RQF LEVEL 5

RENGI501

RENEWABLE ENERGY

Hydro Turbine Generator Installation

TRAINEE'S MANUAL

October, 2024

HYDRO TURBINE GENERATOR INSTALLATION

Korea International Cooperation Agency

TVET Quality Management Project

2024

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TABLE OF CONTENT

ACRONYMS

AC: Alternative Current
AVR: Automatic Voltage Regulator
BS: British Standard
CBT: Competency-Based Training
DC: Direct Current
eg.: example
GPM: Gallon Per Minute
GW: Giga Watt
H: Hour(s)
Hi-Pot: High Potential
HPP: Hdro Power plant
IC: Indicative Content
IGBT: Insulated Gate Bipolar Transistor
KOICA: Korea International Cooperation Agency
KW: KIlo-Watt
KWh: Kilo Watt Hour
LCD: Liquid Cristal Display
LO: Learning Outcome
LOTO: Lock OUT/Tag Out
MINEDUC: Ministry of Education
MSDS: Material Safety Data Sheet
MW: Mega Watt
NDT: None Distructive Test
ŋ: Efficiency
P: Power
PI: Polarization Index
PPE: Personal Protective Equipment
PWM: Pulse Width Modulation
Q: Flow rate
ROI: Return On Investment
RPM: Revolution Per Minute
RTB: Rwanda TVET Board
s: Second(s)
SESG: Self Excited Synchronous Generator
SWG: Standard Wire Gauge
t: time
TQUM Project: TVET Quality Management
TVET: Technical Vocation and Education Training
V: Volt
VPI: Vaccuum Pressure impregnation
W: Work

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in renewable energy specifically for the module of **"Hydro Turbine Generator 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.

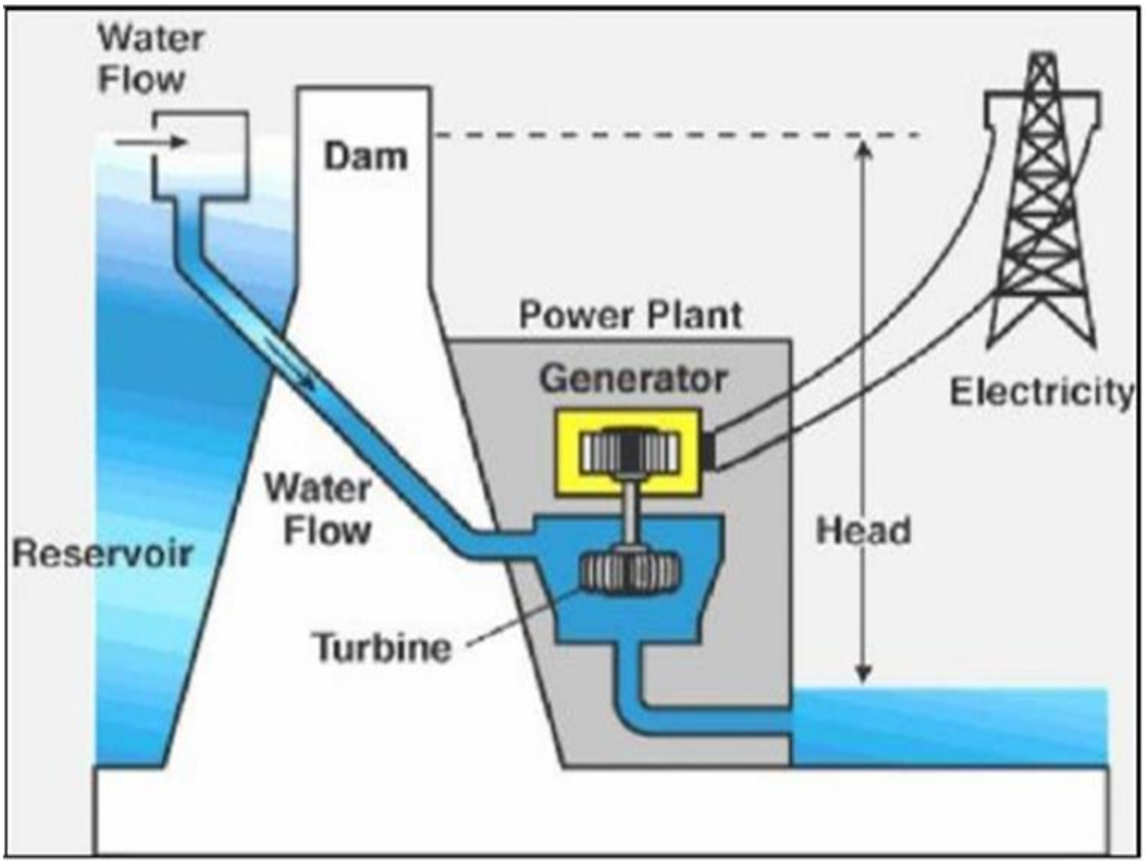
The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

As a trainee, you will start by asking 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 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 points to remember section.

MODULE CODE AND TITLE: RENGI501- HYDRO TURBINE GENERATOR INSTALLATION

Learning Outcome 1: Apply fundamental of hydropower plant
Learning Outcome 2: Assemble hydro turbine generator components
Learning Outcome 3: Carry out hydro turbine generator tests


Water
Flow
Dam
Power Plant
Generator
Electricity
Water
Flow
Reservoir
Head
Turbine

Indicative contents
1.1. Describing hydropower generation principles **1.2. Identifying hydropower plant site** **1.3 .Identifying hydropower plant structures**

Key Competencies for Learning Outcome 1: Apply Fundamental of Hydropower Plant

Knowledge	Skills	Attitudes
• Description of form of energy and their conversion. • Description of energy sources. • Introduction to hydropower plant. • Classification of hydropower plant • Identification of measurement head and flow rate • Identification of electrical power • Description of hydropower plant site • Identification of hydropower plant Structures	• Measuring of head and Flow rate • Conducting site survey • Estimating hydrology parameters • Selecting hydro-electric power station site. • Calculating of electrical power	• Being careful • Being participate in selection of hydropower plant site. • Having accuracy in measuring of head and flow rate • Respecting time management

Duration: 40 hrs

Learning outcome 1 objectives:

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

1. Describe clearly form of energy and hydropower plant structure based on hydropower plant types
2. classify correctly Classification of hydropower plant based on their types
3. Conduct correctly Measuring of head and Flow rate based on classification of hydropower plant
4. Conduct clearly site survey and Estimate correctly hydrology parameters based on data required
5. Select clearly Hydro-electric power station site based on their types

Resources

Equipment	Tools	Materials
• safety shoes • Barometric altimeter • GPS Altimeter and watch • Buckets • First Aid Kit	• Torpedo level • Spades • Hammer • tape measure • Spirit level • Hoes • Calculator	• Water filled tubes • drawing instruments • Drawing paper/Sheet (A0-A4) • Pens • Pencils • Pegs

Indicative content 1.1: Describing Hydropower Generation Principles

Duration : 15hrs

Theoretical Activity 1.1.1: Description of forms of energy and their sources in hydropower plant

Tasks:

1: Answer the following questions:

i. Define the term energy in hydro power plant
ii. Explain the following forms of energy in hydro power plant:
    a) Potential energy.
    b) Kinetic energy.
    c) Mechanical energy.
    d) Electrical energy.
iii. Outline the applications of energy
iv. By using examples Compare renewable from non-renewable energy

2: Present your findings to the whole class and trainer

3: Follow trainer's clarification and ask for questions if any

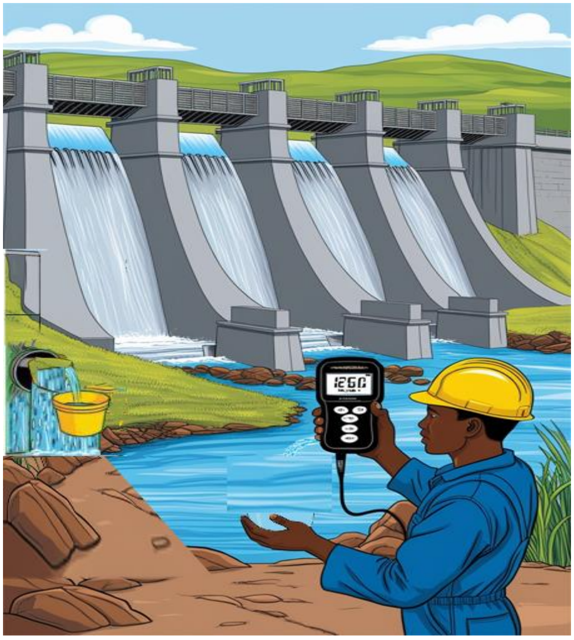
4: Read the Key readings 1.1.1 in the manual

Key readings 1.1.1: Description of forms of energy and their source

- **Definition of energy**

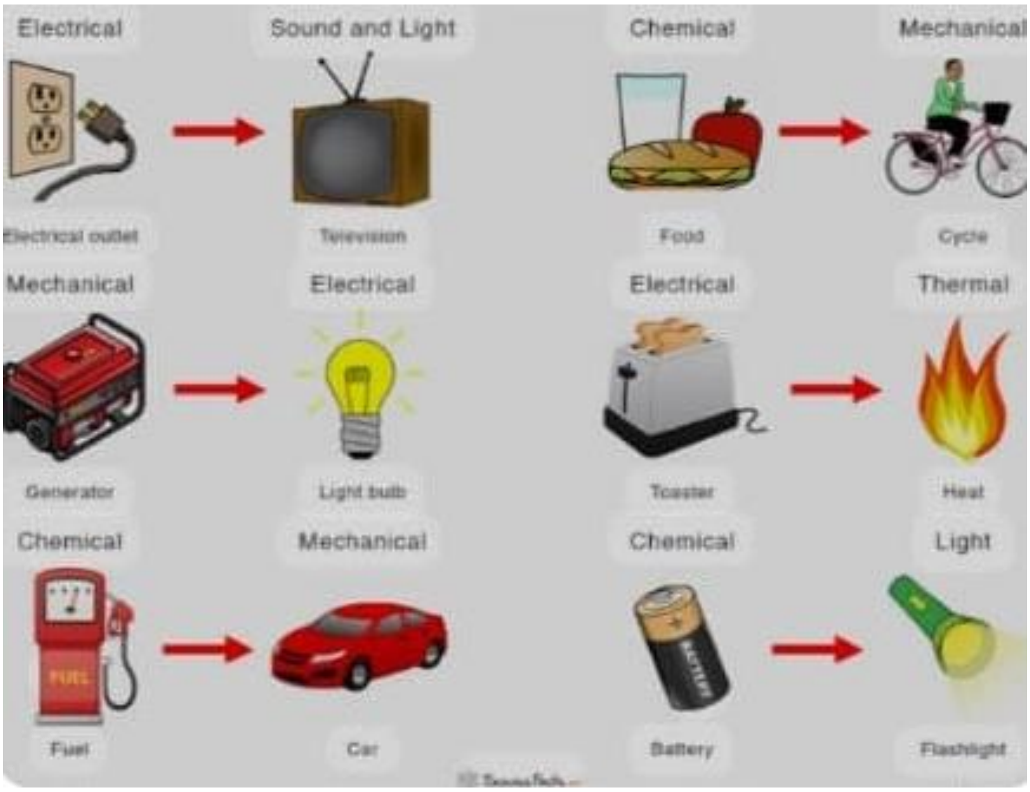
  It is the ability to do work or apply force to move an object. It exists in various form such as kinetics, potential, thermal, chemical and electrical and can be transformed from one to another

- **Forms of energy**



- **Electrical energy:** is a form of energy resulting from the flow of electric charge. Energy is the ability to do work or apply force to move an object. In the case of electrical energy, the force is electrical attraction or repulsion between charged particles.
- **Mechanical energy:** Mechanical energy is the sum of kinetic and potential energy in an object used to work.
- **Thermal /heat energy:** Thermal energy is the energy that comes from heat. This heat is Generated by the movement of tiny particles within an object.
- **Kinetic energy:** In physics, the kinetic energy of an object is the energy that it possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity.
- **Potential energy:** the energy possessed by a body by virtue of its position relative to others, stresses within itself, electric charge, and other factors.
- **Chemical energy:** Chemical energy is energy stored in the bonds of chemical compounds, like atoms and molecules. This energy is released when a chemical reaction takes place.
- **Nuclear energy:** the energy released during nuclear fission or fusion, especially when used to generate electricity.
- **Electromagnetic energy:** is a form of energy that is reflected or emitted from objects in the form of electrical and magnetic waves that can travel through space.
- **Conversion of energy Law of energy conversion:** the law of energy conversion, often known as the principle of conservation of energy, state that energy cannot be created or destroyed, only converted from

one form to another. For instance, electrical energy can be converted into thermal energy (heat) or mechanical energy (motion).



Energy source

- **Comparison between renewable and non-renewable energy sources**
    - ✓ **Renewable energy**

      It is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.

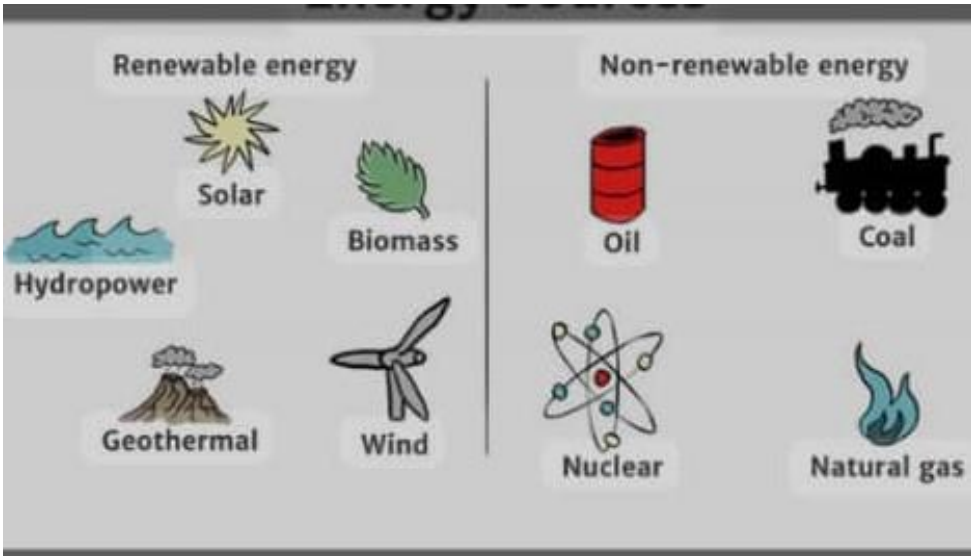
        - **The major types of renewable energy sources are**
            a) Biomass, includes:
                - ➢ Wood and wood waste
                - ➢ Municipal solid waste
                - ➢ Landfill gas and biogas
                - ➢ Ethanol
                - ➢ Biodiesel

            b) Hydropower
            c) Geothermal
            d) Wind
            e) Solar
    - ✓ **Non-renewable energy**

      It comes from sources that will run out or will not be replenished in our lifetimes. Most non-renewable energy sources are fossil fuels: coal, petroleum, and natural gas. Carbon is the main element in fossil fuels.

- **Application of energy:**

  We divide our energy use among four economic sectors: residential, commercial, transportation, and industrial. Heating and cooling us homes, lighting office buildings, driving cars and moving freight, and manufacturing the products we rely on in our daily lives are all functions that require energy.



Theoretical Activity 1.1.2: Description of hydropower plant and their classifications

Tasks:

1: Answer the following questions:

i. What do you understand the term hydropower plant?
ii. Describe the working principle of hydropower plant?
iii. List down advantages and disadvantages of hydropower plant?
iv. Classify hydropower plant according their types

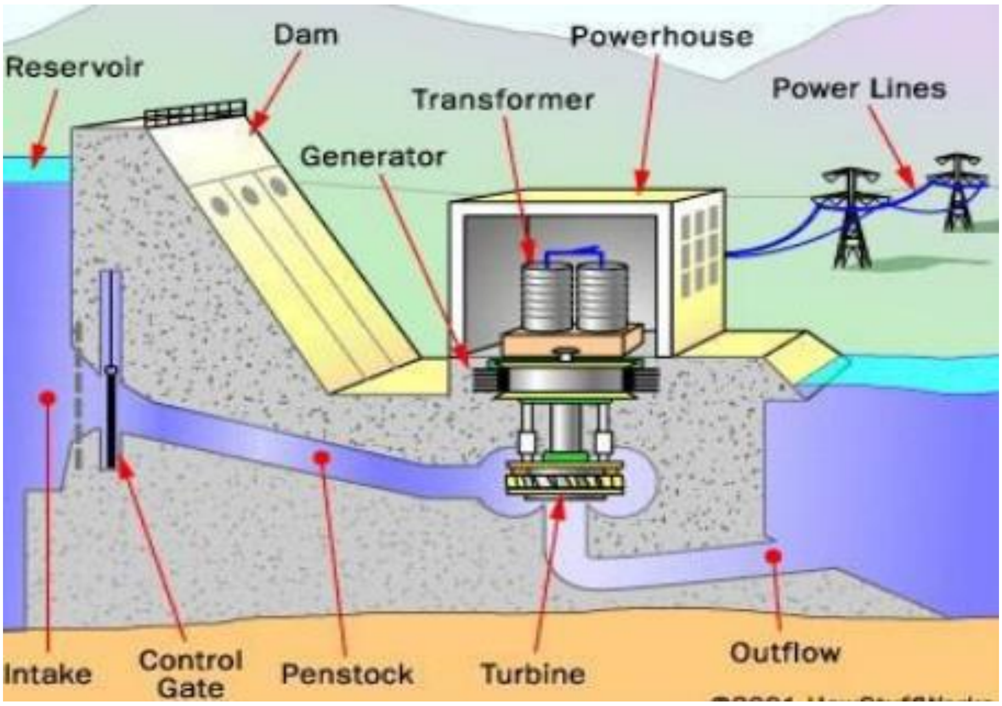
2: Present your findings to the whole class and trainer
3: Follow expert view and ask for clarification if any
4: Read the Key readings 1.1.2 in trainee manual

Key readings 1.1.2: Description of Hydropower plant according to their classification

- **Definition of hydropower plant**

Hydropower plant is also known as hydro-electric power plant, is facility that generate electricity by harnessing the kinetic energy of flowing or falling of water. The process Typically involves a dam built across a river to create a reservoir. Water released from the reservoir flows through turbines, causing them to spin this mechanical energy is then converted into electrical energy by a generator. Hydropower plant are valued for their ability to produce renewable energy and provide a reliable power source

- **Working principle of hydro power plant**

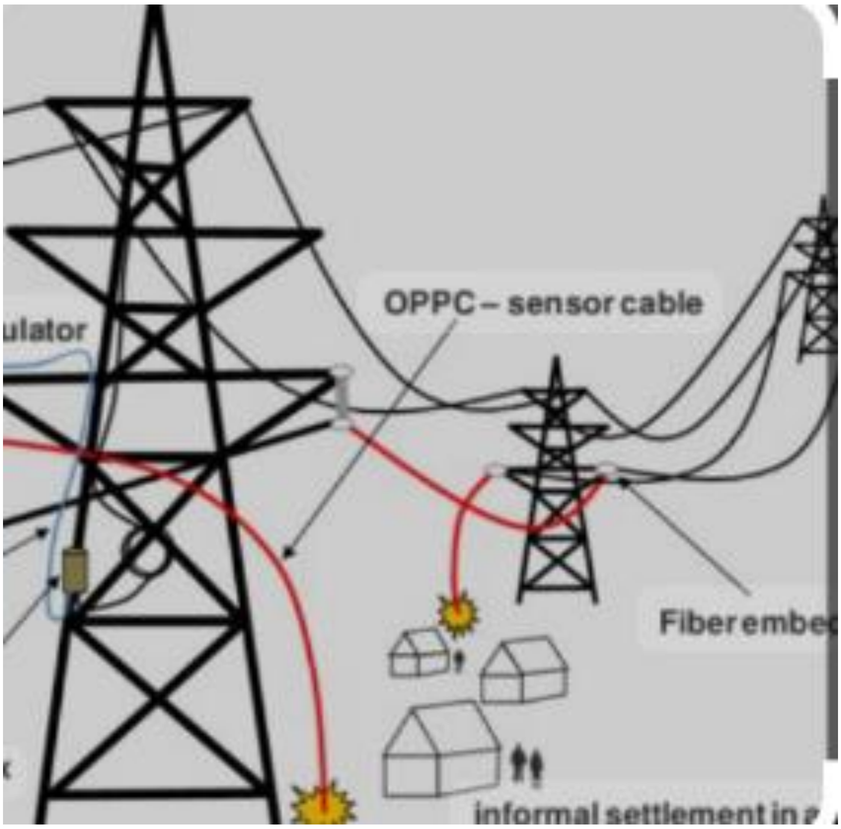


✓**Working principle of hydropower plant involves several key steps:**

- **Water source and reservoir**: water is collected in reservoir created by building dam across river or stream
- **Release of water:** control the gate or the valves release water from reservoir, allowing it to flow through a conduit or penstock
- **Flow through turbine** the following water passes through turbine, which are large blades that spin as

the water flows over them

- **Electricity generation:** the spinning turbines are connected to a generator .as turbine turns they drive the generator which converts mechanical energy into electrical energy
- **Transmission:** the generated electricity is the transmitted through power lines to homes, business or other users
- **Return of water**: after passing through the turbines the water is discharged back into the river downstream



✓ **Advantages**

- It requires no fuel as water is used for the generation of electrical energy.
- It is quite neat and clean as no smoke or ash is produced.
- It requires very small running charges because water is the source of energy which is available free of cost.
- It is comparatively simple in construction and requires less maintenance.
- It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.

- It is robust and has a longer life.
- Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.
- Although such plants require the attention of highly skilled persons

✓ **Disadvantages**

- It involves high capital cost due to construction of dam.
- There is uncertainty about the availability of huge amount of water due to dependence on weather conditions.
- Skilled and experienced hands are required to build the plant.
- It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers

- **Classification of the hydro power plant**

✓ **Classification according to availability of the head:**

According to availability of water head the hydroelectric power plants may be classified into low head hydroelectric power plants, medium head hydroelectric power plants, and high head hydroelectric power plants.

Though there is no definite line of demarcation for low, medium and high heads but the head below 30 metres is considered low head, the head above 30 metres and below 300 metres are considered as medium head and above 300 metres is considered as high head

- **Low head hydroelectric power plant**

A typical low head installation on a river consists essentially of a dam across the stream to back up the river and create a fall, the water flowing through the turbines and remerging the river below the dam.

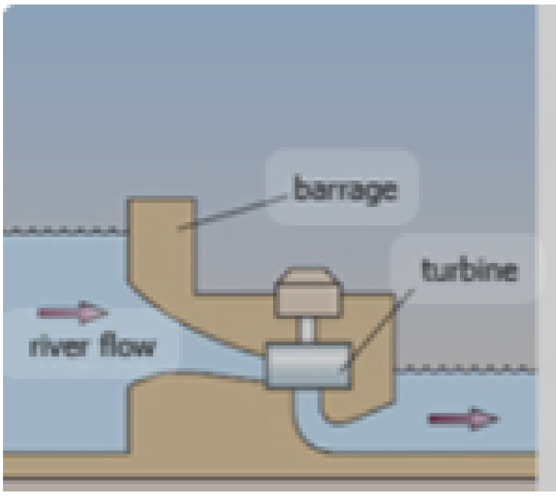
A dam or barrage constructed across the river creates the necessary head. The power plant is located near the dam and therefore, no surge tank is required.

Either one half of the barrage has regulating gates for discharge of surplus water while the plant is in front of second half or the plant is constructed by the side of the river.

In low head power plants Francis, propeller or Kaplan turbines are employed. Since for given output, large quantity of water is required, head being low, therefore pipes of large diameter and short length are required in low head plants.

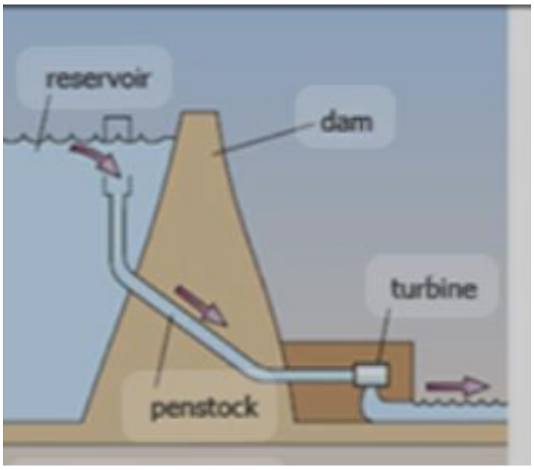
Structure of such plants is extensive and expensive.

Generators employed in such plants are of low speed and large diameter.



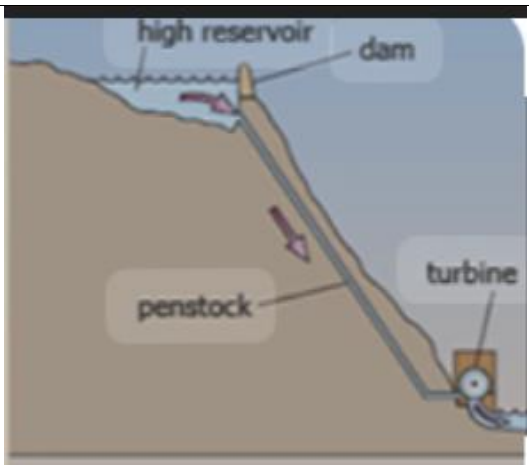
- **Medium head hydroelectric power plants:**

  In these power plants, the river water is usually tapped off to a fore bay on one bank of the river as in case of a low head plant.



- **High head hydroelectric power plants:**

  If high head is available, a site may be chosen, where a stream descending a steep lateral valley can be dammed and a reservoir for storage of water is formed



- ✓ **Classification according to the nature of the load**

  According to the Nature of the load, Hydro-power plant is classified into: Base load plant and Peak load plant.

  - **Base load plants**

    They are those which supply the base load of the distribution system. Such plants are required to supply constant power when connected to the grid. This type of HPP generally, does not consist of water storage reservoir system.

  - **Peak load plants**

    They are those which will supply power during peak load condition only. These HPP can also be used for base load. This HPP generally consists of storage reservoir.

- ✓ **Classification according to the quantity of water available:**

  According to the extent of water flow regulation available the hydroelectric power plants may be classified into the following:

  - **Run-off power plants without poundage:**

    Some hydro power plants are so located that the water is taken from the river directly, and no poundage or storage is possible.

  - **Run-off river power plants with poundage:**

    The usefulness of run-off river power plants is increased by poundage. Poundage refers to storage at the plant, which makes it possible to cope, hour to hour, with fluctuations of load throughout a week or some longer period depending on the size of poundage. With enough poundage, the firm capacity of the power plant is increased.

- ✓ **Classification of hydropower plant according to the power generated**

  There may be little variation in power generation range according to the useful situation and norms of the particular country.

100kW to 1MW either isolated or feeding into a grid	Mini hydropower plant
1MW to 15MW Usually feeding into a Grid	Small hydropower plant
15MW to 100MW usually feeding into a Grid	Medium hydropower plant
100MW to above usually feeding into a large grid.	Large hydropower plant

- ✓ **Classification of hydropower plant according to the grid connection**
  - **Local grid or isolated power plant and extensive grid or grid connected HPP**
    1. **Local grid or isolated power plant**:
       In the local grid system, the electricity generated from HPP will be distributed for the small locality near by the HPP. Highly sophisticated and costly electromechanical and distribution systems are not necessary for local grid system. The generated power from this HPP may not be high grade of standard.
    2. **Extensive grid or grid connected HPP**:
       In extensive grid or national grid system electricity generated by various HPP will be loaded into a one type of grid system. The load distribution from this type of HPP will be wide. In a small country like Nepal, one national grid is used for all the different parts of the country. The electromechanical components for this type of system are sophisticated and costly.

- ✓ **Classification of hydropower plant according to water economy**

  Hydropower plants can also be classified based on water economy, which refers to how water is used, stored, and managed for power generation. The three main classifications are:
  - **Run-of-river (ROR) hydropower plants:**
    Water economy: Minimal water storage or no storage at all.

These plants rely on the natural flow of water in a river or stream.

Key features: They use the continuous flow of water to generate electricity without altering the river significantly. Water flows through the turbines and returns to the river downstream.

Water management: Since there is little to no storage, these plants are highly dependent on seasonal and weather conditions. They operate effectively in areas where river flow is consistent year-round.

- **Reservoir (Storage) hydropower plants:**

  Water economy: Significant water storage capability. These plants store large amounts of water in a reservoir created by a dam.

  Key Features: Water can be stored and released as needed, allowing the plant to generate electricity based on demand, independent of river flow conditions.

  Water Management: Reservoir plants offer flexibility in water usage and can be managed to produce energy during dry seasons or peak demand periods. They also help in flood control, irrigation, and water supply regulation.

- **Pumped storage hydropower plants:**

  Water economy: Recycled water use. Water is pumped between two reservoirs at different elevations.

  Key features: Water is pumped from the lower reservoir to the upper reservoir during periods of low energy demand using excess electricity. During peak demand, the stored water is released from the upper reservoir to generate electricity.

  Water management: These plants are used primarily for energy storage rather than continuous generation. They do not rely on a natural water supply but instead recycle water between the two reservoirs, making them highly efficient for grid balancing and managing peak energy demands.

✓ **Classification according to the topography**

Hydropower plants can be classified according to topography based on the physical characteristics of the landscape where they are built. The main types include:

- **High-head hydropower plants:**

  Topography: Typically located in mountainous or hilly regions with steep elevation changes.

  Key features: These plants utilize the large vertical drop (or "head") of water to generate power. Water from a high elevation is directed down a steep slope through penstocks to turbines at a much lower elevation.

Examples: Plants in the Alps, Andes, or Himalayas.

Application: Efficient in regions with steep terrain, where a significant height difference can generate strong water pressure.

- **Medium-head hydropower plants:**

  Topography: Located in areas with moderate slopes, such as valleys or foothills, where the elevation change is noticeable but not as steep as in high-head plants.

  Key Features: These plants make use of moderate vertical drops and may use dams to create artificial heads. The water flow is less intense compared to high-head plants but still generates substantial power.

  Examples: Hydropower stations in rolling hill regions or on river systems with moderate slopes.

  Application: Common in regions with moderate elevation changes and river systems where a steady flow of water is available.

- **Low-head hydropower plants:**

  Topography: Built in flat or gently sloping areas, typically along large, slow-moving rivers with little natural elevation change.

  Key Features: These plants have a small height difference between the water source and the turbines. To compensate for the low head, they often rely on large volumes of water and may use barrages or weirs to create slight elevation changes.

  Examples: Plants on large rivers in lowland regions.

  Application: Suitable for large, slow-flowing rivers or lakes where the terrain is flat, and water volume compensates for the lack of head.

Theoretical Activity 1.1.3. Description of measuring head and flow rate of hydropower plant

Tasks:

1: Answer the following questions:

i. Explain the head of water in the power plant

ii. Describe the types of methods to be used for head measurement
iii. Explain the types of methods to be used for flow rate measurement

2: Present your findings to the whole class and trainer
3: Follow expert view and ask for clarification if any
4: Read the Key readings 1.1.3 in trainee manual

Key readings 1.1.3: Description of measuring head and flow rate of hydropower plant

- **Definition of terms:**

Head is referring to the vertical distance between the source of water such as a dam or reservoir and the point where water is released or fall to generate electricity.
Flow rate is the total volume of a fluid that flows past a fixed point in a river or stream over time. Volumetric flow rates can be measured in various units such as: Liters/sec (lps), cubic feet/sec (cfs), gallons/min (gpm), cubic meters/sec (cms)

- **Methods of water flow rate measurement**

These methods include: Bucket method/volumetric tank method, float method, weirs, meters

✓ **Bucket method**

The Bucket method is a simple way to measure the flow rate using household items. It requires a stopwatch, a large bucket, and preferably two to three people.

Steps used to measure the flow rate using the bucket method

1. Measure the volume of the bucket or container. Keep in mind that a typical 5gallon bucket is often actually less than 5 gallons.
2. Find a location along the stream that has a waterfall. If none can be found, a waterfall can be constructed using a weir (see Figure Four).
3. With a stopwatch, time how long it takes the waterfall to fill the bucket with water. Start the stopwatch simultaneously with the start of the bucket being filled and stop the
4. stopwatch when the bucket fills. The bucket should not be filled by holding it below the surface of the stream because it is not the true flow rate.
5. Record the time it takes to fill the bucket.
6. Repeat steps two and three about six or seven times and take the average. It is a good idea to do a few trial runs before recording any

data so that one can get a feel for the timing and measurements required.

7. Only eliminate data if major problems arise such as debris from the stream interfering with the flow.
8. The flow rate is the volume of the bucket divided by the average time it took to fill the bucket.

No	Time(second)	Bucket volume(gallon)
1	13.2	5
2	14	5
3	14.5	5
4	13	5
5	13.4	5
6	13.1	5

Here is an example using data found for the flow rate of the Jolly Giant Creek on Humboldt:

State University grounds: Using this data, the volumetric flow rate (Q) is equal to the volume of the bucket (V) divided by the average time (t).

Q=v/t $t = \frac{13.2+14s+14.5s+13s+13.4s+13.1s}{6\text{trials}}$ = 13.5 second

Hence $v = 5gallons$

$t = 13.5\ seconds$

$Q = \frac{\text{v}}{\text{t}}$ =$Q = \frac{5\text{gallons}}{13.5\text{ seconds}}$ = 0.37gallons/second

So the flow rate is 0.37 gallons/second or Q = 0.37 gal/sec * 60 sec/min =22.2 gallons/minute.

Therefore, the flowrate (Q) is 22.2 GPM.

- ✓ **Float method**

  The float method (also known as the cross-sectional method) is used to measure the flow rate for larger streams and rivers. It is found by multiplying a cross sectional area of the stream by the velocity of the water.

  - **Steps used to measure the flow rate using the float method:**

1. Locate a spot in the stream that will act as the cross section of the stream.
2. Using a meter stick, or some other means of measurement, measure the depth of the stream at equal intervals along the width of the stream (see Figure Three). This method is similar to hand

calculating a Riemann sum for the width of the river.

3. Once this data is gathered, multiply each depth by the interval it was taken in and add all the amounts together. This calculation is the area of a cross section of the stream.
4. Decide on a length of the stream, typically longer than the width of the river, to send a floating object down
5. Using a stopwatch, measure the time it takes the float to travel down the length of stream from step 4.
6. Repeat step five 5-10 times and determine the average time taken for the float to travel the stream. Throw the float into the water at different distances from the shoreline in order to gain a more accurate average.
7. Divide the stream length found in step 4 by the average time in step 6 to determine the average velocity of the stream.
8. The velocity found in step 7 must be multiplied by a friction correction factor. Since the top of a stream flows faster than the bottom due to friction against the stream bed, the friction correction factor evens out the flow. For rough or rocky bottoms, multiply the velocity by 0.85. For smooth, muddy, sandy, or smooth bedrock conditions, multiply the velocity by a correction factor of 0.9. [4]
9. The corrected velocity multiplied by the cross sectional area yields the flow rate in volume/time. (Be sure to keep consistent units of length/distance when measuring the cross section and the velocity eg. meters, feet).

