INDUSTERIAL ELECTRICAL MACHINES AND DRIVES SERVICING

Level II

LEARNING GUIDE #32

Unit of competence: Industrial Electrical Machines and Drives Servicing Level II

Module Title: Maintaining and repairing industrial electrical machines and drives

LG Code: EEL EMD2 M08LO3-LG32

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LO3: Troubleshoot faults in an Electrical System or equipment

Instruction Sheet :1	Learning Guide 32

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

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

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

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

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.

3. Read the information written in the "Information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5, Sheet 6, Sheet 7, Sheet 8 and Sheet 9" in page 4,8,11,16,22,27,31,34 and 38 respectively".
4. Accomplish the "Self-check 1, Self-check 2, Self-check 3 , Self-check 4 , Self-check 5 , Self-check 6, Self-check 7, Self-check 8 and Self-check 9" in page 7,10,15,21,28,30,33,37 and 39 respectively".
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1 and Operation Sheet 2" in page 40 and 41 respectively.
6. Do the "LAP test" in page 42

Information Sheet :1	Follow safety policies and procedures

1.1. Introduction

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

- **Electrical Safety Work Practices Plan**

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

- **Qualified Person**

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

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

1.2. General Safety Rule

- Get the right tool for the right job

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

1.3. Personal Protective Equipment (PPE)

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

The following points should be observed:

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

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

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

Self-Check -1	Written Test

Directions: Choose the best answer.

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

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

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet :2	Prepare maintenance records

2.1. Preventive maintenance schedule

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

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

- ✓ **Daily maintenance**

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

- ✓ **Weekly maintenance**

1) Check belt tension. In the case of sleeve bearing machines the air gap between-rotor and stator should be checked. 2) Blow out dirt from the windings of protected type motors situated in dusty locations. 3) Examine starting equipment for burnt contacts where motor is started and stopped frequently. 4) Examine oil in the case of oil ring lubricated bearings for contamination by dust, grit etc. (this can be roughly judged from the color of the oil). 5) Check the intensity of vibrations during operation of the motor. 6) Clean filters where provided.

- ✓ **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.

- **Haly-Yearly Maintenance**

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

- **Annual Maintenance**

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

Self-Check -2	Written Test

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

1. One is not a type of Daily maintenance?

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

2. Which one of the following Monthly maintenance?

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

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

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

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

Score = ____________

Rating: _____________

Name: _________________________ Date: _______________

Information Sheet :3	Isolate Circuit or equipment to be diagnosed

3.1. Introduction

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

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

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

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

Expert troubleshooters have a good understanding of the operation of electrical components that are used in circuits they are familiar with, and even ones they are not. They use a system or approach that allows them to logically and systematically analyze a circuit and determine exactly what is wrong. They also understand and effectively use tools such as prints, diagrams and test instruments to identify defective components. Finally, they have had the opportunity to develop and refine their troubleshooting skills.
If you want to troubleshoot like the pros you will need to develop your skills in each of these areas. Let's look at them in more detail.

- **Understand how the circuit works**.

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

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

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

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

3.2. Isolation Procedures

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

The aim of an isolation procedure is to:

- isolate all forms of potentially hazardous energy to ensure that an accidental release of hazardous energy does not occur
- control all other hazards to those doing the work
- ensure that entry to a restricted area is tightly controlled.

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

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

3.3. Locks and danger tags

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

When using locks or danger tags, consider the following:

- tags should be dated and signed
- locks should be accompanied by a corresponding tag to identify who has locked out the plant

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

3.4. Out-of-service tags

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

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

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

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

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

Self-Check -3	Written Test

Directions: Choose the best answer

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

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

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

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

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

(Continued)

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

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

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

(Continued)

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

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

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

Self-Check -4	Written Test

Directions: Choose the best answer

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

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

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

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

Score = ____________

Rating: _____________

Name: _________________________ Date: _______________

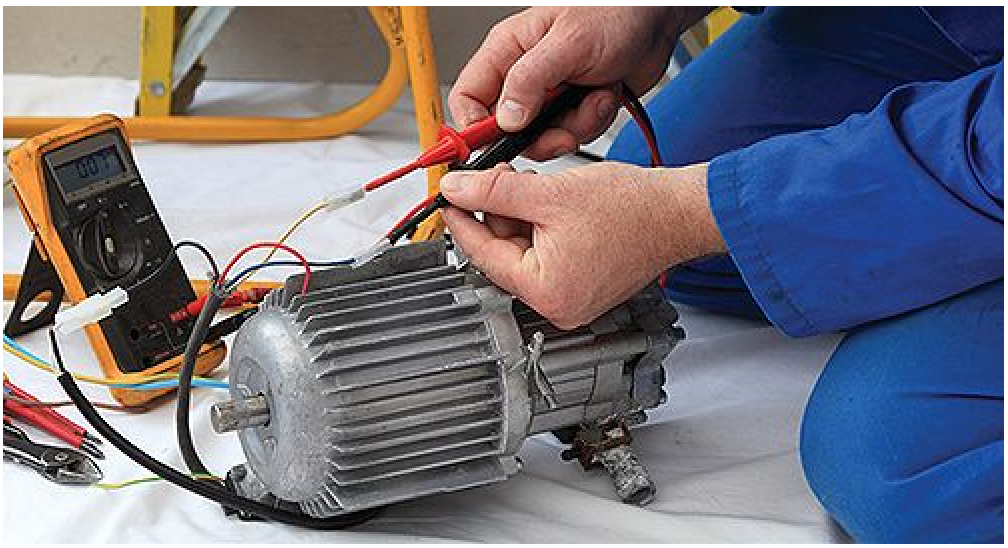
Information Sheet :5	Perform necessary electrical test on the system or equipment

