Industrial Electrical/Electronics Control Technology

Level-II

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Module Title: - Performing Commissioning of Electrical Equipment/Systems

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Table of Content

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Acronym

AC	Alternating Current
CT	Current Transformer
Cx	Commissioning
DC	Direct Current
FAT	Factory Acceptance Testing
HRC	High Rapturing Capacity
HT	High Tension
HV	High Voltage
LED	Light Emitting Diode
LT	Low Tension
LV	Low Voltage
MCC	Motor Control Center
OHS	Occupational Health and Safety
PPE	Personal Protective Equipment
PT	Potential/Voltage Transformer
SAT	Site Acceptance Testing
SIT	Site Integration Testing
VOM	Voltmeter

Introduction to the Module

In the field of Industrial Electrical Engineering; commissioning of electrical equipment/systems helps to verify system conditions after has been energized with rated system (service) voltage for which it is designed. Also, to ensure the correct protection, metering system for correct directionality. Its purpose is to assure that tested electrical systems are safe, reliable, perform within manufacturer tolerances, are installed in accordance with design specifications, and conform with applicable standards

This module is designed to meet the industry requirement under the Industrial Electrical/Electronic Control Technology occupational standard, particularly for the unit of competency: Perform Commissioning of Electrical Equipment/Systems

This module covers the units:

- Commissioning activities
- Commission electrical equipment/systems
- Documentation of commissioning activities

Learning Objective of the Module

- Plan and prepare commissioning activities
- Perform Commission electrical equipment/systems
- Document commissioning activities

Module Instruction

For the effective use of this module’s 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: Commissioning activities

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

- Commissioning procedure
- Work instruction
- Tools, equipment and testing devices
- Potential hazards
- Commissioning activities

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:

- Plan commissioning procedure
- Confirm commissioning of work instruction
- Obtain, estimate and inspect tools, equipment and testing devices
- Identify, prevent and control potential hazards
- Coordinate commissioning activities

1.1. Commissioning procedure

1.1.1. Introduction

What is Commissioning?

Commissioning is the process of planning, documenting, scheduling, testing, adjusting, verifying, and training, to provide a facility that operates as a fully functional system. A process that assures that a component, subsystem, or system will meet the intent of the designer and the user. The purpose of electric systems commissioning is to increase the reliability of electrical power systems after installation by identifying problems and providing a set of baseline values for comparison with subsequent routine tests.

This procedure is the commissioning plan. Specific areas addressed in a commissioning plan include the verification of the installation of all equipment/components, interface connections between equipment and individual systems, and interconnection drawings. The development of this test plan specific to each system and/or component is key to the usefulness of any maintenance program. The plan consists of the schedule of when acceptance and routine tests should be performed, test forms to be used to record the outcome of the tests which are retained for comparison with previous and subsequent tests, and a listing of the required test devices. Since the results of the commissioning tests become baseline test values to compare with later tests and the results of the routine maintenance tests are compiled to identify any downward trend in performance, it is vital to the maintenance program to have accurate and complete records.

To perform the testing, the plan lists all required tests in order of performance and gives a schedule for each test. The work items and schedule depend on many items including the importance and cost of the equipment, consequences of failure, age of equipment, past and future frequency of service, hours of operation, future maintenance availability, environmental conditions, and safety requirements.

1.1.2. General Commissioning Plan

The Commissioning Plan: shall include the requirements for planning, scheduling, coordinating, executing, and documenting Pre-Commissioning, Commissioning, Startup, and Activation activities. There are management, economic, technical, and operational requirements associated with every test plan. Many tests and commissioning are redundant, but are used as checks and balances before system energization to ensure successful startup and operation. The complexity of the system and equipment, experience of the designers/installers/operators, the possible results of a failure, and the costs of the testing are all considered when determining the amount of testing required. The component and system inspections and checks are the key to the success of the program. Sufficient time should be allocated to define the inspections required, perform the check, and document the results.

The main objective of the Commissioning Plan: is to provide an organized and thorough approach to the validation of the equipment, systems, and processes to be completed by the Contractor. Test plans and procedures shall identify, by system and specific tag number, each device or control station to be manipulated or observed during the test procedure and the specific results to be observed or obtained. Test plans also shall be specific as to the support systems required to complete the test work, temporary systems required during the test work (including any temporary construction needed for testing), representatives to be present, and expected test duration.

1.1.2. Commissioning procedure of electrical equipment/system:

- Formulate checklist of machine and equipment parts
- Check completeness of installation based on plans/diagrams
- Perform electrical testing
- Perform no-load and load testing
- Perform monitoring of meters and gauges
- Orient end-user regarding systems operations
- Turn over electrical equipment to end-user

Three types of tools were used within the Annex to support the definition and application of the Commissioning Plan. The following gives an overview of these three types of tools:

- **Standard Models of Commissioning plans**

These standard models include typical lists of tasks with a description of the content of each task. They can be used as a basis to define customized Commissioning Plans adapted to a given project.

- **Checklists**

The minimum version of a Commissioning Plan is a checklist defining the verifications to be performed as the project progresses to ensure that critical actions were effectively performed. The key advantage of the checklist is its simplicity. There would be no need to use a special software or for in-depth training of the users. The main disadvantage is that it defines what to do but not how to do it and does not include a documentation of the results obtained.

In simple projects, where an independent commissioning authority generally will not be involved, the checklist enables the project manager to apply a minimum of quality control. Check points are especially important when proceeding from one project phase to the next. These checklists will be used by each party involved in the project.

- **Matrix for Quality Control**

Its intention is to control the total production process including specifications, design, construction, hand-over and operation. It focuses on avoiding failures on all strategic aspects and phases in this process.

Commissioning plans are developing for three main reasons:

- ***Energy and environment related reasons:*** Global warming has increased the pressure to reduce energy use in plants.
- ***Business related reasons:*** Many companies are developing new services to diversify their activities in the plants and energy industries. They see the commissioning as a way to develop new business for the benefit of their customers.
- ***Technological reasons:*** automation systems are now standard in new buildings and are being installed in many older ones. These systems automatically collect plant operating data and offer possibilities for innovative commissioning services.

The primary obstacles that hinder the acceptance of commissioning as a routine process for all plants are: ***lack of awareness, lack of time, and too high costs***.

Types of commissioning

- **Initial Commissioning (I-Cx)**: is a systematic process applied to production of a new systems and/or an installation of new systems.
- **Retro-Commissioning (Retro-Cx):** is the first-time commissioning which is implemented in an existing system in which a documented commissioning process was not previously implemented.
- **Re-Commissioning (Re-Cx):** is a commissioning process implemented after I-Cx or Retro-Cx when the owner hopes to verify, improve and document the performance of systems.

- **On-Going Commissioning (On-Going Cx):** is a commissioning process conducted continually for the purposes of maintaining, improving and optimizing the performance of systems after I-Cx or Retro-Cx.

1.2. Work instruction

The purpose of electrical testing on systems and their components is two-fold. The first is to check the installation of the *equipment and perform component and systems tests* to ensure that, when energized, the system will function properly. The second is to *develop a set of baseline test results for comparison in future testing* to identify equipment deterioration.

- Commissioning tests are usually performed by independent contractors, the installation contractor, or the manufacturer. Each commissioning test should be witnessed and approved by a person not associated professionally with the person performing the test.
- The individuals who perform the acceptance tests should be certified and/or licensed for the equipment under test.
- The system should be initially checked for *damage, deterioration, and component failures using specific component checks, inspections, and tests defined by the equipment manufacturer.* Then the interconnection of the system components should be checked, using de-energized and energized methods, to verify the proper interconnection and operation of the components, including *on/off control, system process interlocks, and protective relaying functions.* Once the above tests are complete, the system can be energized and operational tests and measurements should be performed.
- All steps and results of the testing should be carefully documented for review and for use in the future for comparison with the results of future tests. Many of the same component tests initially run will be performed at regular intervals as part of a maintenance program. The new results will be compared to the initial results, where variations may be indicative of problems like deterioration of insulation or dirty equipment.
- The steps involved are to *review the system and equipment, develop a general system and specific equipment test plan, provide inspection and checks, perform component testing, verify and check the continuity of wiring, check control functions, calibrate instruments and relays, energize*

portions of the circuits and check for proper operation in a specific order, and, once complete, perform specific checks and control tests on the complete system during initial period of operation.

1.3. Tools, equipment and testing devices

Please refer your learning module/TTLM on "Perform measurement and Calculation"

1.4. Potential hazards

Workplace injury is a major cause of concern for all involved in occupational health and safety. The factors which cause workplace accidents and occupational illnesses are called hazards. The need for systematic management of OHS hazards and their attendant risks applies to all organizations and all activities and functions within an organization. It is important to distinguish between hazard, risk and exposure when undertaking risk management.