✓ **Weir Method**

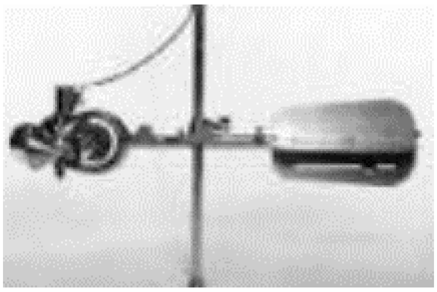
Weirs are small dams that can be used in measuring flow rate for small to medium sized streams (a few meters or wider). They allow overflow of the stream to pour over the top of the weir, creating a waterfall, as seen in Figure

Four.

Weirs increase the change in elevation making the stream flow more consistent which makes flow rate measurements more precise. However, it is very important that all the water in the stream be directed into the weir for it to accurately represent the stream flow. It is also important to keep sediment from building up behind the weir. Sharp crested weirs work best. There are many different types of weirs which include broad crested weirs, sharp crested weirs, combination weirs, v notch weirs and minimum energy loss weirs.

- ✓ **Meters**
  - **Current Meters Method:**

    Meters are devices that measure the stream flow by directly measuring the current. There are many different types of meters by the most common is the Pygmy meter, the vortex meter, the flow probe, and the current meter: They are briefly described below



  - **Pygmy meter:** a wheel is rotated by water flow and the rate of the rotation signifies the water velocity. It is primarily used in measuring discharge

  - **Vortex meter:** velocity is proportional to the downstream frequency of the vortex flow and is read on a digital readout. It is used for measuring flow in pipes.

  - **Current meter:** electronic pulses determine water velocity. Can be used in large bodies of water like oceans to measure the current methods of head measurement altimeters. These can be useful for high-head pre-feasibility studies. Surveying altimeters in experienced hands will give errors of as little as 3% in 100 m. Atmospheric pressure variations need to be allowed for, however, and this method cannot be generally recommended except for approximate readings.

- **Methods of head measurement**
  - ✓ **Topographic map**
    Large-scale maps are very useful for approximate head values, but are not always available or totally reliable. For high-head sites (>100 m) 1:50,000 maps become useful and are almost always available.
  - ✓ **Direct height measurement**
    Hand-held sighting meters' measures angle of inclination of a slope (they are often called inclinometers or Abney levels).
  - ✓ **Flow duration curve**
    The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. The basic time unit used in preparing a flow
  - ✓ **Catchment area:** the area of land from which water flows into a river, lake, or reservoir
  - ✓ **Water reservoir:** a place for storing liquid, especially a natural or artificial lake providing water for a city or other area.

Practical Activity 1.1.4. Measuring head and flow rate in hydropower

Task:

1. Refer to the key readings 1.1.4, you are requested to perform the following task.
   Alpha hydro power plant that will produce 20MW.started its activities of building plant from dam to the powerhouse. You are requested to measure head and flow of water of hydropower plant.
2. Pay attention on trainer's explanations and instructions
3. Measure the flow rate and head following to trainer's instructions.
4. Ask questions for more information.

Key readings 1.1.4: Measuring head and Flow rate in hydropower plant

- **Steps followed for Measuring head and Flow rate in hydropower plant**
  - ✓ **Gross Head Measurement:**

Step 1: Identify the intake point (where water enters the penstock or turbine).

Step 2: Identify the discharge point (where water exits after passing through the turbine).

Step 3: Use GPS or surveying equipment (like a theodolite or a total station) to measure the vertical height difference between the intake and discharge points.

For smaller sites, basic levelling tools or manual tape measures can be used for approximate measurements.

Step 4: Calculate gross head (the total height difference).

- ✓ **Net Head Measurement:**

Step 1: Calculate head losses due to friction in the penstock and bends in the water path.

Step 2: Install pressure gauges or transducers at the intake and turbine inlets to measure water pressure.

Step 3: Subtract these losses from the gross head to get the net head, which represents the actual usable energy.

- **Measuring Flow Rate**
  - ✓ **Direct Flow Measurement Methods:**
    - Weir Method:

Step 1: Install a weir (a barrier across the water channel with a precisely measured opening, typically rectangular or V-notch).

Step 2: Measure the height of the water flowing over the weir using a staff gauge or sensor.

Step 3: Calculate the flow rate

Practical Activity 1.1.5: Calculation of electrical power from hydropower plant

Tasks:

1: You are asked to answer the following questions:

i. Identify the parameters of hydro power plant being calculated and their formulae.

2: Pay attention on trainer's explanations and instructions

3: Referring to procedures and formulas provided in key reading, perform the given tasks

4: Present your work to the trainer/colleague and ask clarification if any.

Key readings 1.1.5. Calculation of electrical power of Hydropower Plant

The theoretical power available from falling water can be calculated using the following **Formula:**

P= WQH*Efficiency/1000 in (KW)

P =theoretical output

W=weight density of water in kgf/m3

Q=flow through turbine in m3/s

H=Head available in metres

The actual useful or effective output depends upon the efficiency of the various parts of the installation.

Example Calculation 1:

Suppose a hydropower plant has the following characteristics:

- Flow rate (Q) = $50\,\mathrm{m}^3/\mathrm{s}$
- Net head (H) = $30\,\mathrm{m}$
- Efficiency (η) = 90% or 0.9

Step 1: Plug values into the formula

$$P = 0.9 \cdot 1000 \cdot 9.81 \cdot 50 \cdot 30$$

Step 2: Simplify the calculation

$$P = 0.9 \cdot 1000 \cdot 9.81 \cdot 1500$$

$$P = 13,239,000\,\mathrm{W} = 13.239\,\mathrm{MW}$$

Plant Capacity Factor = Average Demand(kW)/Installed Capacity(kW)

Utilization Factor

Utilization Factor = Max.Demand(kW)/Installed Capacity(kW)

Plant Use Factor

Plant Use Factor=Actual energy produced(kWh)/Installed Capacity(kW)× no. of operation hours(h) or PlantUseFactor=Average Demand×TInstalled/Capacity×no.of operating hours

Examples 2: A generating station has a maximum demand of 25MW, a load factor of 60%, a plant capacity factor of 50% and a plant use factor of 72%. Find (i) the reserve capacity of the plant (ii) the daily energy produced and (iii) maximum energy that could be produced daily if the plant while running as per schedule, were fully loaded.

Solution:

$$load\ factor = \frac{\text{Average demand}}{\text{maximum demand}}$$

$$0.60 = \frac{\text{Average}\ \ \text{demand}}{25}$$

i) $average\ demand = 25 * 0.60 = \mathbf{15}\boldsymbol{MW}$

$$plant\ capacity\ factor = \frac{Average\ demand}{plant\ capacity}$$

$$0.5 = \frac{15}{\text{plant capacity}}$$

$$plant\ capaty = \frac{15}{0.5} = \textbf{30MW}$$

ii) $Reverse\ capacity\ of\ plant = \text{plant capacity} - \text{maximum demand}$

30-25=**5 MW**

Example 3. Water for a hydro-electric station is obtained from a reservoir with a head of 100 metres. Calculate the electrical energy generated per hour per cubic metre of water if the hydraulic efficiency be 0·86 and electrical efficiency 0·92.

Solution:

Water head, H = 100 m; discharge, Q = 1 m3/sec;

η overall = 0·86 × 0·92 = 0·79

Wt. of water available/sec, W = Q × 1000 × 9·81 = **9810 N**

Power produced = W × H × η overall = 9810 × 100 × 0·79 watts

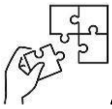
= 775 × 103 watts = **775 kW**

∴ Energy generated/hour = 775 × 1 = **775 kW**

Points to Remember

- **Energy Forms:** Energy manifests in various forms like kinetic, potential, thermal, chemical, electrical, nuclear, and electromagnetic.
- **Types of Energy:** Includes electrical (flow of charge), mechanical (kinetic and potential energy), thermal (heat), chemical (energy in bonds), and nuclear (energy from nuclear reactions).
- **Conservation Principle:** Energy cannot be created or destroyed but can change forms, such as electrical energy converting to thermal energy.
- **Energy Sources:** Renewable sources (e.g., sunlight, wind) replenish naturally, while non-renewable sources (e.g., fossil fuels) are finite.
- **Hydropower Plant Definition:** Hydropower plants generate electricity by converting the kinetic energy of water into mechanical and then electrical energy using turbines.
- **Working Principle:** Water flows through a turbine, turning it to produce mechanical energy, which is then converted into electrical energy for transmission.

- **Advantages and Disadvantages:** Benefits include renewable energy, low running costs, and flood control, but downsides are high setup costs and reliance on water availability.
- **Classification of Hydropower Plants:** Categorized by head height, load type, water management (run-of-river, reservoir, pumped storage), power output, and topography.
- **Measurement of Head and Flow Rate:** Head is the vertical drop from source to outlet, and flow rate measures the water volume passing a point, with methods like bucket, float, weir, and current meters.
- **Power Calculation and Efficiency:** Power output depends on head, flow rate, and efficiency, with plant performance indicators like capacity factor, utilization factor, and plant use factor.



Application of learning 1.1.

1. Hydro power plant located nearby your school produces 10 MW of electrical energy to the users. The owner needs to optimise production of electrical energy to 40 MW. As trainee on level of supervisor, you are requested to measure head and flow rate corresponding to the new capacity of plant.

2. A hydro-electric power station has a reservoir of area 2·4 square kilometres and capacity $5 \times 106\ m^3$. The effective head of water is 100 metres. The penstock, turbine and generation efficiencies are respectively 95%,90% and 85%.
   a. Calculate the total electrical energy that can be generated from the power station.
   b. If a load of 15,000 kW has been supplied for 3 hours, find the fall in reservoir level.

3. A hydro-electric power station has a reservoir of area 2·4 square kilometres and capacity $5 \times 106\ m^3$. The effective head of water is 100 metres. The penstock, turbine and generation efficiencies are respectively 95%,90% and 85%. (i) Calculate the total electrical energy that can be generated from the power station. (ii) If a load of 15,000 kW has been supplied for 3 hours, find the fall in reservoir level.

Indicative content 1.2: Identifying Hydropower Plant Site

Duration : 15hrs

Theoretical Activity 1.2.1: Description of hydropower plant site

Tasks:

1: You are asked to answer the following questions:

i. How do you understand the term site survey?
ii. What are selection criteria for Hydropower Plant site?
iii. Explain at least four examples of hydrology parameters
iv. Identify the steps used to conduct site survey
v. Describe step-by-step guide on how to estimate hydrology parameters

2: Present your findings to the whole class and trainer

3: Follow expert view and ask for clarification if any

4: Read the Key readings 1.2.1 in trainee manual

Key readings 1.2.1 Description of the hydropower plant site

- **Site survey** is to gather information about the site's hydrology parameters, which are crucial for determining the feasibility and potential of the hydroelectric project.
- **Hydrology parameters.** Is measure that describe the flow and behavior of water in the system.it directly affects the amount of electricity generated by the plant. The water flow rate determines the amount of water available to turn the turbines. Which in turn affect affects the plant's capacity to generate electricity.

Monitoring and controlling the water flow rate is essential for the efficient operation of a hydroelectric power plant.

✓ **Steps used to conduct a site survey for a hydroelectric power station:**

- **Define the purpose:** Clearly understand the objectives of the site survey, such as assessing the site's suitability for a specific project, identifying potential hazards, or gathering data for planning and design purposes.
- **Gather information**: Collect as much information as possible about the site, including its history, previous uses, and any existing infrastructure or environmental factors that may impact the

project.

- **Inspect the site**: Conduct a physical inspection of the site to assess its condition, features, and potential challenges. Take note of any obstacles, such as terrain, vegetation, or existing structures, and identify any potential hazards or risks.
- **Measure the site**: Use surveying tools and techniques to measure the site's dimensions, topography, and other relevant features. This will help in creating accurate maps and plans for the project.
- **Document findings**: Document all observations, measurements, and findings during the survey. This documentation should include photographs, sketches, and notes on the site's conditions, features, and potential challenges.
- **Analyze data:** Review and analyze the data collected during the survey to identify potential issues or areas of concern. This analysis will help in developing a comprehensive plan for the project, including resource allocation, timelines, and risk mitigation strategies.
- **Prepare a report**: Compile all findings, analysis, and recommendations into a comprehensive report that summarizes the site survey's results and provides actionable insights for project planning and execution.

✓ **Estimation of hydrology parameters**

- **Step-by-step guide on how to estimate hydrology parameters in a hydro power plant site:**
    - **Define the purpose**:
      Clearly understand the objectives of the hydrology parameter estimation, such as assessing the water body's capacity for hydroelectric power generation, identifying potential flood risks, or estimating water quality parameters.
    - **Gather information**:
      Collect as much information as possible about the water body, including its size, location, and any existing data on its hydrological characteristics, such as flow rates, precipitation patterns, and water quality.
    - **Conduct a site survey**:
      Perform a site survey to gather data on the water body's physical features, such as its shape, depth, and slope, as well as any potential sources of pollution or sedimentation that may impact the hydroelectric power plant's design and operation.

- **Collect historical data**:
  Gather historical data on the water body's hydrological parameters, such as flow rates, precipitation patterns, and water quality measurements. This data can be obtained from government agencies, research institutions, or other relevant sources.
- **Analyze data:**
  Use statistical and modelling techniques to analyse the collected data and estimate the hydrology parameters of interest, such as peak flow rates, average flow rates, or water quality parameters like turbidity or dissolved oxygen levels.
- **Validate the results**:
  Validate the estimated hydrology parameters by comparing existing data or conducting field measurements to verify the accuracy of the estimates.
- **Document findings**:
  Document all observations, measurements, and findings during the estimation process. This documentation should include graphs, charts, and tables illustrating the estimated hydrology parameters and their associated uncertainties.
- **Prepare a report:**
  Compile all findings, analysis, and recommendations into a comprehensive report that summarizes the hydrology parameter estimation results and provides actionable insights for hydroelectric power plant design, construction, and operation, as well as environmental planning and risk assessment.

✓ **Selection criteria of hydro power plant site**

- Presence of waterfalls to provide a massive hydraulic force.
- Presence of deep valley to provide space for reservoir of large volume of water from a river to provide water to drive the turbines.
- Constant supply of water to ensure continuous generation of power.
- Hard basement rock to provide a firm foundation for the construction of a dam.
- Interest and Depreciation
- Reliability of Supply
- Equitable Growth of Different Areas
- Nature of Load

- Transportation Facilities
- Storage Space for Fuel
- Availability of Site for Water Power
- Requirement of Space
- Cost of Land and Taxes
- Cost of Fuel
- Cost of Transmission of Energy

Practical Activity 1.2.2: Conducting the hydro power plant site

Task:

1**:** The company started to construct new hydropower plant that will produce 40MW, refer to the key readings 1.2.2, you are requested to perform the following task. You are tasked to conduct the Hydropower Plant site

2: Pay attention on trainer's explanations and instructions

3: Referring to procedures and steps provided, conduct power plant site

4: Present your work to the trainer/colleague and ask clarification if any.

Key readings 1.2.2. Conducting the hydropower plant site

Steps followed for conducting the hydropower plant site

1. Initial site identification and screening

Step 1: Identify Potential Sites:

Use topographical maps, satellite imagery, and hydrological data to identify locations with suitable elevation differences (head) and water sources (rivers, streams, or dams).

Step 2: Preliminary Assessment of Head and Flow:

Conduct a rough estimation of the head (elevation drop) and flow rate (water volume) using available hydrological data, maps, or site visits.

Cross-check flow data with historical hydrological records or flow duration curves to determine seasonal variations in water flow.

Step 3: Assess Accessibility:

Evaluate the accessibility of the site in terms of road networks, proximity to transmission lines, and ease of transporting construction materials.

Step 4: Environmental and Social Screening:

Identify any potential environmental concerns (e.g., biodiversity, wildlife, fish migration) and social impacts (e.g., displacement of communities, land use).

Check if the site is located in a protected area or near sensitive ecosystems.

Step 5: Legal and Regulatory Considerations:

Review national and local regulations governing water rights, energy production, and environmental impact assessments (EIAs).

2. Pre-Feasibility Study

Step 1: On-Site Visit and Survey:

Conduct an on-site visit to observe the river flow, geology, and terrain. Survey the potential intake point, penstock route, powerhouse location, and tailrace.

Take basic measurements of head using a leveling instrument or GPS device and estimate flow rate using a float method or basic weir construction.

Step 2: Hydrological Study:

Perform a detailed analysis of river flow data over time (e.g., using gauging stations or data from hydrological models).

Construct a flow duration curve to understand flow variability throughout the year.

Step 3: Topographical Survey:

Conduct a detailed topographical survey of the site to map the terrain, including the elevation profile from the water intake to the powerhouse.

Use the data to design the layout for the dam or intake, penstock, and powerhouse.

Step 4: Preliminary Environmental and Social Impact Assessment:

Identify major environmental impacts such as habitat loss, water quality issues, and impacts on downstream communities or users.

Points to Remember

- **Site survey** is to gather information about the site's hydrology parameters, which are crucial for determining the feasibility and potential of the hydroelectric project.
- **Hydrology parameters** Is measure that describe the flow and behavior of water in the system
- **Selection criteria of hydro power plant site:** types of land and cost, availability of water, transportation facilities.
- **step-by-step guide on how to estimate hydrology parameters in a hydro power plant site:**

Step1. Define the purpose: Clearly understand the objectives of the hydrology parameter estimation, such as assessing the water body's capacity for hydroelectric power generation, identifying potential flood risks, or estimating water quality parameters.

Step 2. Gather information: Collect as much information as possible about the water body, including its size, location, and any existing data on its hydrological characteristics, such as flow rates, precipitation patterns, and water quality.

Step 3. Conduct a site survey: Perform a site survey to gather data on the water body's physical features, such as its shape, depth, and slope, as well as any potential sources of pollution or sedimentation that may impact the hydroelectric power plant's design and operation.

Step 4. Collect historical data: Gather historical data on the water body's hydrological parameters, such as flow rates, precipitation patterns, and water quality measurements. This data can be obtained from government agencies, research institutions, or other relevant sources.

Step 5. Analyze data: Use statistical and modelling techniques to analyse the collected data and estimate the hydrology parameters of interest, such as peak flow rates, average flow rates, or water quality parameters like turbidity or dissolved oxygen levels.

Application of learning 1.2.

The company is planning to construct 5 MW at given site near the available water, before constructing that new plant to ensure for high efficiency you are required to evaluate the site by taking into account the required plant capacity.

Indicative content 1.3. Identifying Hydro Power Plant Structures

Duration:10hrs

Theoretical Activity 1.3.1: Identification of hydropower plant structures

Tasks:

1: You are asked to answer the following questions:

i. How do you understand the following terms?
   a. Civil structure
   b. Mechanical structure
   c. Electrical and electronics structures

ii. Outline three examples for each of the following structures.
   a. Civil structure
   b. Mechanical structure
   c. Electrical and electronics structures

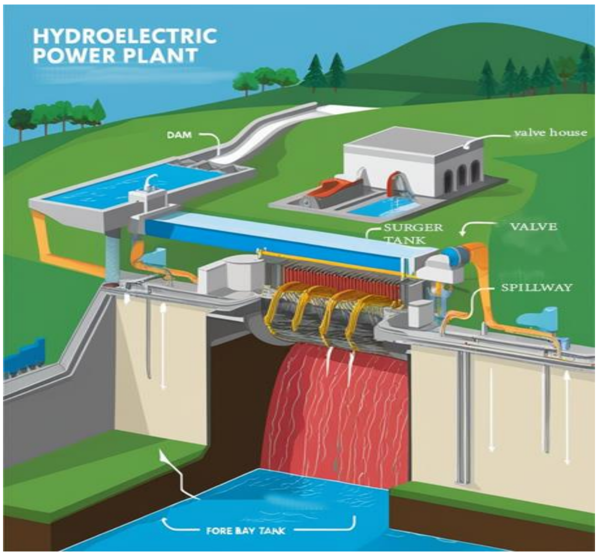
2: Present your findings to the whole class and trainer

3: Follow expert view and ask for clarification if any

4: Read the Key readings 1.3.1 in trainee manual

Key readings 1.3.1 Identifying hydropower plant structures

hydropower plant structures are structures used for ensuring the efficient conversion of water' potential and kinetic energy into electrical power as identification in discussion below



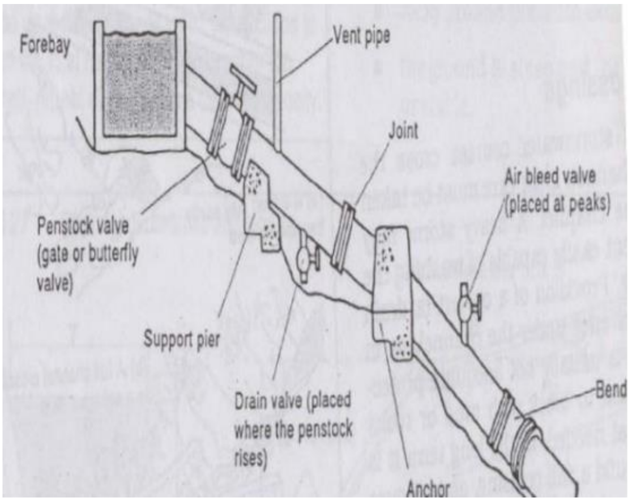
- **Civil structure**

  This refers to the overall infrastructure and design of a hydropower plant, including the dam, headrace channel, fore bay tank, intake structure, penstock, spillway, and power house. These components work together to harness the energy of flowing water and convert it into electricity.

1. **Headrace channel:** This is a channel or tunnel that carries water from the fore bay tank to the penstock. Its purpose is to provide a controlled and efficient flow of water to the turbines in the power house.
2. **Fore bay tank**: This is a reservoir that stores water from the headrace channel before it enters the penstock. It helps regulate the flow of water and prevents sudden changes in pressure that could damage the penstock or turbines.
3. **Dam:** s a structure built across a river or stream to hold back water and creating a large reservoir

4. **Intake structure**: This is a structure located at the bottom of the dam that allows water to be drawn from the reservoir or lake behind the dam. It is typically equipped with gates or other mechanisms to control the flow of water.

5. **Penstock:** This is a large, underground pipe that carries water from the intake structure to the turbines in the power house. Its purpose is to provide a controlled and efficient flow of water to generate electricity.



6. **Spillway**: This is a structure located on the side of the dam that allows excess water to flow over the top of the dam during periods of high water flow. It helps prevent the dam from overflowing and causing potential damage.

7. **Power house**: This is the building or structure where the turbines are located, and electricity is generated. It is connected to the penstock, which brings water to the turbines, and the generated electricity is then transmitted to the power grid for distribution to consumers.

- **Mechanical structure**
  - a. **Turbine**:

    This is the primary component that converts the kinetic energy of flowing water into mechanical energy, which is then used to generate electricity. The turbine is typically a large, spiral-shaped blade that rotates as water flows through it.

✓ **Types of turbines**

Principally, according to the working of turbine it can be categorized into two types, as:

1. Impulse turbines

Working Principle: Converts the kinetic energy of water into mechanical energy. The water strikes the turbine blades with high velocity.

Characteristics: Operates in air (not submerged in water) and uses high head (elevation) water sources.

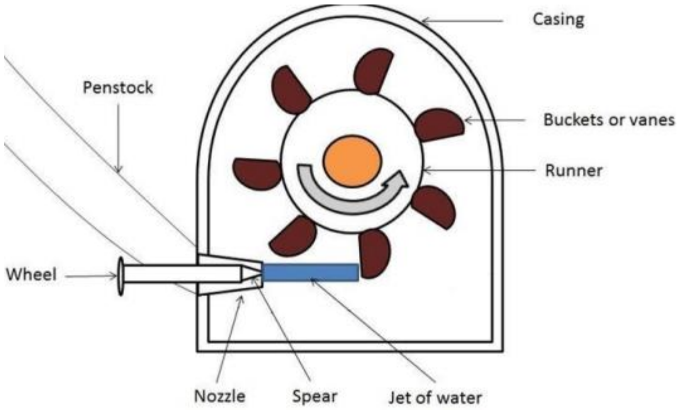
Examples:

- Pelton Turbine
- Turgo Turbine
- Crossflow Turbine

In these turbines the rotor rotates freely in atmospheric pressure. The rotor in never submerged in water of the tailrace. It is kept above the tailrace water level and the nozzles of these turbines are free jet type.

a) **Pelton turbine**

A Pelton turbine is known to be of impulse type. A Pelton turbine is mostly suitable for the sites having relatively high head and low discharge. It is fully free jet turbines. The water jet hits the rotor bucket and the buckets are made in such a way that the middle ridge (splitter edge) divides the free jet into two equal parts and the jet are reserved by almost 165 degrees to obtain maximum possible efficiency. The turbine must be placed above the tailrace canal as cross flow to avoid the watering of the runner. Needle valve is placed at the nozzle to control flow system of this turbine



b) Turgo turbine :

The Turgo turbine is a type of hydro impulse turbine designed for medium to high-head water sources, typically used in hydropower plants where the available head is too low for a Pelton turbine but higher than what would be efficient for a Francis turbine. It operates by converting the kinetic energy of water into mechanical energy through a high-speed water jet striking the turbine blades.

c) **Cross flow turbine Cross flow** is normally classified as an impulse type of turbine. The main feature of the cross flow is the water jet of rectangular cross-section.

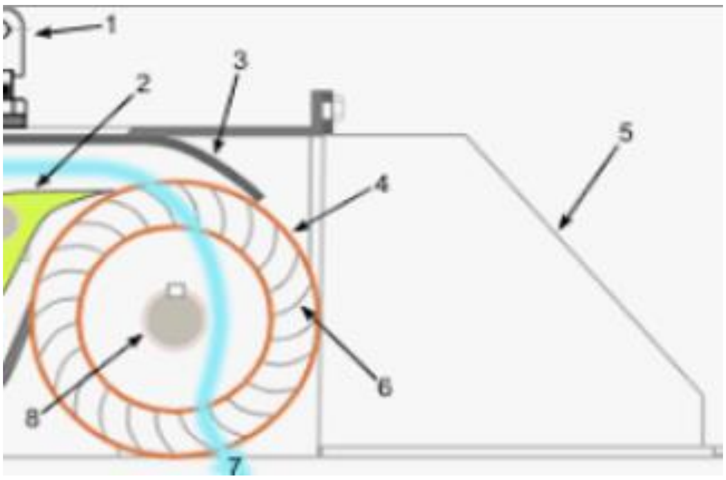


Figure. Cross-flow turbine

1 air-venting valve

2. distributor

3. turbine casing (all thick grey)

4. runner

5. removable rear casing

6. blades

7. water flow

8. shaft

2. Reaction turbines:

Working Principle: Converts both the kinetic and pressure energy of water into mechanical energy. Water flows through and over the blades, creating a reaction force that spins the turbine.

Characteristics: Operates fully submerged in water and is suitable for low to medium head water sources.

Examples:

- Francis Turbine
- Kaplan Turbine

a) Francis turbine It is a reaction turbine. Normally Francis turbine is inward mixed flow T. It works at medium head medium flow rate (with wide range of head).

Working of the Francis turbine

Water under pressure (from reservoir and penstock) enters into the runner from the guide vans towards the centre in radial direction and discharges out of the runner axially. Energy of water transfers to rotational energy of runner and then rotation of shaft. There is a difference of pressure between the guide vanes and the runner which is called reaction pressure and is responsible for the motion of the runner. The pressure at inlet is more than outlet. Water flows through the spiral casing. Water released from a draft tube submersed in water for easy release and reuse of exit water

Refer to the figure above Here are the main components of a Francis turbine and their functions:

1. Runner (Rotor)

Function: Converts the kinetic and pressure energy of water into mechanical energy. It consists of curved blades that direct water flow through the turbine.

Design: The water enters radially and exits axially, passing over the blades, which are designed to create a reaction force that spins the runner.

2. Spiral Casing (Scroll Case)

Function: Directs water evenly around the entire circumference of the runner, ensuring a uniform flow distribution.

Design: Spiral shape that gradually reduces in cross-sectional area to maintain constant water velocity.

3. Stay Vanes /stay ring

Function: Provide structural support to the casing and direct water flow towards the guide vanes.

Design: Stationary and fixed in position, ensuring the water flows smoothly into the guide vanes.

4. Guide Vanes (Wicket Gates)

Function: Regulate the flow of water entering the runner and control the angle of attack on the runner blades.

Adjustment: Can be adjusted to vary the flow rate and turbine power output, optimizing efficiency under different load conditions.

5. Draft Tube

Function: Discharges water from the runner to the tailrace while recovering kinetic energy and reducing velocity to minimize losses.

Design: A gradually expanding tube that increases pressure as water exits, improving overall efficiency.

6. main Shaft

Function: Transfers the mechanical energy from the runner to the generator.

Design: Must withstand the torque produced by the spinning runner and maintain alignment with the generator.

7. Water guiding device:

Function: controls the amount of water flowing into the runner .by adjusting their angle, they regulate the flow rate to match the power demand .

Operation: during periods of low demand the guide vanes close partially to reduce the flow, while during high demand they open wider to allow more water through.

8. Inlet Valve (Main Valve)/ water in let

Function: Controls the flow of water entering the turbine, allowing for start-up, shut-down, and emergency isolation.

9. wide vane:

Function: provide structural stability to the turbine by supporting the spiral casing and ensuring the turbine ‘s mechanical integrity.

Operation : they help maintain the shape and position of thee spiral casing, preventing deformation under water pressure

10. lead caver:

Function: helps enclosure the upper part of the runner, directing water flow efficiently into the turbine blades.

Operation:it ensure that water flows smoothly and directly into the runner minimizing leakage and energy loss.

b The Kaplan turbine is a type of reaction turbine primarily used for low-head, high-flow hydroelectric power plants. It is one of the most efficient turbines for such conditions and is designed to handle large volumes of water with relatively low pressure.

Key Features and Working Principle of the Kaplan Turbine:

1. Reaction Turbine: Unlike impulse turbines (like Pelton), which convert the kinetic energy of water, reaction turbines (including the Kaplan turbine) convert both the pressure and kinetic energy of water. The water flows through the blades, generating lift and rotating the runner.

2. Axial Flow: In a Kaplan turbine, water flows along the axis of the turbine, directly through the runner blades. The runner rotates in response to the combined kinetic and pressure forces of the water.

3. Adjustable Blades: One of the distinctive features of the Kaplan turbine is its adjustable blades. The angle of the blades can be changed according to the water flow conditions, which allows the turbine to maintain high efficiency under varying load and flow conditions.

4. Design:

Runner Blades: The runner of a Kaplan turbine has adjustable blades, typically 4 to 8 blades, that can change their pitch (angle) based on water flow and load demand.

Guide Vanes: Stationary guide vanes direct the water flow into the runner blades at an optimal angle.

5. Head and Flow Range:

Head: Kaplan turbines are most effective at low heads (typically below 30 meters), making them ideal for run-of-river hydroelectric plants or plants with relatively small height differences between the water source and the turbine.

Flow: They can handle large volumes of water and are suitable for applications with high flow rates.

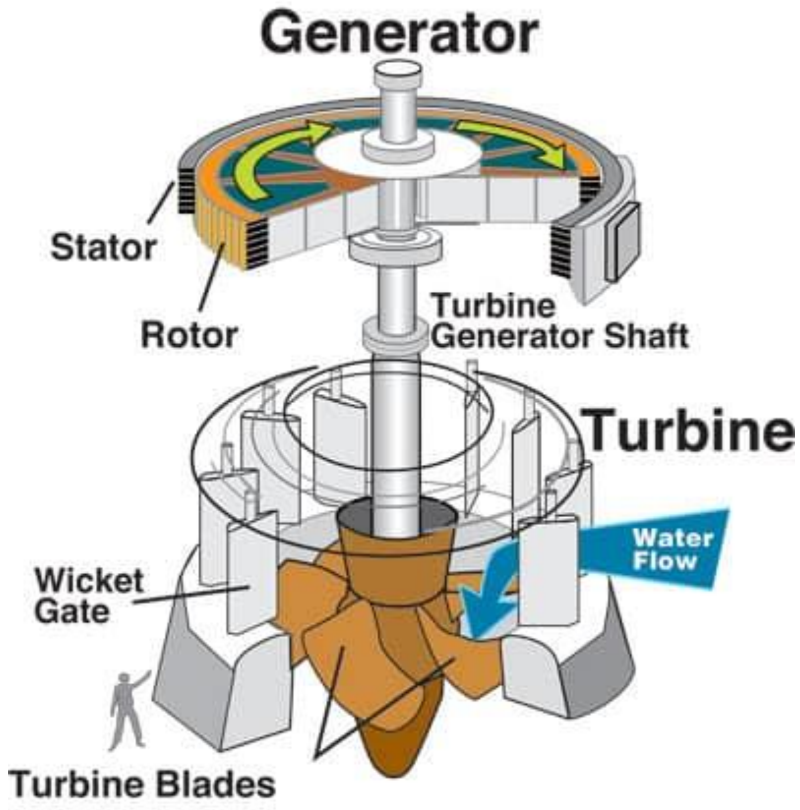
Applications:

Low-Head Hydropower Projects: Kaplan turbines are commonly used in hydropower plants that have a low head (under 30 meters) but a high water flow.

Run-of-River Plants: Suitable for plants that utilize the natural flow of a river or stream without the need for large reservoirs or significant water storage.) Kaplan Turbine.

Electrical and Electronic structures:

a. Generator: This is the primary component that converts the mechanical energy of the turbine into electrical energy. It consists of a rotor and a stator, which work together to generate an alternating current (AC) that can be transmitted to the power grid.



b. **Transformer**: This device steps up or steps down the voltage of the generated electricity to match the voltage requirements of the power grid. It is typically located near the power house and is connected to the generator.

c. **Switch gear**: This is a set of electrical switches and circuit breakers that protect the generator and other electrical components from damage due to overcurrent, short circuits, or other electrical faults. It also helps to distribute the generated electricity to the power grid.

d. Turbine control system: This is a computerized system that controls the speed of the turbine by adjusting the opening and closing of the main inlet valve. It helps to optimize the plant's performance and ensure safe and efficient operation.

e. Communication system: This is a network of communication cables and equipment that allows operators to monitor and control the power plant remotely. It provides real-time data on the plant's performance and allows operators to respond quickly to any issues that may arise.

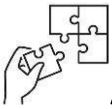
f. Protection system: This is a set of sensors and alarms that monitor the plant's performance and detect any potential safety hazards, such as high-water levels, low water levels, or electrical faults. It triggers alarms and automatically shuts down the plant if any issues are detected.

g. Control and monitoring system: This is a set of sensors, meters, and other monitoring equipment that provides real-time data on the plant's performance, such as water flow, turbine speed, and generator output. It helps operators to monitor the plant's performance and make adjustments as needed to ensure optimal operation.