5.1. Introduction

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

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

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



5.2. Necessary electrical test

- ✓ **Earth Continuity and Resistance Test**

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

✓ existence of continuity in the electrical wiring circuit

✓ existence of any open circuit in the circuit

✓ existence of any short circuit in the circuit

- **AC Motor Winding Continuity Test**

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

- **Multimeter/Continuity test**

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

- **Power Supply Test**

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

- **Ac motor winding resistance test**

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

- **Insulation Resistance test**

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

- **Running AmpsTest**

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

- **No-load Test**

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

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

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

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

- **Performing ground test on phase coils**

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

- ✓ Use the Correct Instruments Use devices specifically designed for ground testing, like a dedicated ground tester.

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

- **Ground Testing Techniques**

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

- **The Importance of Ground**

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

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

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

Self-Check -5	Written Test

Directions: say true or false

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

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

Score = ___________

Rating:

Name: ___________________________ Date: ________________

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

6.1. Introduction

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

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

Estimate is called a damage report or appraisal

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

Self-Check -6	Written Test

Directions: say true or false

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

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

Score = ___________

Rating:

Name: _________________________ Date: _______________

Information Sheet :7	Coordinate other works associated with the problem

7.1. Mechanical Repair section

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

7.2. Shafts and shaft extensions

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

7.3. Bearings

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

7.4. Lubrication

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

7.5. Frame and bearing housings

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

7.6. Dynamic balancing

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

7.7. Testing section

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

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

Self-Check -7	Written Test

Directions: say true or false

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

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

Score = ___________

Rating:

Name: ___________________________ Date: ________________

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

8.1. Records of Maintenance

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

(b) Principle contents :

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

Type of Breakdown	Symptoms	Possible causes	Remedies
Fail to start without load	Motionless and soundless	Power-off	Consult power company
		Switch-off	Switch-on
		No fuse	Install fuse
		Broken wiring	Check wiring and repair
		Broken lead	Check wiring and repair
		Broken windings	Check windings and repair
	Fuse blowing. (Automatic switch trips off, slow start with electromagnetic noise)	Short circuit of circuit switches	Check circuit switches and replace
		Incorrect wiring	Check wiring according to nameplate
		Poor contact at terminals	Lock tightly
		Windings grounded	Factory repair
		Broken windings	Factory repair
		Poor contact of circuit switches	Check and repair
		Broken wiring	Check and repair
		Poor contact of starting switches	Check and repair
		Short circuit of starting switches	Check and repair
		Incorrect connections of starting switches	Connect according to nameplate

Loading after start	Fuse blowing. Fail to restart due to trip-off of automatic switch	Insufficient capacity of fuse	Replace fuse if wiring permits
		Overload	Lighten load
		High load at low voltage	Check circuit capacity and reduce load
	Overheating motor	Overload or intermittent overload	Lighten load
		Under-voltage	Check circuit capacity and power source
		Over-voltage	Check power source
		Ventilation duct clogged	Remove the foreign matter in the duct
		Ambient temperature exceeds 40°C	Correct insulation class F, or lower ambient temperature.
		Friction between rotor and stator	Factory repair
		Fuse blown (Single-phase rotating)	Install the specified fuse
		Poor contact of circuit switches	Check and repair
		Poor contact of circuit starting switches	Check and repair
		Unbalanced three-phase voltage	Check circuit or consult power company

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

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

Remarks:

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

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

Self-Check -8	Written Test

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

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

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

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

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

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

Score = ___________

Rating:

Name: _________________________ Date: _______________

Information Sheet :9	responding unforeseen events

9.1. Introduction

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

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

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

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

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

Self-Check -9	Written Test

Directions: Say true or false

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

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

Score = ___________

Rating: ____________

Name: ___________________________ Date: _______________

Operation Sheet-1	Fault Troubleshooting three phase induction motor

Procedure

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

Operation Sheet-2	Induction Motor No-Load Test

PROCEDURE:

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

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

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

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

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

List of Reference Materials

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

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

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

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

5. Eectric Machinery, 6e, Fitzgerald.

6. Principles of electrical machines(mehta)

7. Theraja

The trainers (who developed the Learning Guide)

No	Trainer Name	Education back graund	Region
1	SERKABEBA ABERA	MSC	DEBUB
2	MULU DAMANE	MSC	ADDIAABEBA
3	ABERA GEBRE	BSC	DIRADAWA
4	ESUBALEW AMSALU	MSC	HARER
5	MERON HUSEN	BSC	HARER
6	SHIMELS CHEKOLE	BSC	AMHARA
7	FISIHA BIREHANU	MSC	AMHARA
8	YIMER SEID	MSC	AFAR
9	HINDA IBRAHIM	BSC	SOMALI
10	TADDELE GASHAW	MSC	SOMALI