SCHEME :K

Name :_______________________
Roll No.:________ Year : 20 ___ 20 __
Exam Seat No. :___________________

LABORATORY MANUAL FOR
RENEWABLE ENERGY TECHNOLOGY (315337)

ELECTRICAL ENGINEERING GROUP

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)

VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programs.

CORE VALUES

MSBTE believes in the following:

Skill development in line with industry requirements

Industry readiness and improved employability of Diploma holders

Synergistic relationship with industry

Collective and Cooperative development of all stake holders

Technological interventions in societal development

Access to uniform quality technical education

A Laboratory Manual For

RENEWABLE ENERGY TECHNOLOGY

(315337)

Semester – V

(EE/EP)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)

Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO 21001:2018) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai- 400051.

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

Certificate

This is to certify that Mr./Ms.………………………………….. ……………..Roll No. …………… of Fifth Semester of Diploma in…………………………..…………………………of Institute …………………………………………………………………... (Code: ………) has completed the term work satisfactorily in course **RENEWABLE ENERGY TECHNOLOGY (315337)** for the academic year 20…….to 20……..as prescribed in the curriculum.

Place: …………...…. **Enrollment No……………..**

Date: ………………. **Exam Seat No: …………….**

Subject Teacher **Head of Department** **Principal**

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programs with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a renewable energy source to develop this industry identified competency in every student. The practical skills are difficult to develop through "chalk and duster" activity in the classroom situation. Accordingly, the "K" scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age old practice of conducting practical to 'verify the theory" (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected. from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the Practical Significance, industry relevant skills, course level Learning outcomes and Relevant Affective Domains which serve key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The basic aim of the course is to impart practical knowledge of renewable energy systems. It helps students understand the working and applications of solar, wind, and other sustainable energy technologies.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

Program Outcomes (POs) to be achieved through this course learning

- **PO 1. Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, sciences and engineering fundamentals and engineering specialization to solve the engineering problems.
- **PO 2. Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.
- **PO 3. Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of system components or processes to meet specified needs.
- **PO 4. Engineering tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.
- **PO 5. Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.
- **PO 6. Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.
- **PO 7. Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

List of Relevant expected psychomotor domain Skills

This Lab manual intends to develop expected psychomotor domain skills of students. The skills mentioned below will be developed through the experiments performed in this Laboratory**.**

1. Ability to make connections.
2. To use the vocabulary of electrical engineering.
3. To identify and measure the quantities using various measuring instruments.
4. Ability to adjust the components.
5. To develop practical skills in identifying renewable energy sources and converting them into electrical energy.

Practical-Course Outcome Matrix

COURSE LEVEL LEARNING OUTCOMES (COS)

- CO1 - Test the performance of the solar panels.
- CO2 - Maintain working of small wind turbines.
- CO3 - Utilize small-capacity hydrogen fuel cell systems for various applications.
- CO4 - Maintain basic components of biogas plant.
- CO5 - Identify major components of the geothermal, ocean and small hydro power plants.

Sr. No.	Title of the Practical	CO1	CO2	CO3	CO4	CO5
1	* Measurement of electrical parameters of the solar cells/panel.	✓	-	-	-	-
2	*Effect of load and inclination angle on solar panel output.	✓	-	-	-	-
3	* Series parallel connection of solar panels.	✓	-	-	-	-
4	Sizing of Solar panels required for a residential house having 500 W electrical load.	✓	-	-	-	-
5	*Measurement of wind speed at different heights and locations.	-	✓	-	-	-
6	Components of small wind turbine (Horizontal axis / Vertical axis).	-	✓	-	-	-
7	*Performance of Induction Generator.	-	✓	-	-	-
8	*Demonstration of hydrogen fuel cell.	-	-	✓	-	-
9	*Demonstration of biogas operated plant. OR Visit to biogas operated Plant.	-	-	-	✓	-
10	Demonstration of geothermal power plant using video/animation.	-	-	-	-	✓
11	Demonstration of tidal and wave power plant using video/animation.	-	-	-	-	✓
12	Demonstration of marine power plant and ocean thermal energy conversion (OTEC) plant using video/animation.	-	-	-	-	✓
13	*Demonstration of small hydro power plant using video/animation. OR Visit to hydro power plant.	-	-	-	-	✓

Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each experiment.
3. Involve students in performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in the students after the completion of the practical exercise.
5. Teachers should give opportunity to students for hands on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected the students by the industry. Circuit diagrams provided in manual include major components only with connections based on general concept. Teachers shall provide inputs to students for connections of additional components if required or any specific connection.
8. Finally give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions.
9. Practical No 08 to 13 is a demonstration expected to conduct using one of suitable tools like experimentation kit, simulation software, animation videos, nearest site visit etc. Respective faculty shall decide appropriate method to conduct this practical as per available resource.

Instructions for Students

1. Listen carefully the lecture given by teacher about subject, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make record all programs.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual.
6. Student shall refer technical magazines.
7. Student should develop habit to submit the practical's on date and time.
8. Student should well prepare while submitting write up of exercise.
9. Attach/paste separate papers wherever necessary.
10. Circuit diagrams provided in manual include major components only with connections based on general concept. Students shall seek inputs from teachers for connections of additional components if required or any specific connection.
11. Practical No 8 to 13 is a demonstration expected to conduct using one of suitable tools like experimentation kit, simulation software, animation videos, nearest plant/site visit etc. Students shall follow the instruction of respective faculty for the performance of this practical and prepare a report accordingly.

Content Page

List of Practical's and Progressive Assessment Sheet

Sr. No	Title of the Practical	Page no.	Date of Performance	Date of Submission	Assessment Marks (25)	Dated sign. of Teacher	Remarks (If any)
1	* Measurement of electrical parameters of the solar cells/panel.	01					
2	*Effect of load and inclination angle on solar panel output.	06					
3	* Series parallel connection of solar panels.	13					
4	Sizing of Solar panels required for a residential house having 500 W electrical load.	21					
5	*Measurement of wind speed at different heights and locations.	29					
6	Components of small wind turbine (Horizontal axis / Vertical axis).	36					
7	*Performance of Induction Generator.	44					
8	*Demonstration of hydrogen fuel cell.	50					
9	*Demonstration of biogas operated plant. OR Visit to biogas operated Plant.	56					

10	Demonstration of geothermal power plant using video/animation.	63					
11	Demonstration of tidal and wave power plant using video/animation.	69					
12	Demonstration of marine power plant and ocean thermal energy conversion (OTEC) plant using video/animation.	75					
13	*Demonstration of small hydro power plant using video/animation. OR Visit to hydro power plant.	81					

Note:
Out of above suggestive LLOs -

- '*' Marked Practical’s (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

Practical No. 1: Measurement of Electrical Parameters of the Solar Cells/Panel.

I Practical Significance:

Measurement of electrical parameters of solar cells/panels, such as voltage, current, and power output, helps evaluate their efficiency and performance. This is essential for optimal system design, maintenance, and maximizing energy generation in real world applications.

II Industry/Employer Expected Outcome(s)

To accurately measure and analyze solar panel parameters to ensure optimal performance, efficiency, and reliability.

III Course Level Learning Outcome(s)

Test the performance of the solar panels

IV Laboratory Learning Outcome(s):

LLO 1.1 Measure current, voltage and power output of the solar cells/panel.
LLO 1.2 Measure current, voltage and power output of the solar panel for shadow effect.

V Relevant Affective Domain related outcome(s)

Follow safety electrical rules for safe practices, Follow ethical practices.

VI Relevant Theoretical Background (With diagrams if required)

Solar cells convert sunlight into electrical energy based on the photovoltaic effect. When exposed to light, they generate a voltage (open circuit voltage, Voc) and current (short-circuit current, Isc). In this practical aims to familiarize you with the fundamental electrical characteristics of solar cells and panels and how to measure them. Understanding these parameters is crucial for evaluating the performance and efficiency of photovoltaic (PV) devices.