Points to Remember

- **Civil Structures:** Key components include the dam, headrace channel, forejbay tank, intake structure, penstock, spillway, and powerhouse, all essential for converting water flow into electricity.
- **Mechanical Structures:** The turbine (impulse or reaction type) converts water's kinetic energy into mechanical energy. Key types include Pelton (high head), Francis (medium head), and cross-flow turbines.
- **Electrical & Electronic Components:** The generator converts mechanical energy to electrical, while transformers, switchgear, and turbine control systems manage voltage, protect equipment, and optimize performance.
- **Flow Regulation:** Main inlet valves, governors, guide vanes, and spillway gates control water flow and turbine speed, ensuring efficient and safe operation.

- **Safety and Maintenance:** Cranes for repairs, protection systems with sensors, and alarms for hazard detection are crucial for plant safety and performance.
- **Monitoring and Communication:** Control systems, communication networks, and monitoring equipment provide real-time data for remote operation and plant optimization.



Application of learning 1.3.

A company of hydropower plant estimates to produce 7.5 MW, needs supervisor for constructing the necessary plant structures before installing the hydro turbine generator in the new hydropower plant to ensure optimal efficiency. You are requested to construct this plant according to its structures.

Learning outcome 1 end assessment

Written assessment

1. Read the following statement and answer by TRUE if the statement is correct or by FALSE if it is wrong.
   i. Hydropower plant is a fluid containment device used to neutralize pressure in conveyance and other processing systems.
   ii. Hydro-power plant is facility that generate electricity by harnessing the kinetic energy of flowing or falling of water.
2. Match the components in column A with their corresponding meaning in Column B

Answers	Column A	Column B
1……….	1.Dam	a. refers to a fluid containment device used to neutralize pressure in conveyance and other processing systems
2……….	2.Surge tank	b. Are pipes or long channels that carry water down from the hydroelectric reservoir to the turbines inside the actual power station.
3……………	3.Penstock	c. It controls water flow to the power station and the letter cuts off supply of water in case the penstock bursts (break).
4………….	4.Valve house	d. a structure built across a river or stream to hold back water and creating a large reservoir
		e. This is a channel or tunnel that carries water from the fore bay tank to the penstock

3. In a hydropower plant system, turbine is a key component. Select the correct type of turbine from the options below:
   a) Impulse turbine
   b) Reaction turbine
   c) Surge turbine

d) Both A and B are correct
e) All of the above are correct

4. The following are electrical parameters, except?
   a) Frequency
   b) Current
   c) Power
   d) Turbine
5. The following statement are advantage of hydro power plant, except?
   a) It requires fuel for the generation of electrical energy.
   b) It is quite neat and clean as no smoke or ash is produced
   c) It does not require a long starting time like a steam power station.
6. Select the letters corresponding to the examples of sources of energy:
   a) Nuclear
   b) Atmosphere
   c) Natural gas
   d) Water
7. Select the letter corresponding to the correct answer for the following statement:

The classification of hydropower plant according to the Availability of head is

   a) High head power plants
   b) Low head power plants.
   c) Medium head power plants.
   d) All above are correct
   e) A and B are correct
8. The following are different methods used for water flow rate measurement, except?
   a) Bucket/volumetric tank method
   b) Salt velocity method
   c) weir notched method
   d) Altimeter
9. Select the letter corresponding to the correct answer for the following statement:

   The following are the individual components for Hydropower Plant construction:

   a) Weir and intake
   b) Sand trap-settling basin
   c) Head race channel
   d) Fore bay and Trash rack
   e) Spillway
   f) All above are correct

Practical assessment

Hydropower plant is to be installed to produce 3 MW you as trainee on level of supervisor before installing the hydro turbine generator of this plant be sure that it will produce peak efficiency, You are requesting to your trainees to implement the intallation of this power plant fundamentals of this hydropower plant by considering the required plant capacity.

References

A.K. Raja, Amit Prakash Srivastava, Manish Dwivedi, (2006). *Power plant Engineering*, New Delhi. Bangalore. Chennai. Mumbai. Ranchi, Pg22-128&Pg364-406.

V.K. MAHTA, ROHIT MAHTA, (2010). *Principles of power system, Mumbai.* New Delhi. Bangalore. Chennai., Pg11-15,27-29, &Pg602-612.

Er. R.K. RAJPUT, (2008). *A Textbook of power plant engineering, Bengaluru.* Chennai. Cochin. Guwahati. Hyderabad. Jalandhar. Kolkata. Lucknow. Mumbai. Ranchi New Delhi. Boston (USA). Accra (GHANA). Nairobi (KENYA)., Pg27-28, &Pg323-358

Gulliver, John S, Arndt, Roger E.A. (1991). Hydropower Engineering Handbook, Bengaluru. McGraw-Hill, Inc. Retrieved from the University of Minnesota Digital ConservancyPg20-200

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Learning Outcome 2: Assemble Hydro Turbine Generator Components

Indicative contents
2.1. Preparing workplace **2.2. Fixing draft tube** **2.3. Fixing turbine** **2.4. Fixing generator**

Key Competencies for Learning Outcome 2: Assemble Hydro Turbine Generator Components

Knowledge	Skills	Attitudes
● Identification of hazard control and safety measures. ● Interpretation of hydro turbine generator diagrams ● Description on fixation of draft tube, turbine and generator ● Description of tools, materials and equipment used in hydro turbine generator installation	● Preparing workplace of Hydro turbine generator components ● Implementing hazard control and safety measures. ● Interpreting of hydro turbine generator diagrams ● Selecting of tools, Materials and equipment ● Setting out a draft tube ● Fixing out a draft tube ● Setting out a turbine ● Fixing a turbine ● Setting out a generator ● Fixing generator	● Being careful ● Being attentive while selecting of tools, materials and equipment ● Being self-confident ● While sixing draft tube of turbine ● Being self-confident while fixing generator

Duration: 60hrs

Learning outcome 2 objectives:

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

1. identify properly of hazard control and safety measures based on preparation of work place
2. interpret clearly hydro turbine generator diagrams according to manufacturer's installation guide
3. select correctly tools, materials and equipment based on activities to be done
4. Fix correctly Draft tube according to manufacturer's installation guide
5. Fix correctly turbine according to manufacturer's installation guide
6. Fix correctly generator according to manufacturer's installation guide

Resources

Equipment	**Tools**	**Materials**
• Torpedo level • First Aid Kit • Personal Protective Equipment • Barometric altimeter • Measuring wheel • Soldering Iron • Telescope insulating pole • Hot air gun • Portable welding machine • Chain block	• Hammer • Micrometer • Spirit level • Tape measure • Spade • Hoes • Torch Wrench • Small Spanner socket set • Large Spanner socket set • Electrician knife + • blades accessories • Insulated flat screwdriver set	• Water filled tubes • Ddrawing instruments • Drawing paper/Sheet (A0-A4) Pens • Pencils • Pegs • Electrode extension cable • Grinding wheel • Eelectrical crocodile clips • Cable mass

• Blower • Computer Aided Design software • Computers • Hydraulic cable lug crimper • Spirit level • Portable drilling machine	• Insulated star screwdriver set • Pipe wrenches • Allen key set • Claw Hammer • Mallet hammer • Socket extension bar Adjustable spanners • multiplier spanner Combination spanners (6-32) Double open end spanners (6-32) • Double ended ring spanners • Heavy duty single ended ring spanner 50 • Hand tool box • Tool for preparing MV cables, Pinch Points cable cutter • Pin punch set (9 pieces) • Tensioning tool • Pulling hoist • extension socket wrench • 1/2 reversible impact wrench • Hummer slugging ring spanner set • Lifting wire rope slings set	earthing • Eye bolt (M6-M12) • Banana plugs • Cleaning detergent • Bloom • Cleaning rugs • Drawing instruments • Drawing paper/Sheet (A0-A4) • Wire and cable Connectors • Miniature circuit breaker • Nuts and bolts • Screws • Rivets • Cable trey • Eye hook • Drill bits

	• Bow shackle set • Riveting tool kit • Set of metric die and tap set with their handles (right/left hand) • File set • Jaw plier • Adjustable locking plier • Hand hacksaw • Snap • Ring plier (external & internal) set • Heavy duty Vice Screw extractor set • Pulley puller tool • Chisel set • Electrical angle grinder • Oil filter wrench • Center punch • Center drill • Scissor	

Indicative content 2.1: Preparing Workplace

Duration : 10hrs

Theoretical Activity 2.1.1: Identification of hazard control and safety measures

Tasks:

1: Answer the following questions:

i. How do you understand the term hazard?

ii. Explain how can you assess hazard

iii. Explain how you can control hazard

2: Present the findings to the whole class and trainer.

3. Follow the expert view and ask for clarification if any.

4: Read the Key readings 2.1.1 in trainee manual

Key readings 2.1.1.: Identification of hazard control and safety measures

- **Definition of hazard:**

  A hazard is any source of potential harm, damage, or adverse health effects on something or someone under certain conditions**.** hazard can exist in various forms, including physical, chemical, biological, or even psychological**.**

- **Types of hazard**

  Common types of hazards are :

  ✓ **physical hazards:** involve environmental factors that can cause harm without direct contact .

  Examples:

  - noise
  - radiation
  - extreme temperatures (heat or cold)
  - vibration
  - electrical hazards
  - heights
  - machinery

  ✓ **Chemical hazards:** involve exposure to chemicals in the form of liquids, gases, vapors, or dust that may be toxic, corrosive, flammables, or reactive.

Examples:

- Pesticides
- Solvents
- Acids
- Cleaning agents
- Asbestos

✓ **Biological hazards**: involve organisms or biological substances that can cause harm to human health.

Examples:

- Bacteria
- Viruses
- Fungi
- Parasites
- Blood borne pathogens

✓ **Ergonomic hazards:** relate to improper physical conditions in the workplace that can cause strain or injury.

Examples:

- poor workstation design
- repetitive movements
- improper lifting techniques
- awkward postures
- overexertion.

✓ **Psychosocial hazards:** involve mental and emotional risks that can negatively impact well-being.

Examples:

- Stress
- Workplace violence
- Bullying
- Harassment
- Job insecurity
- Long working hours

✓ f. **Environmental hazards:** include hazard that stem from the surrounding environment, often due to natural occurrences or pollution.

Examples:

- Earthquakes
- Floods
- Hurricanes
- Air pollution
- Water contamination

- Deforestation

✓ **Mechanical hazards:** relates to machinery, tools and equipment that could cause injury through cutting, crushing, shearing and entanglement.

Examples:

- Unguarded moving parts
- Malfunctioning equipment
- Sharp blades

✓ **Electrical hazard:** are hazards associated with the use of electrical power.

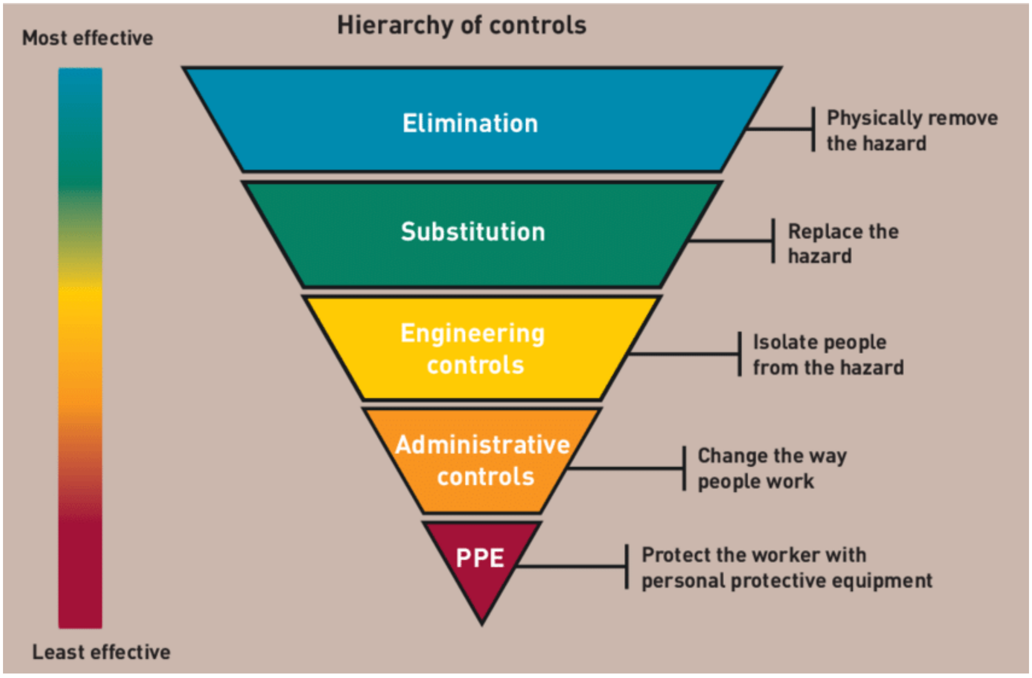
examples: electric shock

- burns
- fires
- caused by faulty wiring
- explosion

3. Hazard assessment.

a. Definition: hazard assessment is the systematic process of identifying , analysing and evaluating potential hazards in a workplace , environment ,or specific task to determine their level of risk.

The purpose of a hazard assessment is to prevent accidents, injuries or illness by recognizing potential dangers and implementing controls to minimize or eliminate them



b. Key steps in hazard assessment:

✓ **Identify hazards:**

Recognise and list all potential hazards that may exist in a particular environment, process, or activity. This includes physical, ergonomic, psychosocial, chemical and biological

- **Assess the risk:**

Evaluate the likelihood and severity of harm that could result from each hazard.

This involve determining how likely it is that the hazard will cause harm and how severe the consequences could be (eg. Injury, illness, property damage)

- **Determine control measures:**

Implement controls to mitigate or eliminate the identified hazards. Controls can be grouped in the following hierarchy:

- Elimination: completely remove the hazard
- Substitution: replace the hazard with something less dangerous
- Engineering controls: isolate people from the hazard (eg. installing safety guards)
- Administrative controls: change the way people work (eg. Training, rotating shifts)
- Personal protective equipment (PPE): Equip workers with safety gear (e.g helmets, gloves)

c. Benefits of hazard assessment

- **Risk Identification:** They help identify potential hazards in the workplace or environment, allowing for proactive measures.
- **Enhanced Safety:** By recognizing risks, organizations can implement controls to prevent accidents and injuries.
- **Regulatory Compliance**: Hazard assessments ensure compliance with local, national, and international regulations, reducing legal liabilities.
- **Improved Decision-Making**: They provide data that supports informed decision-making regarding safety policies and resource allocation.
- **Employee Awareness and Training**: Assessments foster a culture of safety by educating employees about potential hazards and safe practices.
- **Resource Optimization:** By identifying critical areas for improvement, organizations can allocate resources more effectively.
- **Emergency Preparedness:** They facilitate the development of response plans for emergencies, ensuring quicker and more effective reactions.
- **Continuous Improvement:** Regular assessments promote on going evaluation and enhancement of safety protocols.
- **Insurance Benefits:** Companies may benefit from lower insurance premiums by demonstrating effective risk management.
- **Reputation Management:** A commitment to safety can enhance an

organization’s reputation among clients, stakeholders, and the community.

4.Safety measures

Safety measures are actions, protocols, or devices designed to reduced risks and protect individual, property or the environment from harm or danger.

Those safety measures include:

a. Workplace Safety

Hazard Identification: Regularly assess the workplace for potential hazards.

Training Programs: Provide training on safety protocols and equipment use.

Emergency Exits: Clearly mark and keep emergency exits accessible.

First Aid Kits: Ensure availability of well-stocked first aid kits and trained personnel.

b. Personal Protective Equipment (PPE)

Proper Gear: Equip employees with the right PPE based on the hazards present (e.g., helmets, gloves, goggles).

Training on Use: Ensure proper training on how to wear and maintain PPE.

c. Ergonomics

Workstation Design: Optimize workstations to reduce strain and injury (e.g., adjustable chairs, proper keyboard placement).

Breaks and Rotation: Encourage regular breaks and job rotation to prevent repetitive strain injuries.

d. Equipment Safety

Regular Maintenance: Schedule routine maintenance and inspections of equipment to ensure it’s in safe working condition.

Lockout/ Tagout Procedures: Implement procedures to safely shut down and lock out machinery during maintenance.

e. Fire Safety

Fire Extinguishers: Place fire extinguishers in accessible locations and ensure employees know how to use them.

Fire Drills: Conduct regular fire drills to familiarize employees with evacuation routes.

f. Chemical Safety

Material Safety Data Sheets (MSDS): Keep MSDS available for all hazardous materials and ensure employees are trained on their contents.

Proper Storage: Store chemicals according to safety guidelines to prevent spills or reactions.

f. Emergency Preparedness

Emergency Response Plans: Develop and communicate plans for various emergencies (fire, chemical spill, natural disaster).

Regular Drills: Conduct drills to ensure employees know how to respond in emergencies.

g. Health and Wellness Programs

Wellness Initiatives: Promote programs that support mental and physical health (e.g., stress management, fitness activities).

Health Screenings: Offer regular health screenings for early detection of potential issues.

h. Reporting and Feedback Systems

Incident Reporting: Encourage reporting of near misses and incidents without fear of reprisal.

Feedback Mechanism: Implement a system for employees to provide feedback on safety measures and suggest improvements.

i. Continuous Improvement

Regular Reviews: Continuously evaluate and update safety policies and procedures based on feedback, incidents, and new regulations.

5.Hazard control

Hazard control refers to the systematic process of identifying, evaluating, and mitigating risks associated with potential hazards in a workplace or environment. The goal of hazard control is to reduce the likelihood and severity of incidents that can cause harm to people, property, or the environment.

Hazard control include:

a. Elimination

Remove the Hazard: If possible, completely eliminate the hazard from the workplace (e.g., replacing a dangerous chemical with a safer alternative).

b. Substitution

Safer Alternatives: Replace hazardous materials or processes with less hazardous ones (e.g., using water-based paints instead of solvent-based).

c. Engineering Controls

Physical Changes: Implement physical modifications to reduce exposure to hazards (e.g., installing machine guards, improving ventilation systems).

d. Administrative Controls

Policies and Procedures: Develop and enforce safety policies, schedules, and work practices that reduce exposure (e.g., job rotation, limiting hours of exposure to hazardous conditions).

e. Personal Protective Equipment (PPE)

Protective Gear: Provide appropriate PPE, such as gloves, helmets, eye protection, and respirators, to safeguard employees from residual hazards.

f. Training and Education

Safety Training: Regularly train employees on recognizing hazards, safe work practices, and proper use of PPE.

g. Monitoring and Surveillance

Health Monitoring: Regularly assess the work environment and employee health to identify any emerging risks and take corrective actions.

h. Emergency Preparedness

Response Plans: Develop and communicate plans for emergencies related to specific hazards, including evacuation routes and first aid procedures.

i. Incident Reporting and Investigation

Feedback Mechanisms: Encourage reporting of near misses and incidents to identify root causes and implement improvements.

j. Regular Audits and Reviews

Continuous Improvement: Conduct regular safety audits and reviews to assess the effectiveness of hazard control measures and update them as necessary.

Practical Activity 2.1.2: Implementing hazard control and safety measures

Task:

1. Refer to the key readings 2.1.2, Bravo hydropower plant that will produce 50MW is in phase of civil work. you are requested to prepare workplace through in Implementation of hazard control and Safety measures.
2. Pay attention on trainer's explanations and instructions
3. Present your work to the trainer/colleague and ask clarification if any.

Key readings 2.1.2: Implementing hazard control and safety measures

- **Steps followed for Implementing hazard control and Safety measures**

key steps in hazard assessment:

- ✓ **Identify hazards:**
  Recognise and list all potential hazards that may exist in a particular environment, process, or activity. This includes physical, ergonomic, psychosocial, chemical and biological
- ✓ **Assess the risk:**
  Evaluate the likelihood and severity of harm that could result from each hazard.
  This involve determining how likely it is that the hazard will cause harm and how severe the consequences could be (eg. Injury, illness, property damage)
- ✓ **Determine control measures:**
  Implement controls to mitigate or eliminate the identified hazards. Controls can be grouped in the following hierarchy:

- Elimination: completely remove the hazard
- Substitution: replace the hazard with something less dangerous
- Engineering controls: isolate people from the hazard (eg. installing safety guards)
- Administrative controls: change the way people work (eg. Training, rotating shifts)
- Personal protective equipment (PPE): Equip workers with safety gear (e.g helmets, gloves)

Theoretical Activity 2.1.3: Interpretation of hydro turbine generator diagrams

Tasks:

1: Answer the following questions:

i. How do you understand the term symbols?

ii. What are importance of symbols used on hydro turbine generator?

iii. Give and explain types off diagrams needed in interpretation of hydro turbine generator

iv. Explain, how can you review on diagrams while you are interpreting of hydro turbine generator

2**:** Present the findings to the whole class and trainer.

3. Follow the expert view and ask for clarification if any.

4: Read the Key readings 2.1.3 in trainee manual

Key readings 2.1.3 Interpretation of hydro turbine generator diagrams

- **Symbols**

  A symbol is a mark, sign, or object that represents or stands for something else, often conveying a particular meaning or idea.

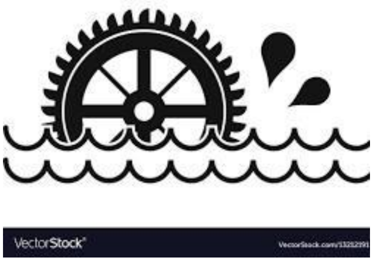
- **Symbols of Turbines and Their Meanings**

1. Rotating Blades:

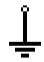
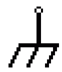
Meaning: Represents the core function of a turbine - the rotating blades that convert fluid energy into mechanical work.

2. Water Wheel:

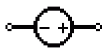
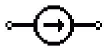
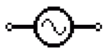
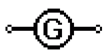
Meaning: Historically, turbines evolved from water wheels



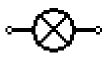
3. Electrical Wiring Symbos

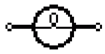
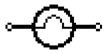
Name	Meaning / Function	Symbol
Earth Ground	Protection against Electrical Shock	
Chassis Ground	Connected to Chassis of a Circuit	
Common Ground	For Analogue and Digital Grounding	

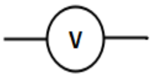
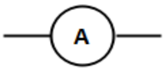
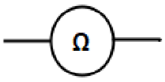
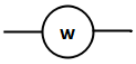
Power Supply Symbols

Name	Meaning / Function	Symbol
Voltage Source	Constant Voltage Source	
Current Source	Constant Current Source	
AC Voltage Source	Source of AC Voltage	
Battery	Constant Voltage Source	
Battery Cell	Constant Voltage Source	
Generator	Mechanical Voltage Source	

Lamp and Light Bulb Symbols

Name	Meaning / Function	Symbol
Lamp or Light Bulb	Generates Light with Flow of Current	

Lamp or Light Bulb	Generates Light with Flow of Current	
Lamp or Light Bulb	Generates Light with Flow of Current	

Symbol	Name	Description
	Voltmeter	It is the symbol that shows Voltmeter which is used to measure the voltage.
	Ammeter	It represents the ammeter whose work is to measure the current in the circuit.
	Ohm meter	It is the symbol of the ohmmeter which is needed to measure the value of a resistor.
	Watt meter	This represents the power meter which shows the power consumption.

4. Gear Symbol

Meaning: Represents the mechanical power transmission aspect of turbines

5. Water Drop:

Meaning: The most direct symbol, representing the water that drives the turbine

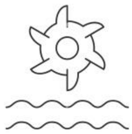
7.Dam:

Meaning: Many hydro turbines are located behind dams, which control the flow of water

8 Hydropower Plant:

Meaning: A more complex symbol representing the entire infrastructure involved in hydropower generation.

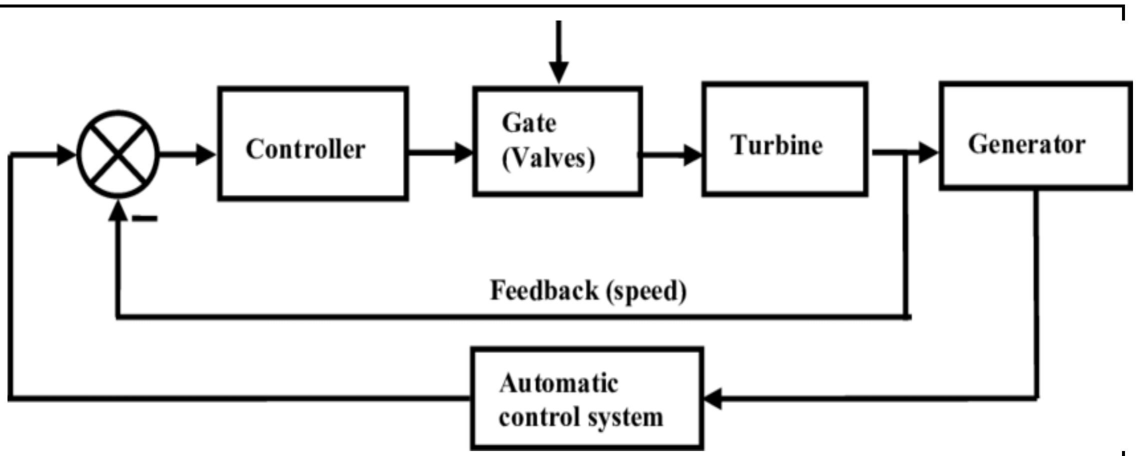
9.hydro turbine generator



Types of diagrams.

A diagram is a simplified visual representation of information, concepts, or relationships. Diagrams are used to illustrate complex ideas, show processes, or convey data in a clear and understandable way. To understand their components, operation, and performance, various diagrams are used. Here are some common types

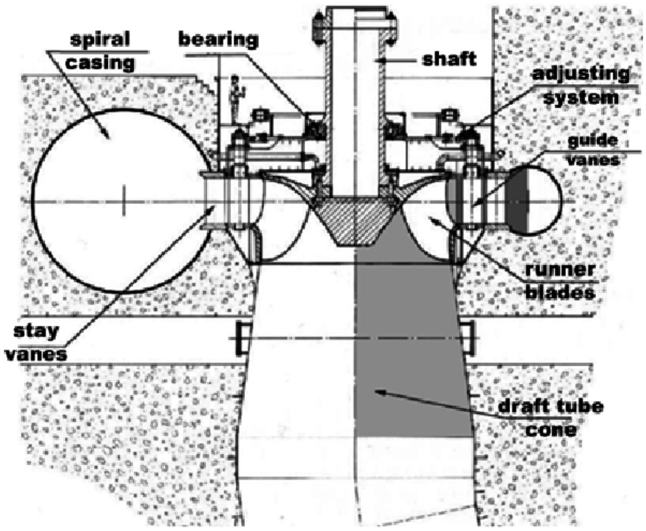
1. System Diagram:
Purpose: Shows the overall layout of the hydro turbine generator system.
Components: Dam, penstock, turbine, generator, transformer, transmission lines.



2. Turbine Cross-Section Diagram:

Purpose: Depicts the internal structure of the turbine.

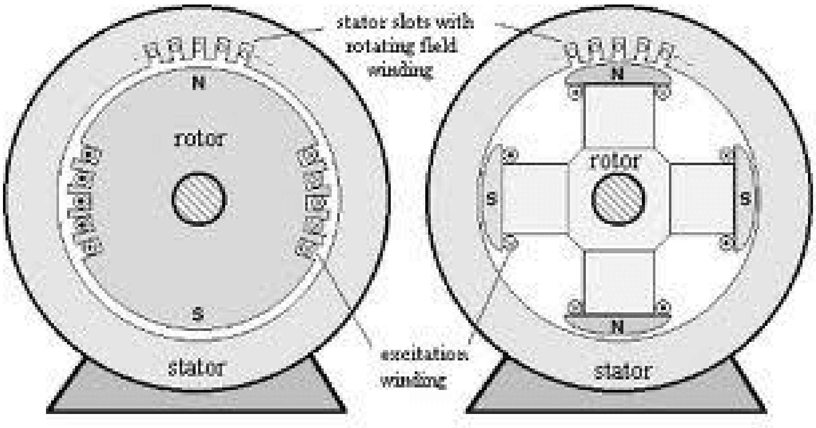
Components: Runner, stator, guide vanes, draft tube.



3. Generator Cross-Section Diagram:

Purpose: Illustrates the internal components of the generator.

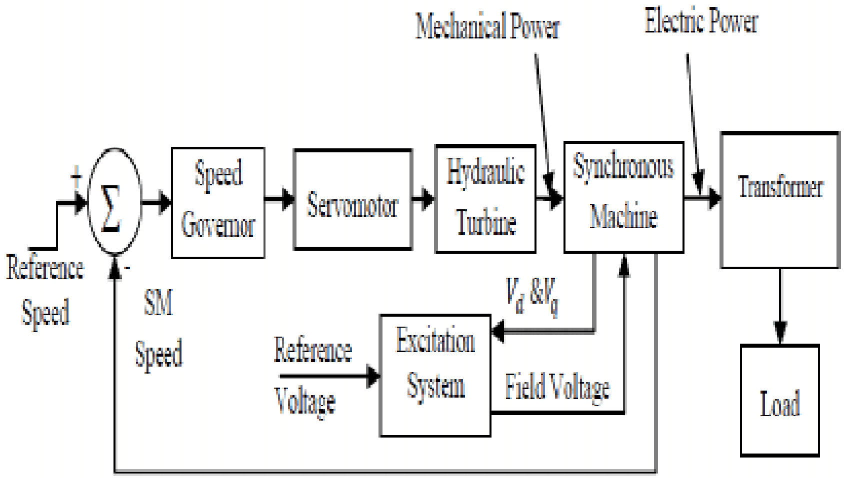
Components: Stator, rotor, field winding, armature winding.



4. Hydraulic Circuit Diagram:

Purpose: Shows the flow of water through the system.

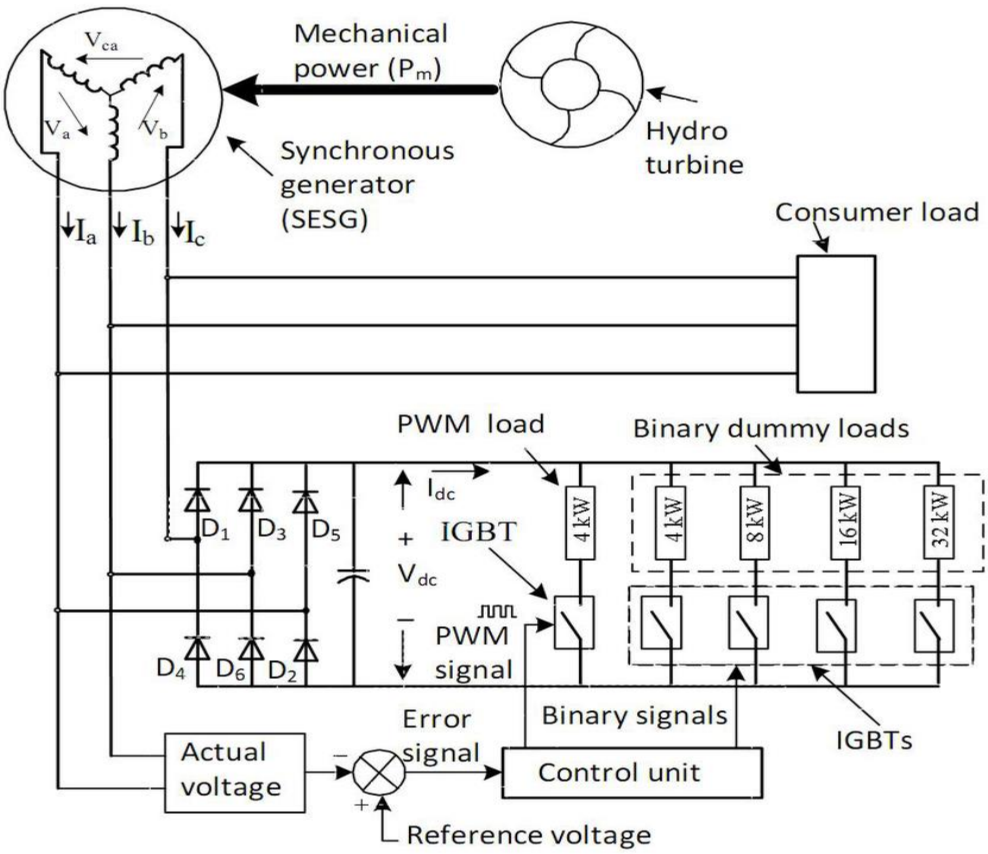
Components: Pipes, valves, gates, turbines.



5. Electrical Circuit Diagram:

Purpose: Represents the electrical connections within the generator and system.

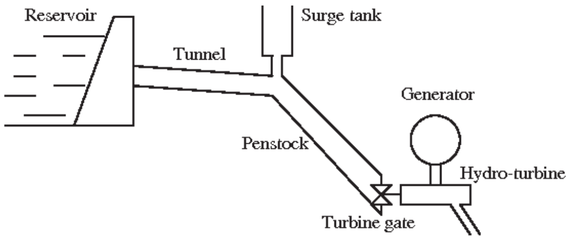
Components: Stator windings, rotor windings, transformers, control devices.



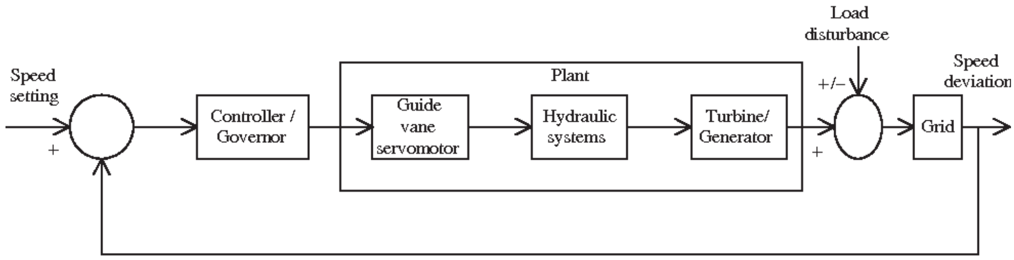
6. Control System Diagram:

Purpose: Depicts the control components and their interactions.

Components: Sensors, controllers, actuators.



