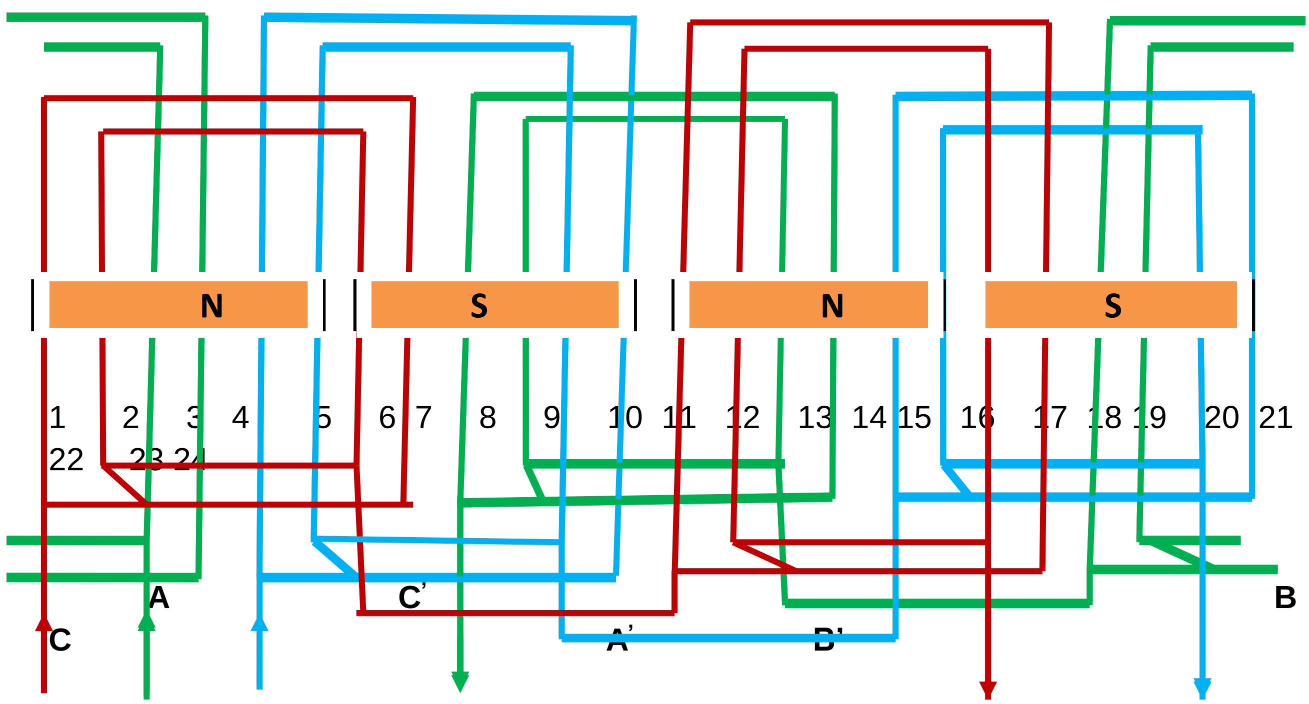


Figure 3.9: Concentric winding coils

Examlpe2*. If No. of Slots* = 36, No. of Poles = 4, No. of phase, m=3 and type of winding is concentric, then

$$Y_p = \frac{36}{4} = 9$$

$$q = \frac{36}{3\times4} = 3$$

Phase apart (phase spread) = 2/3x36/9 = **6**

$Y_L = Y_p|a| + q$, where: a=parallel path, a =1

$$Y_L = 9 + 3 = 12$$

Then coil throw for phase A, 1 – 12 19 - 30

2 – 11 20 - 29

3 – 10 21 – 28

coil throw for phase B, 7 – 18 25 – 36 ,

8 – 17 26 - 35

9-16 27 - 34

then coil throw for phase C, 13 – 24 31 - 6

14 – 23 32 - 5

15 – 22 33 – 4

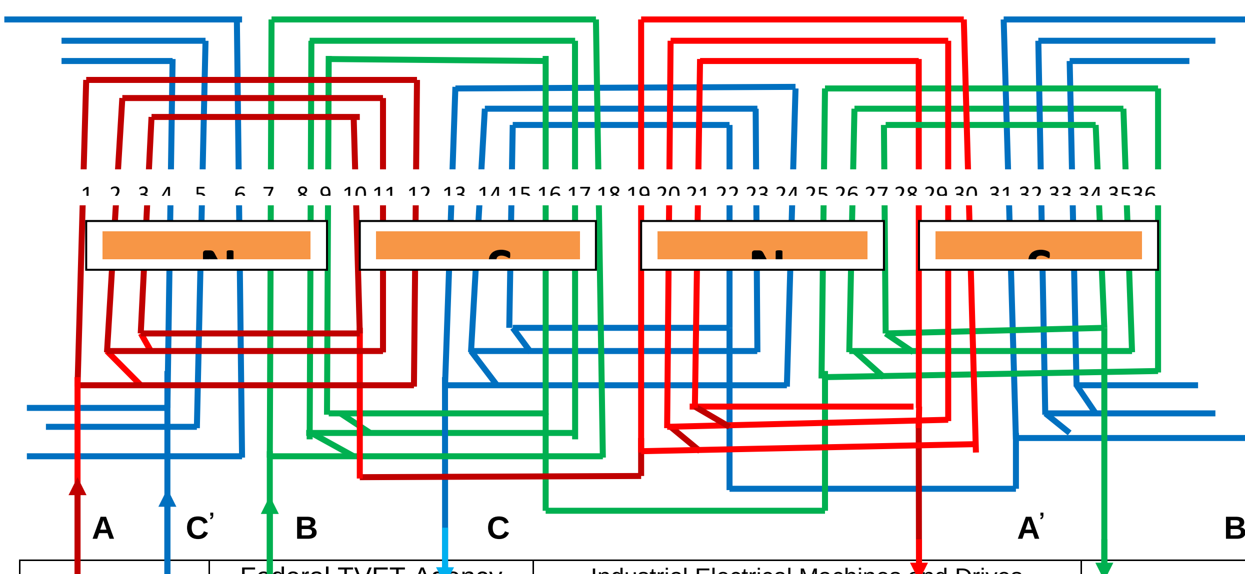


Figure 3.10: Concentric winding coils

Example 3. Design and draw ***(a)*** half coil and ***(b)*** whole coil single layer concentric windings for a 3-phase machine with 24-slots, 4-poles and 60^{o} phase spread

Solution: *(a) half coil concentric winding*

Slots angular pitch $\gamma = \frac{4\times180^0}{24} = 30^0$

Full pitch or Pole pitch= $\frac{24}{4} = 6\ slots\ pitches$

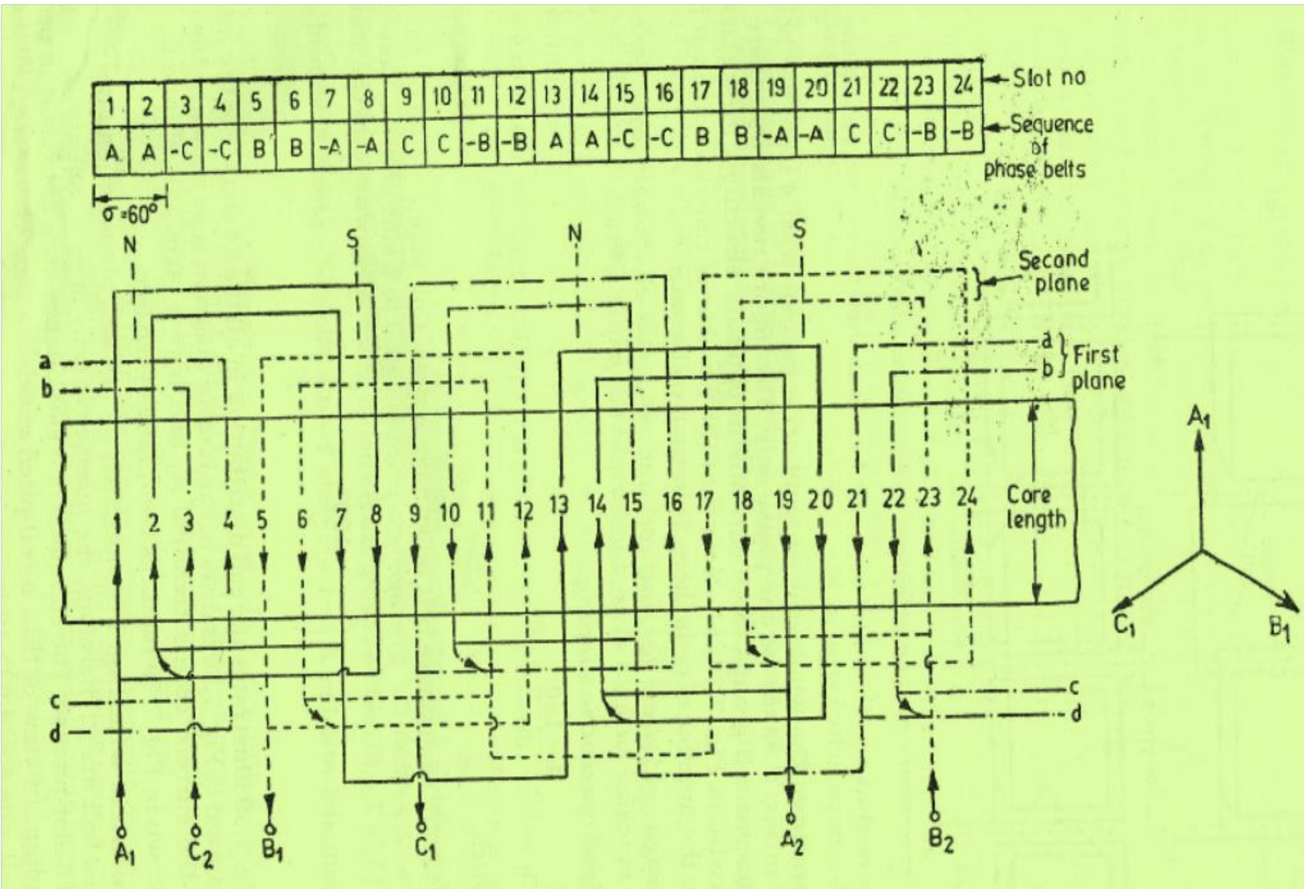


Figure 3.11: 4 poles, 60^{o} phase spread single layer concentric winding (two – plane overhang)

(b) Whole-coil concentric winding

For slot pitch γ = 30o & phase spread σ = 60^0

- ✓ The number of coils per phase belt = 2 ,
- ✓ The number of coils in each coil group = 1
- ✓ The pole pitch=6
- ✓ The coil pitch of 6 slot pitches does not result in proper arrangement of the winding
- ✓ In view of this, a coil pitch of 5 is chosen

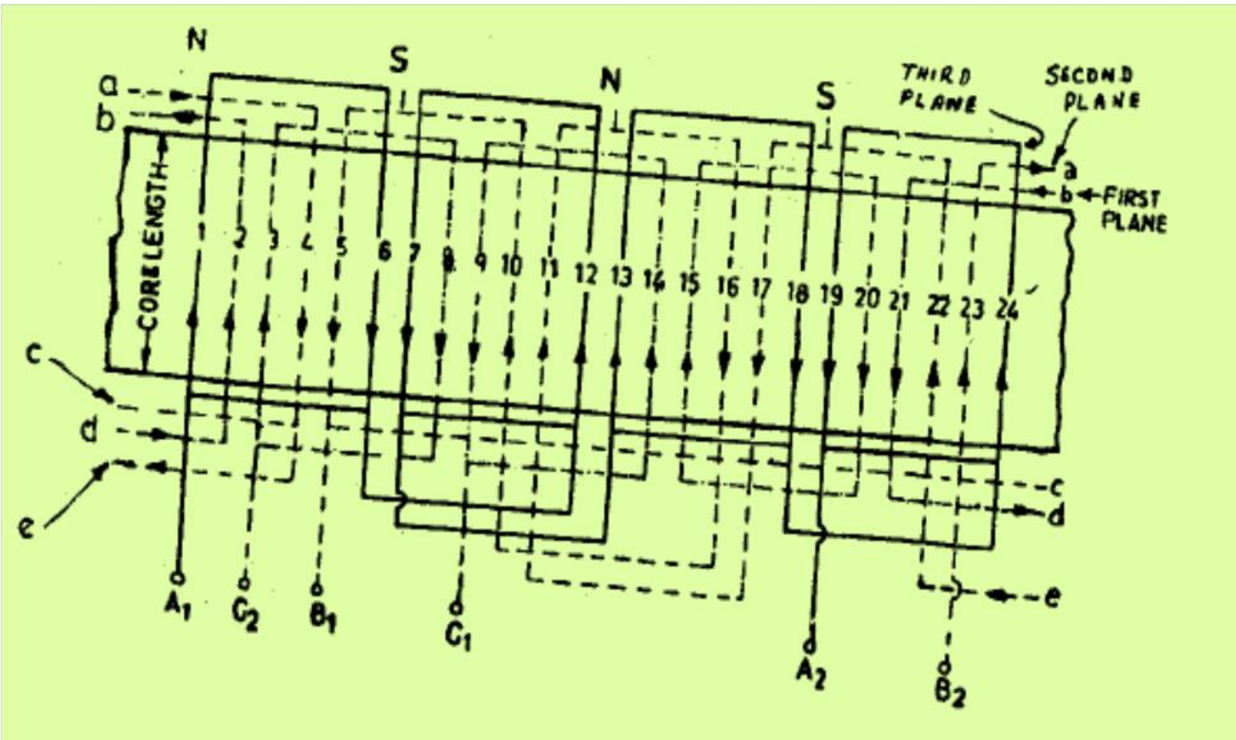


Figure 3.12: Whole-coil winding arrangement of 24 slots, 4 poles, 60^o phase spread, single layer concentric winding (three-plane overhang)

Example:4: Draw the developed winding diagram of a 3 phase induction motor with 18 slots, 2 poles, single layer, full pitched winding with delta connection.

Soln: No. of slots per pole per phase = 18/(2 x 3) = 3 Pole pitch = no. of conductor / pole = 18/2 = 9 Slot angle = 180/ pole pitch = 180/9 = 200 Full pitched winding = coil span = 180 Coil span = winding pitch/slot angle = 180/20 = 9 slots

Winding Table:

Phase	1st pole	2nd pole
R	1 + 9 = 10 3 + 9 = 12	11+ 9 = 20 (2) 13 + 9 = 22(4)
B	5 + 9 = 14	15 + 9 = 24 (6)
Y	7 + 9 = 16 9 + 9 = 18	17 + 9 = 26 (8)

Connections: Rs = 1, Ys = 1 + 120/slot angle = 1+120/20 = 7; Bs = 1 + 240/slot angle = 1+ 240/20 = 13

Winding Diagram

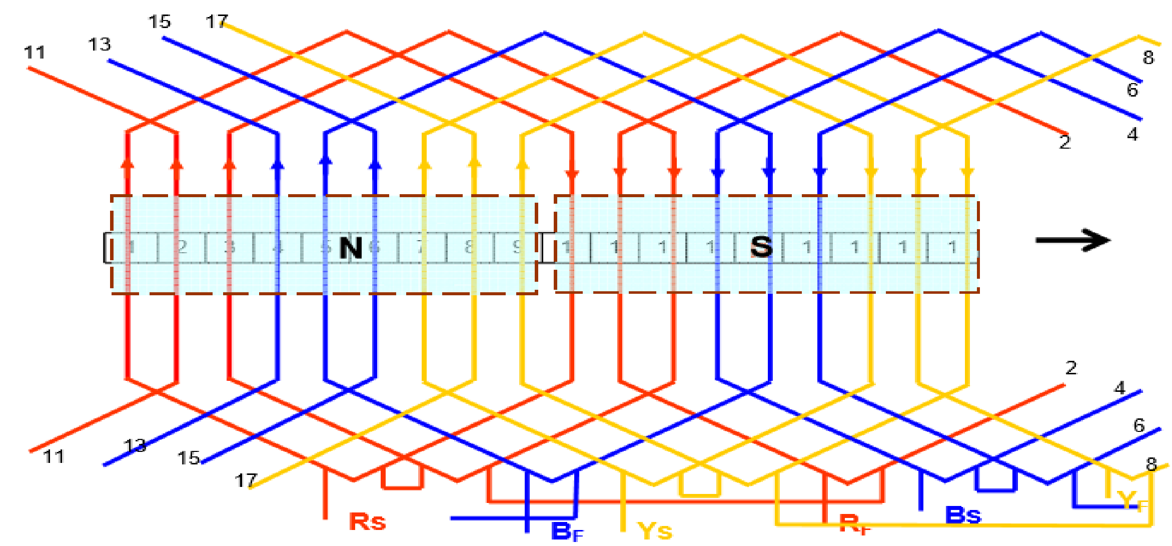


Fig. 23 Winding diagram

Example:5. Design and draw the developed winding diagram of an alternator with following details: No of poles = 2 no. of phases = 3, No. of slots = 24, single layer lap winding, short pitched by one slot.

Soln: No. of poles = 2; No. of conductors = 24; Pole pitch = 24/2 = 12; no of slots/pole /phase =24/ (2x3) = 4 No. of coils = 24/2 = 12 No of coils/pole/phase = 12/(2x3) = 2 Slot angle = 180/pole pitch = 180/12 = 150 Winding pitch = 180 – (slot angle x no of slots shorted) = 180 – 1 x15 = 165 Hence coil span = 1650 = 11 slots Connections: Rs = 1, Ys = 1 + 120/15 = 9; Bs = 1 + 240/15 = 17

Winding Table:

Phase	1st pole	2nd pole
R	1 + 11= 12	13 + 11 = 24
	3 + 11 = 14	15 + 11 = 26 (2)
B	5 + 11 = 16	17 + 11 = 4
	7 + 11 = 18	19 + 11 = 6
Y	9 + 11 = 20	21 + 11 = 8
	11 + 11 = 22	23 + 11 = 10

Winding Diagram:

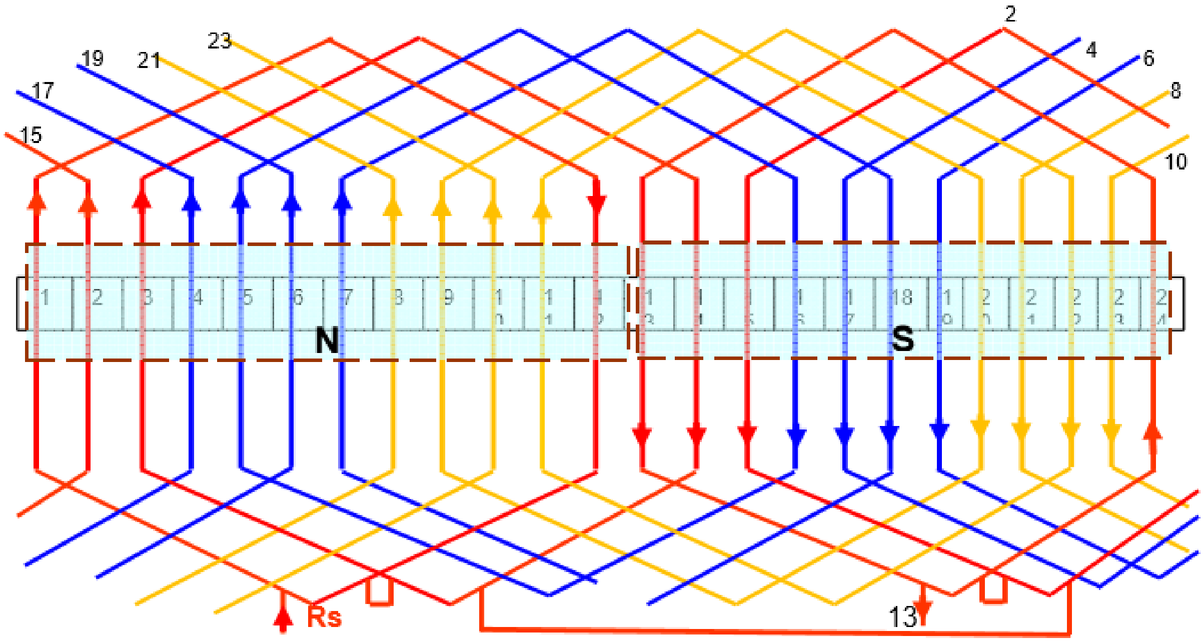


Fig. 25 Winding diagram

Example. 6. Design and draw the developed winding diagram of an alternator with following details: No of poles = 4 no. of phases = 3, No. of slots = 24, single layer wave winding, delta connected.