- ***Hazard*** is the potential for harm, or adverse effect on an employee's health. Anything which may cause injury or ill health to anyone at or near a workplace is a hazard. While some hazards are fairly obvious and easy to identify, others are not - for example exposure to noise, chemicals or radiation.
- ***Risk*** is the likelihood that a hazard will cause injury or ill health to anyone at or near a workplace. The level of risk increases with the severity of the hazard and the duration and frequency of exposure.
- ***Exposure*** occurs when a person comes into contact with a hazard.

Hazard identification

The first step in reducing the likelihood of an accident is hazard identification. Hazard identification is identifying all situations or events that could cause injury or illness. Eliminating or minimizing workplace hazards needs a systematic approach. It is essential to try and anticipate all possible hazards at the workplace - known as the 'what if?' approach.

Classes of hazard

Hazards are classified into five different types. They are

- **Physical** - includes floors, stairs, work platforms, steps, ladders, fire, falling objects, slippery surfaces, manual handling (lifting, pushing, pulling), excessively loud and prolonged noise, vibration, heat and cold, radiation, poor lighting, ventilation, air quality

- **Mechanical and/or electrical** - includes electricity, machinery, equipment, pressure vessels, dangerous goods, fork lifts, cranes, hoists
- **Chemical** - includes chemical substances such as acids or poisons and those that could lead to fire or explosion, cleaning agents, dusts and fumes from various processes such as welding
- **Biological -** includes bacteria, viruses, mold, mildew, insects, vermin, animals
- **Psychosocial environment** - includes workplace stressors arising from a variety of sources.

Note that some physical and chemical hazards can lead to fire, explosion and other safety hazards.

Methods for identifying hazards

The first step in control of a hazard is to identify and list them. There are many methods which are useful for identifying hazards, including

- Injury and illness records - review your workers' compensation data and check the incidence, mechanism and agency of injury, and the cost to the organization. These statistics can be analyzed to alert the organization to the presence of hazards
- Staying informed on trends and developments in workplace health and safety, for example via the internet or ohs publications
- Reviewing the potential impact of new work practices or equipment introduced into the workplace in line with legislative requirements
- Doing walk-through surveys, inspections or safety audits in the workplace to evaluate the organization's health and safety system
- Considering ohs implications when analyzing work processes
- Investigating workplace incidents and 'near hits' reports - in some cases there may be more than one hazard contributing to an incident
- Getting feedback from employees can often provide valuable information about hazards, because they have hands-on experience in their work area

Hazard Control measures

The correct course of action once a hazard is identified is to use control measures. These generally fall into three categories.

- Eliminate the hazard,
- Minimize the risk or
- Use 'back-up' controls when all other options in the previous categories have been exhausted.

The best way to control a hazard is to eliminate it. The elimination of a hazard is the first choice in a system called the '***hierarchy of control'***.

Hierarchy of controls

There is an order of priority in hazard control.

- ***Eliminate the hazard*** from the workplace entirely. This is the best way to control a hazard. An example of elimination is to remove a noisy machine from a quiet area.
- ***Substitute or modify the hazard*** by replacing it with something less dangerous, for example, by using a paint which does not contain asthma-encouraging agents.
- ***Isolate the hazard*** by physically removing it from the workplace or by cordoning off the area in which a machine is used.
- ***Use engineering methods*** to control the hazard at its source. Tools and equipment can be redesigned, or enclosures, guards or local exhaust ventilation systems can be used to close off the source of a hazard.
- ***Use administrative controls***. These are management strategies which can be introduced to ensure the health and safety of employees. Administrative procedures can reduce exposure to hazardous equipment and processes by limiting the time of exposure for example by job rotation or varying the time when a particular process is carried out.
- ***Introduce personal protective equipment (PPE)*** as an interim measure, to reduce exposure to a hazard.

1.5. Commissioning activities

Pre-commissioning and commissioning are two very important and distinct stages of the commissioning process. They are often confused, and it can be tricky to determine what takes place during each of these stages. Let's review the importance of each stage of the commissioning process and what activities take place during each stage. There are a few terms related to off-site and on-site testing.

- ***FAT or Factory Acceptance Testing*** is the testing that's conducted by the manufacturer in the factory prior to shipping to site.
- ***SAT or Site Acceptance Testing*** is the testing that's conducted in the field either by the vendor or by the on-site commissioning team. These are the standalone tests of the equipment to confirm no damage during shipping or installation.
- ***SIT or Site Integration Testing*** is the testing conducted in the field to confirm equipment functions as a subsystem or system.

Typical Mechanical Pre-Commissioning Testing

Pre-commissioning activities vary depending on the equipment to be tested – for example, mechanical versus electrical subsystems. Some typical mechanical pre-commissioning testing includes:

- Pipe flushing which is ensuring that piping is free of blockages or any debris.
- Leak testing to ensure that all fittings and joints do not leak.
- Pressure testing ensuring piping can maintain the pressure of liquid or gas.
- Verification of rotational equipment which is the first rotation of mechanical shafts and bearings to ensure balancing and no excessive vibration.
- HVAC testing which is test and balancing of air flows and duct work, heating and cooling, sensors and controls.

Typical Electrical Pre-Commissioning Activities includes:

- Grounding and bonding checks- confirm the integrity of the ground system and bonding system by measuring the resistance of bonds to ensure bonding to all metallic surfaces is in place.
- Cold loop checks and megger checks- confirm that all cable and conductors are terminated to the correct terminal blocks, as well megger checks apply a voltage across the cable conductor and insulation to confirm that the cable has not been damaged or punctured to degrade the dielectric properties of the cable.
- Hot loop checks- confirm calibration settings and ranges of each control loop from the HMI to the end device including all cables and instruments. This confirms that ranges and setpoints are correct for each control point.

- AC phase checks- verify the installation of each electrical phase in the proper order using a phase rotation meter.
- Transformer checks- prior to the first energization of the transformer, oil samples are taken as well as samples taken after energization. The samples are compared to see if any differences could indicate an internal problem within the transformer. Winding resistance measurements are taken as well to measure insulation resistance. Transformer ratios are measured once tap changes are set to confirm that the primary and secondary windings are correct.
- Open circuit tests- conducted to measure the no-load current losses as well as short-circuit tests performed with reduced voltage to the primary winding to measure full-load current losses. During protection relay testing, primary and secondary injections are performed on CTs and PTs to verify relay inputs are correct. During interlock verification, interlocks are verified by operating equipment without bus voltage applied, and the different operating configurations are verified to confirm that interlocks are functioning correctly before applying any bus power to the system.

Self-check-1.1

<u>Part I</u>: True or False

<u>Direction:</u> Write **True** if the statement is correct and write **False** if the statement is wrong. Write your answer on the space provided before the number.

__________ 1. Commissioning is a process that assures that a component, subsystem, or system will meet the intent of the designer and the user.

__________ 2. The correct course of action once a hazard is identified is to use control measures

__________ 3. The only purpose of commissioning is to develop a set of baseline test results for comparison in future testing to identify equipment deterioration.

__________ 4. Site acceptance testing are the standalone tests of the equipment to confirm no damage during shipping or installation.

__________ 5. The individuals who perform the acceptance tests should not be required to be certified and/or licensed for the equipment under test.

<u>Part II:</u> Identification

<u>Direction:</u> From the given alternatives write the correct answer on the space provided for each of the following questions.

Exposure	**Hazard**	**Site Integration Testing**
Factory Acceptance Testing	**Commissioning plan**	**Risk**

1. __________________ is the potential for harm, or adverse effect on an employee’s health.
2. _________________ is the testing that’s conducted by the manufacturer in the factory prior to shipping to site.
3. _____________________ occurs when a person comes into contact with a hazard.
4. _____________________ is the testing conducted in the field to confirm equipment functions as a subsystem or system.
5. __________________ is the likelihood that a hazard will cause injury or ill health to anyone at or near a workplace.

Part III: Enumeration

Direction: write or list down the following.

