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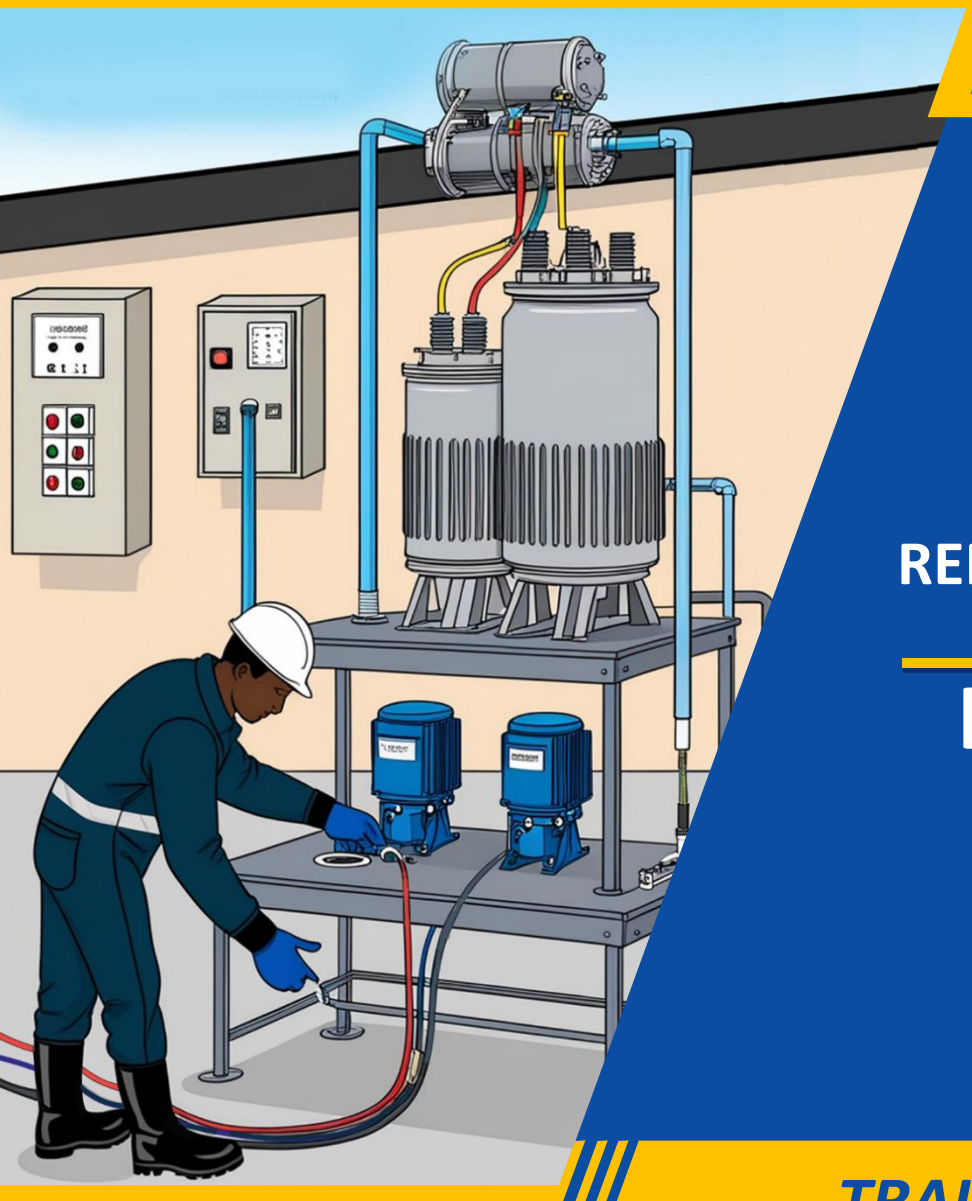

RENAI501

RENEWABLE ENERGY

Hydropower Plant Auxiliaries Installation

TRAINEE'S MANUAL

October, 2024

HYDROPOWER PLANT AUXILIARIES INSTALLATION

KOICA Korea International Cooperation Agency

TQUM TVET Quality Management Project

2024

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TABLE OF CONTENT

ACRONYMS

ACB: Air Circuit Breakers

AF: Air Force

AN: Air Natural

AVR: Automatic Voltage Regulator

CBT/A: Competency Based Training/Assessment

HMI: Human-Machine Interface

HPP: Hydropower plant

KOICA: Korean International Cooperation Agency

OCB: Oil Circuit Breakers

OFAF: Oil Force Air Force

OFWF: Oil Force Water Force

ONAF: Oil Natural Air Force

ONAN: Oil Natural Air Natural

ONWF: Oil Natural Water Force

OPC: Open Platform Communications

P&ID: Piping and Instrumentation Diagram

PLC: Programmable Logic Controller

PPE: Personal Protective Equipment

RTB: Rwanda TVET Board

SCADA: Supervisory Control and Data Acquisition

SF6: Sulphur Hexafluoride

SLD: Single Line Diagram

TQUM: TVET Quality Management Project

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in Renewable Energy specifically for the module of **"Hydropower Plant Auxiliaries Installation".** Trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies. The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

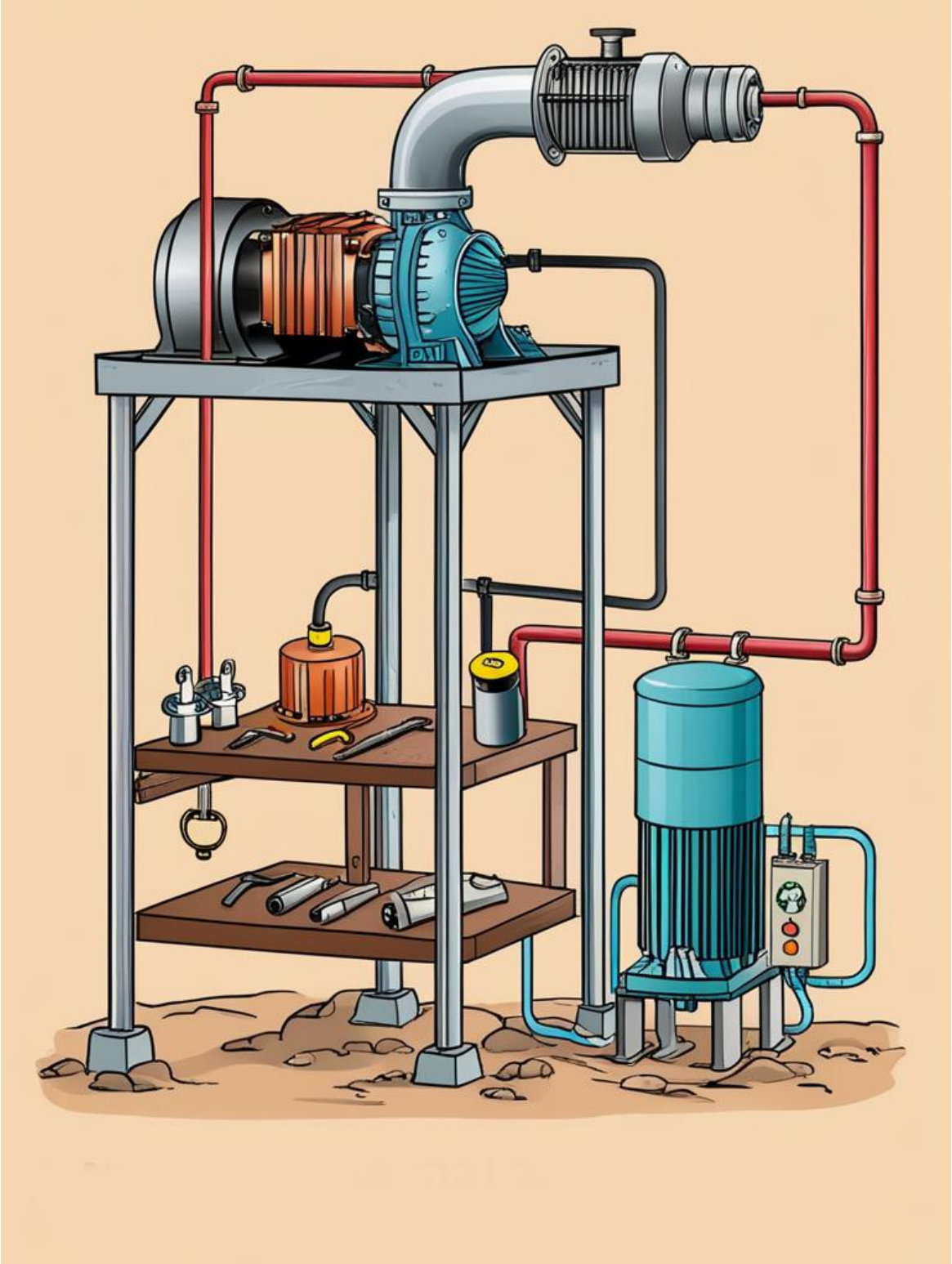
As a trainee, you will start by addressing questions related to the activities, which are designed to foster critical thinking and guide you towards practical applications in the labor market. The manual also provides essential information, including learning hours, required materials, and key tasks to complete throughout the learning process.

All activities included in this training manual are designed to facilitate both individual and group work. After completing the activities, you will conduct a formative assessment, referred to as the end learning outcome assessment. Ensure that you thoroughly review the key readings and the 'Points to Remember' section.

MODULE CODE AND TITLE: HYDROPOWER PLANT AUXILIARIES INSTALLATION

Learning Outcome 1: Perform preliminary activities of Hydropower Plant auxiliaries' installation
Learning Outcome 2: Fix Hydropower Plant auxiliaries
Learning Outcome 3: Connect Hydro power plant auxiliaries

Learning Outcome 1: Perform preliminary activities of Hydropower Plant auxiliaries' installation



Indicative contents
1.1. Identification of powerhouse auxiliaries **1.2. Interpretation of power plants auxiliaries' diagrams** **1.3. Selection of Tools, materials and equipment** **1.4. Site preparation**

Key Competencies for Learning Outcome 1 : Perform preliminary activities of Hydropower Plant auxiliaries' installation

Knowledge	Skills	Attitudes
• Identification of powerhouse auxiliaries • Description of power plants auxiliaries' diagrams interpretation • Description of Tools, materials and equipment • Description of site preparation	• Selecting of Tools, materials and equipment • Preparing the site	• Being careful while selecting tools, materials and equipment used in hydropower plant auxiliaries • Paying attention while preparing the site to minimize accidents that may occur

Duration: 25 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify correctly powerhouse auxiliaries as used in hydropower plant
2. Interpret properly power plants auxiliaries' diagrams in line with powerhouse auxiliaries to be installed
3. Describe effectively tools, materials and equipment used while installing powerhouse auxiliaries as used in hydropower plant
4. Select correctly Tools, materials and equipment based on installation to be performed
5. Prepare properly the workplace according to the workplace preparation policy and procedures

Resources

Equipment	Tools	Materials
• Multimeter • Fire extinguisher, • PPE, • Computer, • Projector, • Drilling machine • wattmeter • Electrical screw-driver • Electric grinder • Clamp-on ammeter • Ladder	• Screw driver kit • Spanners kit • Plier's kit • Electrician knife • Hacksaw • Spirit level • Measurement tape • Electromechanical tool kit.	• Electric cable • Junction box • Lamps • Earth wire • Socket plug • Lamp holder • Mild steel tube • Communication cables.

Indicative content 1.1: Identification of Power House Auxiliaries

Duration: 10hrs

Theoretical Activity 1.1.1: Description of governing system

Tasks:

1: Answer the following questions related to the description of governing system:

i. What do you understand by term governing system used at hydropower plant?

ii. What are the elements of governing system used at hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

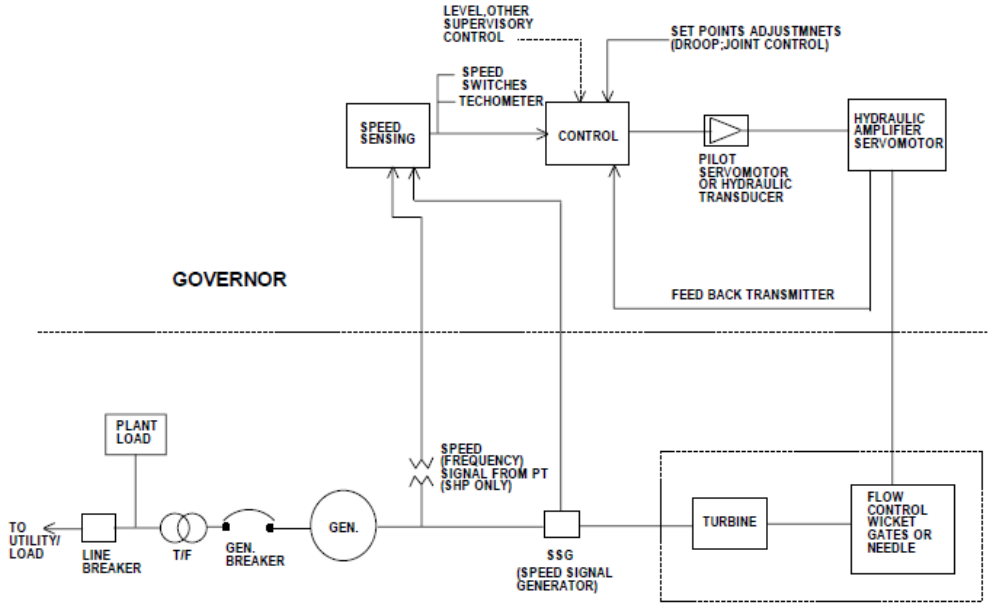
4: For more clarification, read the key readings 1.1.1

Key readings 1.1.1. Description of governing system

- **Governing system**

Definition of governing system

This is a system that controls the water turbine's speed and output by adjusting the flow of water. This is crucial for maintaining efficient and stable operation.



Governing System – Block Diagram (Typical)

Components of the Water Turbine Governing System

- ✓ **Servomotors**
  - **Function**: Adjusts the position of the turbine's guide vanes or wicket gates based on feedback from the sensing system.
  - **Characteristics**: Equipped with feedback mechanisms to ensure precise control over the turbine's speed and load.
- ✓ **Sensing System**
  - **Function**: Monitors real-time parameters such as turbine speed, water flow, and pressure.
  - **Types of Sensors**: Speed sensors, pressure sensors, flow meters.
- ✓ **Controller**
  - **Function**: Receives data from the sensing system and processes it to determine necessary adjustments. It sends commands to servomotors to regulate turbine speed and output.
  - **Types**: Can be digital (PLC-based) or analog, depending on the complexity of the system.
- ✓ **Actuator**
  - **Function**: Converts the control signals from the controller into physical adjustments, such as moving the guide vanes or adjusting the turbine's flow gates.
  - **Types**: Hydraulic or electric actuators, depending on the design of the turbine system.

✓ **Guide Vane (Wicket Gate)**

- **Function**: Directs and controls the flow of water into the turbine. Adjusting the angle of the guide vanes helps control the turbine's speed and load.
- **Operation**: Controlled by servomotors and actuators to optimize performance based on the controller's commands.

Importance of governing system

- ❖ Proper regulation of turbine speed and load ensures that the system operates efficiently, maximizing energy output.
- ❖ Maintaining consistent turbine speed helps stabilize the power grid and ensures reliable electricity generation.
- ❖ Accurate control and adjustment reduce wear and tear on the turbine, extending its operational life and reducing maintenance costs.

Theoretical Activity 1.1.2. Description of excitation system

Tasks:

1: Answer the following questions related to the description of excitation system:

i. What do you understand by term excitation system used at hydropower plant?

ii. What are the elements of excitation system used at hydropower plant?

2: Write the findings on paper, flip charts.

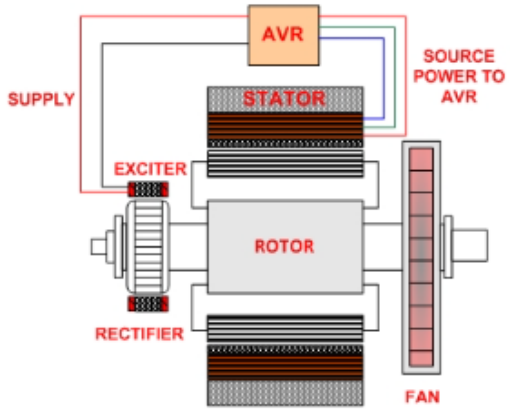
3: Present the findings/answers to the whole class.

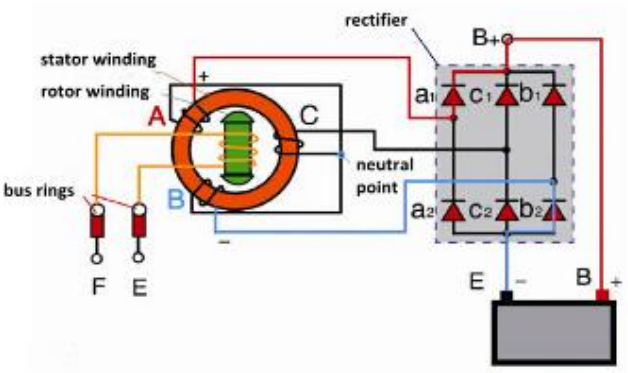
4: For more clarification, read the key readings 1.1.2

Key readings 1.1.2. Description of Excitation System

- **Excitation System**

This is the system for generating and maintaining the magnetic field in the generator's rotor. This system ensures the generator produces the required electrical output and maintains voltage stability.





Components of the Excitation System

- ✓ **Exciter**
  - **Function**: The exciter is a small generator that supplies the necessary direct current (DC) to the rotor windings of the main generator, creating the magnetic field required for electricity generation.
  - **Types**: Can be either static (using semiconductor devices) or rotating (a small generator mounted on the same shaft as the main generator).

- ✓ **Automatic Voltage Regulator (AVR)**
  - **Function**: The AVR automatically adjusts the excitation current to maintain a constant output voltage from the generator, despite variations in load or operational conditions.
  - **Operation**: Monitors the generator's output voltage and provides feedback to the exciter to increase or decrease the excitation current as needed.
- ✓ **Brushes or Slip Ring**
  - **Function**: These components are used to conduct electrical current between the stationary and rotating parts of the generator.
  - **Brushes**: Provide a physical contact point for transferring current to the rotating rotor windings.
  - **Slip Ring**: A rotary electrical connector that allows for the transfer of

electrical signals between stationary and rotating parts of the generator.

✓ **Battery Bank**

- **Function**: Supplies backup power to the excitation system, ensuring it remains operational during start up or in case of a power failure.
- **Role**: Provides the initial excitation current needed to start the generator and supports the excitation system's operation in case of a sudden loss of external power.

Importance of excitation System

- ❖ Proper excitation ensures that the generator operates at peak efficiency, optimizing energy production.
- ❖ Consistent voltage regulation helps stabilize the power grid and maintain the quality of the electrical supply.
- ❖ Backup power from the battery bank ensures uninterrupted operation of the excitation system, even during power outages or system failures.

Theoretical Activity 1.1.3. Description of units control system

Tasks:

1: Answer the following questions related to the description of units control system.

i. What do you understand by term units control system used at hydropower plant?

ii. What are the elements of units control system used at hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.1.3

Key readings 1.1.3. Description of units Control System

- **Units control system**

In hydropower plant; the units control system is responsible for managing the operation of individual generating units to ensure optimal performance, synchronization with the grid, and effective communication between components.

Components of the Units Control System

- ✓ **Synchronization System**
  - **Function**: Ensures that multiple generators or power sources are correctly aligned in phase, voltage, and frequency before connecting to the power grid or operating in parallel.
  - **Operation**: Monitors the electrical characteristics of each unit and adjusts their output to match the grid's parameters. It helps in smooth integration of power sources into the grid and prevents potential disturbances.
- ✓ **Speed Sensor**
  - **Function**: Measures the rotational speed of the turbine or generator.
  - **Operation**: Provides real-time data on the turbine's or generator's speed to the control system. This information is crucial for adjusting the turbine's flow and maintaining stable generator operation.
- ✓ **Communication System**
  - **Function**: Facilitates the exchange of information between different components of the control system, including sensors, controllers, and other operational systems.
  - **Operation**: Ensures that data from sensors and control commands are transmitted effectively throughout the plant. It supports real-time monitoring and control, enabling prompt responses to operational changes or issues.

Importance of the Units Control System

- ❖ Proper synchronization and speed control optimize the performance of each generating unit, enhancing overall plant efficiency.
- ❖ Accurate synchronization helps prevent electrical disturbances and ensures a stable power supply to the grid.
- ❖ Effective communication and data exchange enable real-time monitoring and rapid response to operational changes or issues, improving plant reliability and

performance.

Theoretical Activity 1.1.4: Description of common control system

Tasks:

1: Answer the following questions related to the description of common control system:

i. What do you understand by term common control system used at hydropower plant?

ii. What are the elements of common control system used at hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.1.4

Key readings 1.1.4.: Description of common Control System

- **Common Control System**

The common control system in a hydropower plant ***is designed to integrate various control and monitoring functions into a cohesive system***. It ensures efficient operation, seamless communication, and effective interaction between operators and the plant's systems.

Components of the common control system

✓ **Communication Interface:** Facilitates the exchange of data and control signals between different systems, devices, and components within the plant.

Characteristics

- **Data Transmission**: Handles the transfer of operational data, status updates, and control commands.
- **Protocols**: Utilizes standard communication protocols (e.g., Modbus, OPC, Ethernet) to ensure compatibility and reliability.
- **Integration**: Connects various subsystems such as SCADA, PLCs, sensors, and control units, allowing for coordinated operation and monitoring.