Soln: No. of poles = 4; No. of conductors = 24; Pole pitch = 24/4 = 6; no of slots/pole /phase =24/ (4x3) = 2 No. of coils = 24/2 = 12 Slot angle = 180/pole pitch = 180/6 = 300 Winding pitch = 180 – (slot angle) = 180 – 30= 150 Hence coil span = 1800 / 30 = 6 slots Yb = 6 and Yf = 6

Connections: Rs = 1, Ys = 1 + 120/30 = 5; Bs = 1 + 240/30 = 9

Winding Table:

Phase		
R	1 + 6 = 7	7 + 6 = 13
	13 + 6 = 19	19 + 6 = 25 (1)
	(1 + 1) + 6 = 8	8 + 6 = 14
	14 + 6 = 20	
B	9 + 6 = 15	15 + 6 = 21
	21 + 6 = 27(3)	3 + 6 = 9
	10 + 6 = 16	16 + 6 = 22
	22 + 6 = 28 (4)	
Y	5 + 6 = 11	11 + 6 = 17
	17 + 6 = 23	23 + 6 = 29 (5)
	6 + 6 = 12	12 + 6 = 18
	18 + 6 = 24	

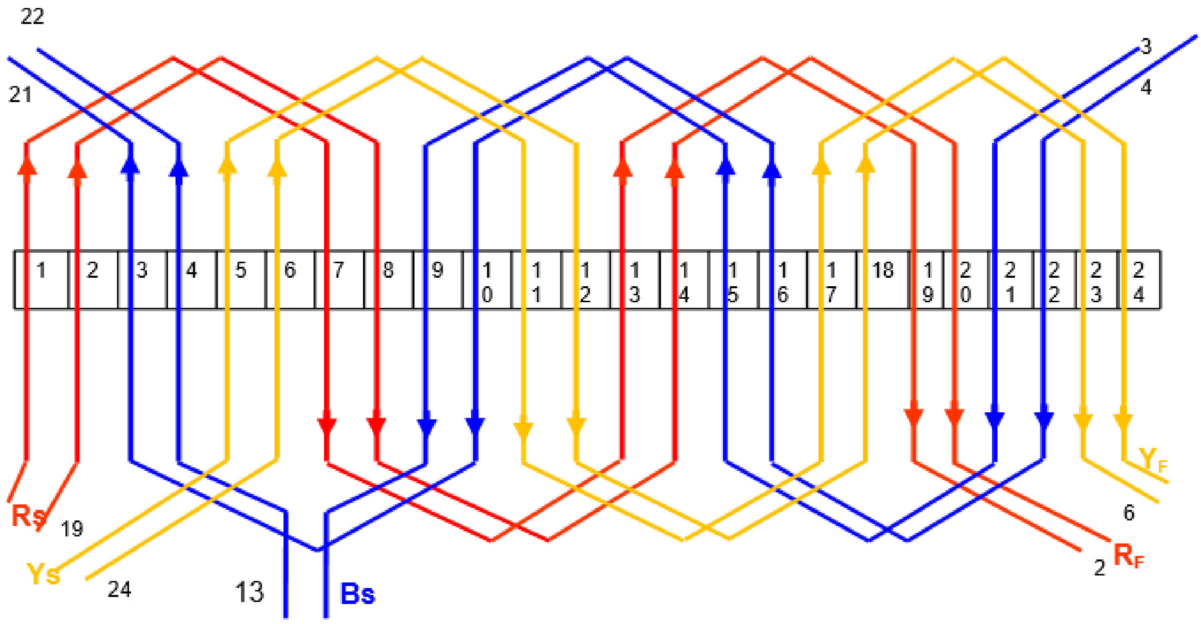


Fig . 24 Winding diagram

3.5.1.2. Mush Winding

- ✓ The coil pitch is the same for all the coils
- ✓ Each coil is first wound on a trapezoidal shaped former. Then the short coil sides are first fitted in alternate slots and the long coil sides are inserted in the remaining slots

- ✓ The number of slots per pole per phase must be a whole number
- ✓ The coil pitch is always odd

For example.1: for 24 slots, 4 poles, single-layer mush winding, the pole pitch is 6 slots pitches. Since the coil pitch must be odd, it can be taken as 5 or 7. Choosing here a coil

Pitch of 5 slot pitches.

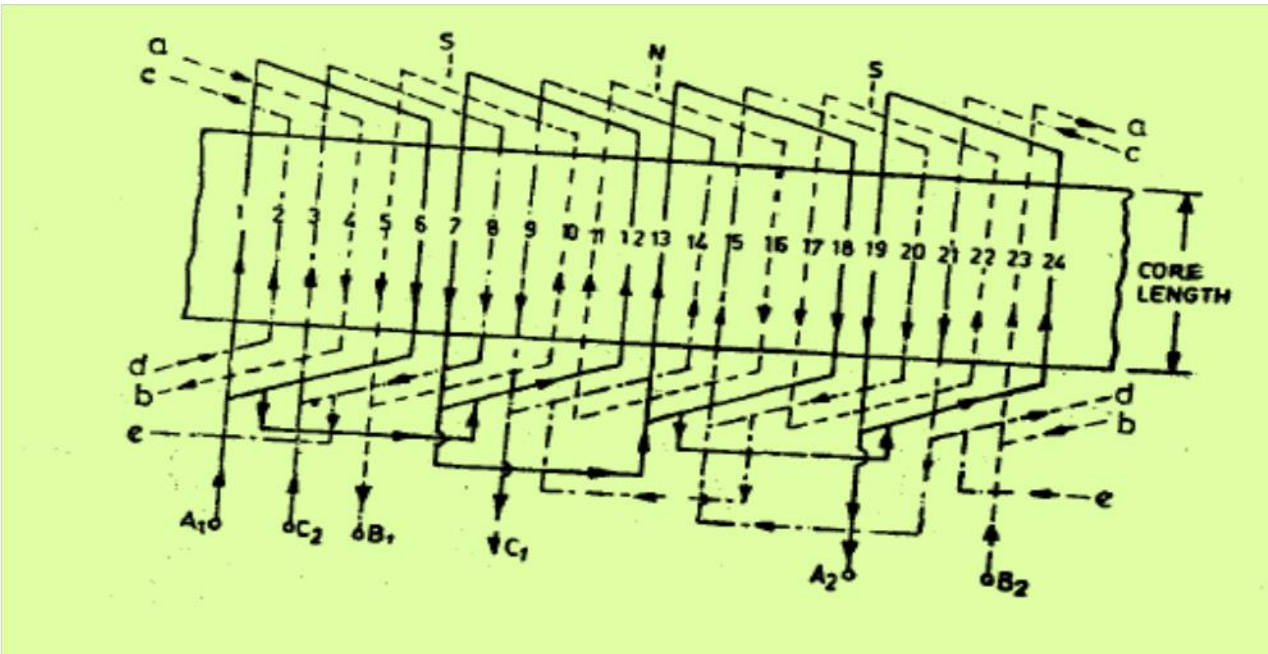


Figure *3.13:* Single – layer mush winding diagram for 24 slots, 4 poles and 60^{o} phase spread

3.5.2. Types of Double Layer Winding

3.5.2.1. Integral slot full pitch winding:- If the number of slots per pole per phase i.e. $q = \frac{S}{mP}$ is an integer, then the winding is called an integral-slot winding.

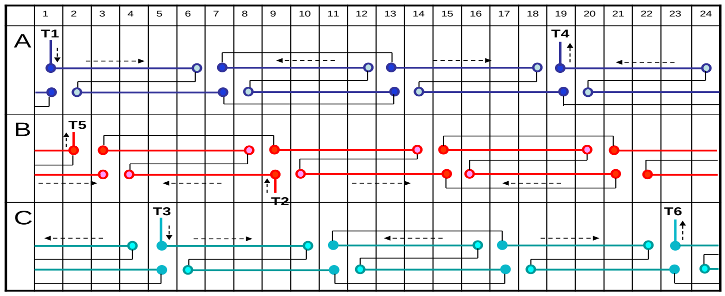


Figure 3.14: Motor Rewinding Diagram

Example 2 : Develop a full-pitch double-layer winding diagram for the following data.

S= 12, P = 2, m = 3, a = 1

Solution

$Y_p = \frac{12}{2} = 6$, $Y_c = \frac{P}{2} = 6$ (full pitch) , a= 1

$q = \frac{12}{3 \times 2} = 2$

Phase sequence : A C' B A' C B'

2 2 2 2 2 2 = 12 Slot

No. of slots	1	2	3	4	5	6	7	8	9	10	11	12
Phase sequence of the upper layer	A	A	C'	C'	B	B	A	A	C'	C'	B	B
Phase sequence of bottom layer	A'	A'	C	C	B'	B'	A'	A'	C	C	B'	B'

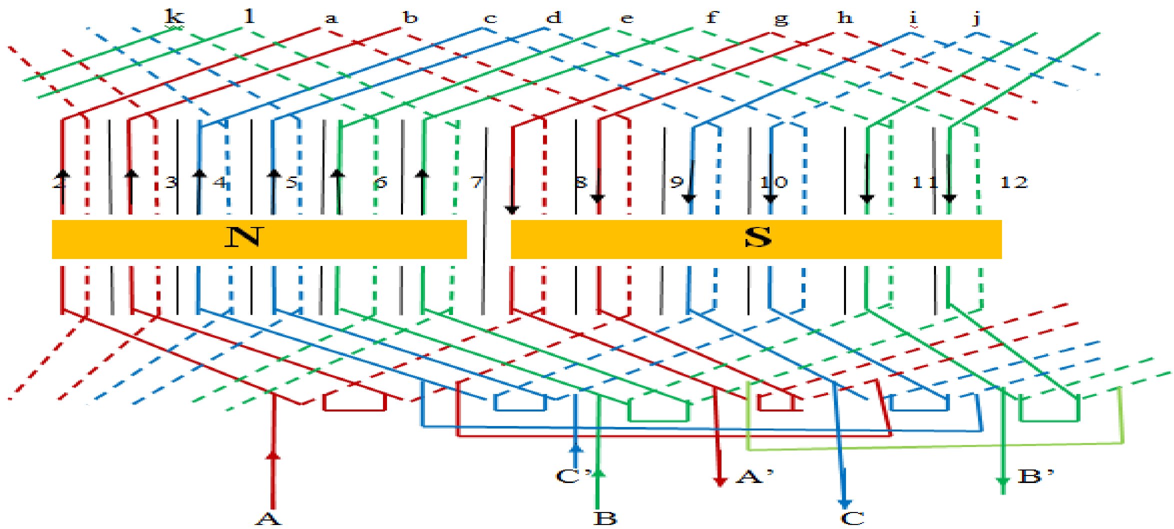


Figure *3.15 Double Layer winding with 12 slots*

Example 3: make a winding table for the armature of a 3-phase machine with the following specifications:

Total number of slots = 24 | Double – layer winding

Number of poles = 4 | Phase spread=60^0

Coil-span = full-pitch

(a) Draw the detailed winding diagram for one phase only

(b) Show the star of coil-emfs. Draw phasor diagram for narrow-spread(σ=60 ^{0}) connections of the 3-phase winding showing coil-emfs for phases A and B only.

Solution: slot angular pitch, $\gamma = \frac{4\times180^0}{24} = 30^0$

Phase spread, $\sigma = 60^0$

Number of slots per pole per phase, $q = \frac{24}{3\times4} = 2$

Coil span = full pitch $= \frac{24}{4} = 6$

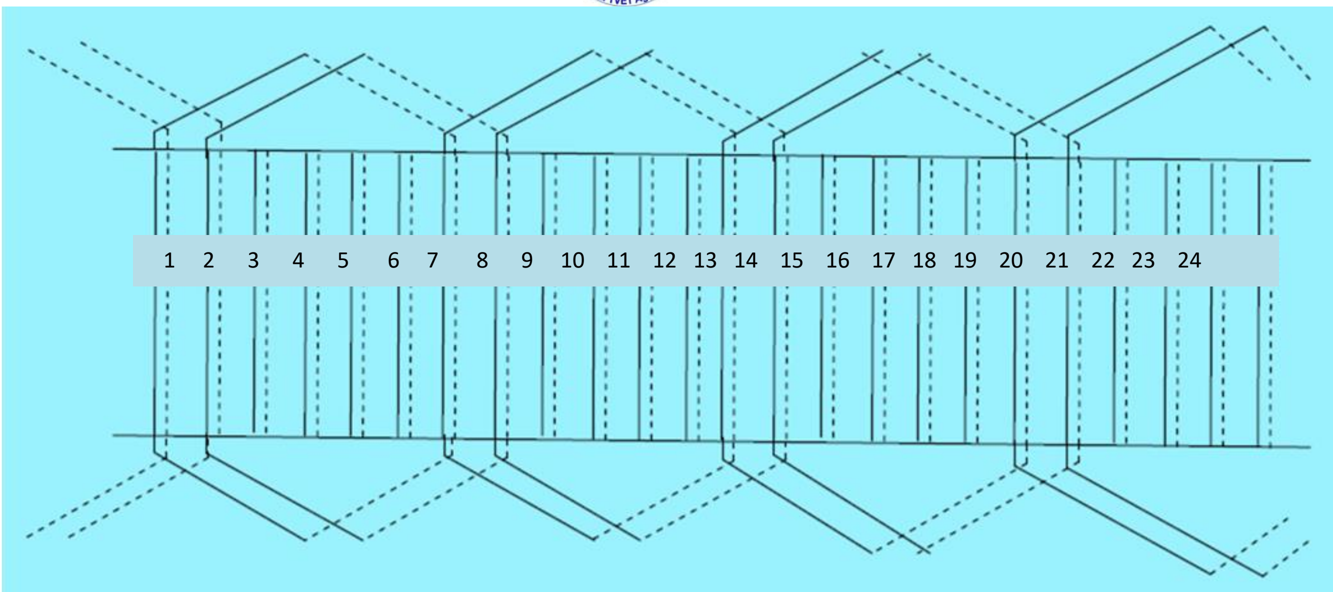
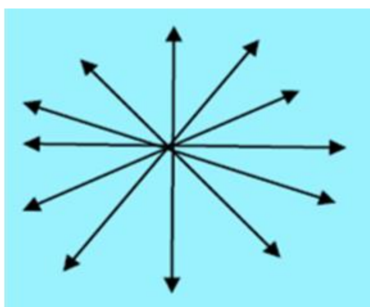
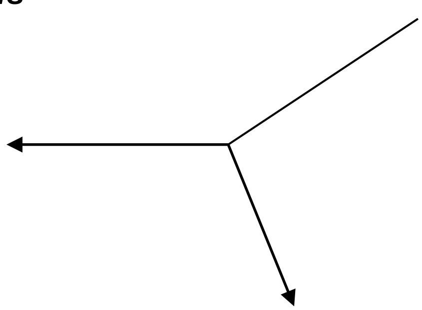


Figure 3.16: Detailed double layer winding diagram for phase A for 3-phase armature having 24 slots, 4 poles, phase spread 60°



b) The ***star*** of ***coil emfs*** can be drawn similar to the star of ***slot emfs*** or star of ***conductor emfs***



Phasor diagram showing the phasor sum of coil-emfs to obtain phase voltages A and B

3.5.2.2. Integral slot chorded winding

- Coil span (coil pitch) **<** pole pitch (***y* < *τ***)
- The advantages of using chorded coils are:
  - ✓ To reduce the **amount of copper** required for the end-connections (or over hang)
  - ✓ To reduce the **magnitude of certain harmonics** in the waveform of phase emfs and mmfs
- The coil span generally varies from **2/3 pole pitch** to **full pole pitch**

Example. Let us consider a double-layer three-phase winding with q = 3, p = 4, (S = pqm = 36 slots), chorded coils y/τ = 7/9

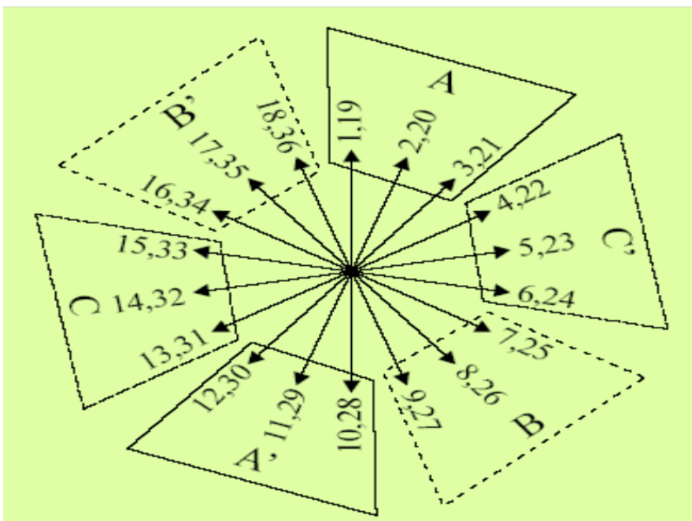


Figure 3.17 The star of slot emf phasors for a double-layer winding p = 4 poles,

q = 3 slots/pole/phase, m = 3, S = 36

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
layer1	A	A	A	C'	C'	C'	B	B	B	A'	A'	A'	C	C	C	B'	B'	B'
layer2	A	C'	C'	C'	B	B	B	A'	A'	A'	C	C	C	B'	B'	B'	A	A

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
layer1	A	A	A	C'	C'	C'	B	B	B	A'	A'	A'	C	C	C	B'	B'	B'
layer2	A	C'	C'	C'	B	B	B	A'	A'	A'	C	C	C	B'	B'	B'	A	A

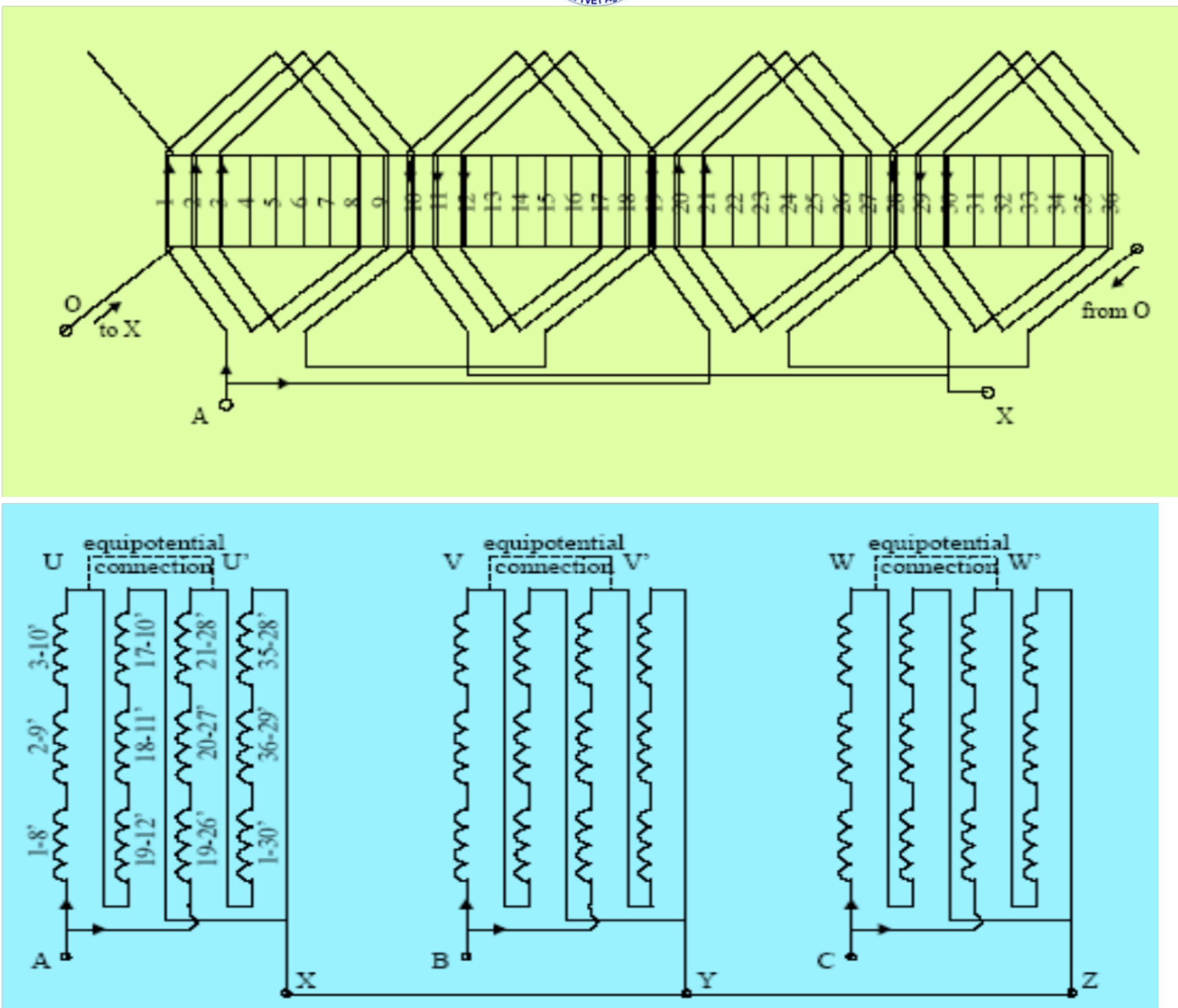


Figure 3.18: Double-layer winding: p = 4 poles, q = 3, y/τ = 7/9, S = 36 slots.

