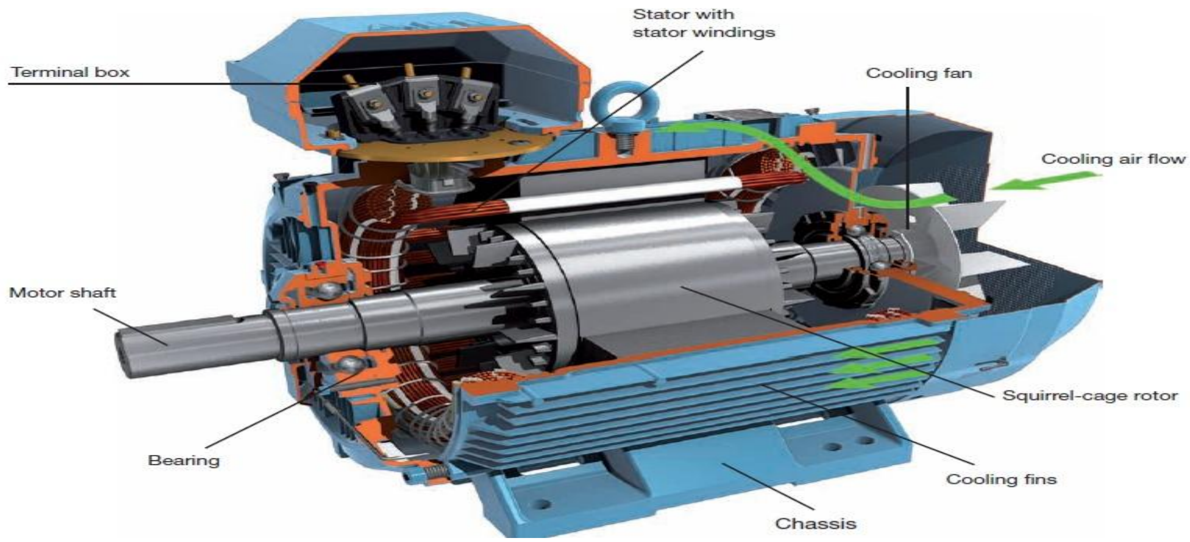
Industrial Electrical/Electronic Control Technology Level-II

Based on March, 2022 Curriculum

Version 1



Module Title: - Maintain and Repair Industrial Electrical Machines and Drives

Module code: EIS IEC2 08 0322

Nominal duration: 180Hour

Prepared by: Ministry of Labor and Skill

August, 2022

Addis Ababa, Ethiopia

Table of contents

Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVT instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

1. NIOSH ………………. National Institute for Occupational Safety and Health
2. AC ....Alternating current
3. DC …………………….Direct current
4. Emf …………………….Electro motive force
5. IM………………………induction motor

Introduction to the Module

In electric filed; Maintain and Repair Industrial Electrical Machines and Drives modules is designed to meet the industry requirements under the industrial machine to performing maintenance, troubleshooting and repair works on Maintain and Repair Industrial Electrical Machines and Drives including diagnose and rectify fault in motor drive system: Carry out **maintain and repair industrial electrical machines and drives**.

This module covers the units:

- Plan, prepare and coordinate works
- Diagnosis and rectify faults in Electrical System or equipment
- Maintain and electrical system
- Complete and report fault diagnosis and rectification activities

Learning Objective of the Module

- Plan coordinate works
- Diagnosis Electrical faults
- Maintain electrical system
- complete report fault diagnosis and rectification activities

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit one: Plan, prepare and coordinate works

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Identifying and requesting Materials, tools, equipment, testing devices and PPE
- Identifying and selecting prevention and control measures for Potential hazards
- Identifying electrical machines and principles of operations
- Preparing Maintenance works and schedules of electrical machines
- Preparing work instructions
- Informing department/personnel on the schedule of work

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify and request Materials, tools, equipment, testing devices and PPE
- Identify and selecting prevention and control measures for Potential hazards
- Identify electrical machines and principles of operations
- Prepare Maintenance works and schedules of electrical machines
- Prepare work instructions
- Inform department/personnel on the schedule of work

1.1. Identify and request materials, tools, equipment, test devices and PPE

1.1. OHS policies /Occupational Health and Safety

Occupational health and safety can be important for moral, legal, and financial reasons. In common-law Authorities, employers have a common law duty (reflecting an underlying moral obligation) to take reasonable care for the safety of their employees. The goals of occupational safety and health programs include fostering a safe and healthy work environment. OHS may also protect co-workers, family members, employers, customers, and many others who might be affected by the workplace environment.

Health, safety and welfare legislation has increased the awareness of everyone to the risks involved in the work- place.

The employer has a duty to care for the health and safety of employees. To do this he must ensure that:

- The plant, tools and equipment are properly maintained.
- The necessary safety equipment – such as personal protective equipment, dust and fume extractors and machine guards – is available and properly used;
- The workers are trained to use equipment and plant safely.
- Take reasonable care to avoid injury to themselves or others as a result of their work activity.

A. **Safety rules for electrical works.**

Before we start any activity in electrical connection we have to think and remind about the five important safety rules in Electricity.

Before you start work:

- Switch off main supply.
- Isolate the circuits.
- Fix the appropriate tags.
- Test that the electricity supply is isolated and
- Always test your testing instruments.

B. Personal Protective Equipment

Your employer is required to provide personal protective equipment. Some of the items of PPE you may use in the electrical and electronics industry are given below.

Clothing:- provides protection from electric arcing/flash burns, flying objects and electric Shock. Ideally, clothing should cover the body completely.

Safety helmets:- should be non-conductive. They provide protection from overhead wires, Structures and falling objects.

Safety glasses:- provide protection from electrical arcing and flying objects.

Insulating gloves:-provide protection from electric shock. They should be worn when Accidental contact with live conductors is possible, but they must never be the sole means of insulation.

Safety footwear:- should be non-conductive. It provides protection from electric shock and falling objects.

1.2. Identify and select prevention and control measure for potential hazard .

1.2.1 Hazard Prevention and Control

Effective controls protect workers from workplace hazards; help avoid injuries, illnesses, and incidents; minimize or eliminate safety and health risks; and help employers provide workers with safe and healthful working conditions. The processes described in this section will help employers prevent and control hazards identified in the previous section.

To effectively control and prevent hazards, employers should:

- Involve workers, who often have the best understanding of the conditions that create hazards and insights into how they can be controlled.
- Identify and evaluate options for controlling hazards, using a "hierarchy of controls."
- Use a hazard control plan to guide the selection and implementation of controls, and implement controls according to the plan.
- Develop plans with measures to protect workers during emergencies and nonroutine activities.

Evaluate the effectiveness of existing controls to determine whether they continue to provide protection, or whether different controls may be more effective. Review new technologies for

Action item 1: Identify control options

Action item 2: Select controls

Action item 3: Develop and update a hazard control plan

Action item 4: Select controls to protect workers during nonroutine operations and emergencies

Action item 5: Implement selected controls in the workplace

Action item 6: Follow up to confirm that controls are effective

Action item 1: Identify control options

A wealth of information exists to help employers investigate options for controlling identified hazards. Before selecting any control options, it is essential to solicit workers' input on their feasibility and effectiveness.

How to accomplish it

Collect, organize, and review information with workers to determine what types of hazards may be their potential to be more protective, more reliable, or less costly.

Present and which workers may be exposed or potentially exposed. Information available in the workplace may include:

- Review sources such as OSHA standards and guidance, industry consensus standards, National Institute for Occupational Safety and Health (NIOSH) publications, manufacturers' literature, and engineering reports to identify potential control measures. Keep current on relevant information from trade or professional associations.
- Investigate control measures used in other workplaces and determine whether they would be effective at your workplace.
- Get input from workers who may be able to suggest and evaluate solutions based on their knowledge of the facility, equipment, and work processes.
- For complex hazards, consult with safety and health experts, including OSHA's On-site Consultation Program.

Action item 2: Select controls employers should select the controls that are the most feasible,

effective, and permanent.

How to accomplish it

- Eliminate or control all serious hazards (hazards that are causing or are likely to cause death or serious physical harm) immediately.
- Use interim controls while you develop and implement longer-term solutions.
- Select controls according to a hierarchy that emphasizes engineering solutions (including elimination or substitution) first, followed by safe work practices, administrative controls, and finally personal protective equipment.
- Avoid selecting controls that may directly or indirectly introduce new hazards. Examples include exhausting contaminated air into occupied work spaces or using hearing protection that makes it difficult to hear backup alarms.
- Review and discuss control options with workers to ensure that controls are feasible and effective.

- Use a combination of control options when no single method fully protects workers.

Action item 3: Develop and update a hazard control plan

A hazard control plan describes how the selected controls will be implemented. An effective plan will address serious hazards first. Interim controls may be necessary, but the overall goal is to ensure effective long-term control of hazards. It is important to track progress toward completing the control plan and periodically (at least annually and when conditions, processes or equipment change) verify that controls remain effective.

Action item 4: Select controls to protect workers during nonroutine operations and emergencies

The hazard control plan should include provisions to protect workers during nonroutine operations and foreseeable emergencies. Depending on your workplace, these could include fires and explosions; chemical releases; hazardous material spills; unplanned equipment shutdowns; infrequent maintenance activities; natural and weather disasters; workplace violence; terrorist or criminal attacks; disease outbreaks (e.g., pandemic influenza); or medical emergencies. Nonroutine tasks, or tasks workers don't normally do, should be approached with particular caution. Prior to initiating such work, review job hazard analyses and job safety analyses with any workers involved and notify others about the nature of the work, work schedule, and any necessary precautions.

Action item 5: Implement selected controls in the workplace

Once hazard prevention and control measures have been identified, they should be implemented according to the hazard control plan.

How to accomplish it

- Implement hazard control measures according to the priorities established in the hazard control plan.
- When resources are limited, implement measures on a "worst-first" basis, according to the hazard ranking priorities (risk) established during hazard identification and assessment. (Note, however, that regardless of limited resources, employers have an obligation to protect workers from recognized, serious hazards.)
- Promptly implement any measures that are easy and inexpensive—e.g., general housekeeping, removal of obvious tripping hazards such as electrical cords, basic lighting—regardless of the level of hazard they involve.

Action item 6: Follow up to confirm that controls are effective

To ensure that control measures are and remain effective, employers should track progress in implementing controls, inspect and evaluate controls once they are installed, and follow routine preventive maintenance practices.

1.3. Identifying electrical machines and principles of operations

1.3.1 Magnetic field

1. When an electric current flows through a conductor, magnetic field around a conductor is setup, similarly when current flows through a stator coil the magnetic field around the coil is also setup and due to this stator current another emf is induced in the rotor and the rotor start rotating but in this process rotor is not self- starting because starting torque is not getting in the rotor, if you give the starting torque then the rotor keep moving.
2. Electric current flows through a conductor, magnetic field around a conductor is setup, similarly when current flows through a stator coil the magnetic field around the coil is also setup and due to this stator current another emf is induced in the rotor and the rotor start rotating but in this process rotor is not self- starting because starting torque is not getting in the rotor, if you give the starting torque then the rotor keep moving.
3. When an electric current flows through a conductor, magnetic field around a conductor is setup, similarly when current flows through a stator coil the magnetic field around the coil is also setup and due to this stator current another emf is induced in the rotor and the rotor start rotating but in this process rotor is not self- starting because starting torque is not getting in the rotor, if you give the starting torque then the rotor keep moving.

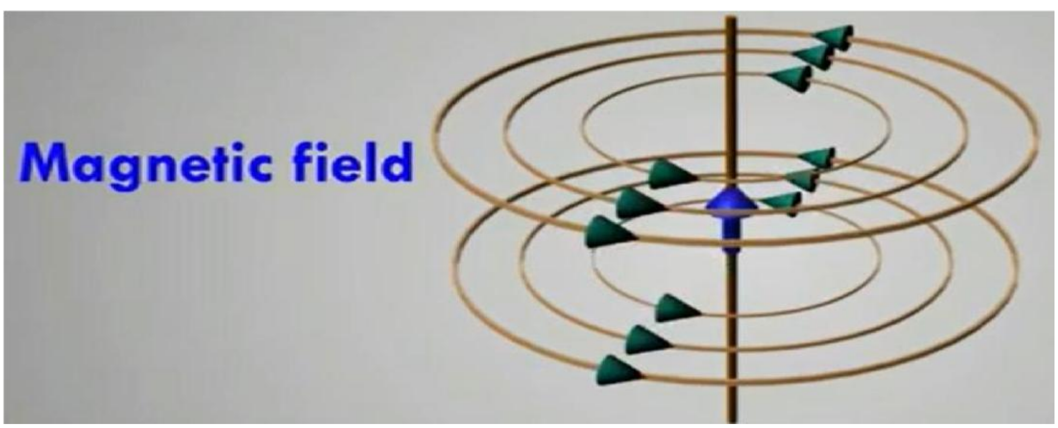


Figure3. 1 magnetic field rotation

Types of magnets

✓ **Permanen 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, orcobalt with other elements. These are known as hard magnetic materials.

(a)Temporarymagnets

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

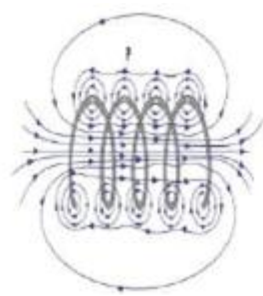


Figure3. 2 magnetic field and the wire carried current

There is a simple rule for remembering the direction of the magnetic field around a conductor. It is called the ***rght-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.

Figure 3.4 : Right-hand rule

Figure3. 3. Right-hand rule

(b) Magnetic Field Produced by aCoil

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.

- ✓ **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.

- ✓ **Mutual-inductance**

When one circuitinduces current flow in a second nearby circuit, it is known as mutual-inductance. The image to the right shows an example of mutual-inductance
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 b ought close to the wire in the primary circuit.

3.1.2. Machines and principles of operations

A. 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 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 magneticfield 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.

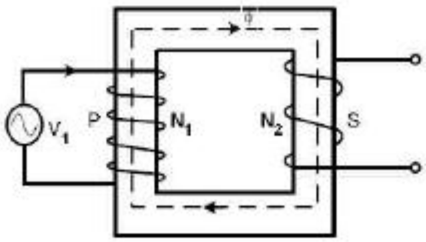


Figure3. 4 Schematic diagram of a two-winding transformer

✓ **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.

V1I1= V2I2

Input VA= Output VA

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

✓ **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 : - E1 & I1 – for primery voltage & current respectively

N1 - for primery turn

E2 - for secondery voltage

N2 - 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**.

Connectiontions of transformer

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.

(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 (Δ) arrangement.

The primary windings are connected in star and the secondary windings are connected in delta. 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.

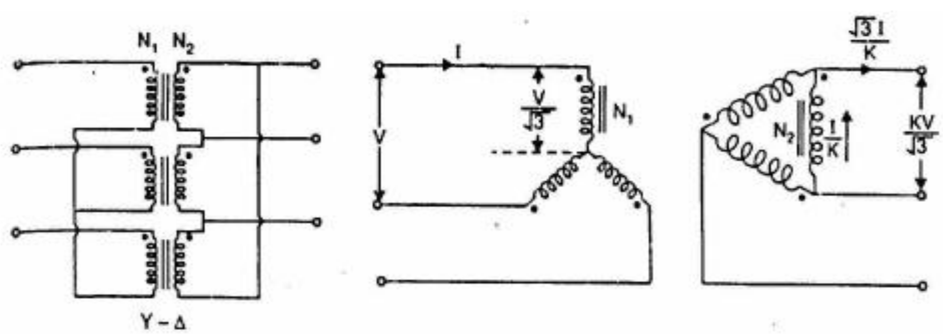


Figure3. 5 Transformer connection

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 (Δ) arrangement. The four most common connections are (i) Y-Y (ii) Δ-Δ (iii) Y- Δ and (iv) Δ -Y.
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.

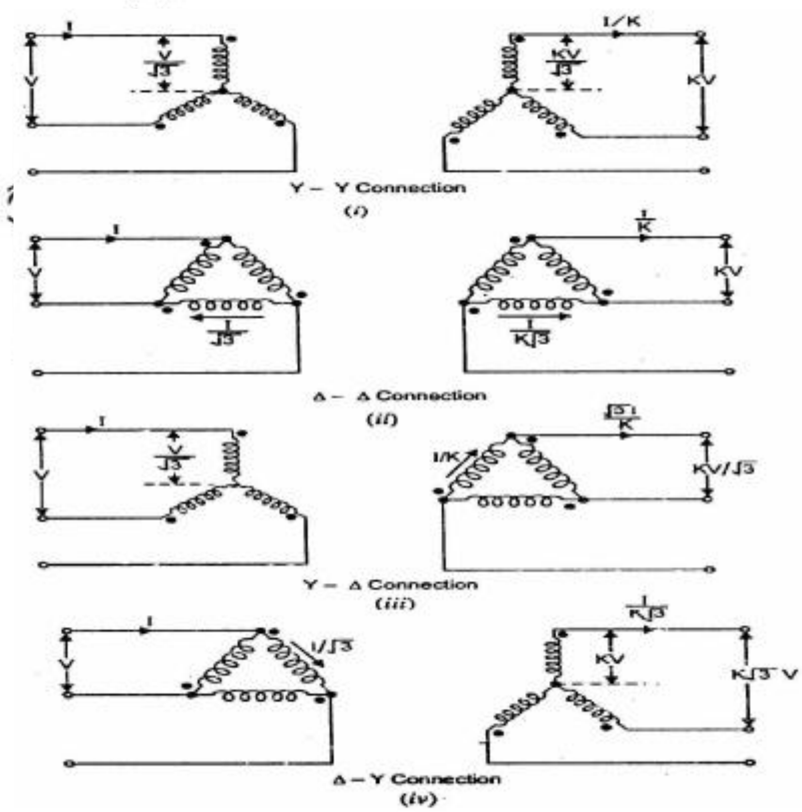


Figure3. 6 Fithree pase transformer connection

- ✓ **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.

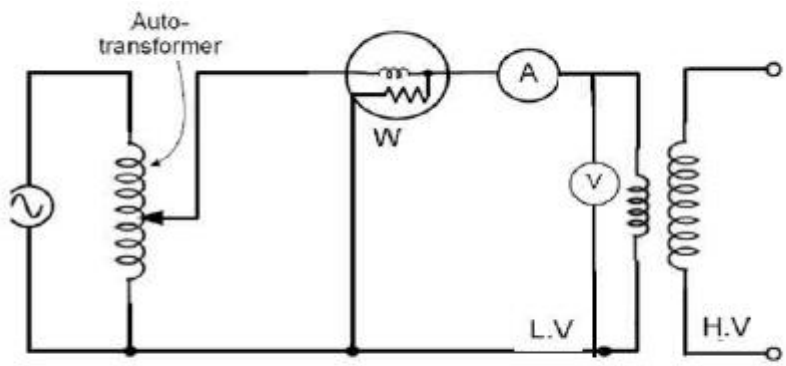


Figure3. 7open circuit test

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 .

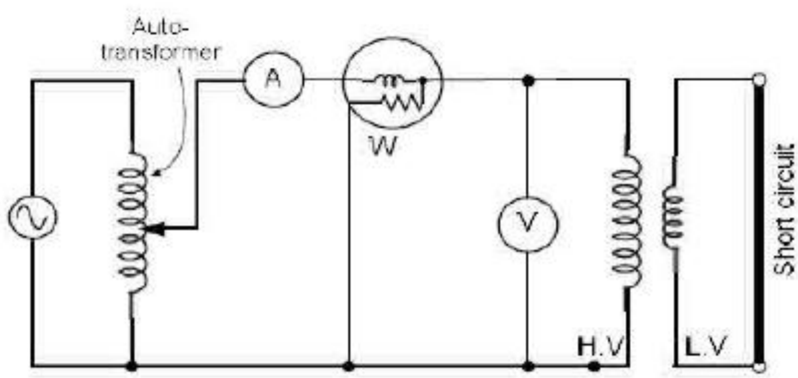


Figure3. 8 short circuit test

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

1.3.5 Types and operation of DC Machine

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 application.

- ✓ Construction of DC Motor

A DC motor like we all know is a device that deals in the conversion of electrical energy to mechanical energy and this is essentially brought about by two major parts required for the construction of DC motor, namely.

1. Stator – The static part that houses the field windings and receives the supply and,
2. Rotor – The rotating part that brings about the mechanical rotations.

Other than that there are several subsidiary parts namely the

1. Yoke of DC motor.
2. Poles of DC motor.
3. Field winding of DC motor.
4. Armature winding of DC motor.
5. Commutator of DC motor.

6. Brushes of DC motor.

All these parts put together configures the total construction of a DC motor. Now let's do a detailed discussion about all the essential parts of DC motor.

The magnetic frame or the yoke of DC motor made up of cast iron or steel and forms an integral part of the stator or the static part of the motor. Its main function is to form a protective covering over the inner sophisticated parts of the motor and provide support to the armature. It also supports the field system by housing the magnetic poles and field winding of the dc motor.

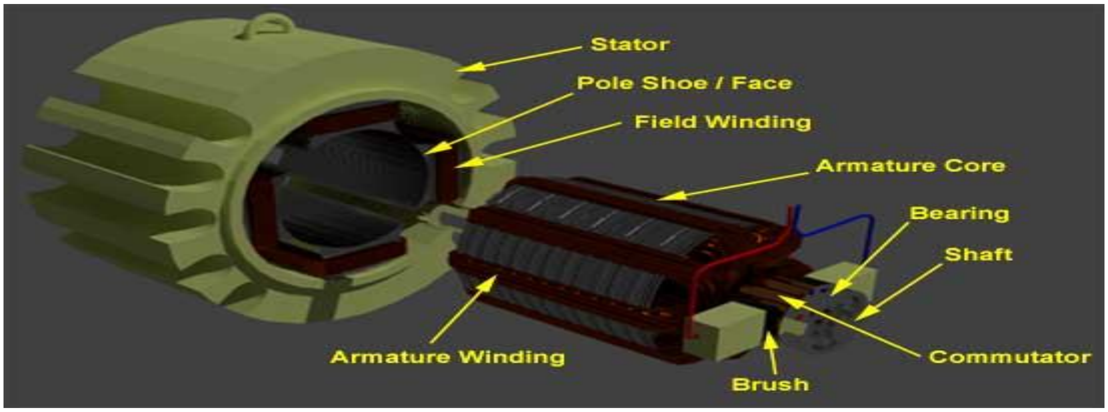


Figure3. 9 parts of DC motor

- ✓ Working or Operating Principle of DC Motor

A DC motor in simple words is a device that converts direct current(electrical energy) into mechanical energy. It's of vital importance for the industry today, and is equally important for engineers to look into the working principle of DC motor in details that has been discussed in this . In order to understand the operating principle of DC motor we need to first look into its constructional feature.

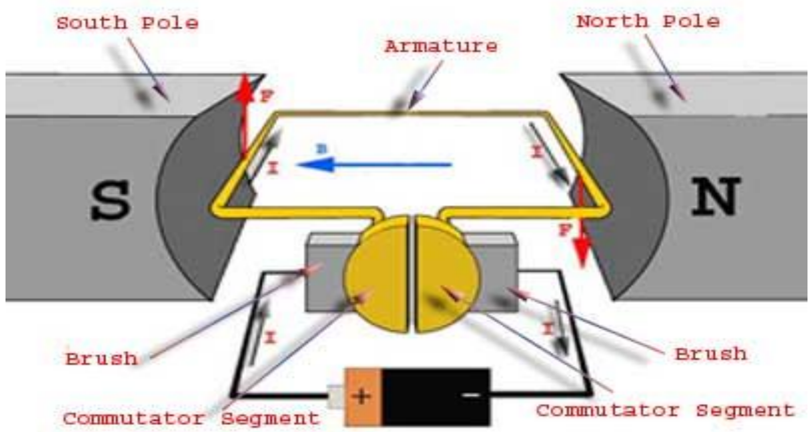


Figure3. 10 Figworking principles of DC motor

The very basic construction of a DC motor contains a current carrying armature which is connected to the supply end through commutator segments and brushes it is placed within the north south poles of a permanent or an electro-magnet as shown in the diagram below.

Now to go into the details of the **operating principle of DC motor** its important that we have a clear understanding of Fleming's left hand rule to determine the direction of force acting on the armature conductors of DC motor.

Fleming's left hand rule says that if we extend the index finger, middle finger and thumb of our left hand in such a way that the current carrying conductor is placed in a magnetic field (represented by the index finger) is perpendicular to the direction of current (represented by the middle finger), then the conductor experiences a force in the direction (represented by the thumb) mutually perpendicular to both the direction of field and the current in the conductor.

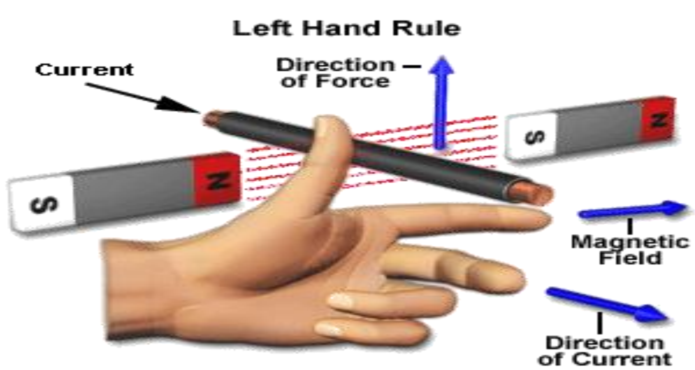


Figure3. 11Fleming's left hand rule

The direction of rotation of a this motor is given by Fleming's left hand rule, which states that if the index finger, middle finger and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of magnetic field, middle finger indicates the direction of current, then the thumb represents the direction in which force is experienced by the shaft of the **DC motor**.

Here in a DC motor, the supply voltage E and current I is given to the electrical port or the input port and we derive the mechanical output i.e. torque T and speed ω from the mechanical port or output port.