1. Types of commissioning

   a) ______________________________

   b) ______________________________

   c) ______________________________

   d) ______________________________

2. Three main reasons for developing commissioning plans

   a) ______________________________

   b) ______________________________

   c) ______________________________

3. The three categories of hazard control measures

   a) ______________________________

   b) ______________________________

   c) ______________________________

4. Write the procedures for commissioning of electrical equipment/system

   a) ______________________________

   b) ______________________________

   c) ______________________________

   d) ______________________________

   e) ______________________________

   f) ______________________________

   g) ______________________________

Unit Two: Commission electrical equipment/systems

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

- Safety policies and procedures
- Electrical testing criteria
- Electrical equipment/systems
- Unforeseen events
- Electrical plan and schematic diagrams
- Test data form

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:

- Follow safety policies and procedures
- Follow electrical testing criteria
- Commission electrical equipment/systems
- Respond to unforeseen events
- Record and revise/update electrical plan and schematic diagrams
- Fill out test data form

2.1. Safety policies and procedures

Series injuries to employees can result from a failure to appropriately safeguard, lockout or tagout machinery and/or equipment. Without proper machine guards, workers can suffer serious injuries to their extremities or can be pulled into a machine by their hair or by loose-fitting clothing. In addition, injuries can occur when maintenance is performed on equipment/ machinery without disabling the power or using lockout/tagout procedures.

1) Ensure that proper safety gear is used. These include safety shoes, safety helmet, safety gloves (Rubber-Electrical), Rubber mat, fire extinguishers etc.…
2) Whenever work is dine on power circuits (LT or HT), all power sources must be isolated by opening and withdrawing the circuit breakers. Earthing switches should be closed or if not, available local earthing should be done.
3) Check and double check that work is being started on the correct panel / equipment. Many accidents occur because the wrong panel / equipment is opened.
4) Tag all breakers and switches. Use padlocks wherever possible.
5) Whenever any work is delegated to another person, it should be only after the competence of the person has been ascertained.
6) Be very clear and precise when giving instructions.
7) Unauthorized personnel must be kept away from the test area. Rope off the area if necessary and erect warning signs.
8) Before starting any test, make a precise plan, including a circuit diagram for the test.
9) Be very carefully while using certain test equipment such as meggers, earth tester, multimeter and high or voltage test sets. If a cable is being tested, ensure that the other end has been secured and that a responsible person has been stationed there.
10) Similar care is to be taken when applying voltage to the low voltage side of a transformer.
11) Treat CT secondary circuits with respect. Do not open a CT secondary circuit when there is current following on the primary. Even when doing primary injection test, first injection 10% rated current on the primary and check all the secondary circuits, before going up to the rated current.

12) After megger or high voltage test on nay equipment, be sure to discharge the equipment to earth after the test, this may be by connecting an insulated wire between the equipment and ground.
13) Before any work is done a motor. ensure that the motor controller has been disconnected and tagged out.
14) When working on any equipment, whenever possible ensure that control of the associated switchgear is local e.g., when working on a motor, keep the local /Remote switch at the switch gear in local position. Control should be returned to the switchgear only after work on the equipment has been completed.
15) Always use proper tools and instruments. Avoid using line tester to check for supply voltage. Always use multimeter for safety propose. Ensure before use, that multimeter has been selected for the correct parameter and range and its lead are instead in the appropriate sockets on the meter.
16) Whenever temporary jumpers are required in testing, use jumpers of long length, so that even if you forget to remove them, they will get somebody else's attention.
17) When working on unfamiliar equipment, read the operating manual carefully before starting the work.
18) when energizing any equipment for the first time, clear off all personal from the vicinity of the equipment. Ensure that fire extinguishers are available and ready.
19) Paralleling of transformers is a potentially dangerous exercise. Do a phasing check at low voltage to ensure that voltage across the bus coupler breaker is zero when both transformers are energized.
20) When applying voltage to the secondary circuit of PTs to check the connections, be sure to isolate the PTs, by removing the control plug or secondary fuses; otherwise, the PTs will get back energized. Even if only one phase PT is being checked, it is necessary to isolate the other phases as well.
21) Before working on circuit breaker mechanism box, always first discharge the closing and tripping springs. This is done by first switching of the control power to the breaker or disconnecting its control plug, tripping the breaker (if closed), then closing it, and then tripping it again. It is very dangerous to work with either spring in charged condition.
22) Never replace a blown HRC fuse with bare wire: use new HRC fuse of proper rating.

2.2. Electrical testing criteria

The testing of electrical power system equipment involves checking the insulation adequacy, electrical properties, protection and control, operation, and other items as they relate to the overall system. Some of these checks are accomplished using de-energized component tests, instrumentation and relay operation and calibration tests, energized functional testing of control circuits, megger testing of power circuits, phase out testing of power circuits, and service testing.

Insulation testing

Insulation can either be solid, liquid, or gaseous dielectric materials that prevent the flow of electricity between points of different potential. Insulation testing is performed to determine the integrity of the insulation. This usually consists of applying a high potential voltage to the item and measuring the leakage current that may flow to ground. Excessive leakage current is an indication of dielectric breakdown and/or impending failure.

Insulation testing, the most common electrical testing performed, can be performed by applying a direct current (dc) or alternating current (ac) voltage. The type and value of the voltage determines whether the test is considered non-destructive or destructive, the higher the voltage the more destructive the test. Usually, destructive tests are only run one time in the factory to verify the initial strength of the insulation, and non-destructive tests are run as acceptance and maintenance tests to measure deterioration from the original value. Both the dc and ac tests are "go no-go" tests. In addition, the dc test can indicate the amount of deterioration and forecast the remaining time for safe operation by comparing the leakage current and test voltage to values from previous tests.

Continuity test: An electrical continuity test is the checking of an electric circuit to see if the current flows throughout the circuit.

Insulation-resistance (megger) testing. For equipment containing electronic components, megger testing must not be performed. However, this equipment should be tested according to manufacturer specifications. In an insulation-resistance test, an applied voltage, from 600 to 5000 volts, supplied from a source of constant potential, is applied across the insulation. The usual potential source is a megohmmeter, also known as a megger, either hand or power operated that indicates the insulation resistance directly on a scale calibrated in megohms.

A megohmmeter that is a hand cranked, a rectifier-type, or battery-operated instrument is suitable for testing equipment rated up to 600 volts. For equipment rated over 600 volts, use of a 1000-volt or 2500-volt motor-driven or rectifier-type megohmmeter is recommended for optimum test results.

Earth resistance test: Earth resistance is the resistance of the ground electrode that is being measured, not that of the test probe. The Test probe is a tool to use measurement of earth resistance. The Earth faults are hazardous and hence need proper earthing to prevent fault current from entering into anybody or metallic object. The purpose of earthing is to minimize the effect of transient voltage that occurred due to a strike of lightning. Four variables affect the earth resistance of a grounding system which includes:

- The composition of the soil
- The moisture content of the soil
- The temperature of the soil
- The depth of the electrode

The resistance of the earth electrode depends upon the resistivity of the soil in which the electrode is inserted. Therefore, it is crucial to measure the resistivity during the design of any earthing installations.

There are six basic test methods to measure earth resistance

- Four Point Method (Wenner Method)
- Three-terminal Method (Fall-of-potential Method / 68.1 % Method))
- Two-point Method (Dead Earth Method)
- Clamp-on test method
- Slope Method
- Star-Delta Method

Difference between Earth Resistance Tester and Megger

No.	Earth Resistance Tester	Megger
1	It measures low resistance.	It measures high resistance.
2	Cannot be used to test the quality of insulation.	Can be used to test the quality of insulation.
3	Cannot function above its specified voltage.	Can function at or above its voltage.
4	It is used to measure the resistance of earthing pit.	It is used for measuring the insulation resistance of the motor winding cable, etc.
5	Its measurements are in Ohms.	Its measurements are in Mega Ohms.

Figure 2. 1: Digital earth resistance tester

Dielectric absorption testing: In a dielectric-absorption test, a voltage supplied from a source of constant potential is applied across the insulation. The test voltage used may have to be significantly higher than the insulation-resistance test in order to obtain measurable current readings. The potential source can be either a meg-ohmmeter, as described above or a high-voltage power supply with an ammeter indicating the current being drawn by the specimen under test. The voltage is applied for an extended period of time, from 5 to 15 minutes, and periodic readings are taken of the insulation resistance or leakage current.

Unlike the insulation-resistance test, the dielectric-absorption test results are independent of the volume and the temperature of the insulation under test. For the dielectric absorption test, the values recorded at each one-minute interval are plotted on log-log paper with coordinates for resistance versus time. The slope of the resulting curve gives a good indication of the insulation condition. A good insulation system will have a slope that is a straight line increasing in respect to time. The characteristic slope of a poor insulation system will be a curve that flattens out with respect to time.