3.6. Fractional Slot Windings

If the number of slots ***q*** of a winding is a fraction, the winding is called a ***fractional slot winding.***

Example: If S = 30 , P = 30 , P = 8, m = 3 ,then $q = \frac{S}{mP} = \frac{30}{3 \times 8} = \frac{5}{4} = 1\frac{1}{4}$

Advantages of fractional slot windings when compared with integral slot windings are:

- a great freedom of choice with respect to the number of slot a possibility to reach a suitable magnetic flux density

- this winding allows more freedom in the choice of coil span
- if the number of slots is predetermined, the fractional slot winding can be applied to a wider range of numbers of poles than the integral slot winding the segment structures of large machines are better controlled by using fractional slot windings
- this winding reduces the high-frequency harmonics in the emf and mmf waveforms

Let us consider a small induction motor with ***p*** = 8 and *q* = 3/2, ***m*** = 3. The total number of slots ***S*** = pqm = 8*3*3/2= 36 slots. The coil span ***y*** is ***y*** = (S/p) = (36/8) = 4slot pitches

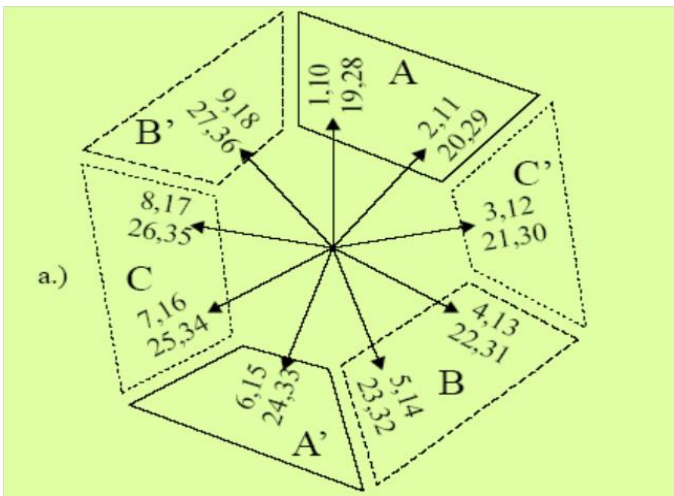


Figure 3.19: Fractionary q (q = 3/2, p = 8, m = 3,S = 36) winding- emf star,

- ✓ The actual value of q for each phase under neighboring poles is 2 and respectively, to give an average of 3/2

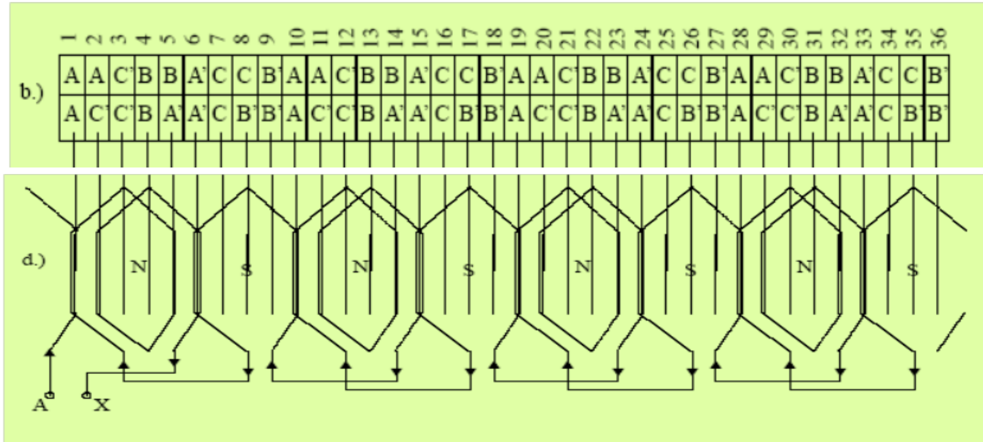


Figure 3.20: Fractionary q (q = 3/2, p = 8, m = 3, S = 36) winding slot/phase allocation & Coils of phases

- **Steps and procedures of designing and laying out fractional slot windings.**

Step 1: First of all find out the number of slots per pole per phase (q) as under;

$$q = \frac{Q}{P}$$

Where:

q= a fraction reduced to its lowest terms

Q = No. of slots per repeat group

Example

With 60 slots, 16 poles, 3 -phase

$$q = \frac{60}{16 \times 3} = \frac{5}{4}$$

Comparing this with the standard form, Q = 5 and P = 4 Thus a unit is of 4 poles (P) and in 4 poles there are 5 slots /phase and hence 15 slots in all.

Step 2 : Find **d,** the number difference between two slots as

$$d = \frac{1 + xQm}{P}$$

Where, m = numbers of phases

x = the smallest number which makes **d** an integer

Example

For the example under consideration,

$$d = \frac{1+x\times5\times3}{4} = \frac{1+1\times5\times3}{4} = 4$$

Step 3: write down the sequence of slots as:

1, **1 + d**, **1 + 2d**, **1 +3d**, ... **mQ** terms

Where, mQ = Slots in a repeatable group.

Example

For the example under consideration, **mQ = 3 X 5 = 15**.

Hence the slot numbers are;

1, 5, 9, 13, 17, 21, 25, 29, 33, 37, 41, 45, 49, 53 and 57 .

Note that these all 15 terms.

Step 4: Since the repeatable group consists of mQ slots, subtract mQ from the above numbers which exceed mQ.

Example

For the example under consideration, mQ =15 and so the slot numbers will appear as:

1, 5, 9, 13, 17-15, 25-15, 29-15, 33-30, 37 -30, 41-30, 45 30, 49-45, 53-45 and 57-45.

i.e

1, ***5***, ***9, 13***, ***2,*** **6, 10, 14, 3, 7, 11**, **15, 4, 8, 12*,***

Step 5 : Allot the first one third of the above slot numbers to phase A, next, one third to phase C and then remaining one third to phase B. (with phases sequence AC'B)

Example

For the example under consideration, the distribution is as follows.

Phase A : ***1, 2, 5, 9, 13***

Phase C: **3, 6, 7, 10, 14**

Phase B: **4, 8, 11, 12, 15**

<u>Step 6</u> ; Assume a suitable pitch and lay out the winding.

Example;

For the example consideration,

$$Pole\ pitch = \frac{15}{4} = 3\frac{3}{4}\ slots$$

We could either select 3 or 4 slots as the coil pitch. Always the smaller value is selected which effects saving in copper due to a smaller over hang.

- **Laying out the winding diagram**

Draw 15 full lines and 15 dotted lines to represent the coil-sides in 15 slot of repeatable group of 4 poles.

- ✓ Draw the north south poles as show in fig. (a) and make the direction of emf's in the upper coil-sides pertaining to phase A.
- ✓ Selecting a coil pitch of 3 slots the coils are completed as shown in fig. ' b'
- ✓ connect these coils, pertaining to phase A, Over a repeatable group of 4 poles .

Note that an arrow is shown at the end of phases A. This signifies that the winding will now continue , in a similar fashion, in the second set of a repeatable pole group.

N.B; Phase apart $= \frac{2}{3} \times \frac{S}{P} = \frac{2}{3} \times \frac{60}{16} = \frac{5}{2} = 2.5 \approx 3slots$

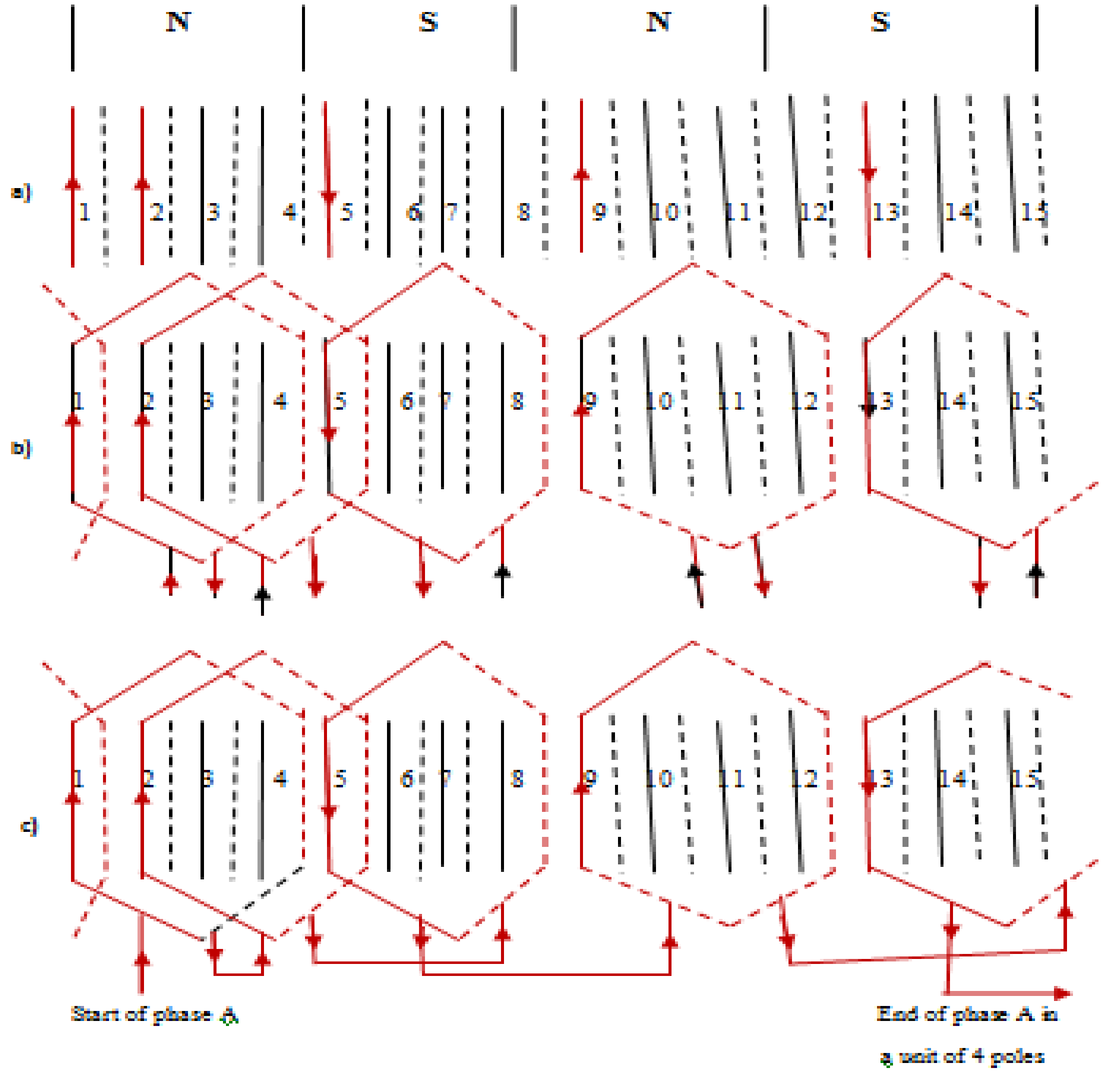


Figure 3.21: Fractional Slot winding with 60 slots 16 poles

Example 2 ; Design a fractional slot winding with the following data

108 slots - 16 Pole - 3 phase

Solution

Step1.

With $q = \frac{108}{18 \times 3} = \frac{9}{4}$

we get Q = 9 and P = 4

Step 2

$$d = \frac{1 + xQm}{P} = \frac{1 + (x * 9 * 3)}{4} = \frac{1 + (1 * 9 * 3)}{4} = 7$$

Step 3 The sequence of slots is,

1, 1 + d, 1 +2d, . . . mQ terms

Since mQ = 27, the sequence of the above 27 slots is,

1, 1 + 7, 1 + 14, 1 + 21, 1 + 28 , 1 + 35 , 1 + 42, 1 + 49, 1 + 56, 1 + 63, 1 + 70 , 1 + 77, 1 + 84, 1 + 91, 1 + 98, 1 + 105, 1 + 112, 1 + 119, 1 + 126, 1 + 133, 1 + 140, 1 + 147, 1 + 154, 1 + 161, 1+168, 1 + 175, 1 + 182,

Step 4 Taking account of the 27 slots in a repeatable group of 4 poles, the above slot numbers will become;

1, 8, 15, 22, 2, 9, 16, 23, 3,

10, 17, 24, 4, 11, 18, 24, 5, 12,

19, 26, 6, 13, 20, 27, 7, 14, 21,

Step 5 Re-arranging and allotting to each phase in order

Phase A → 1, 2, 3, 8, 9, 15, 16, 22, 23

Phase C → 4, 5, 10, 11, 12, 17, 18, 24, 25,

Phase B → 6, 7, 13, 14, 19, 20, 21, 26, 27,

Phase apart = 2/3 x27/4=5

Yp =108/16 =27/4=6¾

$\therefore Y_c = 6$

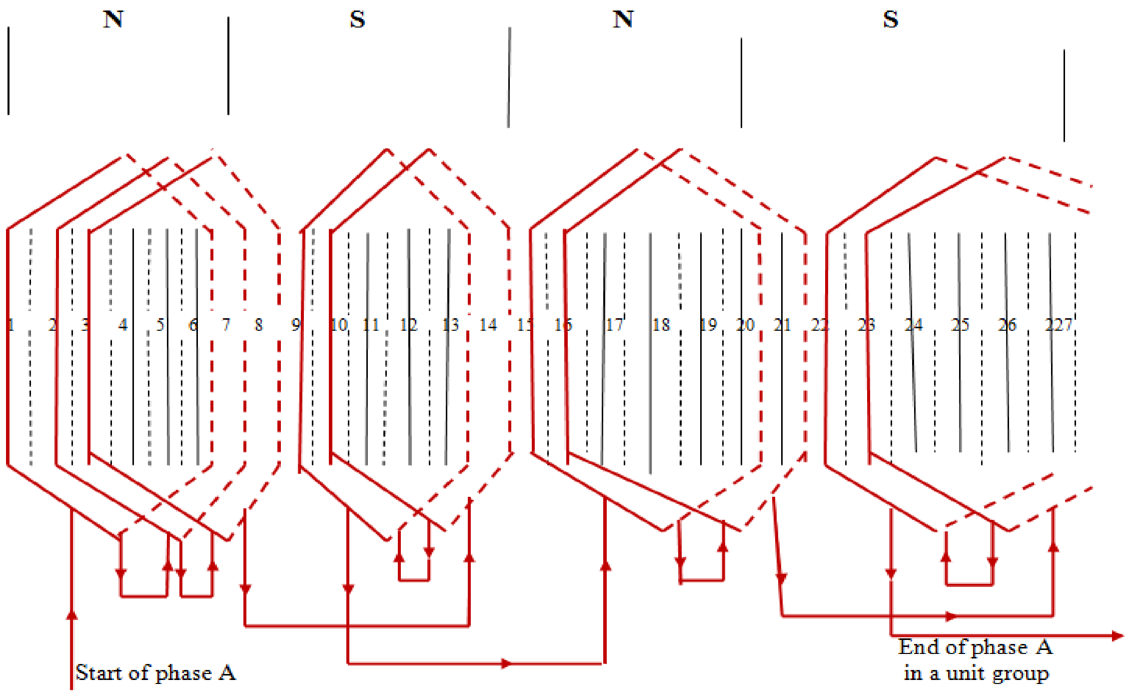


Figure 3.22: Fractional slot winding for 108 slots and 16 poles

Self-Check -3	Written Test

Directions: Choose the best answer

1. -------- It is the distance between the two active sides of the same coil under adjacent opposite poles. It is expressed in terms of number of slots per pole or electrical degrees.

A. Single layer B. Coil Span or coil pitch

C. Full pitch coil D. a and c

2.-------- A coil having a coil span equal to 1800ed is called a full pitch coil,

A double layer B .Full pitch coil

C. Coil Span or coil pitch D. None of the above

3.--------- : A coil having a coil span less than 1800ed by an angle â, is called a short pitch coil,

A. Short pitch coil B. Full pitch coil

C. Coil Span or coil pitch D. all of the above

4.-----------is the Distance between the poles in terms of slots is called pole pitch

A double layer B Full pitch coil
C. Coil Span or coil pitch D Pole Pitch

5._____Whenoneormoreturnsareconnectedinseriesandplacedinalmostsimilarmag neticpositions

A. coil B. double layer

C. Full pitch coil D. Coil Span or coil pitch

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: ___________________________ Date: ______________

Information Sheet – 4	Check and identify readings of electrical measuring instruments and refer defective instruments or calibration/replacement

4.1. Introduction

The measurement of an amount is based on some international standards which are completely accurate compared with others. Generally, measurement of any quantity is done by comparing it with derived standards with which they are not completely accurate. Thus, the errors in measurement are not only due to error in methods, but are also due to derivation being not done perfectly well. So, 100% measurement error is not possible with any methods.

It is very important for the operator to take proper care of the experiment while performing on industrial instruments so that the error in measurement can be reduced. Some of the errors are constant in nature due to the unknown reasons, some will be random in nature, and the other will be due to gross blunder on the part of the experimenter.

4.2. Errors in Measurement System

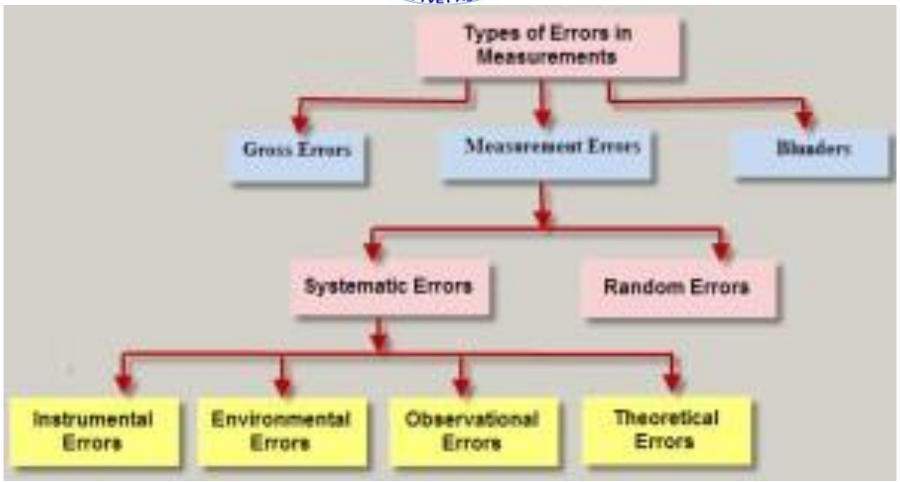
An error may be defined as the difference between the measured value and the actual value. For example, if the two operators use the same device or instrument for finding the errors in measurement, it is not necessary that they may get similar results. There may be a difference between both measurements. The difference that occurs between both the measurements is referred to as an ERROR.