The input and output port variables of the **direct current motor** are related by the parameter K.

$$T = KI \ and \ E = K\omega$$

So from the picture above we can well understand that motor is just the opposite phenomena of a DC generator, and we can derive both motoring and generating operation from the same machine by simply reversing the ports.

Detailed Description of a DC Motor

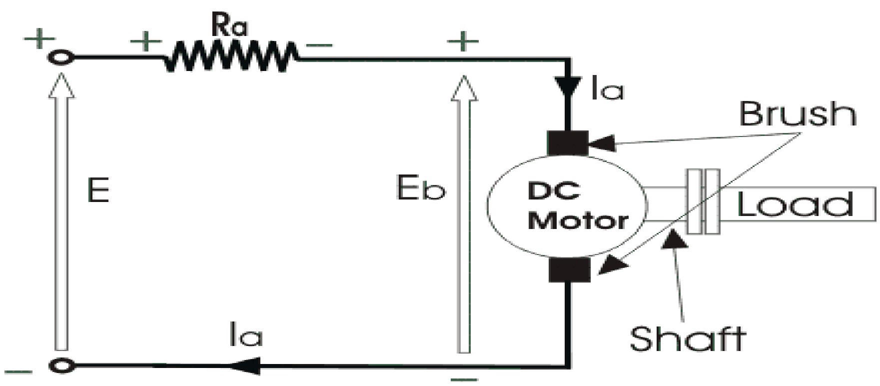


Figure3. 12detailed description

The direct current motor is represented by the circle in the center, on which is mounted the brushes, where we connect the external terminals, from where supply voltage is given. On the mechanical terminal we have a shaft coming out of the Motor, and connected to the armature, and the armature-shaft is coupled to the mechanical load. On the supply terminals we represent the armature resistance R_a in series. Now, let the input voltage E, is applied across the brushes. Electric current which flows through the rotor armature via brushes, in presence of the magnetic field, produces a torque T_g . Due to this torque T_g the dc motor armature rotates. As the armature conductors are carrying currents and the armature rotates inside the stator magnetic field, it also produces an emf E_b in the manner very similar to that of a generator. The generated Emf E_b is directed opposite to the supplied voltage and is known as the back Emf, as it counters the forward voltage.

$$E_b = \frac{P.\varphi.Z.N}{60.A} \dots\dots\dots\dots\dots\dots\dots(1)$$

Where, P = no of poles φ = flux per pole Z= No. of conductors A = No. of parallel paths and N is the speed of the DC Motor. So, from the above equation we can see E_b is proportional to speed 'N'. That is whenever a direct current motor rotates, it results in the generation of back Emf. Now lets represent the rotor speed by ω in rad/sec. So E_b is proportional to ω. So, when the speed of the motor is reduced by the application of load, E_b decreases. Thus the voltage difference between supply voltage and back emf increases that means $E - E_b$ increases. Due to this increased voltage difference, armature current will increase and therefore torque and hence speed increases. Thus a DC Motor is capable of maintaining the same speed under variable load. Now armature current I_a is represented by

$$I_a = \frac{E - E_b}{R_a}$$

Now at starting, speed ω = 0 so at starting E_b = 0.

$$\therefore\ I_a = \frac{E}{R_a} \dots\dots\dots\dots\dots\dots\dots\dots(2)$$

Now since the armature winding electrical resistance R_a is small, this motor has a very high starting current in the absence of back Emf. As a result we need to use a starter for starting a DC Motor.

Now as the motor continues to rotate, the back Emf starts being generated and gradually the current decreases as the motor picks up speed.

Types of DC Motor

The direct current motor or the DC motor has a lot of application in today's field of engineering and technology. Starting from an electric shaver to parts of automobiles, in all small or medium sized motoring applications DC motors come handy. And because of its wide range of application different functional **types of DC motor** are available in the market for specific requirements. The **types of DC motor** can be listed as follows-

- DC motor
- Permanent Magnet DC Motor
- Separately Excited DC Motor
- Self Excited DC Motor
- Shunt Wound DC Motor
- Series Wound DC Motor
- Compound Wound DC Motor
- Short shunt DC Motor
- Long shunt DC Motor
- Differential Compound DC Motor
- Short Shunt DC Motor

- Long Shunt DC Motor

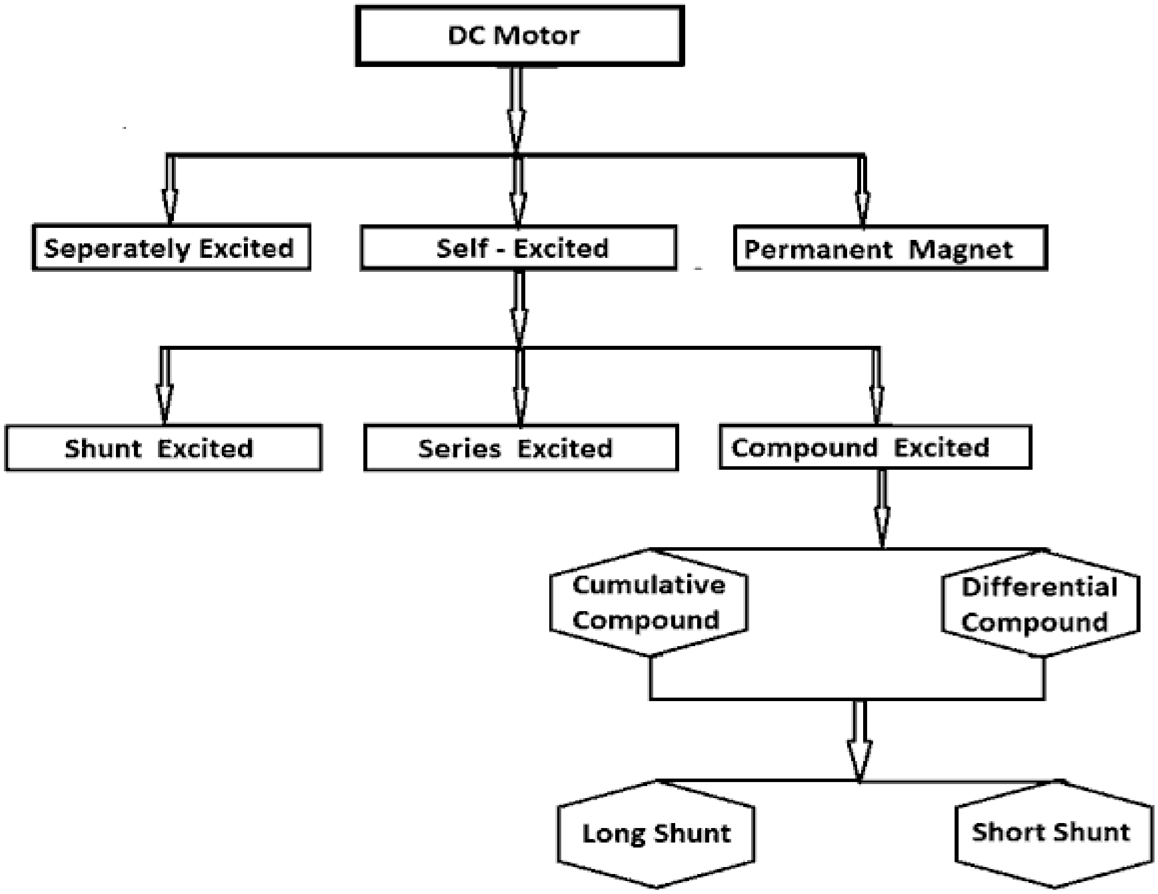


Figure3. 13types of machine

✓ **Permanent Magnet DC Motor**

The **permanent magnet DC motor** consists of an armature winding as in case of an usual motor, but does not necessarily contain the field windings. The construction of these types of DC motor are such that, radially magnetized permanent magnets are mounted on the inner periphery of the stator core to produce the field flux. The rotor on the other hand has a conventional DC armature with commutator segments and brushes. The diagrammatic representation of a permanent magnet DC motor is given below. The torque equation of DC motor suggests $T_g = K_a \varphi I_a$. Here φ is always constant, as permanent magnets of required flux density are chosen at the time of construction and can't be changed there after. For a permanent magnet DC motor $T_g = K_{a1} I_a$ Where, $K_{a1} = K_a.\varphi$ which is another constant. In this case the torque of DC Motor can only be changed by controlling armature supply.

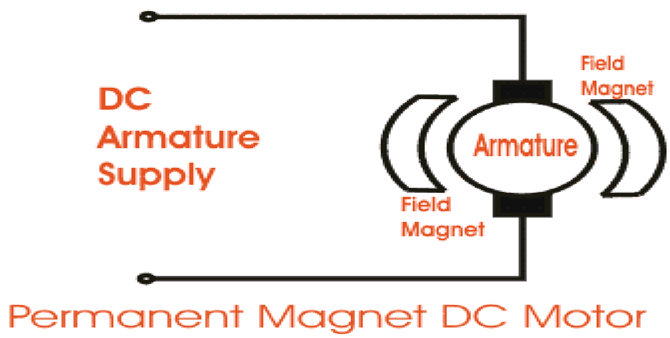


Figure3. 14 permanent magnet

- ✓ **Separately Excited DC Motor**

  As the name suggests, in case of a separately excited DC motor the supply is given separately to the field and armature windings. The main distinguishing fact in these types of DC motor is that, the armature current does not flow through the field windings, as the field winding is energized from a separate external source of DC current as shown in the figure beside.

  From the torque equation of DC motor we know $T_g = K_a\ \varphi\ I_a$ So the torque in this case can be varied by varying field flux φ, independent of the armature current I_a.

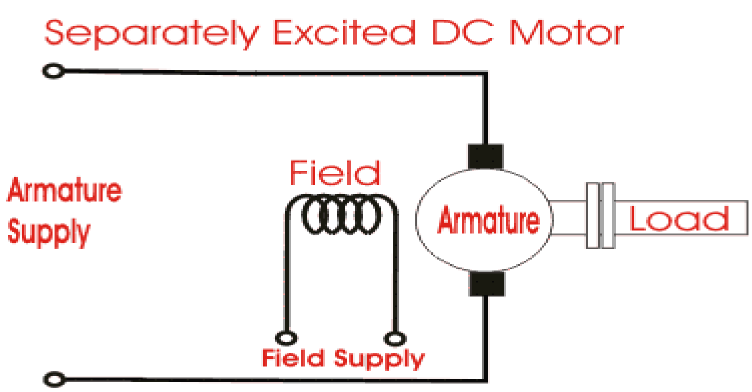


Figure3. 15 separately exited DC motor

Self-Excited DC Motor

Direct motors are named according to the connection of the field winding with the armature. There are 3 types:

1. Shunt wound DC motor.
2. Series wound DC motor.
3. Compound wound DC motor.

Let's now go into the details of these types of self excited DC motor.

Shunt Wound DC Motor

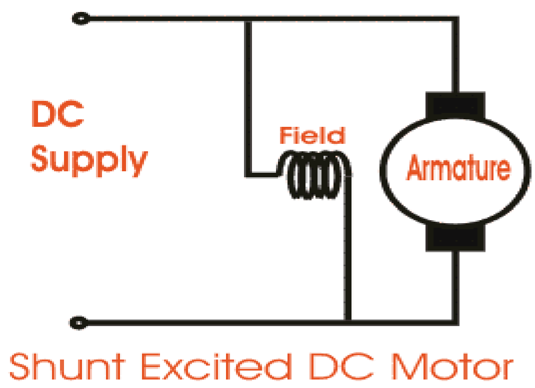


Figure.3. 16.shunt wound DC motor

In case of a **shunt wound DC motor** or more specifically shunt wound self excited DC motor, the field windings are exposed to the entire terminal voltage as they are connected in parallel to the armature winding as shown in the figure below.

To understand the characteristic of these types of DC motor, lets consider the basic voltage equation given by, $E = E_b + I_a R_a \cdots\cdots\cdots\cdots\cdots\cdots (1)$

[Where E, E_b, I_a, R_a are the supply voltage, back emf, armature current and armature resistance respectively]

$Now,\ E_b = k_a \phi \omega \cdots\cdots\cdots\cdots\cdots\cdots (2)$

[since back emf increases with flux φ and angular speed ω]

Now substituting E_b from equation (2) to equation (1) we get,

$E = k_a \phi \omega + I_a R_a$ $\therefore \omega = \dfrac{E - I_a R_a}{k_a \varphi}$----------(3)

The torque equation of a DC motor resembles, $T_g = K_a \phi I_a \cdots\cdots\cdots\cdots\cdots\cdots\cdots (4)$

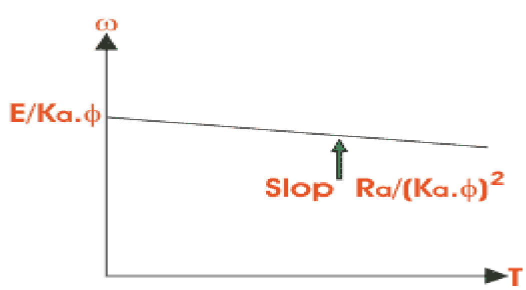


Figure.3. 17.characterstics of DC motor

The shunt wound DC motor is a constant speed motor, as the speed does not vary here with the variation of mechanical load on the output.

Series Wound DC Motor

In case of a series wound self excited DC motor or simply **series wound DC motor**, the entire armature current flows through the field winding as its connected in series to the armature winding. The series wound self excited DC motor is diagrammatically represented below for clear understanding.

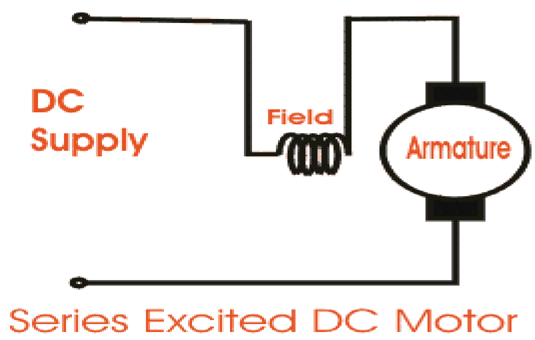


Figure.3. 18. Series exited DC motor

Now to determent the torque speed characteristic of these types of DC motor, lets get to the torque speed equation. From the circuit diagram we can see that the voltage equation gets modified to

$$E = E_b + I_a(R_a + R_s) \cdots\cdots\cdots\cdots\cdots\cdots (5)$$

Whereas back emf remains $E_b = k_a\varphi\omega$ Neglecting saturation we get, $\phi = K_1 I_f = K_1 I_a$

[since field current = armature current]

$Therefore,\ E_b = k_a K_1 I_a \omega = K_s I_a \omega \ \cdots\cdots\cdots\cdots\cdots\cdots (6)$From equation (5) and

$$\omega = \frac{E}{K_s I_a} - \frac{R_a + R_s}{K_s}$$

(6)

From this equation we obtain the torque speed characteristic as

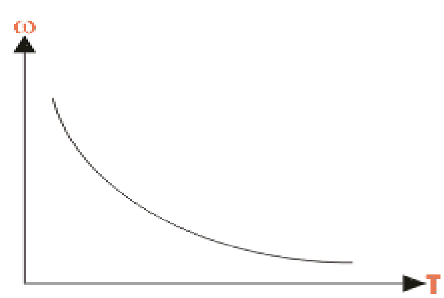


Figure.3. 19. Series exited DC motor

In a series wound DC motor, the speed varies with load. And operation wise this is its main difference from a shunt wound DC motor.

✓ **Compound Wound DC Motor**

The compound excitation characteristic in a DC motor can be obtained by combining the operational characteristic of both the shunt and series excited dc motor. The compound wound self excited DC motor or simply **compound wound DC motor** essentially contains the field winding connected both in series and in parallel to the armature winding as shown in the figure below: The excitation of compound wound DC motor can be of two types depending on the nature of compounding.

✓ **Cumulative Compound DC Motor**

When the shunt field flux assists the main field flux, produced by the main field connected in series to the armature winding then its called cumulative compound DC motor.

$\phi_{total} = \phi_{series} + \phi_{shunt}$

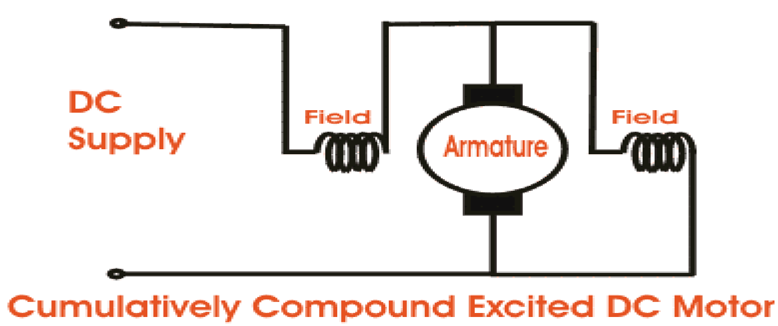


Figure.3. 20. Cumulative Compound DC Motor

✓ **Differential Compound DC Motor**

In case of a differentially compounded self excited DC motor i.e. differential compound DC motor, the arrangement of shunt and series winding is such that the field flux produced by the shunt field winding diminishes the effect of flux by the main series field winding.

$\phi_{total} = \phi_{series} - \phi_{shunt}$The net flux produced in this case is lesser than the original flux and hence does not find much of a practical application. The compounding characteristic of the self-excited DC motor is shown in the figure below.

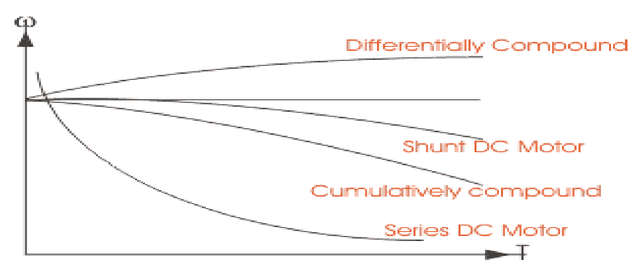


Figure.3. 21.Differential Compound DC Motor

Both the cumulative compound and differential compound DC motor can either be of short shunt or long shunt type depending on the nature of arrangement.

Short Shunt DC Motor

If the shunt field winding is only parallel to the armature winding and not the series field winding then its known as short shunt DC motor or more specifically short shunt type compound wound DC motor.

Long Shunt DC Motor

If the shunt field winding is parallel to both the armature winding and the series field winding then it's known as long shunt type compounded wound DC motor or simply long shunt DC motor. Short shunt and long shunt type motors have been shown in the diagram below.

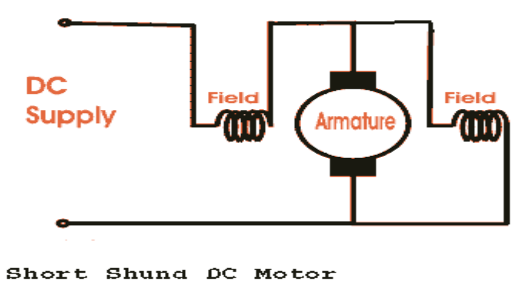


Figure.3. 22. short shunt DC motor

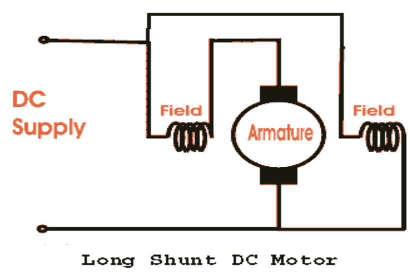


Figure.3. 23. long shunt Dc motor

1.3.2 The efficiency of DC machines

Determination of Efficiency

The efficiency of DC machine like any other machine is determined by the ratio of output power to that of the input power.

$$Efficiency\ (\eta) = \frac{output}{input} \cdots\cdots(1)$$

$$or,\ \eta = \frac{input - losses}{input} \cdots\cdots(2)$$

$$or,\ \eta = \frac{output}{output + losses} \cdots\cdots(3)$$

There are three methods of determining the efficiency of a machine.

1. Direct method
2. Indirect method
3. Regenerative method

The 1st equation is giving an idea about the direct estimation of the efficiency. In this method the machine is fully loaded and the output is directly measured. This method of measurement is only applied for the small machines. The 2nd and 3rd equations are giving an idea about the indirect estimation of the efficiency. Indirect method is helpful of determining the efficiency of shunt wound generator and compound wound generators. In this method it is required to determine to determine the losses only. So, power supply is required to supply the losses only without loading the machine. For the regenerative method of determining efficiency, it is required to have two identical machines. One machine is used as motor and drives the other and the other is used as generator and feedback the power into the supply. Two machines are mechanically coupled. Therefore the losses can be determined because the internal power drawn is only to supply losses of the two machines. Except these testes, the insulation test and the test for making the commutation satisfactory is done while building up the machine.

1.3.3 DC motor starter

Starting Methods of DC Motor

As a direct consequence of the two above mentioned facts i.e high starting current and high starting torque of DC motor, the entire motoring system can undergo a total disarray and lead towards into an engineering massacre and non-functionality. To prevent such an incidence from occurring several starting methods of DC motor has been adopted. The main principal of this being the addition of external electrical resistance R_{ext} to the armature winding, so as to increase the effective resistance to $R_a + R_{ext}$, thus limiting the armature current to the rated value. The new value of starting armature current is desirably low and is given by. $Therefore,\ I_a = \dfrac{E}{R_a + R_{ext}}$ Now as the motor continues to run and gather speed, the back emf successively develops and increases, countering the supply voltage, resulting in the decrease of the net working voltage. Thus now,

$$Therefore,\ I_a = \frac{E - E_b}{R_a + R_{ext}}$$

when the back emf produced is at its maximum. This regulation of the external electrical resistance in case of the starting of DC motor is facilitated by means of the starter.

Starters can be of several types and requires a great deal of explanation and some intricate level understanding. But on a brief over-view the main types of starters used in the industry today can be illustrated as:-

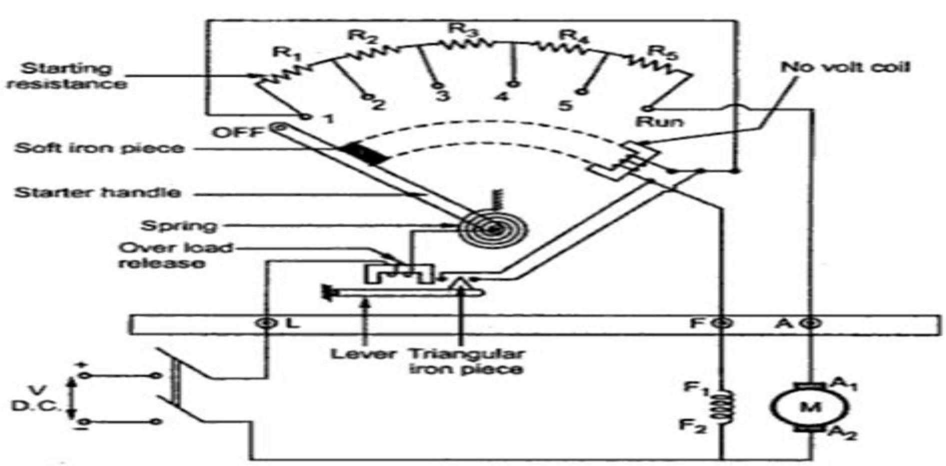


Figure.3. 24. Three point starter

1.3.4 Speed control of DC motor

Speed Regulation of DC Motor

On application of load the speed of a DC motor decreases gradually. This is not at all desirable. So the difference between no load and full load speed should be very less. The motor capable of maintaining a nearly constant speed for varying load is said to have good speed regulation i.e the difference between no load and full load speed is quite less. The speed regulation of a permanent magnet DC motor is good ranging from 10 - 15% whereas for DC shunt motor it is somewhat less than 10 %. DC series motor has poor value of regulation. In case of compound DC motor for DC cumulative compound the speed regulation is around 25 % while differential compound has its excellent value of 5 %.

Speed control means intentional change of the drive speed to a value required for performing the specific work process. Speed control is a different concept from speed regulation where there is natural change in speed due change in load on the shaft. Speed control is either done manually by the operator or by means of some automatic control device.One of the important features of DC motor is that its speed can be controlled with relative ease. We know that the emf equation of DC motor is given as,

$$E = \frac{NP\phi Z}{60A}$$

N = 60A E / PZØ N = E / kØ where, k = PZ/60A N = V - I_a R_a / kØ Therefore speed (N) of 3 types of DC motor – SERIES, SHUNT and COMPOUND can be controlled by changing the quantities on RHS of the expression. So speed can be varied by changing

1. Terminal voltage of the armature V.
2. External resistance in armature circuit R_a.
3. Flux per pole φ.

The first two cases involve change that affects armature circuit and the third one involves change in magnetic field. Therefore speed control of DC motor is classified as

1. Armature control methods
2. Field control methods.

Armature Control of DC Series Motor

Speed adjustment of DC series motor by armature control may be done by any one of the methods that follow,

1. **Armature Resistance Control Method:** This is the most common method employed. Here the controlling resistance is connected directly in series with the supply of the motor as shown in the fig.

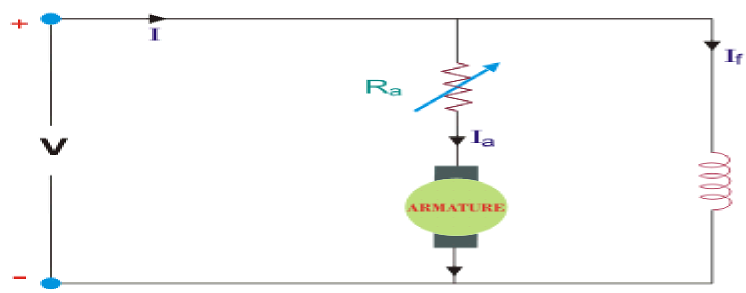


Figure.3. 25 . Armature Resistance Control Method

2. The power loss in the control resistance of DC series motor can be neglected because this control method is utilized for a large portion of time for reducing the speed under light load condition. This method of speed control is most economical for constant torque. This method of speed control is employed for DC series motor driving cranes, hoists, trains etc.
3. Shunted Armature Control: The combination of a rheostat shunting the armature and a rheostat in series with the armature is involved in this method of speed control. The voltage applied to the armature is varies by varying series rheostat R_1. The exciting current can be varied by varying the armature shunting resistance R_2. This method of speed control is not economical due to considerable power losses in speed controlling resistances. Here speed control is obtained over wide range but below normal speed.
4. Armature terminal voltage control: The speed control of DC series motor can be accomplished by supplying the power to the motor from a separate variable voltage supply. This method involves high cost so it rarely used.