Polarization index testing: The polarization index is a specialized application of the dielectric absorption test. The index is the ratio of insulation resistance at two different times after voltage application, usually the insulation resistance at 10 minutes to the insulation resistance at 1 minute. The use of polarization-index testing is usually confined to rotating machines, cables, and transformers. A polarization index less than 1.0 indicates that the equipment needs maintenance before being placed in service. The insulation resistance is recorded after 1 minute, then again after 10 minutes. The polarization index is the quotient of the 10-minute and 1-minute readings as shown in the following equation:

$$PI = R_{10}/R_1 \text{ (dimensionless)}$$

Where:

PI = polarization index R = resistance.

High-potential testing: A high-potential test (hi-pot) consists of applying voltage across an insulation at or above the dc equivalent of the 60-Hz operating crest voltage. The dc equivalent of the 60-Hz operating crest voltage is calculated using the following equation:

$$Vac = Vdc/\sqrt{2}$$

Where:

Vdc is the equivalent dc voltage
Vac is the operating crest ac voltage

AC high-potential testing. Alternating-current high-potential tests are made at voltages above the normal system voltage for a short time, such as 1 minute. The test voltages to be used vary depending on whether the device or circuit is low or high voltage, a primary or control circuit, and whether it was tested at the factory or in the field. Manufacturers' instructions and the applicable standards should be consulted for the proper values.

Phase sequence test: Phase rotation testers are useful portable devices designed to check the direction of phase rotation in motorized machinery with three-phase supplies. These testers provide LED indication of both clockwise and anti-clockwise rotation. They are ideal for checking phase sequence in motors, pumps and air conditioning units. They can also be called *phase sequence indicators, phase sequence meters of phase sequence testers*.

Figure 2. 2: Phase sequence tester

Lock rotor test: The Blocked Rotor Test of an induction motor is similar to the short circuit test of a transformer. In this test, the shaft of the motor is locked so that it cannot move and the rotor winding is short-circuited. In the slip ring motor, the rotor winding is short-circuited through the slip rings. In the case of the cage motors, the rotor bars are permanently short-circuited. It is also known as the Locked Rotor Test.

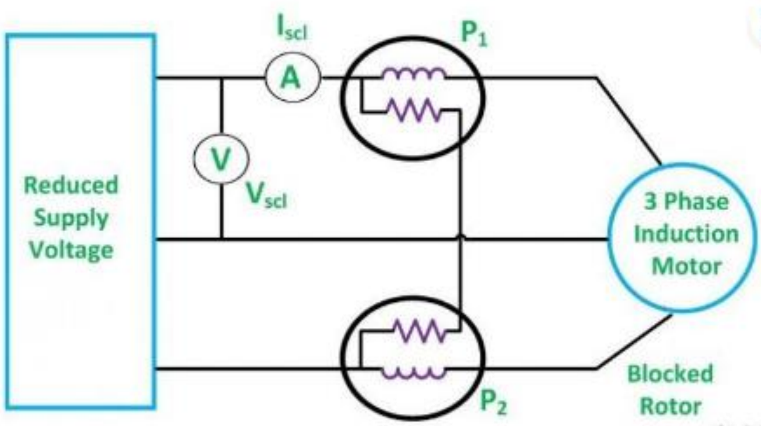

Figure 2. 3: The circuit diagram of the blocked rotor test

A reduced voltage at the reduced frequency is applied to the stator through a three-phase autotransformer so that full-load rated current flows in the stator. The following three readings are obtained from the blocked rotor test. They are as follows:

- Total power input on the short circuit P_{sc} = algebraic sum of the two wattmeter readings

The power input on the locked rotor test is equal to the sum of copper losses of the stator and the rotor for all three phases. The core and the mechanical losses are negligible as the reduced voltage is applied to the stator and, as a result, the rotation of the rotor is not allowed.

- Reading of the ammeter

$$I_{scl} = \text{short circuit line current}$$

- Reading of the voltmeter

$$V_{scl} = \text{short circuit line voltage}$$

$$P_{sc} = \sqrt{3}\, V_{scl} I_{scl} \cos\varphi_{sc}$$

This test should be performed at a reduced frequency. In order to obtain accurate results, the Blocked Rotor Test is performed at a frequency *25 percent or less than* the rated frequency.

2.3. Electrical equipment/systems

The component inspection and checks are the key to the success of any commissioning program. Each component of the system should be initially checked for damage, deterioration, and failures by a procedure using inspections and tests as defined by the specific equipment manufacturer. The equipment manuals from the manufacturer identify the minimum required receipt inspections, handling and installation procedures, drawing and wiring verification, de-energized and energized component tests, minimum testing baseline and report requirements for on-going maintenance, and requirements for repair and retesting if certain checks and tests produce unsatisfactory results

2.3.1. Transformer testing

Transformer turns-ratio and polarity tests: The turns-ratio test is used to determine the number of turns in one winding of a transformer in relation to the number of turns in the other windings of the same phase of the transformer. The polarity test determines the vectoral relationship of the various transformer windings. The tests are applicable to all power and distribution transformers. The turns-ratio test and the polarity test can be done on transformers of all sizes.

Polarity means the direction of the induced voltages in the primary and the secondary winding of the transformer. If the two transformers are connected in parallel, then the polarity should be known for the proper connection of the transformer. There are two types of polarity one is Additive, and another is Subtractive.

Additive Polarity: In additive polarity, the same terminals of the primary and the secondary windings of the transformer are connected. ***Subtractive Polarity:*** In subtractive polarity, different terminals of the primary and secondary side of the transformer is connected.

Let A_1 and A_2 be the positive and negative terminal, respectively of the primary side of the transformer and a_1, a_2 are the positive and negative terminal of the secondary side of the transformer. If A_1 is connected to a_1 and A_2 is connected to a_2 that means similar terminals of the transformer are connected, then the polarity is said to be ***additive***. If A_1 is connected to a_2 and A_2 to a_1, that means the opposite terminals are connected to each other, and thus the voltmeter will read the ***subtractive polarity***.

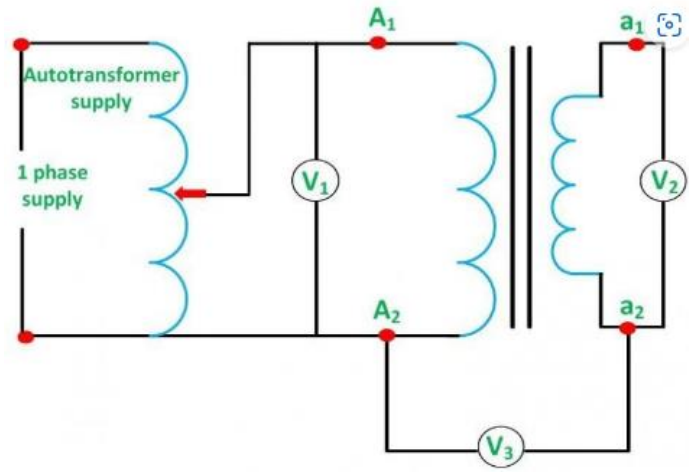

Figure 2. 4: Circuit Diagram of Polarity Test of Transformer

When the voltmeter reads the difference that is ($V_1 - V_2$), the transformer is said to be connected with opposite polarity know as subtractive polarity and when the voltmeter reads ($V_1 + V_2$), the transformer is said to have additive polarity.

Open and short circuit tests

Open and short circuit tests are performed on a transformer to determine the:

- Equivalent circuit of transformer
- Voltage regulation of transformer
- Efficiency of transformer

Open Circuit (No-Load) Test on Transformer

The open circuit test is performed to determine the *no load losses or core losses as well as the turns ratio, no load currents, magnetizing components and core loss components of the transformer*. or convenience, the supply is connected to the LV side of the transformer and the HV side of the transformer is left open. Voltmeters, ammeters and watt meter are connected as shown in the figure below.

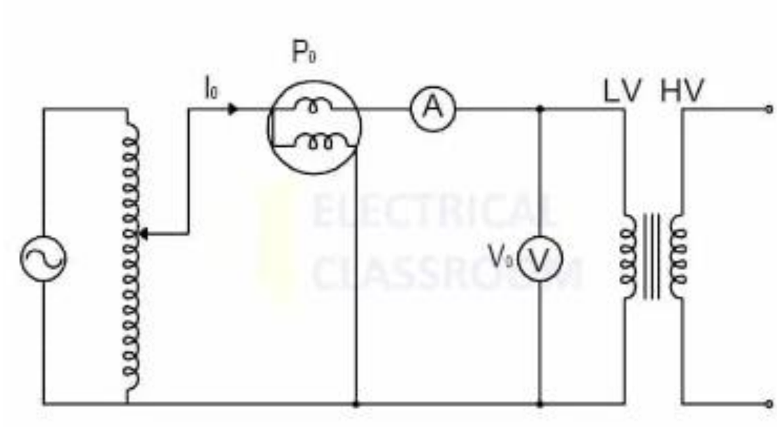

Figure 2. 5: Transformer open circuit test

Open circuit test Procedure

- Apply rated voltage to the LV side of the transformer.
- Measure the no-load current Io, power Po, and input voltage Vo.
- Measure the open-circuited HV side voltage if the transformer ratio needs to be calculated.