(a) General layout form

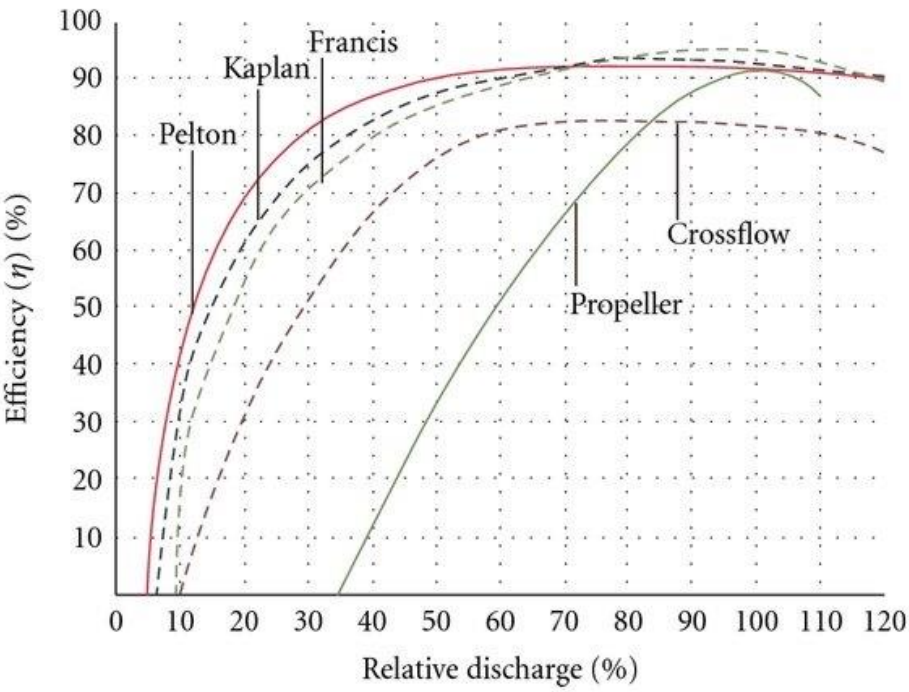


(b) block diagram form

7. Performance Curves:

Purpose: Graphs that show the relationship between turbine output power, flow rate, and head.

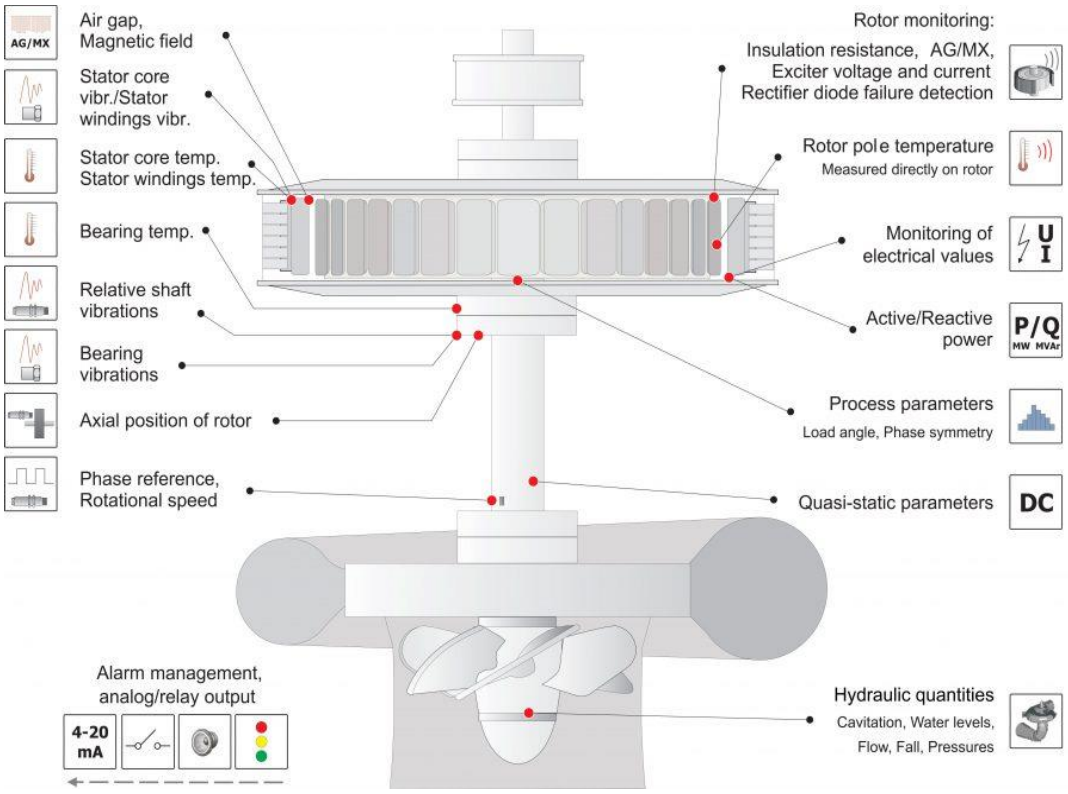
Types: Efficiency curves, head-discharge curves, power-discharge curves.



8. Vibration Analysis Diagrams:

Purpose: Visualizes the vibration patterns of the turbine and generator.

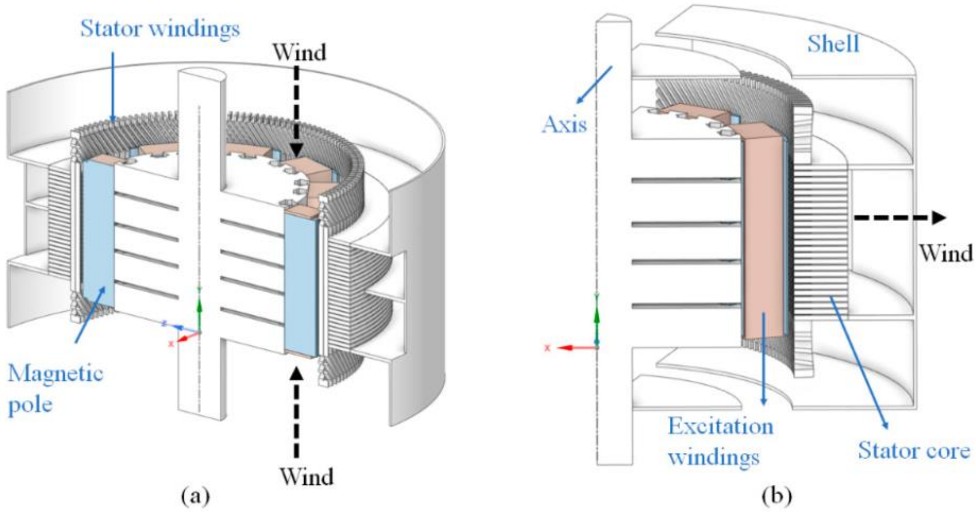
Types: Time-domain waveforms, frequency spectra.



9. Thermal Analysis Diagrams:

Purpose: Shows the temperature distribution within the turbine and generator.

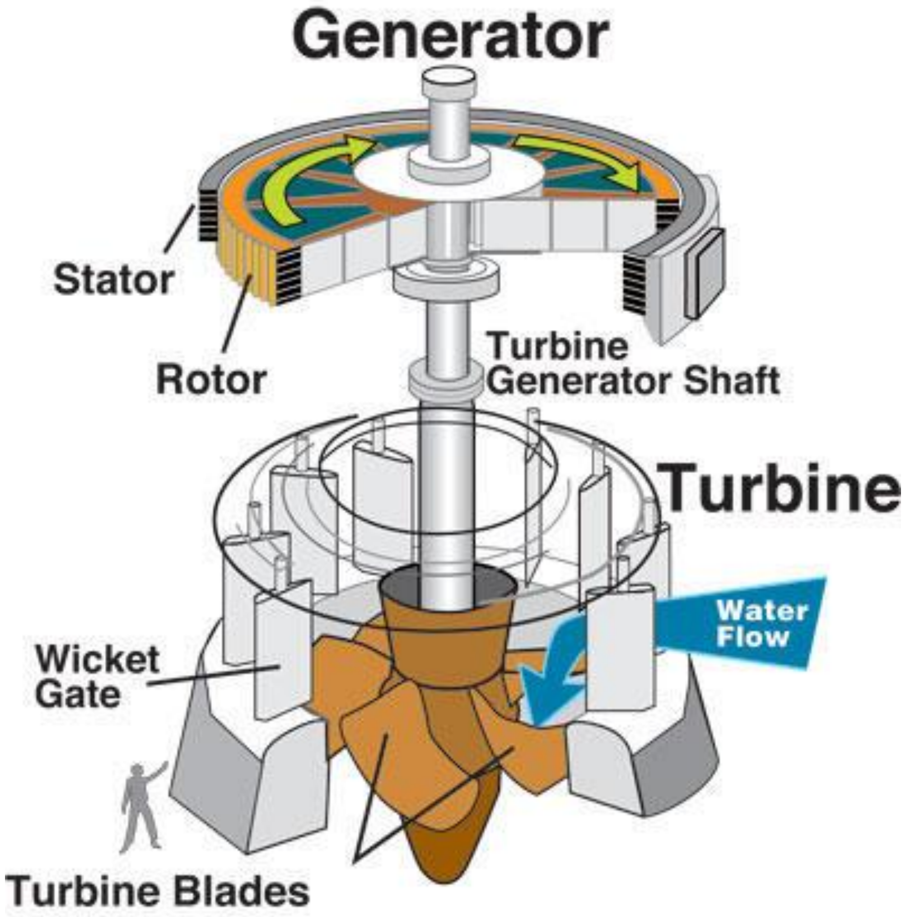
Types: Temperature profiles, thermal gradients.



10. Stress Analysis Diagrams:

Purpose: Analyzing stress in hydro turbine generators is crucial for ensuring their safe, efficient, and reliable operation.

11. pictorial representation diagram of hydro turbine generator:



These diagrams are essential for understanding the design, operation, and maintenance of hydro turbine generators. They help technicians, and operators visualize the system and its components, identify potential issues, and optimize performance.

- **Reviews of diagrams.**

The following are Reviews of diagrams:

- **Layout Diagrams:** These diagrams provide an overview of the generator's components and their arrangement. They are essential for understanding the overall structure and spatial relationships.
- **Cross-Section Diagrams:** These diagrams offer a detailed view of the generator's internal structure, showing the arrangement of key components like the stator, rotor, bearings, and cooling system. They are crucial for visualizing the internal workings and identifying critical areas.
- **Penstock Diagrams**: These diagrams illustrate the layout of the penstock, which is the pipe that carries water from the dam to the turbine. They are crucial for understanding the hydraulic system and optimizing water flow.
- **Turbine Flow Diagrams**: These diagrams depict the flow of water through the turbine, including the various stages and components involved. They are

essential for understanding the turbine's hydraulic performance and optimizing efficiency.

- **Thermal Diagrams**
- **Block Diagrams:** These diagrams represent the control system as a series of interconnected blocks, each representing a specific function or component. They are useful for understanding the control system's logic and functionality.
- **Efficiency Curves:** These diagrams plot the generator's efficiency against various operating parameters, such as load, speed, and water flow rate. They are essential for evaluating the generator's overall performance and identifying areas for improvement.
- **Power Output Curves:** These diagrams show the generator's power output as a function of different operating conditions. They are useful for understanding the generator's capacity and performance limits.
- **Torque Curves**: These diagrams plot the torque produced by the generator as a function of speed. They are useful for analysing the generator's mechanical performance and identifying potential issues.

Theoretical Activity 2.1.4: Selection of tools, materials, equipment

Tasks:

1: Answer the following questions:

i. Define the following terms:

a. Tool
b. Material
c. Equipment
d. Identify tools, materials and their functions

2: Present the findings to the whole class and trainer.

3. Follow the expert view and Ask for clarification if any.

4: Read the Key readings 2.1.4 in trainee manual

Key reading 2.1.4 Selection of tools, materials, equipment and selection criteria

- **Tools**

Define tools: A tool is an instrument or device used to accomplish a task. It can be a simple object like a hammer or a screwdriver, or a more complex piece of equipment like a machine tool. Tools are used in various fields, including construction, manufacturing, gardening, and even education.

Here are some examples of hand tools tools:

- **Hand tools:** hammers, screwdrivers, wrenches, pliers, saws

  ✓ **Hand Tools Used in Hydro Turbine Generators**

While hydro turbine generators are primarily operated and maintained using specialized equipment and machinery, there are still numerous hand tools that are essential for various tasks. Here are some common hand tools used in hydro turbine generator maintenance and repair.

General Hand Tools

- **Screwdrivers:** Used for tightening or loosening screws

- **Wrenches:** Used to tighten or loosen nuts and bolts.

- **Pliers:** Used for gripping, bending, and cutting wires or small objects.

- **Hammer:** Used for driving nails, striking objects, and breaking materials.

- **Chisels:** Used for cutting or shaping materials

- **Files:** Used for smoothing or shaping metal surfaces.

Tape Measure

Torpedo Level

Flashlight

Utility Knife

- **Wire brushes:** A wire brush is a tool consisting of a brush whose bristles are made of wire, most often steel wire. The steel used is generally a medium- to high-carbon variety and very hard and springy.

- **Standard wire gauge:** British Standard Wire Gauge is a set of wire sizes given by BS 3737:1964, and is generally abbreviated to SWG. It is also known as: Imperial Wire Gauge or British Standard Gauge. Use of SWG sizes has fallen greatly in popularity, but is still used as a measure of thickness in guitar strings and some electrical wire.

- **Bench vices:** A vice is a mechanical apparatus used to secure an object to allow work to be performed on it. Vises have two parallel jaws, one fixed and the other movable, threaded in and out by a screw and lever metal-working vise or machinist's vise, is used to clamp metal instead of wood.

- **Power tools**

Some examples of power tools

- **An electrical angle grinder**

An electrical angle grinder is a versatile power tool commonly used for grinding, cutting, sanding, polishing, and sharpening various materials, including metal, stone, wood, and tiles. Here's a detailed breakdown of the key features, uses, and safety considerations for an angle grinder:

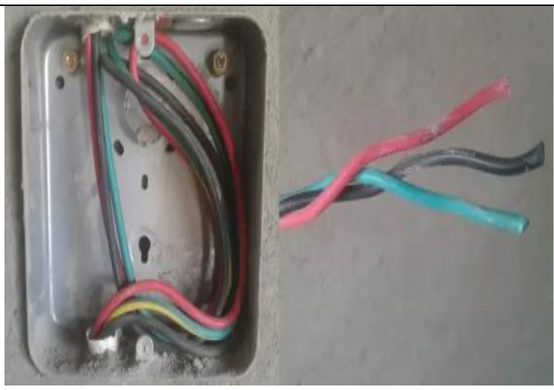
1. Key Features

Motor: Electrical angle grinders are equipped with a powerful motor (usually ranging from 500W to 2500W) that drives the disc at high speeds, typically between 5,000 to 12,000 RPM.

- **Drilling machine:** Drilling machine is a tool used to create holes in various materials, such as wood, metal, plastic concrete and masonry. drills come in various types and sizes ranging from handheld electric drills to larger, stationary machines like drill presses.

- **Materials.**
  - **Lugs:** are the electrical connectors that terminate the electrical circuit.

  - **Wire.**



A wire is a conductor that is used to carry electrical current. There are various types of wire, including copper wire, aluminium wire, stranded wire, and solid wire.

- **Conduit**

A conduit is a tube or pipe that is used to protect and route the electrical wire. There are a variety of types of conduits. They include metal conduits, plastic conduits, and flexible conduits.

- **Circuit breakers**

Circuit breakers are devices that are used to protect against electrical overloads. They are designed to trip when there is an overload, protecting the electrical system and preventing a fire from starting.

➢ **Wire nuts**

Wire nuts are a type of electrical connector that is used to secure two or more electrical wires together.

➢ **Electrical tape**

➢ **Cable ties**

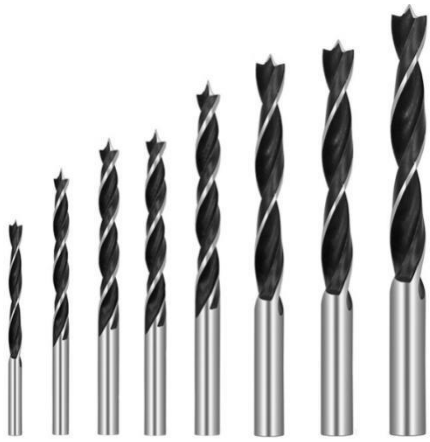
Cable ties, also known as zip ties or tie wraps, are a popular and convenient way to organize and secure cables and wires.

➢ **Cable clamps**

Cable clamps, also known as wire clamps or cord clamps, are a type of fastening device that is used to secure and organise cables and wires.

- **Drill bits:** They are materials attached to drilling machine to create holes in various materials, such as wood, metal, plastic, masonry and concrete



- **Equipment.**
    - **Multimeter**

There are two types:

DIGITAL and ANALOGUE A Digital Multimeter has a set of digits on the display and an Analogue Multimeter has a scale with a pointer (or needle).
You really need both types to cover the number of tests needed for designing and repair-work. We will discuss how they work, how to use them and some of the differences between them.


- **Wattmeter**

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit. Electromagnetic wattmeters are used for measurement of utility frequency and audio frequency power; other types are required for radio frequency measurements.

This true RMS watt meter is capable of measuring up to 6000 watts, 600 volts (AC), 10 amps (AC) and power factor. The R5000 features a large backlit LCD display and maximum, minimum and data hold functions.

Features

- Measures Watt, AC Voltage/Current and Power Factor
- Large backlit dual LCD display
- Max/Min and Data Hold Functions
- Cat. III 600V safety rating
- Low battery indicator and auto shut off

- **Energy meter:** An electricity meter, electric meter, electrical meter, or energy meter is a device that measures the amount of electric energy consumed by a residence, a business, or an electrically powered device. Electric utilities use electric meters installed at customers' premises for billing purposes.

Measures the electricity consumed by a single-phase or three-phase circuit downstream of the electricity distribution metering.

Displays electricity consumption in kWh, as well as current, active energy, reactive energy and power.

MID compliance ensures accuracy of the metering with a view to recharging for the electricity used.

- **Tachometer**

A tachometer is an instrument used to measure the rotational speed of an object, typically in revolutions per minute (RPM). It is commonly used in vehicles, machinery, and industrial equipment to monitor the speed of rotating parts such as engines, shafts, turbines, or motors. There are different types of tachometers depending on the application and method of measurement, including analog, digital, and non-contact models.

1. Types of Tachometers

a) Analog Tachometers

Description: These use a needle and dial to display RPM. The needle moves in response to changes in the rotational speed of the engine or machinery.

Use: Commonly used in older vehicles and machines.

Features: Simple design, usually driven by a mechanical or electrical connection to the rotating shaft.

b) Digital Tachometers

Description: These tachometers use a digital display to show the RPM. They are more accurate and easier to read compared to analogue tachometers.

Use: Found in modern vehicles, industrial machinery, and laboratory equipment.

Features: May include additional functions such as memory storage, peak hold, and alarms for over speed conditions.

c) Contact Tachometers

Description: These require direct contact with the rotating part to measure RPM. They often use a wheel or sensor that touches the rotating surface.

Use: Common in industrial settings where direct measurement is possible.

Features: Simple, accurate measurements but may require shutting down machinery for setup.

d) Non-Contact Tachometers (Optical or Laser)

Description: These devices measure RPM without physical contact by using a laser or infrared light that reflects off a rotating part.

Use: Ideal for measuring the speed of parts that are hard to access or when contact is not practical or safe (e.g., high-speed turbines).

Features: Safe, fast, and non-intrusive. Typically, more expensive but very accurate.

e) Magnetic Tachometers

Description: These use magnetic sensors to detect the speed of rotation by counting the magnetic pulses generated by a rotating part.

Use: Found in industrial machinery and automotive applications where magnetic coupling is available.

Features: High reliability and can be used in harsh environments.

- ✓ **Applications**
  - **Automotive:** Tachometers are essential in cars to monitor engine speed, helping drivers avoid over-revving the engine, which can cause damage.
  - **Industrial Machinery:** Used to measure the speed of motors, pumps, fans, conveyor belts, and other rotating machinery in factories or plants.
  - **Generators and Turbines:** Essential for monitoring the rotational speed of turbines or generators in power plants, including hydro, wind, and thermal power plants.
  - **Aviation:** In aircraft, tachometers measure the rotational speed of the propellers or jet engines to ensure safe operation.
  - **Laboratory and Testing:** In research and development settings, tachometers are used to measure the speed of equipment or components during testing and experiments.
- ✓ **Selection criteria**
  - **Quality**

The quality of tools, equipment, and materials is critical in many fields, particularly in areas like manufacturing, research, engineering, and construction. The quality impacts performance, accuracy, durability, safety, and cost-efficiency.

Qualities criteria of tools, materials and equipment are:

1. Accuracy and Precision:

High-quality tools ensure precision in measurements and work. For example, in scientific research, precision instruments like high-grade calipers, balances, or spectrometers are essential for accurate data collection.

2. Durability and Longevity:

Superior materials and well-crafted equipment tend to last longer, reducing the need for frequent replacements or repairs. This can be seen in both hand tools and large industrial machinery.

3. Safety:

Faulty or low-quality equipment can lead to accidents, injuries, or malfunctions. Ensuring high standards in manufacturing tools (e.g., electrical, mechanical, or lab-based) mitigates risks.

4. Efficiency:

High-quality materials often result in higher efficiency. For instance, better cutting tools for machining operations can reduce waste, improve speed, and provide better surface finishes.

5. Reproducibility and Reliability:

In research, especially in physics and mathematics, experiments must be reproducible. Good quality tools and materials reduce inconsistencies, ensuring experiments or results can be replicated.

6. Cost-effectiveness:

While initially more expensive, investing in higher-quality tools often saves money in the long run due to reduced maintenance, less downtime, and fewer replacements.

7. Professional Results:

For artisans, engineers, or even researchers, the quality of tools and materials directly influences the final outcome. For example, a physicist using precision instruments will get more accurate results, leading to credible findings.

8. Sustainability:

Higher-quality materials and tools may come with certifications ensuring they are sustainably sourced or more energy-efficient. This is important in reducing environmental impact.

- **Compatibility**

The compatibility of tools, materials, and equipment is crucial in ensuring safety, functionality, and efficiency in various applications

- **Compatibility criteria of tools, materials and equipment are:**

1. Material Compatibility

- Chemical Resistance: Ensure materials are chemically compatible to avoid corrosion, degradation, or chemical reactions. For example, using incompatible metals (like aluminium and copper) can lead to galvanic corrosion.
- Thermal Compatibility: Some materials expand or contract differently when exposed to temperature changes. This can lead to warping, cracks, or other structural failures if incompatible materials are used together.

- Physical Properties: Materials with similar hardness, flexibility, and strength should be used to ensure structural integrity and longevity.

2. Tool Compatibility

- Tool Size and Specification: The size of tools must be compatible with the parts or materials they are used on. For instance, wrenches and sockets must match bolt sizes to avoid damage.
- Material of Tools: Ensure that the material of the tool is suitable for the task. For example, softer materials like plastic cannot be cut with high-speed steel tools.
- Electrical Compatibility: Tools should be compatible with the power supply they are connected to, considering voltage, current, and frequency specifications.

3. Equipment Compatibility

- Safety: Equipment needs to be compatible with the materials and tools used to ensure safe operation. For instance, using equipment rated for specific pressures, loads, or temperatures is vital to prevent accidents.
- Power and Connectivity: Ensure equipment is compatible with power sources (voltage, phase, and frequency) and connections such as hose sizes, electrical plugs, or data connectors.
- Automation Systems: In automated systems, compatibility with control protocols and software (e.g., PLCs or SCADA systems) is essential for seamless integration.

4. Environmental Factors

- Temperature and Humidity: Environmental conditions like extreme temperatures and high humidity can affect the performance and longevity of tools, materials, and equipment.
- Exposure to Elements: Materials and equipment exposed to UV light, moisture, or chemicals need to be resistant or protected to avoid degradation.

Safety

Safety criteria for tools, materials, and equipment are essential to ensure safe working conditions and prevent accidents. These criteria help maintain the integrity of the tools and materials while protecting the user and surrounding environment.

1. Safety Criteria for Tools

- Ergonomics: Tools should be designed to minimize strain on the user. Features like comfortable grips, proper weight distribution, and reduced vibration help prevent injuries like repetitive strain injuries (RSI).
- Sharpness and Condition: Cutting tools (e.g., saws, knives) should be sharp to avoid slippage that can occur with dull blades. Regular inspection and maintenance are necessary to keep tools in good working condition.
- Insulation: Tools used in electrical work must be properly insulated to prevent shocks. Double-insulated tools are preferred in high-voltage environments.
- Guarding: Moving parts, such as those in saws and grinders, should have safety guards to protect users from direct contact and debris.
- Calibration and Maintenance: Precision tools should be regularly calibrated to maintain accuracy and safety. Malfunctioning tools may lead to errors and unsafe conditions.
- Locking Mechanisms: Tools should have locking mechanisms to avoid accidental activation or deactivation, especially with power tools.

2. Safety Criteria for Materials

- Non-Toxicity: Materials used in production should not emit harmful fumes or chemicals, particularly in environments where workers are exposed over long periods. MSDS (Material Safety Data Sheets) should be available for hazardous materials.
- Fire Resistance: Flammable materials should be clearly labeled and stored appropriately. Non-flammable alternatives should be used, when possible, in high-heat environments.
- Strength and Integrity: Materials should be able to handle the stresses they are exposed to during use without breaking or deforming. Testing for load-bearing capacities, tensile strength, and impact resistance is critical.
- Thermal Stability: Materials must be stable under the temperature conditions they will encounter. Some materials may become brittle in cold or melt under excessive heat.
- Corrosion Resistance: For applications involving moisture or chemicals, materials should be corrosion-resistant to maintain structural integrity and prevent accidents.
- Disposability: Hazardous materials should have proper disposal guidelines to prevent environmental contamination or harm to personnel.

3. Safety Criteria for Equipment

- Compliance with Standards: All equipment should meet safety standards set by regulatory bodies such as OSHA (Occupational Safety and Health Administration), ANSI, ISO, or other relevant organizations.
- Emergency Shutoffs: Equipment should have easily accessible emergency

stop mechanisms in case of malfunction or dangerous situations. This applies to both automated and manually operated equipment.

- Load Capacity: Equipment must not be overloaded beyond its rated capacity, whether it's lifting, bearing weight, or handling electrical loads. Overloading can lead to mechanical failure or accidents.
- Regular Inspections and Maintenance: Equipment should be inspected regularly for wear and tear, damage, and operational faults. Preventative maintenance is key to ensuring long-term safety.
- Noise and Vibration: High-noise and vibration-producing equipment must have proper controls like sound dampening or vibration isolation to prevent long-term harm to workers (e.g., hearing damage, hand-arm vibration syndrome).
- Safety Features: Equipment should include built-in safety features like automatic shutoff, overload protection, safety locks, and guards.
- Electrical Safety: Ensure proper grounding, fusing, and insulation for all electrical equipment. GFCI (Ground Fault Circuit Interrupter) devices should be used in areas where electrical equipment is exposed to moisture.

4. Personal Protective Equipment (PPE)

- PPE Requirements: Operators and workers must be equipped with appropriate PPE such as gloves, helmets, goggles, ear protection, and respirators to protect against hazards associated with the tools, materials, and equipment used.
- Proper Use and Training: Workers should be trained on how to safely use tools and equipment, handle hazardous materials, and wear appropriate PPE.

5. Environmental and Operational Considerations

- Ventilation: Work areas should be well-ventilated when using tools or materials that release dust, fumes, or gases. This is particularly important in confined spaces.
- Proper Storage: Tools, materials, and equipment must be stored correctly when not in use to prevent accidents like trips, falls, or inadvertent activation.
- Training and Supervision: Workers should be properly trained in the use of tools and equipment, and safety supervisors should ensure all safety procedures are followed.

Functionality

When assessing the functionality of tools, materials, and equipment, certain criteria must be met to ensure they are suitable for their intended purpose. Below are key functionality criteria to consider:

1. Purpose & Suitability

- Relevance to Task: The tool, material, or equipment should be appropriate for the specific job or function it is intended for.
- Design Fit: The design and dimensions must match the required task (e.g., a wrench that fits a particular size bolt).
- Material Compatibility: Tools or materials must be compatible with the working material (e.g., metal-specific cutting tools).

2. Durability & Strength

- Material Quality: The tool should be made from materials that can withstand regular use without breaking or wearing out quickly.
- Load-bearing Capacity: Equipment must handle the expected physical loads or stresses, such as weight, pressure, or force.
- Resistance to Wear and Tear: Consider the lifespan and how well the tool or material resists abrasion, corrosion, or environmental exposure.

3. Precision & Accuracy

- Measurement Accuracy: Tools used for measurement (e.g., calipers, levels) must provide precise and reliable readings.
- Operational Consistency: The equipment should perform the same way every time, ensuring uniformity in results.
- Tolerances: Tools and materials must meet necessary tolerances for accuracy in fit, form, or function.

4. Safety

- Protective Features: Tools should include features that minimize risk to the user, such as insulation, guards, or ergonomic handles.
- Compliance with Standards: Equipment must comply with relevant safety standards and regulations (e.g., electrical safety, pressure ratings).
- Ease of Handling: The tool or equipment should not pose unnecessary risks due to awkward design, sharp edges, or heavy weight.

5. Efficiency

- Speed of Use: The tool or equipment should improve the efficiency of the task, making it quicker and easier to complete.
- Energy Consumption: Equipment that uses power should operate efficiently, consuming as little energy as necessary.
- Operational Time: The tool or equipment should minimize downtime, allowing for extended use without frequent adjustments or repairs.

6. Maintenance & Repairability

- **Ease of Maintenance**: Tools and equipment should be easy to clean, lubricate, or otherwise maintain for long-term use.
- **Spare Parts Availability**: Components that may wear out or break should be readily available for repair or replacement.
- **Repairability**: Ideally, the equipment should be easy to disassemble and repair without specialized knowledge.

7. Ergonomics

- **Comfort of Use**: Tools should be designed to minimize physical strain on the user, especially if they will be used for extended periods.
- **Weight and Balance**: Tools and equipment should not be overly heavy or poorly balanced, which can lead to fatigue or accidents.
- **User-friendly Interfaces**: Machines or complex tools should feature controls that are intuitive and easy to operate.

8. Cost-Effectiveness

- **Value for Money**: Tools and materials should provide good performance relative to their cost.
- **Operational Costs:** Consider ongoing expenses like energy use, replacement parts, or frequent reordering of materials.
- **Return on Investment (ROI):** Equipment should deliver a good return on investment, improving productivity or quality to justify the expense.

Points to Remember

Definition of hazard: is any source of potential harm, damage, or adverse health effects on something or someone under certain conditions**.** hazard can exist in various forms, including physical, chemical, biological, or even psychological**.**

- Hazard assessment.
- Definition of hazard assessment
- key steps in hazard assessment
- Definition of Safety measures

✓ **Safety measures include:**

a. Workplace Safety

b. Personal Protective Equipment (PPE):
c. Ergonomics
d. Equipment Safety
e. Fire Safety
f. Chemical Safety
f. Emergency Preparedness
g. Health and Wellness Programs
h. Reporting and Feedback Systems
i. Continuous Improvement

- ✓ **Hazard assessment.**

a. Definition: hazard assessment is the systematic process of identifying, analysing and evaluating potential hazards in a workplace, environment, or specific task to determine their level of risk.

- ✓ **Key steps in hazard assessment:**

- **Identify hazards:**

Recognise and list all potential hazards that may exist in a particular environment, process, or activity. This includes physical, ergonomic, psychosocial, chemical and biological

- **Assess the risk:**

Evaluate the likelihood and severity of harm that could result from each hazard.
This involve determining how likely it is that the hazard will cause harm and how severe the consequences could be (eg. Injury, illness, property damage)

- **Determine control measures**

- **A symbol** is a mark, sign, or object that represents or stands for something else, often conveying a particular meaning or idea
- **Definition of diagrams:** is a simplified visual representation of information, concepts, or relationships.
- **Types of diagrams:** System Diagram, Turbine Cross-Section Diagram, Generator Cross-Section Diagram, Hydraulic Circuit Diagram, Electrical Circuit Diagram, Control System Diagram, Vibration Analysis Diagrams, Thermal Analysis Diagrams, Stress Analysis Diagrams,
- **Reviews of diagrams.**
  - ➢ Layout Diagrams
  - ➢ Cross-Section Diagrams
  - ➢ Penstock Diagrams
  - ➢ Turbine Flow Diagrams

- Thermal Diagrams
- Block Diagrams

Define tools: A tool is an instrument or device used to accomplish a task. It can be a simple object like a hammer or a screwdriver, or a more complex piece of equipment like a machine tool. Tools are used in various fields, including construction, manufacturing, gardening, and even education.

Some examples of hand tools

- Screwdrivers
- Wrenches
- Pliers
- Hammer
- Chisels
- Files
- Tape Measure
- Torpedo Level
- Utility Knife

Some examples of power tools

- An electrical angle grinder
- Drilling machine

Some examples of materials

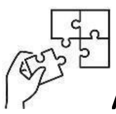
- Lugs
- wire.
- Conduit.
- Circuit breakers
- Drill bits

Some examples of Equipment

- Multimeter
- Wattmeter
- Energy meter
- Tachometer

Selection criteria for tools, materials and equipment

- Quality
- Compatibility
- Safety
- Functionality



Application of learning 2.1

hydropower plant that will produce 2.5MW needs supervisor for preparing a workplace before installing the hydro turbine generator in that hydropower plant to ensure reliable power and maximum efficiency. Ask your trainees to prepare a workplace.

Indicative content 2.2: Fixing Draft Tube

Duration : 10hrs

Theoretical Activity 2.2.1. Description for fixing a draft tube and turbine

Tasks:

1: You are asked to answer the following questions asked relate on Description for Fixing a draft tube and turbine

i. Define the draft tube.

ii. Explain the purpose of draft tube in hydro turbine generator installation

iii. Identify the types of draft tube.

iv. Describe the steps used while setting out of draft tube

v. Why do we need to make positioning of the draft tube

2: Present your findings to the whole class and trainer

3: Follow expert view and ask for clarification if any

4: Read the Key readings 2.2.1 in trainee manual

Key reading 2.2.1: Description for Fixing a draft tube and turbine

- **Fixing of draft tube**

❖ **Definition of draft tube**

It is a component of a hydroelectric power plant that helps to control the flow of water from the reservoir to the turbine. The positioning of the draft tube is crucial for efficient and safe operation of the plant.

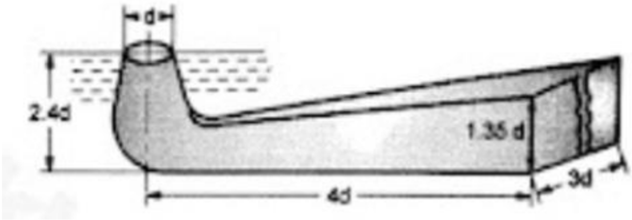
❖ **Purpose of draft tube**

➢ It converts a large proportion of the kinetic energy rejected at outlet of the turbine into useful pressure energy

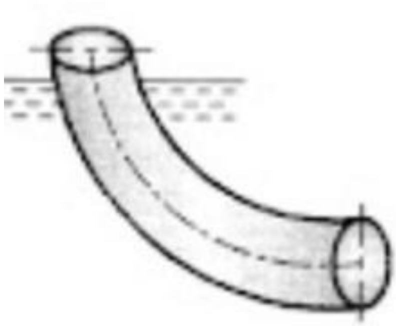
➢ It permits a negative head to be established at outlet of the runner and thereby increase the net head on the turbine

❖ **Types of draft tube**

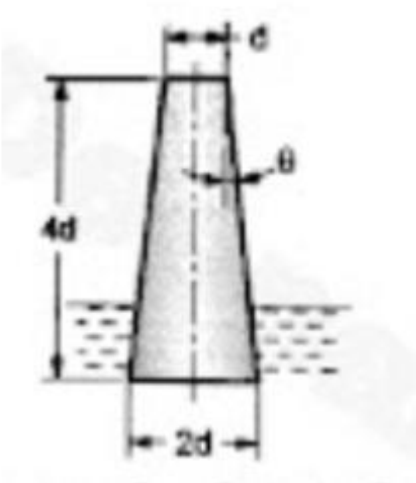
1. **Elbow with varying cross section: i**s similar to the bent draft tube except the bent part is of varying cross section with regutangular outlet. The horizontal portion of draft tube is generally inclined upwards to prevent entry of air from the exist end



2. **Simple elbow type draft tube:** it consist sof an extended elbow type tube. Generally used when turbine has to be placed close to the tail-race



3. Conical diffuser: its distinctive conical shape features gradually expanding cross section from the inlet to the outlet.