✓ **Human-Machine Interface (HMI):** Provides operators with a visual and interactive interface to monitor, control, and manage the hydropower plant's operations.

Characteristics:

- **Graphical Display**: Features dashboards, charts, and graphical representations of the plant's status, including real-time data on turbines, generators, and other critical components.
- **Control Features**: Allows operators to input commands, adjust settings, and respond to alarms or notifications.
- **User Interaction**: Designed for ease of use, with intuitive controls and user-friendly layouts to support efficient decision-making and operational management.

Working Principle of the Common Control System

- **Data Collection**: Sensors and control systems collect data on various operational parameters.
- **Communication**: The communication interface transmits this data to central control systems and other relevant subsystems, ensuring that information is accurately shared and up-to-date.
- **HMI Display**: The HMI receives data from the communication interface and presents it to operators in a comprehensible format, enabling real-time monitoring and control.
- **Operator Actions**: Operators use the HMI to monitor plant performance, make adjustments, and respond to alerts based on the information displayed.

Importance of the Common Control System

- Streamlines the management of plant operations by integrating data and control functions into a cohesive system.
- Enhances visibility into plant performance and operational status through graphical displays and real-time data.
- Empowers operators to efficiently manage and adjust plant operations, improving overall plant efficiency and responsiveness.
- Ensures reliable and effective data exchange between various components and systems, supporting coordinated and informed decision-making.

Theoretical Activity 1.1.5: Description of protection system

Tasks:

1: Answer the following questions related to the description of protection system.

i. What do you understand by term protection system used at hydropower plant?
ii. What are the elements of protection system used at hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.1.5

Key readings 1.1.5. Description of Protection System

- **Protection system**

The protection system in a hydropower plant ***is designed to safeguard the plant's equipment and ensure safe and reliable operation.*** It detects and responds to abnormal conditions such as faults, overloads, and other issues that could damage equipment or disrupt operations.

Components of the protection system and their functions

- ✓ **Current Protection Relay:** Monitors electrical currents in the system and detects abnormal current levels that could indicate faults or overloads. It trips the circuit breaker to isolate the faulted section and prevent damage to equipment.
- ✓ **Voltage Protection Relay:** Monitors voltage levels and protects against deviations that could harm the equipment. It triggers corrective actions or alarms if voltage levels exceed or fall below predefined thresholds.
- ✓ **Frequency Protection Relay:** Ensures the generator operates within its specified frequency range. It detects frequency deviations and initiates protective actions if the frequency falls outside the acceptable range.
- ✓ **Overload Protection Relay:** It protects equipment from damage due to excessive load conditions. It monitors the load and disconnects the affected circuit if an overload condition is detected.
- ✓ **Reverse Power Protection Relay:** Prevents reverse power flow, which can occur if a generator or turbine starts supplying power back into the system. It trips the circuit breaker to protect equipment from potential damage caused by reverse power flow.

- ✓ **Temperature Sensors:** It monitors the temperature of critical components such as bearings, windings, and transformers. It provides data to the protection system to prevent overheating and potential damage.
- ✓ **Differential Relay:** It detects differences in current between two points in the system, indicating possible faults. It isolates the faulted section by tripping the circuit breaker if a differential current is detected.
- ✓ **Circuit Breaker:** Its automatically disconnects the electrical circuit in the event of a fault or abnormal condition. It is operated by relays to isolate faulted sections and protect the system from damage.
- ✓ **Ground Fault Protection Relay:** Detects ground faults that could cause safety hazards or equipment damage. It trips the circuit breaker to isolate the faulted section and prevent further issues.
- ✓ **Voltage and Current Transformer:** It measures and steps down voltage and current levels for monitoring and protection purposes. It provides accurate readings of electrical parameters for use by relays and the protection system.

Importance of the Protection System

- ❖ Protects critical equipment from damage due to faults, overloads, and other abnormal conditions.
- ❖ Maintains the stability and reliability of the power generation system by isolating faults and minimizing disruptions.
- ❖ Ensures the safety of personnel and equipment by promptly addressing hazardous conditions and preventing accidents.

Theoretical Activity 1.1.6: Description of SCADA system

Tasks:

1: Answer the following questions related to the description of SCADA system.

i. What do you understand by term SCADA system used at hydropower plant?
ii. What are the main parts of SCADA system used at hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

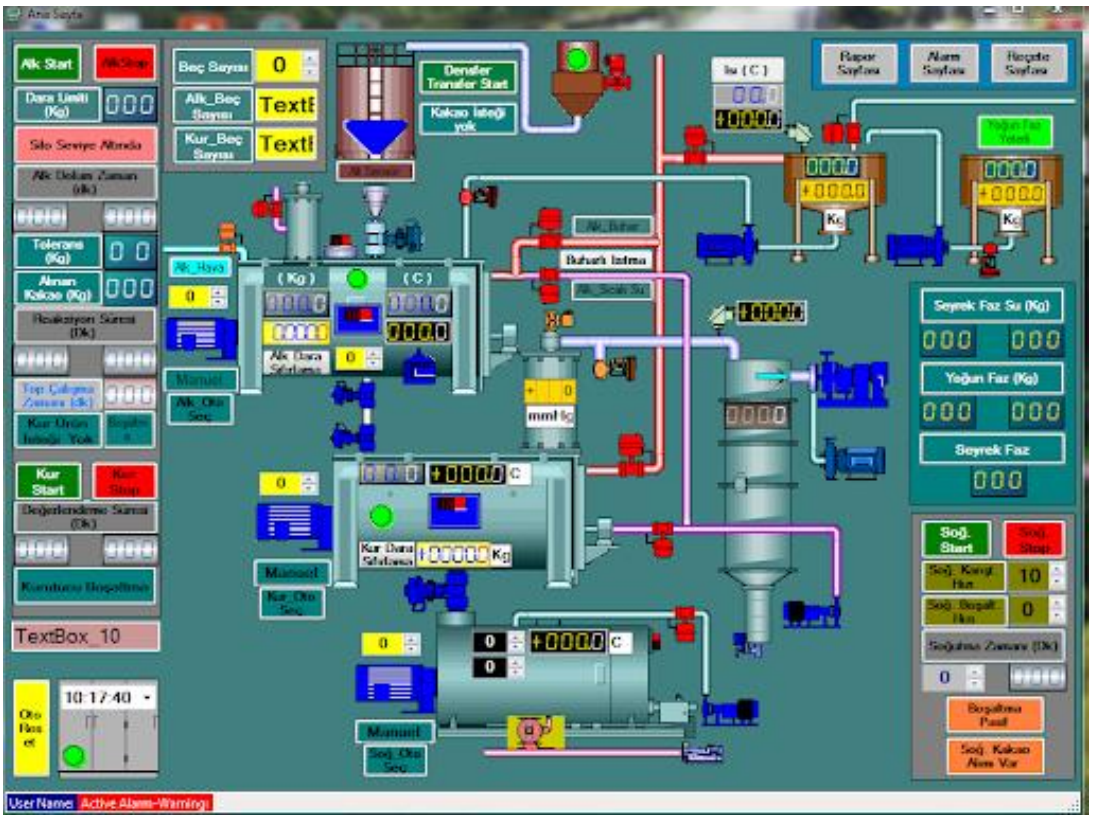
4: For more clarification, read the key readings 1.1.6

Key readings 1.1.6: Description of SCADA System

- **SCADA System**

Supervisory Control and Data Acquisition (SCADA) is a crucial system used in hydropower plants for monitoring, controlling, and optimizing plant operations. It provides a centralized interface to oversee the entire plant, ensuring efficient and reliable performance.

SCADA is an automated control system used to monitor and manage industrial processes and infrastructure. In a hydropower plant, SCADA systems collect real-time data from various sensors and devices, allowing operators to oversee operations, make informed decisions, and execute control commands from a central location.



- **Main Parts of SCADA**

✓ **Data Acquisition:** Collects real-time data from field devices such as sensors, meters, and actuators throughout the hydropower plant. Includes data collectors and input/output (I/O) modules that interface with field devices to gather operational data.

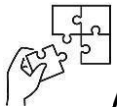
- ✓ **Communication Infrastructure:** Transmits data between field devices and the central control system. It ensures that data from various sources is delivered reliably and efficiently. Includes communication networks (e.g., Ethernet, wireless, fiber optics) and communication protocols (e.g., Modbus, DNP3, OPC) to facilitate data exchange.
- ✓ **Control Software:** Provides the tools and algorithms needed to monitor and control the plant's operations. It processes data collected from field devices and executes control commands based on predefined rules and operator input. Includes SCADA software applications running on servers or workstations, which handle data processing, control logic, and system integration.
- ✓ **Human-Machine Interface (HMI):** Offers a graphical interface for operators to interact with the SCADA system. It displays real-time data, visualizes system status, and allows operators to issue commands and adjustments. Includes graphical dashboards, control panels, and user interfaces that present data in an intuitive and accessible manner.
- ✓ **Data Storage:** Archives historical data collected from the plant for analysis, reporting, and compliance purposes. It supports long-term storage and retrieval of operational data. Includes databases and data historians that store time-series data and historical records.
- ✓ **Alarm and Event Management:** Monitors for abnormal conditions or faults and generates alarms or notifications to alert operators. It helps in rapid response to issues and provides a record of events for troubleshooting. Includes alarm management systems and event logging tools that track system anomalies and operator actions.
- ✓ **Reporting and Analysis:** Provides tools for generating reports and analyzing data to assess plant performance, identify trends, and optimize operations. Includes reporting tools and analytical software that generate operational reports, performance summaries, and trend analyses.

Importance of SCADA system

- ❖ Enhances operational efficiency by providing a centralized system for monitoring and control.
- ❖ Ensures reliable plant operations through real-time monitoring and rapid response to issues.
- ❖ Supports performance optimization through data analysis and reporting.
- ❖ Improves safety by detecting and alerting operators to potential issues before they escalate.

Points to Remember

- **Governing System** is a system that controls the water turbine's speed and output by adjusting the flow of water.
- **Governing system has the following elements:** Servomotor, Sensing system, Controller, Actuator and Guide vane.
- **Excitation System** is the system for generating and maintaining the magnetic field in the generator's rotor. This system ensures the generator produces the required electrical output and maintains voltage stability.
- **Excitation System has the following elements:** Exciter**,** automatic Voltage Regulator (AVR)**,** Brushes or Slip Ring and Battery Bank.
- **The units control system** is responsible for managing the operation of individual generating units to ensure optimal performance, synchronization with the grid, and effective communication between components.
- **Units Control System has the following elements:** Synchronization System, Speed Sensor and Communication System
- **Common control system** is designed to integrate various control and monitoring functions into a cohesive system.
- **Common Control System has the following elements:** Communication Interface and Human-Machine Interface (HMI)
- **The protection system** is designed to safeguard the plant's equipment and ensure safe and reliable operation. It detects and responds to abnormal conditions such as faults, overloads, and other issues that could damage equipment or disrupt operations.
- **Protection system has the following elements:** Current protection relay, Voltage protection relay, Frequency protection relay, Overload protection relay, Reverse power protection relay, Temperature sensors, Differential relay, Circuit breaker, Ground fault protection relay and Voltage and current transformer.
- **Supervisory Control and Data Acquisition (SCADA)** is the system used for monitoring, controlling, and optimizing plant operations. It provides a centralized interface to oversee the entire plant, ensuring efficient and reliable performance.
- **The following are the main Parts of SCADA:** Data Acquisition, Communication Infrastructure, Control Software, Human-Machine Interface (HMI) and Data Storage.



Application of learning 1.1.

You are requested to go to the powerhouse constructed in your school and mention all powerhouse auxiliaries.

Indicative content 1.2: Interpretation of Power Plants Auxiliaries' Diagrams

Duration: 3 hrs

Theoretical Activity 1.2.1: Description of power plants auxiliaries 'diagrams interpretation

Tasks:

1: Answer the following questions related to the interpretation of power plants auxiliaries' diagrams:

i. What do you understand by the term symbol?
ii. What do you understand by the term diagrams?
iii. What are the types of electrical diagrams?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.2.1

Key readings 1.2.1.: Description of power plants auxiliaries' diagrams interpretation

- **Symbols**

Symbols are standardized graphical representations used in diagrams to depict various components and systems in a hydropower plant. Understanding these symbols is essential for accurately interpreting the diagrams.

SN	Name of the symbols	Graphical representation of the symbols
1	Single phase circuit breaker	
2	Isolator/disconnector	

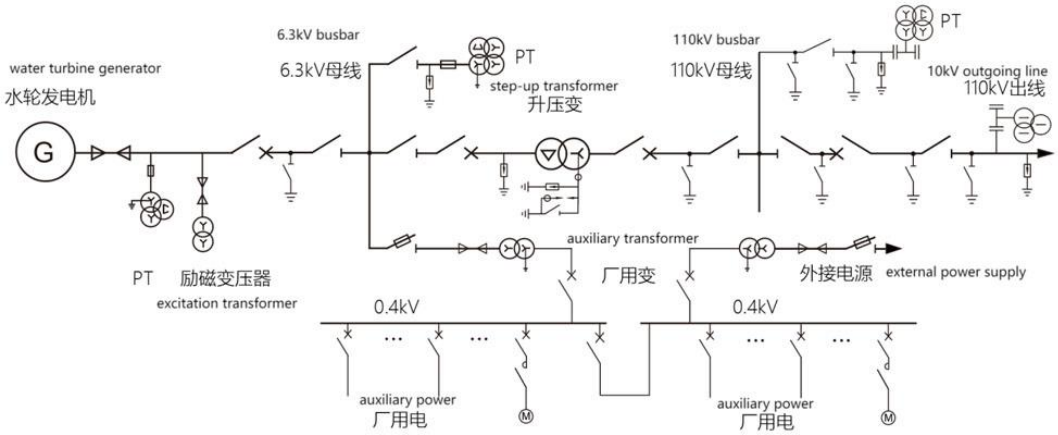
3	Isolator-switch/ load break switch	
4	Fuse- switch	
5	Fuse – switch – disconnector	
6	Ammeter	
7	Voltmeter	
8	Surge arrester	
9	Current transformer	
10	Earth switch	

- **Types of diagrams**

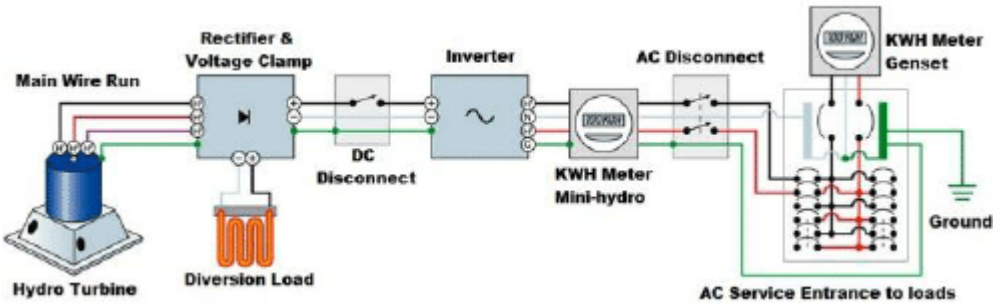
Diagrams used in hydropower plants represent different aspects of the system and help in understanding the layout and operation of the plant.

✓ **Single Line Diagram (SLD)**

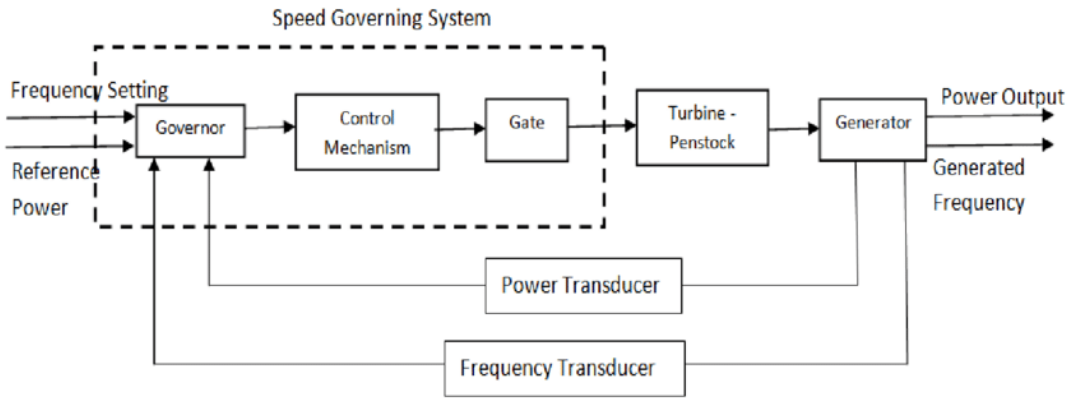
- **Purpose**: Provides a simplified representation of the electrical distribution system, showing the main components and their connections.
- **Details**: Includes transformers, generators, buses, circuit breakers, and major electrical connections.



- ✓ **Piping and Instrumentation Diagram (P&ID)**: Shows the piping, valves, and instrumentation used in the plant, along with the process flow and control elements. It includes symbols for pumps, valves, sensors, and controllers, as well as the piping routes.
- ✓ **Wiring Diagram**: Details the wiring and connections between electrical components and control systems. It shows how electrical connections are made, including terminal blocks, wires, and connections between relays and controllers.



- ✓ **Block Diagram**: Provides an overview of the major components and their functional relationships. It includes high-level representations of system components and their interactions, without detailed wiring or piping.



- ✓ **Layout Diagram**: Displays the physical arrangement of equipment and

components in the plant. It shows the placement of turbines, generators, pumps, and other equipment within the plant's physical space.

- **Review of Diagrams**

Reviewing diagrams involves examining each type of diagram to understand the layout, connections, and operation of the hydropower plant systems.

- ✓ **Interpret Symbols**: Identify and interpret the symbols used in each diagram to understand the types of components and their functions.
- ✓ **Analyze Connections**: Look at how components are connected in each diagram, including electrical connections in the SLD, piping routes in the P&ID, and wiring details in the wiring diagram.
- ✓ **Check Consistency**: Ensure that the information presented in different diagrams is consistent. For example, check that the components shown in the P&ID match those in the SLD.
- ✓ **Understand Functionality**: Determine how each component and connection contributes to the overall operation of the plant. For instance, understand how a pump in the P&ID interacts with the electrical system shown in the SLD.
- ✓ **Verify Layout**: Review the layout diagram to ensure that the physical arrangement of equipment aligns with the operational and safety requirements.

Steps of interpreting of hydropower plants auxiliaries' diagrams

1. **Identify Symbols**: Recognize standard symbols for turbines, pumps, generators, and valves.
2. **Understand Flow Paths**: Trace the flow of water and energy through the system.
3. **Review Components**: Note key components like penstocks, draft tubes, and cooling systems.
4. **Check Connections**: Examine how components are interconnected and their operational relationships.
5. **Delve into Details**: Look at specific details like control valves and measurement points.
6. **Consult Documentation**: Use manuals or schematics for ultimate accuracy.

Points to Remember

- **Symbols** are standardized graphical representations used in diagrams to depict various components
- **Diagrams** used in hydropower plants represent different aspects of the system and help in understanding the layout and operation of the plant.
- **The following are the types diagrams:** Single Line Diagram (SLD), Piping and Instrumentation Diagram (P&ID), Wiring Diagram, Block Diagram and Layout Diagram.
- **Steps of interpreting of hydropower plants auxiliaries' diagrams**
    1. Identify Symbols
    2. Understand Flow Paths
    3. Review Components
    4. Check Connections
    5. Delve into Details
    6. Consult Documentation

Application of learning 1.2.

You are requested to go to the electrical workshop to read and interpret hydropower plants auxiliaries' diagrams.

Indicative content 1.3: Selection of Tools, Materials and Equipment

Duration: 8hrs

Theoretical Activity 1.3.1: Identification of Tools, materials and equipment

Tasks:

1: Answer the following questions related to the Identification of Tools, materials and equipment:

i. What do you understand by the term tools, material and equipment used in hydropower plant auxiliaries' installation?

ii. Identify any five (5) materials tools and equipment used in hydropower plant auxiliaries' installation.

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.1

Key readings 1.3.1. Identification of Tools, materials and equipment

- **Identification of Tools, materials and equipment**

- **Tools:** They are the various objects and devices that are designed to assist in performing specific tasks or achieving specific goals
- **Types of tools are**:
- **Hand Tools**: A tool is any instrument or simple piece of equipment that you hold in your hands and use to do a particular kind of work.

SN	Name Of Tool	Image Of Tool	Role
1	Plier		it is used to bend and twist wires whenever you make a screw-terminal connection

2	Screw Driver		it is a portable device that allows you to screw and unscrew easily.
3	spanner		It is used to loosen or attach nuts, bolts or similar fixings
4	Hacksaw		It is a fine-toothed saw designed primarily for cutting through metal.
5	Tape Measure		It is a hand tool commonly used to measure distance or size.
6	Electrician knife		It also serves many functions, including cutting and stripping cables, cutting electrical tape and insulation, and cutting and opening tool boxes and packages.
7	Wire stripper		It is a portable handheld tool used by electricians to remove the protective coating of an electrical wire to replace or repair a wire.

- **Power Tools**: A power tool is a tool that is actuated by an additional power source and mechanism other than the solely manual labor used with hand tools.

SN	**Name of power tools**	**Image of power tools**	**Role**

1	**Drill**		For drilling holes in various materials.
2	**Grinder**		For cutting, grinding, and polishing.
3	**Saws**		For cutting metal, wood, or plastic components

- **Specialized Tools**:
  - **Torque Wrenches**: For applying a specific torque to fasteners.
  - **Calibration Instruments**: For setting and calibrating sensors and instruments.