Sequentially, to understand the concept of errors in measurement, you should know the two terms that define the error. They are true value and the measured value. The true value is impossible to find out the truth of quantity by experimental means. It may be defined as the average value of an infinite number of measured values. Measured value can be defined as the estimated value of true value that can be found by taking several measured values during an experiment.

4.3. Types of Errors in Measurement System

Generally errors are classified into three types:

1. Gross Errors
2. Systematic Errors
3. Random Errors



1. Gross Errors in Electrical Measuring Instruments:

This class of errors mainly covers human mistakes in reading measuring instruments and recording and calculating measurement results. The responsibility of the mistake normally lies with the experimenter. The experimenter may grossly misread the scale. For example, he may, due to an oversight, read the temperature as 31.5°C while the actual reading may be 21.5°C. He may transpose the reading while recording.

For example, he may read 25.8°C and record 28.5`C instead. But as long as human beings are involved, some gross errors will definitely be committed. Although complete elimination of gross errors is probably impossible, one should try to anticipate and correct them. Some **gross errors** are easily detected while others may be very difficult to detect.

- Gross errors may be of any amount and therefore their mathematical analysis is impossible. However, they can be avoided by adopting two means. They are :

  - ✓ Great care should be taken in reading and recording the data.
  - ✓ Two, three or even more readings should be taken for the quantity under measurement.

These readings should be taken preferably by different experimenters and the readings should be taken at a different reading point to avoid re-reading with the same error. It should be understood that no reliance be placed on a single reading. It is always advisable to take a large number of readings as a close agreement between readings assures that no gross error has been committed.

2. Systematic Errors in electrical measuring instruments:

These types of errors are divided into three categories

- ✓ Instrumental Errors

- ✓ Environmental Errors
- ✓ Observational Errors
- ✓ Instrumental Errors

These errors arise due to three main reasons:

(a) Due to inherent shortcomings in the instrument

(b) Due to misuse of the instruments

(c) Due to loading effects of instruments

(a) Inherent shortcomings of instruments:

These errors are inherent in instruments because of their mechanical structure. They may be due to construction, calibration or operation of the instruments or electrical measuring devices. These errors may cause the instrument to read too low or too high. For example, if the spring (used for producing controlling torque) of a **permanent magnet instrument** has become weak, the instrument will always read high. Errors may be caused because of friction, hysteresis or even gear backlash.

While making precision measurements, we must recognize the possibility of such errors as it is often possible to eliminate them, or at least reduce them to a great extent by using the following methods :

(i) The procedure of measurement must be carefully planned. Substitution methods or calibration against standards may be used for the purpose.

(ii) Correction factors should be applied after determining the instrumental errors.

(iii) The instrument may be re-calibrated carefully.

(b) Misuse of instruments:

There is an old saying that instruments are better than the people who use them. Too often, the **types of errors** caused in measurements are due to the fault of the operator than that of the instrument.

A good electrical measuring instrument used in an unintelligent way may give erroneous results. Examples which may be cited for this misuse of the instrument may be a failure to adjust the zero of instruments, poor initial adjustments, using leads of too high a resistance etc.

No doubt the above improper practices may not cause a permanent damage to the instrument but all the same, they cause errors. However, there are certain ill practices like using the instrument contrary to manufacturer's instructions and specifications which in addition to producing errors cause permanent damage to the instruments as a result of overloading and overheating that may ultimately result in failure of the electrical measuring instrument and sometimes the system itself.

(C) Loading effects:

One of the most common errors committed by beginners is the improper use of an instrument for measurement work. For example, a well calibrated voltmeter may give a misleading voltage reading when connected across a high resistance circuit. The same voltmeter, when connected in a low resistance circuit, may give a more dependable reading. These examples illustrate that the voltmeter has a loading effect on the circuit, altering the actual circuit conditions by the measurement process.

Therefore errors caused by loading effects of the meters can be avoided by using them intelligently. For example, when measuring a low resistance by ammeter-voltmeter method a voltmeter having a very high value of resistance should be used. In planning any measurement, the loading effect of instruments should be considered and corrections for these effects should be made, if needed, or more suitable **electrical measuring instruments** should be used. Preferably those methods should be used which result in negligible or no loading effects. Static and Dynamic Characteristics of Electrical Measuring Instruments

(ii) Environmental Errors:

These **errors in electrical measuring instruments** are due to conditions external to the measuring device including conditions in the area surrounding the instrument. These may be effects of temperature pressure, humidity, dust, vibrations or of external magnetic or electrostatic fields. The corrective measures employed to eliminate or to reduce these undesirable effects are:

- Arrangements should be made to keep the conditions as nearly as constant as possible. For example, the temperature can be kept constant by keeping the equipment in a temperature controlled enclosure.
- Using equipment which is immune to these effects. For example, variations in resistance with temperature can be minimized by using resistance materials which have a very low resistance temperature coefficient.
- Employing techniques which eliminate the effects of these disturbances. For example, the effect of humidity dust etc. can be entirely eliminated by hermetically sealing the equipment.

- In case it is suspected that external magnetic or electrostatic fields can affect the readings of the electrical measuring instruments, magnetic or electrostatic shields may be provided.

- Applying computed corrections: Efforts are normally made to avoid the use of application of computed corrections, but where these corrections are needed and are necessary, they are incorporated for the computations of the results.

(iii) Observational errors:

There are many sources of observational errors. As an example, the pointer of a voltmeter rests slightly above the surface of the scale. Thus an error on account of PARALLAX will be incurred unless the line of vision of the observer is exactly above the pointer. To minimise parallax errors, highly accurate meters are provided with mirrored scales, as shown in the figure 'errors due to parallax'.

When the pointer's image appears hidden by the pointer, observer's eye is directly in line with the pointer. Although a mirrored scale minimizes parallax error, an error is necessarily present though it may be very small. Since the parallax errors arise on account of the pointer and the scale not being in the same plane, we can eliminate this error by having the pointer and the scale in the same plane as shown in figure arrangements showing scale and pointer in the same plane'.

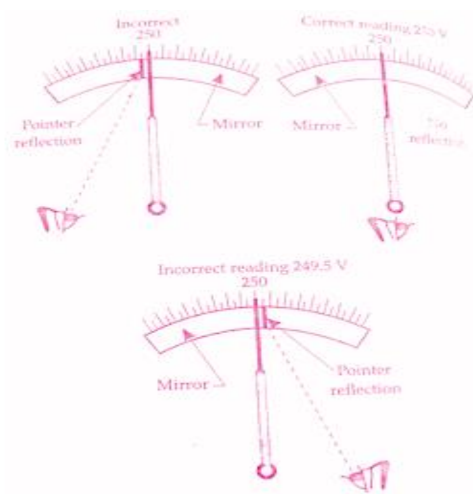


Fig 4.1. Errors due to parallax

There are human factors involved in measurement. The sensing capabilities of individual observers affect the accuracy of measurement. No two persons observe the same situation in exactly the same way where small details are concerned. For example, there are observational errors in measurements involving timing of an event. One observer may tend to anticipate the signal and read too soon.

Different experimenters may produce different results, especially when sound and light measurements are involved since no two observers possess the same physical responses. Modern electrical instruments have a digital display of output which completely eliminates the errors on account of human observational or sensing powers as the output is in the form of digits.

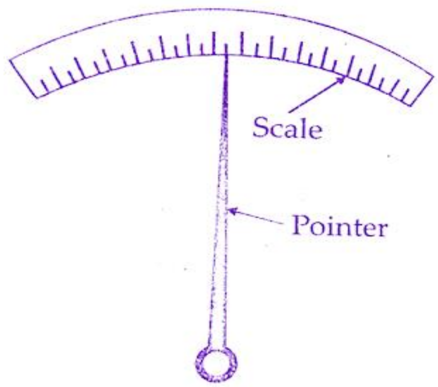


Fig.3.2. Arrangements showing scale and pointer in the same plane

3. Random (Residual) Errors in electrical measuring instruments: :

It has been consistently found that experimental results show variation from one reading to another; even after all systematic errors have been accounted for. These **types of errors in electrical measuring instruments** are due to a multitude of small factors which change or fluctuate from one measurement to another and are due surely to chance. The quantity being measured is affected by many happenings throughout the universe.

We are aware of and account for some of the factors influencing the measurement, but about the rest we are unaware. The happenings or disturbances about which we are unaware are lumped together and called "Random" or "Residual". Hence the errors caused by these happenings are called ***Random (or Residual) Errors***. Since these type of errors remain even after the systematic errors have been taken care of, we call these errors as ***Residual (Random) Errors***.

Self-Check -4	Written Test

Directions: Choose the best answer

1. An error may be defined as the difference between the measured value and the actual
2. Different experimenters may produce the same results
3. Great care should be taken in reading and recording the data

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _____________

Information Sheet –5	Check and tight Connectors, bolts, nuts and screws

5.1. Introduction

A pressurized bolted flange joint assembly begins to leak, creating a safety hazard. A rotor with its blades separates from the nacelle and spins off a wind turbine, crashing to the ground. Under constant vibration from the engine of an ocean freighter, loose bolts on a large piece of mining equipment work their way off the bolted joints and roll around the hull, inflicting further damage to the equipment.

Bolted joints are critical to the safe operation of many types of equipment in a wide range of applications, including power generation, manufacturing, mining, and transportation.

In a bolted joint, tightening the nut actually stretches the bolt a small amount, like pulling on a stiff spring. This stretching, or tension, results in an opposing clamp force that holds the two sections of the joint together. If the bolt comes loose, this clamp force weakens.

Loose bolts are not just an irritating nuisance. If the joint is not quickly retightened, the application may begin to leak fluid or gas, the bolt may break, equipment may become damaged, or catastrophic accidents may occur.

5.2. Causes of Loose Bolts

There are at least five causes of loose bolts, which can occur separately or in combination:

- **Under - tightening.**

By definition, an under-tightened bolt is already loose and the joint does not have enough clamp force to hold the individual sections together. This can lead to sideways slippage between sections, placing unwanted shear stress on the bolt that could eventually cause it to break.

- **Vibration**

Experiments on bolted joints under vibration show that many small "transverse" movements cause the two sections of the joint to move in parallel with each other and with the bolt head or nut. These repeated movements work against the friction between the bolt and joint threads that is holding the joint together. Eventually, vibration will cause the bolt to "unwind" from the mating threads and the joint to lose its clamp force.

- **Embedding**

The design engineers who specify the tension on a bolt allow for a break-in period, during which bolt tightness relaxes to a certain degree. This relaxation is caused by micro-embedding of the bolt head and/or nut into the joint surface, and can occur with both soft materials, such as composites, as well as hard, polished metals. If the joint has not been designed properly, or if the specified tension was not achieved on the bolt at the start, this embedment of the joint can lead to a loss of clamp force.

- **Gasket creep**

Many bolted joints include a thin, flexible gasket between the bolt head and the surface of the joint to seal the joint completely against gas or liquid leaks. The gasket itself acts as a spring, pushing back against the pressure of the bolt and the joint face. Over time, and especially near high heat or corrosive chemicals, the gasket may "creep," which means it loses its springiness, leading to loss of clamp force. This can also happen if the gasket area directly next the bolt is crushed or if the bolts are not tightened evenly across the entire face of the joint.

- **Differential Thermal Expansion**

If the material of the bolt and the joint are different, large differences in temperature due to rapid environmental changes or cycling industrial processes can cause bolt material to expand or contract rapidly, possibly loosening the bolt.

- **Shock**

Dynamic or alternating loads from machinery, generators, wind turbines, etc., can cause mechanical shock – a sudden force applied to the bolt or the joint – causing the bolt threads to slip relative to the threads of the joint. Just as with vibration, this slippage can ultimately lead to loosening of the bolts.

5.3. Steps to Prevent Loose Bolts

Because loose bolts are so common, an astonishing array of devices has been invented to prevent them from occurring. Here are five basic types of prevention methods:

- **Washers**

Washers are typically wider than the bolt head, with the additional surface area adding extra friction to the joint to maintain the clamp force. However, simple split washers, sometimes called helical spring washers, have been found to actually loosen the bolt under vibration even faster than a joint with no washer. Conical, or Belleville washers, are cup-shaped washers that perform little better than spring washers in vibration tests.
Several types of locking washers have been developed, with flutings, ribs or teeth that dig into the surface of the joint during the tightening process, in order to prevent loosening. This may cause permanent damage to the joint finish or surface, which may be unacceptable, such as in critical aerospace applications where surface indentations may cause fatigue stresses. It may also prevent re-tightening of the joint to the proper tension.

Wedge-locking washers work in sets of two, with each washer having opposite facing wedges that interact with each other and with the joint and nut surfaces to prevent self-turning of the bolt. The wedges are designed to add tension (stretch) to the bolted joint if the bolt begins turning due to vibration or shock, preventing a loss of clamp force.

- **Mechanical devices**

Numerous clever gimmicks have been developed to lock a tightened nut into place on a bolted joint. Castellated nuts have a slotted end and are used with a cotter pin or wire that fits through a hole drilled in the bolt. Locking fastener systems have a shaped flat retainer, similar to a washer, and a clip that fits into a groove on the bolt head. Tab washers have two tabs on opposite sides, which fold up to secure the bolt head or nut after installation, and may have teeth that can penetrate the surface of the joint to hold it in place. While these devices do prevent the nut from falling off the bolt, they generally do not help the joint maintain the specified clamp force.

- **Prevailing torque nuts**

Nylon or metal inserts inside a nut (sometimes called a “lock nut”) can add extra friction to prevent loosening. A related idea is to fit a spring inside the nut, which firmly grasps the bolt threads and is designed to move in the opposite direction of the nut if vibration or other forces cause it to unwind. Nylon inserts cannot be used in harsh chemical or high-heat applications, and typically can’t be reused because the bolt threads cut grooves into the nylon, diminishing its ability to hold after re-tightening. Because the insert on most lock nut styles only covers part of the internal threads, a strong transverse motion or shock can still cause the bolt to self-loosen.

- **Double nuts**

According to an article in Fastener + Fixing, the idea of using two nuts, a thick one and a thinner one (called a jammer nut), has been used for over 150 years to prevent loosening of bolted joints. A modern application is a system using two nuts each having different sized threads which advance at different rates on a dual-threaded bolt. In this way, transverse motions that may cause one nut to advance will not affect the second nut.

- **Adhesives**

Liquid adhesives, as well as heated thermoplastic coatings or solid adhesive patches, have successfully been used to ensure bolts in certain applications do not come loose. The problem is that they make it harder to disassemble the joint later.

Self-Check -5	Written Test

Directions: Choose the best answer

1. Nylon or metal inserts inside a nut (sometimes called a “lock nut”) can add extra friction to prevent loosening.
2. Washers are typically wider than the bolt head, with the additional surface area adding extra friction to the joint to maintain the clamp force.
3. Loose bolts are just an irritating nuisance.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: ___________________________ Date: ______________

Information Sheet :6	Conduct regular routine/visual/sensory inspection

6.1. Visual Inspection

A regular visual inspection should be carried out in all electrical installations. A visual inspection of this type does not necessarily need to be carried out by an electrician, but it should reveal any areas which are obviously in need of attention.

A visual inspection should look for:

- Breakages
- Wear & deterioration
- Signs of over heating
- Missing parts (covers, screws) and
- Loose fixings and confirm
- Switchgear accessibility (no obstructions) and
- Doors of enclosures are secure It should also check the operation of
- Equipment – switch on & off where equipment is not in regular use or where it is left off or on standby for long periods and
- Residual current devices using test button.(It is recommended that, independent of any other inspection and test regime, residual current devices undergo a push-button test at least twice per year to ensure that they operate correctly when needed).

These routine checks need not to be carried out by an electrically skilled person but should be done by someone who is able to safely use the installation and recognize any obvious defects.

Self-Check -6	Written Test

Directions: Choose the best answer

1. A regular visual inspection should be carried out in all electrical installations
2. Residual current devices using test button.(It is recommended that, independent of any other inspection and test regime

Note: **Satisfactory rating - 1 points** **Unsatisfactory - below 1 points**

Score = ___________

Rating: ____________

Name: ___________________________ Date: ______________

Operation Sheet-1	**Rewinding stator coils of single phase AC motor**

Procedure:

1 Note down the name plate data before dismantling the motor.

2 Dismantle the motor after making the end-plates with punch marks.

3 Note down the coil data before stripping off the damaged winding.

4 Strip off the damaged coils

5 Prepare a winding diagram.

6 Clean the stator's slot and remove the burnt insulation.

7 Record the data of the coils, both running and starting winding.

8 Record the data of the turns in each coils group.

9 Line the slots with the required type and size of insulating materials.

10 Make the former as per the dimensions of the removed coil.

11 Wind one test coil on the former, insert it in the slot and check its dimension.

12 Change the former, if necessary, and wind the coils.

13 Recheck for untapped joint, sleeves etc. before closing the end plates and reassemble the motor.

14 Test the motor for insulation resistance.

15 Have a trial run on load and note the parameters e.g. intake current, speed, temperature rise, etc.

16 If the trial is successful, dismantle the motor and impregnate with proper insulating varnish.

17 Heat the motor in oven with a controlled temperature 80- 100◦C for 10 to 12 hours.

18 Clean the stator by removing the excessive deposits of varnish on the cores.

19 Reassemble the motor and have a trial run on load and no-load.

Operation Sheet-2	Rewinding stator coils of three phase AC motor

1 Note down the name plate data before dismantling the motor.
2 Dismantle the motor after making the end-plates with punch marks.
3 Note down the coil data before stripping off the damaged winding.
4 Strip off the damaged coils
5 Prepare a winding diagram.
6 Clean the stator's slot and remove the burnt insulation.
7 Record the data of the coils
8 Record the data of the turns in each coils group.
9 Line the slots with the required type and size of insulating materials.
10 Make the former as per the dimensions of the removed coil.
11 Wind one test coil on the former, insert it in the slot and check its dimension.
12 Change the former, if necessary, and wind the coils.
13 Recheck for untapped joint, sleeves etc. before closing the end plates and reassemble the motor.
14 Test the motor for insulation resistance.
15 Have a trial run on load and note the parameters e.g. intake current, speed, temperature rise, etc.
16 If the trial is successful, dismantle the motor and impregnate with proper insulating varnish.
17 Heat the motor in oven with a controlled temperature 80- 100◦C for 10 to 12 hours.
18 Clean the stator by removing the excessive deposits of varnish on the cores.
19 Reassemble the motor and have a trial run on load and no-load.

LAP Test	**Practical Demonstration**

Task 1. Develop a single phase, single layer AC lap winding for a 4 pole AC machine having 24 slots.

Task 2. Develop a single phase, single layer AC lap winding for a 4 pole AC machine having 48 slots.

Task 3. Develop and draw ***(a)*** half coil and ***(b)*** whole coil single layer concentric windings for a 3-phase machine with 24-slots, 4-poles and 60^{o} phase spread.

List of Reference Materials

1. A. Bellini, F. Filippetti, C. Tassoni, G. A. Capolino, "Advances in diagnostic techniques for induction motors", *IEEE Trans. Energy Convers.*, vol. 55, no. 12, pp. 4109-4126, Dec. 2008.

2. M. J. Devaney, L. Eren, "Detecting motor bearing faults", *IEEE Instrum. Meas. Mag.*, vol. 7, no. 4, pp. 30-50, Dec. 2004.

3. J. Faiz, B. M. Ebrahimi, "Mixed fault diagnosis in three-phase squirrel-cage induction motor using analysis of airgap magnetic field", *in Proc. Prog. Electro-Magn. Res. Symp.*, pp. 239-355, 2006.

4. M. E. H. Benbouzid, "A review of induction motors signature analysis as a medium of faults detection", *IEEE Trans. Ind. Electron.*, vol. 47, no. 5, pp. 984-993, Oct. 2000.