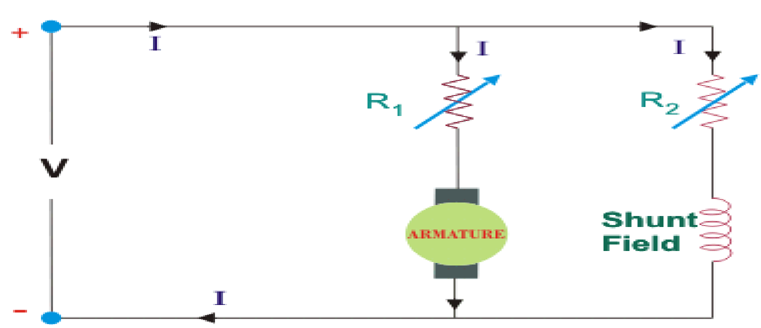


Figure.3. 26. Armature Resistance Control Method

- ✓ **Field Control of DC Series Motor**

The speed of DC motor can be controlled by this method by any one of the following ways –

1. Field Diverter Method This method uses a diverter. Here the field flux can be reduced by shunting a portion of motor current around the series field. Lesser the diverter resistance less is the field current,

less flux therefore more speed. This method gives speed above normal and the method is used in electric drives in which speed should rise sharply as soon as load is decreased.

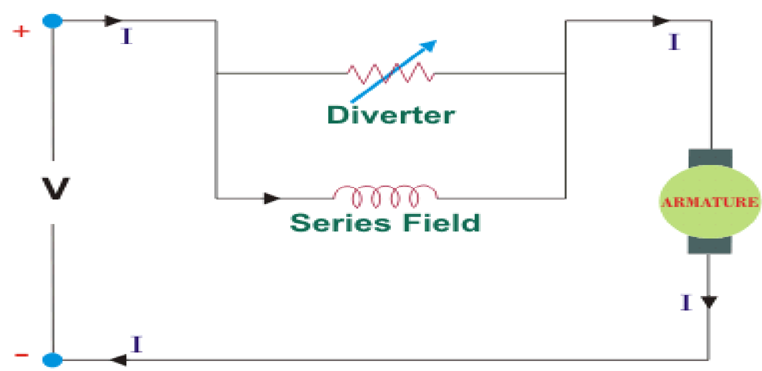


Figure.3. 27. Field Control of DC Series Motor

1. Tapped Field Control This is another method of increasing the speed by reducing the flux and it is done by lowering number of turns of field winding through which current flows. In this method a number of tapping from field winding are brought outside. This method is employed in electric traction.

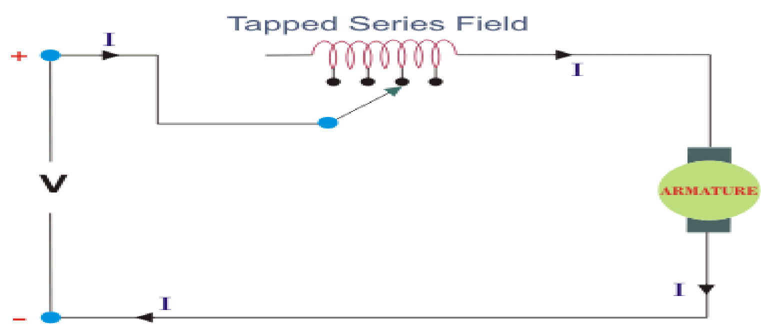


Figure.3. 28.Speed Control of DC Shunt Motor

- ✓ **Field Control of DC Shunt Motor**

By this method speed control is obtained by any one of the following means –

1. **Field Rheostat Control of DC Shunt Motor**

In this method, speed variation is accomplished by means of a variable resistance inserted in series with the shunt field. An increase in controlling resistances reduces the field current with a reduction in flux and an increase in speed. This method of speed control is independent of load on the motor.

Power wasted in controlling resistance is very less as field current is a small value. This method of speed control is also used in DC compound motor.

Limitations of this Method of Speed Control

- Creeping speeds cannot be obtained.
- Top speeds only obtained at reduced torque.
- The speed is maximum at minimum value of flux, which is governed by the demagnetizing effect of armature reaction on the field.

2. **Field Voltage Control**

This method requires a variable voltage supply for the field circuit which is separated from the main power supply to which the armature is connected. Such a variable supply can be obtained by an electronic rectifier.

Armature Control of DC Shunt Motor

Speed control by this method involves two ways. These are :

1. **Armature Resistance Control**

In this method armature circuit is provided with a variable resistance. Field is directly connected across the supply so flux is not changed due to variation of series resistance. This is applied for DC shunt motor. This method is used in printing press, cranes, hoists where speeds lower than rated is used for a short period only.

2. **Armature Voltage Control**

This method of speed control needs a variable source of voltage separated from the source supplying the field current. This method avoids disadvantages of poor speed regulation and low efficiency of armature-resistance control methods. The basic adjustable armature voltage control method of speed d control is accomplished by means of an adjustable voltage generator is called Ward Leonard System. This method involves using a motor-generator (M-G) set. This method is best suited for steel rolling mills, paper machines, elevators, mine hoists, etc. This method is known as Ward-Leonard System. Advantages

1. Very fine speed control over whole range in both directions
2. Uniform acceleration is obtained
3. Good speed regulation
4. It has regenerative braking capacity

Disadvantages

5. Costly arrangement is needed , floor space required is more
6. Low efficiency at light loads
7. Drive produced more noise.

1.2.5 Further problems on DC machines

Losses in DC Machine

- As we know "Energy neither can be created nor it can be destroyed, it can only be transferred from one form to another". In DC machine, mechanical energy is converted into the electrical energy. During this process, the total input power is not transformed into output power. Some part of input power gets wasted in various forms. The form of this loss may vary from one machine to another. These losses give in rise in temperature of machine and reduce the efficiency of the machine. In DC Machine, there are broadly four main categories of energy loss.
- **Copper Losses or Electrical Losses in DC Machine or Winding Loss**

The copper losses are the winding losses taking place during the current flowing through the winding. These losses occur due to the resistance in the winding. In DC machine, there are only two winding, armature and field winding. Thus copper losses categories in three parts; armature loss, field winding loss, and brush contact resistance loss. The copper losses are proportional to square of the current flowing through the winding.

- **Armature Copper Loss in DC Machine**

Armature copper loss = $I_a^2R_a$ Where, I_a is armature current and R_a is armature resistance. These losses are about 30% of the total full load losses.

- **Field Winding Copper Loss in DC Machine**

Field winding copper loss = $I_f^2R_f$ Where, I_f is field current and R_f is field resistance. These losses are about 25% theoretically, but practically it is constant.

- **Brush Contact Resistance Loss in DC Machine**

Brush contact loss attributes to resistance between the surface of brush and commutator. It is not a loss which could be calculated separately as it is a part of variable losses. Generally, it contributes in both the types of copper losses. So, they are factor in the calculation of above losses.

- **Core Losses or Iron Losses in DC Machine or Magnetic Losses**

As iron core of the armature is rotating in magnetic field, some losses occurs in the core which is called core losses. Normally, machines are operated with constant speed, so these losses are almost constant. These losses are categorized in two form; Hysteresis loss and Eddy current loss.

- **Hysteresis Loss in DC Machine**

Hysteresis losses occur in the armature winding due to reversal of magnetization of the core. When the core of the armature exposed to magnetic field, it undergoes one complete rotation of magnetic reversal. The portion of armature which is under S-pole, after completing half electrical revolution, the same piece will be under the N-pole, and the magnetic lines are reversed in order to overturn the magnetism within the core. The constant process of magnetic reversal in the armature, consume some amount of energy which is called hysteresis loss. The percentage of loss depends upon the quality and volume of the iron.

The Frequency of Magnetic Reversal

$$f = \frac{PN}{120}$$ Where, P = Number of poles N = Speed in rpm

Steinmetz Formula

The Steinmetz formula is for the calculation of hysteresis loss.

$$Hysteresis\ loss\ P_h = \eta B_{max}^{1.6} fV \ \ watts$$

Where, η = Steinmetz hysteresis co-efficient B_{max} = Maximum flux Density in armature winding F = Frequency of magnetic reversals V = Volume of armature in m^3.

- ✓ **Eddy Current Loss in DC Machine**

According to Faraday's law of electromagnetic induction, when an iron core rotates in the magnetic field, an emf is also induced in the core. Similarly, when armature rotates in magnetic field, small amount of emf induced in the core which allows flow of charge in the body due to conductivity of the core. This current is useless for the machine. This loss of current is called eddy current. This loss is almost constant for the DC machines. It could be minimized by selecting the laminated core.

- ✓ **Mechanical Losses in DC Machine**

The losses associated with mechanical friction of the machine are called mechanical losses. These losses occur due to friction in the moving parts of the machine like bearing, brushes etc, and windage losses occurs due to the air inside the rotating coil of the machine. These losses are usually very small about 15% of full load loss.

- ✓ **Stray Load Losses in DC Machine**

There are some more losses other than the losses which have been discussed above. These losses are called stray-load losses. These miscellaneous losses are due to the short-circuit current in the coil undergoing commutation, distortion of flux due to armature and many more losses which are difficult to find. These losses are difficult to determine. However, they are taken as 1 % of the whole load power output.

Applications of DC Motors

The main applications of the three types of direct current motors are given below.

Series Motors

The series DC motors are used where high starting torque is required, and variations in speed are possible. For example – the series motors are used in Traction system, Cranes, air compressors, Vaccum Cleaner, Sewing machine, etc.

Shunt Motors

The shunt motors are used where constant speed is required and starting conditions are not severe. The various applications of DC shunt motor are in Lathe Machines, Centrifugal Pumps, Fans, Blowers, Conveyors, Lifts, Weaving Machine, Spinning machines, etc.

Compound Motors

The compound motors are used where higher starting torque and fairly constant speed is required. The examples of usage of compound motors are in Presses, Shears, Conveyors, Elevators, Rolling Mills, Heavy Planners, etc.

The small DC machines whose ratings are in fractional kilowatt are mainly used as control device such in Techno generators for speed sensing and in Servo motors for positioning and tracking.

Applications of DC Generators

The applications of the various types of DC Generators are as follows:-

Separately Excited DC Generators

Separately excited DC Generators are used in laboratories for testing as they have a wide range of voltage output.

Used as a supply source of DC motors.

Shunt wound Generators

- DC shunt wound generators are used for lighting purposes.
- Used to charge the battery.
- Providing excitation to the alternators.
-

Series Wound Generators

- DC series wound generators are used in DC locomotives for regenerative braking for providing field excitation current.
- Used as a booster in distribution networks.
- Over compounded cumulative generators are used in lighting and heavy power supply.
- Flat compounded generators are used in offices, hotels, homes, schools, etc.
- Differentially compounded generators are mainly used for arc welding purpose.

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

- ✓ **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.

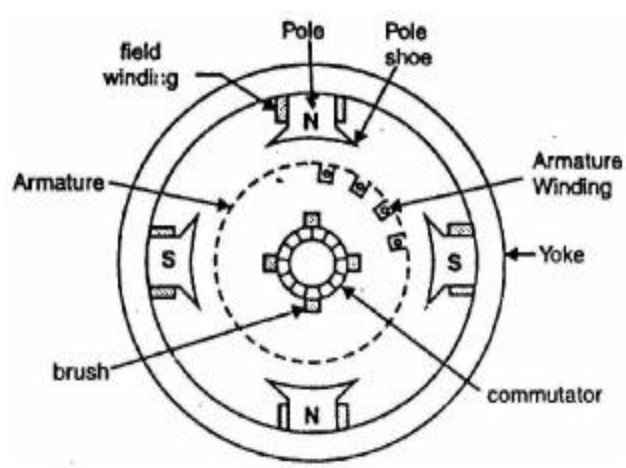


Figure3. 29.Dc. generators

- ✓ **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.

- ✓ **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.

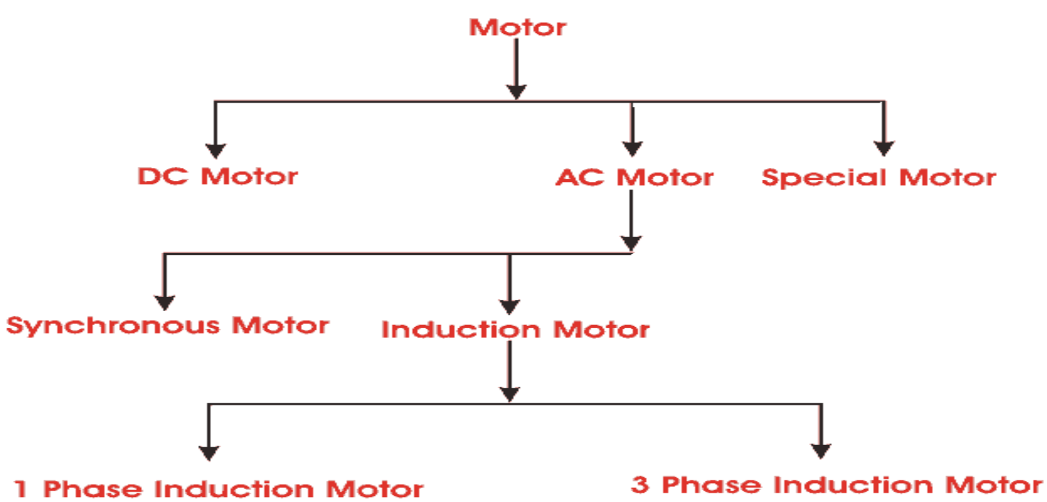
- ✓ **Brushes**

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.

1.3.5. AC machines

- ✓ Types and characteristics of single phase AC motor

The primary **classification of motor** or **types of motor** can be tabulated as shown below,



AC Single Phase Motors

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. Here, we shall focus our attention on the construction, working and characteristics of commonly used single-phase motors.

Types of Single Phase AC Motors

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

I. **Induction Type Motors**

1. Split Phase Induction Motor
   - A. Resistance Start
   - B. Capacitor Start
   - C. Capacitor Start Capacitor Run
   - D. Permanent Capacitor
2. Shaded Pole Induction Motor
3. Repulsion Start Induction Motor

II. Commutator Motors

1. AC Series Motor
2. Universal Motor
3. Repulsion Type Motors
   - A. Repulsion Start Induction Run
   - B. Repulsion Induction Motor

III. Synchronous Motors

1. Reluctance Motor
2. Hysteresis Motor

1. Split phase induction motor

- Permanent-split capacitor motor

One way to solve the single phase problem is to build a 2-phase motor, deriving 2-phase power from single phase. This requires a motor with two windings spaced apart 90^{o} electrical, fed with two phases of current displaced 90^{o} in time. This is called a permanent-split capacitor motor .

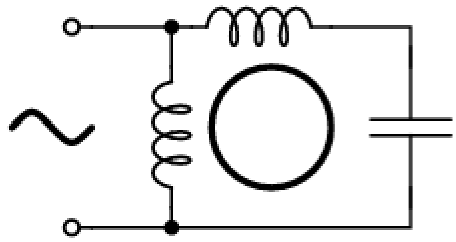


Figure. 3. 30 Permanent-split capacitor induction motor.

This type of motor suffers increased current magnitude and backward time shift as the motor comes up to speed, with torque pulsations at full speed. The solution is to keep the capacitor (impedance) small to minimize losses. The losses are less than for a shaded pole motor. This motor configuration works well up to 1/4 horsepower (200watt), though, usually applied to smaller motors. The direction of the motor is easily reversed by switching the capacitor in series with the other winding. This type of motor can be adapted for use as a servo motor, described elsewhere is this chapter.

- ✓ Capacitor-start induction motor

In Figure below a larger capacitor may be used to start a single phase induction motor via the auxiliary winding if it is switched out by a centrifugal switch once the motor is up to speed. Moreover, the auxiliary winding may be many more turns of heavier wire than used in a resistance split-phase motor to mitigate excessive temperature rise. The result is that more starting torque is available for heavy loads like air conditioning compressors. This motor configuration works so well that it is available in multi-horsepower (multi-kilowatt) sizes.

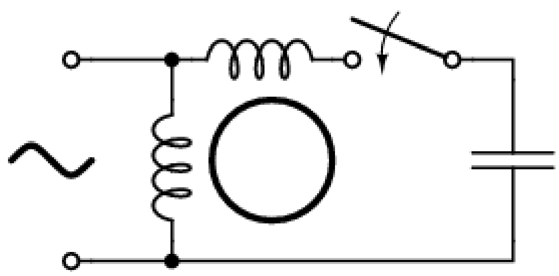


Figure.3. 31Capacitor-start induction motor.

- ✓ Capacitor-run motor induction motor

A variation of the capacitor-start motor (Figure below) is to start the motor with a relatively large capacitor for high starting torque, but leave a smaller value capacitor in place after starting to improve running characteristics while not drawing excessive current. The additional complexity of the capacitor-run motor is justified for larger size motors.

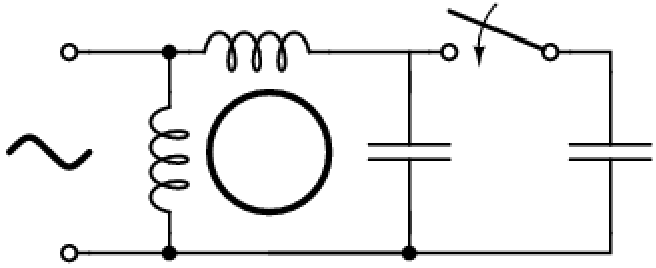


Figure.3. 32Capacitor-run motor induction motor.

A motor starting capacitor may be a double-anode non-polar electrolytic capacitor which could be two + to + (or - to -) series connected polarized electrolytic capacitors. Such AC rated electrolytic capacitors have such high losses that they can only be used for intermittent duty (1 second on, 60 seconds off) like motor starting. A capacitor for motor running must not be of electrolytic construction, but a lower loss polymer type.

- ✓ Resistance split-phase motor induction motor

If an auxiliary winding of much fewer turns of smaller wire is placed at 90^{o} electrical to the main winding, it can start a single phase induction motor. (Figure below) With lower inductance and higher resistance, the current will experience less phase shift than the main winding. About 30^{o} of phase difference may be obtained. This coil produces a moderate starting torque, which is disconnected by a centrifugal switch at 3/4 of synchronous speed. This simple (no capacitor) arrangement serves well for motors up to 1/3 horsepower (250 watts) driving easily started loads.

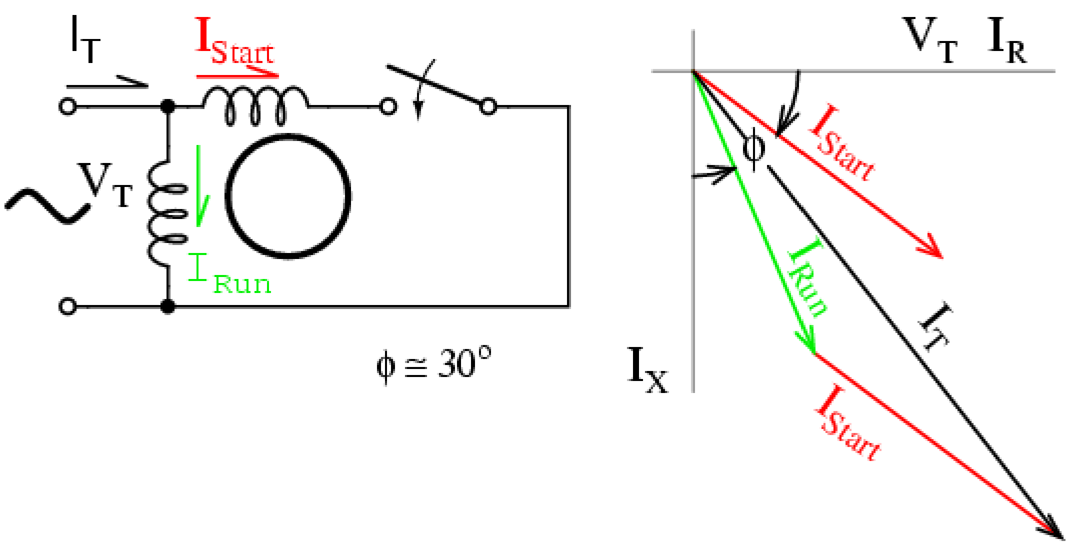


Figure.3. 33 Resistance split-phase motor induction motor.

This motor has more starting torque than a shaded pole motor (next section), but not as much as a two phase motor built from the same parts. The current density in the auxiliary winding is so high during starting that the consequent rapid temperature rise precludes frequent restarting or slow starting lo

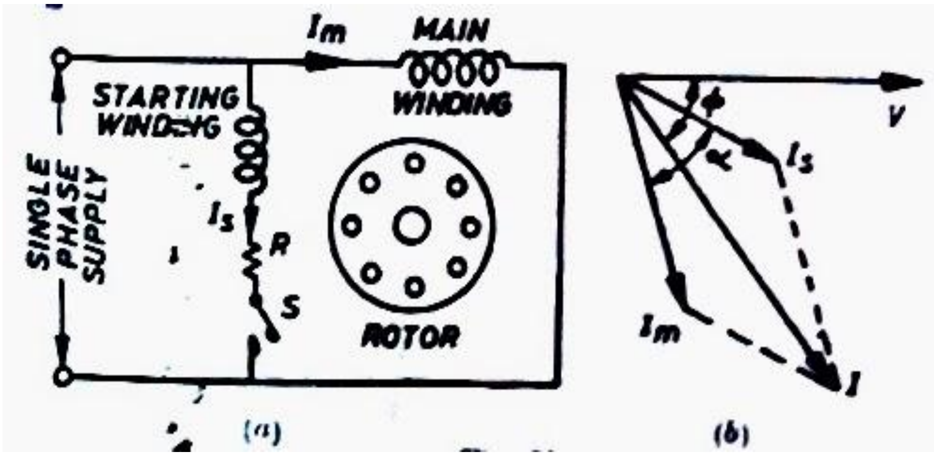


Figure.3. 34 Resistance split-phase motor induction motor.

- ✓ Split phase induction motor

In split-phase motor, the main-winding has low resistance but high reactance whereas the starting winding has a high resistance but low reactance. The resistance of the starting winding may be increased either by connecting a high resistance R in series with it or by choosing a high-resistance fine copper wire for winding purposes.

Hence, as shown in Fig (b), the current Is drawn by the starting winding lags behind the applied voltage by a small angle whereas current Im taken by the main winding lags behind V by a very large angle. Phase angle between Is and Im is made as large as possible because the starting torque of a split-phase motor is proportional to sin α.

A centrifugal switch S is connected in series with the starting winding and is located inside the motor. Its function is to automatically disconnect the starting winding from the supply when the motor has reached 70 to 80 per cent of its full load speed. The centrifugal switch is necessary because the auxiliary winding cannot support high currents for more than a few seconds without being damaged because it is made of fine wire. In case of a capacitor start motor its is necessary because most motors use a cheap electrolytic capacitor that can only carry a.c current for a short period of time.

- In the case of split-phase motors that are hermetically sealed in refrigeration units, instead of internally mounted centrifugal switch, an electromagnetic type of relay is used. As shown in Fig. 31-6, the relay coil is connected in series with main winding and the pair of contacts which are normally open, is included in the starting winding. During starting period when Im is large, relay contacts close thereby allowing Is to flow and the motor starts as usual. After motor speeds up to 75 per cent of full-load speed, Im drops to value that is low enough to cause the contacts to open.

- These motors are often used in preference to the costlier capacitor-start motors. Typical applications are : fans and blowers, centrifugal pumps and separators, washing machines, small machine tools, duplicating machines and domestic refrigerators and oil burners etc. Commonly available sizes range from 1/20 to 1/3 h.p. (40 to 250 W) with speeds ranging from 3,450 to 865 r.p.m.

As shown in Fig. 31-8, the direction of rotation of such motors can be reversed by reversing the connections of ono of the two stator windings (riot both). For this purpose, the four leads are brought outside the frame.
As seen from Fig. 31-9, the connections of the starting winding have been reversed.

The speed regulation of standard split-phase motors is nearly the same as of the 3-phase motors. Their speed varies about 2 to 5% between no load and full- load' For this reason such motors are usually regarded as practically constant-speed motors.

1.3.2. Capacitor motors

- ✓ **Capacitor-start Induction run motors**

In these motors, the necessary phase difference between I_s and I_m is produced by connecting a capacitor in series with the starting winding as shown in Fig. The capacitor is generally of the electrolytic type and is usually mounted on the outside of the motor as a separate unit.

The capacitor is designed for extremely short-duty service and is guaranteed for not more than 20 periods of operation per hour, each period not to exceed 3 seconds. When the motor reaches about 75 per cent of fulls peed, the centrifugal switch S opens and cuts out both the starting winding and the capacitor from the supply, thus leaving only the running winding across the lines.