- **Application and Uses of tools**:
- **Hand Tools**: Used for general assembly, maintenance, and minor adjustments. Essential for precision tasks and manual operations.
- **Power Tools**: Improve efficiency in tasks like drilling, cutting, and grinding. Used in the installation of large components or when precision and speed are required.
- **Specialized Tools**: Used for specific tasks that require precise measurements or settings, ensuring correct installation and operation of components.
- **Materials:** the elements, constituents, or substances of which something is composed or can be made.
- **Types of materials**:
- **Structural Materials**:
  - **Steel**: Used for constructing frames, supports, and structural components.
  - **Concrete**: Used for foundations and structural supports.

❖ **Electrical Materials**:

SN	Name of material	Image of material	Role
1	Electrical Tape		It is to insulate and protect wires and other connections .
2	Screws		They are used to hold objects together
3	Wire		It is used for establishing electrical conductivity between two devices of an electrical circuit.
4	connectors		They create an electrical connection between two components , enabling the electrical signal to pass

- **Sealing and Gasket Materials**:
  - **Rubber Gaskets**: For sealing joints and preventing leaks.
  - **Sealants**: For waterproofing and sealing gaps.
- **Application and Uses of materials**:
- **Structural Materials**: Provide the necessary support and stability for installing machinery and components.
- **Electrical Materials**: Ensure safe and effective electrical connections and prevent electrical faults.
- **Sealing and Gasket Materials**: Prevent leaks, ensure the integrity of joints, and protect against environmental factors.
- **Equipment**

Equipment refers to a broader category of machinery, apparatus, or instruments used to perform specific functions or tasks, often in more complex or specialized applications.

- **Types of equipment are**:
- **Installation Equipment**:
  - **Cranes**: For lifting and positioning heavy equipment and components.
  - **Forklifts**: For moving and transporting materials and equipment.
- **Testing Equipment**:
  - **Multimeters**: For measuring electrical parameters such as voltage, current, and resistance.
  - **Pressure Gauges**: For measuring fluid pressure in systems.
- **Safety Equipment**:
  - **Personal Protective Equipment (PPE)**: Includes helmets, gloves, safety glasses, and hearing protection.
  - **Lifting Gear**: Includes hoists, slings, and shackles for safe lifting operations.
- **Application and Uses of equipment**:
- **Installation Equipment**: Essential for handling and positioning heavy and bulky components during installation.
- **Testing Equipment**: Used to verify the correct operation of electrical and mechanical systems, ensuring safety and performance.
- **Safety Equipment**: Protects personnel during installation and maintenance tasks, reducing the risk of accidents and injuries.
- **Selection Criteria**
- **Compatibility**: Check that tools and equipment can handle the specific sizes and

types of components. Ensure materials are suitable for the intended use and environment.

- **Quality**: Choose high-quality products from reputable manufacturers to ensure longevity and reduce the risk of failure or malfunction.
- **Safety**: Verify that equipment meets safety standards and that materials are free from defects. Ensure that safety equipment is properly maintained and used.
- **Functionality**: Select tools and equipment based on their ability to perform the required tasks efficiently. Ensure materials meet the specifications for their intended applications

Theoretical Activity 1.3.2: Description of auxiliary transformer

Tasks:

1: Answer the following questions related to the description of auxiliary transformer:

i. What do you understand by the term power transformer/auxiliary transformer?
ii. What are the parts of power transformer?
iii. What is the role of each part of transformer?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.2

Key readings 1.3.2. Description of auxiliary transformer

- **Transformers**

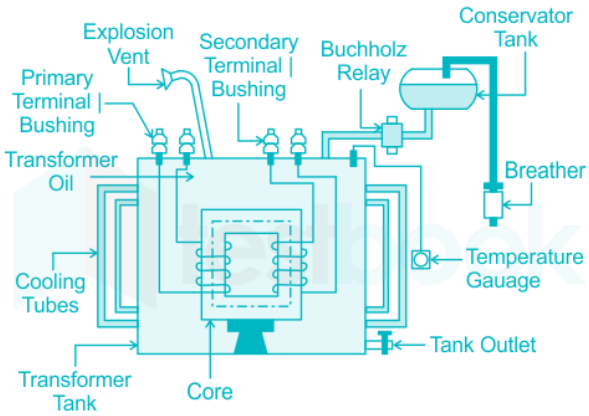
Definition

It is a static machine used to transfer electrical energy between circuits through electromagnetic induction in electrical power systems.

An auxiliary transformer is a type of electrical transformer used to supply power to secondary systems within an industrial facility or power generation plant that are not directly involved in the primary power production.

Transformer has various parts, each playing a specific role in their operation

Parts of Transformer



Construction of Transformer

✓ **Parts of transformer are:**

- **Core**: It is typically made of laminated silicon steel to minimize energy losses due to eddy currents and hysteresis
  - ❖ **Role**: The core provides a path for the magnetic flux generated by the current flowing through the windings.
- **Windings**:
  - **Primary Winding**: Receives the input voltage from the power source. It is connected to the high-voltage side of the transformer.
  - **Secondary Winding**: Delivers the output voltage to the load. It is connected to the low-voltage side.
    - ❖ **Role**: Windings are coils of wire (usually copper or aluminium) that create a magnetic field when current flows through them. The ratio of turns in the primary and secondary windings determines the voltage transformation ratio.
- **Insulation**: Insulation materials, such as oil or paper, are used to separate the windings from the core and from each other. This helps prevent electrical shorts and maintains safety and efficiency.
- **Tap Changer**: Allows for the adjustment of the transformer's output voltage to match varying load conditions or to correct voltage

imbalances. It can be manual or automatic and is typically located on the high-voltage side.

- **Cooling System**:
  - **Oil**: In many power transformers, oil serves as both an insulator and a coolant. The oil circulates through the transformer to carry away heat generated by electrical losses.
  - **Cooling Fans**: In some designs, external fans are used to help dissipate heat from the transformer's surface.
  - **Radiators**: These are used to enhance heat dissipation from the transformer oil to the surrounding environment.
- **Bushings**: These are insulating structures that provide a safe path for the electrical connections between the transformer windings and external power lines. They prevent electrical leakage and ensure reliable connection.
- **Breather**: A silica gel or other desiccant-based device that absorbs moisture from the air entering the transformer tank. This helps keep the insulating oil dry and prevents damage to the insulation.
  - ❖ **Role**: Absorbs moisture from the air entering the transformer, helping to maintain the quality of the insulating oil and prevent damage to internal components.
- **Tap Changer Mechanism**: Facilitates voltage adjustments by changing the connection points of the windings through various taps. It can be on-load (adjustable while the transformer is operating) or off-load (adjustable only when the transformer is de-energized).
- **Tank**: The metal enclosure that contains the core, windings, and insulation oil.
  - ❖ **Role**: It provides structural support and protection from environmental elements.

Types of Transformers

Transformers can be classified into different categories on the basis of the following factors.

❖ **Position of the winding around the magnetic core**

- Core Type
- Shell Type

- **According to the** turn Ratio **or transformation ratio**
  - Step-up
  - step- down
- **Types of service**
  - Power Transformer
  - Distribution Transformer
  - Auto Transformer
  - Isolation Transformer
  - Instrument Transformer
    - Potential Transformer
    - Current Transformer
- **On the basis of supply**
  - Single Phase
  - Three Phase
- **On the basis of Cooling**
  - Air Natural (AN) or Self cooled
  - Air Force (AF)
  - Oil Natural Air Natural (ONAN)
  - Oil Natural Air Force (ONAF)
  - Oil Force Air Force (OFAF)
  - Oil Natural Water Force (ONWF)
  - Oil Force Water Force (OFWF)

- **Auxiliary transformer at power plant**

An **auxiliary transformer** is a type of electrical transformer used to supply power to secondary systems within an industrial facility or power generation plant that are not directly involved in the primary power production.

Functions and Role

- **Powering Auxiliary System:** It provides electrical power to auxiliary systems that are essential for the plant's operation but are not directly involved in power generation. This plays major function in hydropower plant including:
  - **Lighting:** Illuminating the plant for operational and safety purposes.
  - **Control Systems:** Powering control panels, sensors, and instrumentation used for monitoring and controlling the plant's operations.
  - **Cooling Systems:** Supplying power to cooling systems that maintain

optimal temperatures for equipment like generators and transformers.
- **Ventilation:** Ensuring proper ventilation within the plant.

❖ **Voltage Transformation:**
- **Stepping Down Voltage:** It typically steps down high voltage from the main power system to lower voltages suitable for auxiliary equipment. This is crucial for providing the correct voltage levels needed for different systems.
- **Voltage Stability:** It helps maintain stable voltage levels for sensitive equipment and control systems.

❖ **Operational Independence:**
- **Isolated Power Supply:** By having a dedicated auxiliary transformer, the plant ensures that auxiliary systems have a separate and stable power supply. This separation can be important in maintaining plant operations if there are issues with the main power generation systems.
- **Backup:** It acts as a backup power source for critical systems that support the operation and safety of the plant.

Theoretical Activity 1.3.3: Description of measurement transformer

Tasks:

1: Answer the following questions related to the description of measurement transformer:

i. What do you understand by the term measurement transformer?
ii. What are two (2) types of measurement transformers?
iii. What is the role of each type of measurement transformer?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.3

Key readings 1.3.3: Description of measurement transformer

- **Measurement transformers**

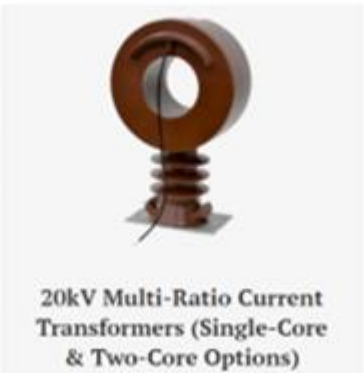
These are specialized electrical devices used to scale down high voltages and currents to manageable levels for measurement, monitoring, and protection purposes in electrical systems. They play a crucial role in providing accurate data for analysis and ensuring the safety and reliability of electrical installations.

✓ **Types of measurement transformers**

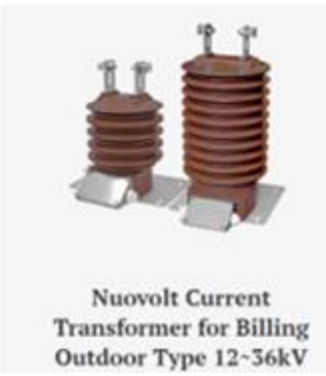
The two main types of measurement transformers are **current transformers (CTs)** and **voltage transformers (VTs)** (also known as potential transformers).

1. Current Transformers (CTs)

20kV Two-Core Current Transformer (for Polluted Regions)



20kV Multi-Ratio Current Transformers (Single-Core & Two-Core Options)



Nuovolt Current Transformer for Billing Outdoor Type 12~36kV

❖ **Purpose:** Current transformers are used to measure high electrical currents by producing a proportional lower current that can be safely measured by instruments and used for protection relays.

❖ **Working principles**

- **Primary Winding:** The primary winding of a CT is connected in series with the conductor carrying the high current to be measured.
- **Secondary Winding:** The secondary winding of the CT produces a reduced current proportional to the primary current. This lower current can be safely routed to measuring instruments or protection devices.
- **Ratio:** CTs are designed with a specific current ratio (e.g., 100:5), where 100A in the primary winding produces 5A in the secondary winding.

Applications

- **Measurement:** To measure high currents and provide readings to meters and recording devices.
- **Protection:** To provide input to protective relays that can trip circuit breakers in the event of overloads or faults.

2. Voltage Transformers (VTs) or Potential Transformers (PTs)

- **Purpose:** Voltage transformers are used to measure high voltages by stepping them down to lower, manageable voltages that can be safely measured and used for monitoring and protection.
- **Working principles**

  - **Primary Winding:** The primary winding is connected to the high-voltage circuit to measure the voltage.
  - **Secondary Winding:** The secondary winding produces a lower voltage proportional to the primary voltage. This lower voltage is safe for connection to measuring instruments and control systems.
  - **Ratio:** VTs are designed with a specific voltage ratio (e.g., 10,000:100), where 10,000V in the primary winding produces 100V in the secondary winding.

- **Applications**

  - **Measurement:** To measure high voltages and provide readings to voltmeters and other monitoring devices.
  - **Protection:** To provide input to protective relays that can respond to overvoltage conditions or other electrical faults.

✓ **Characteristics of Measurement Transformers**

- **Accuracy:** Measurement transformers are designed to provide accurate scaling of current or voltage. Accuracy is crucial for reliable measurement and protection.
- **Safety:** By stepping down high voltages and currents, measurement transformers allow for safe operation and measurement without exposing personnel or equipment to high electrical levels.
- **Isolation:** They provide electrical isolation between high-voltage circuits and measurement or control devices, which helps protect sensitive equipment and personnel.

Theoretical Activity 1.3.4: Description of neutral grounding transformer

Tasks:

1: Answer the following questions related to the description of neutral grounding transformer:

i. What do you understand by the term neutral grounding transformer?
ii. Identify any three (3) types of neutral grounding transformer.
iii. What is the role of each type of neutral grounding transformer?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.4

Key readings 1.3.4: Description of neutral ground transformer

- **Neutral ground transformer**

✓ **Definition**

A Neutral Grounding Transformer (NGT) is a type of transformer used primarily in electrical power systems to provide a grounding point for the neutral of a power system. Its main functions include:

Function of Neutral grounding transformer

1. Grounding the Neutral

The NGT is used to establish a stable and effective ground reference for the neutral point of a power system. This helps in managing and controlling fault currents, improving system stability, and ensuring safety.

In a three-phase power system, the neutral point is the point where the three phase voltages meet. Grounding this neutral point helps in providing a reference voltage and protecting the system from high-voltage transients.

2. Limiting Fault Currents

- **Fault Protection:** The NGT helps in limiting the magnitude of fault currents that can flow to the ground during single-line-to-ground faults. By doing so, it prevents excessive current from damaging equipment and causing system

instability.

- **Current Limiting:** It often includes impedance, which limits the amount of fault current that can flow through the ground.

3. Enhancing System Protection

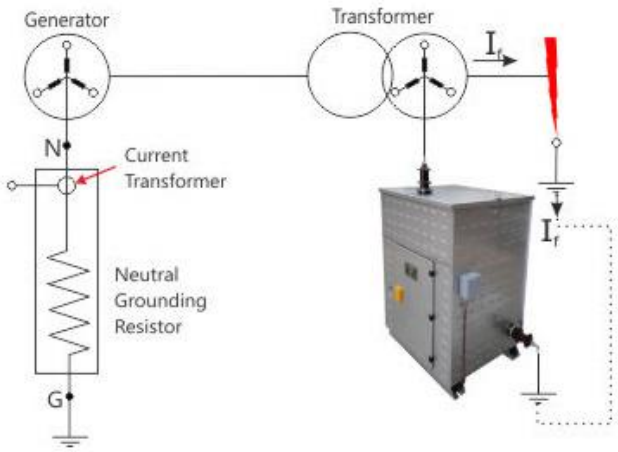
- **Fault Detection:** Proper grounding helps in detecting and isolating faults quickly. This minimizes the impact of faults on the rest of the system and helps in maintaining system reliability.
- **Safety:** Provides a safe path for fault currents to flow to the ground, reducing the risk of electrical shock and damage to equipment.

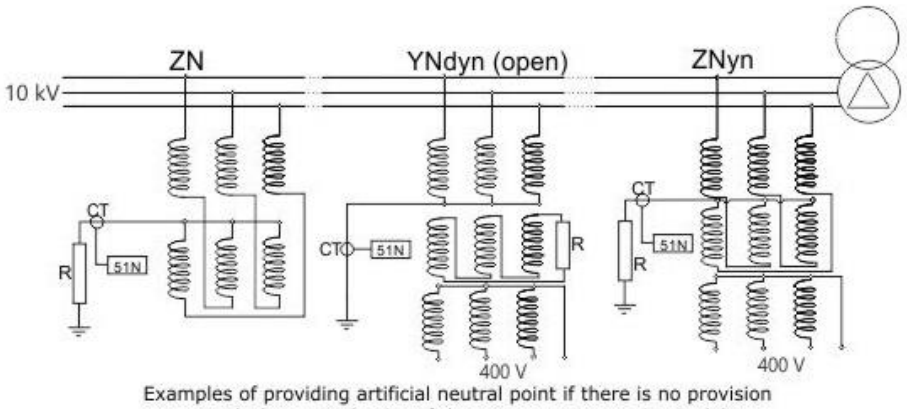
4. Improving System Stability

- **Voltage Control:** By grounding the neutral, the NGT helps in maintaining the system voltage within acceptable limits, thereby improving the overall stability and reliability of the power system.

✓ **Types of Neutral Grounding Transformers**

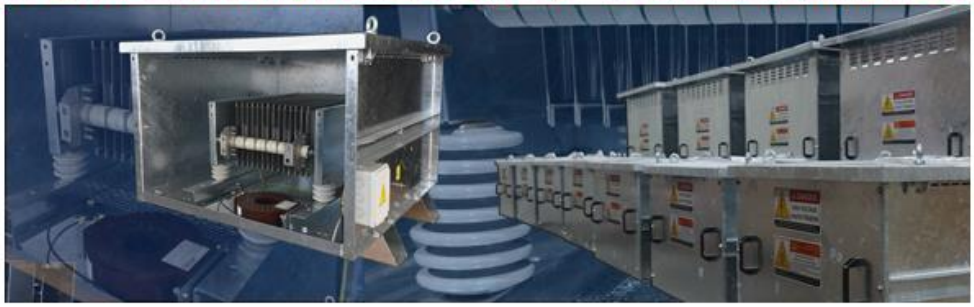
1. **Wye-Delta (Y-Δ) Transformer:** Commonly used in systems where a delta-connected secondary winding is used to provide a grounded neutral. The delta winding provides a path for the fault current, and the wye winding is connected to the neutral point.
2. **Resistor Grounded Transformer:** Includes a resistor in series with the neutral connection. Limits the fault current to a predetermined value, providing controlled grounding.





Examples of providing artificial neutral point if there is no provision to reach the neutral point of the source or connection is delta

Neutral Grounding Resistor (NGR) - Neutral Earthing Resistors



3. **Reactance Grounded Transformer:** Includes an inductive reactance in series with the neutral connection. Limits fault currents and can help in tuning the system to specific requirements.
4. **Peterson Coil (Grounding Coil):** Uses a coil connected in series with the neutral to limit fault currents and provide a degree of reactance to the system.

- **Application of neutral grounding transformer**
  - **Industrial Power Systems:** Used in industrial settings to ground the neutral of large electrical systems.
  - **Utility Power Grids:** Employed by utility companies to manage the neutral grounding in high-voltage transmission and distribution systems.
  - **Data Centers and Critical Infrastructure:** Ensures a reliable and safe grounding system to protect sensitive equipment and maintain operational integrity.

Theoretical Activity 1.3.5: Description of control panel

Tasks:

1: Answer the following questions related to the description of control panel:

i. What do you understand by the term control panel?
ii. What are the type control panel?
iii. What is the role of each type of control panel?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.5

Key readings 1.3.5: Description of control panel

- **Control panels**

In a hydropower plant, Control panels are crucial for managing, monitoring, and operating the various systems involved in generating electricity. These panels provide operators with the means to control the plant's operations, ensure safety, and optimize performance.

✓ **Types of Control panels**

1. **Main Control Panel** is the central hub for monitoring and controlling the entire hydropower plant.

- **Components:**

  - **Human-Machine Interface (HMI):** Provides graphical representation of the plant's operations, including real-time data and alarms.
  - **Control Switches:** Allow operators to start/stop turbines, control gates, and adjust generator settings.
  - **Indicators and Meters:** Display parameters like voltage, current, power output, and hydraulic conditions.
  - **Alarm Systems:** Alert operators to any anomalies or operational issues.

2. **Turbine Control Panel** specifically designed to control the operation of the turbine(s) in the plant.

- **Components of turbine Control Panel:**

  - **Turbine Control System:** Manages turbine speed, load, and synchronization with the grid.
  - **Governor Controls:** Regulate turbine speed and match it with the required power output.
  - **Hydraulic Controls:** Control the hydraulic systems that operate the turbine's moving parts.
  - **Safety Interlocks:** Ensure safe operation by preventing actions that could damage the turbine.

3. Generator Control Panel manages the electrical output from the generator.

- **Components**
  - **Excitation Control:** Regulates the magnetic field of the generator to control output voltage and power.
  - **Protection Relays:** Protect the generator from faults such as overcurrent, under-voltage, and over-temperature.
  - **Synchronization Equipment:** Ensures the generator is properly synchronized with the electrical grid.

4. Hydraulic Control Panel manages the hydraulic systems that control water flow and pressure.

- **Components**

  - **Valve Controls:** Regulate the flow of water through the turbines.
  - **Pressure Gauges:** Monitor the pressure in hydraulic systems.
  - **Flow Meters:** Measure the volume of water flowing through the plant.

5. Penstock Control Panel controls the flow of water through the penstock, which directs water to the turbines.

- **Components:**

  - **Gate Controls:** Operate the gates or valves that control water flow.
  - **Level Sensors:** Monitor water levels in the reservoir and penstock.