Calculation of core losses and magnetizing components

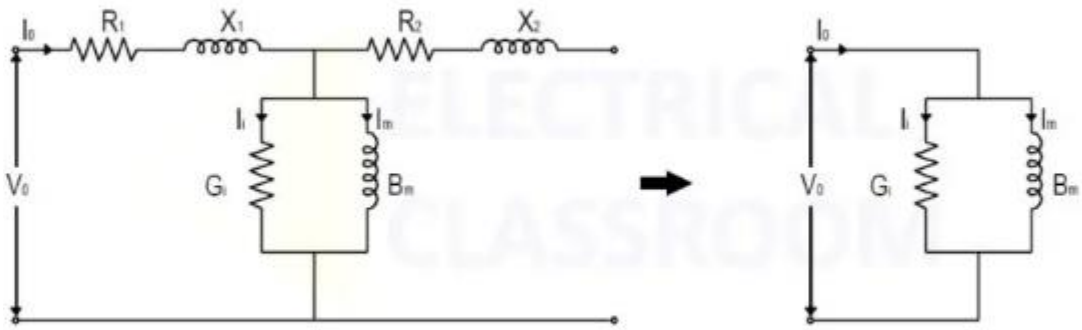

Figure 2. 6: Transformer equivalent circuit for no load test

As no load is connected to the secondary, the current flow and the losses due to winding resistance and reactance are very less and can be neglected and the circuit is simplified. Neglecting the copper loss, we calculate the core losses and the core loss components.

$$P_o = V_o.I_o.Cos\phi$$

$$I_m = I_o.Sin\phi$$

$$Cos\phi = \frac{P_o}{V_o.I_o}$$

$$I_i = I_o.Cos\phi$$

Where, I_m is the magnetizing current and I_i is the core loss component.

Core admittance, $$Y_o = G_i + jB_m = \sqrt{G_i^2 + B_m^2}$$

Also, $$Y_o = \frac{I_o}{V_o}$$ The conductivity of the core, $$G_i = \frac{P_o}{V_o^2}$$

Where Y_0 is the core admittance, G_i is the conductivity of the core, B_m is the Susceptance of the core.

Short Circuit (load) test

The purpose of conducting a short circuit test is to determine the *winding resistance, reactance, and the copper loss of the transformer*. For convenience a variable voltage source is connected to the HV side of the transformer and the LV side of the transformer is short circuited. This is because, the voltage required for short circuit test is typically 5 percent of the rated value. Since the current rating of HV is less than the LV, the current drawn at 5 percent of rated voltage of HV is low. At the same time, if we apply voltage to LV winding, the current drawn from the supply will be very high. It is difficult to arrange a low voltage – high current power source.

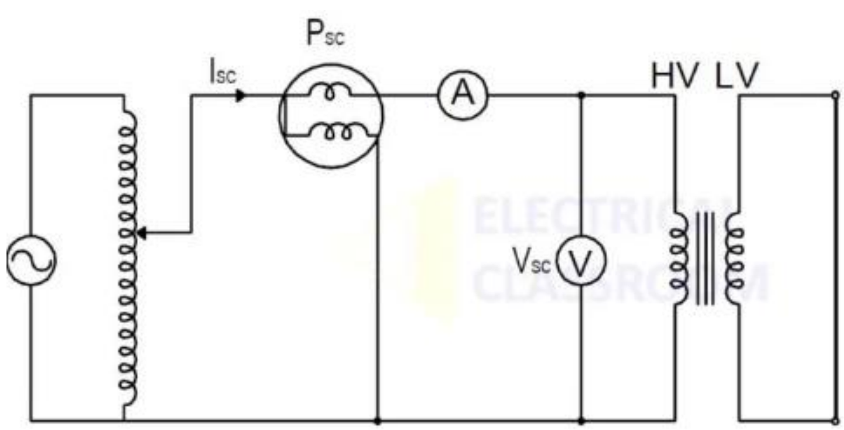

Figure 2. 7: Transformer short circuit test

Short circuit test Procedure

- Gradually raise the supply voltage from zero, until the transformer draws its rated current.
- Note down the voltmeter readings V_{sc}, wattmeter reading P_{sc}, and ammeter reading I_{sc}.

It can be noted that the applied voltage, V_{sc}, required to circulate current I_{sc} is very small compared to the rated voltage of the winding (typically 5% of rated voltage). Therefore, the excitation current required is too small and can be neglected.

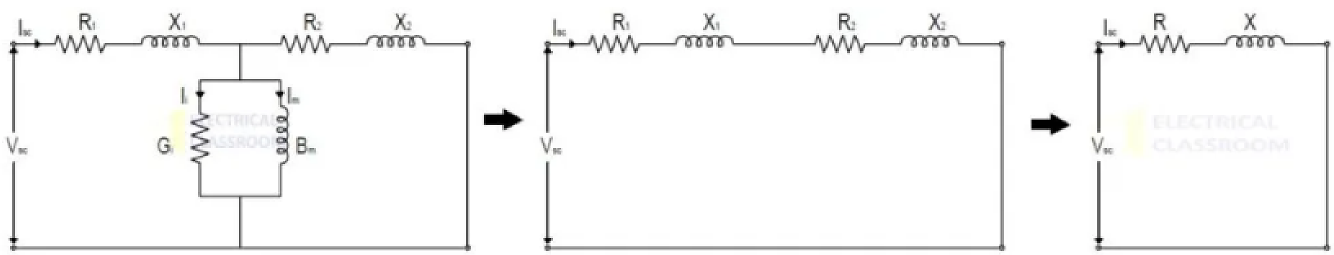

Figure 2. 8: Transformer equivalent circuit for load test

Where $R = R_1 + R_2$ and $X = X_1 + X_2$

The power input to the transformer measured by P_{sc} corresponds to copper loss. Therefore;

$$P_{sc} = P_{I^2R} \qquad V_{sc} = I_{sc}.Z$$

Where,

$$Z = R + jX = \frac{V_{sc}}{I_{sc}}$$

The resistance offered by the coil,

$$R = \frac{P_{sc}}{I_{sc}^2}$$

The Susceptance of the core,

$$X = \sqrt{Z^2 - R^2}$$

2.3.2. Generators Testing

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment.

- ***Winding resistance test.*** The main stator winding resistance is very low. A meter capable of readings in the milli-ohm range would be required. A standard VOM can be used to check for continuity, shorts or grounds. The winding resistance is measured with a dc bridge and compared with the calculated design values.
- ***DC overpotential test***. Perform a dc overpotential (hi pot) test to assess the dielectric strength of the insulation of a generator. The ac voltage used in this test is the factory test value. For stator windings this value is typically calculated to be twice the rated voltage plus 1,000. High pot each phase separately with the other two phases and the winding temperature detectors grounded. Capacitors and surge arrestors should be disconnected during this test. Measure the voltages. Now the generator can be run with no load and tested by performing the constant excitation test and the current measurements.
- ***No-load test***. This test will determine whether a problem exists in the generator or regulator system. The theory behind this test is as follows. The output voltage of a generator is dependent on its speed, design, load, and exciter input current. If the speed and exciter input are known, the output voltage at no load can be measured and compared to the design value. With the generator shut down, connect voltmeter to the generator output. Disconnect the leads at the regulator and connect a 12-volt battery capable of supplying one amp to the leads. Check to make sure that the battery is connected to the leads with the correct polarity. With no load on the generator, (main breakers open) run the generator at rated speed. Measure generator output voltage. Shut the generator down. Compare the voltage reading with design value, if they match the regulator is functioning properly.
- ***Load test.*** This test will determine whether a problem with the sequence of the loading of the generator exists. With no load on the generator, (main breaker open) run the generator at rated speed. Gradually add load as sequenced.

2.3.3. Transfer switch

The first step towards acceptance of any device is verification of nameplate data. The nameplate on all equipment shall be checked against one-lines and schematics. The transfer switch shall be checked for completeness of assembly. All equipment shall be carefully examined upon receipt to ensure that no damage has occurred during shipment such as loose parts and insulation damage. The Switch shall be checked for proper alignment and manual operation. The switch insulation resistance (phase-to-phase and phase-to-ground) shall be measured in normal and emergency positions. The wiring of the potential transformer to the control device should be checked for continuity and the control fuse should be checked to confirm size. The transfer switch should be checked for proper grounding. The timer settings should be checked against design parameters.