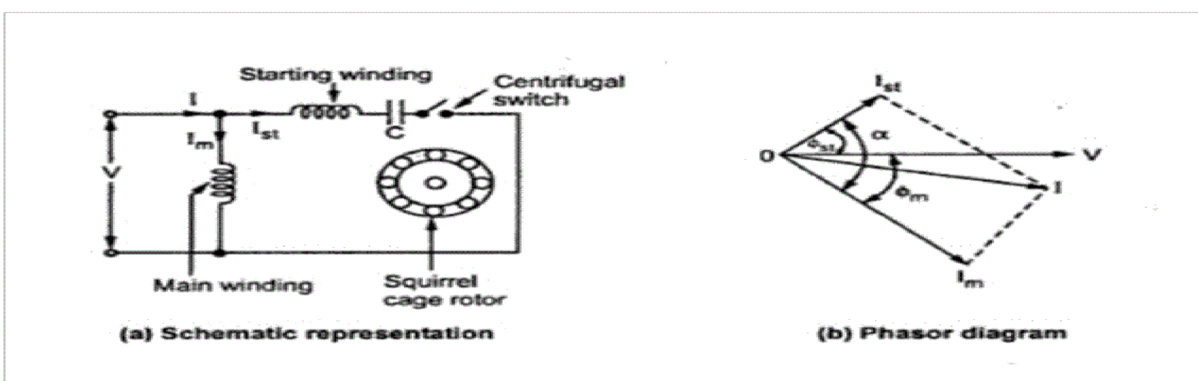


Figure.3. 35 Capacitor-start Induction run motors

As shown in Fig, current I_m drawn by the main winding lags the supply voltage V by a large angle whereas I_s leads V by a certain angle. The two currents are out of phase with each other by about 80° (for a 200-W 50-Hz motor) as compared to nearly 30 degrees for a Split phase motor. Their resultant current I is small and is almost in phase with V .

Since the torque developed by a split-phase motor is proportional to the sine of the angle between I_s and I_m, it is obvious that the increase in the angle (from 30 to 80) alone increases the starting torque to nearly twice the value developed by a standard split phase induction motor. Other improvements in motor design have made it possible to increase the starting torque to a value as high as 350 to 450 per cent.

✓ Shaded-pole motors

Shaded Pole Induction Motors - Working and Construction

Shaded pole motor is a split phase type single phase induction motor. The shaded pole motor is very popular for ratings below 0.05 HP (~ 40 W) because of its extremely simple construction.

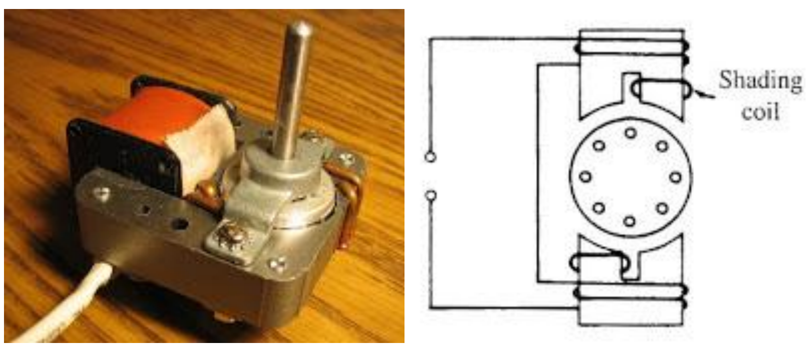


Figure.3. 36 Shaded-pole motors

It has salient poles on the stator excited by single-phase supply and a squirrel cage rotor. A portion of each pole is surrounded by a short-circuited turn of copper strip called shading coil.

A shaded pole motor and its schematic diagram are shown in the figures above.

Construction of Shaded Pole Induction Motor

A shaded pole motor may be 2 pole or 4 pole. Here we are considering a 2 pole shaded pole motor. The pictures in this article also shows a 2 pole motor.

Stator

Figure.3. 37 Stator

The stator has salient poles. Usually 2 to 4 poles are used. Each of the poles has its own exciting coil. A part of each pole is wrapped by a copper coil. The copper coil forms a closed loop across each pole. This loop is known as the ***shading coil***.

The poles are laminated. A slot is cut across the lamination of the pole. The slot is approximately one third distance from the edge of the pole. The short circuited copper coil described above is placed in this slot. So we can call this part as the shaded part and other part of the pole as unshaded part.

Selecting a 2 poled stator gives a synchronous speed of 3000 rpm while a 4 poled stator speed will be 1500rpm for 50Hz supply.

Rotor

The rotor of shaded pole induction motors is Squirrel Cage type rotor. The rotor bars are provided with a 60 degree skew. This is to obtain an optimum starting torque and for limiting the torque dip during run up.

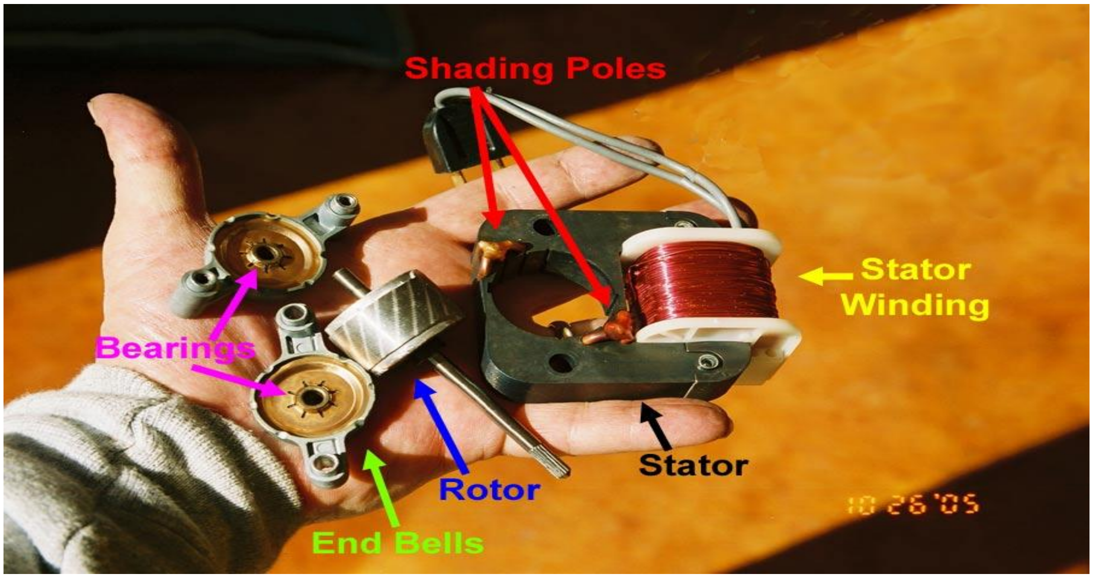


Figure.3. 38 Parts of a Shaded Pole Induction Motor

Air gap length between stator and rotor is of the order 0.25 to 0.5 mm. Too short air-gap may result in starting-torque variations due to rotor slotting.

Shaded pole induction motor has no commutator, brushes, collector rings, contactors, capacitors or moving switch parts, so it is relatively cheaper, simpler and extremely rugged in construction and reliable. Absence of centrifugal switch eliminates the possibility of motor failure due to faulty centrifugal switch mechanisms.

Working of Shaded Pole Induction Motor

The operation of the motor can be understood by referring to figure which shows one pole of the motor with a shading coil. Considering a cycle of alternating current (fig 1) applied to the stator winding we will explain the working of shaded pole motor.

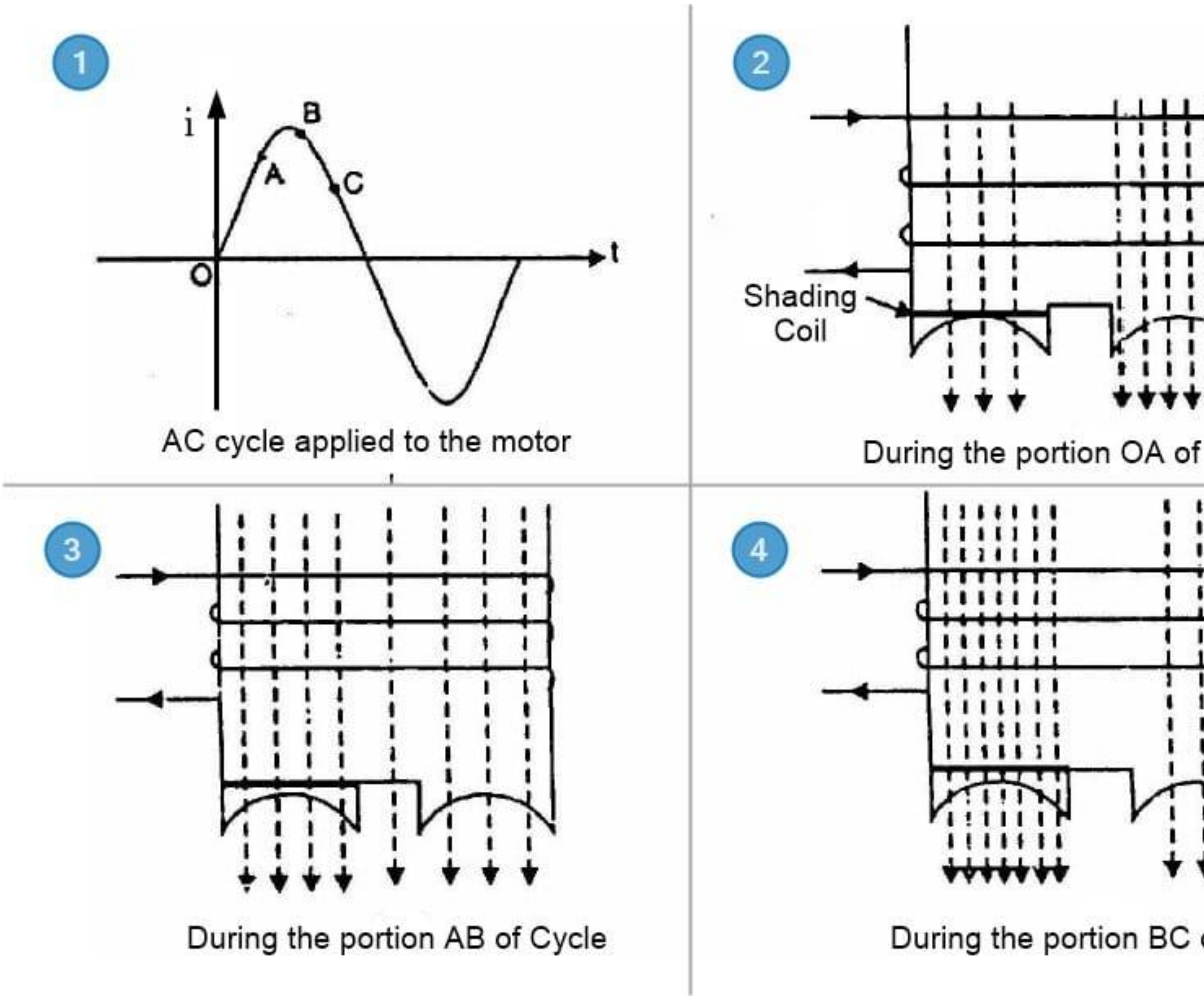


Figure.3. 39 Working of Shaded Pole Induction Motor

- *<u>During the portion OA</u>*

During the portion OA of the alternating-current cycle [Fig 1], the flux begins to increase and an e.m.f. is induced in the shading coil. The resulting current in the shading coil will be in such a direction (Lenz's law) so as to oppose the change in flux. Thus the flux in the shaded portion of the pole is weakened while that in the unshaded portion is strengthened as shown in figure 2.

- *<u>During the portion AB</u>*

During the portion AB of the alternating-current cycle, the flux has reached almost maximum value and is not changing. Consequently, the flux distribution across the pole is uniform [See Fig 3] since no current is flowing in the shading coil.

- *<u>During the portion BC</u>*

As the flux decreases (portion BC of the alternating current cycle), current is induced in the shading coil so as to oppose the decrease in current. Thus the flux in the shaded portion of the pole is strengthened while that in the unshaded portion is weakened as shown in Fig 4.

The effect of the shading coil is to cause the field flux to shift across the pole face from the unshaded to the shaded portion. This shifting flux is like a rotating weak field moving in the direction from unshaded portion to the shaded portion of the pole.

The rotor is of the squirrel-cage type and is under the influence of this moving field. Consequently, a small starting torque is developed. As soon as this torque starts to revolve the rotor, additional torque is produced by single-phase induction-motor action. The motor accelerates to a speed slightly below the synchronous speed and runs as a single-phase induction motor.

Important Characteristics of Shaded Pole Motors

Some of the important characteristics of shaded pole induction motors are given below. The details of characteristics of shaded pole motor will be discussed later.

1. The salient features of this motor are extremely simple construction and absence of centrifugal switch.
2. Since starting torque, efficiency and power factor are very low, these motors are only suitable for low power applications e.g., to drive: (a) small fans (b) toys (c) hair driers (d) desk fans etc.

Types of Single Phase Induction Motor

The single phase induction motors are made self starting by providing an additional flux by some additional means. Now depending upon these additional means the single phase induction motors are classified as:

1. Split phase induction motor.
2. Capacitors start inductor motor.
3. Capacitor start capacitor run induction motor (two value capacitor method).
4. Permanent split capacitor (PSC) motor .
5. Shaded pole induction motor.

1. Split Phase Induction Motor

In addition to the main winding or running winding, the stator of single phase induction motor carries another winding called auxiliary winding or starting winding. A centrifugal switch is connected in series with auxiliary winding . The purpose of this switch is to disconnect the auxiliary winding from the main circuit when the motor attains a speed up to 75 to 80% of the synchronous speed. We know that the running winding is inductive in nature. Our aim is to create the phase difference between the two winding and this is possible if the starting winding carries high resistance. Let us say I_{run} is the current flowing through the main or running winding, I_{start} is the current flowing in starting winding, and V_T is the supply voltage.

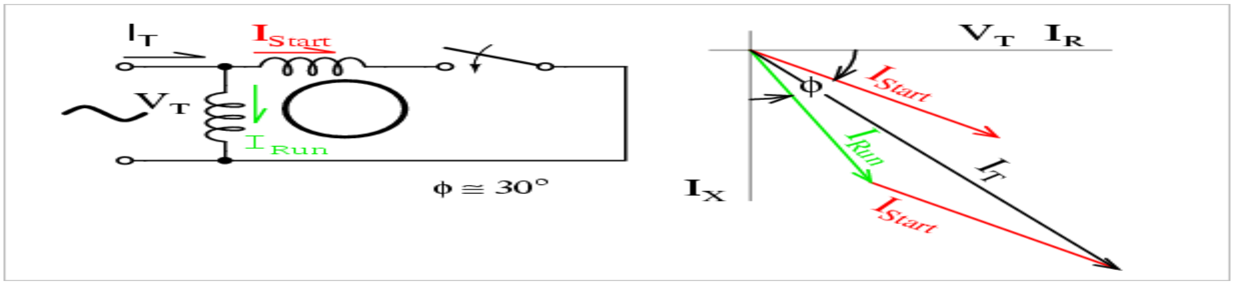


Figure.3. 40 Split Phase Induction Motor

We know that for highly resistive winding the current is almost in phase with the voltage and for highly inductive winding the current lag behind the voltage by large angle. The starting winding is highly resistive so, the current flowing in the starting winding lags behind the applied voltage by very small angle and the running winding is highly inductive in nature so, the current flowing in running winding lags behind applied voltage by large angle. The resultant of these two current is I_T. The resultant of these two current produce rotating magnetic field which rotates in one direction. In **split phase induction motor** the starting and main current get splitted from each other by some angle so this motor got its name as split phase induction motor.

Applications of Split Phase Induction Motor

Split phase induction motors have low starting current and moderate starting torque. So these motors are used in fans, blowers, centrifugal pumps, washing machine, grinder, lathes, air conditioning fans, etc. These motors are available in the size ranging from 1 / 20 to 1 / 2 KW.

Capacitor Start IM and Capacitor Start Capacitor Run IM

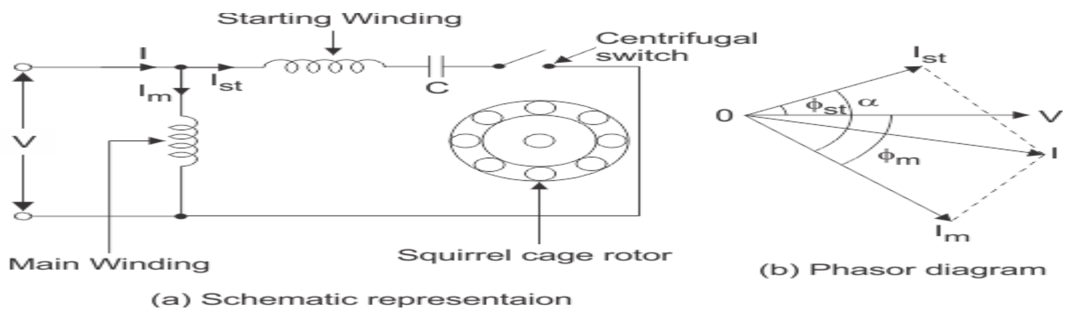


Figure.3. 41 spltphase induction motor

The working principle and construction of Capacitor start inductor motors and capacitor start capacitor run induction motors are almost the same. We already know that single phase induction motor is not self starting because the magnetic field produced is not rotating type. In order to produce rotating magnetic field there must be some phase difference. In case of split phase induction motor we use resistance for creating phase difference but here we use capacitor for this purpose. We are familiar with this fact that the current flowing through the capacitor leads the voltage. So, in capacitor start inductor motor and capacitor start capacitor run induction motor we are using two winding, the main winding and the starting winding. With starting winding we connect a capacitor so the current flowing in the capacitor i.e I_{st} leads the applied voltage by some angle, φ_{st}.

The running winding is inductive in nature so, the current flowing in running winding lags behind applied voltage by an angle, φ_m. Now there occur large phase angle differences between these two currents which produce an resultant current, I and this will produce a rotating magnetic field. Since the torque produced by these motors depends upon the phase angle difference, which is almost 90°. So, these motors produce very high starting torque. In case of capacitor start induction motor, the centrifugal switch is provided so as to disconnect the starting winding when the motor attains a speed up to 75 to 80% of the synchronous speed but in case of capacitor start capacitors run induction motor there is no centrifugal switch so, the >capacitor remains in the circuit and helps to improve the power factor and the running conditions of single phase induction motor.

- ✓ Application of Capacitor Start IM and Capacitor Start Capacitor Run IM

These motors have high starting torque hence they are used in conveyors, grinder, air conditioners, compressor, etc. They are available up to 6 KW.

- ✓ Permanent Split Capacitor (PSC) Motor

It has a cage rotor and stator. Stator has two windings – main and auxiliary winding. It has only one capacitor in series with starting winding. It has no starting switch. Advantages and Applications No centrifugal switch is needed. It has higher efficiency and pull out torque. It finds applications in fans and blowers in heaters and air conditioners. It is also used to drive office machinery.

✓ Shaded Pole Single Phase Induction Motors

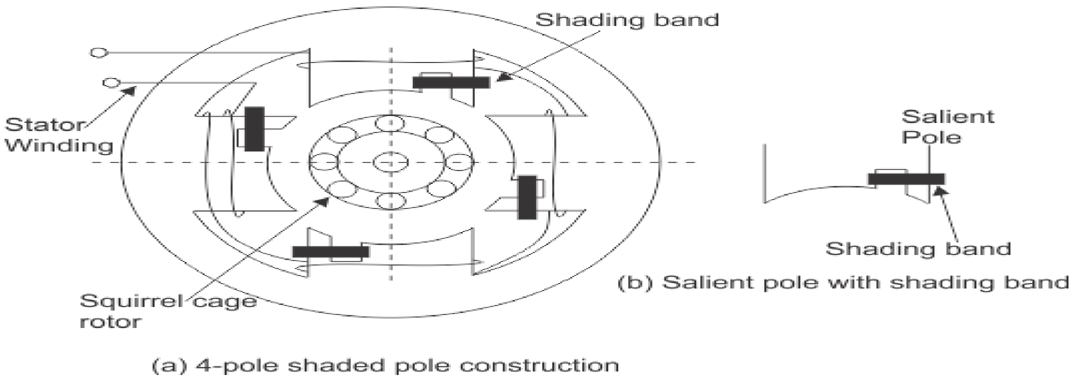


Figure.3. 42 4 pole shahded pole constraction

The stator of the **shaded pole single phase induction motor** has salient or projected poles. These poles are shaded by copper band or ring which is inductive in nature. The poles are divided into two unequal halves. The smaller portion carries the copper band and is called as shaded portion of the pole.

ACTION: When a single phase supply is given to the stator of shaded pole induction motor an alternating flux is produced. This change of flux induces emf in the shaded coil. Since this shaded portion is short circuited, the current is produced in it in such a direction to oppose the main flux. The flux in shaded pole lags behind the flux in the unshaded pole. The phase difference between these two fluxes produces resultant rotating flux.

We know that the stator winding current is alternating in nature and so is the flux produced by the stator current. In order to clearly understand the working of shaded pole induction motor consider three regions-

1. When the flux changes its value from zero to nearly maximum positive value.
2. When the flux remains almost constant at its maximum value.
3. When the flux decreases from maximum positive value to zero.

Advantages and Disadvantages of Shaded Pole Motor

The advantages of shaded pole induction motor are

1. Very economical and reliable.
2. Construction is simple and robust because there is no centrifugal switch.

The disadvantages of shaded pole induction motor are

1. Low power factor.
2. The starting torque is very poor.
3. The efficiency is very low as, the copper losses are high due to presence of copper band.

4. The speed reversal is also difficult and expensive as it requires another set of copper rings.

Applications of Shaded Pole Motor

Applications of Shaded pole motors induction motor are- Due to their low starting torques and reasonable cost these motors are mostly employed in small instruments, hair dryers, toys, record players, small fans, electric clocks etc. These motors are usually available in a range of 1/300 to 1/20 KW.

1.3.4 Reluctance motors

- ✓ Working Principle of Three Phase Induction Motor

An electrical motor is such an electromechanical device which converts electrical energy into a mechanical energy. In case of three phase AC operation, most widely used motor is **Three phase induction motor** as this type of motor does not require any starting device or we can say they are self starting induction motor. For better understanding the **principle of three phase induction motor**, the basic constructional feature of this motor must be known to us. This Motor consists of two major parts: Stator: **Stator of three phase induction motor** is made up of numbers of slots to construct a 3 phase winding circuit which is connected to 3 phase AC source. The three phase winding are arranged in such a manner in the slots that they produce a rotating magnetic field after 3Ph. AC supply is given to them. Rotor: **Rotor of three phase induction motor** consists of cylindrical laminated core with parallel slots that can carry conductors. Conductors are heavy copper or aluminum bars which fits in each slots & they are short circuited by the end rings. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed because this arrangement reduces magnetic humming noise & can avoid stalling of motor.

AC Motors

Charles Proteus Steinmetz's first job after arriving in America was to investigate problems encountered in the design of the alternating current version of the brushed commutator motor. The situation was so bad that motors could not be designed ahead of the actual construction. The success or failure of a motor design was not known until after it was actually built at great expense and tested. He formulated the laws of magnetic hysteresis in finding a solution. Hysteresis is a lagging behind of the magnetic field strength as compared to the magnetizing force. This produces a loss not present in DC magnetics. Low hysteresis alloys and breaking the alloy into thin insulated laminations made it possible to accurately design AC commutator motors before building.

AC commutator motors, like comparable DC motors, have higher starting torque and higher speed than AC induction motors. The series motor operates well above the synchronous speed of a conventional AC motor. AC commutator motors may be either single-phase or poly-phase. The single-phase AC version suffers a double line frequency torque pulsation, not present in poly-phase motor. Since a commutator motor can operate at much higher speed than an induction motor, it can output more power than a similar size induction motor. However commutator motors are not as maintenance free as induction motors, due to brush and commutator wear.

- ✓ Single phase series motor

If a DC series motor equipped with a laminated field is connected to AC, the lagging reactance of the field coil will considerably reduce the field current. While such a motor will rotate, operation is marginal. While starting, armature windings connected to commutator segments shorted by the brushes look like shorted transformer turns to the field. This results in considerable arcing and sparking at the brushes as the armature begins to turn. This is less of a problem as speed increases, which shares the arcing and sparking between commutator segments The lagging reactance and arcing brushes are only tolerable in very small uncompensated series AC motors operated at high speed. Series AC motors smaller than hand drills and kitchen mixers may be uncompensated. (Figure below)

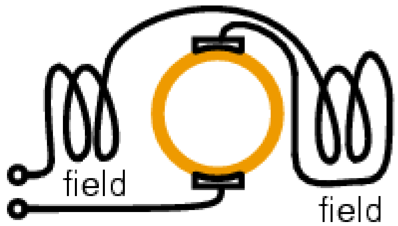


Figure.3. 43 ***Uncompensated series AC motor.***

A. Compensated series motor

The arcing and sparking is mitigated by placing a compensating winding the stator in series with the armature positioned so that its magnetomotive force (mmf) cancels out the armature AC mmf. (Figure below) A smaller motor air gap and fewer field turns reduces lagging reactance in series with the armature improving the power factor. All but very small AC commutator motors employ compensating windings. Motors as large as those employed in a kitchen mixer, or larger, use compensated stator windings.

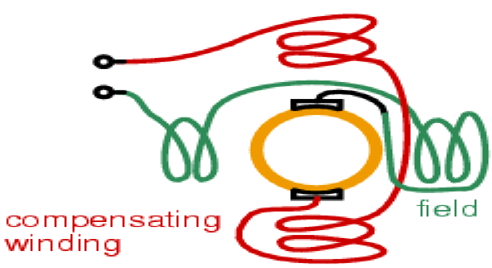


Figure.3. 44 ***Compensated series AC motor.***

B. Universal motor

It is possible to design small (under 300 watts) *universal motors* which run from either DC or AC. Very small universal motors may be uncompensated. Larger higher speed universal motors use a compensating winding. A motor will run slower on AC than DC due to the reactance encountered with AC. However, the peaks of the sine waves saturate the magnetic path reducing total flux below the DC value, increasing the speed of the "series" motor. Thus, the offsetting effects result in a nearly constant speed from DC to 60 Hz. Small line operated appliances, such as drills, vacuum cleaners, and mixers, requiring 3000 to 10,000 rpm use universal motors. Though, the development of solid state rectifiers and inexpensive permanent magnets is making the DC permanent magnet motor a viable alternative.

B. Repulsion motor

A repulsion motor (Figure below) consists of a field directly connected to the AC line voltage and a pair of shorted brushes offset by $15^{o}$to 25^{o} from the field axis. The field induces a current flow into the shorted armature whose magnetic field opposes that of the field coils. Speed can be conrolled by rotating the brushes with respect to the field axis. This motor has superior commutation below synchronous speed, inferior commutation above synchronous speed. Low starting current produces high starting torque.