6. Grid Connection Panel manages the connection between the hydropower plant and the electrical grid.

- **Components:**

  - **Circuit Breakers:** Protect the system from electrical faults and overloads.
  - **Transformers:** Adjust voltage levels for grid compatibility.
  - **Synchronizers:** Ensure that the power produced by the plant is in phase with the grid.

7. Auxiliary Control Panels manage various auxiliary systems and support functions within the plant.

- **Components:**

  - **Cooling Systems:** Control cooling systems for generators and other equipment.
  - **Lighting Controls:** Manage lighting within the plant for operational and safety purposes.
  - **Fire Alarm Systems:** Monitor for fire detection and suppression systems.

7. **Remote Control Panel** allows operators to control and monitor the plant from a remote location.

- **Components:**

  - **Remote Monitoring Software:** Provides access to real-time data and control functions from a remote site.
  - **Communication Equipment:** Includes routers, modems, and communication interfaces.

Theoretical Activity 1.3.6: Description of switchgear

Tasks:

1: Answer the following questions related to the description of switchgear:

i. What do you understand by the term switchgear?
ii. What are the type switchgears?
iii. What is the role of each type of switchgear?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.3.6

Key readings 1.3.6. Description of switching gears

- **Switching gear**

✓ **Definition**

Switching gears in a hydropower plant are critical for controlling and protecting electrical circuits and equipment. They manage the flow of electrical power from the generators to the grid, ensuring safe and reliable operation.

✓ **Types of switching gears**

1. **Circuit Breakers** protect electrical circuits from overloads and short circuits by interrupting the current flow when a fault is detected.

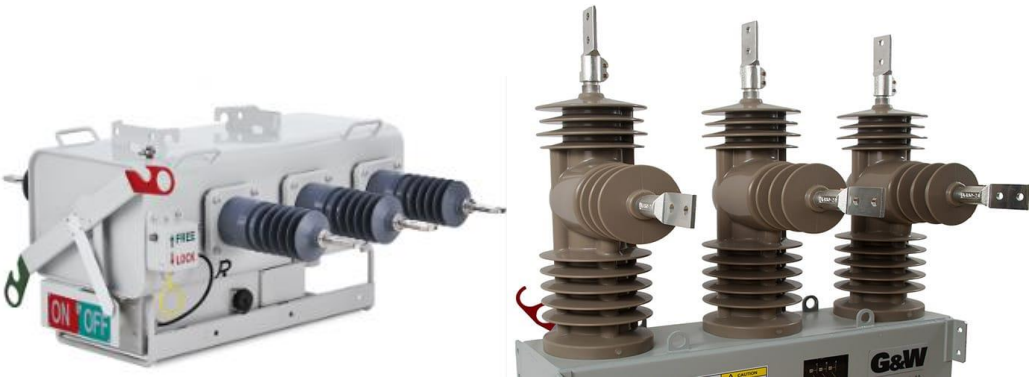
Circuit breaker has different types:

- **Air Circuit Breakers (ACBs):** Used for high-current applications, offering protection and control.
- **Oil Circuit Breakers (OCBs):** Typically used in outdoor substations, utilizing oil for insulation and arc quenching.
- **Sulphur Hexafluoride (SF6) Circuit Breakers:** Use SF6 gas for insulation and are known for their compact size and high performance.

2. **Disconnect Switches (Isolators)** provide a means to isolate sections of the electrical system for maintenance or emergency purposes. They disconnect the circuit when no load is present.

- **Isolator has different types:**
  - **Manual Isolators:** Operated manually, often used in lower voltage applications.
  - **Motorized Isolators:** Equipped with electric motors for remote operation, used in high-voltage applications.

3. **Load Break Switches** allow the switching of electrical circuits under load conditions, providing both switching and protection.

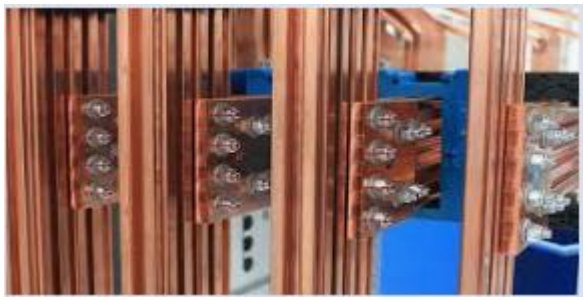


- **Load break switches have different types:**
  - **Indoor Load Break Switches:** Used within the plant building for controlling medium-voltage circuits.
  - **Outdoor Load Break Switches:** Designed for external use, often found in substations or along transmission lines.
  - **Circuit Switchers** combine the functions of a circuit breaker and a disconnect switch, allowing for both protection and isolation of circuits.

4. **Protection Relays** detect abnormal conditions (such as overcurrent or undervoltage) and trigger the operation of circuit breakers or other protective devices.

- **Protections relay have different types:**
  - **Overcurrent Relays:** Detect excessive current and initiate tripping of the circuit breaker.
  - **Differential Relays:** Monitor the difference in current between two points to detect faults within the protected zone.

6. **Busbars** conduct electrical power between different components and circuits within the switching gear assembly.



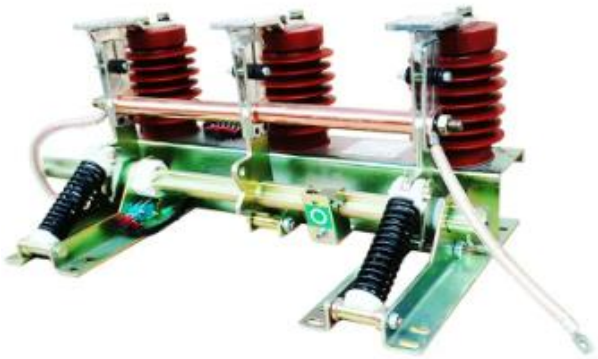
- **Busbars have different types:**
  - **Insulated Busbars:** Encased in insulating material to prevent short

circuits and ensure safety.

- **Bare Busbars:** Used in open-air or well-ventilated areas where insulation is not required.

7.Grounding Switches provide a safe path to ground for electrical equipment, ensuring that no hazardous voltages remain present during maintenance or fault conditions.

Ground switches is also termed as an earth switch, which is automatically connect a circuit to the ground when it is isolated.



8. Fuse Cut-outs protect circuits by disconnecting them in the event of an overload or short circuit.

Cut-out has different types:

- **Distribution Fuse Cut-outs:** Used for medium-voltage distribution lines.
- **Expulsion Fuse Cutouts:** Provide protection by physically expelling the fuse element during a fault.

Practical Activity 1.3.7: Selecting of Tools, materials and equipment

Task:

1: Referring to previous theoretical activities 1.3.1, go to the electrical workshop and perform the following task:

Select tools, materials and equipment used in used in installation powerhouse auxiliaries.

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary.

4: Read key reading 1.3.1

5: Perform the task provided in the application of learning 1.3.

Key readings 1.3.1 Selection of Tools, materials and equipment

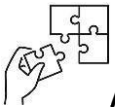
- **Selection criteria**

When selecting tools, materials, and equipment for hydropower plant installation, several important criteria should be considered to ensure efficient, safe, and reliable.

1. Quality and Durability
2. Safety Standards
3. Compatibility and Functionality
4. Efficiency and Precision
5. Environmental Conditions
6. Cost and Availability
7. Ease of Use and Training
8. Energy Efficiency
9. Reliability and Performance
10. Vendor Support and Warranty

Points to Remember

- Tools used in hydropower plant auxiliaries' installation may include **Pliers screwdrivers, electrician knife, drills, and saws.**
- Materials used in hydropower plant auxiliaries' installation may include B**olts, nuts, wires, cables, and steel.**
- Equipment used in hydropower plant auxiliaries' installation includes **forklifts, Cranes, Multimeters, Personal Protective Equipment.**
- The following selection criteria of tools, materials and equipment used in installation of hydropower plant auxiliaries must be take into consideration: Functionality, Safety, Quality and Compatibility.



Application of learning 1.3.

You are requested to go to the renewable workshop to select tools, materials and equipment used while installing powerhouse auxiliaries.

Indicative content 1.4: Site Preparation

Duration: 4 hrs

Theoretical Activity 1.4.1: Description of site preparation

Tasks:

1: Answer the following questions related to the description of site preparation

i. What do you understand by site preparation on hydropower plant?
ii. What are the steps to follow while preparing site of hydropower plant?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 1.4.1

Key readings 1.4.1.: Site preparation

- **Site preparation**

✓ **Definition**

Site preparation refers to the process of preparing a specific area for construction or development.

Site preparation steps may include:

✓ **Apply Policy and procedures for site preparation:**

Ensure that all site preparation activities follow established guidelines to maintain safety, environmental protection, and operational efficiency

Steps of applying policy and procedures for site preparation:

1. **Understand Regulations and Policies**: Begin by thoroughly understanding the applicable regulations, industry standards, and organizational policies related to hydropower plant construction and site preparation. This includes environmental regulations, safety standards, and quality controls.
2. **Develop Detailed Procedures**: Create detailed procedures for site preparation tasks such as land clearing, grading, excavation, and infrastructure installation. These procedures should include specific instructions, safety measures, and

compliance requirements.

3. **Communicate Procedures**: Ensure that all team members and contractors are well-informed about the procedures. This might involve meetings, training sessions, and distributing written documentation.
4. **Monitor and Enforce Compliance**: Regularly monitor site activities to ensure adherence to the procedures. Address any deviations or non-compliance issues promptly and adjust procedures as needed based on feedback and inspections.
5. **Documentation**: Keep comprehensive records of all procedures, including changes, inspections, and compliance checks. Documentation is crucial for audits, reporting, and continuous improvement.

- ✓ **Workplace ventilation:**

Provide adequate ventilation to ensure a safe and healthy working environment, especially in areas with potential airborne contaminants.

- **Steps of ventilating the workplace:**

1. **Assess Ventilation Needs**: Evaluate the specific needs based on the nature of the work, potential pollutants, and the design of the workspace. Identify areas where natural or mechanical ventilation is necessary.
2. **Install Ventilation Systems**: Set up appropriate ventilation systems such as exhaust fans, air filtration units, and proper ductwork. Ensure systems are capable of handling the expected volume of air and contaminants.
3. **Ensure Proper Airflow**: Design the ventilation system to ensure effective airflow throughout the workspace. This may involve positioning vents and fans to prevent stagnant air and ensure proper air exchange.
4. **Regular Maintenance**: Perform regular maintenance on ventilation systems, including cleaning filters, inspecting fans, and checking for any obstructions in ducts.
5. **Monitor Air Quality**: Regularly monitor the air quality to ensure it remains within safe limits. This may involve air sampling and testing for pollutants such as dust, fumes, and gases.

- **Workplace Cleaning Procedures:**

Maintain a clean and organized workspace to promote safety, prevent accidents, and ensure operational efficiency.

Steps of work place cleaning:

1. **Create a Cleaning Schedule**: Develop a cleaning schedule that outlines daily, weekly, and monthly cleaning tasks. This should include general cleaning as well as specific procedures for areas prone to spills or contamination.
2. **Assign Cleaning Responsibilities**: Designate personnel responsible for carrying

out cleaning tasks. Ensure they have the necessary training and resources to perform their duties effectively.

3. **Use Appropriate Cleaning Materials**: Provide appropriate cleaning supplies and equipment, such as brooms, mops, disinfectants, and waste bins. Ensure that cleaning agents are suitable for the types of contaminants present.
4. **Implement Cleaning Procedures**: Establish clear procedures for cleaning tasks, including how to handle and dispose of waste, how to clean different surfaces, and how to maintain equipment.
5. **Inspect and Review**: Conduct regular inspections to ensure that cleaning procedures are being followed and that the workplace remains clean and safe. Address any issues or improvements needed.

- **Safety Compliance:**

Ensure all activities on-site adhere to safety regulations and standards to protect workers and prevent accidents.

Safety compliance steps:

1. **Develop a Safety Plan**: Create a comprehensive safety plan that addresses potential hazards, emergency procedures, and safety measures specific to the site preparation activities. Include guidelines for handling machinery, materials, and environmental conditions.
2. **Conduct Risk Assessments**: Perform thorough risk assessments to identify potential hazards associated with site preparation activities. Develop and implement control measures to mitigate these risks.
3. **Provide Safety Training**: Train all personnel on safety protocols, proper use of personal protective equipment (PPE), and emergency response procedures. Regularly update training as needed and provide refresher courses.
4. **Enforce Safety Measures**: Implement safety measures such as signage, barriers, and protective equipment. Ensure that all workers adhere to these measures and take corrective actions if non-compliance is observed.
5. **Perform Safety Audits**: Conduct regular safety audits and inspections to verify compliance with safety standards and regulations. Document findings and take corrective actions to address any deficiencies.
6. **Incident Reporting and Investigation**: Establish a process for reporting and investigating safety incidents and near-misses. Use the findings to improve safety practices and prevent future occurrences.

Practical Activity 1.4.2: Preparing the site

Task:

1: Referring to previous theoretical activity 1.4.1, go to the site and perform the following task:

Prepare the site for hydropower plant auxiliaries' installation

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 1.4.2

5: Perform the task provided in the application of learning 1.4

Key readings 1.4.2. Preparing the site

- **Site preparation**

Definition

Site preparation refers to the process of preparing a specific area for construction or development.

- **Steps for site preparation are:**

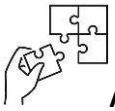
1. **Apply Policy and Procedures:** Applying policies and procedures involves adhering to established guidelines and standards to ensure that site preparation for installing hydropower plant auxiliaries is conducted systematically and in compliance with regulatory and organizational requirements.
2. **Workplace Ventilation:** Workplace ventilation ensures that the installation site has adequate airflow to maintain a safe and comfortable working environment, particularly when working with equipment and materials that may generate fumes, dust, or other airborne contaminants.
3. **Workplace Cleaning Procedures:** Workplace cleaning procedures involve maintaining a clean and organized site to promote safety, efficiency, and compliance with health and safety standards during the installation of hydropower plant auxiliaries.
4. **Safety Compliance:** Safety compliance involves adhering to safety regulations and standards to ensure a safe working environment during the site preparation

and installation of hydropower plant auxiliaries.

Points to Remember

Site preparation refers to the process of preparing a specific area for construction or development.

- **Steps for site preparation are:** Apply Policy and procedures, Workplace ventilation, Workplace cleaning procedures and Safety compliance



Application of learning 1.4.

The school located near the river, plan to construct a hydropower plant in order to supply the school infrastructure and the works of constructing a power house is ended, you are requested to prepare the site for hydropower plant auxiliaries' installation.

Learning outcome 1 end assessment

Theoretical assessment

I. Match the power plant auxiliaries in the column A with their role in column B

Answer	Elements	Role/function
1……	**1) Excitation System**	A) It controls the turbine's speed and output by adjusting the flow of water.
2…….	**2) Units Control System**	B) It ensures efficient operation, seamless communication, and effective interaction between operators and the plant's systems.
3…..	**3) Water Turbine Governing System**	C) It collects real-time data from various sensors and devices, allowing operators to oversee operations, make informed decisions, and execute control commands from a central location.
4…..	**4) Protection System**	D) adequate airflow to maintain a safe and comfortable working environment, particularly when working with equipment and materials that may generate fumes, dust, or other airborne contaminants.
5…..	**5) SCADA System**	E) It is responsible for managing the operation of individual generating units to ensure optimal performance, synchronization with the grid, and effective communication between components.
6……	**6) Common Control System**	F) It detects and responds to abnormal conditions such as

		faults, overloads, and other issues that could damage equipment or disrupt operations.
7…….	**7) Workplace ventilation**	G) It is essential for generating and maintaining the magnetic field in the generator's rotor

II. Encircle the letter corresponding to the correct answer

1. The following are the components of Units Control System, **EXCEPT**

a) Synchronization System

b) Speed Sensor

c) Communication System

d) SCADA

e) None of the above

2.Tthe following are the components of excitation System, **EXCEPT**

a) Exciter

b) Automatic Voltage Regulator

c) Actuator

d) Brushes or Slip Ring

e) Battery Bank

3. The function of servomotor is:

a) Monitors real-time parameters such as turbine speed, water flow, and pressure.

b) Adjusts the position of the turbine's guide vanes or wicket gates based on feedback from the sensing system.

c) Receives data from the sensing system and processes it to determine necessary adjustments.

d) Converts the control signals from the controller into physical adjustments, such as moving the guide vanes or adjusting the turbine's flow gates.

4. The function of brushes are:

a) Supplies the necessary direct current (DC) to the rotor windings of the main generator, creating the magnetic field required for electricity generation.

b) Adjusts the excitation current to maintain a constant output voltage from the generator, despite variations in load or operational conditions.

c) Provide a physical contact point for transferring current to the rotating rotor windings.

d) Provides the initial excitation current needed to start the generator and supports the excitation system's operation in case of a sudden loss of external power.

5. The following are the components of Protection System, **EXCEPT:**

a) Battery bank

b) Overload Protection Relay

c) Temperature Sensors

d) Differential Relay

e) Voltage and Current Transformer

6) The following are materials used while installing powerhouse auxiliaries, **EXCEPT:**

a) Steel

b) Concrete

c) Cables

d) Rubber Gaskets

e) hammer

7) The following are selection criteria considered while selecting tools, materials and equipment **EXCEPT:**

a) Compatibility

b) Definition

c) Quality

d) Safety

e) Functionality

8) Based on types of services a transformer has the following types, **EXCEPT**

a) Power Transformer
b) Distribution Transformer
c) Auto Transformer
d) Core Type
e) Instrument Transformer

9) Based on types of cooling system of transformer, a transformer has the following types, **EXCEPT**

a) Oil Natural Air Natural

b) Oil Natural Air Force
c) Shell cooled
d) Oil Force Air Force
e) Oil Natural Water Force
f) Oil Force Water Force

10) The following are the roles of auxiliary transformer at hydropower, **EXCEPT**:

a) Lighting
b) Control Systems
c) Tripping when in case of fault
d) Stepping Down Voltage
e) A, b and d are correct
f) All the above
g) None of the above

11) The following are the components of Hydraulic Control Panel, **EXCEPT:**

a) Valve Controls
b) Level Sensors
c) Pressure Gauges
d) Flow Meters

III. Answer the following statements related to the types of diagrams and role transformer parts by **True** if the statement is correct or **False** if the statement in incorrect related to the transformer parts

a) Wiring Diagram details the wiring and connections between electrical components and control systems. It shows how electrical connections are made, including terminal blocks, wires, and connections between relays and controllers.

b) Single Line Diagram provides a simplified representation of the electrical distribution system, showing the main components and their connections.

c) Layout Diagram provides an overview of the major components and their functional relationships. It includes high-level representations of system components and their interactions, without detailed wiring or piping.

d) Block Diagram displays the physical arrangement of equipment and components in the plant.

e) Windings are coils of wire (usually copper or aluminium) that create an electrical field when current flows through them.

f) Tap Changer allows for the adjustment of the transformer's output voltage to match varying load conditions or to correct voltage imbalances.

g) Breather absorbs moisture from the air entering the transformer, helping to maintain the quality of the insulating oil and prevent damage to internal components.

h) Core provides a path for the electrical flux generated by the current flowing through the windings

i) Isolators Provide a means to isolate sections of the electrical system for maintenance or emergency purposes. They disconnect the circuit when on load is present.

j) Bus-bars conduct electrical power between different components and circuits within the switching gear assembly

l) Earth Switches automatically connect a circuit to the ground when it is connected.

m) Remote Monitoring Software provides access to real-time data and control functions from a remote site.

n) Differential Relays monitor the difference in current between two points to detect faults within the protected zone.

IV. Match the Equipment in column A with the definition/role in the column B

SN	Equipment (column A)	Definition/ROLE (Column B)
1….	**1) Measurement transformers**	A) Is a type of transformer used primarily in electrical power systems to provide a grounding point for the neutral of a power system.
2…	**2) Alarm Systems**	B) Provides graphical representation of the plant's operations, including real-time data and alarms.
3…	**3) Indicators and Meters:**	C) Are specialized electrical devices used to scale down high voltages and currents to manageable levels for measurement, monitoring, and protection purposes in electrical systems.
4…	**4) Neutral Grounding Transformer (NGT)**	D) Regulates the magnetic field of the generator to control output voltage and power
5…	**5) Human-Machine Interface (HMI):**	E) Alert operators to any anomalies or operational issues.
6…	**6) Control Switches**	F) Display parameters like voltage, current, power output, and

		hydraulic conditions.
7…	**7) Safety Interlocks**	G) Regulate turbine speed and match it with the required power output.
8….	**8) Turbine Control System**	H) Allow operators to start/stop turbines, control gates, and adjust generator settings.
9…..	**9) Excitation Control**	I) Manages turbine speed, load, and synchronization with the grid.
10…..	**10) Governor Controls**	J) Ensure safe operation by preventing actions that could damage the turbine

Practical assessment

The school located near the river, school management staff plans to construct a hydropower plant in order to supply electrical power to the school infrastructure and the works of constructing a power house is ended, you are requested to prepare the site and select tools, materials and equipment to be used for hydropower plant auxiliaries' installation. Tools, materials and equipment are available. The task must be performed in 3hours.

END

References

Jones, R. (2022). *Hydropower systems. .* Renewable Energy Press.

Smith, J. (2023). *Installation and operation of hydropower plant auxiliaries.* Hydropower Engineering Institute.

Taylor, J. (2023). *Installation and maintenance of Neutral Grounding Transformers.* Electrical Engineering Press.

Williams, A. (2022). *Hydropower plant auxiliaries: Diagrams and symbols.* Hydropower Engineering Institute.