2.3.4. AC/DC drives

Drives are controllers used to vary the speed of a motor. Controllers are electronic devices that should never be megger tested. They typically come equipped with internal testing capabilities. Any diagnostic tests shall be performed as indicated in the manufacturer's manual. A visual inspection of the controller, enclosure, nameplates, connections, and drawings shall be performed. After removal of the controller enclosure cover, the controller shall be checked for physical damage and any debris from installation such as wire strands shall be removed using clean, dry, low-pressure air. All terminal connections shall be checked for tightness. The drive should be energized with no connection to the load and diagnostic test should be run. Motors should be tested separately as indicated in the motor paragraph.

2.3.5. Motors

A visual test of the motor shall be performed to ensure that the motor was not damaged in transit from the factory. Check that no loose items such as shaft keys, couplings, etc., are present. Check all connections for tightness and proper insulation. A mechanical test of the motor shall be performed to check that the motor is free from interference. The insulation resistance test (megger) shall be performed for motors less than or equal to 200 hp and 480V. For motors greater than or equal to 200 hp and 2400V the insulation resistance and polarization index are required.

A phase check should first be performed by momentarily energizing or "bumping" the motor to confirm the proper direction of rotation. This will confirm that the correct phase connections have been made. Once the correct phasing is confirmed, the motor is ready for energization

2.3.6. Cables Testing

For commissioning of cables, the receipt inspection and testing is performed while the cable is still on the reel. The exposed sections of the cables are visually inspected for signs of physical damage, the end caps are checked for tightness. The cable types and configuration are checked for correctness against drawings and purchasing documents. Continuity tests are performed on each conductor and the shield. For power cables, insulation resistance tests are performed between each conductor and each conductor and the shield.

2.4. Unforeseen events

Accidents, Malfunctions and Unplanned Events refers to events or upset conditions that are not part of any activity or normal operation of the Project will occur during commission process. Even with the best planning and the implementation of preventative measures, the potential exists for accidents, malfunctions or unplanned events to occur during any Project phase, and if they occur, for adverse environmental effects to result if these events are not addressed or responded to in an environmentally appropriate manner.

Many accidents, malfunctions and unplanned events are, however, preventable and can be readily addressed or prevented by good planning, design, emergency response planning, and mitigation. By identifying and assessing the potential for these events to occur

As the Project is being designed, and will be constructed and operated, according to best practice for health, safety, and environmental protection to minimize the potential environmental effects that could result from the Project, as well as those that could result from accidents, malfunctions or unplanned events. Prevention and mitigation will be accomplished by the following general principles:

- Use best management practices and technology for carrying out the Project while controlling permitted/allowable releases to the environment and consequent environmental effects;
- Incorporate safety and reliability by design, and application of principles and practices of process and mine safety management;
- Develop and apply procedures and training aimed at safe operation of the facilities that prevent or avoid the potential upsets that might lead to accidents, malfunctions or unplanned events; and
- Implement effective emergency preparedness and response

2.5. Electrical plan and schematic diagrams

Electrical drawings can represent anything from a single-line power distribution, to a power or control circuit, and are prepared using various symbols for electrical devices and their interconnections with lines representing conductors or wires used for interconnections. To read and understand electrical drawings, it is necessary to know the following:

- ➢ Symbols used for representing electrical devices

- Their interconnections, legends, terminology, and abbreviations
- Sheet numbering and column format for each sheet
- Wire and terminal numbering (an important aspect in understanding electrical drawings).

2.6. Test data form

Objectives of the commissioning process are:

- To support quality management through monitoring and checking of the installation.
- To verify system performance through testing, verification and Functional performance testing of the completed installation.
- To move the completed facility from the "static completion" state to the optimal "dynamic" operating state.

Testing forms

The test forms should contain the test procedures, and all the required Functional Performance Testing items. Electrical testing and verification forms to be completed are as follows wherever applicable, but not limited to:

- System and equipment warranty dates form.
- Switchboard test form.
- Motor control center test form.
- Transformer test form

Low voltage motor control centers (MCC): Manufacturer shall carry out the following pre-service tests and measurements after the board is energized.

- all pre-service checks, inspections and testing as recommended by the manufacturer.
- check and record nameplate data.
- check and inspect the MCC to ensure they are installed in accordance with the manufacturer's recommendations and to the Code requirements.
- check the installation is complete and is ready and safe to carry out the testing.
- check and report the MCC enclosure is suitable for the environment in which it is installed.
- check and test grounding is completed and satisfactory prior to carrying out any test.
- check and record the entire MCC is clean and free of debris before the testing.
- check the mechanical operation of the switches or breakers.

- check all connecting bolts are tightened to the correct torque values.
- Megger test
- set all protective devices to the settings as per the reviewed Coordination Study.
- check and record the size of all fused switches and fuses.
- Check, set and record the rating and setting of the overload relays.
- check all the indication lights and control switches for correct functions.
- check all control functions for proper functioning and connections.
- check all interface contacts for control and indications for proper functioning and connections.
- after the MCC is energized, check and test phase sequence and the available voltages.
- check motor running current and for correct rotation.

Sample Test form for switch board and circuit breakers

Switchboard and Circuit Breakers	Items tested /checked by Contractor	Items witnessed By project engr.
a) No visible damage to impair safety.	*Yes/No/N.A.	*Yes/No/N.A.
b) Appropriate devices provided for isolation and switching.	*Yes/No/N.A.	*Yes/No/N.A.
c) Every circuit breaker provided with a legible and durable identification label	*Yes/No/N.A.	*Yes/No/N.A.
d) An up-to-date schematic diagram displayed.	*Yes/No/N.A.	*Yes/No/N.A.
e) All accessible live parts screened with insulating plate or earthed metal	*Yes/No/N.A.	*Yes/No/N.A.
f) All exposed conductive parts effectively earthed.	*Yes/No/N.A.	*Yes/No/N.A.
g) Earthing system effectively connected.	*Yes/No/N.A.	*Yes/No/N.A.
h) Warning notice displayed at main bonding connections.	*Yes/No/N.A.	*Yes/No/N.A.
i) All protective devices are functioned properly and correctly set	*Yes/No/N.A.	*Yes/No/N.A.
j) Initial /maintenance test carried out according to relevant recognized standards and manufacturers' recommendation, where appropriate, with test reports. (Insulation resistance test, pressure test etc.)	*Yes/No/N.A.	*Yes/No/N.A.
k) Other inspection items as required by the manufacturers of related equipment are satisfactory	*Yes/No/N.A.	*Yes/No/N.A.

Self-check-2.1

Part I: True or False

Direction: Write **True** if the statement is correct and write **False** if the statement is wrong. Write your answer on the space provided before the number.

__________ 1. Transformer turn ratio determines the vectoral relationship of the various transformer windings.

__________ 2. Lock rotor test of an induction motor is similar to the short circuit test of a transformer.

__________ 3. The testing of electrical power system equipment involves checking the insulation adequacy, electrical properties, protection and control, operation, and other items as they relate to the overall system.

__________ 4. Excessive leakage current is an indication of dielectric breakdown and/or impending failure.

__________ 5. Insulation testing is performed to determine the integrity of the insulation.

Part II: Matching

Direction: match column A with column B. writes your answer on the space provided before the number.

	Column A	Column B
______	1. Earth resistance test	A. No-load test.
______	2. Phase sequence test	B. Measures high resistance.
______	3. Short circuit test	C. Used to check the direction of phase rotation
______	4. Open circuit test	D. Measures low resistance.
______	5. Megger test	E. Load test.
		F. Used to check polarity of a machine
		G. Voltage on generators

Part III: Enumeration

Direction: write or list down the following.

1. Factors that affect the earth resistance of a grounding system
   a) ____________________________
   b) ____________________________

c) ______________________________
d) ______________________________

2. Open and short circuit tests are performed on a transformer to determine
   a) ______________________________
   b) ______________________________
   c) ______________________________
3. Objectives of commissioning process
   a) ______________________________
   b) ______________________________
   c) ______________________________

Operation sheet 2.1: Transformer Polarity test

- **Operation title: Polarity test**
- **Purpose:** To identify and measure the polarities of Transformer
- **Instruction:** Using the figure below and given equipment's identify and measure the polarities of Transformer. You have given 45 minutes for the task.