- **Steps to set out a draft tube**

1. **Turn off the generator:** Before you start any repair work, make sure to turn off the generator and unplug it from the power source.
2. **Remove the cover:** Locate the draft tube and remove the cover that protects it. This will give you access to the tube.
3. **Remove the tube:** Carefully remove the draft tube from its holder or support structure.
4. **Inspect the tube:** Check the tube for any signs of damage or wear. If the

tube is damaged, it may need to be replaced.

5. **Clean the tube:** If the tube is clogged

- **Positioning of the draft tube**

  Positioning of draft tube is important for several reasons such are:

1. **Water flow:** The tube should be positioned in a way that allows water to flow through it easily. If the tube is clogged or blocked, it can impede the flow of water and reduce the efficiency of the turbine.
2. **Alignment:** The tube should be aligned with the turbine shaft to ensure that the water flow is directed properly. If the tube is not aligned correctly, it can cause the turbine to operate inefficiently or even damage the turbine.
3. **Height and depth:** The tube should be positioned at the correct height and depth to ensure that it is fully submerged in the water stream. If the tube is not submerged properly, it can cause the turbine to operate inefficiently or even damage the turbine.
4. **Design and manufacturer's instructions**: The exact positioning of the draft tube will depend on the specific design of the hydro turbine generator and the water source. It is recommended to consult the manufacturer's instructions or seek the help of a professional technician to ensure that the tube is positioned correctly.

- **Here are some key points to consider while fixing draft tube:**

1. **Alignment**: The draft tube should be aligned correctly with the turbine and the penstock (the conduit that carries water from the reservoir to the turbine). Misalignment can lead to inefficiencies and increased wear and tear.
2. **Elevation**: The elevation of the draft tube should be carefully controlled to ensure that water flows smoothly and at a consistent rate. This helps to prevent surges that could damage the turbine or other components.
3. **Support Structure**: The draft tube needs to be supported properly to withstand the high pressures and flows of water. The support structure should be designed to handle the forces exerted by the water without deforming or failing.
4. **Accessibility**: The draft tube should be accessible for maintenance and inspection. This may involve having ladders or platforms for workers to access the tube safely.
5. **Material Selection**: The draft tube should be made from materials that can withstand the conditions of the water flow and the operational

environment. Common materials include steel, concrete, and composites.

6. **Flow Control**: The draft tube often includes mechanisms for controlling the flow of water, such as gates or valves. These should be easily adjustable

- **Steps of fixing a draft tube in a hydro turbine generator**

1. **Turn off the generator:** Before you start any repair work, make sure to turn off the generator and unplug it from the power source.
2. **Remove the cover:** Locate the draft tube and remove the cover that protects it. This will give you access to the tube.
3. **Inspect the tube:** Check the tube for any signs of damage or wear. If the tube is damaged, it may need to be replaced.
4. **Clean the tube: If** the tube is clogged or dirty, use a cleaning brush or a small vacuum to remove any debris.
5. **Replace the tube:** If the tube is damaged or worn, remove the old tube and replace it with a new one.
6. **Reassemble the generator:** Once the tube is fixed or replaced, reassemble the generator and turn it back on to test it.

Practical Activity 2.2.2: Fixing a draft tube

Task:

1: Referring to the previous theoretical activities 2.2.1, Perform the following task: As a technician you are requested to fix a draft tube according to the procedures of installing of draft tube

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

Key reading 2.2.2: Fixing a draft tube

- **Steps of fixing a draft tube in a hydro turbine generator**

1. Turn off the generator: Before you start any repair work, make sure to turn off the generator and unplug it from the power source.

2. Remove the cover: Locate the draft tube and remove the cover that protects it. This will give you access to the tube.

3. Inspect the tube: Check the tube for any signs of damage or wear. If the tube is damaged, it may need to be replaced.

4. Clean the tube: If the tube is clogged or dirty, use a cleaning brush or a small vacuum to remove any debris.

5. Replace the tube: If the tube is damaged or worn, remove the old tube and replace it with a new one.

Points to Remember

- ✓ **Steps to set out a draft tube**

1.Turn off the generator: Before you start any repair work, make sure to turn off the generator and unplug it from the power source.

2. Remove the cover: Locate the draft tube and remove the cover that protects it. This will give you access to the tube.

3. Remove the tube: Carefully remove the draft tube from its holder or support structure.

4. Inspect the tube: Check the tube for any signs of damage or wear. If the tube is damaged, it may need to be replaced.

5. Clean the tube: If the tube is clogged

- ✓ **Positioning of the draft tube**

Positioning of draft tube is important for several reasons such are:

1. Water flow: The tube should be positioned in a way that allows water to flow through it easily. If the tube is clogged or blocked, it can impede the flow of water and reduce the efficiency of the turbine.

2. Alignment: The tube should be aligned with the turbine shaft to ensure that the water flow is directed properly. If the tube is not aligned correctly, it can cause the turbine to operate inefficiently or even damage the turbine.

3.Height and depth: The tube should be positioned at the correct height and depth to ensure that it is fully submerged in the water stream. If the tube is not submerged properly, it can cause the turbine to operate inefficiently or even damage the turbine.

Application of learning 2.2

A new building of pico- hydro power plant at the river is there to increase electricity in for rural area unfortenately this power plant didn't produce the power as designed because of draft tube that was disconnected to the penstock. Ask your trainees to fix the draft tube of plant.

Indicative content 2.3: Fixing Turbine

Duration : 10 hrs

Theoretical Activity 2.3.1. Description of fixing a turbine process

Tasks:

1: Answer the following questions:

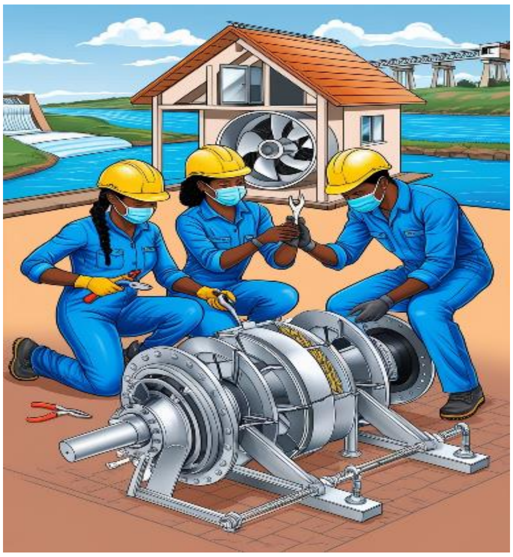
i. Identify five (5) key components considered while fixing a turbine
ii. Describe steps by steps the fixing process of turbine
iii. What is the purpose of final Adjustments?
iv. Purpose of setting out in fixing of turbine?

2: Present your findings to the whole class and trainer
3: Follow expert view and ask for clarification if any
4: Read the Key readings 2.3.1 in trainee manual

Key reading 2.3.1: Description of Fixing a turbine

- **Fixation of turbine**

Definition of turbine is a machine that converts the kinetic energy of a moving fluid (liquid or gas) into mechanical energy.



1. Key Components considered while fixing the turbine

- **Turbine Rotor and Blades**: The rotor is the central part of the turbine that rotates when water flows over it. The blades are attached to the rotor and capture the energy from the water flow.

- **Shaft and Generator:** The shaft connects the rotor to the generator, which converts mechanical energy into electrical energy. The generator is housed within a casing that protects it from water and debris.
- **Draft Tube and Penstock:** The draft tube directs water from the reservoir to the turbine, while the penstock carries water from the reservoir to the turbine intake.
- **Guide Vanes**: this control the flow of water into the turbine, regulating the speed and torque of the rotor.
- **Bearings and Seals**: Bearings support the rotor shaft, while seals prevent water from leaking out of the turbine casing.

Setting Out

Purpose: Establish the exact location and alignment of the turbine.

Process: Use surveying tools and techniques to mark the site on the ground. This ensures that the turbine is positioned correctly according to the design specifications and operational requirements.

2. Turbine Parts Positioning

Purpose: Arrange the turbine components in the correct order and orientation.

Process: Carefully unpack and organize the turbine parts. Ensure that each component is positioned according to the assembly manual or design specifications. This step is crucial for ensuring that all parts fit together correctly and are oriented properly.

3. Lifting

Purpose: Lift heavy turbine components into place.

Process: Use cranes or hoists to lift the turbine parts onto their respective positions. Ensure that the lifting equipment is properly calibrated and safe to use. Carefully position each part to avoid any damage or misalignment.

4. Alignment and Clearance

Purpose: Ensure that the turbine components are properly aligned and have the correct clearance.

Process: Use precision tools and techniques to align the turbine shafts, rotors, and other moving parts. Ensure that there is adequate clearance between components to prevent friction and wear. Misalignment can lead to inefficiency and potential damage, so this step must be done carefully.

5. Mounting

Purpose: Secure the turbine components to the foundation or support structure.
Process: Attach the turbine to its foundation or support structure using bolts, brackets, or other fastening methods. Ensure that the mounting is secure and that the turbine is level. This step is critical for the stability and safety of the turbine.

- **Fixing Process**
  - **Preparation:**

Shut down the Plant: Ensure that the turbine is not operational before starting any repair work.

- ❖ **Drain the Water**: Remove water from the penstock and draft tube to prevent flooding during the repair process.
- ❖ **Safety Measures:** Implement all necessary safety protocols, including personal protective equipment (PPE) and emergency procedures.
- ➢ **Inspection:**
- ❖ **Visual Inspection:** Check for any visible signs of wear, damage, or corrosion.
- ❖ **Non-Destructive Testing (NDT):** Use techniques like ultrasonic testing or radiographic testing to inspect the internal structure of the turbine for any hidden issues.
- ➢ **Replacement of Worn Parts:**
- ❖ **Rotor and Blades**: If the rotor or blades are worn out, replace them with new components.
- ❖ **Shaft and Bearings:** Replace any damaged or worn shafts and bearings to ensure smooth operation.
- ❖ **Seals and Gaskets**: Replace old or damaged seals and gaskets to prevent leaks.
- ➢ **Alignment and Installation:**
- ❖ **Realign the Turbine**: Ensure that the turbine is properly aligned with the shaft and generator. Misalignment can lead to inefficiencies and increased wear.
- ❖ **Install New Components:** Carefully install new or repaired components, ensuring they fit snugly and are securely fastened.
- ➢ **Testing and Commissioning:**
- ❖ **Reassemble the Turbine**: Once all components are installed, reassemble the turbine.
- ❖ **Fill the Penstock:** Gradually fill the penstock with water to test the turbine's operation.
- ❖ **Monitor Performance**: Use monitoring systems to observe the

turbine's performance and ensure it operates within acceptable parameters.

- **Final Adjustments:**
- **Adjust Guide Vanes**: Fine-tune the guide vanes to optimize the flow of water and the turbine is output.
- **Calibrate Instruments**: Ensure that all measurement instruments and control systems are calibrated correctly.
- **Maintenance and Documentation:**
- **Regular Maintenance**: Implement a regular maintenance schedule to keep the turbine in optimal condition.

Record Keeping: Document all repairs and maintenance activities for future reference and compliance purposes.

Practical Activity 2.3.2: Fixing a turbine

Task:

1: Referring to Key reading 2.3.2, you are requested to fix a turbine according to the procedures.

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

Key reading 2.3.2: Fixing a turbine

- **Keys steps to consider for fixing a turbine:**

  Step 1. Planning and preparation

  Step 2. Shutdown procedure

  Step 3. Safety procedure

  Step 4. Disassemble turbine components

  Step 5. Inspect and diagnosis

  Step 6. Components replacement or repair

  Step 7. Reassemble of turbine

  Step 8. Testing and calibration

  Step 9. Commissioning and start up

  Step 10. Preventive maintenance

Points to Remember

- **Definition of turbine** is a machine that converts the kinetic energy of a moving fluid (liquid or gas) into mechanical energy.
- **Key components considered while fixing the turbine are:**

  - ✓ **Turbine rotor and blades**: the rotor is the central part of the turbine that rotates when water flows over it. The blades are attached to the rotor and capture the energy from the water flow.
  - ✓ **Shaft and generator:** the shaft connects the rotor to the generator, which converts mechanical energy into electrical energy. The generator is housed within a casing that protects it from water and debris.
  - ✓ **Draft tube and penstock:** the draft tube directs water from the reservoir to the turbine, while the penstock carries water from the reservoir to the turbine intake.
  - ✓ **Guide vanes**: this controls the flow of water into the turbine, regulating the speed and torque of the rotor.
  - ✓ **Bearings and seals**: bearings support the rotor shaft, while seals prevent water from leaking out of the turbine casing.

- **Keys steps to consider for fixing a turbine includes:**

  Step 1. Planning and preparation
  Step 2. Shutdown procedure
  Step 3. Safety procedure
  Step 4. Disassemble turbine components
  Step 5. Inspect and diagnosis
  Step 6. Components replacement or repair
  Step 7. Reassemble of turbine
  Step 8. Testing and calibration
  Step 9. Commissioning and start up
  Step 10. Preventive maintenance

Application of learning 2.3

The company started to build a Pico - hydro power plant that will produce 2MW at the village; this plant needs a supervisor for fixing turbine. As a trainee for level 5, you are required to do this task.

Indicative content 2.4: Fixing Generator

Duration : 30 hrs

Theoretical Activity 2.4.1: Description of setting out

Tasks:

1: Answer the following questions:

i. How do you understand the term setting out?

ii. What are the purposes of setting out?

iii. Explain at least 5 steps consider when you are in setting out

2: Present your findings to the whole class and trainer

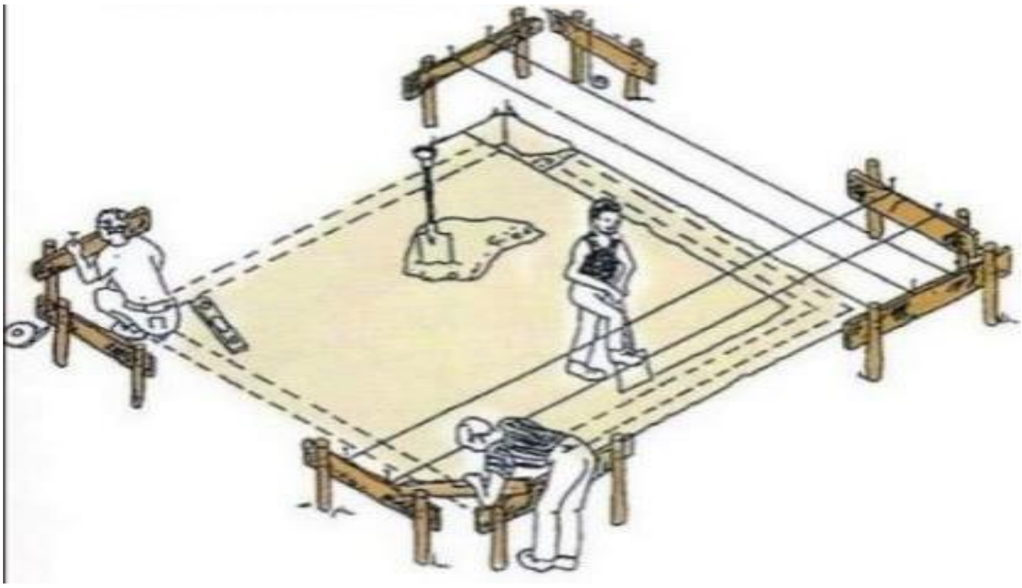
3: Follow expert view and ask for clarification if any

4: Read the Key readings 2.4.1 in trainee manual

Key reading 2.4.1: Description of setting out

- **Definition**

  Setting out is the process of marking or establishing the exact positions of structures, boundaries, and construction elements on the ground based on design plans and drawings. It translates the design details from architectural or engineering plans into real-world points and lines on the construction site.



1. Setting out for a hydro generator

Setting out for a hydro generator involves laying out and marking the positions of key components for the installation and alignment of a hydroelectric power generation system. This process requires precision to ensure that the turbine, generator, and associated components are installed correctly to harness the water flow efficiently.

✓ **Purpose of setting out on hydro generator:**

1. Accurate Placement of Equipment

- **Correct Alignment of Turbines and Generators**: Hydro generators must be accurately positioned relative to the water flow to ensure optimal energy generation. Proper setting out guarantees that turbines are aligned with water intakes and outflows for efficient energy conversion. Maximizing Water Pressure: The proper positioning of the penstock (which directs water to the turbine) and its connection to the generator ensures maximum pressure and efficiency. Inaccurate setting out could reduce the water's energy, leading to inefficiencies in electricity generation.

2. Safety and Structural Integrity

- **Structural Soundness of Dams and Powerhouses**: Hydropower facilities often include large structures like dams, spillways, and powerhouses. Setting out ensures these are placed on stable ground, avoiding potential structural failures, landslides, or collapse.
- **Flood Control and Spillway Efficiency:** Proper setting out of the spillway (which controls water release) is essential for managing water levels and preventing flooding. Accurate alignment ensures that excess water can be safely diverted, protecting the integrity of the dam and surrounding areas.

3. Optimization of Water Resources

- **Efficient Water Flow Management:** Setting out helps optimize the flow of water through the system, ensuring that the maximum amount of kinetic energy is captured. Misalignment or incorrect placement could lead to water wastage or energy loss.
- **Maximizing Power Generation:** Precise setting out allows the generator to operate at its designed capacity, ensuring that the hydro plant produces the expected amount of energy based on water availability and flow.

4. Prevention of Operational Issues

- **Avoids Misalignment Issues:** Poor setting out can cause misalignment between key components like the penstock, turbine, and generator, leading to mechanical stress, increased wear and tear, or even breakdowns.

- **Ensures Smooth Operation:** Proper setting out minimizes the risk of operational issues such as cavitation (formation of air bubbles in water flow), which can damage turbines, or vibration problems that could affect the generator's performance.

5. Environmental and Ecological Considerations

- **Minimizing Environmental Impact:** Hydropower projects have significant environmental impacts, such as altering water flow and affecting aquatic ecosystems. Precise setting out ensures minimal disruption to the natural landscape and ecological systems.
- **Water Flow Diversion**: Correctly setting out intake and outflow points can help mitigate environmental concerns such as erosion, fish migration disruption, and water quality degradation.

6. Efficiency of Maintenance and Operation

- **Future Maintenance Access**: Proper setting out provides clear access routes and space for future maintenance or upgrades of the hydro generator and associated components. Well-placed service roads, maintenance buildings, and access points make it easier to perform necessary repairs without disrupting plant operations.
- Long-term Operational Reliability: The precise placement of structural and mechanical elements contributes to the long-term reliability of the plant, reducing the need for frequent adjustments or costly repairs.

7. Cost Control and Budget Efficiency

- **Avoids Costly Mistakes:** Misplacing critical components like turbines, generators, or dams due to incorrect setting out could lead to expensive delays or repairs, increasing the project’s overall cost.
- **Efficient Use of Resources:** Accurate setting out minimizes waste of materials and labor by ensuring construction proceeds according to plan. It also reduces the likelihood of rework due to positioning errors.

8. Compliance with Design and Regulations

- **Meeting Engineering Standards**: Hydropower projects must adhere to strict engineering standards to ensure safety and functionality. Setting out ensures that the project complies with technical specifications, regulatory guidelines, and legal boundaries.
- **Regulatory Approval:** Authorities require precise setting out to approve a project’s construction, especially when it affects public resources like water bodies. Proper positioning helps in obtaining necessary permits and avoiding regulatory conflicts.

9. Long-Term Project Success

- **Maximizing Project Lifespan:** Proper setting out ensures that the hydro generator and its components function correctly for their expected lifespan. Poor positioning could shorten the life of the facility due to mechanical wear, inefficiencies, or environmental damage.
- **Future Expansion Considerations:** Accurate setting out can also provide room for future upgrades, such as increasing the capacity of the plant or adding new turbines. It ensures that any expansions can be integrated seamlessly without major redesigns.

✓ **Below are the key steps typically used for setting for generator:**

1. Site Survey and Preparatory Work

- **Site Assessment**: Conduct a detailed survey of the project site to assess terrain conditions, water flow, and structural layout.
- **Geotechnical Survey**: Evaluate soil and rock conditions to determine foundation requirements for the generator and powerhouse.
- **Topographical Mapping**: Use GPS, total station, and other survey tools to create a topographical map of the area

2. Reference Points and Benchmarks

- **Establish Benchmarks**: Set up permanent benchmarks (datum points) using high-precision GPS or surveying equipment. These serve as reference points for vertical and horizontal alignment throughout the project.
- **Mark Key Axes**: Mark the main longitudinal and transverse axes of the hydro generator setup (the alignment of the penstock, turbine, and generator) on the ground.

3. Positioning the Powerhouse

- **Marking Foundation Points**: Set out the exact position of the powerhouse, ensuring the correct orientation based on the flow of water from the penstock or dam.
- **Excavation Points**: Mark the locations for excavation based on the depth and dimensions of the foundation required to support the weight and operational load of the hydro generator system.

4. Setting Out the Turbine

- **Mark the Turbine Pit**: Set out the position of the turbine pit or housing, ensuring it is aligned with the water flow (penstock). The turbine's position is critical for converting water energy into mechanical energy efficiently.
- **Alignment Check:** Use levels, laser instruments, or a total station to ensure the turbine's alignment with the penstock, ensuring optimal water flow and

turbine operation.

5. Setting Out the Generator

- **Generator Foundation:** Set out and mark the position of the hydro generator base, ensuring it is aligned perfectly with the turbine. This alignment is vital to efficiently transfer the mechanical energy from the turbine to the generator.
- **Marking Bolts and Anchor Points**: Mark the positions for anchor bolts and other critical attachment points for securing the generator to its foundation.

6. Alignment and Levelling

- **Horizontal and Vertical Alignment**: Use levelling instruments to ensure the generator and turbine are positioned at the correct elevation and orientation. Proper alignment reduces mechanical stress and enhances operational efficiency.

7. Penstock Installation and Water Flow Setup

- **Penstock Alignment**: Ensure the penstock (the conduit that delivers water to the turbine) is properly aligned with the turbine and foundation layout. This step ensures that water flows with the right pressure and angle to maximize energy output.
- **Water Control Structures**: Set out the positions for gates, valves, and control structures that regulate water flow into the turbine.

8. Final Inspection and Adjustments

- **Conduct Final Checks**: Perform a thorough inspection of the alignment, dimensions, and layout of the entire system (penstock, turbine, and generator) before proceeding to the installation.
- **Adjustment of Points**: Make any necessary adjustments to the positions based on measurements and alignment tests.

9. Documentation

- **Record Measurements and Set Out Points:** Keep detailed records of all set-out points, including benchmarks, alignments, and elevation data, to ensure precision throughout the construction and installation process.
- **As-Built Drawings:** After installation, update site drawings with the actual measurements and positions of the installed equipment.

Practical Activity 2.4.2 Setting out

Task:

1: Referring to previous activities 2.4.1 you are requested to set out according to the procedures.

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

4:Read the Key Readings 2.4.2 for further information

Key reading 2.4.2: Setting out the generator

- **Key steps typically used for setting for generator:**
  - ✓ Site Survey and Preparatory Work
  - ✓ Reference Points and Benchmarks
    - **Establish Benchmarks**:
      Set up permanent benchmarks (datum points) using high-precision GPS or surveying equipment. These serve as reference points for vertical and horizontal alignment throughout the project.
    - **Mark Key Axes**:
      Mark the main longitudinal and transverse axes of the hydro generator setup (the alignment of the penstock, turbine, and generator) on the ground.
  - ✓ **Positioning the Powerhouse**
    - **Marking Foundation Points**: Set out the exact position of the powerhouse, ensuring the correct orientation based on the flow of water from the penstock or dam.
    - **Excavation Points**: Mark the locations for excavation based on the depth and dimensions of the foundation required to support the weight and operational load of the hydro generator system.

Theoretical Activity 2.4.3 Description of generator parts positioning

Tasks:

1: Answer the following questions relating to describe the Hydropower Plant site:

i. How do you understand the term generator parts positioning?
ii. What are the purposes of generator parts positioning?
iii. Explain at least four steps for generator parts positioning?

2: present your findings to the whole class and trainer

3. Follow expert view and ask for clarification if any

4. Read the Key readings 2.4.3 in trainee manual

Key readings 2.4.3 Description Generator parts positioning

- **Definition**

  Generator parts positioning refers to the specific arrangement or placement of the various components within a generator to ensure proper functioning, efficiency, safety, and ease of maintenance.

  It involves organizing the parts such as the engine, alternator, rotor, stator, cooling system, fuel system, and control panels in a way that maximizes performance and minimizes risks like overheating, mechanical wear, or system failure.

- **The purpose of hydro generator parts positioning**

  The purpose of hydro generator parts positioning is to optimize the efficiency, safety, and reliability of the generator while converting the mechanical energy from flowing water into electrical energy.

  Proper positioning of the hydro generator's components is critical for several key reasons:

  - ✓ **Maximizing Energy Conversion Efficiency**
    - **Smooth Mechanical to Electrical Energy Transfer**:
      The turbine must be positioned to capture maximum kinetic energy from water flow. The rotor and stator must be aligned properly to ensure the efficient conversion of this mechanical energy into electrical energy.
    - **Minimizing Energy Losses:**
      Precise positioning reduces mechanical losses (e.g., friction in bearings) and electrical losses (e.g., heat dissipation in the stator).
  - ✓ **Ensuring Safety**
    - **Avoiding Overheating**:
      Proper placement of the cooling system (water jackets, cooling ducts) around the generator's heat-generating parts, such as the rotor and stator, prevents overheating and ensures continuous, safe operation.
    - **Safe Water Flow Management**:
      Positioning components like the penstock and draft tube properly ensures controlled water flow, preventing dangerous water pressure build-up or inefficient turbine operation.
  - ✓ **Optimizing Durability and Maintenance**
    - **Ease of Access**:
      Critical parts like the control panel, bearings, and rotor are positioned for easy access, facilitating regular inspections, maintenance, and repairs.
    - **Reduced Wear and Tear**:
      Proper alignment of moving parts like the turbine, shaft, and rotor reduces mechanical stress, which extends the life of the generator and minimizes breakdowns.
  - ✓ **Minimizing Vibrations and Noise**
    - **Structural Stability:** The main shaft and bearings must be positioned to reduce vibrations and ensure smooth operation, preventing damage to the system and minimizing noise.

- ✓ **Regulating Power Output**
  - **Efficient Water Flow Control**: Positioning of the governor and turbine ensures the flow of water is controlled based on the power demand, allowing the generator to produce a stable and regulated electrical output.

- **The steps involved in the positioning of hydro generator parts**

1. Site Assessment and Design Planning

Objective: Evaluate the site conditions, such as water flow, terrain, and power demand.

Actions: Analyse water source characteristics (flow rate, head height).

Design the layout of the power plant, including the location of the turbine, generator, and water channels (penstock, draft tube).

Determine the best type of turbine and generator for the specific site

2. Turbine Positioning

Objective: Position the turbine where it can harness the maximum energy from water flow.

Actions: Install the turbine at the lowest point in the system to maximize water pressure (head) and flow rate.

Connect the turbine to the penstock (water inlet) to ensure smooth water flow into the turbine blades. Ensure proper alignment of the turbine with the draft tube for water exit.

3. Main Shaft Installation

Objective: Align the main shaft to transmit mechanical energy from the turbine to the generator's rotor.

Actions: Install the shaft vertically or horizontally, depending on the turbine and generator configuration Ensure the shaft is properly aligned to minimize vibration and friction. Install bearings along the shaft for smooth rotation and support.

4. Rotor and Stator Positioning

Objective: Align the rotor and stator to ensure efficient electromagnetic induction for electricity generation.

Actions: Mount the rotor (the rotating part) on the main shaft.

Install the stator (stationary part) around the rotor.

Ensure precise alignment to maintain consistent spacing between rotor and stator, which is essential for optimal energy conversion.

5. Exciter Installation

Objective: Position the exciter to provide the necessary electrical current to the rotor's magnetic field.

Actions: Place the exciter near or directly attached to the rotor shaft.

Connect the exciter to the control system to regulate the magnetic field and electricity generation.

6. Cooling System Installation

Objective: Position the cooling system to prevent overheating of the rotor, stator, and other components.

Actions: Install cooling ducts or water jackets around the generator's stator and rotor.

Ensure that the cooling system is in direct contact with or near heat-generating parts.

Position any external radiators or water coolers for optimal heat dissipation.

7. Control System and Governor Positioning

Objective: Position the control system to regulate generator output and water flow.

Actions: Install the control panel near the generator for easy access to monitor and control operations.

Position the governor close to the turbine to regulate the water flow based on electrical demand, ensuring the generator produces consistent power output.

8. Penstock and Draft Tube Installation

Objective: Ensure proper water flow into and out of the turbine.

Actions: Install the penstock (water inlet pipe) leading from the reservoir or dam to the turbine.

Ensure the penstock is positioned to direct high-pressure water efficiently to the turbine.

Position the draft tube (water outlet) to direct water smoothly out of the turbine, minimizing energy losses.

9. Electrical Connections and Synchronization

Objective: Position electrical components for power transmission and synchronization with the grid.

Actions: Connect the stator windings to transformers and power lines to transmit electricity.

Ensure that the generator is synchronized with the grid for consistent power delivery.

10. Testing and Adjustments

Objective: Ensure that all components are positioned correctly and functioning properly.

Actions: Conduct tests to check alignment, vibration levels, cooling efficiency, and overall generator performance.

Adjust the positioning of parts as needed to optimize performance, reduce wear, and ensure safety.

- **Lifting generator parts**

- **Definition**

A generator is a key component that converts mechanical energy from the rotating turbine into electrical energy. As water flows through the turbine, it spins the rotor of the generator. This rotation creates a magnetic field that induces an electric current in the coils of wire within the generator, following the principles of electromagnetic induction. The generated electricity is then transmitted through power lines for use in homes, industries, and businesses. Generators in hydropower plants can vary in design and capacity, depending on the specific requirements of the facility.

- **The main parts of a hydropower generator:**

1. Rotor:
The rotating part of the generator that is driven by the turbine. It consists of conductive wire coils and is essential for creating a magnetic field

2. Stator:
The stationary part of the generator that surrounds the rotor. It contains coils of wire where electricity is induced due to the rotating magnetic field of the rotor.

3. Bearings:
These support the rotor and allow it to spin freely with minimal friction, ensuring smooth operation.

4. Shaft:
A solid metal rod that connects the turbine to the rotor. When the turbine spins, it rotates the shaft, which then turns the rotor.

5. Exciter:
A small generator that provides the initial current to the rotor windings, creating a magnetic field necessary for the generator to produce electricity.

6. Cooling System:
This system maintains an optimal temperature for the generator, typically using water or air to dissipate heat generated during operation.

7. Control System:
A system that monitors and regulates the generator's output, ensuring stable electricity generation and integrating with the grid.

8. Power Output Terminals:
Connections where the generated electricity is sent out to the transmission lines.

9. Enclosure:
A protective housing that safeguards the generator components from environmental elements and reduces noise.

- **Definition: Lifting** generally refers to the act of raising or moving something to a higher position

- **The purpose of lifting generator parts**

1. Installation

- **Initial Setup**: During the construction and installation of a hydro generator, large components like the rotor, stator, and turbine need to be precisely lifted and placed into their final positions. Heavy machinery like cranes or hoists is used to lift these parts into the powerhouse or generator housing.
- **Accurate Alignment:** Lifting is crucial for positioning and aligning the generator parts accurately. Misalignment can cause operational inefficiencies or mechanical failure, so precise lifting and positioning are essential.

2. Maintenance

- **Routine Inspection**: Hydro generators require periodic inspection and maintenance to ensure optimal performance. Some parts, such as the rotor or shaft, may need to be lifted out of the assembly for thorough examination or cleaning.
- **Replacement of Worn Parts**: Components like bearings, brushes, or other moving parts may wear out over time and need to be replaced. Lifting the generator or its parts makes it easier to access these internal components for replacement.

3. Repair

- **Accessing Internal Components:** In the event of a breakdown or malfunction, lifting parts of the generator allows technicians to access internal components that need to be repaired. For example, if there is damage to the rotor, it needs to be removed by lifting to conduct the necessary repairs.
- **Component Repair and Refitting**: Some repairs require the removal and refitting of components such as the turbine, rotor, or exciter, which can

only be done by safely lifting the parts.

4. Upgrades

- **Installing New Technology**: Over the lifespan of a hydro generator, technological improvements might necessitate the replacement or upgrade of certain parts. Lifting systems allow for the safe removal of outdated components and the installation of newer, more efficient parts.
- **Capacity Expansion**: In some cases, the generator's capacity may need to be expanded, requiring modifications to the rotor, stator, or other parts. Lifting ensures that these components can be replaced or adjusted to accommodate the upgrade.

5. Transportation

- **Moving Parts On-Site**: Large parts of the generator, such as the turbine or stator, may need to be lifted and moved around the site during construction, installation, or repair. Heavy lifting machinery enables the safe transportation of these parts to and from the generator's location.
- **Off-Site Repair or Fabrication**: In some cases, parts may need to be transported off-site for specialized repairs or refurbishment. Lifting is required to load these components onto transportation vehicles.

6. Ensuring Safety

- **Preventing Damage**: Generator parts are heavy and complex. Improper handling during lifting could lead to damage or deformation of the components. Safe and controlled lifting ensures that parts are moved without being dropped, bent, or otherwise damaged.
- **Worker Safety**: Lifting heavy parts manually or without proper equipment can be dangerous for workers. Using cranes, hoists, or other lifting equipment minimizes the risk of injury, ensuring the safety of personnel on-site.

7. Precise Installation for Functionality

- **Ensuring Generator Efficiency**: Many parts of the hydro generator must be installed with extreme precision to ensure efficient operation. Lifting equipment helps in precisely placing parts like the rotor, stator, and turbine in their exact positions, which is essential for maintaining the generator's performance.
- **Avoiding Misalignment**: Misaligned parts can cause increased wear, vibration, and inefficiency in the generator. Controlled lifting ensures proper alignment, which is critical for long-term operation and avoiding breakdowns.