Indicative contents
2.1. Mounting auxiliary transformer **2.2. Fixing measurement transformer** **2.3. Fixing neutral grounding transformer (NGT)** **2.4. Fixing control panels** **2.5. Fixing switchgear**

Key Competencies for Learning Outcome 2 : Fix Hydropower Plant auxiliaries

Knowledge	Skills	Attitudes
• Description of setting out of hydropower plant auxiliaries • Identification of foundation inspection criteria • Description of mounting techniques	• Setting out hydropower plant location for auxiliary, measurement and neutral grounding transformer, control panels and switchgear • Mounting auxiliary and measurement transformer, neutral grounding transformer, control panels and switchgear • Fixing of auxiliary and measurement transformer, neutral grounding transformer, control panels and switchgear	• Being accurate while setting out • Being careful while mounting and fixing auxiliary and measurement transformer, neutral grounding transformer, control panels and switchgear • Being attention while mounting and fixing auxiliary and measurement transformer, neutral grounding transformer, control panels and switchgear to minimize accidents that may occur

Duration: 40hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Describe correctly setting out activity performed at hydropower plant before fixing hydropower plant auxiliaries
2. Identify properly foundation inspection criteria as the activity performed at hydropower plant before fixing hydropower plant auxiliaries.
3. Describe clearly mounting techniques used for mounting hydropower plant auxiliaries.
4. Set out accurately location of hydropower plant auxiliaries based on manufacturer's installation guide.
5. Mount precisely hydropower plant auxiliaries based on manufacturer's installation guide.
6. Fix tightly hydropower plant auxiliaries based on manufacturer's installation guide

Resources

Equipment	Tools	Materials
• PPE • Multimeter • fire extinguisher • drilling machine • wattmeter • electrical screw driver • electric grinder • clamp-on ammeter	• Screw driver kit • pliers kit • spanners kit • Hammers • drilling machine • saws	• cable • bolts and nuts • mild steels • timbers

Indicative content 2.1: Mounting Auxiliary Transformer

Duration: 14hrs

Theoretical Activity 2.1.1: Description of setting out, foundation inspection, positioning and mounting while fixing power plant auxiliaries

Tasks:

1: Answer the following questions related to the description of setting out, foundation inspection, positioning and mounting while fixing power plant auxiliaries

i. What do you understand the term setting out?
ii. What is the purpose of foundation inspection?
iii. What do you understand by the term positioning?
iv. What do you understand by the term mounting?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 2.1.1

Key readings 2.1.1. Description of setting out, foundation inspection and mounting techniques for fixing power plant auxiliaries

- **Setting out**

  Definition

  Setting out" typically refers to the process of accurately marking and establishing the position of structures, equipment, or components in construction and engineering projects. This ensures that everything is placed according to the design specifications and plans.

- **Steps of Setting Out:**

  1. **Surveying:** Use surveying tools (like total stations or levels) to measure and mark the correct locations on the ground based on architectural or engineering drawings.
  2. **Reference Points:** Establish reference points (benchmarks) that help ensure accuracy throughout the project. These points serve as guides for measurements.
  3. **Site Preparation:** Clear and prepare the site according to the design, ensuring that it is ready for the placement of structures or equipment.
  4. **Marking:** Use stakes, paint, or other markers to indicate where foundations,

walls, or equipment will be located.

5. **Checking Dimensions:** Verify that all marked points align with the design dimensions and layout to prevent errors before construction begins.
6. **Leveling:** Ensure that the marked positions are level and meet elevation requirements, which is crucial for structures like foundations and floors.

❖ **Importance of Setting Out:**

- It ensures that all components are placed correctly, preventing costly mistakes.
- A well-planned set out can streamline the construction process
- Ensures adherence to building codes and regulations.

- **Foundation inspection**

Definition

Foundation inspection is a critical step in the construction process that ensures the integrity and safety of a building's foundation.

- **Steps of foundation Inspection:**

1. **Visual Inspection:**

- **Cracks:** Check for visible cracks in the foundation walls, floors, and ceilings. Note their size, direction, and location, as they can indicate different issues.
- **Settlement:** Look for signs of uneven settling, such as sloping floors or misaligned windows and doors.
- **Water Damage:** Inspect for signs of water intrusion or moisture, such as efflorescence, mold, or damp spots.

2. **Structural Integrity:**

- **Reinforcement:** Verify that steel reinforcement bars (rebar) or other supports are properly placed and meet engineering specifications.
- **Concrete Quality:** Assess the quality of the concrete mix used and look for any signs of spalling or deterioration.

3. **Drainage and Grading:**

- **Site Grading:** Ensure the site is graded away from the foundation to prevent water pooling.
- **Drainage Systems:** Check the condition of drainage systems (like French drains or gutters) to ensure they effectively divert water away from the foundation.

4. **Soil Conditions:**

- **Soil Type:** Evaluate the soil composition and type, as different soils have varying load-bearing capacities.
- **Compaction:** Ensure that the soil has been adequately compacted to prevent future settlement.

5. **Piers and Footings:**

- **Footing Depth:** Confirm that footings are deep enough to meet local codes and the engineering design.

- **Pier Alignment:** Inspect the alignment and spacing of piers, ensuring they support the load effectively.

❖ **Importance of Foundation Inspection:**

- Ensures that the foundation is stable and can support the structure safely.
- Identifies potential issues early, helping to prevent costly repairs in the future.
- A sound foundation is crucial for maintaining property value and preventing depreciation.

- **Positioning**

Definition

Positioning refers to the careful placement and alignment of an equipment within a designated space to ensure optimal operation, safety, and accessibility.

- **Steps for positioning transformer or other electrical equipment:**

1. **Location:** Choose a location that allows for easy access for maintenance and inspections. Avoid areas prone to flooding, excessive heat, or vibrations. Ensure adequate ventilation.
2. **Foundation:** Position the transformer on a solid, level foundation (often a concrete pad) that can support its weight and absorb vibrations. Ensure the area is graded to direct water away from the transformer or others electrical equipment.
3. **Clearance:** Maintain appropriate clearances around the transformer or others electrical equipment as per local electrical codes and manufacturer recommendations. This includes space for heat dissipation and maintenance access. Keep pathways clear for safe movement around the transformer, particularly in emergency situations.
4. **Alignment:** Ensure that the transformer or others electrical equipment is aligned properly with its electrical connections to prevent strain on cables and connectors. Position the transformer to facilitate easy access to terminal boxes and cooling systems, if applicable.
5. **Grounding:** Position the transformer to allow for effective grounding practices, ensuring all grounding connections are easily accessible.
6. **Cooling and Ventilation:** Ensure that the position allows for adequate airflow around the transformer to prevent overheating. If the transformer has cooling fans or systems, position it to optimize their effectiveness.
7. **Surrounding Equipment:** Position the transformer or others electrical equipment at a safe distance from other electrical equipment, ensuring there is no interference or risk of overheating.
8. **Compliance:** Follow all relevant codes, standards, and guidelines for transformer or others electrical equipment positioning to ensure safety and compliance.

❖ **Importance of Proper Transformer Positioning:**

- Reduces the risk of accidents and facilitates safe maintenance.
- Enhances the performance of the transformer and the overall electrical system.
- Proper positioning can extend the lifespan of the transformer by preventing mechanical stress and overheating.

- **Mounting**

  Definition

  - Mounting refers to the process of securely attaching or positioning an object or equipment in a specific location. This can involve a variety of methods and techniques, depending on the type of object being mounted and its intended use.

- **Types of Mounting:**
  - **Fixed Mounting:** Involves permanently attaching the object to a surface (e.g., mounting a machine to a concrete foundation).
  - **Adjustable Mounting:** Allows for some degree of movement or adjustment (e.g., mounting brackets for televisions that can swivel).
  - **Temporary Mounting:** Used for short-term needs, often employing clamps or other non-permanent fixtures.
- **Mounting techniques:**
  - **Bolting:** Using bolts and anchors to secure heavy objects.
  - **Welding:** For permanent mounts, welding provides strong, durable connections.
  - **Adhesives:** Some objects can be mounted using strong adhesives or double-sided tapes.
  - **Brackets and Supports:** Using brackets to hold items in place, common for shelves, equipment, or signage.

Practical Activity 2.1.2: Mounting an auxiliary transformer

Task:

1: Referring to previous theoretical activity 2.1.1, go to the prepared site and perform the following task:

Mount auxiliary transformer.

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 2.1.2

5: Perform the task provided in the application of learning 2.1.

Key readings 2.1.2: Mounting an auxiliary transformer

- **Mounting an auxiliary transformer**
  - **Definition**

Mounting an auxiliary transformer" refers to the process of installing a transformer that supports the primary power system by providing necessary auxiliary power for equipment and systems.

- **Steps for mounting an auxiliary transformer**

1. Setting Out

- **Planning and Layout:** Verify the transformer's location according to the plant's layout and electrical design. Ensure it's positioned in an area that allows for proper ventilation and access.
- **Site Preparation:** Mark the exact spots for foundation bolts or pads, ensuring alignment with the transformer's mounting points.

2. Foundation Inspection

- **Foundation Quality:** Inspect the foundation for structural integrity and ensure it has been constructed to specifications (e.g., concrete strength, curing time).
- **Level and Stability:** Check that the foundation is level and stable. Any discrepancies could affect the alignment and operation of the transformer.

3. Transformer Positioning

- **Lifting Equipment:** Use cranes or specialized lifting equipment rated for the transformer's weight. Ensure all lifting gear is in good condition and properly

calibrated.

- **Alignment and Clearance:** Position the transformer accurately over the foundation. Ensure it is aligned with the mounting holes and that there is sufficient clearance around it for electrical connections and maintenance access.

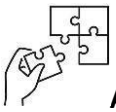
4. Mounting and Anchoring

- **Mounting:** Carefully lower the transformer onto the foundation, ensuring it aligns with the pre-marked positions.
- **Anchoring:** Secure the transformer to the foundation using the specified anchors and bolts. Verify that all fasteners are tightened to the correct torque specifications.
- **Check Alignment:** Confirm that the transformer remains properly aligned and adjust if necessary.

Points to Remember

Steps for mounting an auxiliary transformer

1. Setting Out
2. Foundation Inspection
3. Transformer Positioning
4. Mounting and Anchoring



Application of learning 2.1

The school has prepared site for mounting an auxiliary transformer for supplying the school facilities. You are requested to go to the prepared site to set out and mount an auxiliary transformer.

Indicative content 2.2: Fixing Measurement Transformer

Duration: 8 hrs

Practical Activity 2.2.1: Fixation of measurement transformer

Task:

1: Referring to the previous theoretical activity.2.1.1, Go to the prepared site and perform the following task:

Fix measurement transformer.

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 2.2.1.

5: Perform the task provided in the application of learning 2.2.

Key readings 2.2.1. Fixation of measurement transformer

- **Fixation of measurement transformer**

  Definition

  Fixation of measurement transformer" refers to the process of securely installing a measurement transformer within an electrical system.

- **Steps for fixing a measurement transformer:**

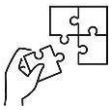
  1. **Mark the Position:** Use a level to mark where the CT and PT will be fixed, ensuring it's in line with the conductor.
  2. **Drill Holes:** If needed, drill holes in the mounting surface for screws or bolts.

3. **Install Mounting Bracket (if applicable):** Secure the bracket to the wall or structure.
4. **Positioning:** Install the CT and PT on the designated busbar or conductor, ensuring it's in a location that facilitates accurate measurement and is accessible for maintenance.
5. **Alignment:** Ensure the CT and PT are aligned properly to avoid mechanical stress or misalignment issues.
6. **Secure the CT and PT:** Use screws or clamps to fix the CT and PT in place. Ensure it's tightly secured to avoid movement

Points to Remember

Steps for fixing a measurement transformer:

1. Mark the Position
3. Install Mounting Bracket (if applicable)
4. Positioning
5. Alignment
6. Secure the CT and PT



Application of learning 2.2.

The school has prepared site for fixing a measurement transformer for measurement the voltage and current of electrical system of the school facilities. You are requested to go to the prepared site to set out and fix the measurement transformer.

Indicative content 2.3: Fixing Neutral Grounding Transformer (NGT).

Duration:6 hrs

Practical Activity 2.3.1: Fixation of neutral grounding transformer (NGT)

Task:

1: Referring to the previous theoretical activity.2.1.1, Go to the prepared site and perform the following task:

Fix neutral grounding transformer.

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 2.3.1.

5: Perform the task provided in the application of learning 2.3.

Key readings 2.3.1: Fixation of Neutral Grounding Transformer (NGT)

- **Fixation of Neutral Grounding Transformer (NGT)**

Definition

Fixing a Neutral Grounding Transformer (NGT)" refers to the process of installing a transformer that connects the neutral point of a power system to the ground.

Steps for fixing an NGT:

1. **Foundation Check:** Verify that the foundation or mounting pad where the NGT will be installed is level, strong, and meets the design specifications.
2. **Marking:** Mark the mounting points or anchor locations on the foundation based on the NGT's dimensions and mounting requirements.
3. **Alignment:** Position the NGT according to the marked locations. Ensure it is aligned correctly with the mounting points or foundation.
4. **Mounting Hardware:** Use the specified mounting hardware, such as bolts, brackets, or clamps, to secure the NGT to the foundation or mounting pad. Ensure all hardware is appropriate for the transformer's weight and size.
5. **Securing:** Tighten all mounting bolts and hardware to the recommended torque specifications. Ensure that the NGT is firmly anchored and will not shift or vibrate.

Points to Remember

Steps for fixing neutral grounding transformer (NGT):

1. Foundation Check
2. Marking
3. Alignment
4. Mounting Hardware
5. Securing

Application of learning 2.3.

The school has prepared site for fixing a neutral grounding transformer for providing stable reference point for the neutral of an electrical system of the school facilities. You are requested to go to the prepared site to set out and fix the neutral grounding transformer

Indicative content 2.4: Fixing Control Panels

Duration: 6 hrs

Practical Activity 2.4.1: Fixation of control panel

Task:

1: Referring to the previous theoretical activity.2.1.1, Go to the prepared site and perform the following task:

Fix control panel.

2: Apply safety precautions

3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 2.4.1

5: Perform the task provided in the application of learning 2.4.

Key readings 2.4.1; Fixation of control panels

Fixing control panels involves a systematic approach to ensure they are securely mounted and properly connected for optimal functionality.

Steps for Fixing Control Panels:

1. **Marking:** Mark the mounting points or anchor locations on the foundation based on the control panel dimensions and mounting requirements.
2. **Position Brackets:** If required, attach mounting brackets to the wall or surface where the control panel will be installed.
3. **Secure Brackets:** Use appropriate screws or anchors to secure the brackets firmly, ensuring they are level and aligned.
4. **Lift and Position the Panel:** With assistance, lift the control panel into position on the mounted brackets or directly onto the surface.
5. **Alignment:** Ensure the control panel is level and properly aligned.
6. **Fasten the Panel:** Use screws or bolts to secure the control panel to the mounting brackets or surface as per the manufacturer's recommendations.

Points to Remember

Steps for Fixing Control Panels:

1. Marking
2. Position Brackets
3. Secure Brackets
4. Lift and Position the Panel
5. Alignment
6. Fasten the Panel

Application of learning 2.4.

The school has prepared site for fixing a control panel for housing different switching elements of an electrical system of the school facilities. You are requested to go to the prepared site to set out and fix the control panel.

Indicative content 2.5: Fixing Switchgears

Duration: 6 hrs

Practical Activity 2.5.1: Fixation of switchgears

Task:

1: Referring to the previous theoretical activity.2.1.1, Go to the prepared site and perform the following task:

Fix switchgears.

2: Apply safety precautions

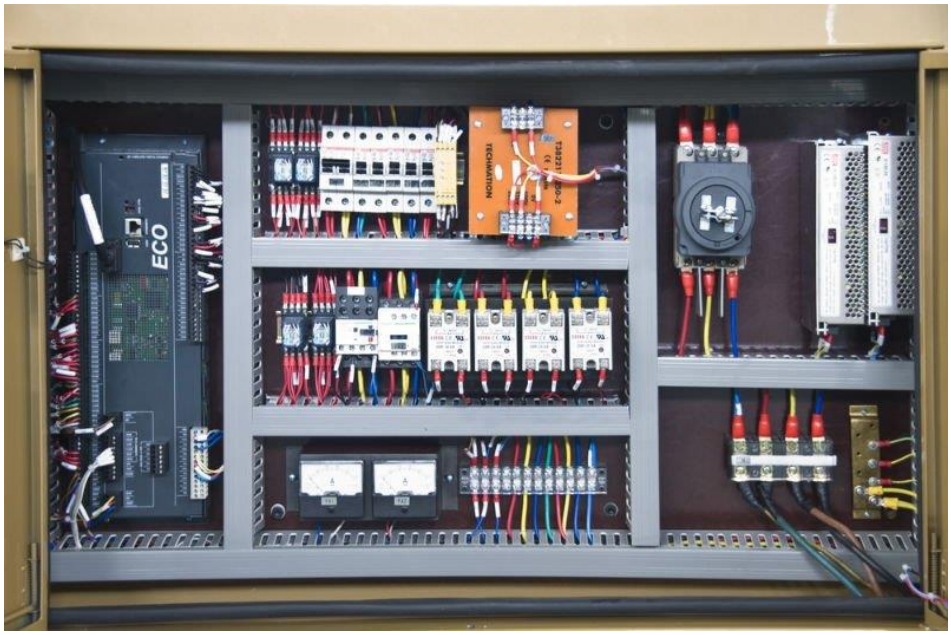
3: Present your work to the trainer/the workshop assistant. Ask for clarification where necessary

4: Read key reading 2.5.1

5: Perform the task provided in the application of learning 2.5.

Key readings 2.5.1 Fixation of switchgear

Fixing switchgear involves careful installation and connection to ensure safe and reliable operation.



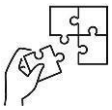
Steps for Fixing Switchgear:

1. **Marking:** Mark the mounting points or anchor locations in the control panel based on the switchgear's dimensions and mounting requirements.
2. **Position Brackets:** If required, attach mounting brackets to the wall or surface where the switchgears will be installed.
3. **Lifting and Positioning:** Using appropriate lifting equipment (if necessary), carefully lift the switchgear into position.
4. **Alignment:** Ensure the switchgear is aligned with other connected equipment and is level.
5. **Securing the Switchgear:** If required, use anchor bolts to secure the switchgear to the foundation or mounting surface to prevent movement. Tighten all screws and bolts as per the manufacturer's recommendations.

Points to Remember

Steps for Fixing Switchgear

1. Marking
2. Position Brackets
3. Lifting and Positioning
4. Alignment
5. Securing the Switchgear



Application of learning 2.5.

The school has fixed control panel for housing different switchgears to control the operation and protection of an electrical system of the school facilities. You are requested to go to set out and fix the switchgears inside the control panel.

Learning outcome 2 end assessment

Written assessment

I. Match the steps of fixing power plant auxiliaries in column A with their meaning in column B.

Answer	Steps of fixing power plant auxiliaries	Meaning
1….	1) Setting out	A) Refers to the careful placement and alignment of an equipment within a designated space to ensure optimal operation, safety, and accessibility.
2…	2) Marking	B) refers to the process of securely attaching or positioning an object or equipment in a specific location.
3…	3) Positioning	C) Use stakes, paint, or other markers to indicate where foundations, walls, or equipment will be located.
4..	Mounting	E) Refers to the process of accurately marking and establishing the position of structures, equipment, or components in construction and engineering projects

II. Encircle the letter corresponding to the correct answer

i. The following are the types of mounting, **Except:**

a) Fixed Mounting

b) Adjustable Mounting

c) Temporary Mounting

d) Permanent mounting

ii. The following are the mounting techniques, **Except:**

a) Bolting

b) Accessibility

c) Welding

d) Adhesives

e) Brackets and Supports

iii. While inspecting the foundation by visual inspection, the following are the points/elements to inspect, **Except:**

a) Cracks

b) Settlement

c) Reinforcement

d) Water Damage

iv. The following are the importance of setting out, **Except:**

a) It ensures that all components are placed correctly, preventing costly mistakes.

b) Identifies potential issues early, helping to prevent costly repairs in the future.

c) A well-planned set out can streamline the construction process

d) Ensures adherence to building codes and regulations.

III. Answer by **True** if the statement is correct and **False** if the statement is wrong

a) Mounting is done to provide stability, safety, and functionality to equipment or objects

b) Anchoring secure the transformer to the foundation using the specified anchors and bolts.

c) Leveling ensure that the marked positions are level and meet elevation requirements, which is not crucial for structures like foundations and floors.

Practical assessment

The school is located near the river, and the school management plan to construct hydropower plant at the river for suppling electrical power to school facilities, after construction of a power house. You are requested to fix the following hydropower plant auxiliaries: auxiliary transformer, measurement transformers, neutral grounding transformer, control panel and switchgears. The task must be done in 8 hours.