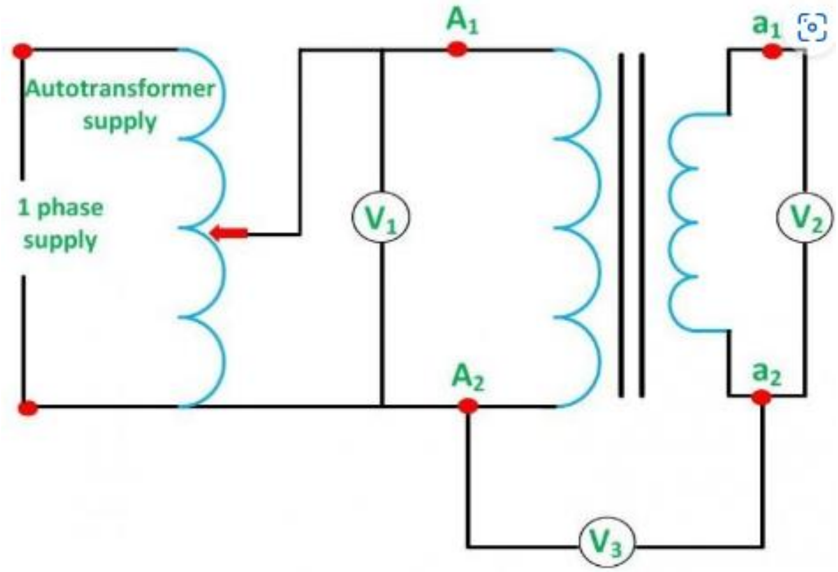

Figure 2. 9: figure given for operation sheet 2.1

- **Tools and equipment:**
  - Digital multimeter
  - Screw driver
  - 2.5 mm^2 flexible wire
  - Autotransformer
  - Stepdown transformer
- **Steps in doing the task**
  1. Steps to Perform Polarity Test
  2. Connect the circuit as shown in the above circuit diagram figure and set the autotransformer to zero position.
  3. Switch on the single-phase supply
  4. Record the values of the voltages as shown by the voltmeter V1, V2 and V3.

5. If the reading of the V3 shows the addition of the value of V1 and V2 that is V3 = V1+V2 the transformer is said to be connected in additive polarity.
6. If the reading of the V3 is the subtraction of the readings of V1 and V2, then the transformer is said to be connected in subtractive or negative polarity.
7. Complete Your work by confirming the recorded measurement

- **Quality Criteria:** use VOM with ±0.5 accuracy
- **Precautions:** use PPE.

Operation sheet 2.2: Earth Resistance Test

Operation title: Four-point method (Wenner Method)

- **Purpose:** To measure the soil resistivity

Instruction: Using the figure below and given equipment's measure the resistivity of soil. You have given 1 hour for the task.

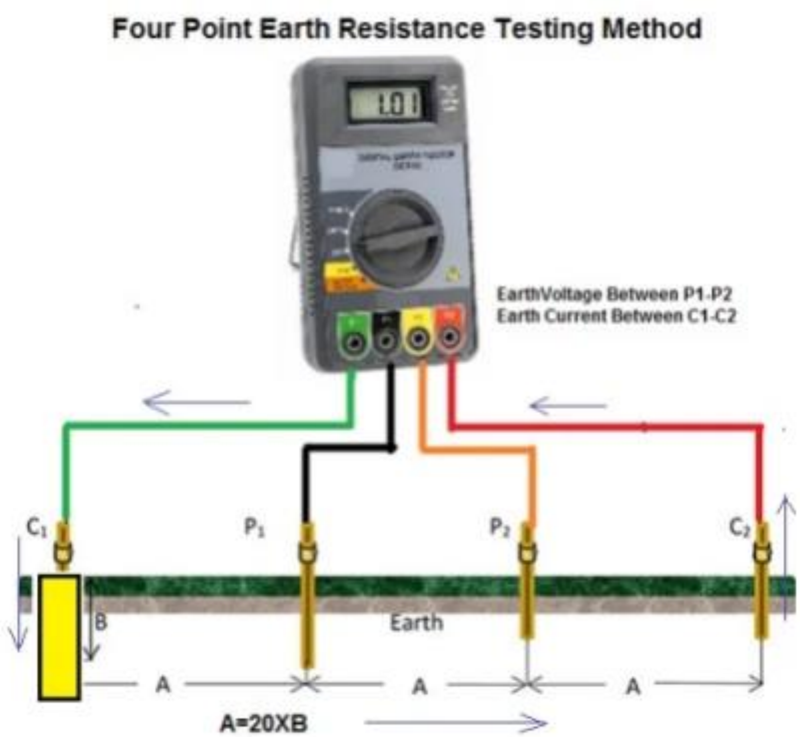

Figure 2. 10: Figure given for operation sheet 2.2

- **Tools and equipment:**
  - Earth Tester (4 Terminal)
  - 4 No's of Electrodes (Spike)

- 4 No's of Insulated Wires
- Hammer
- Measuring Tap

Connections:

- First, isolate the grounding electrode under measurement by disconnecting it from the rest of the system.
- Earth tester set has four terminals, two current terminals marked C1 and C2 and two potential terminals marked P1 and P2.
- P1 = Green lead, C1 = Black lead, P2 = Yellow lead, C2 = Red lead
- In this method, four small-sized electrodes are driven into the soil at the same depth and equal distance from one another in a straight line.
- The distance between earth electrodes should be at least 20 times greater than the electrode depth in ground.
- Example, if the depth of each earth electrode is 1 foot then the distance between electrodes is greater than 20 feet.
- The earth electrode under measurement is connected to C1 Terminal of Earth Tester.
- Drive another potential Earth terminal (P1) at depth of 6 to 12 inches from some distance at C1 Earth Electrode and connect to P1 Terminal of Earth Tester by insulted wire.
- Drive another potential Earth terminal (P2) at depth of 6 to 12 inches from some distance at P1 Earth Electrode and connect to P2 Terminal of Earth Tester by insulted wire.
- Drive another Current Electrode (C2) at depth of 6 to 12 inches from some distance at P2 Earth Electrode and connect to C2 Terminal of Earth Tester by insulted wire.
- Connect the ground tester as shown in the picture.

Steps in doing the task

Step 1: Press START and read out the resistance value. This is the actual value of the ground Resistance of the electrode under test.

Step 2: Record the reading on the Field Sheet at the appropriate location. If the reading is not stable or displays an error indication, double check the connections. For some meters, the RANGE and TEST CURRENT settings may be changed until a combination that provides a stable reading without error indications is reached.

Step 3: The Earthing Tester has basically Constant Current generator which injects current into the earth between the two current terminals C1 (E) and C2 (H).

Step 4: The potential probes P1 & P2 detect the voltage ΔV (a function of the resistance) due to the current injected in the earth by the current terminals C1 & C2.

Step 5: The test set measures both the current and the voltage and internally calculates and then displays the resistance. R=V/I

Step 6: If this ground electrode is in parallel or series with other ground rods, the resistance value is the total value of all resistances.

Step 7: Ground resistance measurements are often corrupted by the existence of ground currents and their harmonics. To prevent this it is advisable to use Automatic Frequency Control (AFC) System. This automatically selects the testing frequency with the least amount of noise enabling you to get a clear reading.

Step 8: Repeat above steps by increasing spacing between each electrode at equal distance and measure earth resistance value.

Step 9: Average the all readings

Step 10: An effective way of decreasing the electrode resistance to ground is by pouring water around it. The addition of moisture is insignificant for the reading; it will only achieve a better electrical connection and will not influence the overall results. Also a longer probe or multiple probes (within a short distance) may help.

Lap Test-1

- Task-1: Perform continuity, insulation resistance and ground test on Transformer.
- Task-2: Perform open and short test on transformer.
- Task-3: Perform continuity, insulation resistance, ground test and phase sequence test on three phase Motor and Generator
- Task-4: Perform continuity, insulation resistance, ground test and No-load test on Generators
- Task-4: Record measurements using standard procedure

Unit Three: Documentation of commissioning activities

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

- Inspection
- Tools/equipment
- Commissioning report
- Datasheet for newly installed system
- Orientation and technical assistance

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:

- Inspect electrical equipment/system
- Clean and check tools/equipment
- Prepare commissioning report
- Monitor datasheet for newly installed system
- Provide orientation and technical assistance

3.1. Inspection

The fundamental reason for inspecting and testing an electrical installation is to determine whether new installation work is safe to be put into service, or an existing installation is safe to remain in service until the next inspection is due. The inspector carrying out the inspection and testing of any electrical installation must have a sound knowledge and experience relevant to the nature of the installation being inspected and tested, and to the technical standards.