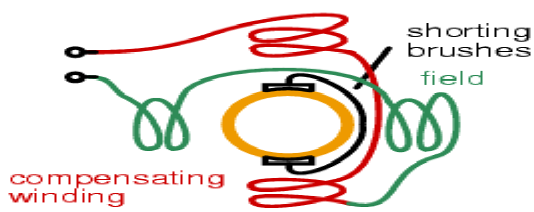


Figure.3. 45 Repulsion AC motor

- ✓ Repulsion start induction motor

When an induction motor drives a hard starting load like a compressor, the high starting torque of the repulsion motor may be put to use. The induction motor rotor windings are brought out to commutator segments for starting by a pair of shorted brushes. At near running speed, a centrifugal switch shorts out all commutator segments, giving the effect of a squirrel cage rotor . The brushes may also be lifted to prolong bush life. Starting torque is 300% to 600% of the full speed value as compared to under 200% for a pure induction motor.

- The *single phase series motor* is an attempt to build a motor like a DC commutator motor. The resulting motor is only practical in the smallest sizes.
- The addition of a compensating winding yields the *compensated series motor*, overcoming excessive commutator sparking. Most AC commutator motors are this type. At high speed this motor provides more power than a same-size induction motor, but is not maintenance free.
- It is possible to produce small appliance motors powered by either AC or DC. This is known as a *universal motor*.
- The AC line is directly connected to the stator of a *repulsion motor* with the commutator shorted by the brushes.
- Retractable shorted brushes may start a wound rotor induction motor. This is known as a *repulsion start induction motor*.

1.3.5. Reluctance motors

A **reluctance motor** is a type of electric motor that induces non-permanent magnetic poles on the ferromagnetic rotor. Rotor does not have any windings. Torque is generated through the phenomenon of magnetic reluctance.

There are various types of reluctance motor:

- Synchronous reluctance motor
- Variable reluctance motor
- Switched reluctance motor
- Variable reluctance stepping motor.

Reluctance motors can deliver very high power density at low cost, making them ideal for many applications. Disadvantages are high torque ripple (the difference between maximum and minimum torque during one revolution) when operated at low speed, and noise caused by torque ripple. Until the early twenty-first century their use was limited by the complexity of designing and controlling them. These challenges are being overcome by advances in the theory, by the use of sophisticated computer design tools, and by the use of low-cost embedded systems for control, typically based on microcontrollers using control algorithms and real-time computing to tailor drive waveforms according to rotor position and current or voltage feedback. Before the development of large-scale integrated circuits the control electronics would have been prohibitively costly.

Applications

- Analog electric meters.
- Some washing machine designs.
- Control rod drive mechanisms of nuclear reactors.
- Hard disk drive motor.

  ✓ Hysteresis Motor

a synchronous electric motor in which the torque results from hysteresis when a heavy core made of magnetic material that has a wide hysteresis loop undergoes magnetic reversal. At powers of up to 100 watts and a frequency of 400 hertz, the power characteristics of hysteresis motors are somewhat better than those of synchronous motors. Hysteresis motors are durable and reliable in operation and are noiseless and capable of running at various speeds. They are widely used in low-power electric drives and automatic control systems. Reluctance-hysteresis synchronous motors with a power of 10-15 microwatts, running at a speed not exceeding several rpm and with an efficiency of less than 1 percent, are used in automatic controls.

A type of synchronous motor in which the rotor consists of a central nonmagnetic core upon which are mounted rings of magnetically hard material. The rings form a thin cylindrical shell of material with a high degree of magnetic hysteresis. The cylindrical stator structure is identical to that of conventional induction or synchronous motors and is fitted with a three-phase or a single-phase winding, with an auxiliary winding and series capacitor for single-phase operation. *See* Induction motor, Synchronous motor

When the motor is running at synchronous speed, the hysteresis material is in a constant state of magnetization and acts as a permanent magnet. Full-speed performance is therefore exactly the same as in a permanent-magnet synchronous motor.

The outstanding special feature of a hysteresis motor is the production of nearly constant, ripple-free torque during starting. Hysteresis motors are widely used in synchronous motor applications where very smooth starting is required, such as in clocks and other timing devices and record-player turntables, where smooth starting torque reduces record slippage. Hysteresis motors are limited to small size by the difficulty of controlling rotor losses caused by imperfections in the stator mmf wave.

- ✓ Hysteresis Motor

Hysteresis motor is defined as a synchronous motor that is having cylindrical rotor and works on hysteresis losses induced in the rotor of hardened steel with high retentivity. It is a single phase motor and its rotor is made of ferromagnetic material with non magnetic support over the shaft.
It consists of

1. Stator
2. Single phase stator winding
3. Rotor
4. Shaft
5. Shading coil

- ✓ **Stator:** stator of hysteresis motor is designed in a particular manner to produce synchronous revolving field from single phase supply. Stator carries two windings,

(a) Main winding
(b) Auxiliary winding.
In another type of design of hysteresis motor the stator holds the poles of shaded type.

✓ **Rotor:** Rotor of hysteresis motor is made of magnetic material that has high hysteresis loss property. Example of this type of materials is chrome, cobalt steel or alnico or alloy.

Hysteresis loss becomes high due to large area of hysteresis loop.

Rotor does not carry any winding or teeth. The magnetic cylindrical portion of the rotor is assembled over shaft through arbor of non magnetic material like brass. Rotor is provided with high resistance to reduce eddy current loss.

Starting behavior of a **hysteresis motor** is like a single phase induction motor and running behavior is same as a synchronous motor. Step by step its behavior can be realized in the working principle that is given below. **At the Starting Condition**

- ✓ When stator is energized with single phase AC supply, rotating magnetic field is produced in stator.
- ✓ To maintain the rotating magnetic field the main and auxiliary windings must be supplied continuously at start as well as in running conditions.

At the starting, by induction phenomenon, secondary voltage is induced in the rotor by stator rotating magnetic field. Hence eddy current is generated to flow in the rotor and it develops rotor. Thus eddy current torque is developed along with the hysteresis torque in the rotor. Hysteresis torque in the rotor develops as the rotor magnetic material is with high hysteresis loss property and high retentivity.

The rotor goes under the slip frequency before going to the steady state running condition.

So it can be said that when the rotor starts to rotate with the help of these eddy current torque due to induction phenomenon, it behalves like a single phase induction motor.

At Steady State Running Condition

- When the speed of the rotor reaches near about the synchronous speed, the stator pulls the rotor into synchronism.
- At the condition of synchronism, the relative motion between stator field and rotor field vanishes. So there is no further induction phenomenon to continue. Hence no eddy current to generate in the rotor. Thus the torque due to eddy-currents vanishes.
- At the time of rotor's rotation at the synchronous speed, rotating magnetic field flux in the stator produces poles on the rotor by induction; they are named as north (N) and south (S) poles. Thus rotor behaves as a permanent magnet having rotor axis as the induced magnetic axis.
- For high residual magnetism or retentivity the rotor pole strength remains sustainable or unchanged. Again higher the retentivity, higher is the hysteresis torque and the hysteresis torque is independent of the rotor speed always. The high retentivity enables the continuous magnetic locking between stator and rotor and thus the motor rotates at synchronous speed.
- The maximum work done to establish the hysteresis losses under the magnetization cycle in the rotor is equal to the surface area inside B – H hysteresis curve.
- In lower load torque, the needed work done to rotate the rotor is equal to maximum magnetizing work of hysteresis phenomenon available already in the rotor. So induced magnetic pole axis always follows the rotating magnetic field axis of stator without any lag angle.

- But when the load torque is sufficiently high, the maximum magnetizing work in rotor by hysteresis phenomenon cannot fulfill the work done needed to rotate the rotor.
- So the induced magnetic field axis or rotor pole axis lags the rotating magnetic field axis of the stator at an angle δ_h. Hence the rotor pole axis tries to catch up the stator magnetic field axis.
- If the load torque is increased, this lagging angle will be increased up to δ_{max} before dropping below the synchronous condition.
- The rotor poles are attracted towards the moving stator poles and runs at synchronous speed.
- As there is no slip at steady state running condition, only hysteresis torque is present to keep the rotor running at synchronous speed and it behaves like a synchronous motor.

Hysteresis Power Loss, P_h in Hysteresis Motor

Hysteresis power loss in the rotor of the hysteresis motor is given by Where, f_r is the frequency of flux reversal in the rotor (Hz) B_{max} is the maximum value of flux density in the air gap (T) P_h is the heat-power loss due to hysteresis (W) k_h is the hysteresis constant

From the equation of the hysteresis torque, it is clear that hysteresis torque is independent of frequency and speed.

- ✓ Torque-Speed Characteristic of Hysteresis Motor

Torque – speed characteristics of hysteresis motor is given below. We know that constant Hysteresis Torque occurs in the hysteresis motor. This constant valued torque allows the motor to synchronize

any load it can accelerate. The normal operating range is mentioned with dark vertical line.

- ✓ Speed-Torque Characteristics

The speed – torque characteristics of a hysteresis motor is shown below. The torque is almost constant from starting to running condition. At starting condition the starting torque is the eddy current torque along with the hysteresis torque. But in the running condition net running torque

means only the hysteresis torque.

There are various types of hysteresis motor by construction.

They are

1. Cylindrical hysteresis motors**:** It has cylindrical rotor.
2. Disk hysteresis motors: It has annular ring shaped rotor.
3. Circumferential **–** field hysteresis motor: It has rotor supported by a ring of non magnetic material with zero magnetic permeability.
4. Axial – field hysteresis motor: It has rotor supported by a ring of magnetic material with infinite magnetic permeability.

The main **advantages of hysteresis motor** are given below.

- As no teeth and no winding in rotor, no mechanical vibrations take place during its operation.
- Its operation is quiet and noiseless as there is no vibration.
- It is suitable to accelerate inertia loads.
- Multispeed operation can be achieved by employing gear train.

The **disadvantages of hysteresis motor** are given below.

- **Hysteresis motor** has poor output that is one – quarter of output of an induction motor with **same** dimension.
- Low efficiency
- Low torque.
- Low power factor
- This type of motor is available in very small size only.

They are widely used in

1. Sound producing equipments,
2. Sound recording instruments,
3. High quality record players,
4. Timing devices
5. Electric clocks,
6. Tele printers.

1.3.3 Construction and working principle of three phase AC motors

✓ operating principle of a 3ph induction motor

An **electric motor** converts electrical energy into a mechanical energy which is then supplied to different types of loads. A.c. motors operate on an a.c. supply, and they are classified into synchronous, single phase and 3 phase induction, and special purpose motors. Out of all types, 3 phase induction motors are most widely used for industrial applications mainly because they do not require a starting device.

A **3 phase induction motor** derives its name from the fact that the rotor current is induced by the magnetic field, instead of electrical connections.

The operating principle of a 3 phase induction motor is based on the production of r.m.f.

✓ Production of a rotating magnetic field

The **stator** of an induction motor consists of a number of overlapping windings offset by an electrical angle of 120°. When the primary winding or stator is connected to a three phase alternating current supply, it establishes a rotating magnetic field which rotates at a synchronous speed.

The direction of rotation of the motor depends on the phase sequence of supply lines, and the order in which these lines are connected to the stator. Thus interchanging the connection of any two primary terminals to the supply will reverse the direction of rotation.

The number of poles and the frequency of the applied voltage determine the synchronous speed of rotation in the motor's stator. Motors are commonly configured to have 2, 4, 6 or 8 poles. The synchronous speed, a term given to the speed at which the field produced by primary currents will rotate, is determined by the following expression.

Synchronous speed of rotation = (120* supply frequency) / Number of poles on the stator

- ✓ Production of magnetic flux

A rotating magnetic field in the stator is the first part of operation. To produce a torque and thus rotate, the rotors must be carrying some current. In induction motors, this current comes from the rotor conductors. The revolving magnetic field produced in the stator cuts across the conductive bars of the rotor and induces an e.m.f.

The rotor windings in an induction motor are either closed through an external resistance or directly shorted. Therefore, the e.m.f induced in the rotor causes current to flow in a direction opposite to that of the revolving magnetic field in the stator, and leads to a twisting motion or torque in the rotor.

As a consequence, the rotor speed will not reach the synchronous speed of the r.m.f in the stator. If the speeds match, there would be no e.m.f. induced in the rotor, no current would be flowing, and therefore no torque would be generated. The difference between the stator (synchronous speed) and rotor speeds is called the slip.

The rotation of the magnetic field in an induction motor has the advantage that no electrical connections need to be made to the rotor.

- ✓ What results is a motor that is:

- Self-starting
- Explosion proofed (because of the absence of slip rings or commutators and brushes that may cause sparks)
- Robust in construction
- Inexpensive
- Easier to maintain

1.3.6. Types of three phase motors

Three Phase Induction Motor

The operating principle of an asynchronous motor involves creating an induced current in a conductor when the latter cuts off the lines of force in a magnetic field, hence the name "induction motor". The combined action of the induced current and the magnetic field exerts a driving force on the motor rotor.

Let's take a shading ring ABCD in a magnetic field B, rotating round an axis xy (C Fig. 1). If, for instance, we turn the magnetic field clockwise, the shading ring undergoes a variable flux and an induced electromotive force is produced which generates an induced current (Faraday's law).

According to Lenz's law, the direction of the current is such that its electromagnetic action counters the cause that generated it.

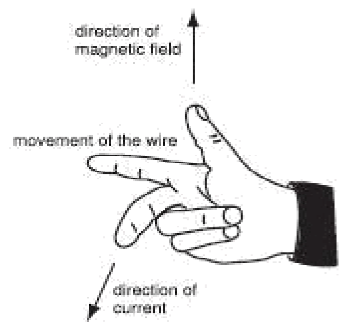


Figure.3. 46.Rule of three fingers of the right hand to find the direction of the force

An easy way to define the direction of force F for each conductor is to use the rule of three fingers of the right hand (action of the field on a current, – Fig. 2).

The thumb is set in the direction of the inductor field. The index gives the direction of the force. The middle finger is set in the direction of the induced current.

The shading ring is therefore subject to a torque which causes it to rotate in the same direction as the inductor field, called a rotating field. The shading ring rotates and the resulting electromotive torque balances the load torque.

A **three phase induction motor** runs on a three phase AC supply. **3 phase induction motors** are extensively used for various industrial applications because of their following advantages -

- They have very simple and rugged (almost unbreakable) construction
- they are very reliable and having low cost
- they have high efficiency and good power factor
- minimum maintenance required
- **3 phase induction motor is self starting** hence extra starting motor or any special starting arrangement is not required

They also have some disadvantages

- speed decreases with increase in load, just like a DC shunt motor
- if speed is to be varied, we have sacrifice some of its efficiency
- Construction of a 3 phase induction motor

Just like any other motor, a **3 phase induction motor** also consists of a stator and a rotor. Basically there are two types of 3 phase IM - 1. **Squirrel cage induction motor** and 2. **Phase Wound induction motor (slip-ring induction motor)**. Both types have similar constructed rotor, but they differ in construction of rotor. This is explained further

- ✓ Stator

  The stator of a 3 phase IM (Induction Motor) is made up with number of stampings, and these stampings are slotted to receive the stator winding. The stator is wound with a 3 phase winding which is fed from a 3 phase supply. It is wound for a defined number of poles, and the number of poles is determined from the required speed. For greater speed, lesser number of poles is used and vice versa. When stator windings are supplied with 3 phase ac supply, they produce alternating flux which revolves with synchronous speed. The synchronous speed is inversely proportional to number of poles ($Ns = 120f / P$). This revolving or rotating magnetic flux induces current in rotor windings according to Faraday's law of mutual induction.

- ✓ Rotor

  As described earlier, **rotor of a 3 phase induction motor** can be of either two types, **squirrel cage rotor** and **phase wound rotor** (or simply - wound rotor).

- ✓ Squirrel cage rotor

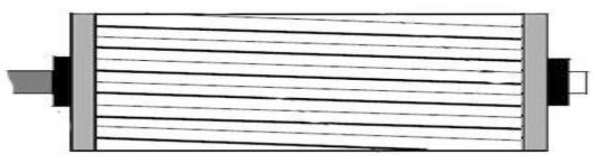


Figure.3. 47 Squirrel cage type rotor

Most of the induction motors (upto 90%) are of squirrel cage type. **Squirrel cage type rotor** has very simple and almost indestructible construction. This type of rotor consist of a cylindrical laminated core, having parallel slots on it. These parallel slots carry rotor conductors. In this type of rotor, heavy bars of copper, aluminum or alloys are used as rotor conductors instead of wires. Rotor slots are slightly skewed to achieve following advantages -

1. it reduces locking tendency of the rotor, i.e. the tendency of rotor teeth to remain under stator teeth due to magnetic attraction.
2. increases the effective transformation ratio between stator and rotor
3. increases rotor resistance due to increased length of the rotor conductor

The rotor bars are brazed or electrically welded to short circuiting end rings at both ends. Thus this rotor construction looks like a squirrel cage and hence we call it. The rotor bars are permanently short circuited, hence it is not possible to add any external resistance to armature circuit.

- ✓ Phase wound rotor

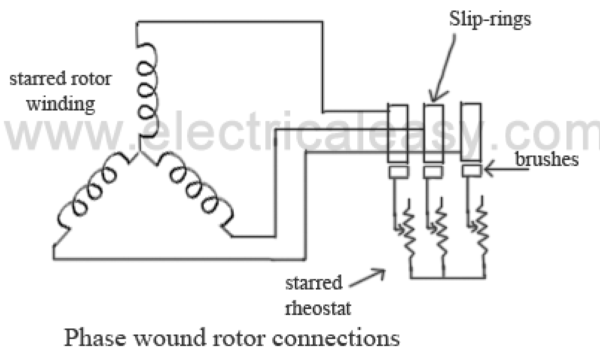


Figure.3. 48wound rotor

Phase wound rotor is wound with 3 phase, double layer, distributed winding. The number of poles of rotor are kept same to the number of poles of the stator. The rotor is always wound 3 phase even if the stator is wound two phase.

The three phase rotor winding is internally star connected. The other three terminals of the winding are taken out via three insulated sleep rings mounted on the shaft and the brushes resting on them. These three brushes are connected to an external star connected rheostat. This arrangement is done to introduce an external resistance in rotor circuit for starting purposes and for changing the speed / torque characteristics.

When motor is running at its rated speed, slip rings are automatically short circuited by means of a metal collar and brushes are lifted above the slip rings to minimize the frictional losses.

1.3.7. Asynchronous motor

Introduction

Three-phase asynchronous motors can be considered among the most reliable electrical machines: they carry out their function for many years with reduced maintenance and adapt themselves to different performances according to the requirements of both production as well as service applications.

As already said, these motors find their application in the most different industrial sectors, such as food, chemical, metallurgical industries, paper factories or water treatment and extractive systems. The applications concern the equipment with machine components running at fixed or variable speed such as for example lifting systems as lifts or good hoists, transporting systems as conveyors, ventilation and air conditioning installations, without forgetting the commonest use with pumps and compressors.

Structure of the asynchronous motor

In order to understand better how a three-phase asynchronous motor is structured, here is a brief description of the main parts which constitute the rotating machine, i.e. the parts where the electrical phenomena generating the operation originate. The first element we describe is the stator, which can be defined as the assembly of the fixed parts performing the function of supporting - at least partially - the motor, but fundamentally it constitutes the part of the magnetic circuit which includes the inductor windings housed in special slots made in correspondence with its internal surface. The stator, shown in Figure 1, is constituted by silicon steel alloy or by steel laminations, insulated one from the other. From its structure it depends how much it is affected by time-variable magnetic flows which cause losses due to hysteresis (linked to the nonlinear magnetization of the material) and to induced "eddy currents". In the slots obtained in the structure of the laminations, three primary windings are inserted (each of them constituted by more coils differently connected between them),to which the supply voltage is applied and which generate the magnetic field. The three-phase stator windings can be star- or delta-connected; this can be achieved with motors equipped with terminal box with 6 terminals, so that it is possible to feed the same motor with different three-phase network voltages. An example of double indication could be 230VΔ - 400VY or 400VΔ - 690VY, where the symbol Y or Δ refer to the connection of the stator windings; for example, taking into consideration.

1 Three-phase asynchronous motor

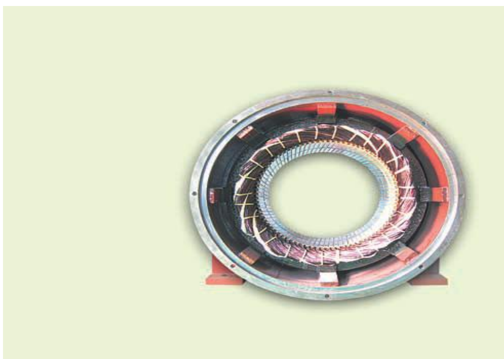


Figure.3. 49.Stator of a three-phase asynchronous motor

The second element is the rotor, which is positioned inside the stator and constitutes the induced circuit of the motor. For a squirrel-cage motor, the rotor - as represented in Figure 2 – is constituted by a system of bars (in copper or aluminum), which are coaxial to the rotation axis and directly die-cast in the slots made along the external periphery of the ferromagnetic; they are closed in short-circuit by two rings located on the extremities and constituting also a mechanical fixing. Thus, an extremely compact and robust rotor is obtained, to which also the motor shaft is fixed. The induced magnetic field, which constitutes the operation principle of the motor, makes the motor shaft rotate, thus converting the electrical energy into mechanical energy. the second case (400VΔ - 690VY), the indication means that the delta-windings of the motor can be connected to a three-phase network at 400V (phase-to-phase voltages), whereas, if for the same motor the windings are star-connected, the motor itself can be connected to a supply network at 690V (the star-windings shall be subjected to the network voltage reduced by 3 times).

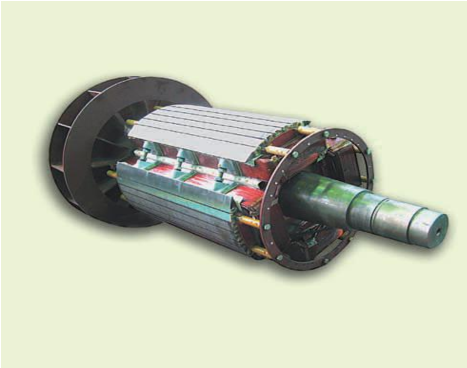


Figure.3. 50.Rotor of a three-phase asynchronous motor

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- ✓ Three-phase asynchronous motor

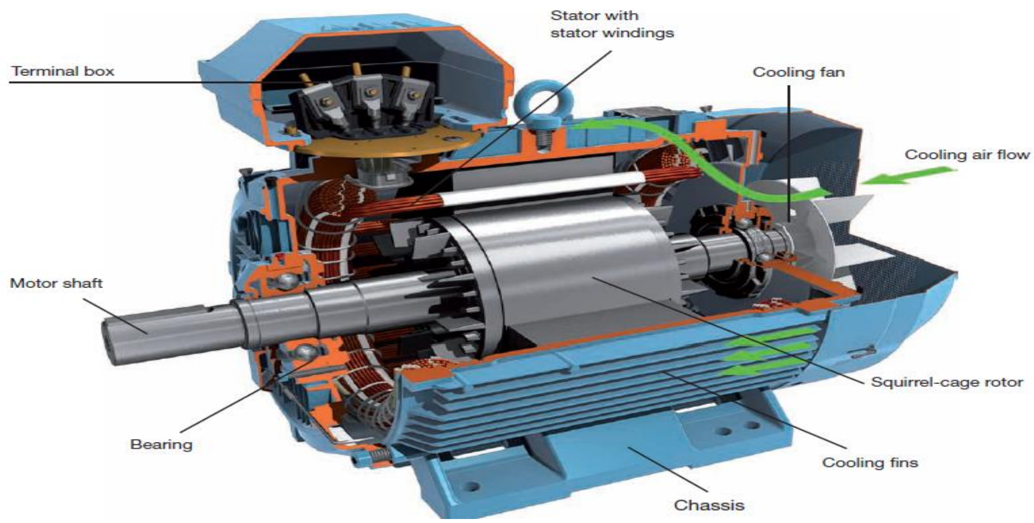
There are other mechanical components which constitute Figure 3: Overall view and cross section of an asynchronous motor the motor. The main ones are:
- the two bearings mounted on the stator and having the function to support the motor shaft;
- the chassis which, thanks to the cooling fins, dissipate the heat produced especially by the stator and which houses also the connection terminal box;
- the fan, which provides for cooling.

A general representation of the assembly together with a section plane of the asynchronous three-phase motor .

Parts of three phase motor

- ✓ Bearing
- ✓ Motor shaft
- ✓ Terminal box
- ✓ Stator with
- ✓ stator windings
- ✓ Cooling fan
- ✓ Cooling air flow
- ✓ Squirrel-cage rotor
- ✓ Cooling fins

- ✓ Chassis



Figure,3. 51 Three-phase asynchronous motor

1.4. Preparing maintenance works and schedules of electrical machines

1.4.1 Types of maintenance

A. 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.

B. 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 prdetermined 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.

C). 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

D) 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.

E) 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.

F. 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 900C,

- ✓ Preventive Maintenance for Motor Survival

An effective motor maintenance program boosts productivity, reduces unnecessary downtime, maximizes motor efficiency, and saves dollars. Unscheduled downtime in modern plant operations results in high costs and possible loss of business. That's why a well-planned preventive maintenance program is key to dependable, long-life motor operation. However, a preventative maintenance program for motors won't

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Unscheduled downtime in modern plant operations results in high costs and possible loss of business. That's why a well-planned preventive maintenance program is key to dependable, long-life motor operation. However, a preventative maintenance program for motors won't work if you don't have the proper test equipment, tools, and training for the process. When developing a plan, consider the equipment you'll need, and allow adequate time for performing inspections and maintaining accurate records.

A variety of maintenance methods may apply for each type of motor, controller, or related equipment in your facility. You should choose the best methods for your facility and then determine how best to apply those methods. For example, consider whether you should check for possible bearing trouble on a motor by feeling components for high temperature and listening for unusual sounds, or installing temperature-monitoring devices and making inspections using a stethoscope or an infrared scanner. The following presents basic guidelines to follow when implementing an effective motor maintenance program.