Key steps involved in lifting generator parts:

1. **Pre-Lift Planning**

- **Site Assessment**: Inspect the site where the generator parts will be lifted. Check for obstacles, ground conditions, and the availability of space for lifting equipment.
- **Weight Calculation**: Determine the weight of each part to be lifted, as this will dictate the type of lifting equipment required. Generators have large and heavy components such as the rotor, stator, and turbine.
- **Lifting Plan**: Develop a detailed lifting plan that includes:
- **Sequence of Lifting**: Specify the order in which components will be lifted and assembled.
- **Equipment**: Identify the cranes, hoists, slings, or other lifting tools needed.
- **Load Paths**: Determine the load path and ensure it is free of obstacles.
- **Safety Measures:** Plan for the placement of personnel, emergency procedures, and communication strategies.

2. Selection of Lifting Equipment

- **Cranes**: Depending on the size and weight of the components, use an overhead crane, mobile crane, or gantry crane.
- **Hoists**: For lighter parts, a chain hoist or hydraulic hoist can be used.
- **Lifting Slings and Shackles**: Select appropriate slings (e.g., wire rope, chain, or synthetic slings) and shackles based on the weight and shape of the part.
- **Spreaders and Lifting Beams**: For large or awkwardly shaped parts like the stator or rotor, use spreader bars or lifting beams to distribute the load evenly.

3. Inspection of Lifting Gear

- **Check Equipment Integrity**: Inspect all cranes, hoists, slings, shackles, and lifting beams for any signs of wear, damage, or fatigue. Make sure they are rated for the load being lifted.
- **Certifications and Load Ratings**: Ensure that all lifting equipment has up-to-date certifications and that its load rating exceeds the weight of the part being lifted.
- **Test Lift**: Conduct a test lift with a small load to verify the equipment's functionality.

4. Preparation of Generator Parts

- **Lifting Points Identification**: Identify and secure appropriate lifting points on the generator parts. These points should be designed or reinforced to handle the weight and stresses of lifting.
- **Attach Lifting Slings**: Securely attach the lifting slings or chains to the

designated lifting points. Use shackles or clevises if necessary, ensuring a firm and balanced grip.

- **Balance Check:** Ensure the part is balanced and will not tilt or swing uncontrollably during the lift.

5. Safety Precautions

- **Personnel Safety:** Only authorized and trained personnel should be involved in the lifting operation. Ensure all workers are wearing proper personal protective equipment (PPE), including helmets, gloves, and safety boots.
- **Clear Communication:** Establish clear communication between the crane operator, and other workers. Hand signals, radios, or flaggers should be used to ensure smooth coordination.
- **Safety Zone:** Set up a safety perimeter around the lifting area to keep unauthorized personnel clear of the operation.

6. Lifting the Generator Parts

- **Controlled Lift**: Begin lifting slowly and steadily to avoid sudden movements. Check that the part remains level and balanced as it is raised off the ground.
- **Vertical Lift:** Always lift the part vertically. Avoid dragging or pulling the part, which could cause uneven loading on the lifting equipment and increase the risk of accidents.
- **Monitor the Load:** Continuously monitor the load for any signs of instability or shifting. Stop the lift if any issues arise and adjust as necessary.
- **Guide Ropes**: Use guide ropes (tag lines) attached to the part to control any swinging or spinning during the lift.

7. Positioning and Setting the Parts

- **Aligning with Precision:** Slowly lower the part into its designated position. Ensure proper alignment with other parts of the generator (e.g., rotor inside the stator, turbine aligned with the shaft).
- **Final Adjustments:** Once the part is in place, make any necessary fine adjustments to ensure proper fit and alignment. This may involve moving the part slightly or rotating it into position.
- **Securing the Part**: After positioning, secure the part using bolts, clamps, or other fasteners to prevent movement. Double-check that all connections are tight and secure.

8. Post-Lift Inspection

- **Check for Alignment:** Ensure that the lifted part is correctly aligned and connected to other components. For parts like the rotor, check the air gap between the rotor and stator to ensure proper clearance.
- **Verify Connections:** Inspect all mechanical connections (e.g., bolts, couplings) to ensure they are secure and meet the required torque specifications.
- **Remove Lifting Equipment:** Carefully remove all lifting slings, shackles, and other equipment from the part once it is securely in place.

9. Documentation and Reporting

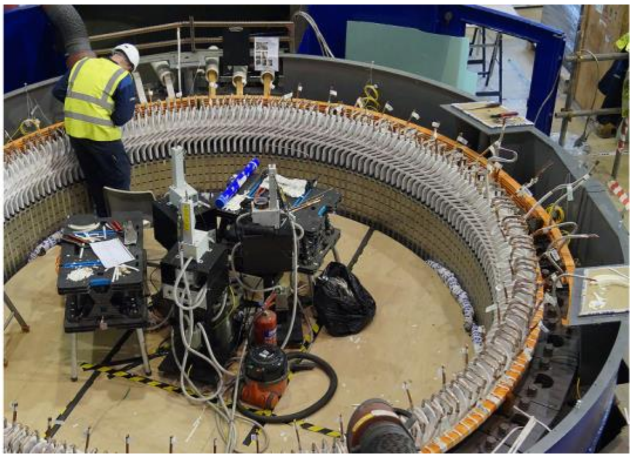
- **Record the Lift:** Document the lifting procedure, including any challenges encountered and the final position of the part. This information can be valuable for future reference, inspections, and maintenance.
- **Incident Reporting:** Report any incidents or near-misses that occurred during the lift. This helps improve safety protocols for future operations.

10. Testing and Commissioning

- **Functional Testing**: After lifting and positioning all parts, conduct functional tests to ensure the generator operates as expected. This may involve spinning the rotor, checking electrical outputs, and monitoring for vibrations or noises.
- **Commissioning:** Once all tests are successful and the generator is functioning properly, proceed with the final commissioning of the generator.

Assemble stator cores.

- **Definition:** The stator core of a hydro generator is a crucial component that plays an essential role in the generation of electricity. Its primary purpose is to provide a path for the magnetic field while minimizing energy losses.



- **Purpose of stator cores**

1. Magnetic Field Conduction

The stator core is designed to conduct the magnetic field generated by the rotor. This magnetic field is necessary for inducing an electrical current in the stator windings, which ultimately produces electricity.

It provides a low reluctance path for the magnetic field, ensuring that the magnetic flux flows efficiently through the core to maximize the interaction between the rotor's magnetic field and the stator windings.

2. Mechanical Support

The stator core provides the structural foundation for the stator windings. It securely holds the windings in place while the generator operates.

It also resists mechanical stresses, including forces generated by the rotation of the rotor, magnetic interactions, and thermal expansion due to heat during operation

3. Minimizing Energy Losses (Hysteresis and Eddy Currents)

The stator core is made of laminated sheets of electrical steel to reduce eddy current losses. Eddy currents are unwanted circulating currents that generate heat and energy losses within the core material. The lamination of the core minimizes these losses.

The core also reduces hysteresis losses, which are energy losses that occur due to the repeated magnetization and demagnetization of the core material as the magnetic field changes during operation. The use of high-grade materials in the core helps reduce this energy waste.

4. Improved Efficiency

A well-designed stator core significantly improves the overall efficiency of the hydro generator. By minimizing losses due to hysteresis and eddy currents, more of the mechanical energy from the turbine is converted into electrical energy.

The core's ability to efficiently guide the magnetic field into the stator windings maximizes the generator’s electrical output.

5. Thermal Management

The stator core also helps with thermal dissipation. During operation, the core heats up due to eddy currents and hysteresis losses. Its design, including the lamination, helps manage and spread out the heat, preventing overheating of the stator windings and ensuring the longevity of the generator.

Some stator cores are equipped with cooling channels or ventilation to further manage temperature and prevent damage due to excessive heat.

6. Durability and Longevity

The stator core contributes to the overall durability and longevity of the hydro generator. Since it holds the stator windings and interacts with the rotor's magnetic field continuously, its structural integrity is critical for ensuring that the generator operates reliably over long periods.

A well-maintained stator core prevents electrical faults, mechanical failure, and reduces the need for costly repairs or replacements.

7. Impact on Power Output and Quality

The design and condition of the stator core directly affect the quality of the electricity generated. Any issues with the core, such as warping, degradation, or damage to the lamination, can lead to inefficient power generation, increased losses, and potentially affect the voltage stability and frequency of the output electricity.

Ensuring the stator core is properly aligned and in good condition helps maintain consistent power output and reduces the likelihood of fluctuations in the electrical grid.

Below are the general steps followed in the assembly of stator cores on generator

1. Pre-Assembly Preparations

- **Site Inspection and Preparation**: Ensure the assembly area is clean, dry, and free of dust or debris. Proper environmental conditions must be maintained to avoid contamination of the core components.
- **Check Components**: Inspect all components of the stator core, such as laminations (thin sheets of electrical steel), mounting frames, cooling ducts, and fastening elements. Ensure that all parts are clean, undamaged, and free of rust or dirt.
- **Tools and Equipment Setup:** Ensure that all necessary tools, cranes, hoists, and safety gear are available and in working condition. The assembly often requires precision equipment for lifting and positioning.

2. Mounting the Stator Frame

- **Positioning the Frame**: Place the stator frame (or the core support structure) on the foundation within the generator housing. This frame will hold the stator laminations in place. It needs to be securely fastened to avoid shifting during assembly or operation.
- **Alignment**: Ensure that the stator frame is aligned accurately with the generator foundation. Alignment is critical to ensure proper interaction between the rotor and stator. Use leveling instruments to verify the horizontal and vertical alignment.

3. Lamination Installation

- **Stacking Laminations:** The stator core is built from thin sheets of electrical steel called laminations. These laminations are stacked one on top of the other to form the core. The lamination stacking is done layer by layer, either horizontally or vertically depending on the design.

- **Insulating the Laminations**: Each lamination is insulated to reduce eddy current losses. Ensure the insulating coating on the laminations is intact and that each layer is placed without damaging the insulation.
- **Securing Laminations**: As the laminations are stacked, they are typically clamped in place using steel bars, bolts, or other fasteners to prevent shifting during the stacking process. The core clamping system is essential for keeping the laminations tightly packed.
- **Cooling Ducts**: During the stacking process, ensure that cooling ducts or air gaps are properly spaced between the layers of laminations, as specified in the design. These ducts allow for effective cooling of the stator during operation.

4. Core Tightening and Clamping

- **Core Pressing:** Once the laminations are fully stacked, the stator core needs to be pressed and clamped tightly to ensure that there are no gaps between the laminations. This is critical to reduce vibration and avoid mechanical instability during operation.
- **Applying Pressure:** Specialized hydraulic jacks or presses are used to apply pressure uniformly across the stator core. This step ensures the core is tightly compressed.
- **Final Clamping:** After pressing, the core is permanently clamped into position using tightening bolts, wedges, or clamps that hold the core securely in place within the stator frame.

5. Electrical Connection of Stator Windings

- **Winding Slot Preparation**: The stator core contains slots for the stator windings. These slots must be prepared by ensuring they are free of debris or damage before inserting the windings.
- **Inserting Windings**: Copper or aluminum windings (coils) are carefully inserted into the stator core slots. Each winding is placed according to the generator's design specifications to ensure proper electromagnetic interaction with the rotor.
- **Insulating Windings**: Each winding must be properly insulated from the core and from each other to prevent short circuits or electrical faults. Insulating materials such as epoxy or varnish are applied to secure and insulate the windings.

6. Securing the Windings

- **Tying and Bracing:** Once the windings are in place, they are tied or braced to ensure they remain securely positioned during operation. This prevents the windings from shifting due to vibrations or centrifugal forces during operation.

- **End-Winding Support:** The ends of the windings (where they exit the stator core) are supported with braces to reduce movement and minimize stress on the connections.

7. Testing and Inspection

- **Electrical Testing:** After assembling the stator core and inserting the windings, several electrical tests are performed to ensure proper insulation, continuity, and the absence of short circuits. Common tests include:
- **Insulation Resistance Test:** To ensure the windings are properly insulated.
- **Hi-Pot Test (High-Potential Test):** To check the dielectric strength of the insulation.
- **Resistance Measurement:** To verify that the windings are correctly installed and have consistent electrical resistance.
- **Dimensional Inspection:** Verify that the assembled stator core is dimensionally accurate, particularly the air gap between the stator and the rotor. Misalignment or incorrect dimensions can lead to operational issues.
- **Thermal Inspection:** Check the cooling ducts and any integrated cooling systems to ensure they are functioning correctly and will provide adequate heat dissipation during operation.

8. Final Assembly

- **Connecting to the Terminal Box**: The stator windings are connected to the terminal box, which leads to the external electrical grid. These connections are crucial for transmitting the generated electricity.
- **Core Grounding:** The stator core must be properly grounded to ensure safety and to prevent electrical faults.

9. Final Tightening and Inspection

- **Final Torque Check**: Ensure all bolts, clamps, and fasteners used to hold the core and windings in place are properly tightened to their specified torque values. This is essential to avoid mechanical failure or loosening during operation.
- **Visual Inspection:** Conduct a thorough visual inspection of the stator core assembly to identify any potential defects or issues.

10. Commissioning

- **Initial Testing:** Once the stator core is fully assembled, the entire generator is subjected to a series of tests, including low-speed rotation, electrical tests, and operational tests.

- **Full Load Testing**: The generator is gradually brought up to full operational speed and load to verify that all components, including the stator core, are functioning as designed.

Wind Stator Coils

- **Definition: Stator coils** are the wire windings located on the stator of an electric motor or generator. These coils are typically made of copper or aluminium and are wound around the stator core to form electromagnets when an electric current flows through them.

- **The purpose of winding stator coils** in a hydro generator is to enable the conversion of mechanical energy from flowing water into electrical energy. Hydro generators are a type of generator used in hydroelectric power plants, and the stator coils play a critical role in this energy conversion process.
  - ✓ **Key purposes include:**

1. Generating Electromagnetic Fields: The stator coils, when wound and connected to an electrical circuit, generate a magnetic field when current flows through them. This magnetic field interacts with the rotor (which is driven by the mechanical energy of water through a turbine), inducing an electrical current.

2. Inducing Electromotive Force (EMF): As the rotor spins inside the stator, it creates a changing magnetic field. This varying magnetic field induces an electromotive force (EMF) in the stator coils, according to Faraday's law of electromagnetic induction. The induced voltage is what generates electricity.

3. Efficient Energy Conversion: Properly wound stator coils ensure efficient conversion of mechanical energy into electrical energy. The arrangement and quality of the windings affect the efficiency and output of the hydro generator.

4. Supporting Three-Phase Power Generation: In most hydro generators, stator coils are wound in a configuration that supports three-phase power generation, which is commonly used for distributing electrical power across grids due to its efficiency and stability.

- ✓ **Designing and calculating the windings of stator coils**

Designing and calculating the windings of stator coils for hydro generators involve several critical parameters, such as the number of turns per coil, the cross-sectional area of the conductor, the winding pitch, and the voltage and current ratings. These calculations are essential for optimizing the generator's performance and ensuring it operates efficiently.

- ✓ **Key Parameters in Stator Coil Calculations**

Stator coil calculations are critical in the design and performance evaluation of electric machines such as generators and motors. The key parameters involved in these calculations include:

1. Conductor Dimensions

- **Conductor Cross-Sectional Area (A):** Determines the current-carrying capacity and resistance.
- **Conductor Material:** Typically copper or aluminum, influencing resistance and thermal conductivity.

2. Number of Turns (N)

- Total turns in each coil determine the induced voltage (back EMF) in the stator winding.

3. Coil Resistance (R)

- Calculated using: R

$$R = \rho \frac{l}{A}$$

Where:

  - ρ: Resistivity of the conductor material.

- l: Length of the conductor.
- A: Cross-sectional area.

A copper wire has a length of 2 meters and a cross-sectional area of $1 \times 10^{-6}\,\mathrm{m}^2$. The resistivity of copper is $1.68 \times 10^{-8}\,\Omega \cdot \mathrm{m}$. Calculate the resistance of the wire.

Solution:

The formula for resistance based on resistivity is:

$$R = \rho \cdot \frac{L}{A}$$

Where:

R = Resistance (in ohms, Ω)

ρ = Resistivity (in $\Omega \cdot \mathrm{m}$)

L = Length of the wire (in meters, m)

A = Cross-sectional area (in square meters, m^2)

Given:

$\rho = 1.68 \times 10^{-8}\,\Omega \cdot \mathrm{m},\ L = 2\,\mathrm{m},\ A = 1 \times 10^{-6}\,\mathrm{m}^2$

Substitute the values:

$$R = \left(1.68 \times 10^{-8}\right) \cdot \frac{2}{1 \times 10^{-6}}$$

$$R = \left(1.68 \times 10^{-8}\right) \cdot 2 \times 10^{6}$$

$R = 3.36 \times 10^{-2}\,\Omega$

4. Inductance (L)

- Depends on the geometry of the coil, the number of turns, and the magnetic permeability of the surrounding material.
- Self and mutual inductances impact performance in AC machines.

5. Coil Pitch (Y)

- Defines how far apart the coil sides are placed. Impacts harmonics and the quality of the sinusoidal waveform.

6. Slot Fill Factor

- Ratio of the conductor area to the slot area, indicating the efficiency of space usage in the stator slots.

7. Thermal Parameters

- Heat dissipation capacity, thermal conductivity, and maximum temperature rise, which affect the insulation and durability of the coil.

8. Voltage per Coil (V)

- Given by Faraday's law:

$$V = N\frac{d\phi}{dt}$$

Where:

- N: Number of turns.
- $\frac{d\phi}{dt}$: Rate of change of magnetic flux.

9. Frequency (f)

- Affects the skin effect and the eddy current losses in the stator windings.

10. Magnetic Flux Density (B)

- Impacts the core and coil design to avoid saturation.

11. Winding Factor

- Accounts for the distribution and pitch factor of the winding, impacting the induced EMF.

12. Insulation Parameters

- Thickness, dielectric strength, and thermal aging characteristics.

13. Winding Configuration

The stator can be wound in a star (Y) or delta (Δ) configuration, which affects the voltage and current distribution.

Star (Y): Line voltage = √3xPhase voltage

Delta (Δ): Line voltage = Phase voltage

14. Flux per Pole:

The magnetic flux per pole is related to the strength of the rotor's magnetic field and the area of the stator poles. It plays a crucial role in determining the induced EMF.

Formula:

ϕ = B x A [Webber]

B = Magnetic flux density (Tesla)

A = Area of each pole (m^2)

Additional Considerations:

- **Core Dimensions:** Directly impact the coil length and magnetic properties.
- **Slot Geometry:** Affects the distribution of the winding and thermal performance.

Operating Environment: Factors like vibration, temperature, and humidity influence design constraints.

A generator has 24 slots, each with 100 turns in the coil. The machine operates at 60 Hz and produces a magnetic flux per pole of 0.02 Weber. The coil's conductor cross-sectional area is $1\,\mathrm{mm}^2$, and the length of the conductor is 40 meters. The resistivity of the conductor material is $1.7 \times 10^{-8}\,\Omega \cdot \mathrm{m}$. The total slot area is $0.002\,\mathrm{m}^2$. Calculate the induced EMF, the total resistance of the coil, the power loss due to resistance, and the slot fill factor.

Answer:

Induced EMF (E):

Using the formula:

$$E = 4.44 \cdot f \cdot N \cdot \phi$$

Where:

$f = 60\,\mathrm{Hz}$,

$N = 100$ turns,

$\phi = 0.02\,\mathrm{Wb}$:

$$E = 4.44 \cdot 60 \cdot 100 \cdot 0.02 = 533.28\,\mathrm{V}$$

So, the induced EMF is 533.28 V.

Resistance of One Coil (R):

Using the formula:

$$R = \rho \cdot \frac{l}{A}$$

$l = 40\,\mathrm{m}$,
$A = 1\,\mathrm{mm}^2 = 1 \times 10^{-6}\,\mathrm{m}^2$:

$$R = 1.7 \times 10^{-8} \cdot \frac{40}{1 \times 10^{-6}} = 0.68\,\Omega$$

So, the resistance of one coil is 0.68 Ω.

Power Loss due to Resistance:

Using the formula:

$$P_{\text{loss}} = I^2 \cdot R$$

First, we need the current, which can be derived from the power generated by the machine. Assuming the generator produces 3 kW:

$$P = I \cdot E \quad \Rightarrow \quad I = \frac{P}{E} = \frac{3000}{533.28} = 5.63\,\mathrm{A}$$

Now, calculate the power loss:

$$P_{\text{loss}} = 5.63^2 \cdot 0.68 = 21.4\,\mathrm{W}$$

So, the power loss due to resistance is 21.4 W.

Slot Fill Factor:

Using the formula:

$$\text{Fill Factor} = \frac{A_c}{A_s}$$

Where:
$A_c = 100\,\text{turns} \times 1\,\mathrm{mm}^2 = 100\,\mathrm{mm}^2 = 1.0 \times 10^{-4}\,\mathrm{m}^2$,
$A_s = 0.002\,\mathrm{m}^2$:

$$\text{Fill Factor} = \frac{1.0 \times 10^{-4}}{0.002} = 0.05$$

Steps for Winding the Stator Coils of a Hydro generator

1. Preparation of the Stator Core:

- **Clean the core**: Ensure that the stator core is clean and free from any debris, oil, or contaminants. This ensures good insulation and a smooth winding process.
- **Check insulation**: Inspect the core slots for insulation barriers. Slot liners or other insulating materials are used to prevent electrical short circuits between the core and windings.
- **Install slot liners**: If not pre-installed, insert slot liners (often made of materials like Nomex or mica-based insulations) into each stator slot to protect the windings from short circuits.

2. Preparation of the Conductors:

- **Cut and shape conductors**: The copper conductors are cut to the required length and shaped to fit into the stator slots. In large generators, these conductors are often bar-shaped or rectangular rather than simple wires.

- **Pre-insulate conductors**: Conductors are typically pre-insulated to withstand high voltage and prevent short circuits between turns. Layers of mica tape or other high-quality insulation materials are wrapped around the conductors.

3. Winding the Stator:

- **Manual or machine-assisted winding**: For smaller generators, the winding can be done manually by inserting the coils into the slots, while large generators may use automated winding machines to precisely position the conductors.
- **Layer winding**: The winding may involve multiple layers, depending on the number of turns required for the generator. Each layer of conductors must be carefully positioned within the slots.
- **Phase grouping**: The coils are grouped into phases (usually three phases), and each phase is wound in a specific pattern, such as a lap or wave winding, to create the correct electromagnetic field distribution.

4. Securing the Windings:

- I**nsert wedges and spacers**: Once the coils are placed in the slots, wedges and spacers are inserted above the windings to hold them securely in place. This prevents the windings from moving due to electromagnetic forces during operation.
- **Tighten the windings**: Special tools may be used to press and tighten the windings into the slots to ensure there is no slack, which can cause movement and wear during generator operation.

5. End Winding and Connection:

- **Form end windings**: The portions of the coils that extend beyond the core (end windings) are carefully shaped and secured to ensure proper electrical connections and mechanical stability.
- **Connect the coil ends**: The coil ends of each phase are connected according to the winding configuration (e.g., star or delta). This step involves carefully brazing or soldering the connections and applying insulation to the joints.

6. Testing and Inspection:

- **Continuity and insulation tests**: After winding, electrical tests are performed to ensure the continuity of the windings and the integrity of the insulation. High-voltage tests (such as a megger test) are used to check for insulation resistance.

- **Resistance measurement:** The resistance of each phase winding is measured to ensure it meets the design specifications.
- **Visual inspection:** The entire winding is visually inspected for any misalignment, loose wires, or insulation damage.

7. Vacuum Pressure Impregnation (VPI):

- **Impregnating the windings**: The stator, with its windings, is often placed in a vacuum chamber where insulating resin is introduced under pressure. This process ensures that the resin fully penetrates the windings, filling any voids and improving electrical insulation.
- **Baking:** After impregnation, the stator is baked in an oven to cure the resin, making the windings more durable and resistant to moisture and electrical stresses.

8. Final Assembly:

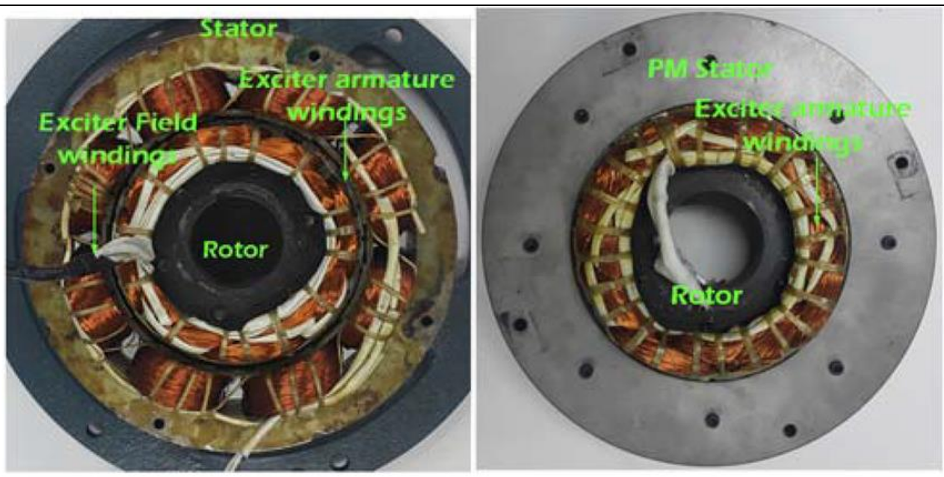
- **Assemble stator components**: Once the windings are fully cured, any final components, such as terminal boxes and cooling ducts, are assembled.
- **Mount stator in the generator:** The completed stator is then mounted in the generator housing, and it is aligned with the rotor to ensure proper operation.

9. Final Testing:

- **High-potential (Hi-Pot) testing:** A high-voltage test is performed to ensure that the insulation can handle the operating voltage.
- **Electrical performance tests**: The stator windings are tested under load conditions to ensure that the generator will perform according to design specifications.
- **Mechanical checks**: The mechanical integrity of the windings, including their alignment and the fit of wedges and spacers, is inspected before the final operation.

Wind exciter field coils

- **Definition:** Winding exciter field coils for a hydro generator is a precise and critical task, as these coils are responsible for generating the magnetic field that excites the main generator rotor, allowing it to produce electrical energy.



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- **The purpose of winding exciter field coils**

The purpose of winding exciter field coils to provide the necessary magnetic field that induces voltage in the rotor, which then transfers to the stator to generate electricity. The exciter field coils are part of the excitation system, which is critical for controlling and maintaining the generator's output.

- **Key functions of winding exciter field coils include:**

1. Producing the Magnetic Field for the Rotor: The exciter field coils generate a magnetic field when direct current (DC) passes through them. This magnetic field is used to magnetize the rotor, allowing it to interact with the stator's magnetic field.

2. Controlling Generator Output Voltage: By adjusting the current supplied to the exciter field coils, the strength of the magnetic field can be controlled. This allows the regulation of the voltage output of the hydro generator to match the load requirements or grid specifications.

3. Providing Stable Operation: The exciter field coils ensure that the rotor maintains a stable magnetic field as it spins, helping to keep the generator operating efficiently and preventing voltage fluctuations.

4. Enabling Self-Excitation or External Excitation: Depending on the design, the exciter field coils can be part of a self-excitation system, where a small part of the generator's output is fed back to power the exciter, or an external excitation system, where a separate source supplies the exciter coils.

- **Below are the steps typically followed to wind exciter field coils for hydro generator:**

1. Preparation

- **Review Design Specifications**: Start by reviewing the design parameters for the exciter field coils, such as the number of turns, wire gauge, coil dimensions, insulation type, and resistance specifications.

- **Gather Materials and Tools**: Collect all the necessary materials, including copper or aluminum wire, insulation materials, spacers, and the winding machine. Ensure that all tools, such as tensioners, clamps, and measuring instruments, are ready for use.

2. Core Inspection and Preparation

- **Clean the Core**: Before winding the exciter field coils, inspect the exciter's core (or the structure around which the coils will be wound). Ensure the core is clean and free of dirt, dust, and any contaminants.
- **Check Core Insulation**: Inspect and, if necessary, apply insulation material to the core to prevent the windings from coming into direct contact with it, which could lead to electrical faults.

3. Set Up the Winding Machine

- **Install Wire on the Winding Machine**: Load the copper or aluminium wire onto the winding machine. Ensure the wire is of the correct gauge as specified in the design.
- **Set the Machine Parameters:** Set the winding machine to the correct number of turns per coil and wire tension, ensuring that the tension is controlled to avoid damage to the wire during the winding process.

4. Start Winding the Exciter Coils

- **Begin Winding**: Start the winding process, laying the wire in even layers around the core or bobbin. The number of turns should be consistent, and the wire should be placed uniformly without overlapping or gaps to ensure proper coil geometry.
- **Control Tension**: Maintain appropriate tension throughout the winding process to ensure that the wire is evenly distributed and tightly wound. If the tension is too loose, the coil may not fit properly in its designated slot, and if too tight, the wire could break or the insulation could be damaged.

5. Layer Insulation Between Coils

- **Apply Layer Insulation:** If the exciter coil has multiple layers, apply insulation between each layer of wire. This insulation is usually made of materials like mica, Nomex, or varnish to provide adequate electrical isolation between layers.
- **Check for Uniformity:** Ensure that the insulation between layers is evenly applied and that there are no exposed areas where the wire could potentially come into contact with other layers or components.

6. Completion of Coil Winding

- **Finishing the Coil**: Once the specified number of turns have been wound, cut the wire and secure the coil ends. Leave enough wire at the ends for connecting the coil to the exciter circuit.
- **Insulating the Coil Ends**: Apply insulation to the ends of the coils to protect them from short circuits and mechanical damage.

7. Securing and Forming the Coils

- **Tie the Coils**: Secure the finished coil using ties, lacing, or clips to prevent the windings from loosening or moving during installation or operation. Ensure that the ties do not damage the insulation or deform the coil.
- **Forming the Coil**: Shape the coil according to the specific requirements of the exciter field. This may involve bending or adjusting the coil to fit into the designated slots or housing.

8. Coil Impregnation and Varnishing

- **Varnish or Epoxy Impregnation**: To increase the mechanical strength, improve insulation, and reduce vibrations, impregnate the wound coil with varnish or epoxy. This step also enhances the coil's resistance to environmental factors such as moisture and dirt.
- **Vacuum Pressure Impregnation (VPI):** In some cases, the coil is placed in a vacuum chamber where varnish or epoxy is forced into the windings under pressure to ensure that all gaps are filled and the insulation is uniform.
- **Curing**: After varnishing, the coils are baked in an oven to cure the varnish or epoxy. This process hardens the insulation and provides a durable coating that protects the coil during operation.

9. Testing and Inspection

- **Electrical Testing**: Perform several electrical tests to ensure the quality and functionality of the wound coil:
- **Insulation Resistance Test**: Check the insulation resistance between the coil windings and the core or between different layers of the coil.
- **Continuity Test:** Test the electrical continuity of the coil to ensure that there are no breaks in the winding.
- **Hi-Pot Test (High-Potential Test):** Apply a high voltage to check the dielectric strength of the insulation.
- **Resistance Measurement:** Measure the coil's resistance to verify that it meets the design specifications.

- **Visual Inspection**: Conduct a thorough visual inspection to identify any potential issues, such as insulation damage, uneven winding, or improperly secured wires.

10. Coil Installation in the Exciter

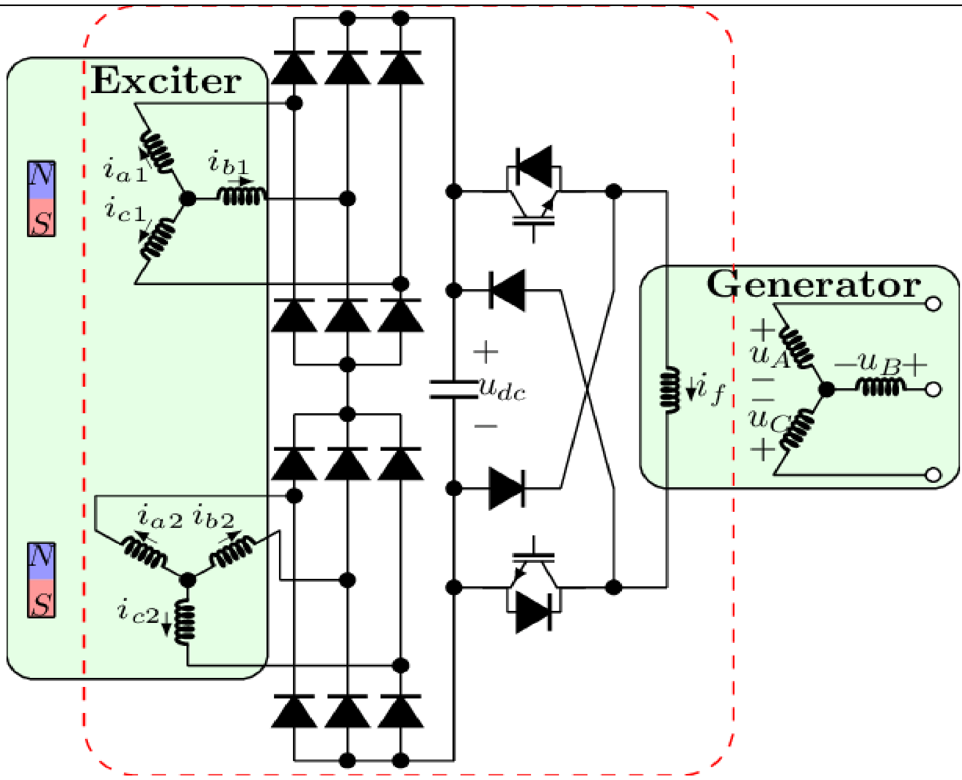
- **Position the Coil:** Place the completed exciter coil into its designated slot or around the exciter core. Ensure that the coil fits snugly and is properly aligned according to the design.
- **Secure the Coil in Place**: Use fasteners, wedges, or brackets to securely hold the coil in place, preventing any movement or vibration during operation.
- **Connect the Coil Ends**: The ends of the exciter coil are then connected to the exciter circuit, ensuring a proper electrical connection.

11. Final Testing and Commissioning

- **Exciter Field Testing:** Once the coils are installed and connected, the exciter is subjected to a series of tests, including functional tests to ensure that it generates the required magnetic field to excite the main generator rotor.
- **Commissioning**: After successful testing, the exciter and its field coils are commissioned and integrated into the overall hydropower generator system.

Connect exciter rotating diodes

- **Definition:** exciter rotating diodes are components in the excitation system of a synchronous generator or alternator, typically part of brushless excitation systems. These diodes convert the alternating current (AC) produced by the exciter's armature into direct current (DC), which is then fed into the rotor's windings.



The purpose of connecting exciter rotating diodes

In a hydro generator, the purpose of connecting exciter rotating **diode** is similar to their use in other synchronous generators but tailored to the specific needs of hydroelectric power plants.