END

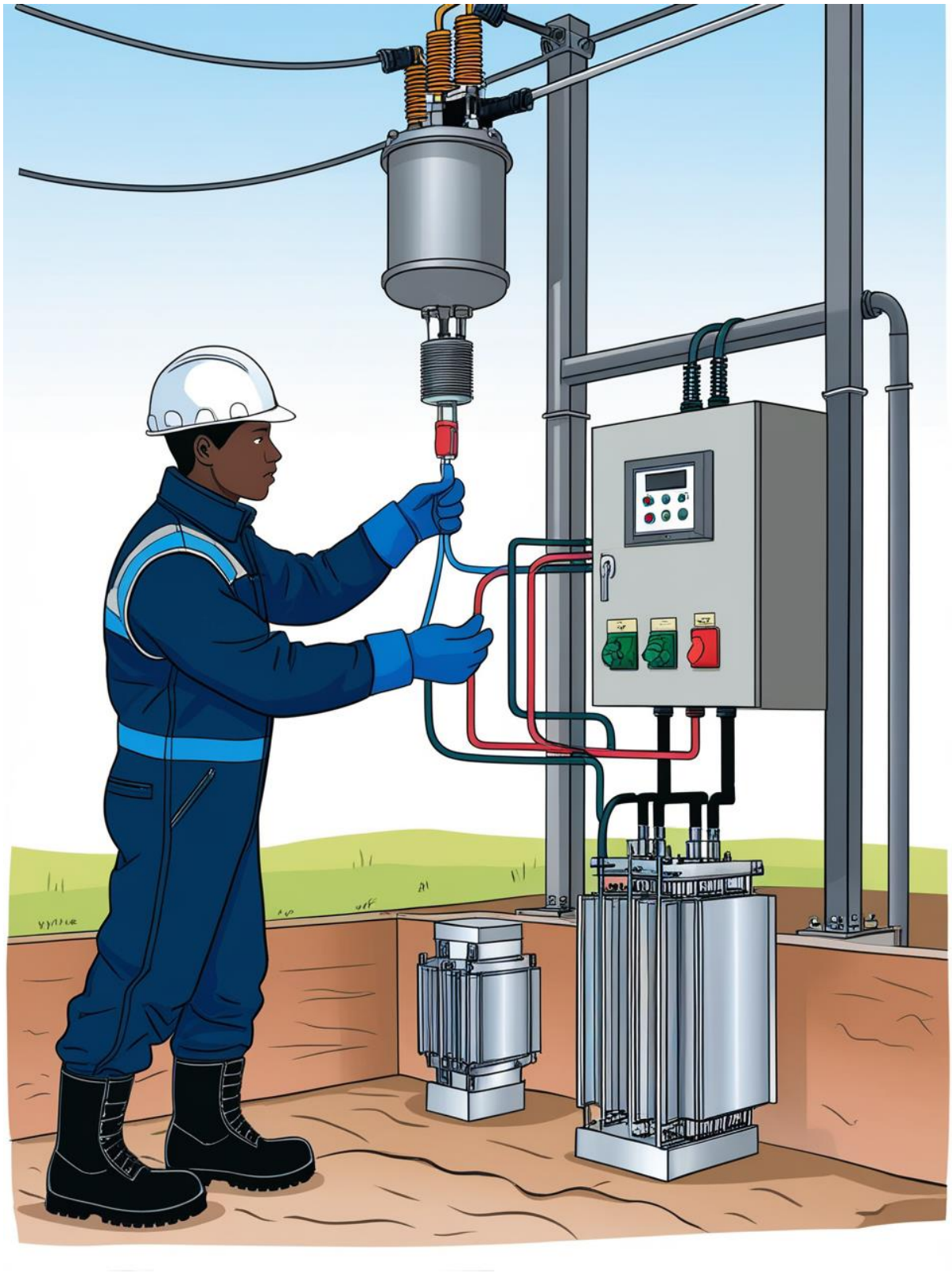
References

Brown, L. ((2023).). *Installation procedures for electrical transformers and switchgear. .* Power Systems Publishing.

Clark, R. ((2022).). *Guidelines for fixing and maintaining Neutral Grounding Transformers.* Power Systems Association.

Johnson, R. ((2022).). *Guidelines for mounting auxiliary transformers and switchgear.* Electrical Engineering Association.

Taylor, J. (2023). *Installation and maintenance of Neutral Grounding Transformers.* Electrical Engineering Press.



Indicative contents

3.1. Connecting auxiliary transformer

3.2. Connecting measurement transformer

3.3. Connecting of neutral grounding transformer

3.4. Connecting control panel

3.5 Connecting switchgear

3.6: Testing functionality of HPP auxiliaries

3.7. Documentation and record filing

3.8. Developing As-built drawing

3.9. Elaborating the report

Key Competencies for Learning Outcome 3: Connect hydropower plant auxiliaries

Knowledge	Skills	Attitudes
• Description on Connecting auxiliary transformer • Description on Connecting measurement transformer • Description on Connecting of neutral grounding transformer. • Description on Connecting control panel • Description on Connecting switchgear • Description on	• Connecting auxiliary transformer • Connecting measurement transformer • Connecting of neutral grounding transformer. • Connecting control panel • Connecting switchgear • Testing functionality of HPP auxiliaries	• Being attentive when connecting, auxiliary transformer, measuring transformer, neutral grounding transformer, control panel, switch gear • Being accurate while testing functionality of HPP auxiliaries • Paying attention when connecting hydropower plant auxiliaries to minimize

Testing functionality of HPP auxiliaries ● Description on Documentation and record filing ● Description on Developing As-built drawing ● Description on Elaborating the report		accidents that may occur

Duration: 25hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Describe effectively connecting process of each power plant auxiliary.
2. Connect correctly auxiliary transformer according to the wiring diagram
3. Connect correctly measurement transformer according to the wiring diagram
4. Connect correctly Neutral grounding transformer according to the wiring diagram
5. Connect correctly Control panel equipment according to the wiring diagram
6. Connect correctly Switchgear equipment according to the wiring diagram
7. Perform accurately functionality test of hydropower plant auxiliaries based on their working principle
8. Develop effectively as-built diagram and report based on installation

Resources

Equipment	Tools	Materials
● Computer ● Printers ● PPE ● Multimeter ● Fire Extinguisher ● Drilling Machine ● Wattmeter ● Power Electrical ● Electric Grinder ● Screw driver ● Clamp-On Ammeter ● Labelling Machine	● Screw Driver Kit ● Plier's Kit ● Spanners Kit ● Allen Key Kit.	● Cables ● Connectors ● Cables Ties ● Tape Insulator ● Rail.

Indicative content 3.1: Connecting Auxiliary Transformer

Duration: 3hrs

Theoretical Activity 3.1.1: Description of auxiliary transformer connection

Tasks:

1: Answer the following questions related to description of auxiliary transformer connection

I. What do you understand by connecting an auxiliary transformer in hydropower plant?
II. What are the types of connections that are made on auxiliary transformer in hydropower plant?
III. What the steps for connecting an auxiliary transformer?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.1.1**

Key readings 3.1.1: Description of auxiliary transformer connection

- **Connecting an auxiliary transformer**

Definition

Connecting an auxiliary transformer typically involves integrating a smaller transformer with a larger power system to provide additional power or voltage regulation for specific applications. These transformers are often used to supply power to auxiliary systems, such as control circuits, lighting, or other equipment that doesn't require the full capacity of the main transformer.

- **Types of connection on auxiliary transformer**
  - ✓ **Electrical connection**

In a hydropower plant (HPP), the electrical connection of an auxiliary transformer involves the integration of the transformer into the plant's electrical system to provide power to various auxiliary systems.

- Apply Connection procedures

Procedures for electrical connection of an auxiliary transformer in a hydropower plant are:

1. Planning and Preparation

- Study the transformer datasheets, schematics, and electrical diagrams.
- Ensure all personnel are trained and understand the safety protocols.

2. Physical Installation

- Place the auxiliary transformer in its designated location according to the installation drawings.
- Ensure proper alignment with mounting foundations and clearance for ventilation.
- Securely mount the transformer using appropriate hardware.

3. Electrical Connections

- Connect the primary side of the transformer to the high-voltage power source and connect the secondary side to the load circuits, ensuring correct phase and neutral wiring.
- Use appropriate cable insulation and terminals to prevent electrical faults. Ensure all terminations are clean, tight, and correctly insulated.

- Connect control circuits, such as protection relays, alarms, and meters.
- Verify the calibration and functionality of all instrumentation.

4. Testing and Commissioning

- ❖ Measure insulation resistance of the transformer windings using a megohmmeter.
- ❖ Compare the results with the manufacturer's specifications.
- ❖ Check for continuity in primary and secondary windings.
- ❖ Verify that there are no short circuits or open circuits.
- ❖ Energize the transformer in stages to monitor for any abnormalities.
- ❖ Check voltages, currents, and temperatures to ensure normal operating conditions.

Primary terminal connection

❖ **Steps of connecting primary terminals are:**

1. Connect High-Voltage Cables:

- Locate the primary terminals for the high-voltage side of the transformer.
- Attach the high-voltage cables to the primary terminals. For three-phase systems, connect each phase (L1, L2, L3) to the corresponding terminal.
- If the system includes a neutral, connect the neutral wire to the designated terminal.

2. Insulation and Termination:

- Strip the insulation from the cable ends properly and prepare them for termination.
- Use appropriate lugs or connectors for securing cables to the terminals.
- Insulate all connections with heat shrink tubing or insulating tape to prevent electrical hazards.

3. Grounding:

- Connect the transformer's grounding terminal to the plant's grounding system.
- Ensure a low-resistance path to ground to protect against electrical faults.

Secondary terminal connection

❖ **Steps of connecting primary terminals are:**

1. Connect Low-Voltage Cables:

- ❖ Locate the secondary terminals for the low-voltage side.
- ❖ Attach the low-voltage cables to the secondary terminals, ensuring correct phase alignment and neutral connections.

2. Insulation and Termination:

- Strip and prepare the cable ends.
- Use suitable lugs or connectors.

- Apply insulation to prevent exposure and potential electrical hazards.

3. **Protection Devices:**
   - Connect and set up circuit breakers or fuses for protection on the secondary side.
   - Connect and configure protective relays for overcurrent, differential protection, etc.

✓ **Connecting cooling systems**

Connecting the cooling system of a transformer is a crucial step to ensure that the transformer operates within its optimal temperature range and to prevent overheating.

Types of cooling

Transformers require effective cooling systems to manage the heat generated during operation and ensure they operate within safe temperature limits. Various cooling methods are used depending on the transformer's size, design, and operational environment.

❖ **Primary types of cooling systems used in transformers are:**

1. Air Cooling Systems

- **Natural Air Cooling:** Utilizes natural convection to dissipate heat from the transformer's surface into the surrounding air.
  - **Application:** Common in small to medium-sized transformers where cooling requirements are lower.
  - **Advantages:** Simple and cost-effective, requires minimal maintenance.
  - **Disadvantages:** Limited cooling capacity, less effective in high ambient temperatures.

- **Forced Air Cooling:** Uses fans or blowers to force air over the transformer's surface or through cooling ducts to enhance heat dissipation.
  - **Application:** Suitable for medium to larger transformers where natural cooling is insufficient.
  - **Advantages:** Improved cooling efficiency compared to natural cooling.
  - **Disadvantages:** Requires additional power for fans and periodic maintenance.

2. Oil Cooling Systems

- **Oil-Immersed Cooling:** The transformer is immersed in oil, which absorbs and transfers heat. Natural convection circulates the oil around the core and windings.
    - **Application:** Common in many standard distribution transformers.
    - **Advantages:** Effective for transformers of various sizes, provides good thermal conductivity.
    - **Disadvantages:** Requires oil management, including filtration and periodic replacement.

- **Oil-Immersed with Air Forced Cooling:** Similar to ONAN but includes external fans to force air over the radiator to increase heat dissipation.
    - **Application:** Used for transformers needing higher cooling capacity, especially in outdoor or high-load scenarios.
    - **Advantages:** Enhanced cooling efficiency compared to ONAN.
    - **Disadvantages:** Additional maintenance for fans, increased power consumption.

- **Oil-Immersed with Water Cooling:** Combines oil cooling with an external water-cooling system, where the oil is cooled by a water-cooled heat exchanger.
    - **Application:** Suitable for large transformers requiring significant cooling.
    - **Advantages:** Provides high cooling capacity, suitable for very large transformers.
    - **Disadvantages:** Complex system with higher initial and maintenance costs, requires a reliable water source.

- **Oil-Immersed with Forced Oil Circulation:** Uses internal or external pumps to circulate the oil through radiators or coolers.
    - **Application:** Used for large transformers with high cooling demands.
    - **Advantages:** Enhanced cooling efficiency, can manage higher heat loads.
    - **Disadvantages:** Requires additional equipment and maintenance.

3. Water Cooling Systems

- **Water-Immersed Cooling:** The transformer is cooled by immersing it in water or using water as the cooling medium circulated through a heat exchanger.
    - **Application:** Less common; used in specific high-performance or

custom applications.
    - **Advantages:** Efficient for very high-capacity transformers.
    - **Disadvantages:** Complex, high initial cost, and maintenance.

- **Water-External Cooling**: Uses water-cooled heat exchangers to remove heat from the transformer's cooling oil or directly from the transformer.
    - **Application:** Large transformers where oil cooling alone is insufficient.
    - **Advantages:** Effective cooling, suitable for high-load scenarios.
    - **Disadvantages:** Requires a continuous water supply, complex system setup.

4. Hybrid and Specialized Cooling Systems

- **Combination of Cooling Methods**: Utilizes a combination of air, oil, and water-cooling systems to achieve optimal cooling performance.
    - **Application:** High-power transformers with variable cooling needs.
    - **Advantages:** Flexible and can be tailored to specific cooling requirements.
    - **Disadvantages:** Complex system management, higher cost.

- **Low-Temperature Cooling Systems**: Uses advanced techniques such as cryogenic cooling or specialized refrigerants to achieve very low operating temperatures.
    - **Application:** Specialized applications where extreme temperature control is required.
    - **Advantages:** Provides very high cooling efficiency.
    - **Disadvantages:** High cost, complexity, and specific maintenance requirements

Auxiliary Transformer cooling

Auxiliary Transformer cooling refers to the methods used to manage the temperature of auxiliary transformers in electrical power systems.

Because these transformers handle power that supports the operation of the main electrical system, their reliable operation is crucial. Cooling is necessary to prevent overheating and ensure efficient operation.

❖ **Factors considered for cooling an auxiliary transformer**

- **Transformer Size and Load:** The cooling system should match the transformer's size and the load it handles. Larger transformers or those with higher loads generally require more advanced cooling solutions.

- **Ambient Conditions:** The environment where the transformer operates affects cooling choices. In areas with high ambient temperatures or limited ventilation, forced air or oil cooling may be necessary.
- **Maintenance Requirements:** Different cooling systems have varying maintenance needs. For example, oil systems require regular checks of oil quality and levels, while air systems need periodic fan maintenance.
- **Cost and Complexity:** Balance the initial setup costs with operational efficiency. Advanced systems like water cooling or hybrid methods can be more expensive but offer higher cooling capacities.
- **Reliability and Safety:** Ensure the cooling system is reliable and meets safety standards to prevent overheating and potential damage to the transformer.

Connecting protective system

Connecting protective systems to a transformer is crucial to ensure its safety and reliability. These systems include the relaying system and the earthing (grounding) system.

Relaying system

The relaying system monitors transformer parameters and provides protection by isolating the transformer in case of faults.

❖ **Steps for connecting and configure the relaying system are:**

1. **Protection Relay Selection:**

- Select appropriate protection relays based on the transformer's specifications and protection needs. Common types include overcurrent relays, differential relays, and thermal overload relays.
- Determine the protection functions required, such as overcurrent, differential, and earth fault protection.

2. **Relay Wiring and Connection:**

- Install CTs on the primary and secondary sides of the transformer to measure the current and provide input to the relays.

- Install VTs if voltage-based protection is required.
- Connect CTs and VTs to the appropriate relay terminals. Ensure correct polarity and wiring according to the relay's manual.
- Use appropriately rated cables and ensure secure and accurate connections.

3. **Relay Settings and Calibration:**

- Configure the relay settings based on the transformer's specifications, including current settings, time delays, and fault thresholds.
- Perform functional tests to ensure the relay operates correctly and responds to simulated fault conditions.

4. **Communication and Integration:**

- Integrate the relay with the plant's control system or SCADA (Supervisory Control and Data Acquisition) for remote monitoring and control.
- Configure alarms and indicators to signal when protection actions are taken.

Earthing system

An effective earthing system is essential for safety and to ensure that the transformer operates correctly.

❖ **Steps for connecting and set up the earthing system are:**

1. **Earthing System Design**

- Decide on the type of earthing system to use (e.g., solidly grounded, resistance-grounded, or impedance-grounded).
- Identify grounding points, including transformer body, neutral points, and system connections.

2. **Grounding Connections**

❖ **Transformer Grounding**

- Connect the transformer's body to the grounding system using a heavy gauge grounding conductor.
- Connect the transformer neutral point to the grounding system.

❖ **Grounding Electrode System**

- Install grounding electrodes (rods, plates, or mesh) in accordance with local codes and standards.
- Connect the grounding electrodes to the transformer grounding system using suitable conductors.

❖ **Bonding:**

- Ensure proper bonding of all metallic parts of the transformer and related equipment to the grounding system.

3. **Testing and Verification:**
   - Measure the resistance of the grounding system to ensure it is within acceptable limits (typically below 5 ohms).
   - Verify that all grounding connections have good continuity and are properly bonded.

Practical Activity 3.1.1: Connecting an auxiliary transformer

Task:

1: Referring to the previous theoretical activity 3.1.1, go to the site and perform the following task:

Connect auxiliary transformer.

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.1.1**

5: Perform the task provided in the application of learning 3.1

Key readings 3.1.1: connecting auxiliary transformer

- **Connecting auxiliary transformer**

Connecting an auxiliary transformer involves specific electrical steps to ensure safety and functionality.

Steps of Connection of an Auxiliary Transformer

1. **Primary and Secondary Connections:**
   - Connect the primary side of the transformer to the high-voltage power source.

- Connect the secondary side to the load circuits, ensuring correct phase and neutral wiring.

2. Insulation and Termination:

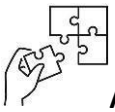
- Use appropriate cable insulation and terminals to prevent electrical faults.
- Ensure all terminations are clean, tight, and correctly insulated.

3. Control and Instrumentation Connections:

- Connect control circuits, such as protection relays, alarms, and meters.
- Verify the calibration and functionality of all instrumentation.

Points to Remember

- **Connecting an auxiliary transformer** typically involves integrating a smaller transformer with a larger power system to provide additional power or voltage regulation for specific applications.
- **Types of connection of an auxiliary transformer are the following:** Electrical connection, connecting protective system and Connecting cooling systems
- **Steps for connection an auxiliary transformer are:** Primary and Secondary Connections, Insulation and Termination, Control and Instrumentation Connections, cooling systems connection and protective system connection



Application of learning 3.1

The project of constructing hydropower plant that will produce 1MW to supply a rural area is on its final stage. As hydropower plant technician you are asked by the hydropower plant owner to connect an auxiliary transformer.

Indicative content 3.2: Connecting Measurement Transformer

Duration: 3 hrs

Theoretical Activity 3.2.1: Description of measurement transformer

Tasks:

1: Answer the following questions related to description of measurement transformer connection

i. What do you understand by connecting measurement transformer?
ii. What are the types of measurement transformers?
iii. What are the connecting tips for measurement transformers?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.2 .1**

Key readings 3.2.1.: Description on connecting measurement transformer

- **Connecting measurement transformers**

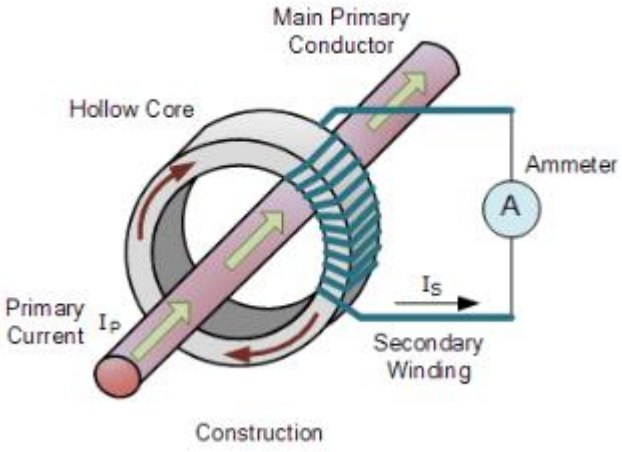
Connecting a measurement transformer involves integrating a transformer specifically designed to measure electrical parameters like voltage, current, or power in an electrical system. These transformers are crucial for monitoring and controlling power systems safely and accurately.

✓ **Types of measurement transformers:**

- Current transformer (CT)
- Voltage transformer (VT)

Current Transformer

A current transformer (CT) is an electrical device used to measure and monitor the current flowing through a conductor, typically in high-voltage circuits. It functions by producing a reduced current proportional to the current flowing in the circuit, allowing for safe and accurate measurement and monitoring.



❖ **Steps for connecting current transformers (CTs) are:**

1. **Selection and Placement:**
   - Select CTs based on the transformer's rating, primary current, and measurement accuracy requirements.
   - Install CTs on the primary conductors of the transformer, usually around the conductors or bus bars.

2. **Wiring and Connections:**
   - CTs are placed around the primary conductors to measure the current flowing through them.
   - Connect the secondary terminals of the CTs to the measurement devices or protection relays. The secondary side should be connected to the instrumentation devices and should never be left open-circuited while the transformer is energized.
   - Ensure correct polarity of the CT connections. The polarity markings (P1, P2, S1, S2) on the CT should be followed to maintain accuracy.

3. **Insulation and Safety:**
   - Use appropriately rated insulated wires for the secondary connections.
   - Avoid opening the CT secondary circuit under load to prevent high voltage from appearing across the terminals.

4. **Testing and Calibration:**
   - Verify the CT turns ratio to ensure it matches the design specifications.
   - Test the CT using a primary current injection or a secondary current source to verify that it provides accurate readings.