- ✓ Motor maintenance.

Lubricate regularly according to manufacturer's instructions. On sleeve bearings and other oil-lubricated machines, check oil reservoirs on a regular basis. For example, in poor environments, change oil at least once a month. Never over-lubricate; excess grease or oil gets into windings and deteriorates insulation. Be sure to use only the lubricant specified for the machine in question. However, check into the possibility of using modern lubricants, which have excellent life and lubricating qualities.

On essential motors, or those you frequently duty cycle, check bearings daily (or at least weekly) using a stethoscope, infrared scanner, or vibration analyzer. Check bearing surface temperature with a thermometer, electronic temperature sensing device, or stick-on temperature indicating labels. Compare the temperature of hot bearings with the temperature of normally operating bearings. Check oil rings and keep an eye on excessive endplay.

- ✓ Check air gap between the rotor and stator with feeler gages at least annually.

Make the measurements at the top, bottom, and both sides of the stator. Differences in readings obtained from year-to-year indicate bearing wear.

- ✓ Check belt tension. Belts should have about 1 in.

of play. Be sure to firmly seat sheaves with little or no play. Couplings should be tight within tolerances, and should operate without excessive noise. You should make an alignment check on all motor gensets and motor-load couplings when you suspect trouble.

- ✓ Inspect brushes and commutator of DC motors for excessive wear.

Be sure all brushes are of the proper type, hardness, and conductivity, and that they fit properly in brush holders. Check spring pressure of brush holders with a small scale. In most instances, pressure should be 2 to 2.5 lb/sq in. of brush cross-sectional area. Call manufacturers or a service company to solve recurring problems of brush chatter, excessive brush wear, sparking, streaking, or threading of commutator.

- ✓ Check mounting of motors regularly.

Inspect mounting bolts and steel base plates for possible warping and concrete base plates for cracking or spalling. Annually, perform vibration analysis tests. Excessive vibration may be hard to detect by hand; but it could be enough to shorten motor life significantly. You can accomplish field vibration analysis with portable instruments that identify vibrations and display their amplitudes and frequencies. Then, you can identify and correct the source of the problem.

- ✓ Keep the motor clean and cool.

In dirty operating environments, blow out dirt with dry compressed air (no more than 50 lb) as often as needed. In high-temperature locations where high reliability is a priority, consider the use of oversized motors. Excessive ambient temperatures will shorten motor life. Pull and disassemble important motors during summer/holiday shutdowns for a thorough inspection, testing, cleaning, check of bearings, couplings or accessories, or complete reconditioning.

- ✓ Keep accurate records.

Perform annual insulation-resistance tests and other appropriate test. You should also visually inspect important motors, as well as perform voltage and current checks. Record and compare all values each year. The trend of the readings indicates the condition of the motor and offers a guide to its reliability. Motor control maintenance. Keep control equipment clean. In dirty operating environments, blow out dirt weekly, otherwise a quarterly or semiannual cleaning should be adequate.

Check operation of contactors and relays by hand, feeling for any binding or sticking. Moving parts should operate without excessive friction. Look for loose pins, bolts, or bearings. If the control is dirty, wipe or blow it clean.

Check contacts for pitting, and signs of overheating such as discoloration of metal or charred insulation. Make sure contact pressure is adequate (see the manufacturer's specifications) and is the same on all poles. Watch for frayed flexible leads.

On essential controls, perform contact-resistance tests with a low-resistance ohmmeter on a regular basis. Proper contact resistance should be about 50 micro-ohms. Record the readings for future comparison to identify trends.

Inspect, clean, and check overload relays for proper setting. In general, maintenance requirements for these relays include checking that: the rating or trip setting takes into account ambient temperature as well as the higher inrush currents of modern, energy-efficient motors; contacts are clean and free from oxidation; the relay will operate dependably when needed.

To ensure reliable operation, test and calibrate relays every one to three years. You can use special equipment to perform these tests, such as OL-relay testers.

- ✓ Preventive maintenance of motors and controls

A well-planned preventive maintenance program is the key to dependable, long-life operation of motors and generators. In modern plant operations, unscheduled stoppage of production or long repair shutdowns are intolerable. The high cost of the resultant downtime eats deeply into profits. Although management probably realizes the value of a good preventive maintenance (PM) program, they sometimes resist

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The first step is to show that PM pays dividends. For example, illustrate the advantages gained by employing a motor maintenance program. You can do this by collecting case histories of motor breakdowns and the cost of resultant lost production. Show how budgeted PM costs are significantly less than the cost of lost production.

Second, select the best approach. Organizing and setting up the budget for a motor PM program is usually a difficult chore. The program must be effective and, at the same time, its cost must be kept to a practical minimum. Don't underestimate the importance of this initial planning. A PM program won't work if you don't have the proper test equipment and tools, along with trained men to properly apply them. Consider which equipment you'll need and the time required to perform inspections and keep accurate records. Determine which procedures are essential and whether they should be performed by facility electricians or a service organization geared to do the job.

Finally, select the best motor-maintenance techniques. For each type of motor, controller, or related equipment, a variety of maintenance methods may be selected. Choose the best methods and determine to what extent they should be applied. For example, should you check for possible bearing trouble on a motor simply by feeling components for over temperature and listening for unusual sounds, or should you install temperature monitoring devices and make inspections using a stethoscope or an infrared scanner?

- ✓ Basic guidelines to motor maintenance

Here are some valuable guidelines that you can use in your PM program.

Lubrication. Lubricate regularly according to manufacturer's instructions. On sleeve-bearing and other oil-lubricated machines, check oil reservoirs on a regular basis. In poor environments, change oil at least once a month. Never over-lubricate; excess grease or oil can get into windings and deteriorate insulation. Be sure to use only the lubricant specified for the machine in question. However, you should also check into the possibility of using modern lubricants that have excellent life and lubricating qualities.

<u>Bearing inspection</u>. Bearing failures are one of the most common causes of motor failures. Typical bearing problems include improper lubrication, misalignment of the motor with the load, replacement with the wrong type bearing, excessive loading, and harsh environments.

On essential motors or those that are heavily used or frequently duty cycled, you should check bearings daily using a stethoscope or infrared scanner (or camera, if appropriate). Check bearing surface temperature with a thermometer, electronic temperature sensing devices, or stick-on temperature indicating labels. Compare temperature of hot bearings with the temperatures of normally operating bearings. Check oil rings and watch for excessive end play.

<u>Rotor/stator inspection.</u> Check air gap between the rotor and stator with feeler gages at least annually. Measurements should be made at the top, bottom, and on both sides of the stator. Differences in readings obtained from year to year indicate bearing wear.

<u>Belt inspection.</u> Check belt tension; belts should have about 1 in. of play. Sheaves should be seated firmly with little or no play. Couplings should be tight, within tolerances, and should operate without excessive noise. An alignment check should be made on all motor-generator sets and on motor-load couplings when trouble is suspected.

<u>Brush/commutator inspection.</u> Inspect brushes and commutators of DC motors for excessive wear. Check brushes for proper type, hardness, conductivity, and fit in brush holders. Check holder spring

pressure with a small scale. In most instances, pressure should be 2 to 2 1/2 lbs per sq in. of brush cross-sectional area. Call manufacturer or service company to solve recurring problems of brush chatter, excessive brush wear, and sparking, streaking, or threading of commutator.

<u>Motor mount inspection.</u> Check mounting bolts, steel base plates for possible warping, and concrete base for cracking or spelling.

Annually, perform vibration-analysis tests. Excessive vibration may be hard to detect by hand, but it could be enough to shorten motor life significantly. It can cause bearing failure, metal fatigue of parts, or failure of windings. The cause of vibration is usually mechanical in nature, such as excessive belt tension, defective sleeve or ball bearings, misalignment, or improper balance. The most common cause is the unbalance of a rotating member (the motor rotor, rotating load, or other drive train component). Simple testing of the motor is done by uncoupling the load or removing the belts and then running the motor. Electrical problems also can cause vibration.

Field vibration analysis can be accomplished by using a portable instrument that identifies vibrations and displays their amplitudes and frequencies.

Motor temperature control. Restricted ventilation will cause a motor to operate at a higher than desired temperature. Dirt, dust, chemicals, snow, oil, grass, weeds, etc., can clog ventilation passages of an open-frame motor. Keep motor clean and cool. In poor environments, blow out dirt with dry compressed air (no more than 50 lbs) as often as needed.

Open drip proof and totally enclosed motors are protected but must not be installed where air flow will be restricted or where excessive ambient temperatures might be encountered. In high-temperature locations, consider the use of energy-efficient motors that operate cooler than standard motors. Excessive ambient temperatures will shorten motor life.

Pull and disassemble important motors during summer shutdowns for thorough inspection, testing, cleaning, checking of bearings, couplings or accessories, or complete reconditioning.

<u>Record keeping.</u> Keep accurate records. Perform annual insulation-resistance (IR) and other appropriate tests. Important motors should also receive a thorough visual inspection, as well as voltage and current checks. All values should be recorded and compared each year. The trend of the readings will indicate the condition of the motor and offer a guide to its reliability.

- ✓ Basic guidelines to control maintenance

<u>Cleanliness.</u> In poor environments, blow out dirt weekly; in normal environments, a quarterly or semi-annual cleaning should be adequate. Make sure that dust or contamination is kept off high-voltage equipment. This is important because dust may contain conducting materials that could form unwanted circuit paths, resulting in current leakage or possible grounds or short circuits.

Moving parts inspection. Moving parts should operate easily without excessive friction. Check operation of contactors and relays by hand, feeling for any binding or sticking. Look for loose pins, bolts, or bearings. If the control is dirty, it should be wiped or blown clean.

Contact inspection. Check contacts for pitting and signs of overheating, such as discoloration of metal, charred insulation, or odor. Be sure contact pressure is adequate and the same on all poles; verify with manufacturer's specification. Watch for frayed flexible leads.

Contact resistance testing. On essential controls, perform contact-resistance tests with a low-resistance ohmmeter on a regular basis. Proper contact resistance should be about 50 micro-ohms.

Record readings for future comparison. This will indicate trends in the condition of contacts.

Overloads relay inspection. Overload relays should receive a thorough inspection and cleaning. You also should check for proper setting. In general, maintenance requirements for these relays include checking that the rating or trip setting takes into account ambient temperature as well as the higher inrush currents of modern, energy-efficient motors. You also should verify that contacts are clean and free from oxidation and that the relay will operate dependably when needed. Relays should be tested and calibrated every one to three years. Special equipment such as an OL relay tester can be use.

1.5.Preparing work instruction

1.5.1. Definition of work instruction

Work instructions describe how to perform an activity, either via text or using videos, images and pictograms. For new employees, the work instruction is a concrete guide that leads them step-by-step through the task at hand. For experienced employees, it serves primarily as a reference book, as they are already familiar with the process flow. Especially on the shopfloor of assemblies, maintenance of machines or testing of end products, the work instruction is of great importance in order to be able to realize the added value of the company efficiently. But also in other areas of the company, e.g. in administration, work instructions serve as a valuable store of knowledge and the basis for smooth processes.

Why is it becoming increasingly important to phrase good work instructions?

Customer-specific products are booming, so that companies must also offer their goods in batch size 1. As a result, the variation and combination of different tasks to be performed at a workplace and by an employee are also increasing sharply. An employee has to master an almost infinite number of processes. In order not to be overtaxed and not to forget anything during the process execution, he must be able to access the work instructions simply and quickly. At the same time, due to the shortage of skilled workers, companies face the challenge of training unskilled workers very quickly or performing tasks at the highest precision possible with less workers due to the Corona-crisis.

- ✓ create a work instruction in the correct way

The work instruction should be prepared by a qualified and experienced employee who is directly involved in the respective process (e.g. from work preparation). It is also advisable to consult the quality assurance and quality management departments. In addition to technical completeness and correctness, company-wide standards regarding format and the use of images and texts should be observed. Further, the work instructions should be flexible and easy to adapt to future changes. At the end of the creation process, there is a defined release and acceptance process according to the four- or six-eyes principle. Read **here** why you should not use popular word processing applications to create digital work instructions.

- ✓ Work instruction must answer

A professional work instruction is clearly structured and comprehensible. The following questions should be answered:

1. What do I have to do?

A precise job description explains what needs to be done.

2. How do I do it?

Exact execution is described.

3. When and in what order should I do it?

The time schedule is presented step by step.

4. What do I have to do it with?

The tools for correct implementation are listed and their use is explained if necessary.

5. What do I have to consider?

Complete safety instructions are the be-all and end-all when it comes to preventing risks and avoiding dangers.

6. What is the validity of the work instructions?

The work area and user group of the work instruction are defined.

7. Who is my contact person?

In case of queries or change requests, the user has to know who is responsible for the work instruction.

- ✓ quick initial creation of work instructions
- ✓ integration of images and videos
- ✓ easy and flexible change options
- ✓ recording and integration of the user's feedback
- ✓ conformity with existing standards

In addition to the specialized creation of work instructions, it is important that the software is a component for the provision and use of the created work instructions, so that the employee has easy and quick access. This makes scrolling through paper instructions a thing of the past.

Modern work instructions are the central element for creating value and achieving corporate goals, because they store and manage valuable expertise and provide it in the right place at the right time. In addition, a work instruction must answer all questions relating to a process. Therefore, it requires a carefully considered structure. With the help of special worker assistance software, the digital creation and management of work instructions is just a cinch.

There are a few different types of reports, depending on the purpose and to whom you present your report. Here's a quick list of the common types of reports:

- ✓ **Academic report:** Tests a student's comprehension of the subject matter, such as book reports, reports on historical events, and biographies
- ✓ **Business reports:** Identifies information useful in business strategy, such as marketing reports, internal memos, SWOT analysis, and feasibility reports
- ✓ **Scientific reports:** Shares research findings, such as research papers and case studies, typically in science journals

Reports can be further divided into categories based on how they are written. For example, a report could be formal or informal, short or long, and internal or external. In business, a **vertical report** shares information with people on different levels of the hierarchy (i.e., people who work above you and below you), while a **lateral report** is for people on the author's same level, but in different departments.

There are as many types of reports as there are writing styles, but in this guide, we focus on academic reports, which tend to be formal and informational.

- ✓ structure of a report

The structure of a report depends on the type of report and the requirements of the assignment. While reports can use their own unique structure, most follow this basic template:

Executive summary: Just like an abstract in an academic paper, an executive summary is a standalone section that summarizes the findings in your report so readers know what to expect. These are mostly for official reports and less so for school reports.

Introduction: Setting up the body of the report, your introduction explains the overall topic that you're about to discuss, with your thesis statement and any need-to-know background information before you get into your own findings.

Body: The body of the report explains all your major discoveries, broken up into headings and subheadings. The body makes up the majority of the entire report; whereas the introduction and conclusion are just a few paragraphs each, the body can go on for pages.

Should be included in a report

There are no firm requirements for what's included in a report. Every school, company, laboratory, task manager, and teacher can make their own format, depending on their unique needs. In general, though, be on the lookout for these particular requirements—they tend to crop up a lot:

Title page: Official reports often use a title page to keep things organized; if a person has to read multiple reports, title pages make them easier to keep track of.

Table of contents: Just like in books, the table of contents helps readers go directly to the section they're interested in, allowing for faster browsing.

Page numbering: A common courtesy if you're writing a longer report, page numbering makes sure the pages are in order in the case of mix-ups or misprints.

Headings and subheadings: Reports are typically broken up into sections, divided by headings and subheadings, to facilitate browsing and scanning.

Citations: If you're citing information from another source, the citations guidelines tell you the recommended format.

Works cited page: A bibliography at the end of the report lists credits and the legal information for the other sources you got information from.

As always, refer to the assignment for the specific guidelines on each of these. The people who read the report should tell you which style guides or formatting they require.

1.6. Informing department/personnel on the schedule of work

1.6.1 Types of Work Schedules

Before we begin, it's important to understand that many of these work schedule types are similar to one another. Each term may describe a slight difference in days or hours worked.
Because of these similarities and differences, you can combine individual work schedule types to create your own unique plan. For example, you could combine terms to develop a fixed part-time seasonal morning shift or a full-time rotating on-call shift.
It all depends on the needs of your business and the availability of your employees.

1) Standard

A standard business schedule is one where employees work set days (usually Monday through Friday) and set hours (usually 9 a.m. to 5 p.m.). This is often referred to as a "9-to-5 work schedule."
The standard work schedule is common enough that most employees will already be used to working those regular hours. Employees also like the standard schedule because it's easy to plan for — they know they will be working from 8 a.m. to 5 p.m. Monday through Friday.
From an employer's perspective, this type of schedule is one of the easiest to fit into a 24-hour day. And since most scheduling apps are built around this work day, you don't have to force your software to fit another type of work schedule.

2) Fixed

Fixed is similar to the standard work schedule — set days and set hours — but can apply to alternative work times, such as Tuesday through Saturday from 10 a.m. to 6 p.m.
For employers, a fixed schedule allows for long-term planning and makes it easier to calculate labor costs. It also makes creating the schedule much simpler because the work hours are set from day to day, week to week, and month to month.
With a fixed schedule, you don't have to change your regular template every time you make a new work schedule.
3) Full-Time

A full-time work schedule type indicates that an employee will work 37-40 hours per week. They may work five 8-hour days, four 10-hour days, or six 6.5-hour days. The days worked don't matter, just the total amount of hours.
A full-time type of work schedule provides employers and employees with stability and predictability. But when you build a team where all employees work full time, it can be difficult and costly to find someone to work overtime.
With all full-time employees, you may encounter a dilemma in which you need a few hours of extra work but can't find any volunteers or don't want to pay overtime and the workload doesn't warrant hiring a new employee.
4) Part-Time

A part-time work schedule is one in which an employee works fewer than full-time hours. Because of the reduced hours, employees may only work two or three days per week and may not work the regular eight hours per day.

This kind of schedule works well for certain types of businesses (e.g., restaurants and coffee shops) but can create extra headaches for other types of businesses (e.g., offices and call centers).
For managers, a team composed of only part-time employees means that you'll have to deal with a larger pool of individuals when creating your schedule. That's not always a bad thing, but it can make sorting through availability a major undertaking.
5) Shift

Another of the more common work schedule types, shift work is usually reserved for businesses that operate more than 10 hours in a single day.

If a business stays open around the clock (24 hours), they will usually set up a first shift (e.g., 7 a.m. to 3 p.m.), a second shift (e.g., 3 p.m. to 11 p.m.), and a night, or third, shift (e.g., 11 p.m. to 7 a.m.).

Depending on your business, shift work means your employees will be required to work what might be considered irregular hours. Early or late shifts are ideal for those employees going to school or taking care of their family or sick relatives, but most people would rather work a more “normal” 9-to-5 schedule.

6) Freelance

A freelance schedule is relatively new amongst work schedule types. Essentially, a freelancer can work whenever they choose as long as the work gets done by a set deadline.

For an employer, incorporating a freelance type of work schedule means that you relinquish a great deal of control over when your “employee” works. However, if you find a person you can trust to get the job done correctly and on-time, a freelance schedule makes a good deal of sense.

But if your freelancer isn’t focused or you don’t want to give up control of when your employees work, this type of schedule may not be right for you.

7) Unpredictable

An unpredictable work schedule changes from week to week in an erratic manner (i.e., not following a regular pattern). Many states have laws regulating and even prohibiting unpredictable work schedule types, and unpredictable work schedules are difficult for both employees and employers.

For employees, it’s almost impossible to plan activities outside of work (e.g., doctor’s appointments, childcare, etc.) because they have no idea when they will work next.

For employers, an unpredictable type of work schedule requires recreating your template from scratch every time.

8) Seasonal

A seasonal work schedule is in effect for only a few months out of the year. Typical seasonal work schedule types include holiday (November through December) and summer (June, July, and August).

For those businesses that are only open for a few months out of the year or need to hire extra personnel during the holidays, a seasonal schedule is ideal. But hiring seasonal employees means you’ll have to fill your already-busy schedule with interviewing, on boarding, and training.

9) Flex

On a flex schedule, you require your employees to work a certain amount of core hours in a certain place . The employee can then work the remainder of their hours when and where they want.

A flex work schedule is a wonderful benefit you can offer your employees. But it can make organizing team meetings and other group functions extremely difficult because your employees are coming and going as they please outside of the core hours.

If you encounter an emergency and need to rally the troops, you may have to send out emails or texts rather than meeting face-to-face.

10) Alternate

An alternate work schedule is a broad term used to refer to any work schedule type that is different from the schedule used by others in your business. Alternate schedules are usually implemented to accommodate employee needs (e.g., pregnancy, medical requirements, family issues).
An alternate work schedule means that you have to hire a new employee to take the place of (or make up for) the hours the original employee vacated. Alternate work schedules are usually temporary but can become regular if the issues that necessitated the new hire persist.

11) Compressed

A compressed work schedule type is one in which employees work the same amount of hours in fewer days when compared to the standard “9-to-5” model. An example might be 7 a.m. to 5 p.m. Monday through Thursday.
A compressed type of work schedule provides fixed work hours, which make it easier to plan and predict labor costs. Compressed schedules also give employees a better work/life balance because they know they will have an extra day off every week to take care of personal issues.

12) Rotating

A rotating work schedule type is usually applied to shift work. It is set up so that employees work first shift one week, second shift the next week, and third shift the following week. You can also rotate shifts from day to day.
The downside of a rotating type of work schedule is that employees suffer from decreased engagement because their work hours never stabilize.
For certain professions (e.g., nursing, police officers, fire fighters), a rotating work schedule is a necessary part of the job, but for other professions, a rotating type of work schedule can cause more problems than it attempts to solve.

13) Split

A split work schedule means that an employee may work a few hours at one point during the day, have several hours off, and then work the rest of their hours during another part of the day.
For example, an employee might work 7 a.m. to 9 a.m., be off for five hours, and then finish working from 2 p.m. to 5 p.m.
A split type of work schedule can be unduly difficult for your employees. Local, state, and federal laws often dictate the minimum amount of time between two split shifts, which means your employee will have to leave your business and then return several hours later.
For some employees, this may allow them to pick up children from school or take care of personal issues. But it also means that they have to deal with two separate commutes.
That alone can put undue stress on your employee and make a split shift less than ideal.

14) On-Call

An on-call schedule is one where the employee is available to work any time, day or night, as the employer demands. On-call work schedules typically rotate between employees so that one person doesn’t have to work all the time.
Most employers use an on-call type of work schedule to plan for emergencies or to prepare for no call, no show employees.

Physicians often work one on-call day or weekend per month in case an emergency arises. For other businesses, you might set up an on-call schedule in case the regularly scheduled employee gets sick or can't make it in for some reason.

15) Overtime

An overtime schedule means working more than the standard full-time hours each week. Wages for overtime work are usually higher than that for hours fewer than 40 (e.g., time-and-a-half or double time).

You may find that overtime is necessary during big projects or during certain times of the year. But employers avoid overtime as much as possible because it gets very expensive very quickly.

In some cases, employers will ask one or two employees to work a few hours of overtime here and there in order to keep labor costs low while still covering the hours necessary to get the job done.

16) No Set Schedule

In this type of work schedule, the employee has a set of responsibilities and tasks that they must complete, but you — the employer — don't dictate the hours they must work.

So, for example, if the employee can finish their assignments in less than a full 40-hour work week, they can take the rest of the week off. Similarly, with no set schedule, they could opt to work early in the morning or late at night.

Sling makes quick work of even the most complicated work schedule type thanks to its flexibility and built-in artificial intelligence. What once took hours now takes mere minutes thanks to:

- Templates that make recurring work schedule types as close as the click of a button
- Notifications that reveal overlapping shifts and double-bookings
- Reminders that keep time-off, availability, and shift-trade requests visible while you schedule
- Budget and overtime restrictions that prevent you from exceeding the numbers your business needs to thrive
- Open shifts that let your employees pick when they want to work on a first-come, first-served basis
- Automatic messages sent right to your employees' mobile devices informing them when their shift starts, if a new shift is available, or if someone would like to trade shifts

Then, once the schedule is set, you can harness the power of Sling's other features — onboard time clock with geofencing, labor cost tracking and analysis, group communications, newsfeed, and task list — to simplify and streamline the time it takes to organize and manage your workforce.

For more free resources to help you manage your business better, organize and schedule your team, and track and calculate labor costs, visit GetSling.com today.

Self check .1.

Part I. say true or false

1.Shunt wound motor the field winding is connected in series with the armature

2.Transformer is electric machine that converts mechanical energy into electrical energy

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

4.Work instructions are also called work guides

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

Part II. 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

II. 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

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

Operation sheet. 1.1: Plan, prepare and coordinate works

- **Operation title: Maintenance of DC machine**
- **Purpose:** Assemble and disassemble of DC motor

  Instruction: Using the correct Procedures for Assemble and Disassemble of Dc Motor then identify each constructional parts.
- Steps in doing the task

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

  Step1. First unfasten (Unlock) all tighten screws by using Allen key, socket wrench or adjust able wrench.

  Step 2. Disassemble the end plate of the motor part at both sides.

  Step 3. Takeout the armature from the inside of stator.

  Step 4. Identify each part of series, shunt and compound wound Dc motors.

  Step 5. Assemble all constructional parts of DC motor, according to disassembling procedure or sequence.

  Step 6. Set (bring back) all tools and equipment from picked up store room at proper placement.

- **Quality Criteria:** the given geometrical shape is measured with 1mm accuracy
- **Precautions:** use the given ruler with straight edge.

Lap Test-1

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.