Electrical testing involves some degree of hazard and before the commencement of any tests, the inspector must take steps to ensure that they work in a safe manner and also consider the safety of others when the test takes place. Before any equipment is to be allowed for it must meet the specific safety standard.

Enclosure:

- No evidence of hazard to operator
- No evidence of damage
- Appropriate material
- Protects contents from operating environment

Power Source – Direct wired into facility covered

- Proper voltage and current rating for wiring method
- Suitable for permanent installation by a qualified person
- Proper loading and overcurrent protection in branch circuit

Grounding

- Equipment grounding conductor included in the circuit.
- Equipment grounding conductor properly terminated.
- All non- current carrying exposed metal surfaces properly bonded.

Foreign power supplies and equipment

- The connection to facility power is made with appropriate adapters
- Correct wire ampacity for use in the United States

- Is the voltage, frequency, and phasing correct for application

Marking Requirements

- Equipment marked with potential hazards (stored energy, open buss, etc.)
- The voltage, current, and frequency properly marked on equipment.
- The make, model, and drawing number properly marked on equipment.
- Supporting document supplied for inspection.

Internal Wiring

- The Polarity correct such that the hot conductor(s) is interrupted by the breaker or fuse.
    - Mains higher than 220 VAC require a breaker or fuse on each hot conductor.
- Multi- phase equipment has the phasing correct.
- The equipment grounding conductor properly attached to a paint free surface using correct fasteners.
- For different voltages that are being used the separation is adequate for the application.
- The wiring terminals the correct size for the conductors.
- Is the wire sized adequately for the load?
- Clearance/Creep distances for high voltage equipment adequate.
- All cables installed in neat workman- like manner.
- All conductors protected from sharp edges, and are wire bends gentle.
- Equipment that generates heat has to have sufficient room for air circulation and/or cooling.
- Equipment that has any stored energy (capacitor) needs an automatic discharge for any stored energy

Test performed

- Actual ohm's readings are required and documented for all continuity checks and verifications.
- Field installed mains AC power plug will be tested to ensure wires properly phased and connections tightened. .

3.2. Cleaning and checking tools/equipment

Tools and equipment require proper care and maintenance, not only for longevity but also to remain useful and safe for the task at hand. Here are some care and maintenance practices for tools and equipment.

Proper storage

Proper storage entails shielding tools from harsh weather conditions, damage and theft. It is particularly crucial for metallic tools to be kept away from moisture to avoid rusting. Having a cabinet where these tools and equipment are stored will be vital to ensuring a secure storage area. Also, greasing, lubricating or oiling metallic tools and equipment is essential to prevent rust from forming while keeping the tools in the best condition for future tasks.

Using tools and equipment for their right task

Using a tool for the task it is intended helps to keep it in its best shape. This reduces unnecessary damage and protects the user. It is also important to check whether the tools are in the right condition before using them.

Cleaning after use

Storing dirty tools without cleaning them can cause them to deteriorate. Routine cleaning reduces the chances of rust and can reduce the rate of wear and tear.

Inspect tools regularly

Regular inspection of tools is beneficial since it provides an opportunity to see if tools may need repair or replacing. Inspections can help to prevent a situation where a last-minute trip to the store to purchase a new tool or spare parts delays a project. It is recommended to keep checking your tools at regular intervals. If there is any damage, repair them or replace them.

- ✓ *Cracked or loose handles:* Damaged wooden handle is prone to break while in use causing injuries. Hence, it is required to replace them. However, if the handle is not partially damaged, sand it down. Sand till it gets smooth enough for further use. Finish the process by coating it with linseed oil.
- ✓ *Mushroomed heads on wedges and chisels:* Mushroom head implies that the striking edge has become malformed through use. In this situation, the head of the tool can shatter on impact. To solve this problem, keep it sharpened. Do it in every six months for better results.

Read and follow manuals

The manuals that come with equipment, especially power tools, have important and useful guidelines. They instruct and advise on the best way to keep equipment in optimal condition.

3.3. Commissioning report

Contractor shall include the commissioning plan and shall schedule for all tests and equipment start-up in the construction schedule. Testing forms and reports associated with the electrical systems shall be directed to the Owner, to the Consultant, and to the Commissioning Authority.

Forms and reports to be issued shall include:

- Shop drawings, issued and accepted.
- Equipment testing and verification forms.
- Testing forms.
- Reports resulting from tests.
- Testing schedule.

3.4. Datasheet for newly installed system

Equipment verification: The Contractor shall complete the equipment verification forms for each piece of equipment. The forms shall be included in the commissioners System Description Manual. The equipment data shall include, but is not limited to:

- Manufacturer’s name, address and telephone number.
- Distributors’ name, address and telephone number.
- Make, model number and serial number, year built.
- Voltage, ampere rating, fault rating, frequency, breaker size, fuse size, overload size.
- Equipment enclosure type.
- Any other special characteristics

3.5. Orientation and technical assistance

Technical assistance is understood as the transfer, adaptation, mobilization and utilization of services, skills, knowledges and technology. Training and instruction shall be provided by qualified technicians and shall be conducted in a classroom setting at the equipment or system. Each session shall be structured to cover:

- Operating and Maintenance Manual.
- Operating procedures.
- Maintenance procedures.

- Trouble-shooting procedures.

The training and instruction requirement for the electrical system shall include a walk-through of the building by the Contractor. During the walk-through the Contractor shall:

- Identify, describe and explain the function of the equipment.
- Detail explanation of the operation, including mechanical operation and electrical operation of the equipment; procedures and sequence of operation; procedures of switching, isolation and emergency switching.
- Detail explanation of the maintenance of the equipment including the procedures and items to check for.
- Safety procedures to be implemented before the maintenance.
- Interlock, interface and control with other equipment.
- Fault finding procedures.
- When each session has been completed, the Commissioning Authority shall sign to certify completion.

Self-check-3.1

Part I: True or False

Direction: Write **True** if the statement is correct and write **False** if the statement is wrong. Write your answer on the space provided before the number.

__________ 1) The fundamental reason for inspecting and testing an electrical installation is to determine whether new installation work is safe to be put into service.

__________ 2) Training and instruction shall be provided by qualified technicians and shall be conducted in a classroom setting at the equipment or system.

__________ 3) Before any equipment is to be allowed to be used it is not necessary to meet the specific safety standard.

Part II: Matching

Direction: match column A with column B. writes your answer on the space provided before the number.

	Column A	Column B
______	1. Earth resistance test	a) No-load test.
______	2. Phase sequence test	b) Measures high resistance.
______	3. Short circuit test	c) Used to check the direction of phase rotation
______	4. Open circuit test	d) Measures low resistance.
______	5. Megger test	e) Load test.

Part III: Enumeration

Direction: write or list down the following.

1. Forms and reports to be issued shall include:

   a) ____________________________

   b) ____________________________

   c) ____________________________

   d) ____________________________

Reference

Books

- Machinery and Equipment Safety– an introduction 1st edition Department of Consumer and employment protection. Government of Western Australia
- Commissioning Major Electrical Systems Instructor: George E. Thomas, PE 2013 5272 Meadow Estates Drive, Fairfax, VA 22030-6658, Phone & Fax: 703-988-0088.
- Testing and Commissioning Procedure for Electrical Installation, 2007 edition. Architectural Services Department the Government of The Hong Kong Special Administrative Region.
- Design and Commissioning Report, Rev. 1 Chief of Nuclear Safety (CNS) , Office of Environmental Management July 2017.

Internet sources

- https://orm.uottawa.ca/sites/orm.uottawa.ca/files/hazard-identification-risk-assessment.pdf
- https://www.osha.gov/sites/default/files/2018-12/fy11_sh-22318-11_Mod_3_ParticipantManual.pdf
- https://electricalnotes.wordpress.com/2020/03/01/methods-of-earth-resistance-testing-part-2/
- https://axis-india.com/what-is-earth-resistance-how-to-measure-it/
- https://www.electricaltechnology.org/2022/03/polarity-test-of-transformer.html
- https://circuitglobe.com/polarity-test-of-transformer.html
- https://www.electrical4u.com/open-and-short-circuit-test-on-transformer/
- https://circuitglobe.com/open-circuit-and-short-circuit-test-on-transformer.html
- https://www.electricalclassroom.com/open-circuit-test-short-circuit-test/
- https://www.designingbuildings.co.uk/wiki/Tool_and_equipment_care_and_maintenance
- https://www.moglix.com/blog/tips-to-clean-maintain-electronic-tools/

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