5. Eectric Machinery, 6e, Fitzgerald.

6. Principles of electrical machines(mehta)

7. Theraja

Instruction Sheet :1	LG32: Troubleshoot faults in an Electrical System or equipment

This learning guide is developed to provide you the necessary information regarding the following learning outcome and content coverage

- Follow safety policies and procedures
- prepare maintenance records
- Isolate Circuit or equipment to be diagnosed
- identify Indicators/Symptoms of fault or failure
- Perform necessary electrical test on the system or equipment
- Estimate Extent of the fault to accomplish the job and the spare parts needed
- Coordinate other works associated with the problem
- Record details of fault, possible cause, corrective action, recommendation to eliminate the problem
- respond unforeseen events

This guide will also assist you to attain the learning outcome and contents stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Follow safety policies and procedures
- prepare maintenance records
- Isolate Circuit or equipment to be diagnosed
- identify Indicators/Symptoms of fault or failure
- Perform necessary electrical test on the system or equipment
- Estimate Extent of the fault to accomplish the job and the spare parts needed
- Coordinate other works associated with the problem
- Record details of fault, possible cause, corrective action, recommendation to eliminate the problem
- respond unforeseen events

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the "Information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6, Sheet 7, Sheet 8 and Sheet 9" in page 4,8,11,16,22,27,31,34 and 38 respectively".
4. Accomplish the "Self-check 1, Self-check 2, Self-check 3 , Self-check 4 , Self-check 5 , Self-check 6, Self-check 7, Self-check 8 and Self-check 9" in page 7,10,15,21,28,30,33,37 and 39 respectively".

5. If you earned a satisfactory evaluation from the “Self-check” proceed to “Operation Sheet 1 and Operation Sheet 2” in page 40 and 41 respectively.
6. Do the “LAP test” in page 42

Information Sheet :1	Follow safety policies and procedures

1.1. Introduction

Safety is the number one priority in any job. Every year, electrical accidents cause serious injury or death. Many of these casualties are young people just entering the workplace. They are involved in accidents that result from carelessness, from the pressures and distractions of a new job, or from a lack of understanding about electricity. This content is designed to develop an awareness of the dangers associated with electrical power and the potential dangers that can exist on the job or at a training facility.

- **Electrical Safety Work Practices Plan**

This safety procedure provides guidelines for safely working around electrical hazards. It includes provisions for training, lockout requirements, and specific types of work practices and the required precautionary practices when using portable electric equipment. Employees will be trained in specific hazards associated with their potential exposure. This training will include isolation of energy, hazard identification, premises wiring, connection to supply, generation, transmission, distribution installations, clearance distances, use of personal protective equipment and insulated tools, and emergency procedure

- **Qualified Person**

Those persons who are permitted to work on or near exposed energized parts and are trained in the applicable electrical safe work practices. Qualified persons shall, at a minimum, be trained in and familiar with:

- ✓ the skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment,
- ✓ the skills and techniques necessary to determine the nominal voltage of exposed live parts, and
- ✓ The clearance distances specified in Table I and the corresponding voltage to which the qualified person will be exposed.

1.2. General Safety Rule

- Get the right tool for the right job
- Report immediately defective equipment or measuring devices such as melt meter
- Keep your work shop clean always
- Work care fully
- Learn the use tools and measuring device correctly
- Learn the correct procedure before doing any jobs
- Report all accident
- Do not open or close avian switch or any power supply with out permission
- Be sure your hands are dry before you handle electrical appliances
- Make a change in wiring only after the current has been put off
- Every circuit must be fused
- Bare wire must be insulated to around short circuit
- Do not work close to power lines

1.3. Personal Protective Equipment (PPE)

Construction and manufacturing worksites, by nature, are potentially hazardous places. For this reason,safety has become an increasingly large factor in the working environment. The electrical industry, in particular, regards safety to be unquestionably the most single important priority because of the hazardous nature of the business. A safe operation depends largely upon all personnel being informed and aware of potential hazards. Safety signs and tags indicate areas or tasks that can pose a hazard to personnel and/or equipment. Signs and tags may provide warnings specific to the hazard, or they may provide safety instructions (Figure 1-2).To perform a job safely, the proper protective clothing must be used. Appropriate attire should be worn for each particular job site and work activity.

The following points should be observed:

iv. Hard hats, safety shoes, and goggles must be worn in areas where they are specified. In addition, hard hats shall be approved for the purpose of the electrical work being performed but metal hats are not acceptable!

v. Safety earmuffs or earplugs must be worn in noisy areas.

vi. Clothing should fit snugly to avoid the danger of becoming entangled in moving machinery. Avoid wearing synthetic-fiber clothing such as polyester material as these types of materials may melt or ignite when exposed to high temperatures and may hard hat Goggles Cotton only, no polyester Tight sleeves and trouser legs No rings on fingers Safety shoe.

vii. Remove all metal jewelry when working on energized circuits; gold and silver are excellent conductors of electricity. Confine long hair or keep hair trimmed when working around machinery

Self-Check -1	Written Test

Directions: Choose the best answer.

9. Which one of the following safety equipment?
   I. Measuring instrument C. Glove
   J. Hand tool D. All of the above
10. _______ must be worn in noisy areas.

E. Safety shoos
F. Ear plug
G. Hat
H. All of the above

***Note:* Satisfactory rating - 1 points** **Unsatisfactory - below 1 point**

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :2	Prepare maintenance records

2.1. Preventive maintenance schedule

Preventive maintenance is the maintenance which has to be carried out to the equipment, in a preplanned way before serious breakdown takes place. If a record is maintained for certain measurable parameters like body and bearing temperature, insulation resistance, earth resistance etc., it is possible from the scrutiny of this record to predict the occurrence of future trouble and necessary steps can be taken to prevent the occurrence of serious breakdown.

The interval of doing various maintenance operations, depend upon the type of equipment, ambient condition and other factors. It is difficult to lay down hard and fast rules covering all conditions but for average normal industrial duty under-mentioned time schedule will serve as guide. This can be modified to suit other conditions at site.

- ✓ **Daily maintenance**

1) Examine visually earth connections and motor leads. 2) Check motor windings for overheating. 3) Examine control equipment. 4) Check condition of bearings. 6) Add oil, if necessary, 7) Check end play.

- ✓ **Weekly maintenance**

1) Check belt tension. In the case of sleeve bearing machines the air gap between-rotor and stator should be checked. 2) Blow out dirt from the windings of protected type motors situated in dusty locations. 3) Examine starting equipment for burnt contacts where motor is started and stopped frequently. 4) Examine oil in the case of oil ring lubricated bearings

for contamination by dust, grit etc. (this can be roughly judged from the color of the oil). 5) Check the intensity of vibrations during operation of the motor. 6) Clean filters where provided.

- **M onthly maintenance**

1) Overhaul controllers. 2) Inspect and clean oil circuit. 3) Renew oil in high speed bearings in damp and dusty locations. 4) Wipe brush holders and check bedding of brushes of slip-ring motors. 5) Check that the connections of temperature detectors and space heaters, where provided, are proper and these are in working order.

- **Haly-Yearly Maintenance**

1) Clean windings of motors subjected to corrosive or other elements, also bake and varnish them, if necessary. 2) In the case of slip-ring motors, check slip-rings for grooving or unusual wear. 3) Check grease in ball and roller bearings and make it up where necessary taking care to avoid overfilling. 4) Drain all oil bearings, wash with petrol to which a few drops of oil have been added, flush with lubricating oil and refill with clean oil.

- **Annual Maintenance**

  - Check all high speed bearings and renew, if necessary.
  - Blow out all motor windings thoroughly with clean dry air. Make sure that the pressure is not so high as to damage the insulation.
  - Clean and varnish dirty and oily windings.
  - Overhaul motors which have been subjected to severe operating conditions.
  - Renew switch and fuse contacts if damaged.
  - Check oil for its dielectric strength.
  - Renew oil in starters subjected to damp or corrosive elements.
  - Check insulation resistance to earth and between phases of motor windings, control gear and wiring.
  - Check resistance of earth connections.
  - Check air gaps.
  - Check condition of all fasteners.

Self-Check -2	Written Test

Directions: Answer all the questions listed below**.** Choose the best answer

15. One is not a type of Daily maintenance?

    A . Check motor winding for overheating.
    B. Check resistance of earth connections.
    C . Check condition of bearing
    D . none of the above

2. Which one of the following Monthly maintenance?

    A. Over haul controllers.
    B. Inspect and clean oil circuit.
    C. Renew oil in high speed bearings in dampand dusty locations
    D. all of the above

3. One is not a type of Annual maintenance**?**

    A. Renew switch and fuse contacts if damaged.
    B. Check oil for its dielectric strength.
    C . Examine control equipment.
    D. none of the above

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ____________

Rating: ______________

Name: _________________________ Date: _______________

3.1. Introduction

Before any plant is inspected, maintained, cleaned or repaired, where practicable, it must be shut down and its energy sources locked out and tagged as part of an isolation procedure (often called Lockout Tagout) to ensure the safety of those doing the work. Equipment can malfunction for a variety of reasons. Mechanical contacts and parts can wear out; wires can overheat and burn open or short out; parts can be damaged by impact or abrasion; etc. Equipment may operate in a manner far different than it was designed to, or not at all. Typically, when equipment fails there is a sense of urgency to get it fixed and working again. If the defective equipment is part of an assembly line, the whole assembly line could be down causing unexpected "time off" and lost revenue. If you are at a customer site to repair equipment, the customer may watch you, knowing that they are paying for every minute you spend troubleshooting and repairing their equipment. Either one of these scenarios – and there are more, can put a lot of pressure on you to solve the problem quickly.

So, What is troubleshooting? It is the process of analyzing the behavior operation of a faulty circuit to determine what is wrong with the circuit. It then involves identifying the defective component(s) and repairing the circuit. Depending on the type of equipment, troubleshooting can be a very challenging task. Sometimes problems are easily diagnosed and the problem component easily visible. Other times the symptoms as well as the faulty component can be difficult to diagnose. A defective relay with visual signs of burning should be easy to spot, whereas an intermittent problem caused by a high resistance connection can be much more difficult to find.

What makes an expert Troubleshooter? One trait of expert troubleshooters is that they are able to find virtually any fault in a reasonable amount of time. Easy faults, complicated faults, they find them all. Another trait is that they typically replace only the components that are defective. They seem to have a knack for finding out exactly what is wrong. No trial and error here. So what is their secret?

You might think that a person who has a very good understanding of how the equipment works, should be able to troubleshoot it effectively. Being a good at troubleshooting requires more than this.

Expert troubleshooters have a good understanding of the operation of electrical components that are used in circuits they are familiar with, and even ones they are not. They use a system or approach that allows them to logically and systematically analyze a circuit and determine exactly what is wrong. They also understand and effectively use tools such as prints, diagrams and test instruments to identify defective components. Finally, they have had the opportunity to develop and refine their troubleshooting skills.

If you want to troubleshoot like the pros you will need to develop your skills in each of these areas. Let's look at them in more detail.

- **Understand how the circuit works**.

This consists of understanding the operation of all the components that are used in the circuit. This could include such components as: push buttons, contactors, various types of switches, relays, sensors, motors, etc.

Electrical circuits typically control or operate mechanical systems and components. You also need to understand how these mechanical aspects of the equipment operate to carry out the work.
You need to be able to determine how the circuit works under normal conditions and what effect changing one of the circuit inputs has on the circuit operation. For example, what happens to the overall circuit operation when a push button is pressed; which relays energize, which lights illuminate, does the pump start or stop, etc. You also need to be able to determine what effect a faulty component may have on the circuit operation.

- **Use a logical, systematic approach to analyze the circuit's behavior**.

This is critical. There are several approaches that troubleshooters use. They may have different steps or processes but they have the following in common: They all approach problems systematically and logically thus minimizing the steps and ruling out trial and error. One such approach used to teach troubleshooting is called the "5 Step Approach". A summary of the key steps are: Observe Most faults provide clues as to their cause. There could be visual clues such as signs of damage or improper operation. Don't forget to use your other senses; sounds and smells can also provide valuable clues. Through careful observation and some reasoning, most faults can be identified to the actual component with very little testing.

3.2. Isolation Procedures

An isolation procedure is a set of predetermined steps that should be followed when workers are required to perform tasks such as inspection, maintenance, cleaning, repair and construction.

The aim of an isolation procedure is to:

- isolate all forms of potentially hazardous energy to ensure that an accidental release of hazardous energy does not occur

- control all other hazards to those doing the work
- ensure that entry to a restricted area is tightly controlled.

The following lock-out process is the most effective isolation procedure:

- shut down the machinery and equipment
- identify all energy sources and other hazards
- identify all isolation points
- isolate all energy sources. In the case of electrical equipment 'whole current isolation', such as the main isolator, should be used instead of 'control isolation' by way of the stop button on a control panel
- control or de-energise all stored energy
- lock-out all isolation points, using padlocks, multi- padlock hasps and danger tags.
- Danger Tag machinery controls, energy sources and other hazards.

3.3. Locks and danger tags

Every person working on isolated equipment should fit their own lock and/or danger tag. Alternatively, another management approved system that achieves an equivalent level of safety may be used.

When using locks or danger tags, consider the following:

- tags should be dated and signed
- locks should be accompanied by a corresponding tag to identify who has locked out the plant
- tags and locks should only be removed by the person who applied them or by the supervisor after consultation with the signatory of the danger tag. In the event
- that the person who applied the danger tag is unavailable, their tag or lock may only be removed in accordance with a management approved procedure
- danger Tags and/or locks should be fitted to all isolation points.

3.4. Out-of-service tags

Out-of-service tags are used to identify equipment or machinery that has been taken out of service due to a fault, damage or malfunction (refer to Figure 3).

The out-of-service tag is to be securely fixed to the operating control power isolator with the appropriate details completed on the tag (explaining the reason for the machine being 'out of service').

The out-of-service tag should not be removed until the equipment is safe to be returned to service, or the reason for the out-of-service tag no longer exists.

The out-of-service tag may be removed by:

- the person who attached it
- the supervisor responsible for the operation or repair of the equipment
- the maintenance person who carried out the repairs.

Self-Check -3	Written Test

Directions: Choose the best answer

1. Which one the aim of an isolation procedure
   A. control all other hazards to those doing the work
   B. ensure that entry to a restricted area is tightly controlled
   C. safety materials
   D. A, and B
2. ______ is not the following lock-out process is the most effective isolation procedure:
   A. shut down the machinery and equipment
   B. identify all energy sources and other hazards
   C. identify all isolation points
   D. none of the above
3. out-of-service tag may be removed by
   A. the person who attached it
   B. the supervisor responsible for the operation or repair of the equipment
   C. the maintenance person who carried out the repairs.

D. all of the above

:***Note:*** **Satisfactory rating - 2 points** **Unsatisfactory - below 2 point**

Score = ____________
Rating: _____________

Name: ___________________________ Date: ________________

Information Sheet :4	**Identify Indicators/Symptoms of fault or failure**

Trouble	Cause	Remedy
Contacts chattering	1. Poor contact in control circuit 2. Low voltage	1. Replace the device 2. Check coil terminal voltage/general voltage fluctuation/voltage dips during starting
Welding or freezing	1. Current inrush abnormal 2. Tip pressure low 3. Low voltage 4. Ingressed foreign matter preventing contact closing 5. Short-circuit/ground fault	1. Check shorts/grounds. Check motor load current. Use higher size contactor 2. Replace contacts/springs. Contact carrier may be damaged 3. Check coil terminal voltage and voltage dips during starting 4. Clean contacts with Freon 5. Remove fault. Ensure correctly rated fuse/circuit breaker is used
Short tip life tip overheating	1. Filing or dressing 2. High current interruption 3. Low tip pressure 4. Foreign matter ingress 5. Short-circuits/ground fault 6. Loose power circuit connection 7. Persistent overload	1. Ensure silver tips are not filed. Rough spots or discoloration do not harm tips or cause malfunction 2. Replace with higher size device. Check current levels/faults 3. Replace contacts/springs. Contact carrier may be damaged 4. Clean contacts with Freon. Check enclosure for ambient condition suitability 5. Remove fault. Check correctly rated fuse/circuit breaker is used 6. Tighten 7. Check motor load current. Install larger device

(Continued)

Coils open circuit	1. Mechanical damage	1. Handle/store coils with care
Overheated coil	1. Overvoltage or high ambient temperature 2. Coil unsuitable 3. Shorted turns due to mechanical damage 4. Undervoltage/magnet seals in failure 5. Pole faces dirty 6. Obstruction to moving elements	1. Check terminal voltage less than 110% of rated voltage 2. Replace with correct coil 3. Replace coil 4. Check coil terminal voltage. This should be at least 85% of rated voltage 5. Clean pole faces 6. Check free movement of contact and armature assembly
Overload relay Tripping	1. Persistent overload 2. Corrosion or loosening 3. Unsuitable thermal units 4. High coil voltage	1. Check excessive motor currents, current unbalance. Take corrective action 2. Clean/tighten 3. Replaced with correct size for the application and conditions 4. Check coil voltage is within 110% of rated capacity
Trip failure	1. Thermal units not suitable 2. Mechanical bindings, dirt, corrosion, etc. 3. Damaged relay 4. Relay contact welded	1. Apply proper thermal units 2. Clean/remove particles/obstruction, etc. to restore to proper functioning condition. Replace relay/thermal unit if not possible 3. Replace relay and thermal units 4. Replace contact or entire relay as necessary
Magnetic and mechanical parts noisy magnet	1. Shading coil broken 2. Magnet faces dirty/rusty 3. Low voltage	1. Replace magnet and armature assembly 2. Clean 3. Check coil terminal voltage/voltage fluctuation/motor starting voltage dips

Trouble	Cause	Remedy
Failure to drop out	1. Sticky substance on pole face 2. Voltage persistence 3. Worn or corroded parts failing to separate	1. Clean 2. Check coil terminal voltage/control circuit 3. Replace defective parts
	4. Residual magnetism caused by lack of air gap in magnet path. 5. Welding of contacts.	4. Replace magnet and armature 5. See 'Contacts – Welding or freezing'
Pneumatic timers erratic timing	1. Ingress of foreign matter in valve	1. Replace complete timing head. Return timer to factory for repair and adjustment
Failure of contact operation	1. Actuating screw not correctly adjusted 2. Worn/broken parts in snap switch	1. Adjust as per manual service instructions 2. Replace switch
Limit switches damaged parts	1. Actuator overtravel	1. Use resilient actuator. Operate within device tolerance limits
Manual starters failure to reset	1. Latching mechanism damaged	1. Replace starter

Trouble	Cause	Corrective Action
Contactor/Relay closing failure	Supply voltage failure Low voltage Open-circuited coil Pushbutton, interlocks, or relay contact not making Loose connections or broken wire Incorrect pushbutton connection Open o/l relay contact Mechanical parts damaged, corroded, not properly aligned/assembled, etc.	Check fuses/disconnect switch. Check power supply. Ensure correct size of wire Replace Adjust to ensure correct movement, easy operation, and correct contact pressure Check circuit. Isolate circuit first Check with wiring diagram Reset relay Clean/align and adjust for proper operation

(Continued)

Trouble	Cause	Corrective Action
Contactor or relay fails to open	Incorrectly connected pushbutton	Check connection with wiring diagram and rectify
	Worn shim in magnetic circuit	Replace shim
	Residual magnetism holds armature closed	
	Pushbutton, interlock, or relay contact fails to open coil circuit	Make adjustment for correct movement, ease of operation, and proper opening
	'Sneak' circuits	Check for insulation failure
	Welding of contacts	See 'Excessive corrosion of contacts'
	Mechanical part malfunction due to damage corrosion, etc.	Clean mechanical parts. Check for free movement Remove obstruction/ingressed matter. Repair or replace worn or damaged parts
Contact corrosion/welding	Contact spring pressure not adequate. Overheating or arcing on closing	Adjust for correct contact pressure. Replace spring or worn contacts if necessary
	Reduction of effective contact surface area due to pitting, etc.	Dress up contacts with fine file. Replace if badly worn
	Abnormal operating conditions	Check rating and load. In case of severe operating condition replace open contactors with oil-immersed or dust-tight equipment Instruct operator in proper control of manually operated device
	Chattering of contacts due to external vibrations	Check control switch contact pressure. Replace spring if it fails to give rated pressure
	Sluggish operation	Tighten all connections. If problem persists mount/ move control, so that

		vibrations are decreased Clean and adjust mechanically. Align bearings. Check free movement
Arc lingers across contacts	Blow out problem Series blow out may be short-circuited Shunt blow out may be open Ineffective blowout coil	Check blow out type with wiring diagram. Check blow out circuit Check rating. Replace in case of improper application. Check polarity and reverse coil if necessary