Key purposes include:

1. AC to DC Conversion for Rotor Field: The rotating diodes rectify the AC generated by the exciter into DC, which is required to energize the rotor's magnetic field. This magnetic field interacts with the stator, allowing the hydro generator to produce electricity.

2. Brushless Excitation: The rotating diodes enable a brushless excitation system, eliminating the need for brushes and slip rings. In hydro generators, this is particularly important because of the large size and high-power output, where brushes would suffer from wear, require frequent maintenance, and reduce reliability.

3. Increased Reliability: Hydropower plants often run continuously for long periods. The rotating diodes reduce mechanical contact points, increasing overall system reliability and reducing the risk of downtime due to mechanical failures like worn brushes.

4. Reduced Maintenance in Difficult Environments: Hydro generators are often located in remote or difficult-to-access areas. By using brushless excitation with rotating diodes, maintenance demands are reduced, as these solid-state devices are less prone to failure compared to traditional brush systems.

5. Improved Efficiency: Brushless systems are more efficient since they eliminate electrical losses and mechanical friction associated with brushes and slip rings, optimizing the performance of large hydro generators.

General steps for connecting exciter rotating diodes are:

1. Safety Preparations

- **Power Down and Isolate the Generator**: Ensure the generator is completely shut down, de-energized, and isolated from any power sources. Lock-out/tag-out (LOTO) procedures should be followed to prevent accidental energizing during installation.
- **Wear Proper PPE**: Use personal protective equipment (PPE), including gloves, safety glasses, and insulated tools, to ensure safety during the installation process.
- **Inspect the Work Area**: Ensure the exciter and rotor areas are clean, dry, and free of any debris that might interfere with the connection or cause contamination.

2. Gather Components and Tools

- **Rotating Diodes:** Ensure you have the correct rotating diodes as specified in the hydro generator design. These diodes are usually mounted on the diode wheel of the exciter.
- **Heat Sinks and Fasteners**: Collect any heat sinks, insulating washers, spacers, and fasteners (screws, bolts, etc.) required for mounting the diodes.
- **Multi meter or Ohmmeter:** Prepare testing equipment to check the diodes after installation.
- **Insulated Tools**: Use insulated tools like wrenches and screwdrivers to avoid accidental electrical contact.

3. Access the Diode Wheel Assembly

- **Open the Exciter Compartment**: Access the exciter rotor assembly, where the diode wheel is located. The diode wheel is typically mounted on the generator's rotor shaft and rotates with it.
- **Inspect the Diode Wheel:** Ensure the diode wheel and its mounting areas are free of debris and in good condition. If necessary, clean the surfaces where the diodes will be installed.

4. Check Diodes Before Installation

Test the Diodes: Before installing, use a multi meter to test each diode to ensure it is functioning properly**:**

- Set the multi meter to diode mode.
- Test the forward bias by placing the positive probe on the anode and the negative probe on the cathode. You should see a voltage drop (typically around 0.5V to 0.7V for silicon diodes).
- Reverse the probes to test the reverse bias; there should be no current flow (the multi meter should display "OL" or no reading).
- Replace Any Faulty Diodes: If any diodes fail the test, replace them with new, functioning diodes.

5. Mount the Rotating Diodes

- **Identify the Diode Polarity:** Ensure the diodes are installed with the correct polarity. The cathode and anode must be connected to the appropriate terminals on the diode wheel.
- **Cathode (marked with a band):** Connects to the positive terminal of the rotor winding.
- A**node**: Connects to the exciter armature output.
- **Place Diodes on the Diode Wheel**: Position the diodes in their designated spots on the diode wheel, ensuring the proper orientation of each diode (anode and cathode connections).
- **Install Insulating Washers and Spacers**: Insert any insulating washers or spacers required to electrically isolate the diodes from the mounting surface, ensuring that the diodes do not short to the chassis or rotor shaft.

6. Secure the Diodes

- **Fasten the Diodes**: Use the appropriate screws, bolts, or clamps to secure the diodes in place. Ensure the fasteners are tightened to the specified torque to avoid loose connections but not over-tightened, as this could damage the diode or heat sink.
- **Mount Heat Sinks (If Applicable):** In some systems, heat sinks are mounted with the diodes to dissipate heat generated during operation. Attach the heat sinks securely, ensuring good thermal contact between the diode and heat sink.

7. Connect the Diode Terminals

- **Connect the Diode Leads**: Attach the leads or wires from the exciter armature output and the rotor field winding to the appropriate terminals on the rotating diodes. Ensure that the wires are properly insulated and secured with connectors or fasteners.

- **Exciter Armature Output:** Connects to the anode side of the diodes.
- **Rotor Field Winding**: Connects to the cathode side of the diodes (positive DC output).
- **Tighten Connections**: Ensure all electrical connections are tight and secure to prevent loose connections that could cause sparking or high resistance.

8. Final Testing

- **Continuity Check:** Use a multimeter to check the continuity of the connections. Verify that there is proper continuity through the diodes in the forward direction and no continuity in the reverse direction.
- **Test the Complete Circuit**: Verify that the entire exciter-to-rotor circuit is properly connected and there are no open or short circuits.
- **Check Insulation Resistance**: Measure the insulation resistance between the diode connections and the diode wheel (rotor shaft) to ensure there is no unintended grounding or shorting.

9. Reassemble the Exciter Compartment

- **Close the Exciter Cover:** Once all connections have been tested and confirmed, close the exciter compartment and secure all covers and access panels.
- **Clean the Work Area:** Ensure the workspace is clean and that no tools or debris are left inside the generator or exciter compartments.

10. Commissioning

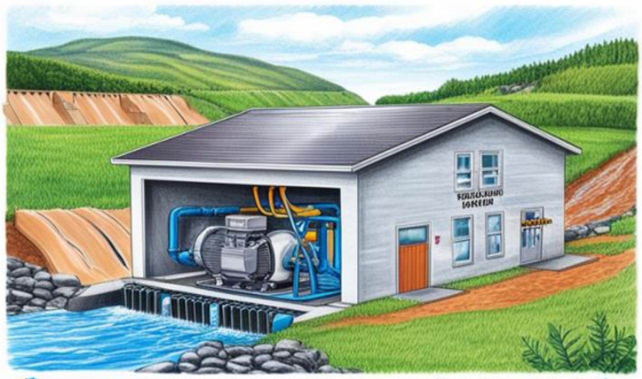
- **Power Up the Generator:** After completing the diode installation and securing the exciter compartment, power up the generator and monitor its performance.
- **Monitor Output:** Check that the exciter is supplying the correct DC voltage to the rotor field winding and that the rotating diodes are functioning correctly (no signs of overheating, abnormal noise, or electrical failure).
- **Full-Load Testing**: Once initial checks are successful, conduct full-load testing to ensure the entire excitation system, including the rotating diodes, is working as expected under operational conditions.

Alignment and clearance

- **Definition:**
  - Alignment generally refers to the proper arrangement or

positioning of something in relation to something else, ensuring that parts or elements are in the correct order or relationship.

- ❖ Clearance refers to the act or state of allowing or providing free space, passage, or authorization for something



✓ **The purpose of alignment and clearance**

Purpose of Alignment:

1. Precision and Functionality: In mechanical or structural contexts, alignment ensures that parts are correctly positioned, allowing them to work together smoothly and without excessive wear or malfunction (e.g., wheel alignment in cars, machine part alignment).

2. Efficiency: In organizational or business settings, alignment ensures that teams, departments, or processes are working toward the same strategic goals, reducing confusion and maximizing effectiveness.

3. Consistency: In educational contexts, alignment of curriculum, instruction, and assessments ensures that students are learning what is intended and being assessed fairly on the same standards.

4. Harmonization: Alignment in social, political, or ethical contexts ensures that values, policies, or actions are in agreement with a broader group or set of principles, leading to cooperation and unity.

Purpose of Clearance:

1. Prevent Damage or Interference: In mechanical or engineering contexts, clearance ensures that there is sufficient space between moving parts to prevent friction, collisions, or wear that could damage the components or reduce efficiency.

2. Ensure Safety: Clearance in transportation or construction ensures that vehicles or objects can pass safely under bridges, through tunnels, or between obstacles (e.g., the clearance between a plane's wings and airport structures).

3. Regulatory Compliance: In security or customs contexts, clearance ensures that individuals or goods meet necessary regulations and have the required authorization to proceed (e.g., customs clearance, security clearance for sensitive information).

4. Efficient Elimination: In medical contexts, clearance ensures that the body efficiently removes drugs or toxins, allowing for proper dosing and treatment.

✓ **Steps involved in alignment and clearance for a hydro generator.**

1. Preparation and Safety

- **Power Down the Generator**: Ensure the hydro generator is completely shut down, de-energized, and isolated from any power sources. Follow lock-out/tag-out (LOTO) procedures to prevent accidental start up during alignment.
- **Ensure Clean Working Environment:** Make sure the workspace is clean and free of any debris or obstructions that could affect the alignment process.
- **Gather Tools and Instruments:** Prepare necessary tools and instruments, including dial indicators, laser alignment tools, feeler gauges, micro meters, spirit levels, torque wrenches, and any manufacturer-recommended instruments.

2. Visual Inspection

- **Inspect Foundation and Baseplate:** Check the foundation and baseplate of the hydro generator for cracks, settlement, or misalignment. Any irregularities in the foundation can affect the overall alignment of the machine.
- **Check Rotor and Stator Components**: Conduct a visual inspection of the rotor, stator, bearings, and shaft to identify any signs of wear, deformation, or damage that could affect alignment.
- **Inspect Bearings:** Ensure the bearings (thrust and guide bearings) are in good condition and seated properly, as they play a vital role in rotor positioning.

3. Rotor-Stator Alignment

The rotor-stator alignment is crucial for preventing contact between the rotor and the stator, which could cause damage and inefficiency.

a. centring the Rotor in the Stator

- **Measure Air Gap:** The air gap between the rotor and stator must be uniform all around. Use feeler gauges or specialized air gap measurement tools to check the clearance between the rotor and the stator at multiple points (typically 4-8 points around the rotor).
- **Adjust the Air Gap**: If the air gap is uneven, adjust the rotor's position to achieve a uniform gap. This may involve shifting the rotor using jacks, adjusting bearing clearances, or using shims.
- **Rotational Checks:** Slowly rotate the rotor by hand (if possible) to verify the air gap remains consistent at all points around the circumference.

b. Radial Alignment

- **Use Dial Indicators:** Attach dial indicators to the stator and measure the radial displacement of the rotor as it rotates. The goal is to minimize radial run out (the variation in distance between the rotor and stator).
- **Adjust Bearings:** If radial run out is detected, adjust the bearings or use shims under the generator footings to centre the rotor properly within the stator.

4. Axial Alignment

Axial alignment refers to the positioning of the rotor along its length relative to the stator, as well as the alignment of the generator shaft to the turbine shaft.

a. Shaft Alignment

- Check Shaft Coupling: The generator's shaft must be properly aligned with the turbine's shaft to ensure smooth transmission of power. Misalignment in the coupling can cause vibrations and stress on the generator.
- Laser Alignment: Use a laser alignment tool to check the angular and parallel alignment of the shafts. Follow the manufacturer's guidelines to adjust the alignment until the shafts are within acceptable tolerances.
- Use Dial Indicators for Manual Alignment: If a laser alignment tool is unavailable, dial indicators can be used to check the coupling alignment manually. Measure the offset and angular misalignment, and make adjustments by shifting the position of the generator relative to the turbine.

b. Axial Air Gap Check

- Measure Axial Clearances: Check the axial clearance (also known as the end float) between the rotor and stator. Excessive axial misalignment can lead to thrust bearing wear and rotor instability.

- Adjust Thrust Bearing: If the axial clearance is not within specified limits, adjust the thrust bearing or its shims to bring the rotor back to the correct axial position.

5. Bearing Clearance and Alignment

Bearings are critical for the smooth rotation of the rotor, and any misalignment or improper clearance in the bearings can cause friction, overheating, and damage.

a. Guide Bearing Clearance

- Check Radial Bearing Clearances: Measure the radial clearance in the guide bearings, which support the rotor and keep it centred. Use feeler gauges or micro meters to ensure the clearances are within manufacturer-specified tolerances.
- Adjust Bearing Clearance: If the clearances are too tight or too loose, adjust the guide bearings by adding or removing shims or adjusting bearing housing bolts.

b. Thrust Bearing Alignment

- Check Thrust Bearing Condition: Inspect the thrust bearing for wear or misalignment. The thrust bearing maintains the axial position of the rotor, so its alignment is critical for proper operation.
- Adjust Thrust Bearing Load: Ensure the thrust bearing is carrying the correct load. Adjust the shims or bearing pads to achieve the desired axial positioning of the rotor.

6. Final Adjustments and Tightening

- Tighten Mounting Bolts: Once all the alignments (radial, axial, shaft) are correct, tighten all foundation bolts, bearing housing bolts, and any other mounting hardware to the specified torque values.
- Recheck Alignment After Tightening: After tightening, recheck the alignment, as tightening bolts can sometimes shift the alignment slightly.

7. Clearance Verification

- Air Gap Measurement: Recheck the air gap between the rotor and stator to verify that it remains consistent and within the specified clearance range after all adjustments are made.
- Bearing Clearance Check: Ensure the radial and axial clearances in the bearings are correct and within tolerances after all adjustments.

8. Testing and Monitoring

- Initial Rotation Test: Slowly rotate the generator by hand or using the turning gear (if available) to ensure there is no rubbing or interference between the rotor and stator, and to check for smooth operation.
- Vibration Monitoring: After alignment, conduct a trial run with the

generator running at low speed and gradually increase to full speed. Use vibration sensors to monitor for any unusual vibrations or noise that may indicate misalignment.

- Load Test: Conduct a load test to check that the generator operates efficiently under load, with proper alignment maintained.

Practical Activity 2.4.4 Generator parts positioning

Task:

1. Refer to the key readings 2.4.4 you are requested to perform the following task. You are requested to position generator parts

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

Key readings 2.4.4 Generator parts positioning

Steps for Generator parts positioning.

Lifting generator parts.

- Assemble stator cores.
- Wind stator coils.
- Wind exciter field coils
- Connect exciter rotating diodes
- Alignment and clearance

Theoretical Activity 2.4.5 Description of generator parts positioning

Tasks:

1. Answer the following questions relating to describe the Hydro generator mounting:
    i. How do you understand the term generator mounting?
    ii. What are the purposes of generator parts positioning?
    iii. Explain at least four steps for generator mounting?

2: Present your findings to the whole class and trainer

3. Follow expert view and ask for clarification if any
4. Read the Key readings 2.4.5 in trainee manual

Key readings 2.4.5: Description of hydro generator mounting

- **Mounting**
  - **Definition:** hydro generator mounting refers to the process or method of installing or securing a hydro generator, which is a device that converts the kinetic energy of flowing water into electrical energy, onto a structure or surface. This involves ensuring that the hydro generator is properly aligned, stable, and securely positioned in a way that allows it to function efficiently.
  - **The purposes of hydro generator mounting include:**

1. Stability and Support: Proper mounting ensures the hydro generator is securely positioned to handle the force of moving water without shifting or becoming damaged.

2. Optimal Energy Conversion: Correct alignment and placement allow the hydro generator to capture the maximum kinetic energy from water flow, improving efficiency in electricity generation.

3. Vibration Control: Mounting helps reduce the vibrations caused by water movement, which could otherwise lead to wear and tear or reduced performance of the generator.

4. Protection from Environmental Conditions: A secure mount helps protect the hydro generator from environmental hazards like flooding, debris, or extreme weather conditions, ensuring its longevity.

5. Safety: Proper mounting ensures that the hydro generator operates safely, minimizing risks of malfunction or accidents that could harm maintenance personnel or the environment.

6. Ease of Maintenance: A well-mounted hydro generator allows for easier access during inspection, repair, and maintenance, ensuring that the system remains functional over time.

- **Types of hydro generator mounting**

The mounting of hydro generators is typically categorized based on the orientation of the shaft and the specific design of the hydropower plant.
The two main types of hydro generator mounting are vertical and horizontal mounting, each with its own applications depending on the plant design, water flow, and space availability.

1. Vertical Mounting

- Description: In vertical mounting, the generator's rotor is positioned vertically, with the turbine directly below the generator. The turbine and generator shafts are vertically aligned, and the rotor spins around a vertical axis.
- Application: Vertical mounting is commonly used in large hydropower plants where space for a taller structure is available. It is especially useful in high-head hydropower stations where water falls from a significant height to drive the turbine.

Advantages:

- Compact footprint: Vertical mounting allows the generator to occupy less horizontal space, making it ideal for plants with limited space.
- Better for high-head applications: The vertical design works well in high-head hydroelectric projects where water pressure is higher.
- Efficient energy transfer: The direct vertical alignment between the turbine and the generator provides efficient mechanical energy transfer.

Examples:

Used in Francis turbines or Pelton turbines, which are often installed in high-head plants.

Typically found in large dam-based hydropower stations like those associated with large reservoirs.

2. Horizontal Mounting

- Description: In horizontal mounting, the generator's rotor is placed horizontally, with the turbine located on the same horizontal plane. The rotor spins around a horizontal axis.
- Application: Horizontal mounting is commonly used in small and medium-sized hydropower plants or run-of-river plants, especially when the plant has a low or medium head. It is also used in plants where space is limited in height but more space is available horizontally.

Advantages:

- Easy installation and maintenance: Horizontal generators are easier to install and maintain because of their accessibility, especially in smaller setups.
- Lower structural requirements: They don't require the deep pits needed for vertical generators, reducing civil construction costs.
- Suitable for low-head applications: Horizontal generators work well in plants with lower water pressure and smaller heads.

Examples:

Used with Kaplan turbines, which are suited for low-head installations.

Common in smaller, run-of-the-river hydro plants where water flows directly from a river to drive the turbine without significant height drop.

Specialized Mounting Options

In addition to these two primary types, there are some specialized hydro generators mounting arrangements used in certain scenarios:

3. Suspended or Hanging Mounting

- Description: In suspended mounting, the generator is suspended or "hung" from the ceiling or upper structure. The rotor and stator are aligned vertically, but the generator is mounted above the turbine without direct support from below.
- Application: This mounting type is used in certain vertical configurations, especially where it is advantageous to reduce vibration transmission from the foundation to the generator or when space below the generator is limited.

Advantages:

Reduces the transmission of vibrations from the generator to the plant structure.

Can reduce the overall structural height in vertical configurations.

4. Embedded or Bulb-Type Mounting

- **Description:** In this type, the generator is embedded or placed within the water flow, often inside a bulb structure. The generator is fully integrated with the turbine, and both are submerged in the water.
- Application: Used in bulb turbines for low-head, high-flow applications, particularly in run-of-river plants. The entire assembly is located underwater in the water passageway.
- **Advantages:**
- Compact design: Ideal for low-head installations and run-of-the-river plants where space is limited.
- High efficiency: This design minimizes energy losses as the turbine and generator are integrated into one compact system.

Examples:

Found in low-head, high-flow plants such as in tidal power generation or in certain river-based hydroelectric projects.

5. Inclined Mounting

- **Description:** This is a combination of horizontal and vertical mounting, where the shaft of the turbine and generator is mounted at an inclined angle.

Application: Inclined mounting is used in small hydro or micro-hydro plants, where the water flow or site constraints dictate the use of an inclined shaft.

- **Advantages:**

Optimizes use of space where a strict vertical or horizontal layout isn't feasible.

Suits terrain with moderate slopes or non-traditional plant layouts.

6. Pit-Mounted Generators

- Description: In this type of mounting, the generator is installed in a pit below the ground level. The rotor is positioned vertically, but the entire assembly is recessed into a pit, allowing for easier access to the generator.
- Application: Used in situations where a vertical setup is required, but above-ground space is limited, or where aesthetic considerations call for keeping large components hidden.
- **Advantages:**

Reduces the visible height of the installation.

Provides easy access for maintenance through the pit access.

Summary of Types of hydro generator mounting

1. Vertical Mounting: Used in large, high-head plants; efficient use of space; ideal for tall installations with vertical turbines.

2. Horizontal Mounting: Common in small and medium plants; easier installation and maintenance; suitable for low-head applications.
3. Suspended Mounting: Vertical generators suspended from above; reduces vibration and space requirements below.
4. Bulb-Type or Embedded Mounting: Generator integrated with the turbine in a submerged housing; used in low-head, high-flow applications.
5. Inclined Mounting: Combines horizontal and vertical orientations; suited for certain site-specific conditions.
6. Pit-Mounted Generators: Vertical generators installed below ground level for space and aesthetic benefits.

- **The steps for hydro generator mounting**

typically follow a systematic process to ensure safety, functionality, and efficiency. These steps may vary depending on the type of hydro generator and the installation site, but generally include:

- **The steps for hydro generator mounting**

1. Site Assessment and Preparation:
Evaluate the site for proper water flow and structural support.
Clear the installation area of debris and ensure a stable foundation.
Determine the ideal location for the hydro generator based on water current and terrain.
2. Foundation Construction:
Construct a foundation or platform to support the weight and operation of the hydro generator.
Use materials that are durable and water-resistant, such as concrete or steel.
Ensure the foundation is level, stable, and can withstand environmental pressures like water flow and vibrations.
3. Positioning the Hydro generator:
Carefully position the hydro generator at the designated spot, often using cranes or specialized lifting equipment for larger systems.
Align the device to ensure optimal water flow over the turbines or other energy-capturing components.
4. Securing the Hydro generator:
Bolt or anchor the hydro generator to the foundation or mounting structure to prevent movement during operation.
Ensure all fasteners are tightened and inspected for structural integrity.
5. Connection of Power Systems:
Connect the hydro generator to the electrical grid or power storage systems.
Install and secure all necessary electrical wiring, control panels, and monitoring systems.
6. Testing and Calibration:

Test the hydro generator to ensure proper functionality, including checking for vibrations, noise, and electrical output.

Make any necessary adjustments to the mounting or alignment to optimize performance.

7. Water Flow Management:

Install any required water channels, sluice gates, or screens to control the flow of water to the hydro generator.

Ensure the system is set up to protect the hydro generator from debris or excessive water flow.

8. Final Inspection and Commissioning:

Conduct a thorough inspection to ensure all components are securely mounted, aligned, and functioning properly.

Once all tests and adjustments are complete, the hydro generator is commissioned and begins regular operation.

Practical Activity 2.4.6: Hydro generator mounting

Task:

1: Refer to the key readings 2.4.6 you are requested to perform the following task. You are requested to mount hydro generator

2: Pay attention on trainer's explanations and instructions

3: Referring to procedures and steps provided, to mount hydro generator

4: Present your work to the trainer/colleague and ask clarification if any.

Key readings 2.4.6 Hydro generator mounting

- **Steps followed for hydrogenerator mounting:**

The steps for hydro generator mounting typically follow a systematic process to ensure safety, functionality, and efficiency. These steps may vary depending on the type of hydro generator and the installation site, but generally include:

- **The steps for hydro generator mounting**

1. Site Assessment and Preparation:

Evaluate the site for proper water flow and structural support.

Clear the installation area of debris and ensure a stable foundation.

Determine the ideal location for the hydro generator based on water current and terrain.

2. Foundation Construction:

Construct a foundation or platform to support the weight and operation of the hydro generator.

Use materials that are durable and water-resistant, such as concrete or steel.

Ensure the foundation is level, stable, and can withstand environmental pressures like water flow and vibrations.

3. Positioning the Hydro generator:

Carefully position the hydro generator at the designated spot, often using cranes or specialized lifting equipment for larger systems.

Align the device to ensure optimal water flow over the turbines or other energy-capturing components.

4. Securing the Hydro generator:

Bolt or anchor the hydro generator to the foundation or mounting structure to prevent movement during operation.

Ensure all fasteners are tightened and inspected for structural integrity.

5. Connection of Power Systems:

Connect the hydro generator to the electrical grid or power storage systems.

Install and secure all necessary electrical wiring, control panels, and monitoring systems.

6. Testing and Calibration:

Test the hydro generator to ensure proper functionality, including checking for vibrations, noise, and electrical output.

Make any necessary adjustments to the mounting or alignment to optimize performance.

7. Water Flow Management:

Install any required water channels, sluice gates, or screens to control the flow of water to the hydro generator.

Ensure the system is set up to protect the hydro generator from debris or excessive water flow.

8. Final Inspection and Commissioning:

Conduct a thorough inspection to ensure all components are securely mounted, aligned, and functioning properly.

Points to Remember

Setting out is the process of marking or establishing the exact positions of structures, boundaries, and construction elements on the ground based on design plans and drawings.

Purpose of setting out on hydro generator

1. Accurate Placement of Equipment
2. Safety and Structural Integrity
3. Optimization of Water Resources
4. . Prevention of Operational Issues
5. Environmental and Ecological Considerations

K**ey steps typically used for setting out for generator**

1. Site Survey and Preparatory Work
2. Reference Points and Benchmarks
3. Positioning the Powerhouse
4. Setting Out the Turbine
5. Setting Out the Generator
6. Alignment and Levelling

Definition: hydro generator mounting refers to the process or method of installing or securing a hydro generator, which is a device that converts the kinetic energy of flowing water into electrical energy, onto a structure or surface. This involves ensuring that the hydro generator is properly aligned, stable, and securely positioned in a way that allows it to function efficiently.

The purposes of hydro generator mounting include:

1. Stability and Support:
2. Optimal Energy Conversion:
3. Vibration Control
4. Protection from Environmental Conditions
5. Safety
6. Ease of Maintenance

Types of hydro generator mounting

1. Vertical Mounting
2. Horizontal Mounting
3. Suspended or Hanging Mounting
4. Embedded or Bulb-Type Mounting
5. Inclined Mounting
6. Pit-Mounted Generators

The steps for hydro generator mounting

1. Site Assessment and Preparation
2. Foundation Construction
4. Securing the Hydro generator
5. Connection of Power Systems
6. Testing and Calibration

Application of learning 2.4.

A micro hydropower plant was constructed at the site in order to produce electrical power for electrification of the rural area; the generator parts of that micro-hydropower plant are available at that site. As you Supervisor level electrician you are required to Fix generator properly to turbine.

Learning outcome 2 end assessment

Written assessment

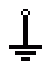
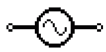
Q1. State whether the following statement are True or False:

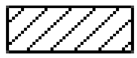
a) Hazard is any source of potential health on something or someone under certain conditions.
b) Hazard control refers to the systematic process of identifying, evaluating, and mitigating risks associated with potential hazards in a workplace or environment
c) psychosocial hazards **relate** to improper physical conditions in the workplace that can cause strain or injury.
d) Safety measures are actions, protocols, or devices designed to reduced risks and protect individual, property or the environment from harm or danger

Q2. The following are methods of hazard control, except

a) Elimination
b) Substitution
c) Engineering Controls
d) Mounting turbine

Q3. Match the components in column A with their corresponding meaning in Column B

Answers	Column A (Name)	Column B (symbol)
1……….	1. AC voltage source	a. 
2……….	2.Earth ground	b. 
3………	3. Dam	c. 

4……….	4. Install Electrical Panel	d. 
5……………..	5.Represents the mechanical power/gear transmission aspect of turbines	e. 

Q4**.** The following are components of hydro turbine installation except

a) Turbine
b) Draft tube
c) Generator
d) Turbine blade
e) Rotor winding
f) Rotor winding

Q5. The followings are key components considered while fixing a turbine except

a) Turbine Rotor and Blades
b) Shaft and Generator
c) Draft Tube and Penstock
d) Guide Vanes
e) Primary winding

Q6. Answer the following statements **True** or **False**

a) Adjust Guide Vanes: Fine-tune the guide vanes to optimize the flow of water and the turbine is output.
b) Calibrate Instruments: Ensure that all measurement instruments and control systems are calibrated correctly.
c) Screwdrivers: Used for tightening or loosening screws
d) Pliers: Used to tighten or loosen nuts and bolts.
e) Wrenches: Used for gripping, bending, and cutting wires or small objects

Q7. The followings are steps used for the fixing turbine except

a) Preparation
b) Inspection
c) Mounting power transformer
d) Replacement of Worn Parts

e) Alignment and Installation
f) Testing and Commissioning
g) Final Adjustments
h) Maintenance and Documentation

Q8**.** Answer the following statements on steps used while setting out a draft tube by **True** or **False**

a) Turn off the generator
b) Remove the cover
c) Remove off the transformer
d) Clean the tube

Q9. The following are the reasons why we are positioning the draft tube except:

a) Water flow: The tube should be positioned in a way that allows water to flow through it easily. If the tube is clogged or blocked, it can impede the flow of water and reduce the efficiency of the turbine.
b) Alignment: The tube should be aligned with the turbine shaft to ensure that the water flow is directed properly?
c) Height and depth: The tube should be positioned at the correct height and depth to ensure that it is fully submerged in the water stream?
d) Design and manufacturer's instructions: The exact positioning of the draft tube will depend on the specific design of the hydro turbine generator and the water source
e) Ensure that the input electricity energy is converted into mechanical energy

Q10. the following are steps followed while fixing draft tube except

a) Turn off the generator
b) Remove the cover Inspect the tube
c) Clean the tube Replace the tube
d) Reassemble the generator
e) Remove the rectifier

Q11. Answer the following statement by **True** or **False**

a) Lugs are the electrical connectors that terminate the mounting of generator electrical circuit?
b) Cable clamps, also known as wire clamps or cord clamps, are a type of fastening device that is used to secure and organise cables and wires?
c) purpose of draft tube It converts a large proportion of the kinetic energy rejected at outlet of the turbine into useful pressure energy?
d) The purpose of hydro generator parts positioning is to optimize the efficiency, safety, and reliability of the generator while converting the mechanical energy from flowing water into electrical energy**?**

e) Rotor, Stator and Bearings are examples of the main parts of a hydropower generator?
f) Lifting generally refers to the act of raising or moving something to a higher position?
g) Winding exciter field coils for a hydro generator is a precise and critical task, as these coils are responsible for generating the magnetic field that excites the main generator rotor, allowing it to produce electrical energy?
h) Stability and Support are examples of the purposes of hydro generator mounting?

Practical assessment

A Hydropower Plant is aiming to achieve a capacity of 50 MW by installing a hydro turbine generator in the new facility. You have been assigned the task of assembling the components of the hydro turbine generator, while taking into account the necessary plant efficiency requirements.

References

Micro Hydro Power. (n.d.). *Micro hydro turbine installation process*. Retrieved from https://www.micro-hydro-power.com/micro-hydro-turbine-installation-process.htm

United Nations Industrial Development Organization (UNIDO). (2021). *Part 2: Hydro turbine generator (in English)*. Retrieved from https://www.unido.org/sites/default/files/files/2021-04/Part%202%20Hydro%20Turbine%20Generator%20%28in%20English%29.pdf

Indian Institute of Technology Roorkee. (n.d.). *Hydro generator and excitation system tests*. Retrieved from https://iitr.ac.in/Departments/Hydro%20and%20Renewable%20Energy%20Department/static/Modern_hydroelectric_engg/vol_1/Chapter-12_Hydro_Generator_and_Excitation_System_Tests.pdf

ResearchGate. (2016). *Design, construction, and testing of generator for hydropower plant*. Retrieved from https://www.researchgate.net/publication/299436917_Design_Construction_and_Testing_of_Generator_for_Hydropower_Plant

http://www.fstgenerator.com

Learning Outcome 3: Carry out Hydro Turbine Generator Tests

Indicative contents
3.1. Conducting functionality test **3.2. Conducting performance tests** **3.3. Elaborating report**

Key Competencies for Learning Outcome 3: Carry out Hydro Turbine Generator Tests

Knowledge	Skills	Attitudes
• Description of mechanical test • Description of electrical test • Description of performance tests. • Description of report	• Testing mechanical parts of hydro turbine generator • Testing electrical parameters of generator • Conducting performance test • Elaborating report	• Being careful • Being attentive in elaborating report • Having teamwork in group • Having critical thinking

Duration: 8hrs

Learning outcome 3 objectives:

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

1. Describe properly functionality test based on working principle of hydro turbine generator.
2. Conduct accurately functionality test based on working principle of hydro turbine generator.
3. Identify clearly electrical parameter test based on designer's parameters
4. Elaborate properly the report based on hydro turbine generator's performance.
5. Conduct correctly performance tests based on designer's parameters

Resources

Equipment	**Tools**	**Materials**
• Micromneter • Digital Multimeter • Ground resistance tester • Differential pressure switches • Phase comparator • Insulation Resistance tester • Telescope insulating pole • Mega-ohmmeter • Speed meter	• Insulated screwdriver set, , Allen key set • Mallet hammer • Combination spanners (6-32) • extension socket wrench • 1/2 reversible impact wrench • Lifting wire rope slings set • Jaw plier • Hand toolbox	• Pens • Papers • Pencils • Eraser • Handbooks • notebooks • Wire and cable connectors • Miniature circuit breaker Hydro-mechanical over speed device • Electrical over speed device • Connecting leads

Indicative content 3.1: Conducting Functionality Test

Duration: 8hrs

Theoretical Activity 3.1.1: Description of mechanical test of hydro turbine generator

Tasks:

1: Answer the following questions:

i. Explain the following Mechanical test:

a) Rotor runout test
b) Bearing alignment test
c) Shaft alignment test
d) Balance test
e) Torsional vibration analysis
f) No load test

2: Present the findings to the whole class and trainer.

3: Follow the expert view and ask for clarification if any.

4: Read the key readings 3.1.1. in trainee manual

Key readings 3.1.1: Description of mechanical test of hydro turbine generator

- **Conducting functionality test**

✓ **Mechanical test**

It is a crucial test performed on hydro turbine generators to ensure their performance and safety.

It is conducted to assess the rotor's mechanical integrity and to check for any potential issues that could affect the turbine's operation.

These tests typically include:

- **Run-out tests**:
  These tests are performed to measure the rotor's axial and radial run-out. The axial run-out refers to the movement of the rotor along its axis, while the radial run-out refers to the movement of the rotor perpendicular to its axis.
- **Bearing Alignment tests:**
  These tests are conducted to measure the alignment of the bearings. Specialized tools are used to measure the angular and axial misalignments of the bearings. The results of these tests help engineers identify any issues related to the bearings' alignment, which can affect the turbine's efficiency and performance.
- **Alignment tests**:
  These tests are conducted to measure the alignment of the shaft. Specialized tools are used to measure the angular and axial misalignments of the shaft. The results of these tests help engineers identify any issues related to the shaft's alignment, which can affect the turbine's efficiency and performance.
  During the shaft alignment test, the turbine's shaft is subjected to a series of mechanical tests to determine its alignment and performance
- **Balance tests**:
  These tests are conducted to determine if the rotor is balanced properly. An imbalanced rotor can cause vibrations, which can lead to premature wear and tear of the turbine's components.
- **Torsional vibration** analysis is a method used to assess the dynamic behaviour of rotating machinery, such as turbines, generators, and other power generation equipment. It is performed to identify potential issues related to torsional vibrations, which can affect the performance and safety of the equipment.
  During the torsional vibration analysis, engineers use specialized software and simulation tools to model the dynamic behaviour of the rotating machinery.