Voltage Transformer

A voltage transformer (VT), also known as a potential transformer (PT), is an electrical device designed to measure and monitor the voltage in a high-voltage system by stepping it down to a lower, more manageable level.

Connecting voltage transformer (VTs), is essential for accurate monitoring and protection of electrical systems.

❖ **Steps for connecting voltage transformer are:**

1. **Selection and Placement:**

- Select VTs based on the transformer's voltage rating and accuracy requirements for measurement and protection.
- Install VTs connected to the high-voltage side of the transformer, where they step down the voltage to a lower, manageable level.

2. **Wiring and Connections:**
   - Connect the primary terminals of the VT to the high-voltage circuit.
   - Connect the secondary terminals to the measurement devices, such as voltmeters, or to relays for voltage-based protection
   - Maintain proper polarity to ensure accurate measurements.
3. **Insulation and Safety:**

- Use high-quality insulated cables for connecting the secondary side of the VT.
- Ensure the VT secondary circuit is not open under load conditions to prevent high voltage from appearing across the terminals.

4. **Testing and Calibration:**

- Verify the VT turns ratio and ensure it matches the specifications.
- Test the VT by applying a known voltage to check for accurate output and calibration.

Instrumentation devices

Instrumentation devices are instruments designed to provide accurate readings and control of physical variables, such as temperature, pressure, flow, level, and

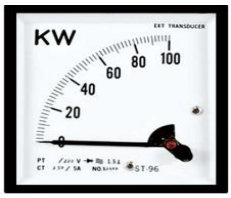
electrical parameters. They convert physical quantities into readable signals that can be displayed, recorded, or used to control processes.

❖ **The instrumentation devices are:**

- **Measurement Devices:** Common devices include ammeters, voltmeters, power meters, and energy meters.

Ammeter 

voltmeter 

power meter 

energy meter 

- **Protection Relays:** These devices use inputs from CTs and VTs to provide protective functions such as overcurrent, undervoltage, and differential protection.

❖ **Steps for connecting instrumentation devices:**

1. **Understand the System Requirements:**
   - Determine what physical parameters need to be measured (e.g., temperature, pressure, flow).
2. **Wiring and Integration:**
   - Connect the secondary terminals of the CTs to the current measurement devices or relays. Use appropriate connections to ensure accuracy and reliability.
   - Connect the secondary terminals of the VTs to the voltage measurement devices or relays. Ensure proper wiring for accurate voltage readings.
3. **Calibration and Testing:**
   - Calibrate instrumentation devices according to manufacturer specifications.
   - Test the system under operational conditions to verify that all measurement

and protection devices function correctly.

4. **Signal Conditioning:**
   - For accurate readings, ensure that signal conditioning devices, such as isolators or amplifiers, are properly configured if needed

Practical Activity 3.2.2: connection of measurement transformer

Task:

1: Referring to the previous theoretical activity 3.2.1, go to the site and perform the following task:

Connect measurement transformers.

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.2.2**

5: Perform the task provided in the application of learning 3.2

Key readings 3.2.2: Connecting Measurement transformer

- **Connecting Measurement transformer**

Connecting a measurement transformer, such as a current transformer (CT) or voltage transformer (VT), involves careful steps to ensure accuracy and safety.

✓ **Steps for Connecting a Measurement Transformer**

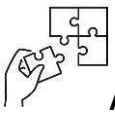
1. **Preparation and Safety Precautions**
   - Review the installation manual and wiring diagrams for the specific measurement transformer.
   - Wear appropriate personal protective equipment (PPE) and ensure that the power supply is disconnected before starting.
2. **Mounting the Transformer**
   - Install the transformer in a suitable location, ensuring accessibility for future maintenance.

- Mount the transformer securely to avoid vibrations or movement that could affect performance.

3. **Electrical Connections**
   - **Primary Connections:**
     - For a CT, connect the primary winding in series with the conductor who's current you want to measure.
     - For a VT, connect the primary winding across the high-voltage circuit.
   - **Secondary Connections:**
     - Connect the secondary terminals to the measurement or protective devices (like meters or relays) according to the wiring diagram.
   - **Grounding:** Ensure proper grounding of the transformer to prevent electrical hazards.

Points to Remember

- **Connecting a measurement transformer** involves integrating a transformer specifically designed to measure electrical parameters like voltage, current, or power in an electrical system. These transformers are crucial for monitoring and controlling power systems safely and accurately.
- **Types of measurement transformers:** Current transformer (CT), Voltage transformer (VT)
- **Steps for Connecting a Measurement Transformer are:** Preparation and Safety Precautions, Mounting the Transformer and Electrical Connections



Application of learning 3.2

The project of constructing hydropower plant is on its final stage. As hydropower plant technician you are asked by the hydropower plant owner to connect measurement transformer.

Indicative content 3.3: Connecting of Neutral Grounding Transformer.

Duration: 3hrs

Theoretical Activity 3.3.1: Description of neutral grounding transformer connection

Tasks:

1: Answer the following questions related description of neutral grounding transformer connection

i. What do you understand by connecting neutral grounding transformer?

ii. What are the steps for connecting neutral grounding transformer?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.3 .1**

Key readings 3.3.1. Description on connection of neutral grounding transformer

- **Connecting a neutral grounding transformer**

Connecting a neutral grounding transformer in a hydroelectric power plant (HPP) involves integrating a transformer that serves to ground the neutral point of a power system, particularly in high-voltage applications.

- ✓ **Steps for connecting neutral grounding transformer**
- **Grounding system construction**

A **ground system** (or grounding system) is an electrical safety mechanism designed to connect electrical installations to the earth.

- **Components of grounding System**
  - **Ground Electrodes**: Typically made from copper or galvanized steel (rods, plates, or rings).

- **Grounding Conductors**: Wires connecting the electrodes to the electrical system.
- **Bonding**: Connects all conductive parts to prevent voltage differences.

❖ **Installation process**

- Drive ground rods vertically into the earth, ensuring a low-resistance connection.
- For ground plates or rings, bury them at the required depth.
- Ensure proper connections with grounding conductors, using appropriate connectors and bonding techniques.

Grounding Resistance Measurement:

Refers to the process of determining the electrical resistance between a grounding system (or grounding electrode) and the earth. It also ensures that the grounding system provides an effective low-resistance path to the earth.

❖ **Common Methods used to measure grounding resistance**

- **Fall-of-Potential Method**: Uses three electrodes to accurately measure resistance by applying a known current and measuring the resulting voltage.
- **Two-Point Method**: Involves two electrodes to measure resistance, suitable for smaller systems.
- **Clamp-on Ground Resistance Tester**: Measures resistance without disconnecting the grounding system, providing a quick and non-intrusive option.

Fixing Grounding Rods

❖ **Installation Steps**:

1. Identify an area with good soil conductivity, away from structures.
2. Use a hammer or driving tool to drive the rod vertically into the ground until only a few inches remain above the surface. Ensure the rod is straight.
3. Use grounding clamps or connectors to securely attach grounding conductors to the rod. Ensure tight connections to minimize resistance.

Testing Grounding Resistance

Use a grounding resistance tester and follow the selected measurement method (e.g., Fall-of-Potential).

❖ **Steps for testing grounding resistance**:

1. For the Fall-of-Potential method, place the current electrode at a distance (typically 50 feet) from the ground rod. Place the potential electrode in between the current electrode and the ground rod.
2. Connect the tester to the electrodes and perform the test, which measures the voltage drop and calculates resistance.
3. Document the measured resistance value for future reference and compliance checks.
4. Compare measured resistance to acceptable limits (often less than 5 ohms for most systems) to ensure the grounding system is effective.

Connecting grounding conductor to transformer terminal

❖ **Steps for Connecting grounding conductor to transformer terminal are:**

1. Locate the designated grounding terminal or point on the transformer. This is often labelled as "Ground" or "GND."
2. Identify the grounding conductor that will be connected to the transformer. Ensure it is of the correct size and type as specified by code and transformer requirements.
3. Measure the length of the grounding conductor needed to reach from the transformer terminal to the grounding system. Cut the conductor to the appropriate length.
4. Strip the insulation from the ends of the grounding conductor, exposing enough bare metal to make a secure connection. Ensure that the length of exposed conductor matches the requirements of the grounding clamp or terminal.
5. Position the grounding clamp around the exposed end of the grounding conductor.
6. Tighten the clamp securely to ensure a solid connection. Ensure the clamp makes good contact with the conductor and the transformer terminal.
7. Insert the end of the grounding conductor into the transformer's grounding terminal if it is a terminal block type.
8. Tighten the terminal screw or connector to secure the conductor in place. Ensure that the connection is firm and there is no movement or loosening.

Connecting primary terminal to generator neutral terminal

❖ **Steps Connecting primary terminal to generator neutral terminal**

1. Locate the primary terminal or connection point on the generator where you will be making the connection. This is typically labelled or identified in the generator's wiring diagram.
2. Identify the neutral terminal on the generator. This terminal is usually part of the generator's neutral grounding system.
3. Choose an appropriately sized conductor for the connection. The size should comply with local codes and the generator's specifications.
4. Cut the conductor to the required length and strip the insulation from the ends to expose enough bare wire for a secure connection.
5. Place one end of the conductor onto the primary terminal and the other end onto the neutral terminal of the generator.
6. Use terminal lugs or connectors designed for the size of your conductor. Ensure they are rated for the current and voltage of your system.
7. Securely tighten the connectors to the terminals. Ensure there is a firm, solid connection with no movement.
8. If using a bus bar to connect multiple terminals, install the bus bar securely in the designated location.

9. Attach one end of the conductor to the primary terminal connection on the bus bar and the other end to the neutral terminal connection.
10. Tighten all connections to ensure a solid, reliable connection.

Practical Activity 3.3.2: connecting a neutral grounding transformer

Task:

1: Referring to the previous theoretical activity 3.3.1, go to the site and perform the following task:

Connect neutral grounding transformer.

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.3.2**

5: Perform the task provided in the application of learning 3.3

Key readings 3.3.2: Connecting a Neutral Grounding Transformer

- **Connecting a Neutral Grounding Transformer**

Connecting a neutral grounding transformer (NGT) is a critical process for ensuring system stability and safety.

✓ **Steps for Connecting a Neutral Grounding Transformer**

1. Identify Connection Points

- Identify the terminals for connecting to the system's neutral point.
- Locate the grounding terminal on the transformer.

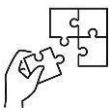
2. **Grounding Connection**

- Connect the grounding terminal of the NGT to a grounding electrode system. This may involve:
  - Driving a grounding rod into the ground.
  - Connecting the grounding conductor to an existing grounding system.
- Verify that all grounding connections are secure and free of corrosion.

3. **Connect to the Neutral Point**
   - Connect the NGT's primary winding (usually marked as H1 and H2) to the neutral point of the system (typically the transformer or generator neutral).
   - Ensure correct phase connections if the NGT is to provide grounding for specific phases.
4. **Connection to Ground**
   - Connect the secondary winding of the NGT to the ground. This is usually done through a resistor or inductor, depending on the grounding scheme (solidly grounded, impedance grounded).
   - Ensure that the grounding conductor is properly secured and connected

Points to Remember

- **Connecting a neutral grounding transformer** in a hydroelectric power plant (HPP) involves integrating a transformer that serves to ground the neutral point of a power system, particularly in high-voltage applications.
- **Steps for connecting Neutral Grounding Transformer (NGT)are:** Identify Connection Points, Grounding Connection, Connect to the Neutral Point and Connection to Ground



Application of learning 3.3

The project of constructing hydropower plant is on its final stage. As hydropower plant technician you are asked by the hydropower plant owner to connect neutral grounding transformer.

Indicative content 3.4: Connecting Control Panel

Duration: 3 hrs

Theoretical Activity 3.4.1: Description on control panel connection

Tasks:

1: Answer the following questions related description of control panel connection

i. What do you understand by connecting control panel?
ii. What are the steps for connecting a control panel?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.4 .1**

Key readings 3.4.1. Description of control panel connection

- **Connecting a control panel**
  - ✓ **Definition**

Connecting a control panel involves setting up and integrating various components such as controllers, indicators, switches, relays, and communication devices to create a functional and efficient system for monitoring and controlling electrical processes.

❖ **Steps for connecting control panel are:**

1. **Grounding**

Proper grounding is crucial for both safety and proper operation of the control panel.

Steps to follow while creating grounding:

- **Identify Grounding Points**: Determine the grounding points on the control panel, typically marked or specified in the panel's documentation.
- **Use Correct Grounding Wire**: Use the appropriate gauge of grounding wire as specified by your project requirements and local codes.
- **Connect Grounding Wire**: Attach the grounding wire to the designated grounding terminal on the panel. Ensure a solid connection to the panel's metal enclosure.
- **Verify Grounding**: Ensure that all grounding connections are secure and that the panel is properly bonded to the building's grounding system.

2. Wiring and terminations

Correct wiring and terminations are key to ensuring the control panel functions as intended.

Steps to follow during wiring and terminations:

- Plan Your Wiring Layout
- Select Appropriate Wires
- Strip Wires Properly
- Make Connections.
- Label Wires

3. Component installation

- **Circuit breaker**

Steps for installing circuit breakers are:

- Install the circuit breaker on the DIN rail or panel backplate.
- Connect the incoming power supply (hot wire) to the circuit breaker's line terminal. Connect the load (outgoing wire) to the load terminal of the breaker. In some cases, a neutral wire may need to be connected to a neutral bus bar or terminal on the panel, depending on the configuration.

- **Relays**

Steps for installing relays are:

- Secure the relay to the DIN rail or panel base.
- Connect the relay coil terminals to the control circuit. Ensure proper polarity if required.
- Connect the load wires to the relay's contact terminals. Typically, you'll have Normally Open (NO) and Normally Closed (NC) terminals. Connect your circuit

according to the required control logic.

- **Fuses**

Steps for installing fuses are:

- Install fuse holders on the panel or a designated fuse block.
- Connect the incoming supply wire to one terminal of the fuse holder and the outgoing wire to the other terminal. Ensure the fuse rating matches the circuit's requirements.

- **Meters**

Steps for installing meters are:

- Install the meter in a cut out on the panel front or use a mounting bracket.
- Connect the meter to the appropriate power supply or measurement points. For example, voltage meters will connect across the measurement points, while current meters will be wired in series with the load.
- Follow the manufacturer's instructions for calibration and setup.

- **Contactors**

Steps for connecting contactors are:

- Install the contactor on the DIN rail or panel back plate.
- Connect the coil terminals to the control circuit. This will energize the coil to operate the contactor.
- Connect the load wires to the contactor's contact terminals (NO or NC). Ensure proper connections for the load circuits.

- **Push button**

Steps for installing push button are:

- Install the push buttons in a panel cut out or mounting box.
- Connect the terminals of the push button to the control circuit. Typically, you'll connect one terminal to the input and the other to the control logic or relay coil.

- **Switches**

Steps for installing switches are

- Install the switches in the panel's front or designated cut outs.
- Connect the switch terminals to the circuit you want to control. Typically, you'll connect one terminal to the incoming supply and the other to the load.

- **Indicators**

  - Install indicators in the panel's front panel or indicator block.

Connect the indicator's terminals to a power supply that matches its voltage rating.

Practical Activity 3.4.2. Connecting of control panel

Task:

1: Referring to the previous theoretical activity 3.4.1, go to the site and perform the following task:

Connect control panel

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.4.1**

5: Perform the task provided in the application of learning 3.4

Key readings 3.4.1: connecting control panel

- **Connecting a control panel**

Connecting a control panel involves setting up and integrating various components such as controllers, indicators, switches, relays, and communication devices to create a functional and efficient system for monitoring and controlling electrical processes.

Steps for connecting control panel are:

1. **Grounding:** Proper grounding is crucial for both safety and proper operation of the control panel.

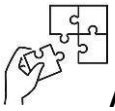
2. **Wiring and terminations:** Correct wiring and terminations are key to ensuring

the control panel functions as intended.

3. **Component installation:** Component installation of a control panel involves the careful integration of various electrical and control components necessary for monitoring and managing the power generation process.

Points to Remember

- **Connecting a control panel** involves setting up and integrating various components such as controllers, indicators, switches, relays, and communication devices to create a functional and efficient system for monitoring and controlling electrical processes.
- **Steps for connecting control panel are:** grounding, wiring and terminations, component installation



Application of learning 3.4

The project of constructing hydropower plant is on its final stage. As hydropower plant technician you are asked by the hydropower plant owner to connect control panel.

Indicative content 3.5: Connect Switchgear.

Duration: 2hrs

Theoretical Activity 3.5.1: Description of switchgear connection

Tasks:

1: Answer the following questions related description of switchgear connection

i. What do you understand by connecting switch gear?
ii. What are the steps for switch gear connection?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.5 1**

Key readings 3.5.1: Description on connecting switch gear

- **Connecting switchgear**
  - ✓ **Definition**

Connecting switchgear refers to the process of installing and integrating electrical equipment designed for controlling, protecting, and isolating electrical circuits and devices. Switchgear is essential in power systems, including industrial plants, substations, and hydroelectric power plants (HPPs).

❖ **Steps for connecting a switch gear are:**

1. **Grounding**
   - Locate the designated grounding terminals or bus bars on the switchgear.
   - Use conductors of appropriate size as specified by the equipment manufacturer and local electrical codes.

- Connect the grounding conductors securely to the grounding terminals on the switchgear. Ensure the connections are tight and free of corrosion.
- Check for continuity and proper grounding with a multimeter to ensure a solid connection

2. Cooling

- Ensure that the switchgear installation area has adequate ventilation to allow for natural air circulation.
- If the switchgear requires forced cooling (e.g., fans or air conditioning units), install them according to the manufacturer's specifications.
- Ensure that cooling systems are properly aligned to direct airflow across critical components.
- applicable, install temperature sensors or monitors to keep track of the operating temperature and ensure it stays within safe limits

3. Cable management

Cable routing

Steps for cables routing

- Route cables along the shortest and most direct path to minimize length and potential for damage.
- Ensure that cables are routed in a way that allows for easy access for maintenance and future modifications.
- Use conduit or armour for cables that are exposed to physical damage.

Cables labelling and termination.

Steps for Cables Labelling and Termination

- Label each cable with clear, durable labels indicating its function, destination, and source. This helps in troubleshooting and maintenance.
- Use the correct tools and connectors for cable termination to ensure secure and reliable connections.
- Inspect terminations to confirm that they are properly made, with no loose wires or improper connections.

4. Control panel wiring

Wiring a control panel involves careful planning and execution to ensure functionality, safety, and ease of maintenance.

Steps for control panel wiring are:

- **Planning and Design:** Understand the System, create a Layout, Select Components

- **Cable Management:** Use Cable Trays and Conduits, Maintain Separation, Avoid Sharp Bends.
- **Wiring Techniques:** Use Proper Wire Sizes, Strip Wires Correctly, Secure Connections
- **Labelling and Documentation:** Label Everything, Document Wiring
- **Testing and Verification:** Check Connections, Perform Continuity Tests, Power-Up

5. Commissioning test

Commissioning tests are critical for ensuring that switchgear installations function correctly and safely.

Essential commissioning tests you should perform on switchgear connections are the following:

1. **Visual Inspection:** Ensure all components are correctly installed, properly aligned, and securely mounted.

2. **Insulation Resistance Testing:** To Check the integrity of the insulation between live conductors and ground.

3. **Continuity Testing**: To Verify that all electrical paths are complete and there are no breaks in

4. **Polarity Check**: Ensure that connections are made according to the correct polarity.

5. **Functional Testing:** To ensure that the switchgear operates as intended under normal operating conditions.

6. **Protection Relay Testing:** To ensure that protection relays are correctly set and operate properly.

7. **Voltage and Current Measurement:** To confirm that voltage and current levels are within the specified limits and that the switchgear is operating correctly.

8. **Circuit Breaker Testing:** To ensure that circuit breakers operate correctly and trip at the appropriate settings.

9. **Earth Fault Testing:** To ensure that the earth fault protection system is working correctly.

10. **System Integration Testing:** To ensure that the switchgear integrates correctly with other systems, such as control systems and monitoring equipment.

Practical Activity 3.5.2: Connection of switchgears

Task:

1: Referring to the previous theoretical activity 3.5.1, go to the site and perform the following task:

Connect switchgear

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.5.2**

5: Perform the task provided in the application of learning 3.5

Key readings 3.5.2: Connection of switchgears

Steps for Connecting Switchgears

1. Preparation and Planning

- **Gather Materials:** Ensure you have all the necessary tools, cables, connectors, and protective equipment.
- **Safety Measures:** Isolate the power supply to the switchgears before starting the connection. Use proper safety gear like gloves, safety glasses, and insulated tools.
- **Read Instructions:** Familiarize yourself with the manufacturer's instructions for both switchgears.

2. Physical Connection

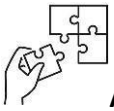
- **Cable Routing:** Plan the cable routes to ensure they are neat, organized, and minimize interference.
- **Cable Termination:** Strip and prepare the cable ends according to the manufacturer's specifications.
- **Connector Installation:** Install the appropriate connectors onto the cables, ensuring a secure and proper fit.
- **Switchgear Connection:** Connect the cables to the designated terminals on the switchgears. Ensure the connections are tight and secure.

3. Testing and Commissioning

- **Visual Inspection:** Check for any loose connections, damaged cables, or other potential hazards.
- **Continuity Test:** Use a multimeter to test the continuity of the connections between the switchgears.
- **Insulation Resistance Test:** Perform an insulation resistance test to ensure the integrity of the insulation.
- **Functional Test:** Energize the switchgears and test their functionality according to the manufacturer's instructions.