Unit Two: Diagnosis and rectify faults in Electrical System or equipment

This unit to provide you the necessary information regarding the following content coverage and topics:

- Isolate circuit or equipment to be diagnosed
- Diagnose and rectifying faults
- Identify Indicators/Symptoms of fault or failure
- Test and rectifying faults in electrical machines
- Estimate the extent of the fault include time and spare parts
- Coordinate other works associated with the problem
- maintenance record
- Respond Unforeseen events

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Isolate circuit or equipment to be diagnosed
- Diagnose and rectifying faults
- Identify Indicators/Symptoms of fault or failure
- Test and rectifying faults in electrical machines
- Estimate the extent of the fault include time and spare parts
- Coordinate other works associated with the problem
- maintenance record
- Respond Unforeseen events

2.1. Isolate circuit or equipment to be diagnosed

2.1.1. 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.

2.1.2 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.

2.1.3 Locks and danger tags

Everypersonworkingonisolatedequipmentshouldfittheirownlockand/or dangertag.Alternatively,anothermanagementapprovedsystemthatachieves 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 eventthat 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

2.1.4 **Out-of-service tags**

Out-of-servicetagsareusedtoidentifyequipmentormachinerythathasbeen taken out of service due to a fault, damage or malfunction (refer to Figure 3).

Theout-of-servicetagistobesecurelyfixedtotheoperatingcontrolpower isolatorwiththeappropriatedetailscompletedonthetag(explainingthe reason for the machine being ‘out of service’).

Theout-of-servicetagshouldnotberemoveduntiltheequipmentissafetobe 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.

2.2. Diagnosing and rectifying faults

2.2.1. Application of motor diagnostics for periodic testing

A. **application of motor diagnostics for predictive maintenance**

A field service company recently initiated a motor diagnostics program utilizing an MCA device. The results were dramatic in that the number of annual motor repairs dropped by over 33% while production remained constant. The impact was an improvement in equipment availability and planned outage overhauls (the correct machines were removed for attention). There was also a direct reduction in emergency work orders by over 66%, which directly translated into a reduction in maintenance overtime costs allowing a higher rate of completed PMs.

Notably, in this study was the fact that electric motor repairs were not eliminated. However, the severity of the remaining repairs was reduced. Following several years of success (1996 to 2001), new management made the decision to eliminate the motor diagnostic program. In less than 18 months, the conditions that existed prior to the application of the program returned. The result was a dramatic increase in maintenance costs associated with the electric motors, increased unplanned downtime, additional overtime man-hours and emergency work orders.

B. The application of motor diagnostics for condition monitoring

A Midwestern transmission manufacturing facility with an existing, and successful, infrared, ultrasonics and vibration program implemented Motor Circuit Analysis to support the program. The results were fairly dramatic within the first quarter of implementation:

- Reduction in troubleshooting time of over 50%
- Reduction of 'no problem found' reports, for rotating machines sent to repair shops, by over 80%
- Reduction of repair costs for rotating machines by over 50%, when repairs were proactive.

2.3. Identify indicator /sysmptoms of fault or failure

2.3.1. Trouble sshooting of eectric motr

The motor should be disassembled as soon as possible. If the motor has ball bearings, they should be replaced. If it has sleeve bearings, the oil wicking material will pit or rust the shaft area located in the bearing window. Replace the oil wick material immediately. If the motor has an oil reservoir and oil ring, the reservoir should be thoroughly cleaned. The windings should be first tested with an ohmmeter.

A wet winding should never be subjected to a test voltage **that could arc through the wet slot insulation**.

The baking temperature shouldn't exceed 93°C. The ohmmeter test should read infinity after baking. After the windings have been cleaned, dried, and tested, they will need a coat of air-drying varnish. When water soaks the slot insulation, the copper windings and the core become a form of battery. A small voltage can be read (with a millivoltmeter) between the winding and the frame when the slot insulation is wet.

A zero reading indicates the motor has been baked long enough.

A megohmmeter, hi-pot, or surge tester can be used when an ohmmeter test shows infinity.

- ✓ Most Common Rotor Problems

This is a review of the rotor problems found in Chapter 3, with more detailed information:

1. Open rotor bars
2. Open end rings
3. Misaligned rotor/stator iron
4. Rotor dragging on the stator
5. Rotor loose on shaft

1. Open Rotor Bars

Open rotor bars or end rings usually necessitate **replacing the motor**.

Open rotor bars are usually caused by:

- ✓ Overload burnout,
- ✓ Arcing in the slot from a shorted winding,
- ✓ Loose bar vibration,
- ✓ Thermal growth stress (from starting),
- ✓ Flaws in bar material (casting flaw), and Poor connections with end rings.

Open rotor bars cause **loss of power**. If too many rotor bars are open, a loaded motor will draw amperes high enough to open its protection device. With no load, the amperes will be very low. Slow starting and lower-than-rated RPM are a sign of broken rotor bars.

2. Open End Rings

Open end rings muse uneven torque and some power loss.

Causes of open end rings and/or cracked end rings include the following:

- ✓ Motor burned out from overload;
- ✓ Motor redesigned for a higher speed (without increased size of end ring);
- ✓ Ring material drilled away for balancing; thermal growth stress; and
- ✓ Mechanical damage.

A bubble or void in an end ring can cause an **electrical vibration**. This type of vibration can't be corrected by balancing. It can be detected by cutting the power and allowing the motor to coast. Electrically mused vibrations will always cease as soon as the power is shut off.

3. Misaligned Rotor/Stator Iron

A motor with a misaligned rotor will draw **high amperes and will lose power**. The magnetic path becomes distorted, causing the magnetizing amperes to increase. The stator windings will char and resemble an overload burnout.

Possible causes of a misaligned rotor include:

- ✓ Wrong bearing shim placement
- ✓ Bearings not installed correctly on the shaft (extended race on wrong side)
- ✓ Wrong bearing width
- ✓ Captive bearing not held as originally placed
- ✓ End bells interchanged
- ✓ Stator core shifted on its shell
- ✓ A rotor shifted on its shaft

A rotor replaced with a shorter rotor. A rotor with the same diameter but longer than the original will work, but some efficiency is lost.

4. Rotor Dragging on the Stator

If the rotor drags on the stator and the bearings aren't worn, **it's common practice to "skim" the rotor on a lathe**. The process increases the air gap, which increases the no-load amperes. The increased amperes are similar to a misaligned rotor and stator iron. The magnetic circuit is degraded, so it takes more amperes to magnetize the motor's iron.

5. Rotor Loose on Shaft

A loose rotor on a shaft makes a **rumbling or vibrating sound**. The sound will cease after the power is turned off (while the motor is coasting). If the motor has operated this way for very long, a red dust will form between the shaft and rotor iron. This dust is oxidized iron, caused by the rubbing action between the shaft and the rotor iron. The same thing happens when a pulley or bearing is loose on a shaft.

2.4. Testing and rectifying faults in electrical machines

2.4.1 Fault finding electrical circuit and rectifying

There is a generally recognized method of approaching fault-finding , which is referred to as the 5-Point Fault Finding approach... the most important factor in this method concerns attaining as much 'information' as possible regarding the 'cause & effect' of the fault, as follows....

- ✓ Gather Information – Ask as many people as possible who were there, when & how the fault occurred
- ✓ Analyze Information – decide the probable cause based on past experience & training
- ✓ Investigate – now attempt to find the fault from your analysis
- ✓ Rectify – once found, safely repair the fault
- ✓ Test – when the fault is put right & restored, test your work before re-energizing

It is understood that sometimes it is not easy to get this information, as you may be the only person on site & no one is there to explain 'what happened', but you need to go the extra half mile to find out, as it will make your job much easier...

Standard/Fundamental Faults

The following is a concise list of typical faults that are the most common causes of a circuit ceasing to operate correctly. Once you learn the symptoms of each it should become straightforward to resolve the issues you will encounter.

Loss of Supply

Why (Loose Connection – Tripped CB – Blown Fuse – Internal Fuse)

- Earth Fault
  Tripping Circuit Breaker/RCD – device will not re-engage (or will for a short while - then possibly a switched circuit contains the fault)

- Dead Short
  Phase to Neutral/Phase to Phase – has the main fuse at origin blown

Correct Protective Device in place

Type B – Type C – Type D Circuit Breakers / S'Type RCD's

- Defective Components
  Switches – Relays –Contactors, etc, not functioning correctly (brings about the decision as to replace or repair)

- Breakdown of Control Circuits
  Internal Wiring/PCB's & Electronics (How far to go for an 'electrician')

Reversed Polarity
At supply Origin – at a single outlet (Phase Neutral reversed or neutral earth reversed) or at a single fitting (Phase – Neutral) – Live Test Vs Dead Test.

- Mostly seen in Industry
  Control Circuits (Internal Fuses) – Contactors (Breakdown of Parts) – 3PH motors (Loss of Phases &/Or burnt out coils) – Single Phase Motors – (Carbon Brushes)

- Initial Faults on newly Installed work
  Reversed Polarity – Discrimination – loose connections – Protective Devices –Faulty Portable equipment – (NB: Cannot be 'ware and tear')

Some details of the symptoms, cause & effects of various faults are...

Note 1* This is why ISOLATION is much more preferable to switching off for maintenance – breaking both poles would eradicate the risk in this case, although the problem would still be in place.

- Fuses & Circuit Breakers:

Fundamental defects

Loss of Supply
Tripped CB – Blown Fuse – Internal Fuse

Potential cause: 1.Overload (time to trip or blow will determine the likelihood)
2.Earth Fault (does it re-engage)
3.Faulty device (is it operating functionally – opens and closes)
4.Dead Short – in real terms this could trip a circuit breaker for the circui that is shorted, & not the Main fuse. Correct Protective Device
Industry
Control Circuits often contain Internal Fuses – what may seem like a loss of supply could be an internal fuse having blown. Single & 3PH motors will react to a restriction in movement by struggling to reach their optimum speed. This will require more power when a restriction is in place & thus create an overload situation.

An earth fault on one phase of a 3 phase supply will disconnect that phase – while the remaining two exert to rotate the apparatus. This is often identified by overheating, buzzing or humming coming from a motor, or the machine thrusting with uneven momentum when attempting to rotate.

Newly Installed work – CB's tripping once power is energised.
Hopefully the installer will have some indication of the most likely 'trouble spot' area within the installation that any fault (earth of short circuit) may have occurred once the Main DB is commissioned and the circuits are switched on – eg: a spur off a ring that was difficult to terminate at the 2nd Fix stage, or a multi-gang switch that had a number of 2 and 3 core cables in the same enclosure, and seemed constricted when the face plate was screwed on.

The same test methods are used for new & existing circuits to locate a fault – but a 'starting-point' is the critical element for fast and effective rectification.

Test 1: Insulation Resistance.

If you are convinced that the Earth is touching the phase (or vice-versa), or the PH is touching the N prior to the load, then you would carry out an IR test at 500 Volts DC between the Ph & E or Ph & N. If a reading of 0.00Ω was seen, then the two cables being tested are in contact with each other. If the reading were less than the maximum for the instrument being used (ie a meter that would normally read >999MΩ was indicating 329MΩ) – and was dropping as the test were being carried out, part of the circuit would be seen as erroneous, and must be further investigated.

Test 2: The 'Half Test Method'

From the above, if a reading of 0.00Ω was seen, then the two cables being tested are in contact with each other at some point in that circuit. To locate the point the circuit must next be disconnected as near to its mid-point as possible. One side would read >999MΩ, and the other would continue to read 0.00Ω. The healthy side can now be disregarded and the half-test carried out again on the damaged side of the circuit. If the initial reading were less than the maximum for the instrument being used and continued dropping as the test were being carried out, part of the circuit would be seen as erroneous, and must be further investigated using the half test method. This type of reading often indicates the connection between PH to E is less substantial – possible one strand of wire or a fraction of a cable in contact with a screw.

Test3: Murray Loop Test

This is a skilled analysis using a dedicated meter which incorporates a number of variable resistors and an ammeter. It is based on the mathematical detail (part of Ohms Law) which establishes that resistance is proportional to length,

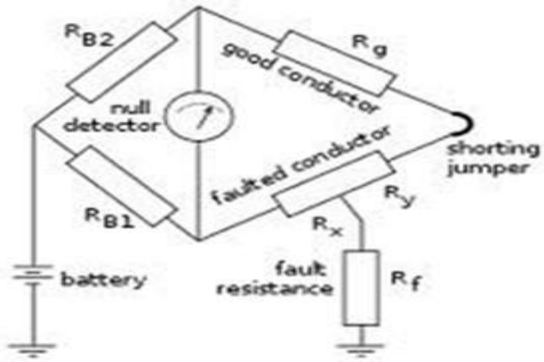

Figure3. 52Murray Loop Test

Murray Loop Test Equation: **A/B = {L+(L-X)}/X**

where A & B are variable resistor readings, and L&X cable lengths.

This is good for very long runs, often underground, to determine where a cable is broken as opposed to where a fault is in place.

Discrimination: Conventional Paradigms

A device trips; causing complete or partial loss of Power, where this could have been avoided & only have separated part of the supply from one protected point of the circuit if correct *discrimination* were in place.

2.5. Estimate Extent of the fault to accomplish the job and the spare parts needed

2. 5.1. 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 o 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

2.6.Coordinate other works associated with the problem

2.6.1 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).

A. 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.

B. 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.

C. 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.

D. 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.

E. 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.

2.6.2. 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.

2.7. Preparing maintenance record

2.7.1. 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.

2.7.1. 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.

A. **Daily maintenance**

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

B. 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.

C. Monthly 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.

D. **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 few drops of oil have been added, flush with lubricating oil and refill with clean oil.

E. 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.

2.8 Responding Unforeseen events

2.8.1 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 .2.

Part I. 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.
4. Dynamic balance of the rotor is essential to the proper operation of a motor.

Part II. fill in the space provide

1. A field service company recently initiated a ----------program utilizing an MCA device.
2. A bubble or void in an end ring can cause an ---------------------.
3. A motor with a misaligned rotor will draw ---------------------------.
4. A loose rotor on a shaft makes a -------------------------------.

Part III Matching

A.	B.
1.Gather Information	A. Ask as many people as possible who were there,
2.Analyze Information	B. past experience & training
3.Investigate	C. now attempt to find the fault from your analysis
4. Rectify	D. once found, safely repair the fault
5.Test	E. fault is put right & restored, test

Operation sheet. 2.1: Diagnosis and rectify faults in Electrical System or equipment

- **Operation title: Diagnose faults**
- **Purpose:** Assemble and disassemble of DC motor

  Instruction: Using the correct
  Procedures for Assemble and Disassemble of Dc Motor then identify each constructional parts.
- Steps in doing the task

  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 adjust able wrench and measure the resstance .
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.
7. First unfasten (Unlock) all tighten screws by using Allen key, socket wrench or adjust able wrench.
8. Disassemble the end plate of the motor part at both sides.
9. Takeout the armature from the inside of stator.
10. Identify each part of series, shunt and compound wound Dc motors.
11. Assemble all constructional parts of DC motor, according to disassembling procedure or sequence.

- **Quality Criteria:** the given defective motors maintain properly
- **Precautions:** use the given hand tools and measuring instrument is the correct one.

Lap Test.2.

- Task-1: Disassemble the motor in a correct way
- Task-2: identify each item
- Task-3: lubricate baring and clean all parts of AC or Dc motors
- Task-4: write and maintenance schedule work procedures

Unit Three: Maintain electrical system

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

- Test/clean/lubricate Electrical system or equipment parts
- Identify and replacing worn-out/malfunctioning electrical system or equipment parts
- Maintain electrical machines within the time frame
- Check and identifying reading of Electrical measuring instruments
- Check and tightening connectors, bolts, nuts and screws
- Advise or informing customers regarding the status and serviceability of the unit
- Conduct routine/visual/sensory inspection regularly with normal operation

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Testing/cleaning/lubricating Electrical system or equipment parts
- Identifying and replacing worn-out/malfunctioning electrical system or equipment parts
- Maintaining electrical machines within the time frame
- Checking and identifying reading of Electrical measuring instruments
- Checking and tightening connectors, bolts, nuts and screws
- Advising or informing customers regarding the status and serviceability of the unit
- Conducting routine/visual/sensory inspection regularly with normal operation

3.1.Test/ Clean/Lubricate electrical system or equipment parts

3.1.1 Introduction

The key to minimizing motor problems is scheduled routine inspection andmaint enance. 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 recordsspecific 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 beaccommodated within planned maintenance periods and provide expert support when returning the equipment back on line.

3.1.2 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:

- 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

Table 3.1. Frequency of Lubricating Oil Analysi

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

3.1.3 Brush and commutator maintenance

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 holde

(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 standard are damaged, new brushes should be fitted.

3.1.4. Identifying and replacing worn-out/malfunctioning electrical system or equipment parts

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.

A. 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.

B. 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.

C. 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. Maintaining electrical machines within the time frame

3.2.1. Maintenance Management of Electrical Equipment

- ✓ The cost of maintenance

Maintenance Management Of Electrical Equipment (Condition Monitoring Based)

The industries are forced to look for different types of maintenance of the electrical equipment rather than usual preventive maintenance being carried out at a fixed interval of time.

Over the past twenty years or so, the concept of maintenance has been assuming different dimensions and changing a lot, perhaps more so than any other management discipline. The changes are due to a huge increase in the number and variety of plant equipment in the industries, which must be properly maintained.

- The electrical equipment with much more complex designs require new maintenance techniques and changing views on maintenance organization and responsibilities.
- Maintenance activities are also responding to changing expectations as follows:

Rapidly growing awareness of the extent to which electrical equipment failure affects safety of plant and personnel and the environment.

- Growing awareness of the connection between maintenance and product quality.
- Increasing pressure to achieve high plant availability remaining cost-effective.

The changes are testing attitudes and skills in all branches of industry to the limit. Maintenance people are required to adopt completely new ways of thinking and acting, as the plant engineers and as the plant managers. At the same time, the limitations of maintenance systems are becoming increasingly apparent, no matter how much they are computerized.

In the face of this avalanche of change, the industries are looking for a new approach to the maintenance to avoid the false starts and dead ends which always accompany major upheavals.

Instead they seek a strategic framework which synthesizes the new developments into a coherent pattern, so that they can evaluate them sensibly and apply those likely to be of most value to them and their companies.

Effort is made in this paper to discuss some aspects of new approach.

- Failures of electrical equipment

An example of electrical equipment failure (photo credit: bralpowerassociate.blogspot.com)

Failure of any electrical equipment or rather any equipment should be taken up seriously. Detailed analysis of each failure should be carried out, which will help in significant reduction of repeated failures of same nature.

It is true that in spite of carrying out regular maintenance, failure of the equipment cannot be totally eliminated. Failures of different types of electrical equipment are reported by all the industries and some of the failures are quite serious resulting in substantial production losses besides causing consequential damage to the adjoining equipment as well.

For example, when the equipment like surge arrestors operating at extra high voltage fail, they explode like a bomb many a times resulting in scattering of solid porcelain pieces to a larger distance causing damage to the adjoining equipment. Similar situation is also observed during incident of fire in electrical switchboards due to heavy short circuit.

Unless regular equipment maintenance is carried out adopting any of the maintenance systems discussed in succeeding points, unscheduled failure of the equipment would go on resulting into large scale production losses in the industries on one hand and would increase the cost of maintenance on the other hand, as the cost of breakdown maintenance is normally more than that of other types of maintenance.

- Breakdown Maintenance Management (BMM)

The heading itself implies simple and straightforward logic – “When a machine breaks down, fix it”. This is a reactive maintenance management technique that waits for machine or equipment failure before any maintenance action is taken; however, it is actually a “no-maintenance” approach of the management.

No expenditure is made on maintenance until a machine or system fails to operate.

Condition monitoring based maintenance management of electrical equipment (on photo: Performing the manufacturer’s recommended maintenance and testing of a circuit breaker will extend the equipment’s useful life; photo credit: plantservices.com)

Few plants adopt a true run-to-failure management philosophy, as in almost all instances, the industries carry out basic preventive maintenance tasks such as lubrication, monitoring of operating parameters and other machine adjustments.

In this type of maintenance, however, the electrical machines and other plant equipment are neither rebuilt, nor are any major repairs made until the machine fails to operate.

- High spare parts inventory cost or high value due to replacement of machine

In absence of anticipated periodic maintenance requirements, the industry that adopting BMM must be able to react immediately to all possible failures within the plant.

This reactive method of management forces the maintenance department to maintain large spare parts inventories that may include spare machines or at least all major components for all the critical equipment in the plant. The alternative is to rely on the equipment vendors that can provide immediate delivery of required spare parts to repair the equipment.

BMM is the most expensive method of maintenance management. The major costs associated with this type of maintenance management are as follows.

High overtime labor cost Regular maintenance could potentially avoid fatal failure and burning of transformers

The equipment may breakdown at any damned hour of day or night and hence it may be necessary to retain additional manpower to carry out the maintenance and repairing within least possible time to bring the equipment back into service to reduce the production losses.

The manpower retained beyond normal duty hours would be paid substantial cost towards overtime.

- High equipment downtime and high cost of maintenance…

This reactive method of maintenance results into rather high equipment downtime in most of the incidents of breakdown.

Many times, all the spare parts required to set right the breakdown are not available and the vendor is approached to purchase the spares. Even if immediate delivery of required spares is affected, substantial time would always be lost before the equipment is repaired and put back into service.

Moreover, the vendor would charge premiums for expedited delivery, which would substantially increase the costs of spare parts besides higher downtime required to correct machine failures. This happens due to the fact that it is not feasible to maintain all the spare parts for all the machines installed in the plant.

Loss of profit due to partial or total stoppage of production

3.4. Checking and identifying reading of Electrical measuring

3.4.1. 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.

✓ 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.

Types of error in measurement system

Generally errors classified in to 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. 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

- ✓ Instrumental Errors

(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.

(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.

- ✓ 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:

- ✓ 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'.

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.

3.5. Checking and tightening connectors, bolts, nuts and screws

- ✓ Check Connection Bolts for Tightness

There are a number of ways to check bolt tightness.

There is the “turn-of-nut” method. There are direct tension indicators, single-use mechanical load cells which show when the required tension in a fastener has been reached.

And then there is calibrated wrench pre-tensioning, one of the simplest methods to check bolts for tightness. Here are the steps you’ll need to take when using this method.

A. Make Sure You've Maintained Your Torque Wrench's Calibration Certificate

Be sure the calibration certificate on your torque wrench is up to date, and keep that information logged to know when it expires. If you're working with a subcontractor, have them submit the calibration certificate for their torque tool.

B. Use An Impact Machine

Make sure you've tightened the bolts to snug-tight condition using an impact machine before checking the bolts with torque. Snug-tight refers to the condition where tightness is achieved with an impact wrench or by hand with a worker using an ordinary wrench.

C. Establish The Bolts' Torque Value

There are standards that designate a bolt's torque value – American Standard, British Standard, etc. Before checking the bolts with a torque wrench, it's important to first identify the torque requirements set by those standards.

D. Inspect The Tightened Bolts

Once you've tightened the bolts, check them using a calibrated torque wrench. When you hear a click sound from the wrench, you know you've reached the proper tightening torque.

If you're not sure whether your torque tools are properly calibrated, Maxpro can help. We have more than two decades of experience in solving difficult-yet-vital bolting applications for our clients.

Our laboratory is accredited in accordance with ISO/IEC 17025 standards for testing and calibration, and can handle calibration for hydraulic, electronic, pneumatic, battery and adjustable clicker torque wrenches, as well as calibrations for pressure gauges and torque transducers.

We make sure our own equipment is calibrated each year annually, according to the requirements of the National Institute of Standards and Technology.

You can rely on us to calibrate your torque tools so you can be sure the bolts you tighten are tightened the right way.

3.6. Advise or inform customers regard the status and serviceability of the unit

3.6.1 Types of customer requirements

Customers' requirements vary based on the products or services sold by a company. Companies can combine various requirements to ensure that they meet as many of the customers' needs or desires as possible. Here is a list of 20 examples of customer requirements:

- Price

The price of a product or service can affect customers' purchasing decisions, as each customer has unique budget allowances or constraints. They may compare prices between competitors to determine which offers the best deal or decide whether they are willing to pay for quality versus convenience. Companies must understand their customers to set the right price or discounts. However, these companies must also price their product or services high enough to ensure they make money.

For example, a haircare company might offer a bundle of three products for a discount. While the customer saves money because the bundle costs less than buying products separately, the company increases its revenue because the value of their purchase ends up being larger.

- Quality

The quality of a product or the materials used to manufacture it can impact purchasing decisions. The definition of quality can vary but may refer to its durability. A customer may consider a high-quality product to be one that lasts a significant amount of time, rather than one that breaks easily.

Quality can also depend on the customer's preferences. For example, they may prefer buying organic foods because they believe those foods have benefits that create a higher quality product. Similarly, a customer may want to purchase a sweater made out of a natural fiber such as cashmere rather than a synthetic material like polyester. Both options serve the same function, but the customer has a particular opinion on which materials provide more quality.

- Functionality

Every product or service has a purpose, which is its function. Often, customers require products and services that solve specific problems or meet specific goals or desires. For example, a customer may want to purchase a couch that they not only can sit on but can also convert into a bed for sleeping. Functional requirements are an essential component of software development—these requirements define what the system does. If a company creates an app, they want to ensure that it accomplishes the tasks desired by customers. For example, the user can click a button to start watching a video.

- Reliability

When customers purchase something, they want the ability to rely on it to perform its intended function. Along with reliability, customers seek durability. They expect that the product or service will last a reasonable lifespan or throughout continued use. Companies looking to provide reliability often need to test their products and services to ensure they can withstand potential challenges. For example, when a customer purchases a car, they expect they can drive it often and in all types of weather. Therefore, car manufacturers perform tests to ensure their models can handle varying temperatures and road conditions.

- Performance

Customers not only require that a product or service performs its intended purpose but also that it does it well. The definition of good performance varies, but examples may include its speed or accuracy when conducting tasks. Customers also purchase products specifically to improve the performance of another product. For example, a person who plays video games on their computer can buy a new graphics card to enable higher video quality.

- Sustainability

Some customers seek products that do not have negative environmental impacts. In response, companies launch products that use less energy to manufacture or recycled materials. Or they may sell products that promote sustainability. For example, car manufacturers sell hybrid or electric models that can help reduce pollution. Another company might notice customers' call for sustainability and begin selling glass straws, which provides a reusable alternative to plastic straws.