Trouble	Cause	Corrective Action
	Note travel of contacts, in case blowout is not used Arc box might be left off or not in correct position if blow out is used Overload	Increasing travel of contacts increases rupturing capacity Ensure that arc box is fully in place Check rating against load
Noisy AC magnet	Improper assembly Broken shading coil Low voltage	Clean pole faces. Adjust mechanical parts Replace Check power supply. Check wire size
Frequent coil failure	High voltage Gap in magnetic circuit. Ambient temperature may be high	Check supply voltage against controller rating Check travel of armature. Adjust magnetic circuit. Clean pole faces Check controller rating against ambient temperature. Replace coil with correctly rated coil for ambient, from manufacturer
Burning of panel/equipment due to starting resistor heat	Frequent starting	Use higher-capacity resistor

Self-Check -4	Written Test

Directions: Choose the best answer

1. _____ is not the following cause noisy a.c magnet?
   A. improper assembly
   B. Broken shading coil
   C. low voltage
   D. none
2. _____ is not the following cause frequent coil failure?
   A. high voltage
   B. Gap in magnetic circuit
   C. Ambient temperature may be high
   D. none of the above

3. Which one of the causes of failure of contact operation?

   A. actuating screw not correctly adjusted
   B. worn
   C. broken parts in snap switch
   D. all of the above

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 point**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

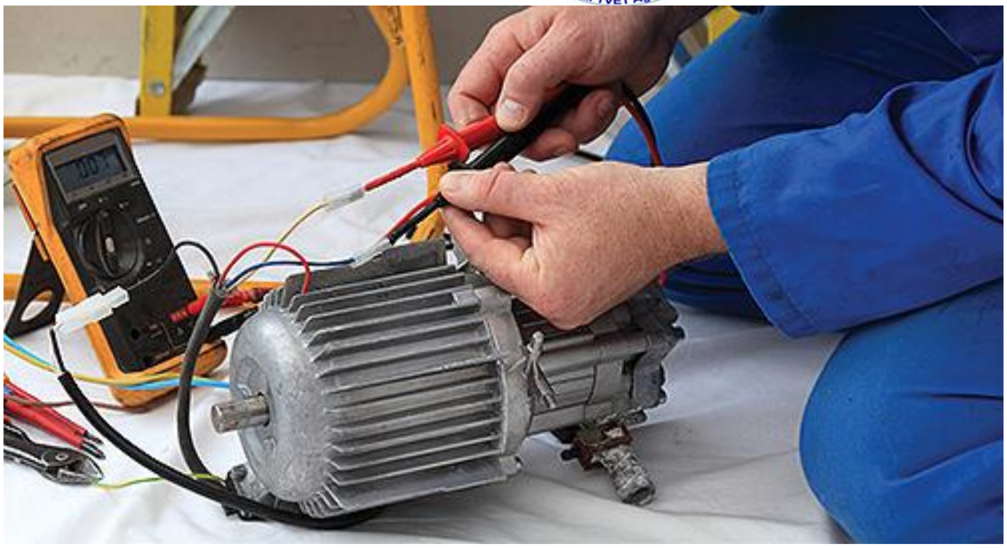
Information Sheet :5	Perform necessary electrical test on the system or equipment

5.1. Introduction

Testing electric motors doesn't have to be a mystery. Knowledge of the basics together with powerful new test equipment vastly simplifies the job. Electric motors have had a reputation for being a mix of science and magic. So when a motor fails to operate it may not be obvious what the problem is. Knowing some basic methods and techniques along with having a few test instruments handy helps detect and diagnose problems with ease. When an electric motor fails to start, runs intermittently or hot, or continually trips its over current device, there my be a variety of causes.

Sometimes the trouble lies within the power supply, including branch circuit conductors or a motor controller. Another possibility is that the driven load is jammed, binding or mismatched. If the motor itself has developed a fault, the fault may be a burnt wire or connection, a winding failure including insulation deterioration, or a deteriorating bearing. A number of diagnostic tools, such as clamp-on ammeters, temperature sensors, a Megger or oscilloscope, can help illuminate the problem. Preliminary tests generally are done using the ubiquitous multimeter. This tester is capable of providing diagnostic information for all kinds of motors. If the motor is completely unresponsive, no ac humming or false starts, take a voltage reading at the motor terminals. If there is no voltage or reduced voltage, work back upstream. Take readings at accessible points including disconnects, the motor controller, any fuses or junction boxes, and so on, back to the over-current device output at the entrance panel. What you’re looking for is essentially the same voltage level as measured at the entrance panel main breaker. When there is no electrical load, the same voltage should appear at both ends of the branch circuit conductors. When the circuit electrical load is close to the circuit capacity, the voltage drop should not exceed 3% for optimum motor efficiency.

In a three-phase hookup, all legs should have substantially equal voltage readings, with no dropped phase. If these readings vary by a few volts, it may be possible to equalize them by rolling the connections, taking care not to reverse rotation. The idea is to match supply voltages and load impedances so as to balance the three legs. If the electrical supply checks out, examine the motor itself. If possible, disengage the load. This may restore motor operation. With power disconnected and locked out, attempt to turn the motor by hand. In all but the largest motors the shaft should turn freely. If not, there is an obstruction inside or a seized bearing. Fairly new bearings are prone to seizure because the tolerances are tighter. This is especially true if there is ambient moisture or the motor has been unused for a while. Often good operation can be restored by oiling front and rear bearings without disassembling the motor. If the shaft turns freely, set the multimeter to its ohms function to check resistance. The windings (all three in a three-phase motor) should read low but not zero ohms. The smaller the motor, the higher this reading will be, but it should not be open. It will usually be low enough (under 30 Ω) for the audible continuity indicator to sound.



5.2. Necessary electrical test

- ✓ **Earth Continuity and Resistance Test**

With a multimeter, measure the resistance between motor frame (body) and earth. A good motor should read less than 0.5 ohms. Any value greater 0.5 ohms indicate trouble with the motor. Further troubleshooting maybe required Continuity refers to being part of a complete or connected whole. In electrical applications, when an electrical circuit is capable of conducting current, it demonstrates electrical continuity. It is also said to be “closed,” because the circuit is complete. In the case of a light switch, for example, the circuit is closed and capable of conducting electricity when the switch is flipped to “on.” The user can break the electrical continuity by flipping the switch to “off,” opening the circuit and rendering it incapable of conducting electricity. In short, by performing continuity test, we can determine the following

- ✓ existence of continuity in the electrical wiring circuit
- ✓ existence of any open circuit in the circuit
- ✓ existence of any short circuit in the circuit

- **AC Motor Winding Continuity Test**

Using a multimeter, check the continuity of motor winding from phase to phase (U to V, V to W , W to U).Each phase to phase must have a continuity if winding is OK. If any particular phase fails the continuity test, your motor is probably burnt. Please see how to identify three phase windings for proper winding identification. U, V, W is a European winding designation

- **Multimeter/Continuity test**

Continuity testers are simple devices designed to verify a complete electrical path through an object or circuit. They are especially useful for checking fuses of all types, light-bulbs, and wire paths. This tester is usually comprised of: 1. Two leads 2. A small body where the leads meet and contain... 3. Some form of indicator.A number of devices are manufactured to assist consumers in testing electrical continuity, ranging from multimeters, which have a wide range of additional applications, to simple electrical continuity testers that light up if electrical continuity is present. These devices use two electrical probes, which form a complete circuit when touched together. Consumers can test the device to ensure that it is working properly by turning it on and touching the probes together – the meter should read zero, or the indicator light should turn on, indicating a closed circuit. When the probes are not touching anything, the metered device will read infinity, showing that the circuit is open

- **Power Supply Test**

For three phase motors, the expected voltage for a 230/400V system is 230V phase to neutral and 400V between each of the three phase supply lines. Check that the correct voltage is applied to the motor using a multimeter. Ensure the terminal for power supply is in good condition. Check the connection bar for terminal (U, V, and W). For three phase motors, connection type is either Star (Y) or Delta

- **Ac motor winding resistance test**

Check the motor winding resistance or ohms reading using a multimeter or ohmmeter for phase to phase terminal (U to V,V to W ,W to U).The ohms reading for each winding must be the same (or nearly the same). Remember that the three phases have identical windings or nearly so!

- **Insulation Resistance test**

Insulation resistance failure of an electric motor is one of the first signs that the motor is about to fail. For a three-phase motor, insulation resistance is usually measured between each motor winding or phase and between each motor phase and motor frame (earth) using an insulation tester or megger. Set the voltage setting of the insulation resistance tester to 500V. Check from phase to phase (U to V, V to W, W to U). Check from phase to motor frame (earth) (U to E, V to E , W to E). Minimum test value of motor insulation resistance is 1 Meg Ohm (1 MΩ). See how to measure insulation resistance of Electric Motor

- **Running AmpsTest**

With the motor running, check the full load amps (FLA) with a suitable meter or preferably a clamp on meter and compare with the name plate FLA. Deviations from rated FLA could signify problems with the motor under test.

- **No-load Test**

Finds magnetizing reactance and combined friction, core and windage power losses
No-Load Test Procedure

- ✓ Apply rated voltage and frequency with no mechanical load.
- ✓ Measure current voltage and power.
- ✓ Uses same test instrument setup as locked-rotor test. Measure IL, VL and PT.

- **Open circuit test and Short circuit test**:

Multimeter can be used for this test. For this, multimeter should be set in resistance mode of measurement. To check the existence of any open circuit or short circuit between any two points in the wiring circuit, the electrical supply to the circuit should be switched off first. Then put the multimeter probes between the two testing points in the circuit. If multimeter reads ohm, it indicates open circuit. If multimeter reads ‘0’ ohm, it indicates short circuit.

- **Performing ground test on phase coils**

Electrical circuits have a separate ground, or 'earth', circuit that provides an alternate low-impedance path for electricity to safely reach the ground, in case of accidental physical contact. Ground testing is used to measure the performance of this circuit and check if it meets requirements. Before you begin testing a ground circuit, there are a few essentials elements you must understand:

- ✓ Use the Correct Instruments Use devices specifically designed for ground testing, like a dedicated ground tester.
- ✓ Understand the Test Apart from the test itself, familiarize yourself with the tools you're going to use and how they operate.
- ✓ Understand the Test Environment You must measure the entire area surrounding the electrode, which is critical to performance.
  - ✓ Probe Placement The probes should be placed properly in relation to buried objects, moisture pockets etc.

- **Ground Testing Techniques**

There are several agencies and organizations which issue guidelines, recommendations and standards for testing grounding safety. Whichever one you follow, the key components are the same, like the ground connections and stakes. These should be carefully inspected annually at the very least, for issues like corrosion, which can increase the resistance.

- **The Importance of Ground**

Ground testing is of two basic types – testing when a facility is being built, and routine testing to ensure that the grounding system is performing as it is meant to.Both types are crucial for a number of reasons

- ✓ A system with faulty grounding can cause catastrophic losses of data, equipment and even human life in case of electrical malfunctions.
- ✓ Equipment operating with inadequate grounding may be exposed to voltage surges and spikes that can damage it.
- ✓ Sensitive equipment is prone to processing data incorrectly or losing it altogether in case grounding is lost.
- ✓ Intermittent faults from bad grounding can create a range of problems, from random shocks to failures that cannot be pinpointed easily.

A build-up of surface static electricity may give shocks, which are easily misdiagnosed as internal faults. This leads to unnecessary and costly repairs or replacement of parts. Grounding protects both equipment and human lives, so it is absolutely essential to make sure it's done right and checked routinely. The world's best grounding system bonding will be useless unless it can reach a low-impedance ground stake, which makes ground testing all the more essential.

Self-Check -5	Written Test

Directions: say true or false

1. For three phase motors, the expected voltage for a 230/400V system is 230V phase to neutral and 400V between each of the three phase supply lines.
2. Insulation resistance failure of an electric motor is one of the first signs that the motor is about to fail.
3. Running Amps Test With the motor running, check the full load amps (FLA) with a suitable meter or preferably a clamp on meter and compare with the name plate FLA
4. Ac motor winding resistance test Check the motor winding resistance or ohms reading using a multimeter or ohmmeter for phase to phase terminal
5. Earth Continuity and Resistance Test With a multimeter, measure the resistance between motor frame (body) and earth.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 point**

Score = ___________

Rating:

Name: ____________________________ Date: ________________

Information Sheet :6	Estimate Extent of the fault to accomplish the job and the spare parts needed

6.1. Introduction

The purpose of estimating is to quickly develop reasonably accurate and consistent time estimates. The technique is simple and based on the following principles:

- **Experience:** for persons who have had practical experience performing maintenance jobs, it is relatively easy to visualize and establish a time requirement for simple, short duration jobs. Because of their experience, ex-craftsmen usually make the best planners.
- **Job breakdown**: long, complex jobs cannot be estimated as a whole. Estimation of such jobs is easier and more accurate when the job is broken down into separate steps or tasks and estimated at that level, then summarized into an estimate for the total job.
- **Accuracy:** pinpoint accuracy in estimating is not justified or achievable because all the variables in maintenance work cannot be known until after the job is completed. In maintenance we therefore look for ± 15% accuracy.

Estimate is called a damage report or appraisal

- Calculates the cost of parts, materials, and labor for repairing a vehicle
- Printed summary of the repairs needed, used by the customer, insurance company, shop management, and technician

Self-Check -6	Written Test

Directions: say true or false

1. The purpose of estimating is to quickly develop reasonably accurate and consistent time estimates.
2. long, complex jobs cannot be estimated as a whole.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 point**

Score = ___________
Rating:

Name: ___________________________ Date: ________________

Information Sheet :7	Coordinate other works associated with the problem

7.1. Mechanical Repair section

The Mechanical Repair section of AR100 covers the major mechanical components of the motor (e.g., shafts, bearings, frames, bearing housings, and laminations). The text here is generously supplemented with tables that provide many important dimensions and tolerances. For electric motor rebuilders, a distinct advantage of AR100 is having these tables in one readily available place, rather than needing to find them in individual source documents from the American Bearing Manufacturers Association (ABMA), International Electro technical Commission (IEC), and National Electrical Manufacturers Association (name).

7.2. Shafts and shaft extensions

The Mechanical Repair section stipulates that shafts and shaft extensions be checked for wear, cracks, scoring, and straightness. To that end, the tolerances for diameters, run-out, and keyways are based on NEMA and IEC standards. The supporting text also provides guidance to help service centers achieve reliable repairs—e.g., that key seats (keyways) should accommodate keys to a tap fit. Dimensional conformity is critical to assure a proper fit when end users install attachments such as couplings on the output shaft.

7.3. Bearings

This section also provides two comprehensive tables of specific housing and journal fits and tolerances for ball and cylindrical roller bearings. Of all the tables in AR100, service centers probably refer to these two the most, because proper fits significantly increase the potential for obtaining full-rated bearing life.

7.4. Lubrication

On the topic of lubrication, practical recommendations in the Mechanical Repair section include: checking grease passages to make sure they are clean, using grease that is compatible with the customer's lubricant, and filling the grease reservoir to about one-third of capacity if the motor manufacturer's instructions are not Verifying grease compatibility is crucial. For example, service centers often use polyurea-based greases, which usually are not compatible with lithium-based greases that many end users employ. Confirming the use of a compatible lubricant as AR100 recommends can prevent a premature bearing failure. The point about grease fill is critical not only to bearing and motor life, but also to the energy efficiency of the motor. Over-lubrication can cause ball or roller "skidding" that increases friction; it also can churn the grease, resulting in higher temperatures and increased losses (i.e., reduced efficiency).The ultimate consequence could be a premature and potentially catastrophic bearing failure.

7.5. Frame and bearing housings

Touching on other aspects of electric motors, the Mechanical Repair section recommends inspecting the frame and bearing housings for cracks and breaks. This is another example of how AR100 goes beyond tests and measurements, providing guidance for more reliable repairs that will result in greater uptime for end users. This section also provides tables for use in verifying that face and flange mounting-surface tolerances, eccentricity, and run-out comply with NEMA and IEC standards. Verification of these tolerances helps protect motors from excessive mechanical stress due to face or flange distortion.

7.6. Dynamic balancing

Dynamic balance of the rotor is essential to the proper operation of a motor. In the absence of a customer-specified level, AR100 prescribes balancing to the International Organization for Standardization's (ISO) quality grade of 2.5 to assure vibration levels are well within NEMA and IEC standard values. A cautionary note also recommends making certain that balance weights do not interfere with other components. Low vibration levels extend bearing life; and adequate clearance between balance weights and other components helps avoid rapid and possibly immediate failure.

7.7. Testing section

Following the good-practice procedures in AR100 builds quality and reliability into each repair. For example, the document devotes an entire section to inspecting and testing repaired motors-often prescribing multiple tests to verify the suitability of a motor to perform in accordance with its nameplate ratings.

Mechanical tests: The recommended mechanical tests include checking the exact operating speed and measuring vibration levels at no load.

Self-Check -7	Written Test

Directions: say true or false

1. Dynamic balance of the rotor is essential to the proper operation of a motor. In the absence of a customer-specified level,
2. Touching on other aspects of electric motors, the Mechanical Repair section recommends inspecting the frame and bearing housings for cracks and breaks.
3. The recommended mechanical tests include checking the exact operating speed and measuring vibration levels at full load.
4. The Mechanical Repair section stipulates that shafts and shaft extensions be checked for wear, cracks, scoring, and straightness
5. This section also provides two comprehensive tables of specific housing and journal fits and tolerances for ball and cylindrical roller bearings.

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 point**

Score = ___________

Rating:

Name: ___________________________ Date: ________________

Information Sheet :8	Record details of fault, possible cause, corrective action, recommendation to eliminate the problem

8.1. Records of Maintenance

(a) It is advisable to use a primed form with yes/no or right/wrong selections for the operator to easily fill out.

(b) Principle contents：

- ✓ Serial number of machines.
- ✓ Load machine type.
- ✓ Models and specifications of motors.
- ✓ Ordinary operating conditions and data.
- ✓ Cause, date and disposition measures at breakdown.
- ✓ Quantity and name of replaced spare parts.
- ✓ Date of maintenance and initial operation. (8) Items and date of maintenance.
- ✓ Special remarks.
- ✓ Name of maintenance personnel.

Type of Breakdown	Symptoms	Possible causes	Remedies
Fail to start without load	Motionless and soundless	Power-off	Consult power company
		Switch-off	Switch-on
		No fuse	Install fuse
		Broken wiring	Check wiring and repair
		Broken lead	Check wiring and repair
		Broken windings	Check windings and repair
	Fuse blowing. (Automatic switch trips off, slow start with electromagnetic noise)	Short circuit of circuit switches	Check circuit switches and replace
		Incorrect wiring	Check wiring according to nameplate
		Poor contact at terminals	Lock tightly
		Windings grounded	Factory repair
		Broken windings	Factory repair
		Poor contact of circuit switches	Check and repair
		Broken wiring	Check and repair
		Poor contact of starting switches	Check and repair
		Short circuit of starting switches	Check and repair
		Incorrect connections of starting switches	Connect according to nameplate
Loading after start	Fuse blowing. Fail to restart due to trip-off of automatic switch	Insufficient capacity of fuse	Replace fuse if wiring permits
		Overload	Lighten load
		High load at low voltage	Check circuit capacity and reduce load
	Overheating motor	Overload or intermittent overload	Lighten load
		Under-voltage	Check circuit capacity and power source
		Over-voltage	Check power source
		Ventilation duct clogged	Remove the foreign matter in the duct
		Ambient temperature exceeds 40°C	Correct insulation class F, or lower ambient temperature.
		Friction between rotor and stator	Factory repair
		Fuse blown (Single-phase rotating)	Install the specified fuse
		Poor contact of circuit switches	Check and repair
		Poor contact of circuit starting switches	Check and repair
		Unbalanced three-phase voltage	Check circuit or consult power company

Kinds of Breakdown	Symptoms	Possible causes	Remedies
Loading after start	Speed falls sharply	Voltage drop	Check circuit and power source
		Sudden overload	Check machine
		Single-phase rotating	Check circuit and repair
	Switch overheat	Insufficient capacity of switch	Replace switch
		High load	Lighten load
	Bearing overheating	Lack of oil	Add oil
		Lack of grease	Add grease
		Misalignment between motor and machine shafts	Re-align
		Over speed of bearing outer-ring	Adjust bracket
		High bearing noise	Replace the damaged bearing

Noise	Electromagnetic noise induced by electricity	Occurrence from its first operation	May be normal
		Sudden sharp noise and smoking	Short circuit of windings Should be repaired at factory
	Bearing noise	Churning sound	May be normal noise from grease circulating through the bearing
		Rattling noise as result of poor lubrication	Add Grease
		Larger noise	Inspect cause -replace the damaged bearing
	Mechanical noise caused by machinery	Loose belt sheave	Adjust key and lock the screw
		Loose coupling or skip	Adjust the position of couplings, lock key and screw
		Loose screw on fan cover	Lock fan cover screw tightly
		Fan rubbing	Adjust fan position
		Rubbing as a result of ingression of foreign matters	Clean motor interior and ventilation ducts
		Wind noise	Noise induced by air flowing through ventilation ducts
		Induced by conveyance machine	Repair machine
Vibration	Electromagnetic vibration	Short circuit of windings	Factory repair
		Open circuit of rotor	Factory repair
	Mechanical vibration	Unbalanced rotor	Factory repair
		Unbalanced fan	Factory repair
		Broken fan blade	Replace fan
		Unsymmetrical centers between belt sheaves	Align central points
		Central points of couplings not in alignment	Adjust the alignment between motor and driven equipment
		Improper mounting installation	Check mounting and alignment
		Motor mounting bed is not strong enough	Reinforce mounting bed
		Mounting bed vibration caused by near machines	Eliminate the vibration source near motor

Remarks:

(1) Circuit switches: These include knife switches, electromagnetic switches, fuse and other connection switch etc.