Points to Remember

- **Definition of connecting switchgear:** Connecting switchgear refers to the process of installing and integrating electrical equipment designed for controlling, protecting, and isolating electrical circuits and devices.
- **Steps for connecting switchgear are**: Preparation and Planning, Physical Connection and Testing and Commissioning



Application of learning 3.5

The project of constructing hydropower plant is on its final stage. As hydropower plant technician you are asked by the hydropower plant owner to connect switch gear.

Indicative content 3.6: Testing Functionality of HPP Auxiliaries

Duration: 2 hrs

Theoretical Activity 3.6.1: Description of testing functionality of HPP auxiliaries

Tasks:

1: Answer the following questions related to the description of testing functionality of HPP auxiliaries

i. What do you understand by testing functionality HPP auxiliaries?

ii. What are the Procedures for conducting functionality test of HPP auxiliaries?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.6.1**

Key readings 3.6.1.: Description on testing functionality of HPP auxiliaries

- **Testing the functionality of** HPP auxiliaries refers to evaluating the operational effectiveness of auxiliary systems associated with a Hydropower Plant (HPP)**.**

Procedures for conducting functionality test of HPP auxiliaries

- **Safety compliance:** Ensure that all safety protocols are followed to protect personnel and equipment during testing.
- **Visual inspection:** Identify any visible issues that could affect the operation of the auxiliary systems.
- **Instrumentation calibration:** Ensure that all measurement and control instruments are accurate and functioning correctly.
- **Performance verification:** Verify that the auxiliary systems are operating within their design parameters and meeting performance specifications.
- **Functional testing:** Test the operational functionality of the auxiliary systems to ensure they work as intended.
- **Documentation and reporting:** Maintain accurate records of the testing process, results, and any issues encountered.
- **Review and follow up.** Ensure that all issues are addressed and that systems are operational before resuming normal operations.

6. **Testing and commissioning**
    - Testing HPP auxiliaries

Testing auxiliaries in a hydropower plant (HPP) involves verifying the proper operation and reliability of systems that support the main power generation equipment.

Steps for testing HPP auxiliaries:

1. **Preparation**: Review system specifications and safety protocols.
2. **Inspection**: Visually inspect all auxiliary components for signs of wear or damage.
3. **Functional Testing**: Operate each auxiliary system under normal and emergency conditions.
4. **Performance Measurement**: Measure key parameters (e.g., flow rates, temperatures, pressures) to ensure they meet specifications.
5. **Control System Verification**: Test control panels and automation systems for correct responses.
6. **Safety Checks**: Validate emergency systems and alarms for proper operation.
7. **Documentation**: Record test results and any issues for future reference and compliance.
8. **Review and Maintenance**:
    - Analyze results and schedule any necessary maintenance or repairs

Practical Activity 3.6.2. Testing functionality of HPP auxiliaries

Task:

1: Referring to the previous theoretical activity 3.6.1, go to the site and perform the following task:

Test functionality of HHP auxiliaries

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.6.2**

5: Perform the task provided in the application of learning 3.6

Key readings 3.6.2: Testing of functionality of HPP auxiliaries

Testing the functionality of HPP auxiliaries refers to evaluating the operational effectiveness of auxiliary systems associated with a Hydropower Plant (HPP)**.**

- **Procedures for conducting functionality test**

1. **Safety compliance:** Ensure that all safety protocols are followed to protect personnel and equipment during testing.
2. **Visual inspection:** Identify any visible issues that could affect the operation of the auxiliary systems.
3. **Instrumentation calibration:** Ensure that all measurement and control instruments are accurate and functioning correctly.

4.**Performance verification:** Verify that the auxiliary systems are operating within their design parameters and meeting performance specifications

5. **Functional testing:** Test the operational functionality of the auxiliary systems to ensure they work as intended.
6. **Documentation and reporting:** Maintain accurate records of the testing process, results, and any issues encountered.
7. **Review and follow up:** Ensure that all issues are addressed and that systems are operational before resuming normal operations.

Points to Remember

- **Testing the functionality of** HPP auxiliaries refers to evaluating the operational effectiveness of auxiliary systems associated with a Hydropower Plant (HPP)**.**
- **Procedures for conducting functionality test:** Safety compliance, Visual inspection, Instrumentation calibration, Performance verification, Functional testing, Documentation and reporting, Review and follow up

Application of learning 3.6

The project of constructing hydropower plant is finished. As hydropower plant technician you are asked by the hydropower plant owner to perform functionality test of hydropower plant auxiliaries before the plant is put into operation.

Indicative content 3.7: Documentation and Record Filing

Duration: 2hrs

Theoretical Activity 3.7.1: Description of documentation and record filling

Tasks:

1: Answer the following questions related to the description of documentation and record filling

I. What do you understand by documentation?
II. What do you understand by record filing?
III. What are the steps for handling documentation and record filing?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings **3.7.1**

Key readings 3.7.1: Description of documentation and record filling

- **Documentation** refers to the process of creating, organizing, and maintaining records that provide evidence of activities, processes, and decisions within an organization.
- **Record filing** involves organizing and storing documents in a systematic manner for easy retrieval and management. A well-structured filing system enhances efficiency and reduces the risk of losing important information

Function of documentation and record filing:

- Adhere to industry regulations and standards.
- Maintain clear, updated records of operations, maintenance, and safety protocols.
- Organize documents for easy retrieval, using consistent naming conventions and indexing.
- Implement access controls for sensitive information.
- Periodically assess and archive outdated documents to keep records relevant and accurate.

Practical Activity 3.7.2. Documentation and record filling

Task:

1: Referring to the previous theoretical activity 3.7.1, go to the site and perform the following task:

To file the record

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.7.2**

5: Perform the task provided in the application of learning 3.7

Key readings 3.7.2: Documentation and record filling

- **Documentation and record filing** is essential for effective project management and compliance, especially in technical fields like engineering and power generation. Here are key steps to manage documentation and filing:

Steps for handling documentation and record filing:

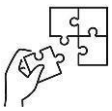
1. **Establish a Filing System**: Choose between physical or digital systems and create categories for easy organization.
2. **Develop a Naming Convention**: Use clear, consistent file names, including project names, document types, and version indicators.
3. **Create Indexes and Catalogs**: Develop an index or catalog for easy retrieval, and use metadata for enhanced searchability in digital files.
4. **Implement Access Control**: Define access permissions for sensitive documents and use version control to track changes.
5. **Regularly Review and Update**: Periodically assess documentation for accuracy and relevance, removing out dated files as necessary.
6. **Monitor Compliance and Quality Control**: Ensure documentation practices meet regulations and standards, implementing quality checks for accuracy.

Points to Remember

- **Documentation and record filling**

Effective documentation and record filing are crucial aspects of commissioning and operating a Hydro Power Plant (HPP). They ensure that all activities are traceable, compliant with regulations, and available for future reference.

- **Steps for handling documentation and record filing:** Establish a Filing System**,** develop a Naming Convention**,** Create Indexes and Catalogs**,** Implement Access Control**,** Regularly Review and Update**,** Monitor Compliance and Quality Control



Application of learning 3.7

You are working on hydropower plant. As hydropower plant technician you are asked by the hydropower plant owner to do documentation and record filing.

Indicative content 3.8: Developing As-Built Drawing

Duration: 2 hrs

Theoretical Activity 3.8.1: Description of developing as- built drawing

Tasks:

1: Answer the following questions related to the description of developing as- built drawing

I. What do you understand by as-built in drawing?
II. What are the functions of developing as- built in drawing?
III. What are the steps of developing as- built drawing?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 3.8.1

Key readings 3.8.1.: Description on developing as- built drawing

- **As-built drawing is** a drawing that the designer, engineer or contractor of a project creates after successfully completing a project.
- **Developing as-built drawings** for a Hydro Power Plant (HPP) is a crucial step in documenting the actual construction and installation of systems and components, ensuring that any deviations from the original design are accurately recorded.

Function of developing as- built are:

- They provide a detailed record of the final specifications, layouts, and alterations made during construction.
- These drawings serve as a reference for future maintenance, renovations, or expansions of the building.
- They ensure that the project complies with regulatory requirements and building codes.
- As-built drawings facilitate clear communication among stakeholders, including architects, engineers, and contractors.
- They help resolve disputes by providing an accurate depiction of the constructed work compared to the original plans.

❖ **Steps to develop as built drawing are:**

1. **Interpreting of HPP auxiliaries designed drawing:** Review the original design drawings to understand the intended layout, dimensions, and functional relationships of the HPP auxiliaries.
2. **Indication of the drawing changes:** Conduct a site survey to compare the as-built conditions with the design drawings. Identify any deviations, modifications, or additions made during construction.
3. **Recording information:** Note all deviations from the design drawings, including changes in layout, component placement, and system configurations.
4. **Annotating and labelling:** Add annotations to the as-built drawings to explain changes, dimensions, and other relevant details. Use clear, concise language.
5. **Validation** Conduct an internal review with the engineering and construction teams to ensure all changes are accurately reflected and documented.

Practical Activity 3.8.2: Development of as- built drawing

Task:

1: Referring to the previous theoretical activity 3.8.1, go to the site and perform the following task:

Develop as built drawing

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading **3.8.2**

5: Perform the task provided in the application of learning 3.8

Key readings 3.8.2: Developing as built drawing

As-built drawing

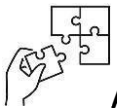
An as-built drawing is a drawing that the designer, engineer or contractor of a project creates after successfully completing a project.

Steps to develop as built drawing

1. **Interpreting of HPP auxiliaries designed drawing:** Review the original design drawings to understand the intended layout, dimensions, and functional relationships of the HPP auxiliaries.
2. **Indication of the drawing changes:** Conduct a site survey to compare the as-built conditions with the design drawings. Identify any deviations, modifications, or additions made during construction.
3. **Recording information:** Note all deviations from the design drawings, including changes in layout, component placement, and system configurations.
4. **Annotating and labelling:** Add annotations to the as-built drawings to explain changes, dimensions, and other relevant details. Use clear, concise language.
5. **Validation** Conduct an internal review with the engineering and construction teams to ensure all changes are accurately reflected and documented

Points to Remember

- **An as-built drawing** is a drawing that the designer, engineer or contractor of a project creates after successfully completing a project.
- **Steps to develop as built drawing:** Interpreting of HPP auxiliaries designed drawing, Indication of the drawing changes, recording information, Annotating and labelling, Validation
- **Steps to develop as-built drawing are:** Interpreting of HPP auxiliaries designed drawing, Indication of the drawing changes, recording information, Annotating and labelling, validation.



Application of learning 3.8

The project of constructing hydropower plant is finished. As hydropower plant technician you are asked by the hydropower plant owner to develop as -built drawing.

Indicative content 3.9: Elaborating the Report

Duration: 2 hrs

Theoretical Activity 3.9.1: Description of elaborating a report

Tasks:

1: Answer the following questions related to the description of elaborating a report

i. What do you understand by a report?
ii. What are the steps for elaborating a report?

2: Write the findings on paper, flip charts.

3: Present the findings/answers to the whole class.

4: For more clarification, read the key readings 3.9.1

Key readings 3.9.1.: Description on elaborating a report

✓ **Report**

A report is a structured document that presents information on a specific topic, often to inform or make recommendations to a particular audience.

Steps to elaborate a report are:

1. **Report format**

a. Title Page:

- **Title:** "Hydropower Plant Report" or a more specific title reflecting the content (e.g., "Feasibility Study for the XYZ Hydropower Plant").
- **Subtitle (if applicable):** Detailed aspect of the report (e.g., "Environmental Impact Assessment" or "Operational Efficiency Review").
- **Author(s):** Name(s) and affiliation(s).
- **Date:** Date of report completion or submission.
- **Affiliation:** Organization or department involved.

b. Table of Contents:

- Automatically generated if using word processing software, listing major sections and sub-sections with page numbers.

c. Executive Summary:

- Brief overview of the hydropower plant project, key findings, and primary recommendations.

d. Introduction:

- **Background:** Description of the hydropower plant, including location and purpose.
- **Objectives:** Goals of the report (e.g., assessing feasibility, evaluating performance).
- **Scope:** Boundaries of the report (e.g., specific aspects like environmental impact or financial analysis).

e. Project Description:

- **Site Description:** Geographic, climatic, and hydrological characteristics.
- **Design Specifications:** Technical details of the plant, including turbine type, dam structure, and capacity.
- **Construction Details:** Timeline, major milestones, and construction methods.

f. Methodology:

- **Approach:** Methods used for analysis (e.g., site surveys, modelling techniques).
- **Data Collection:** Sources of data, including hydrological studies, environmental assessments, and engineering analyses.
- **Analysis:** Techniques used to interpret the data (e.g., simulations, cost-benefit analysis).

g. Findings/Results:

- **Technical Performance:** Efficiency, output, and operational data.
- **Environmental Impact:** Effects on local ecosystems, water quality, and wildlife.
- **Economic Performance:** Cost analysis, economic benefits, and financial viability.

h. Discussion/Analysis:

- **Interpretation:** Insight into the findings, implications for the project.
- **Challenges:** Issues encountered during construction or operation.
- **Comparisons:** Benchmarking against similar projects or industry standards.

i. Recommendations:

- **Operational Improvements:** Suggestions for enhancing efficiency or reducing environmental impact.
- **Future Developments:** Proposals for expansion or upgrades.

j. Conclusion:

- Recap of key findings and overall conclusions about the hydropower plant.

k. Appendices:

- Supplementary material like detailed engineering drawings, raw data, and additional analyses.

l. References/Bibliography:

- List of sources cited or consulted, including technical papers, reports, and standards.

2. Identifying the Report types

a. Feasibility Study Report:

- Assess the viability of the hydropower project, including technical, economic, and environmental feasibility.

b. Environmental Impact Assessment (EIA):

- Detailed examination of the potential environmental effects of the hydropower plant and mitigation measures.

c. Technical Report:

- Focus on the technical aspects of the design, construction, and operation of the plant.

d. Performance Evaluation Report:

- Analyze the operational performance of the plant, including efficiency, reliability, and maintenance needs.

e. Financial Report:

- Review the financial aspects, including cost analysis, revenue projections, and return on investment.

3. Identifying report elements

a. Title and Abstract:

- Clear and concise title with a brief summary of the report's contents.

b. Problem Statement:

- Description of the problem or opportunity the hydropower plant addresses.

c. Methodology Section:

- Detailed explanation of how the data was collected and analysed.

d. Data Presentation:

- Organized presentation of findings through charts, graphs, and tables.

e. Conclusions and Recommendations:

- Summary of findings with actionable suggestions for improvements or decisions.

f. Appendices and Supplementary Material:

- Detailed technical data, project plans, and additional documentation.

g. References:

- Proper citation of all sources and references used in the report.

4. Report filing

a. Formatting for Submission:

- Ensure the report adheres to any specified formatting guidelines (e.g., font size, margins).

b. Electronic Filing:

- Save the report in standard digital formats like PDF for compatibility. Ensure files are named clearly and stored in a structured manner.

c. Hard Copy Filing:

- If physical copies are required, print and bind the report professionally. Organize physical files by date, project, or subject.

d. Document Storage:

- Store electronic reports in a secure and accessible location, such as a dedicated folder in a document management system.

e. Archiving:

Maintain long-term storage for reports, ensuring they are retrievable for future reference or compliance with record-keeping policies

Practical Activity 3.9.2. Elaboration of a report

Task:

1: Referring to the previous theoretical activity 3.9.1, go to the site and perform the following task:

Elaborate a report

2: Apply safety precautions

3: Present your work to the trainer/workshop assistant. Ask for clarification where necessary

4: Read key reading 3.9.2

5: Perform the task provided in the application of learning 3.9

Key readings 3.9.2: Elaboration of report

✓ **Report**

A report is a structured document that presents information on a specific topic,

often to inform or make recommendations to a particular audience.

The steps involved in elaborating a report include:

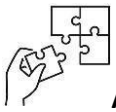
1. **Identify Report Format**: The initial step is to determine the appropriate format for the report, which may vary depending on its intended purpose and audience.
2. **Identifying the Report Types**: Next, it is imperative to ascertain the type of report required. Reports can be classified into several categories, including informational, analytical, and research reports.
3. **Identifying Report Elements**: After establishing the report type, one must delineate the critical elements that will comprise the report. Essential components typically include an executive summary, introduction, methodology, findings, conclusions, and recommendations.
4. **Report Filing**: Finally, it is crucial to establish a systematic approach to report filing. This entails determining the appropriate channels for distribution, whether physical or electronic, and ensuring that all stakeholders can access the document as needed. Proper filing also includes maintaining a record of revisions and approvals, which is vital for accountability and future reference.

Points to Remember

- **Report**

A report is a structured document that presents information on a specific topic, often to inform or make recommendations to a particular audience.

- **Steps to elaborate a report:** Identify report format, Identifying the Report types**,** identifying report elements**,** Report filing



Application of learning 3.9

You are working on hydropower plant as shift. As hydropower plant technician you are asked by the hydropower plant owner to elaborate a technical report.

Written assessment

I. Answer the following statements by **True** if the statement is correct or **False** if the statement is not correct.

a) The primary side of an auxiliary transformer is connected to the low-voltage power source.

b) Forced air cooling systems require additional power for fans and may need periodic maintenance.

c) The secondary side of a current transformer (CT) can be left open while the transformer is energized.

d) Voltage transformers (VTs) step down high voltage to a lower, manageable level for measurement.

e) A Neutral Grounding Transformer (NGT) is used primarily to provide a stable ground reference and control ground fault current.

f) Grounding electrodes should be installed without regard to local codes and safety standards.

g) The resistance of a grounding system should typically be greater than 25 ohms to comply with local codes.

h) A risk assessment must be conducted before testing auxiliary systems in a hydropower plant.

i) It is unnecessary to document calibration results of instruments used in testing.

j) Lockout/tagout procedures should be implemented to ensure safety during testing.

k) Visual inspections should only focus on checking the cleanliness of the testing area.

l) Performance verification involves checking if the auxiliary systems operate within their design parameters.

m) It is unnecessary to maintain safety and compliance records during the commissioning and operation of a hydro power plant.

n) A digital documentation management system is often preferred for its ease of access and storage.

II. Read the following statement and encircle the letter corresponding to the correct answer

a) Which cooling method is most effective for large transformers requiring significant cooling?

a. Natural Air Cooling
b. Oil-Immersed with Forced Oil Circulation
c. Water-External Cooling

b) What is the purpose of using current transformers (CTs) in a transformer's relaying system?

a. To measure voltage
b. To measure current
c. To cool the transformer

c) What is the primary function of a current transformer (CT)?

a. To increase voltage
b. To measure and monitor current
c. To protect against overloads

d) Which of the following should be connected to the secondary terminals of a CT?

a. High-voltage circuit
b. Measurement devices or protection relays
c. Grounding system

e) What must be ensured regarding the secondary circuit of a CT when the transformer is energized?

a. It can be left open-circuited
b. It should be connected at all times
c. It should be disconnected for safety

f) When installing voltage transformers (VTs), where should they be connected?

a. To the low-voltage side
b. To the high-voltage side
c. To the grounding system

g) What is a critical safety precaution when working with voltage transformers (VTs)?

a. Open the secondary circuit to measure voltage
b. Ensure the secondary circuit is not open under load
c. Use un insulated cables for connections

h) What is the primary purpose of a Neutral Grounding Transformer (NGT)?

a. To increase voltage levels
b. To provide a stable ground reference and control ground fault current
c. To enhance system efficiency

i) Which of the following is NOT a step in the installation of grounding electrodes?

a. Drive ground rods into the earth
b. Install solar panels

c. Bury ground plates for good earth contact

j) Which of the following is NOT a purpose of functional testing of switchgear?

a. To verify correct operation under load
b. To measure insulation resistance
c. To test control functions

k) What is the main purpose of a continuity test?

a) To check insulation quality

b) To verify all electrical paths are complete

c) To measure voltage level

l) **During functional testing, what should be tested for each auxiliary system?**

a) Only the electrical connections

b) Start-up and shutdown procedures

c) The colour of the control panel.

Match the Steps for Connecting a Grounding System in column A to their Descriptions in column B

Answer	**A. Steps for Connecting a Grounding System**	**B. Descriptions**
1…….	**1)** Planning and Design	A) Attach grounding electrodes to a central location for grounding.
2……	**2)** Install Grounding Electrodes	B) Assess requirements and create a detailed diagram.
3……	**3)** Connect to Grounding Bus Bar	C) Ensure all connections are tight and measure ground resistance.
4…….	**4)**Bonding and Connecting	D) Install grounding rods, plates, or grids in selected locations.

5……..	**5)** Testing and Verification	E) Use bonding jumpers to connect various metal parts.

Practical assessment

The project of extending an hydropower plant from 1.5W to 3MW, to supply the local areas is on its final stage; As hydropower plant technician you are requested by hydropower plant Owner to connect the following Hydropower plant auxiliaries: Auxiliary transformer, Measurement transformer, Neutral grounding transformer, Control panel, switchgears and test their functionality after that elaborate a report. All tools, equipment and materials are available on the site. The work must be done in 8 hours.

END

References

Brown, M. (2022). *Power plant auxiliaries.* Power Systems Engineering Institute.

Clark, R. (2022). *Installation and connection of electrical transformers and control systems.* Hydropower Technical Association.

Taylor, J. (2023). *Comprehensive guide to connecting and testing auxiliary transformers in hydropower plants.* Energy Engineering Publications.

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