- Transparency

Customers require transparency, which means they want to know what to expect when purchasing a product or service. To enable transparency, companies must avoid hiding information, such as fees or ingredients, when promoting their offerings. One way to promote transparency is through direct communication, such as companies that use social media to inform customers about any service outages. Enabling customers to publish online product reviews is another form of transparency. Establishing transparency can be an advantage for companies because it creates trust, which can lead to other benefits such as customer loyalty.

- Convenience

Customers seek products and services that can save them time and effort. Companies can meet these requirements by understanding how customers use their offerings and determine ways to make them even easier to use. Some, for example, provide convenience by offering same-day delivery. By giving customers the ability to make a purchase online and have it delivered to their home, it saves them the time and effort of having to go to the store, find the item and transport it home.

- Efficiency

Somewhat similar to convenience, customers seek products or services that can help streamline everyday processes. For example, the checkout line at a store can become a time-consuming aspect of shopping. Some stores implement self-service stations, allowing customers to bypass the traditional lines and quickly pay for their items. Another option is the use of apps that let customers pay directly from their phones. Similarly, this can speed up the payment process because customers only need to pull out their phones rather than go into their wallet and find cash or a credit card.

- Risk reduction

When making purchases, some customers consider risk—for example, they want to ensure that they will not lose money. To ease such concerns, many companies offer and promote return or guarantee policies. These policies may help attract customers and make them feel more comfortable making a purchase. For example, a shoe company might provide customers a 30-day window to try their purchase. If the customer determines they do not like the shoes, they can return the product and receive their money back.

- Safety

Safety can be an important consideration for customers, as they want to ensure the product does not cause harm to them or those around them. Companies can promote products by confirming they meet relevant safety regulations or standards. For example, a person might buy a particular car based on how well it performs in crash tests. Or a parent purchasing a toy for their young child looks at features to assess whether their children can play with it safely—for example, they want a toy that does not have sharp edges or small pieces that pose a choking hazard.

- Compatibility

When customers require compatibility, they want the product or service to work or integrate with another one. Often, they want to ensure compatibility with something that they already have access to or own. Companies often include compatibility details to help customers make purchasing decisions. For example, a company that sells memory cards provides a chart or list that tells customers which of its memory cards are compatible with specific models of digital cameras.

- Options

Every customer is unique, so they require options when making purchases. Multiple options allow companies to meet the needs of various customers rather than one specific type. For example, an apparel company offers a t-shirt style in a variety of colors and patterns for customers to choose from. Streaming services often offer multiple subscription plans that vary in price, with some offering ad-free or higher video quality features. With these options, customers weigh the cost of the service versus getting additional features.

- Control

Customers may seek control when interacting with a service or making a purchase. Control can sometimes overlap with the options requirement, as multiple options allow customers to control which subscription plan they purchase from a company, for example. Companies can also provide control to their customers by enabling them to customize their purchases. For example, a shoe company may offer a fully customizable style of shoes. Customers can choose from a variety of colors, patterns and other features to create a unique product that suits their preferences.

- Experience

Defining what constitutes a positive customer experience will vary on the company and its offerings, so customer research is essential. Generally, a positive experience refers to products or services that are easy to understand and use. The customer experience is crucial when developing software or websites, for example. Users must have the ability to easily navigate the website to achieve their goals, such as purchase a product or find an article to read.

- Design

Design can often serve as an umbrella for other requirements, such as experience or accessibility. Design may refer to ease of use—for example, a collapsible umbrella might be more attractive to customers because it takes up less space and is easier to carry. Appearance can also play a critical role in design requirements. If a customer finds a website visually appealing, for example, it can make them more likely to continue visiting and using it.

- Accessibility

Customers require products and services that enable easy access. For example, a banking institution can provide a mobile app that allows customers to access their accounts from anywhere. Accessibility also refers to products and services that people of all abilities can use. For example, a website that hosts videos can provide captions for deaf users, or a company that sells kitchen tools can offer utensils with unique grips for customers who have arthritis. Taking steps to increase the accessibility of their produces and services can help companies meet the needs of as many potential customers as possible.

- Privacy

A common customer requirement when purchasing or using services is privacy. When creating an account, for example, customers may want to ensure that the company does not sell their data to external parties. Companies often provide terms and conditions to inform customers of how their data will or will not be used. To meet customers' requirements, some companies may even promote their commitment to privacy or provide additional privacy options. For example, a social media site may allow its users to disable the use of personalized ads.

- Empathy

Customers want to feel that companies care about and understand their needs. This requirement is essential in customer service, as customers need to speak to someone about their questions or concerns. Companies can also demonstrate empathy through charitable initiatives. For example, a shoe company may offer a promotion in which customers can purchase shoes, and the company will then donate a pair to someone in need or use a portion of sales to make a donation. These initiatives demonstrate that the company understands the needs of its community and wants to provide support.

- Information

Customers want to make informed decisions, so companies must provide relevant or necessary information as guidance. The type of information varies but may consist of details such as product specifications or usage instructions. Readily available information can persuade customers to purchase something because they have a clear understanding of the product and whether it suits their needs. For example, an apparel company can include sizing charts and images on their website, helping customers decide which size to purchase when they cannot try on the clothes.

3.7. Conduct routine/visual/sensory inspection regularly with normal operation

3.7.1 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) andDoors of enclosures are secure It

should also check the operation of Equipment switch on and off where equpment is not in regular use.

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 .3.

Part I . Answer all the questions listed below. Say True / False.

4. Insufficient oil or grease is one of the sources of bearing failure.
5. Hot motor or external environment is not the sources of bearing failure.
6. Bearing should be re lubricated before a long interruption in operation occurs.
7. Keep the bearings dirt-free, moisture free, and lubricated.
8. Working principle is same as 3 phase sq. cage rotor induction motor, having bettertorque and speed.
9. Customers' requirements vary based on the products or services sold by a company

Part II .Fill in the space provide

1.------------- are run for extremely long periods without repairs

2.------------- is one of the main cause of troubles in single phase motors

3.--------------and high cost of maintenance…

Part III. 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. 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
3. Which one of the following is not included in PPE?
   A. Goggle
   B. Glave
   C. Safety shoes
   D. None of the

Operation sheet .3. Maintain electrical system

- **Operation title: Maintain Electrical machine**
- **Purpose:** Assemble and disassemble of Ac motor

Instruction: Using the correct Procedures for Assemble and Maintene of Dc Motor then identify each

constructional parts.

. Given necessary workshop, tools and materials you are required to perform the following tasks within 2 hours.

Material list.

1. Multi meter
2. Screw Driver
3. Megger
4. Phase sequence tester
5. Tachometer

  - Test all parts of the single phase
  - Prepare all Tools, Equipment and Materials

- **Quality Criteria:** dismantle the machine by using correct steps and put in clear place
- **Precautions:** use the right hand tools.

Lap Test .3.

Task1. Measure winding resistance of each phase by setting multimeter to ohmmeter. Be sure all three winding resistance are balanced.

Task 2. Measure insulation resistance of motor using megger for all three phases (reading for each should be above 2MΩ) unless there will ground fault on motor.

Task3. Apply 380 volt to the motor from fused three phase socket outlet with switch. Switch on the power and measure the speed of motor using tachometer. **Note** that the motor is running mechanically in smooth way (noise free), and let it run for a long minutes to check whether it is getting hot (touch with your hand to check overheating).

Unit Four: Complete and report fault diagnosis and rectification activities

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

- Notifying/informing immediate superior completion of work.
- Making performance test
- Preparing and submitting service report
- Documenting rectification of faults
- Cleaning, checking and returning tools, equipment and any surplus materials
- Cleaning up and making safe work area

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Notifying/informing immediate superior completion of work.
- Making performance test
- Preparing and submitting service report
- Documenting rectification of faults
- Cleaning, checking and returning tools, equipment and any surplus materials
- Cleaning up and making safe work area

4.1. Notify /inform immediate superior completion of work.

4.1.1 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.

4.1.2 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.

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.

4.1.3 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

4.2. Making performance test

4.2.1.Performance Testing

Performance Testing is a software testing process used for testing the speed, response time, stability, reliability, scalability and resource usage of a software application under particular workload. The main purpose of performance testing is to identify and eliminate the performance bottlenecks in the software application. It is a subset of performance engineering and also known as "Perf Testing".

The focus of Performance Testing is checking a software program's

- ✓ Speed – Determines whether the application responds quickly
- ✓ Scalability – Determines maximum user load the software application can handle.
- ✓ Stability – Determines if the application is stable under varying loads

- ✓ **Types of Performance Testing**

Load testing – checks the application’s ability to perform under anticipated user loads. The objective is to identify performance bottlenecks before the software application goes live.

Stress testing – involves testing an application under extreme workloads to see how it handles high traffic or data processing. The objective is to identify the breaking point of an application.

Endurance testing – is done to make sure the software can handle the expected load over a long period of time.

Spike testing – tests the software’s reaction to sudden large spikes in the load generated by users.

Volume testing – Under Volume Testing large no. of. Data is populated in a database and the overall software system’s behavior is monitored. The objective is to check software application’s performance under varying database volumes.

Scalability testing – The objective of scalability testing is to determine the software application’s effectiveness in “scaling up” to support an increase in user load. It helps plan capacity addition to your software system.

- ✓ Common Performance Problems

Most performance problems revolve around speed, response time, load time and poor scalability. Speed is often one of the most important attributes of an application. A slow running application will lose potential users. Performance testing is done to make sure an app runs fast enough to keep a user’s attention and interest. Take a look at the following list of common performance problems and notice how speed is a common factor in many of them:

Long Load time – Load time is normally the initial time it takes an application to start. This should generally be kept to a minimum. While some applications are impossible to make load in under a minute, Load time should be kept under a few seconds if possible.

Poor response time – Response time is the time it takes from when a user inputs data into the application until the application outputs a response to that input. Generally, this should be very quick. Again if a user has to wait too long, they lose interest.

Poor scalability – A software product suffers from poor scalability when it cannot handle the expected number of users or when it does not accommodate a wide enough range of users. Load Testing should be done to be certain the application can handle the anticipated number of users.

Bottlenecking – Bottlenecks are obstructions in a system which degrade overall system performance. Bottlenecking is when either coding errors or hardware issues cause a decrease of throughput under certain loads. Bottlenecking is often caused by one faulty section of code. The key to fixing a bottlenecking issue is to find the section of code that is causing the slowdown and try to fix it there. Bottlenecking is generally fixed by either fixing poor running processes or adding additional Hardware. Some **common performance bottlenecks** are

- CPU utilization
- Memory utilization
- Network utilization
- Operating System limitations
- Disk usage

✓ Performance Testing Process

The methodology adopted for performance testing can vary widely but the objective for performance tests remain the same. It can help demonstrate that your software system meets certain pre-defined performance criteria. Or it can help compare the performance of two software systems. It can also help identify parts of your software system which degrade its performance.

Below is a generic process on how to perform performance testing

Identify your testing environment – Know your physical test environment, production environment and what testing tools are available. Understand details of the hardware, software and network configurations used during testing before you begin the testing process. It will help testers create more efficient tests. It will also help identify possible challenges that testers may encounter during the performance testing procedures.

1. **Identify the performance acceptance criteria** – This includes goals and constraints for throughput, response times and resource allocation. It is also necessary to identify project success criteria outside of these goals and constraints. Testers should be empowered to set performance criteria and goals because often the project specifications will not include a wide enough variety of performance benchmarks. Sometimes there may be none at all. When possible finding a similar application to compare to is a good way to set performance goals.
2. **Plan & design performance tests** – Determine how usage is likely to vary amongst end users and identify key scenarios to test for all possible use cases. It is necessary to simulate a variety of end users, plan performance test data and outline what metrics will be gathered.
3. **Configuring the test environment** – Prepare the testing environment before execution. Also, arrange tools and other resources.
4. **Implement test design** – Create the performance tests according to your test design.
5. **Run the tests** – Execute and monitor the tests.
6. **Analyze, tune and retest** – Consolidate, analyze and share test results. Then fine tune and test again to see if there is an improvement or decrease in performance. Since improvements generally grow smaller with each retest, stop when bottlenecking is caused by the CPU. Then you may have the consider option of increasing CPU power.

✓ Performance Testing Metrics: Parameters Monitored

The basic parameters monitored during performance testing include:

- **Processor Usage –** an amount of time processor spends executing non-idle threads.
- **Memory use –** amount of physical memory available to processes on a computer.
- **Disk time –** amount of time disk is busy executing a read or write request.
- **Bandwidth –** shows the bits per second used by a network interface.
- **Private bytes –** number of bytes a process has allocated that can't be shared amongst other processes. These are used to measure memory leaks and usage.
- **Committed memory –** amount of virtual memory used.
- **Memory pages/second –** number of pages written to or read from the disk in order to resolve hard page faults. Hard page faults are when code not from the current working set is called up from elsewhere and retrieved from a disk.
- **Page faults/second –** the overall rate in which fault pages are processed by the processor. This again occurs when a process requires code from outside its working set.
- **CPU interrupts per second –** is the avg. number of hardware interrupts a processor is receiving and processing each second.
- **Disk queue length –** is the avg. no. of read and write requests queued for the selected disk during a sample interval.
- **Network output queue length –** length of the output packet queue in packets. Anything more than two means a delay and bottlenecking needs to be stopped.
- **Network bytes total per second –** rate which bytes are sent and received on the interface including framing characters.
- **Response time –** time from when a user enters a request until the first character of the response is received.
- **Throughput –** rate a computer or network receives requests per second.
- **Amount of connection pooling –** the number of user requests that are met by pooled connections. The more requests met by connections in the pool, the better the performance will be.
- **Maximum active sessions –** the maximum number of sessions that can be active at once.
- **Hit ratios –** This has to do with the number of SQL statements that are handled by cached data instead of expensive I/O operations. This is a good place to start for solving bottlenecking issues.

Hits per second – the no. of hits on a web server during each second of a load test.

Rollback segment – the amount of data that can rollback at any point in time.

Database locks – locking of tables and databases needs to be monitored and carefully tuned.

Top waits – are monitored to determine what wait times can be cut down when dealing with the how fast data is retrieved from memory

Thread counts – An applications health can be measured by the no. of threads that are running and currently active.

Garbage collection – It has to do with returning unused memory back to the system. Garbage collection needs to be monitored for efficiency.

Example Performance Test Cases

- Verify response time is not more than 4 secs when 1000 users access the website simultaneously.
- Verify response time of the Application Under Load is within an acceptable range when the network connectivity is slow.
- Check the maximum number of users that the application can handle before it crashes.
- Check database execution time when 500 records are read/written simultaneously.
- Check CPU and memory usage of the application and the database server under peak load conditions.
- Verify response time of the application under low, normal, moderate and heavy load conditions.

During the actual performance test execution, vague terms like acceptable range, heavy load, etc. are replaced by concrete numbers. Performance engineers set these numbers as per business requirements, and the technical landscape of the application.

Performance Testing is always done for client-server based systems only. This means, any application which is not a client-server based architecture, must not require Performance Testing.

It is of significance to understand the difference between Performance Testing and Performance Engineering. An understanding is shared below:

Performance Testing is a discipline concerned with ***testing and reporting*** the current performance of a software application under various parameters.

Performance Engineering is the process by which software is tested and tuned with the intent of realizing the required performance. This process aims to optimize the most important application performance trait i.e. user experience.

Historically, testing and tuning have been distinctly separate and often competing realms. In the last few years, however, several pockets of testers and developers have collaborated independently to create tuning teams. Because these teams have met with significant success, the concept of coupling performance testing with performance tuning has caught on, and now we call it performance engineering.

4.3. Preparing and submitting service report

4.3.1 Preparation and submission of reports

Preparation is not so terrible as the submission of accounting and tax reports. This is always a difficult period for any company. When the hot season comes, under the name of «preparation and submission of reports» you have to analyze the mass of primary documents, calculate percentages, display coefficients, etc., and in a rather limited time. In modern accounting, changes often occur and it's difficult to keep track of them. And any mistakes are fraught with fines and subsequent proceedings. provides services for the preparation and submission of reports to the tax inspectorate, statistics and extra-budgetary funds in a timely manner in electronic or paper form.

- You save money and time. The compilation of mandatory forms of financial statements requires a good theoretical base and relevant experience. From scratch to do it is difficult and, more importantly, very labor-intensive. If you count the loss of time to study all the nuances, then the cost of reporting at an outsourcing almost always becomes a way to reduce the company's fixed costs.
- You have one problem less. Responsibility for the delivery of financial statements to the tax bears another company. It is only important to clearly state its obligations in the contract. Also, when preparing financial statements by a third-party expert, vulnerabilities of business processes are often found. He is independent in relation to the enterprise and sees all things from the outside.
- Temporary downtime will not lead to problems. If there was not a single operation in the period, it would still be necessary to prepare and submit a zero statement. Tax officers need documents confirming this situation. Drawing up such financial statements is not associated with great difficulties, but in the future you will have a document that does not allow the fiscal authorities to accrue a penalty.

Preparation and submission of reports – is a hot time – it is necessary to analyze the mass of primary documents, calculate percentages, derive coefficients, etc., moreover, in a rather limited time.

For any firm writing and submitting reports – is a very important procedure, because this information is used not only by statisticians and tax authorities, but also by the management of the company, shareholders, higher organizations, etc.

Accountant’s responsibility – this is a guarantee of compliance with the deadlines for the delivery of reports, because otherwise the company will face serious penalties. Thus, the right choice of a specialist, on whose shoulders the preparation and submission of reports will fall, is a guarantee of the smooth running of the enterprise without any interference.

4.4. Documenting rectification of faults

4.4.1 Troubleshooting electrical faults in a manufacturing environment

Electrical Fault

An electrical fault is an abnormal condition caused by equipment failure or wiring defects, causing incorrect operation of machinery or devices. Electrical faults can bring an entire production line to a halt and as a result can be very costly.

Electrical faults typically result from either an open circuit or a short circuit but can also be a combination of these. Other faults may include improper operating voltage, mechanical failure of components, and excessive heating or corrosion.

Troubleshooting Electrical Faults

Electrical faults are the bane of existence for every maintenance and trades professional in the industrial world. Much head scratching and creative use of language has been employed to solve electrical faults over the years! The truth is, downtime is a reality in any corporate or manufacturing environment.

Knowing how to troubleshoot effectively can make all the difference in your organization. It can help to reduce downtime.

Let’s take a look at some common faults and how to diagnose them.

Identifying Electrical Faults

Open circuit faults are most common and are relatively easy to troubleshoot. Typically, this type of fault can be identified quickly as some part of the circuit will not be operating since it is not receiving the voltage required for correct operation. Look for burned out light bulbs, open operating coils, and loose connection or terminal points to cause this type of fault. On equipment with wiring that continually flexes, you may find a broken conductor inside the insulation which causes an open circuit.

Short circuit faults are more difficult to find and repair. Typically, a short circuit occurs when the insulation around a conductor deteriorates and the current finds a path to another conductor or grounded object. This can cause fuses or circuit breakers to operate because of unwanted excessive current flow. Another possibility is that the short circuit will energize other parts of the circuit and cause other components to operate unintentionally. Although a fuse or circuit breaker can open from “old age,” it is more likely an indicator of a short circuit or overcurrent situation.

Low voltage problems can cause relays to chatter or not pick up at all. Motors and components with coils can heat up more than normal and cause electrical insulation to deteriorate and possibly fail.

Over voltage problems generally shorten the lifespan of most components due to greater than normal heating. Lighting and motors are most affected by this problem.

Electro/mechanical faults usually happen to components that are nearing end of life or have manufacturing defects. This type of fault includes things like a pushbutton that no longer closes when pushed or a relay with stuck/welded contacts. This type of fault often exhibits no exterior signs of internal problems.

To be an effective troubleshooter you must always start with a strategy, a systematic approach, if you will. To begin, gather information about the equipment and the fault including prints and manufacturer's manuals.

Understand how the equipment is designed to operate and review documentation of the problem such as work orders, trouble reports, or discussions with the person who reported the problem. Then, follow this systematic approach.

1. Observation

Look for visual signs of malfunctioning equipment including loose components, parts in the bottom of the cabinet, or signs of overheated components. Don't forget to use all your senses including smell, listening for abnormal sounds, and touching to feel for excessive heat or loose components. Also, fully test operate equipment if possible, and note what is working correctly and what is not.

2. Define Problem Areas From your observations decide which parts of the circuit are operating correctly and which are not. Any properly functioning parts of the circuit can be eliminated from the problem areas, decreasing testing time required later.

3. Identify Possible Causes

Once you have identified the problem area, you can now begin to list probable causes. Try to think of every possibility that could cause the problem and rate each by probability. Typically, possibilities would include the following: blown fuses, mechanical components, windings and coils, terminal connections, and wiring.

4. Test Probable Cause

Now that you have a list of most probable causes you can begin testing. Start with the most probable cause. Always know what to expect before you take a meter reading and know what it means if you get a reading different than what you predicted. From your tests you may need to sectionalize the circuit further to reduce the problem area. Continue with this method until you find a suspect component or wire.

5. Replace Component and Test Operate

Once you have proven a component is defective, replace the component and test operate the complete circuit. Make sure you check all features and operations of the circuit. If everything is operating correctly, return the equipment to service. If the circuit still does not operate correctly, you will need to rethink your logic and return to step one.

Tools of the Trade

Many tools are available for electrical troubleshooting.

A common multimeter is a great start and usually all you will need to perform most of your tests. A typical multimeter can measure AC volts, DC volts, resistance, and small flows of current.

Another great addition would be a clip-on ammeter for measuring operating current.

Let's look at what these tools do and when to use them.

1. Ohmmeter

An ohmmeter measures resistance in a circuit and is a great tool for finding short circuits, open coils, or burned out light bulbs. Power to the circuit must be shut off and locked out before taking an ohmmeter reading, and remember, put the leads together and take a reading to prove the meter is operating correctly before starting. It is always good practice to remove one wire from a component before taking a reading to ensure there are no parallel paths in your reading.

2. Voltmeter

A voltmeter measures AC or DC volts in a circuit and is preferred for finding open circuits. Always check your meter on a known voltage source to verify it is working correctly before taking test readings. Try to keep one lead as a reference lead and keep it on neutral or ground. Use the other lead for picking terminals for your test points.

3. Clip-on Ammeter

A clip-on ammeter is useful to measure current draw of components while they are operating. A motor that is drawing more current than normal may have worn bearings or could be overloaded. The clip-on ammeter is also useful for determining current flows in different parts of a circuit.**A Few More Tips**

Never underestimate the power of your own senses in determining faults. The "burnt insulation" smell is almost always a good indication of a failed component.

Listening for abnormal sounds when operating a device can also lead you to discovering a problem.

Looking at components for visual signs of burning is always a good place to start, and checking for overheated equipment can also be an indicator of trouble. Just be careful not to get burned yourself when checking for hot equipment!

4.5. Cleaning, check and return tools, equipment and any surplus materials

4.5.1 Tool Work Habits

A. 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.

B. **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.

C. **Safe maintenance practices**

Always avoid placing tools on or above machinery or an electrical apparatus. Never leave tools unattended where machinery is running.

D. **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 through the entire contents of the box. Avoid accumulating unnecessary junk.

E. **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 neaty 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.

4.6. Cleaning up and making safe work area

4.6.1. Safe working 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 t he work station for a leather goods worker would be the workshop. It is necessary for a worker to prepare his work station and the pieces to bedone but before doing so a worke should be well aware of the safety rules andregulations.

Good housekeeping is a vital factor in preventing accidents. The great majority ofall 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* housekeepi

- ✓ Tripping over loose objects on floors, stairs and platform
- ✓ 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, steel

strappi 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.

Elements of a Good Hou ekeeping

The following are the basic elements of a good housekeeping:

Pssageways: 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.

Let us look at some of these elements in detail:

Keep Passageways Clear: Passageway space should be reserved for the movem ent ofpersonnel, products and materials. It should be kept clean and clear and shouldne ver be used for “bottleneck” or “overflow’’ storage. This also applies topassagewa ys and emergency exits. Blind corners should be eliminated or beadequately prote cted by warning signs.Aisle boundary markings should be drawn to show clearly the spac e which hasbeen reserved for traffic. Markings should be sufficiently wide (say a minimu m of30 mm) and of a color to make them clearly visible. Paint or durable plastic stripscan be used.

Improve Storage Facilities: Tidiness and order are essential in overcomingstorage problems, both in storerooms and in the yard. Good storage utilizes airspace instead of fl oor 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 an d other liquids 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 Wndows: 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

Dsp ose of Scrap and P eventS pillage: 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 .4.

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. improper use of tools resultsin improper maintenance.

_____5.Use each tool only for the job it was designed to do.Keep your tools in good condition. Protect them from rust, nicks, burrs, and breakage.

_____ 6. Always avoid placing tools on or above machinery or an electrical apparatus.

_____ 7. improper use of tools resultsin improper maintenance.

_____ 8.Use each tool only for the job it was designed to do

Part II. Fill in the space proide

1. --------------------- problems can cause relays to chatter or not pick up at all.

2. --------------------- faults are more difficult to find and repair

3. -------------------- faults are most common and are relatively easy to troubleshoot

Part III . Give short answer

1. Define Care of hand tools
2. Mension Safe maintenance practices`s
3. ---------------------- useful to measure current draw of components while they are operating.
4. ------------ measures AC or DC volts in a circuit and is preferred for finding open circuits

Operation sheet .4. Complete and report fault diagnosis and rectification activities

Operation Title :- Diagnose and rectify AC three phase machine

Purpose 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.

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

4.Using the multimeter, check the continuity of winding from phase to phase (Uto V, V to W , W to U).

5.Check the motor winding ohms reading for phase to phase terminal(U to V,Vto W , W to U).

6.Check insulation resistance of motor winding using

7.Check the running amps of the motor

If every step is completed, decide the condition of electrical motor

- **Quality Criteria:** the given defective motors diagnose properly
- **Precautions:** use the given hand tools and measuring instrument is the correct one.

Lap test .4.

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

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MINISTRY OF LABOR AND SKILLS

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