(2) Starting switches: These include Delta-Star starters, compensate starters, reactance starters, resistor starters, starting controllers etc.

Self-Check -8	Written Test

1. Which one is not the Symptoms Bearing over heating Possible of the causes?
   A. Lack of oil
   B. Misalignment between motor and machine shafts
   C. Over speed of bearing outer-ring
   D. none of the above

2. Which one is Symptoms Speed falls sharply Possible of the causes**?**

A. Voltage drop
B. Sudden overload
C. A and B
D. Churning sound

3. Which one is not the Symptoms Electro magnetic noise induced by electricity Possible of the causes?

A. Loose belt sheave
B. Loose coupling or skip
C. Loose screw on fan cover
D. none of the above

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 point**

Score = ___________

Rating:

Name: _________________________ Date: _______________

Information Sheet :9	**responding unforeseen events**

9.1. Introduction

In order to know how to respond to unplanned events or conditions, one must first start in assessing or analyzing the situation. The first response should not be making an action right away, but thinking of the situation and possible solutions. After fully understanding the situation and listing down possible solutions, it's time to take action by trying all possible means to cope with the changes or unexpected events.
If working on a project, it's helpful to create a list of planned vs unplanned events so you can also think of safety measures on how to prevent the unplanned ones even before starting on the project.

Based on these considerations, the potential accidents, malfunctions and unplanned events that were considered by the Study Team for the Sisson Project are

- ✓ Loss of Containment from Tailings Storage Facility (TSF);
- ✓ Erosion and Sediment Control Failure
- ✓ Pipeline Leak;
- ✓ On-Site Hazardous Materials Spill;
- ✓ Release of Off-Specification Effluent from the installation.
- ✓ Failure of a Water Management Pond
- ✓ Failure of a Water Management Pond Pump;
- ✓ Off-Site Trucking Accident
- ✓ Vehicle Collision;
- ✓ Uncontrolled Explosion; and Fire

Respond to unplanned events or conditions in accordance with established procedures.

- ✓ Establish procedures from appropriate personnel In accordance with procedures before any contingencies are implemented.
- ✓ Test Devices / systems and/or Machine is tested whether it conforms to requirements
- ✓ Remove parts or connections for the purpose of testing and pre-test conditions in accordance with established procedures

Final inspections are undertaken to ensure the installed devices / systems conforms to requirements Trainers Methodology

Self-Check -9	Written Test

Directions: Say true or false

1. Establish procedures from appropriate personnel In accordance with procedures before any contingencies are implemented.
2. Test Devices / systems and/or machine is tested whether it conforms to requirements
3. Remove parts or connections for the purpose of testing and pre-test conditions in accordance with established procedures

Note: **Satisfactory rating –5 points** **Unsatisfactory - below 5 points**

Score = ___________
Rating: ____________

Name: ___________________________ Date: ________________

Operation Sheet-1	Fault Troubleshooting three phase induction motor

Procedure

1. Verify the complaint
2. Determine the related symptoms
3. Analyze the symptoms
4. Isolate the trouble
5. Correct the trouble
6. Check for proper operation

Operation Sheet-2	Induction Motor No-Load Test

PROCEDURE:

1.. Apply rated voltage and frequency with no mechanical load
2.. Measure current voltage and power.
3.. Uses same test instrument setup as locked-rotor test. Measure IL, VL and PT

LAP Test	Practical Demonstration

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 2hour.

Task 1. perform no load test for three phase induction motor

Task 1. perform no load test for single phase induction motor

Instruction Sheet :1	LG33: Notify completion of work

This learning guide is developed to provide you the necessary information regarding the following learning outcome and content coverage

- Notifying the completion of work to immediate supervisor
- Making performance tests
- preparing and submitting service report

This guide will also assist you to attain the learning outcome and contents stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Notify the completion of work to immediate supervisor Notify
- Making performance tests
- preparing and submitting service report

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the "Information Sheet 1, Sheet 2 and Sheet 8" in page 4, 7and 16 respectively".
4. Accomplish the "Self-check 1, Self-check 2 and Self-check 3" in page 6,15 and 17 respectively".
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1 and Operation Sheet 2" in page 18.
6. Do the "LAP test" in page 19

Information Sheet – 1	Notify the completion of work to immediate supervisor Notify

1.1. INTRODUCTION

Written notice issued by the owner of a project (or his or her agent) to notify concerned parties that all work on the project has been completed. This notice also sets the period within which concerned parties may exercise their lien rights against one another.

A document recorded by a property owner to notify potential Mechanics Lien claimants that a specific construction project has been completed. The effect of a properly recorded Notice of Completion is to reduce the time in which a subcontractor, material supplier or general contractor can record a Mechanics Lien against a private works construction project.

1.2. Works completion

This concept is not defined nor is there any set date but it follows from practical completion. The process starts with the principal agent issuing a works completion list to the contractor which details defective and incomplete work present at practical completion but which are not required to achieve practical completion. The contractor must remedy the defects in this list in order to achieve works completion.

Once the contractor has addressed all incomplete and defective items on the 'works completion list' he must notify the principal agent to inspect these items, and if satisfied, issue a certificate of works completion. If the principal agent remains unsatisfied then he is required to identify which items have not been completed or rectified to his satisfaction and the contractor must carry out the rectification and completion procedure again in accordance with sub-clause. This procedure may be repeated several times until the principal agent is satisfied that all the items on the work completion list have been appropriately addressed.

Alternatively, should the principal agent not issue a works completion list within 5 working days of the date of practical completion the contractor is obliged to notify both the employer and principal agent in this regard and the principal agent is required to submit a works completion list within 5 working days of receipt of the contractor's notice. Should the principal agent fail to submit the works completion list thereafter, works completion shall be deemed to have been achieved on the expiry of the initial 5 working day period after the issue of the certificate of practical completion.

The only evident incentives that exist for the contractor in relation to works completion is that the contractor has 20 working days to complete and / or rectify the items on the works completion list in order not to forego compensatory interest on the value of outstanding work . The issue of the works completion certificate marks the commencement of the 90 calendar day defects liability period. (NB The Contractor is not entitled to compensatory interest on the value of outstanding work).

1.3. Final completion

At the end of the defects liability period, or when the contractor believes the defects liability period has come to an end, he must submit a notice to the principal agent who is obliged to inspect the works within the period specified in order to determine whether any defects are present. Should any defects be identified, the principal agent is obliged to provide the contractor with a defects list, which have arisen during the defects liability period and which the contractor must rectify in order to achieve final completion of the works.

Similarly, as provided for under works completion, if the principal agent does not issue a defects list within the period prescribed of 5 working days from the end of the defects liability period, the contractor is obliged to notify both the employer and principal agent in this regard and the principal agent is required to submit the defects list within 5 working days of receipt of the contractor’s notice. Should the principal agent fail to submit the works completion list thereafter, final completion shall be deemed to have been achieved on the expiry of the initial 5 working day period after the end of the defects liability period.

The achievement of final completion by the contractor has the following consequences:

- all the contractor’s liabilities and obligations in relation to a subcontractor’s defects comes to an end and any remaining portion of the subcontractor’s defects period is agreed and assumed by the employer ;
- All guarantees, warranties and indemnities provided by the contractor, subcontractors and suppliers are ceded to the employer on the date which the certificate of final completion is issued ; and
- The certificate of final completion constitutes conclusive evidence as to the sufficiency of the works and that the contractors obligations have been fulfilled other than latent defects.

Practical completion, works completion and final completion deal exclusively with the construction period. Once the contractor has achieved final completion he still retains certain obligations in relation to the latent defects liability period. The latent defects liability period commences when construction begins and ends 5 years after the date when final completion was achieved

Self Check 1	Written test

Name: ____________________ Date: ____________

Directions: Answer all the questions listed below. Say true or false

1. Concept is not defined nor is there any set date but it follows from practical completion
2. A document recorded by a property owner to notify potential Mechanics Lien claimants that a specific construction project has been completed.

Note: **Satisfactory rating - 1 points** **Unsatisfactory - below 1 points**

Score = ____________
Rating: _____________

Name: ________________________ Date: ______________

Information Sheet – 2	Make performance tests

2.1. Introduction

Testing electric motors doesn't have to be a mystery. Knowledge of the basics together with powerful new test equipment vastly simplifies the job.

Electric motors have had a reputation for being a mix of science and magic. So when a motor fails to operate it may not be obvious what the problem is. Knowing some basic methods and techniques along with having a few test instruments handy helps detect and diagnose problems with ease.

When an electric motor fails to start, runs intermittently or hot, or continually trips its over current device, there my be a variety of causes. Sometimes the trouble lies within the power supply, including branch circuit conductors or a motor controller. Another possibility is that the driven load is jammed, binding or mismatched. If the motor itself has developed a fault, the fault may be a burnt wire or connection, a winding failure including insulation deterioration, or a deteriorating bearing.

A number of diagnostic tools, such as clamp-on ammeters, temperature sensors, a Megger or oscilloscope, can help illuminate the problem. Preliminary tests generally are done using the ubiquitous multimeter. This tester is capable of providing diagnostic information for all kinds of motors.

- **Electrical measurements**

If the motor is completely unresponsive, no ac humming or false starts, take a voltage reading at the motor terminals. If there is no voltage or reduced voltage, work back upstream. Take readings at accessible points including disconnects, the motor controller, any fuses or junction boxes, and so on, back to the over-current device output at the entrance panel. What you're looking for is essentially the same voltage level as measured at the entrance panel main breaker.

When there is no electrical load, the same voltage should appear at both ends of the branch circuit conductors. When the circuit electrical load is close to the circuit capacity, the voltage drop should not exceed 3% for optimum motor efficiency. In a three-phase hookup, all legs should have substantially equal voltage readings, with no dropped phase. If these readings vary by a few volts, it may be possible to equalize them by rolling the connections, taking care not to reverse rotation. The idea is to match supply voltages and load impedances so as to balance the three legs.

If the electrical supply checks out, examine the motor itself. If possible, disengage the load. This may restore motor operation. With power disconnected and locked out, attempt to turn the motor by hand. In all but the largest motors the shaft should turn freely. If not, there is an obstruction inside or a seized bearing. Fairly new bearings are prone to seizure because the tolerances are tighter. This is especially true if there is ambient moisture or the motor has been unused for a while. Often good operation can be restored by oiling front and rear bearings without disassembling the motor.

If the shaft turns freely, set the multimeter to its ohms function to check resistance. The windings (all three in a three-phase motor) should read low but not zero ohms. The smaller the motor, the higher this reading will be, but it should not be open. It will usually be low enough (under 30 Ω) for the audible continuity indicator to sound.

- **General Inspections**

For the three-phase motor, do the following;

(1) Check the appearance of the motor. Check for burnt, damage to body or cooling fan orshaft.

(2) Manually rotate motor shaft to examine bearing condition. Look out for smooth and free shaft rotation. If shaft rotation is free and smooth, bearing is possibly in good condition, otherwise consider replacing, repair or carry out further diagnosis.

(3) As with all testing and inspections, the motor name plate provides valuable information that will help to ascertain the true health of the motor. Examine the name plate thoroughly and compare values of running amps test.

2.2. Phase Sequence Test

The correct phase sequence is required for the proper operation of any three phase system. It ensures that the load works as desired, when incorrect, the equipment such as the motor may malfunction, rotate in the reverse direction. The phase reversal may damage the motor or the equipment the motor is driving.

It is always important to ensure that the incoming 3-phase conductors have the correct phase sequence before connecting new equipment or before reconnecting motors after maintenance. This might not be obvious by visual inspection, hence the need for a reliable tool. The two commonly used methods are the rotating phase-sequence meter or the static phase-sequence indicator.

2.2.1. Phase sequence meter/indicator

The phase-sequence meter is the most straightforward and commonly used tool for determining the phase sequence. The meter may be digital using semiconductor devices, or rotational (analog) type.

Figure:2.1. A three phase sequence tester

2.2.2. Rotational phase sequence meter

These are small asynchronous motors consisting of an aluminum disk which serves as the rotor. The tester has three windings which are usually connected to the circuit under test. The principle of operation is similar to that of an induction motor.

The meter has coils whose one end of each is connected in a star configuration. The other three ends of the coils are attached to the motor power connections or the circuit under test. The meter contains an aluminum disk which rotates when the current through the coils creates a magnetic field.

The current through the three windings creates a magnetic field that depends on the phase sequence of the incoming power conductors; this causes the disk to rotate in the direction that depends on phase sequence. The meter terminals are marked with a certain phase sequence order. Once the disk rotates, the direction of the arrow on the disk shows the phase sequence, based on the marks.

The tool rotates clockwise when the phase sequence is correct (RYB) and anticlockwise when the phases are reversed. Some general-purpose indicators may determine the phase sequence, power factor and phase shift between the current and voltage.

2.2.3. Static Type Phase-Sequence Indicators

The static indicator is a simple configuration that uses two lamps and an inductor or capacitor. One lamp is connected to one phase such as R and the other to another phase such as Y, while the inductor or capacitor on the remaining third phase. A resistor may be used in series with the lamp to control the amount of current and voltage.

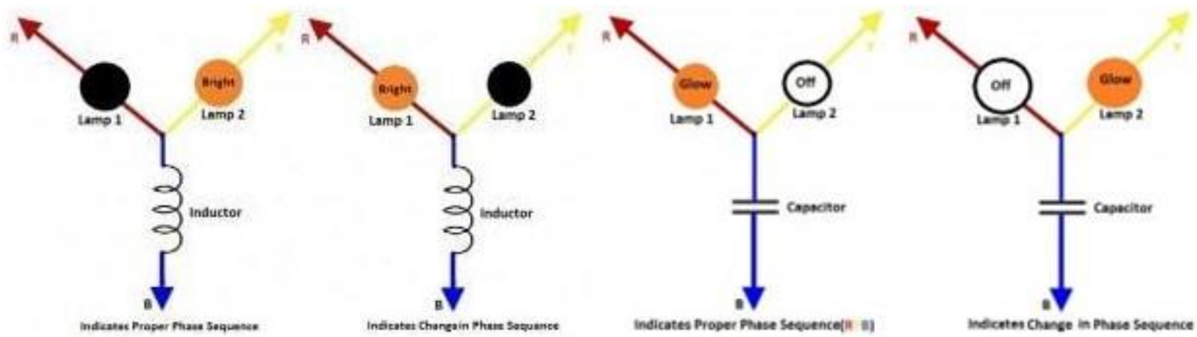
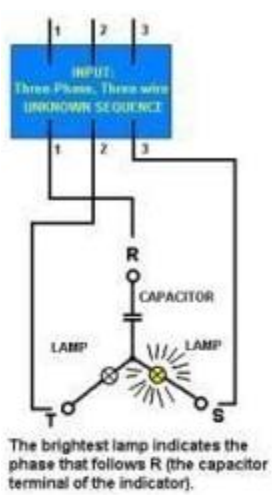


Figure: 2.2. Static phase sequence indicator

If using the inductor, lamp B will be more brighter than A if the phase sequence is correct, while Lamp A becomes brighter when the phases are reversed. However, using the capacitor tester, Lamp A will light on while lamp B will be off. If the sequence is incorrect, lamp B lights up while lamp A remains off.



2.3. Actual Motor Operation Test

2.2.1. All types

- Check the appearance of the motor. Check for body damage or damage to the cooling fan blade or shaft.
- Manually rotate the shaft to check the bearing condition. Check for free & smooth rotation.
- Note the motor data from the motor NAME PLATE .
- **Earth Continuity:** Use your ohmmeter to verify the resistance between earth and motor frame is less than **0.5 Ω.**
- **Power supply –** correct voltage (230 volts per line), 415 v between Ll to L2, L2 to L3, and, L3 to L1,

2.2.2. Single Phase

- ✓ Check the motor winding ohms reading using multimeter or ohmmeter.**(C to S, C to R, S to R).**The reading for start to run should be equal to C to S + C to R.

Correct electrical terminal identification: There are three terminal connections ion a hermetically sealed motor compressor and are as follows: Common (C), Start (S) and Run (R). To identify the correct terminal connection the following procedure applies:

- ✓ The highest resistance reading is between the start and run terminals
- ✓ The middle resistance reading is between the start and common terminals.
- ✓ The lowest resistance reading is between the run and common terminals.

- **Insulation resistance** of motor winding using Insulation tester meter set to the 500 Volt scale. Check from windings to earth **(C to E, S to E, R to E)** Minimum test value of the electric motor is **1 Meg Ohm (1 MΩ).**
- With the motor running, check the running amps of the motor using Clamp on meter.

2.2.3. Three Phase

- Ensure the terminal for power supply is in good condition. Check the connection bar for terminal (U, V, W). Connection type - **STAR OR DELTA**.
- Confirm the power supply VOLTAGE for electric motor. 230/400.
- Using the multimeter, check the continuity of winding from phase to phase **(U to V, V to W , W to U).**Each phase to phase must have a continuity if winding is OK.

- Check the motor winding ohms reading using multimeter or ohmmeter for phase to phase terminal**(U to V,V to W ,W to U)**.The ohms reading for each winding must be the same (or nearly the same).
- **Insulation resistance** of motor winding using Insulation tester meter set to the 500 Volt scale (1000v DC). 1. Check from phase to phase **(U to V, V to W, W to U)** and 2. check from phase to earthing **(U to E, V to E , W to E)**. Minimum test value of the electric motor is **1 Meg Ohm (1 MΩ).**
- With the motor running, check the running amps of the motor using Clamp on meter. Compare to the FLA on the name plate of motor.
- If every step is completed, decide the condition of electrical motor either OK or NEED TO REPAIR.

Every 3 phase motor has six (6) terminals with the supply voltage connected to three (3) of those terminals. The most common configuration of a three-phase motor is the Delta (∆) – Star (Wye) configuration with the Delta side connected to supply voltage. The terminal configuration of a 3 phase motor is shown below:

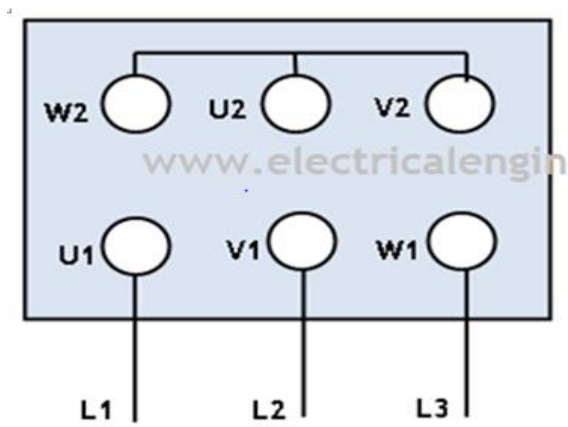


Figure 2.3. Terminals Configuration of a 3 Phase Motor

The **W2U2V2** terminal set is the star side of the 3 phase motor while the **U1VIW1** is the Delta side of the motor connected to the supply voltage.