The analysis typically involves the following steps:

- **Modelling:**
  Engineers create a detailed model of the rotating machinery, including its bearings, and couplings. The model is used to simulate the machine's dynamic behaviour under various operating conditions.
- **Simulation**:
  Engineers perform a series of simulations to assess the machine's response

to different inputs, such as changes in speed, load, and other operating parameters. The simulations help identify potential sources of torsional vibrations and their impact on the machine's performance.

- **Analysis**:
  Engineers analyse the results of the simulations to identify potential issues related to torsional vibrations. This may involve calculating various parameters, such as natural frequencies, mode shapes, and damping ratios, as well as assessing the machine's response to various inputs.
- **Recommendations**:
  Based on the analysis, engineers provide recommendations for improving the machine's performance and reducing the risk of torsional vibrations. This may involve modifying the machine's design, adjusting its operating conditions, or implementing additional damping or control

➢ **The no-load test** is a crucial test performed on hydro turbine generators to assess their performance and efficiency under no-load conditions. It is conducted to determine the turbine's characteristics and performance without any load on the generator.

During the no-load test, the hydro turbine generator is operated without any load on the generator. This is typically achieved by disconnecting the generator from the grid or by using a dummy load to simulate the absence of a load. The test is performed under controlled conditions, such as a constant water flow and a fixed speed, to ensure consistent results.

The no-load test helps engineers assess various parameters of the turbine, including:

1.**Shaft power**:
This parameter measures the power output of the turbine's shaft without any load on the generator. It provides valuable information about the turbine's efficiency and performance.

2.**Torque:**
This parameter measures the torque generated by the turbine's shaft without any load on the generator. It helps engineers assess the turbine's mechanical characteristics and identify any potential issues related to the turbine's bearings or foundation.

3. **Efficiency**:
This parameter measures the turbine's efficiency under no-load conditions. It helps engineers identify any potential losses or inefficiencies in the turbine's design or operation.

4. Stability:
This parameter assesses the turbine's stability under no-load conditions. It

helps engineers identify any potential issues related to the turbine's control system or mechanical components.

The no-load test is an essential step in the commissioning process of a hydro turbine generator. It helps engineers identify any potential issues early on, allowing them to make necessary modifications and ensuring the turbine operates efficiently and safely. By conducting the no-load test, engineers can gather valuable data about the turbine's performance and make informed decisions to improve its efficiency and reliability.

Practical Activity 3.1.2: Conducting mechanical test of hydro turbine

Task:

1: Refer to the key readings 3.1.2, you are requested to perform the following task.

Refer to the previous theoretical activity 3.1.1. Hydro turbine generator installed power plant need to be tested before running power plant. You are requested to perform the following tests:

Mechanical test:

a) Rotor runout speed test
b) Bearing alignment test
c) Shaft alignment test
d) Balance test
e) Torsional vibration analysis
f) No load test

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any

Key readings 3.1.2 Conducting mechanical test of hydro turbine generator

- **Procedures for conducting mechanical test of hydro turbine generator**

✓ **Run-out tests**: These tests are performed to measure the rotor's axial and radial run-out. The axial run-out refers to the movement of the rotor along its axis, while the radial run-out refers to the movement of the rotor perpendicular to its axis.

✓ **Bearing Alignment tests:** These tests are conducted to measure the alignment of the bearings. Specialized tools are used to measure the angular and axial misalignments of the bearings. The results of these tests help engineers identify any issues related to the bearings' alignment, which can affect the turbine's efficiency and performance.

- ✓ **Alignment tests**: These tests are conducted to measure the alignment of the shaft. Specialized tools are used to measure the angular and axial misalignments of the shaft. The results of these tests help engineers identify any issues related to the shaft's alignment, which can affect the turbine's efficiency and performance.
- ✓ During the shaft alignment test, the turbine's shaft is subjected to a series of mechanical tests to determine its alignment and performance

Theoretical Activity 3.1.3. Description of electrical test of hydro turbine generator

Tasks:

1: Answer the following questions:

i. Describe the following Electrical test

a) Voltage builds up test
b) Voltage regulation test
c) Synchronization test
d) Wind resistance test.
e) Winding insulation test
f) Polarization test

2: Present the findings to the whole class and trainer.

3. Follow the expert view and Ask for clarification if any.

4: You are directed to read the key readings 3.1.3.

Key readings 3.1.3: Description of electrical test of hydro turbine generator

Electrical testing of hydro turbine generator and associated electrical systems function reliably and efficiently.

Here are some key electrical tests performed on hydro turbine generators:

1. Insulation Resistance Test

Purpose: Checks the insulation quality of stator windings, which can degrade over time.

Method: Uses an insulation resistance tester (megger) to apply a voltage and measure resistance in mega ohms.

Outcome: Low insulation resistance may indicate moisture, contamination, or insulation damage.

2. Polarization Index (PI) Test

Purpose: Assesses insulation quality by measuring how the insulation resistance changes over time.

Method: Measures insulation resistance over a period (typically 10 minutes) and compares it with a shorter measurement (1 minute).

Outcome: A PI value > 2.0 is generally acceptable, while lower values indicate potential insulation issues.

3. Winding Resistance Test

Purpose: Measures the resistance of the stator and rotor windings to check for uniformity.

Method: Uses a micro-ohmmeter to measure resistance values of each phase winding.

Outcome: Variations may suggest loose connections, damaged coils, or other issues.

4. Dielectric Withstand (Hi-Pot) Test

Purpose: Ensures the insulation can handle high voltage without breaking down.

Method: Applies a high voltage for a set time and checks for insulation breakdown.

Outcome: Failures can indicate weak or damaged insulation, requiring repair.

5. Partial Discharge Test

Purpose: Detects partial discharges, which can indicate insulation weaknesses.

Method: Uses specialized equipment to measure partial discharge levels.

Outcome: Excessive partial discharges suggest insulation degradation.

6. Surge Test

Purpose: Detects short circuits or insulation issues between turns in the winding.

Method: Applies a surge voltage to each winding and compares waveforms.

Outcome: Irregularities indicate winding faults, like shorted turns.

7. Capacitance and Dissipation Factor (Tan Delta) Test

Purpose: Measures the insulation system's condition and detects aging.

Method: Measures capacitance and dissipation factor to assess insulation losses.

Outcome: High dissipation factors suggest insulation aging or moisture ingress.

8. Load Test and Vibration Analysis

Purpose: Ensures the generator performs well under load and identifies mechanical issues.

Method: Runs the generator under load, while monitoring voltage, current, and vibrations.

Outcome: Abnormal vibrations or electrical fluctuations can indicate mechanical misalignments or winding faults.

9. Thermal Imaging

Purpose: Detects overheating in components.

Method: Uses thermal cameras to identify hotspots in the generator.

Practical Activity 3.1.4: Conducting electrical test of hydro turbine

Task:

1: Refer to the key readings 3.1.4, you are requested to perform the following task. Hydro turbine generator installed power plant need to be tested before running power plant. You are requested to perform the following Electrical test (Voltage build up test Voltage Regulation Test, Synchronization Test, Wind resistance test, Winding, insulation test, Polarization test.)

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

4: Ask trainees to read the key reading 3.1.4 in their trainee manual

Key readings 3.1.4: Conducting electrical test of hydro turbine

- **Steps to conduct hydro turbine electrical test**

Here are key steps to consider for testing electrical of hydro turbine generator

1. Initial Visual Inspection

Inspect all electrical connections, cables, and components for signs of wear, damage, corrosion, or loose connections.

Check for dust, dirt, and moisture in the electrical panels and generator

2. Insulation Resistance Testing

Perform insulation resistance tests on the generator's stator and rotor windings using a meg ohmmeter.

Ensure that insulation resistance values meet the manufacturer's specifications; low values may indicate degraded insulation, which can lead to electrical failures.

3. Winding Resistance Testing

Measure the resistance of the generator's windings to identify any imbalances or shorted turns in the stator and rotor windings.

Record the resistance values and compare them to reference values provided by the manufacturer.

4. Polarity and Phase Rotation Testing

Verify the generator's polarity and phase rotation to ensure proper alignment with the grid or electrical system it connects to.

This step is especially important when connecting to a grid or synchronizing multiple generators.

5. Dielectric Strength Testing

Perform a dielectric withstand (or high-potential) test on the generator windings to assess their ability to withstand higher-than-normal operating voltages.

This helps detect weak points in the insulation that might fail under high voltage.

6. Excitation System Testing

Inspect and test the excitation system (voltage regulators and controllers) to ensure it can provide the necessary field current to maintain generator voltage.

Verify the proper functioning of Automatic Voltage Regulators (AVR) and test for stability and responsiveness.

7. Current and Voltage Unbalance Testing

Measure current and voltage across all phases under different loads to ensure uniform distribution.

Imbalances can lead to overheating and inefficiencies, impacting both performance and lifespan.

8. Protection Relay Testing

Test protection relays to confirm they are set correctly and function properly, including overcurrent, overvoltage, under frequency, and differential protection relays.

This helps prevent damage to the hydro turbine generator in case of electrical faults.

9. Load Testing

Perform load tests to evaluate the hydro turbine's performance at different power outputs.

This ensures that the generator can handle varying loads and maintain stability and efficiency.

10. Vibration Analysis

Check for any unusual vibrations using accelerometers on the generator and turbine assembly, as abnormal vibrations can indicate alignment or balance issues.

10. Grounding System Testing

Ensure that the grounding system is effective and complies with standards, as proper grounding is essential for safety and performance

Points to Remember

- **Mechanical test:**

1. **Run-out tests**: These tests are performed to measure the rotor’s axial and radial run-out.
2. **Bearing Alignment tests:** These tests are conducted to measure the alignment of the bearings.
3. **Alignment tests**: These tests are conducted to measure the alignment of the shaft.
4. **Balance tests**: These tests are conducted to determine if the rotor is balanced properly.
5. **Torsional vibration** analysis is a method used to assess the dynamic behaviour of rotating machinery, such as turbines, generators, and other power generation equipment.

The following are mechanical test conducted to the hydro turbine generator: Run-out tests, Bearing Alignment tests, Alignment tests, Balance tests, Torsional vibration

- **Electrical test**

Some key electrical tests performed on hydro turbine generators:

1. Insulation Resistance Test

Purpose: Checks the insulation quality of stator windings, which can degrade over time.

Method: Uses an insulation resistance tester (megger) to apply a voltage and measure resistance in mega ohms.

Outcome: Low insulation resistance may indicate moisture, contamination, or insulation damage.

2. Polarization Index (PI) Test

Purpose: Assesses insulation quality by measuring how the insulation resistance changes over time.

Method: Measures insulation resistance over a period (typically 10 minutes) and compares it with a shorter measurement (1 minute).

Outcome: A PI value > 2.0 is generally acceptable, while lower values indicate potential insulation issues.

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Outcome: Variations may suggest loose connections, damaged coils, or other issues.

4. Dielectric Withstand (Hi-Pot) Test

Purpose: Ensures the insulation can handle high voltage without breaking down.

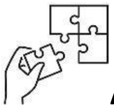
Method: Applies a high voltage for a set time and checks for insulation breakdown.

Outcome: Failures can indicate weak or damaged insulation, requiring repair.

5. Partial Discharge Test

Purpose: Detects partial discharges, which can indicate insulation weaknesses.

Method: Uses specialized equipment to measure partial discharge levels.



Application of learning 3.1.

Hydro Turbine Generator is installed at a power plant needs to be tested before running that power plant. You request to trainee to Perform mechanical and Electrical tests of the hydro-turbine of that plant

Indicative content 3.2: Conducting Performance Tests

Duration: 7hrs

Theoretical Activity 3.2.1: Introduction of performance tests

Tasks:

1: Answer the following questions:

i. Describe the following performance test:

a) Endurance testing
b) Thermal performance testing
c) Operational testing
d) load rejection test
e) Power system stability test

2: Present the findings to the whole class and trainer.

3: Follow the expert view and Ask for clarification if any.

4: You are directed to read the key readings 3.2.1

Key readings 3.2.1.: Introduction to performance tests

- **Endurance testing**

Endurance testing is a type of reliability testing used to evaluate the ability of a device or system to withstand prolonged periods of operation without experiencing any failures or malfunctions.

Methods used in endurance testing:

1. Cycle testing: This involves subjecting the device to a specific number of cycles or repetitions of a particular operation or stress test. This helps to identify any potential issues that may arise due to repeated use or exposure to certain environmental conditions.

2. Environmental testing: Endurance testing can also involve testing the device in different environmental conditions, such as varying temperatures, humidity levels, and altitudes. This helps to determine how the device performs in different scenarios and identify any potential issues that may arise in extreme conditions.

3. Load testing: This involves subjecting the device to a specific load or stress level to determine its ability to handle heavy workloads or prolonged periods of operation. This helps to identify any potential issues that may arise due to excessive stress or strain on the device's components.

4. Vibration testing: Endurance testing can also involve subjecting the device to controlled vibrations to evaluate its ability to withstand external forces and maintain optimal performance.

- **Thermal performance test**

Thermal performance testing in a hydro turbine generator involves evaluating the ability of the device to dissipate heat and maintain optimal operating temperatures. This is important because excessive heat can cause damage to the internal components of the turbine, reduce its lifespan, and affect its performance.

✓ **There are several methods used in thermal performance testing of hydro turbine generators, including:**

1.Junction temperature measurement: This involves using specialized tools to measure the temperature of the turbine's critical components, such as the generator or bearings. This helps to determine the turbine's thermal performance and identify any potential issues.

2. **Heat dissipation testing:** This involves measuring the amount of heat generated by the turbine and how effectively it is dissipated. This can be done using specialized equipment, such as thermal cameras or heat sinks, to monitor the turbine's temperature and performance over time.

3. Cooling system testing: Hydro turbine generators often have cooling systems, such as heat exchangers or radiators, to dissipate heat generated during operation. Thermal performance testing can involve evaluating the effectiveness of these cooling systems in maintaining optimal operating temperatures.

4. **Environmental testing**: Thermal performance testing can also involve testing the turbine in different environmental conditions, such as varying temperatures, humidity levels, and altitudes. This helps to determine how the turbine performs in different scenarios and identify any potential issues that may arise in extreme conditions.

- **Load rejection test**

Load rejection test for a hydro turbine generator is conducted to verify the system's ability to handle sudden loss of load (i.e., when the electrical load on the generator suddenly drops to zero). This test is essential for ensuring the stability of the turbine and generator system under emergency conditions, such as a grid failure or disconnection.

✓ **Purpose of the Load Rejection Test:**

- **Verify the governor's response**: The turbine's governor system should respond quickly to prevent over speed by reducing the water flow through the turbine.

- **Check the protection systems**: Ensure the generator's protective devices, such as over-speed protection and automatic voltage regulator (AVR), function correctly.
- **Test the mechanical stability**: The test evaluates how well the turbine handles mechanical stress caused by a sudden loss of electrical load.
- **Ensure safe shutdown**: In case of over speed, the system should shut down safely without causing damage.

✓ **Steps Involved in a Load Rejection Test:**

1. Prepare the System:

Steady-State Operation: The turbine-generator system must first be operating under a defined electrical load at normal operating conditions.

Safety Protocols: Ensure that all safety measures are in place, including emergency shutdown mechanisms and protective relays.

2. Disconnect the Load:

Simulated Grid Loss: The generator is suddenly disconnected from the electrical load (e.g., by opening the circuit breaker), simulating a grid failure or load rejection.

Monitor Generator Behaviour: Immediately after the load rejection, the turbine's speed will increase due to a sudden drop in electrical load.

3. Governor Response:

Speed Control: The governor should quickly reduce the water flow to the turbine to prevent over speeding. The target is to limit the increase in turbine speed to within acceptable limits (typically 10-15% above rated speed).

Stabilization: The turbine and generator speed should stabilize within a few seconds after the load rejection.

4. Excitation System Response:

Voltage Regulation: The automatic voltage regulator (AVR) should adjust the excitation to maintain the terminal voltage of the generator, preventing overvoltage during the test.

5. Protection System Testing:

Over speed Protection: If the speed exceeds the acceptable limit, the protection system should engage to shut down the turbine and close the wicket gates to stop the water flow.

6. Other Protections: Verify that other protection systems (overvoltage, under voltage, and overcurrent protection) activate as required.

Observe and Record Key Parameters:

1. **Speed Response Curve**: Record the turbine speed during and after load rejection.
2. **Water Flow Reduction**: Measure the speed and efficiency of water flow reduction by the governor.
3. **Voltage and Current**: Record the generator voltage and current behaviour.
4. **Vibration and Temperature**: Monitor any abnormal vibrations or temperature changes in the turbine or generator components.

Post-Test Analysis:

1. **Review Performance**: Compare the turbine and generator performance against design specifications.
2. **Identify Issues**: Look for any irregularities, such as excessive over speed, slow governor response, or malfunctioning protection systems.
3. **Fine-Tune Control Systems**: If necessary, adjust the governor and AVR settings to improve the response to load rejection.
4. **power system stability test** of a hydro power generator is essential for ensuring the generator can remain stable and synchronized with the grid during disturbances or sudden changes in load. Stability testing evaluates the ability of the hydro generator to maintain synchronous operation when exposed to grid faults, load changes, or system disturbances

- **Stability Tests**
  - ✓ **Types of Stability Tests:**
    - Rotor Angle Stability (Transient Stability)
    - Voltage Stability
    - Frequency Stability

1. Rotor Angle Stability Test (Transient Stability)

This test assesses the generator's ability to maintain synchronous operation after a disturbance, such as a fault or a sudden load change. If the rotor angle between generators shifts significantly, the unit may lose synchronism and disconnect from the grid.

- **Key Steps:**
  - ➢ **Disturbance Simulation**: Introduce a disturbance, such as a sudden load increase, load rejection, or a grid fault (e.g., short circuit).
  - ➢ **Fault Clearing**: Simulate the clearing of the fault (e.g., opening the circuit breaker or protection relay response).
  - ➢ **Rotor Angle Monitoring**: Record the rotor angle deviation during and after the disturbance.

- **Stability Criteria**: Analyze whether the generator can restore its normal rotor angle and maintain synchronism with the grid after the disturbance. A small oscillation that decays over time indicates stability, while large oscillations may indicate instability.

2. Voltage Stability Test

Voltage stability refers to the generator's ability to maintain steady voltage levels at the generator terminals and throughout the power system during and after disturbances. Voltage instability can lead to voltage collapse and grid failure.

- **Key Steps:**
  - **Apply a Load Change**: Introduce a sudden change in load (either increase or decrease) to observe the voltage response.
  - **Simulate a Grid Fault**: Test the generator's voltage stability by applying a fault and clearing it (similar to the rotor angle stability test).
  - **Measure Voltage Response**: Monitor the terminal voltage of the generator and nearby busbars during the fault, fault clearing, and post-fault conditions.
  - **AVR Performance**: Verify the performance of the Automatic Voltage Regulator (AVR), ensuring that it adjusts excitation to stabilize the voltage during and after the disturbance.
- **Performance Indicators:**
  - **Voltage Recovery Time**: The time taken for the generator terminal voltage to return to the pre-disturbance level.
  - **Voltage Deviations**: The extent to which the voltage drops or spikes during a disturbance.

3. Frequency Stability Test

Frequency stability measures how the generator handles deviations in grid frequency caused by changes in load or generation imbalance. A well-functioning hydro generator should respond to frequency changes without causing significant fluctuations in system frequency.

- **Key Steps:**
  - **Simulate Frequency Disturbance**: Introduce a sudden change in load or generation, causing the system frequency to shift from its nominal value (50 Hz or 60 Hz depending on the region).
  - **Governor Response**: Evaluate the hydro turbine governor's ability to adjust the water flow to match the new load and stabilize frequency.
  - **Frequency Measurements**: Record the frequency deviation and its

recovery pattern after the disturbance.

- **Performance Indicators:**
  - **Primary Frequency Control**: The immediate response of the governor to correct frequency deviations by adjusting mechanical power output.
  - **Frequency Deviation**: The extent of the frequency drops or increase due to the disturbance.
  - **Recovery Time**: How long it takes for the system to return to nominal frequency.

Practical Activity 3.2.2. Conducting performance tests.

Task:

1: Introduce the activity and ask trainee to read the task described below.

i. Refer to the previous theoretical activity 3.2.1. hydro turbine generator installed in Mukungwa power plant need to be tested before running. You requested to Perform the following Performance test:

a) Endurance testing
b) Thermal Performance testing
c) Operational tests
d) Load rejection test
e) Power system stability test.

2: Pay attention on trainer's explanations and instructions

3: Present your work to the trainer/colleague and ask clarification if any.

Key readings: 3.2.2. Conducting performance tests

- **Key steps for conducting performance tests**

- **Simulate Frequency Disturbance**: Introduce a sudden change in load or generation, causing the system frequency to shift from its nominal value (50 Hz or 60 Hz depending on the region).
- **Governor Response**: Evaluate the hydro turbine governor's ability to adjust the water flow to match the new load and stabilize frequency.
- **Frequency Measurements**: Record the frequency deviation and its recovery pattern after the disturbance.
- **Performance Indicators:**
- **Primary Frequency Control**: The immediate response of the governor to

correct frequency deviations by adjusting mechanical power output.

- **Frequency Deviation**: The extent of the frequency drops or increase due to the disturbance.
- **Recovery Time**: How long it takes for the system to return to nominal frequency.

Points to Remember

- **Endurance testing** is a type of reliability testing used to evaluate the ability of a device or system
- to withstand prolonged periods of operation without experiencing any failures or malfunctions.
- **Thermal performance test**
- Thermal performance testing in a hydro turbine generator involves evaluating the ability of the device to dissipate heat and maintain optimal operating temperatures.
- **Rotor Angle Stability Test (Transient Stability)**
- This test assesses the generator's ability to maintain synchronous operation after a disturbance, such
- **Frequency Stability Test**
- Frequency stability measures how the generator handles deviations in grid frequency caused by changes in load or generation imbalance s a fault or a sudden load change

Application of learning 3.2

Hydro Turbine Generator installed power plant need to be tested before running power plant. You are requested to perform the following electrical test (endurance test, thermal performance test, operational test, load rejection test, power system stability test)

Indicative content 3.3. Elaboration of Report

Duration: 5hrs

Theoretical Activity 3.3.1: Elaboration of report

Tasks:

1: Answer the following questions:

i. Describe the following contents:

a) Introduction of report
b) Report content
c) Reporting method
d) Writing report
e) Report documentation and filling

2: Present the findings to the whole class and trainer.

3. Follow the expert view and Ask for clarification if any.

4: Read the key readings 3.3.1. in trainee manual

Key readings 3.3.1 Elaboration of report

- **Definition of report**

A work report is a formal document that provides an overview of the activities, achievements, and challenges faced by an individual or A report of work is a document that outlines the activities, accomplishments, and challenges faced by an employee during a specific period.

Its primary purpose is to provide a comprehensive overview of an employee's activities and accomplishments during a given period, demonstrating productivity, efficiency, and dedication to their role.

- **The structure of a work report usually includes the following sections:**

- **Introduction**: This section provides background information on the project, task, or study, including its objectives, scope, and significance.
- **Methodology:** This section describes the methods, techniques, and tools used to conduct the work, including any data collection, analysis, or modeling processes.
- **Results**: This section presents the findings, outcomes, or results of the work, including any data, graphs, charts, or visualizations.
- **Discussion:** This section interprets the results, relates them to the objectives of the work, and discusses their implications, limitations, or areas for further research.

- **Conclusion:** This section summarizes the main findings and recommendations, and may also include suggestions for future research or action.
- **References:** This section lists all the sources cited in the report, following a specific citation style (e.g., APA, MLA, Chicago).
- **Appendices:** Include any supplementary materials, such as raw data, additional figures or tables, or detailed descriptions of the research methods.

Common types of report

- **Project report:** This type of report is used to document the progress, achievements, and challenges of a specific project. It typically includes details such as project scope, timeline, resources, and risks.
- **Performance report**: This report is used to evaluate the performance of an individual, team, or department. It often includes metrics such as productivity, quality, and customer satisfaction.
- **Technical report**: This type of report is used to document technical information, such as research findings, experimental results, or design specifications. It is typically written for a technical audience and may include diagrams, charts, and other visual aids.
- **Progress report**: This report is used to provide an update on the progress of a project or task. It often includes details such as completed milestones, remaining work, and any changes or updates to the project plan.
- **Incident report:** This report is used to document and analyze any unexpected events or incidents that have occurred during work. It may include details such as cause, impact, and any corrective actions taken.
- **Status report**: This report is used to provide an overview of the current status of a project or task, including any changes, updates, or issues that have arisen since the last report.
- **Final report**: This report is used to document the final results and findings of a project or task. It often includes a summary of the work, conclusions, and recommendations for future action.

- Benefits of submitting regular reports of work

  Regularly submitting reports of work can have several benefits for employees, include:

- ✓ Improved communication with supervisors
- ✓ Increased accountability the ability to track progress and identify areas for improvement
- ✓ Submitting reports of work can help employees develop strong time

management and organizational skills as well as enhance their ability to prioritize tasks and manage their workload effectively.

Format of Maintenance Report

Prepared by: [Your Names]: ………………………………………………………………

Date: [Insert Date]: ……/…./…….

Location: [Company/Facility Name]:

………………………………………………………………

Department: ……………………………………………………

Table of Contents:

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……………….

1. Executive Summary:

…………………………….

…………………………….

2. Introduction:

…………………………….

………………………………….

…………………………………….

3. Overview of Maintenance Activities:

3.1. Routine Maintenance: ☐

3.2. Preventive Maintenance: ☐

3.3 Emergency repair:

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4. Equipment Performance:

4.1 Key Equipment Issues:

……………………………………………………………………………………

4.2 Downtime Analysis:

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…………………………………………………………………………………………………

5. Materials and Spare Parts Used

1. …………………………………………………………
2. ……………………………………………………….
3. ……………………………………………………….

6. Cost Analysis

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7. Recommendations for Improvement:

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……………………

8. Conclusion:

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……………………

1. Executive Summary

In September 2024, the Maintenance completed various routine, preventive, and emergency maintenance activities at the [Name]. This report summarizes the work carried out, including the performance of key equipment, materials used, and an analysis of costs. The report highlights a significant improvement in equipment uptime due to timely preventive maintenance. However, recommendations are made for addressing recurring issues with [specific equipment].

2. Introduction

The purpose of this report is to provide a detailed account of the maintenance activities conducted. The report covers the types of maintenance performed, key issues encountered, materials used, and cost breakdowns. Regular maintenance activities aim to ensure the smooth operation of equipment, minimize downtime, and extend the lifecycle of equipment.

3. Overview of Maintenance Activities

3.1 Routine Maintenance

Routine maintenance was performed on all critical equipment according to the scheduled timetable.

This includes:

- ✓ Lubrication of bearings and gears on production lines.

- ✓ Calibration of temperature and pressure sensors
- ✓ General cleaning and inspections.
- ✓ No major issues were reported during these activities.

3.2 Preventive Maintenance

Preventive maintenance focused on ensuring the long-term reliability of critical equipment. Key tasks included:

Replacement of worn-out belts and hoses in [Equipment Name].

- ✓ Inspection and tightening of electrical connections on control panels.
- ✓ Oil and fluid changes in hydraulic systems.
- ✓ Vibration analysis and motor diagnostics.

These tasks helped prevent potential breakdowns, especially in the [Specific Machinery], which had shown signs of wear in previous months.

3.3 Emergency Repairs

During the month, two emergency repairs were required:

[Equipment Name] Failure: On September 12, the [specific equipment] failed due to a malfunction in the motor assembly. Repairs were completed within 4 hours, minimizing downtime.

Conveyor Belt Breakdown: On September 21, a tear in the conveyor belt caused an operational halt for 6 hours. The belt was replaced, and the line was restored to full operation.

4. Equipment Performance

4.1 Key Equipment Issues

[Equipment A]: Experienced two brief downtimes due to overheating. This issue is being monitored, and additional cooling measures are being considered.

[Equipment B]: Continued to perform below optimal levels despite preventive maintenance. A thorough investigation is planned for October.

4.2 Downtime Analysis

Overall, the plant experienced 10 hours of downtime in September. The majority of this downtime was caused by the conveyor belt failure, which accounted for 6 hours. Downtime due to other equipment issues was reduced compared to the previous month.

5. **Materials and Spare Parts Used**

The following materials and spare parts were used during maintenance activities:

5x Conveyor Belts

10x Motor Bearings

3x Hydraulic Hoses

2x Temperature Sensors

1x Circuit Board (for [Equipment Name])

These materials were sourced from [Supplier Name], and all replacements were completed within the required maintenance schedule.

6. Cost Analysis

The total cost for maintenance in September amounted to 25,0000 rwf, broken down as follows:

Routine Maintenance : 150000rwf

Preventive Maintenance : 60,000rwf

Emergency Repairs: 40,000rwf

Labor costs contributed 70,000 rwf to the total, while spare parts and materials accounted for 8,000 rwf.

7. Recommendations for Improvement

Increase Frequency of Inspections: To prevent overheating issues in [Equipment A], it is recommended to increase the frequency of thermal inspections and consider adding additional cooling systems.

Upgrade Conveyor Belt Material: The repeated failure of conveyor belts suggests a need for more durable materials.

Improve Spare Parts Inventory: Stock more critical spare parts onsite to reduce repair time during emergencies.

8. Conclusion

Maintenance activities in September were largely successful in reducing equipment downtime and preventing major failures. While the plant experienced some minor setbacks, especially with the conveyor belt, overall equipment performance was satisfactory. The recommendations provided aim to further enhance equipment reliability and reduce future downtime.

Practical Activity 3.3.2.Conduct the maintenance report of generator

Task:

1: Referring to the key readings 3.3.2, you are requested to perform the following task:

Referring to the Hydro power plant finished activity of installing Hydro Turbine Generator and functionality test conducted. You are requested write accurately maintenance report of work doneI. Write the maintenance report of generator.

2: Apply safety precautions

3: Present your work to the trainer/colleague and ask clarification if any.

Key readings 3.3.2. Conduct the maintenance report of generator

The structure of a work report

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Points to Remember

- Work report is a formal document that provides an overview of the activities, achievements, and challenges faced by an individual or A report of work is a document that outlines the activities, accomplishments, and challenges faced by an employee during a specific period.
- The structure of a work report usually includes the following sections:
    - ✓ **Introduction**: This section provides background information on the project, task, or study, including its objectives, scope, and significance.
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    - ✓ **Discussion:** This section interprets the results, relates them to the objectives of the work, and discusses their implications, limitations, or areas for further research.

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- ✓ **References:** This section lists all the sources cited in the report, following a specific citation style (e.g., APA, MLA, Chicago).
- ✓ **Appendices:** Include any supplementary materials, such as raw data, additional figures or tables, or detailed descriptions of the research methods.

Application of learning 3.3

Hydro Turbine Generator installed in a power plant needs to be maintained after 15 years running in operation. You are required to write an accurate maintenance report of work done after repairing.

Learning outcome 3 end assessment

Written assessment

Q1. Match the components in column A with their corresponding function in Column B

Answers	Column A	Column B
1……….	A report	a. It is conducted to assess the rotor's mechanical integrity and to check for any potential issues that could affect the turbine's operation.
2……….	Mechanical test	b. These tests are performed to measure the rotor's axial and radial run-out. The axial run-out refers to the movement of the rotor along its axis, while the radial run-out refers to the movement of the rotor perpendicular to its axis
3…………..	Balance tests	c.is a document that outlines the activities, accomplishments, and challenges faced by an employee during a specific period.
		d. These tests are conducted to determine if the rotor is balanced properly

Q2. Choose the correct answer, the following statement are functionality test of hydro turbine generator, except?

a) Rotor Runout Test
b) Voltage build up test
c) Winding insulation test
d) Operational Tests

Q3. State whether the following statement if is correctly by True and False if is wrong

a) Introduction report provide background information on the project, task, or study, including its objectives, scope, and significance.
b) Conclusion of report interpret the results, relates them to the objectives of the work, and discusses their implications, limitations, or areas for further research.

c) Methodology of report describes the methods, techniques, and tools used to conduct the work, including any data collection, analysis, or mode ling processes

Q4. The following statements are functions of synchronization test? Answer True or False

a) The synchronization test checks the generator's ability to synchronize with the electrical grid?

b) Synchronization not involves matching the generator's voltage, frequency, and phase with the grid before connecting it?

Q5. The following are the key components tested during mechanical tests of a hydro turbine generator, Except?

a) Turbine Shaft
b) Bearings
c) Rotating Components.
d) Winding insulation
e) Wicket Gates
f) Coupling Between Turbine and Generator

Q6. The following statement are potential mechanical issues that can affect generator performance?

a) Rotor Imbalance
b) Misalignment between turbine and generator
c) Worn or damaged bearings
d) Cavitation damage
e) Loose mechanical connections
f) B,C and A are correct
g) All above are correct

Q7. The following are electrical issues identified during hydro turbine generator testing, except?

a. Insulation Breakdown
b. Winding Short Circuits
c. Rotor Alignment
d. Voltage Regulation Problems
e. Synchronization Issues
f. Excessive Harmonics

Q8. The following are the structures of a work report. Except?

a) Introduction
b) Methodology
c) Results
d) Discussion
e) Problem statement
f) Conclusion

g) References
h) Appendices

Practical assessment

During the visit of infrastructure minister to a rural electrified region of 60MW installed capacity, the minister of infrastructure was requested by the local community for explain reason of do not having no sufficient electricity of this region.

The Mayor of district this region locates was appointed by minister to carry out the feasibility study of that insufficient electrification of the region and remedial the issue of the electrification for this region, Mayor was appointed committee of electricity production to explain the reason of insufficiency of produced electricity, the committee was decided that hydro power plant available at time has 40MW power produced, so that there is a constructed small power plant of 30MW at the river down Stream 3km from the old one but they are looking a supervisor level electrician to connect a bought hydro-turbine generator in new plant, after construction of all civil structures, hydraulic water ways.

By following the installation procedures, the electromechanical layout and schematic diagrams provided by developer engineer in user manual and catalogue; Within 8 hours, ask your trainee to perform the assembling and testing turbine generator of the new power plant installed to upgrade electricity demand for the region.

END

References

Raja, A. K., Srivastava, A. P., & Dwivedi, M. (2006). *Power plant engineering* (pp. 22-128, 364-406). New Delhi, Bangalore, Chennai, Mumbai, Ranchi.

Mehta, V. K., & Mehta, R. (2010). *Principles of power system* (pp. 11-15, 27-29, 602-612). Mumbai, New Delhi, Bangalore, Chennai.

Rajput, R. K. (2008). *A textbook of power plant engineering* (pp. 27-28, 323-358). Bengaluru, Chennai, Cochin, Guwahati, Hyderabad, Jalandhar, Kolkata, Lucknow, Mumbai, Ranchi, New Delhi, Boston (USA), Accra (Ghana), Nairobi (Kenya).

Gulliver, J. S., & Arndt, R. E. A. (1991). *Hydropower engineering handbook* (pp. 20-200). Bengaluru: McGraw-Hill, Inc. Retrieved from the University of Minnesota Digital Conservancy.

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