The 3 phase motor is a rugged piece of equipment but as with everything man made, there comes a time when this beautiful piece of machinery fails either due to old age, misapplication, mal-operation or any other adverse cause.

The most common failure mode of a 3 phase AC motor is burnt winding or shorted winding leading to the damage of the motor. Often it is required to test the winding of the 3 phase windings with the aid of a multimeter or ohmmeter to determine whether the motor is still good or burnt or shorted.

2.3.1. How to Test the Winding of a 3 phase Motor

To determine whether a 3 phase motor is still good or has gone bad, a simple ohmmeter test across the windings of the motor will reveal its true state of health. As shown below, the indicated terminal matrix (***blue lines***) shows the way the windings of a 3 phase motor should be tested with an Ohmmeter:

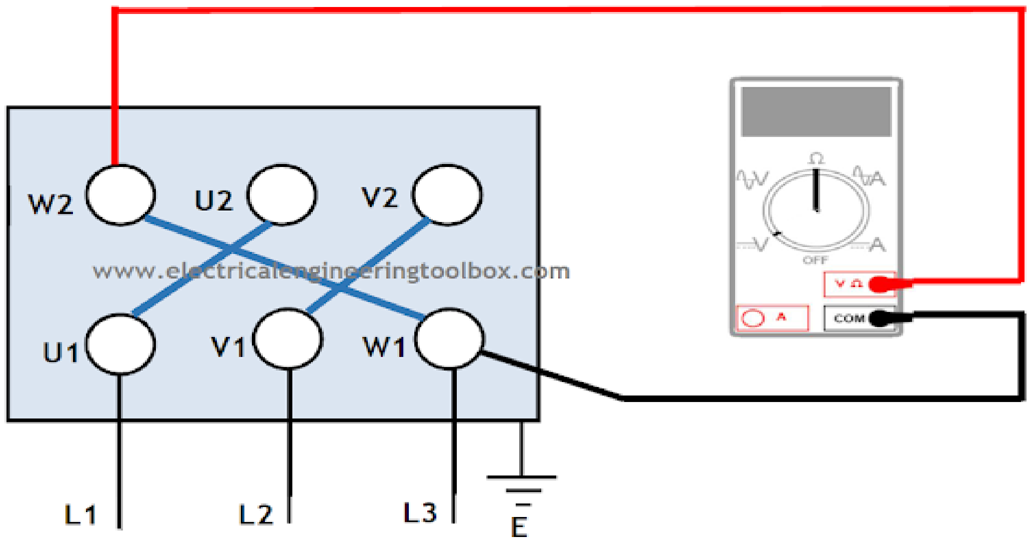


Figure 3.3. windings test of a 3 Phase Motor with an Ohmmeter

The first thing to do before testing the windings of the motor is to remove the links linking terminals **W2U2V2** and the disconnect the motor from supply (L1, L2, L3). A multimeter terminals placed across this matrix of terminals will indicate the following readings for a good 3 phase motor:

- ✓ Terminals **W1W2**, **U1U2**, **V1V2** will indicate ***continuity*** for a good motor
- ✓ Every other terminal combinations should indicate ***Open*** for a good motor
- ✓ Readings between any of the six (6) terminals and the motor frame signifying earth should indicate ***open*** for a good motor.

2.3.2. Ohmmeter Readings for a Bad 3 phase Motor

In the case of a burnt or bad 3 phase motor, this matrix of terminals should indicate the opposite readings for a bad motor:

- ✓ If any of the terminal combinations W1W2, U1U2, V1V2 should indicate ***open*** then the motor is bad.
- ✓ If any other terminal combinations should indicate ***continuity*** instead of ***open***, then the motor is bad.
- ✓ If the reading between any of the six (6) terminals and motor frame should indicate ***continuity***, then the motor is dead.

Self-Check -5	Written Test

Directions: Answer all the questions listed below

I. True / False

______ 1. The phase-sequence meter is the most commonly used tool for determining the phase sequence

______ 2. static indicator is a simple configuration that uses two lamps and an inductor or capacitor.

______ 3. Using Ohm meter one can know whether a 3 phase motor is still good or has gone bad.

______ 4. If the reading between any of the six (6) terminals and motor frame should indicate **continuity**, then the motor is normal.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :3	Prepare and submitting service report

3.1. While reporting include the follow points

		MDL NO	
HP		SER. NO.	
SPEED		FRAME	
STATOR VOLT		TYPE	
AMPS		ID NUMBER	

OF ROTOR BARS ______ # OF STATOR SLOTS ______

INITIAL CONDITION	
TERM. BOX COVER	
TERM. BOX	
COUPLING /PULLEY	
OTHER	
DRV END BRG HOUSING FIT	
OPP. END BRG HOUSING FIT	
CAUSE OF FAILURE:	

BEARINGS			
DRV END BRG REMOVED:SIZE		MANUFACTURER	
OPP END BRG REMOVED: SIZE		MANUFACTURER	
NOTE:			

WINDING	
WINDING CONDITION	
CORE CONDITION	

NO LOAD TEST			
VOLTAGE L1		AMPS L1	
VOLTAGE L2		AMPS L2	
VOLTAGE L3		AMPS L3	
		RPM	

FULL LOAD TEST			
VOLTAGE L1	______	AMPS L1	______
VOLTAGE L2	______	AMPS L2	______
VOLTAGE L3	______	AMPS L3	______
		RPM	

OUTPUT HORSE POWER	______
TORQUE	

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Say True/False

1. When service report is written initial condition of the machine may not be written.
2. When service report is written motor no load test can be written.

Note: **Satisfactory rating – 1 points** **Unsatisfactory - below 1 points**

Score = ____________
Rating: _____________

Name: ___________________________ Date: ________________

Operation Sheet :1	Single phase motor testing

Procedures

1. Check the motor winding (C to S, C to R, S to R).
2. Check Insulation resistance of motor winding from windings to earth (C to E, S to E, R to E).
3. With the motor running, check the running amps of the motor

Operation Sheet :2	Three phase motor testing

Procedures

1. Ensure the terminal for power supply is in good condition.
2. Check the connection bar for terminal (U, V, W) connection type
3. Confirm the power supply VOLTAGE for electric motor.
4. Using the multimeter, check the continuity of winding from phase to phase (U to V, V to W , W to U).

5. Check the motor winding ohms reading for phase to phase terminal(U to V,V to W ,W to U).
6. Check insulation resistance of motor winding using
7. Check the running amps of the motor
8. If every step is completed, decide the condition of electrical motor

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________
Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4hour

Task 1. Test single phase motor

Task 2. Test three phase motor

Instruction Sheet	LG34: clean- up

This learning guide is developed to provide you the necessary information regarding the following learning outcome and content coverage

- Clean ,check and return tools, equipment and any surplus materials
- Check and maintain tools and equipment
- Cleaning work area

This guide will also assist you to attain the learning outcome and contents stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Clean ,check and return tools, equipment and any surplus materials
- Check and maintain tools and equipment
- Cleaning work area

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 and 4.
3. Read the information written in the "Information Sheet 1, Sheet 2, Sheet 3, in page 3, 5 and 8 respectively".
4. Accomplish the "Self-check 1, Self-check 2 and Self-check 3" in page 4, 7 and 12 respectively".

Information Sheet-1	Clean ,check and return tools, equipment and any surplus materials

Fundamentals for Returning surplus materials ware house

- All surplus materials should be identified, inspected, labeled, transferred to another project or returned to Logistics. This can take place during project execution or after project completion and/or cancellation.
- All materials planned for return shall be segregated and transferred to relevant storage facility in accordance with the following criteria:
- Items which have potential use but not part of ‘general stock’ (standard materials) and where required, having shall be returned to surplus storage facilities.
- Items which have potential use and are part of ‘general stock’ and where required, having shall be returned to standard stock storage facilities.
- All other materials should be sent to auction yards within the respective area, flagged for disposal and disposed through sale to other operators or auctioned via public tender.
- Any item that can be immediately used on another approved project or transferred to general stock shall be transferred to the next approved project at the original procurement cost.
- Surplus materials should be properly marked, labeled and preserved at all time in accordance with procedures and guidelines

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Choose the best answer.

4. All materials planned for return shall be segregated and transferred to relevant storage facility in accordance with the following criteria:
5. Items which have potential use and are part of 'general stock' and where required, having shall be returned to standard stock storage facilities

Score = ___________	
Rating: ____________	

Name: _________________________ Date: _______________

Information Sheet-2	Check and maintain tools and equipment

2.1. Tool Work Habits

2.1.1. Keep each tool in its proper storage place.

All divisions have incorporated a Tool Control Program as directed. The Tool Control Program is based on the concept of a family of specialized toolboxes and pouches configured for instant inventory before and after each maintenance action. The content and configuration of each container is tailored to the task, work center, and equipment maintained.

- ✓ Work center containers are assigned to and maintained within a work center. Other boxes and specialized tools are checked out from the tool control center (tool room).
- ✓ Keep your tools in good condition. Protect them from rust, nicks, burrs, and breakage.
- ✓ Keep your tool allowance complete.
- ✓ When you are issued a toolbox, each tool should be placed in it when not in use. When the toolbox is not actually at the work site, it should be locked and stored in a designated area.

2.1.2. Use each tool only for the job it was designed to do.

Each particular type of tool has a specific purpose. If you use the wrong tool when performing maintenance or repairs, you may cause damage to the equipment you're working on or damage the tool itself. Remember, improper use of tools results

in improper maintenance. Improper maintenance results in damage to equipment and possible injury or death to you or others.

2.1.3. Safe maintenance practices

Always avoid placing tools on or above machinery or an electrical apparatus. Never leave tools unattended where machinery is running.

2.1.4. Never use damaged tools.

Abused screwdriver may slip and spoil the screw slot, damage other parts, or cause painful injury. A gauge strained out of shape will result in inaccurate measurements.

Remember, the efficiency of craftsmen and the tools they use are determined to a great extent by the way they keep their tools. Likewise, they are frequently judged by the manner in which they handle and care for them. Anyone watching skilled craftsmen at work notices the care and precision with which they use the tools of their trade. The care of hand tools should follow the same pattern as for personal articles; that is, always keep hand tools clean and free from dirt, grease, and foreign matter. After use, return tools promptly to their proper place in the toolbox. Improve your own efficiency by organizing your tools so that those used most frequently can be reached easily without digging through the entire contents of the box. Avoid accumulating unnecessary junk.

2.2. Care of hand tools

Tools are expensive; tools are vital equipment. When the need for their use arises, common sense plus a little preventive maintenance prolongs their usefulness. The following precautions for the care of tools should be observed:

- ✓ Clean tools after each use. Oily, dirty, and greasy tools are slippery and dangerous to use.
- ✓ NEVER hammer with a wrench.
- ✓ NEVER leave tools scattered about. When they are not in use, stow them neatly on racks or in toolboxes.
- ✓ Apply a light film of oil after cleaning to prevent rust on tools.
- ✓ INVENTORY tools after use to prevent loss.

Self-Check -2	Written Test

Directions: Answer all the questions listed below.

PART I **TRUE/FALSE**

If the statement is correct write TRUE if the statement is in correct write FALSE

_____ 1. Keep your tools in good condition. Protect them from rust, nicks, burrs, and breakage.

_____ 2. Always avoid placing tools on or above machinery or an electrical apparatus.

_____ 3.Remember, improper use of tools resultsin improper maintenance.

_____ 4.Use each tool only for the job it was designed to do.

Note: **Satisfactory rating - 2 points** **Unsatisfactory - below 2 points**

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-3	Clean work area

Work station isdefined as an area, in an office,outfitted with equipment andfurnishings for one or more workers. Normally leather goods are operated in awork shop therefore the work station f or a leather goods worker would be the workshop. It is necessary for a worker to prepare his wor k station and the pieces to bedone but before doing so a worker should be well aware of the safe ty rules andregulations.

3.1. Housekeeping

Good housekeeping involves every phase of industrial operations and should apply thrugh out the entire premises, indoors and out. It is more than merecleanliness. It requires orderly conditions, the avoidance of congestion, andattention to such details as an orderly layout of the whole workplace, the markingof aisles, adequate storagements, and and suitable provision for cleaning andmaintenance. Efficient production and a good working environment are complementary. The elimination of inefficiencies and accedent hazards caused by unfavorable conditions in and about the workplace is essential in getting the job done properly and safely. The attention to these important

Detailswhich may be overlookedwhen management's attention is concentrated upon such am enities as good cloakrooms, canteens, rest rooms, recreational facilities, etc. is widely referred to as "good housekeeping.

A clean, well-ordered, attractive work environment sets the tone of your establishment. It encourages tidy work habits in employees. It helps reducefatigue. It promotes good worker management relations. It also gives a lift to morale, which is reflected in the quality of production and overall efficiency. Good house keeping is also a good advertisement for your company. Customers and clients have more confidence in an organization when they we work being carried out efficiently in clean, pleasant, well ordered surroundings. There's an even more important reason why good house keeping matters it makes the undertaking a safer place to work in.

Good housekeeping is a vital factor in preventing accidents. The great majority of all work accidents are caused during the handling of goods or materials, and by people falling, being hit by falling objects, or striking against objects in the worplace. All these cause can be reduced by good housekeeping practices in fact, good house keeping is the only cure for hundreds of accidents that occur. Here are some kinds of accidents commonly caused by *bad* housekeeping:

- Tripping over loose objects on floors, stairs and platforms
- Articles dropping from above
- Slipping on greasy, wet or dirty surfaces

- Striking against projecting, poorly stacked, or misplaced material
- Tearing the hands or other parts of the body on projecting nails, wire, steelstrappi ng on bales or crates, etc.

Typical examples of poor housekeeping that lead to these accidents are:

- Excessive material, waste or chips in the working area
- Congested aisles
- Tools left on machines
- Waste containers overflowing
- Lockers and workrooms in disorder
- Acids in open containers
- Broken glass
- Electric leads or air lines across aisles
- Dirty light fittings, windows and skylights

Where housekeeping is bad, fire is a constant hazard. It can be caused by many house keeping problems such as oil-soaked rags and clothing igniting from spontaneous combustion, dust collectors not being properly or frequently cleaned, or piles of paper and other packing materials being allowed to accumulate. Poor keeping can also lead to infestation by pests such as rodents and cockroaches and create seri ous health risks.

3.2. Elements of a Good Housekeeping

The following are the basic elements of a good housekeeping:

- **Passageways**: Wide enough for traffic movements, marked off by floor lines from workpositions and storage areas.
- **Space:** Insuring sufficient room for the individual to work.
- **Storage**: Adequate and convenient space for materials and tools.
- **Materials Handling**: Layout planned for materials flow, with efficient methodsand e quipment.
- **Ventilation**: Good general ventilation plus local exhaust ventilation to removeair c ontaminants at the source.
- **Floors and Walls**: They need to be constructed with materials that are easy toclea n and if needed easy to repair.
- **Lighting** Welldistributed artificial light and effective use of available daylight.
- **Amenities**: Clean, up-todate washrooms and lockers for clothing, and cleanand inviting lunch room for e mployees to eat their meals.

- **Waste Removal**: Adequate facilities to prevent congestion and disorr.

Let us look at some of these elements in detail:

Keep Passageways Clear: Passageway space should be reserved for the movement ofp ersonnel, products and materials. It should be kept clean and clear and shouldnever be used fo r "bottleneck" or "overflow'' storage. This also applies topassageways and emergency exit s. Blind corners should be eliminated or beadequately protected by warning signs.Aisle boun dary markings should be drawn to show clearly the space which hasbeen reserved for traffic. Mar kings should be sufficiently wide (say a minimum of30 mm) and of a color to make them clearly vi sible. Paint or durable plastic stripscan be used.

Improve Storage Facilities: Tidiness and order are essential in overcomingstorage problem s, both in storerooms and in the yard. Good storage utilizes airspace instead of floor space, and also saves time-wasting delays. It's important to prevent stores and scraps accumulating on the floor and around machines. Never keep more stores and materials than necessary near machines and provide proper facilities (such as bins, shelves, boxes, racks, etc.) in which to store them.

Keep Floors Clean: Every year thousands of work injuries are caused by people falling. Floor conditions are responsible for many of these accidents. When floors are given the right treatment they are much easier to keep clean and hygienic.Spilt oil and other li quids should be cleaned up at once. Chips, shavings, dust, and similar wastes should never be allowed to accumulate. They should be removed frequently, or better still, be suitably trapped before they reach the floor

Paint the Walls: Paint is one of the cheapest means of renovating walls, and a fresh coat of paint can give a boost to morale. Light-colored walls reflect light. Dirty or dark-colored walls absorb light. Dirty walls have a depressing effect and encourage dirty habits and sloppy attitudes. Choose suitable colors to paint walls, ceilings and working surfaces. See that the paintwork is cleaned down periodically. Color can be harnessed to assist with safety. For example it can be used to warn of physical hazards and to mark obstructions such as pillars. Painting handrails, machine guards and other safety equipment renders them distinctive and also prevents rust. Color can be used to highlight the hazardous parts of machinery but it can never substitute for a needed guard.

Maintain Light Fittings: Attention to light fittings should be an integral part of any good housekeeping programme. Dirty lamps and shades, and lamps whose output has deteriorated with use, deprive employees of essential light. It's been found that lighting efficiency may be improved by 20 to 30 percent simply by cleaning the lamps and reflectors.

Clean the Windows: Clean windows let in light; dirty ones keep it out. Insufficient light causes eye strain and leads to accidents because employees are unable to see properly. Ensure that windows are not blocked by stacked

Dispose of Scrap and Prevent Spillage: It's a common practice to let the floor catch all the waste and then spend time and energy cleaning it up. It is obviously better to provide convenient containers for scrap and waste and educate employees to use them. Safety will benefit, expense will be saved, and the factory will be a better place in which to work. Oily floors are a common accident and fire hazard. Splash guards and drip pans should be installed wherever oil spills or drips may occur. Prevent accidents by keeping oil and grease off the floor.

Get Rid of Dust and Dirt: In some jobs, dust, dirt, chips, etc., are unavoidable. If they can't be collected as part of the process (e.g. by enclosure and exhaust methods) you need a way to clean them up. Vacuum cleaners are suitable for removing light dust and dirt. Industrial models have special fittings for cleaning walls, ceilings, ledges, machinery, and other hard-to-reach places where dust and dirt collect. If light dust is removed by sweeping, floors should be dampened first rather than swept dry. Oiling floors occasionally with light oil helps to lay the dust but take care that slipping hazards do not occur. Remember, it is not only floors that need sweeping. Dust and grime also collect on ledges, shelves, piping, conduits, lamps, reflectors, windows, cupboards, lockers, and so on and all these places need attention.

Self check 3	Written Test

Directions: Answer all the questions listed below.

PART I TRUE/FALSE

If the statement is correct write TRUE if the statement is in correct write FALSE

______1.Good general ventilation plus local exhaust ventilation to removeair contamina nts at the source.

_____2.Keep your tools in good condition. Protect them from rust, nicks, burrs, and breakage.

_____3. Always avoid placing tools on or above machinery or an electrical apparatus.

______4.Remember, improper use of tools resultsin improper maintenance.

_______5.Use each tool only for the job it was designed to do.

***Note:* Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Score = ___________

Rating: ____________

Name: ____________________ Date: _________________

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12. Eectric Machinery, 6e, Fitzgerald.

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14. Theraja

The trainers (who developed the Learning Guide)

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1	SERKABEBA ABERA	MSC	DEBUB
2	MULU DAMANE	MSC	ADDIAABEBA
3	ABERA GEBRE	BSC	DIRADAWA
4	ESUBALEW AMSALU	MSC	HARER
5	MERON HUSEN	BSC	HARER
6	SHIMELS CHEKOLE	BSC	AMHARA
7	FISIHA BIREHANU	MSC	AMHARA
8	YIMER SEID	MSC	AFAR
9	HINDA IBRAHIM	BSC	SOMALI
10	TADDELE GASHAW	MSC	SOMALI