Photovoltaic Effect:

Solar cells are semiconductor devices that convert light energy directly into electrical energy through the photovoltaic effect. When photons (light particles) with sufficient energy strike the semiconductor material (typically silicon), they excite electrons, creating electron-hole pairs.
An internal electric field at the p-n junction of the semiconductor separates these charge carriers. The movement of these separated charges creates an electrical current when an external circuit is connected.

Key electrical parameters include:

- **Open-Circuit Voltage (Voc):** The maximum voltage when no current flows.
- **Short-Circuit Current (Isc):** The current when the output is shorted.
- **Maximum Power Point (Pmax):** The point at which the product of voltage and current is highest.
- **Fill Factor (FF):** Indicates the quality of the solar cell and is calculated as FF = $\frac{Pmax}{Voc\ X\ I\ sc}$.
- **Efficiency (η):** The ratio of electrical output power to incident solar power, showing how effectively the solar panel converts sunlight into electricity.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

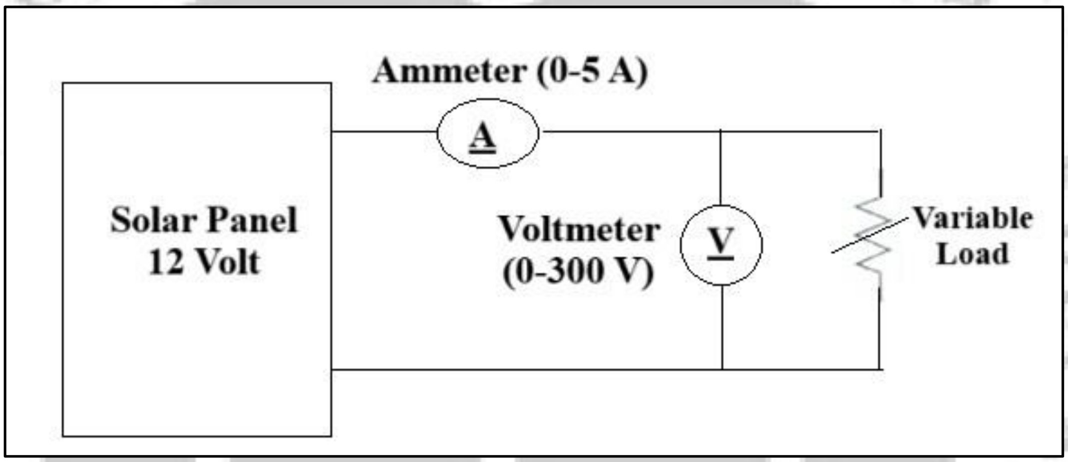

Figure 1.1 : Circuit Diagram

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar panel/cell	12 Volt polycrystalline or monocrystalline solar panel	1
2	Voltmeter	0-300V	1
3	Ammeter	0-5A	1
4	Variable resistor (load)	Nichrome wire, 300 Ω (ohm), 10A, 400V	1
5	Multimeter (optional)	2000 count digital display, 1000V DC/750 V AC ranges, 10 A AC/DC ranges	1
6	Light source (Sunlight or solar simulator)	--	--

IX Precautions to be followed:

1. Connect proper devices.
2. Ensure proper handling of devices to avoid damage due to static electricity.

X Procedure

1. Connect the solar panel in a circuit with a variable resistive load.
2. Measure Voc by keeping the circuit open (no load).
3. Measure Isc by shorting the terminals with an ammeter.
4. Vary the resistance and record corresponding voltage and current values.
5. Plot the V-I curve from collected data.
6. Identify Maximum Power Point (MPP).
7. Calculate Pmax, FF, and efficiency using the formulas above.

XI Observations and calculations:

Sr. No.	Load (Ω)	Voltage (V)	Current (A)	Power (W= V×I)
1.				
2.				
3.				
4.				

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is the working principle of a solar cell?
2. What is Short Circuit Current (Isc), and how is it measured?
3. What is Open Circuit Voltage (Voc), and how is it measured?
4. Draw and describe the block diagram of PV system.

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XVI References/Suggestions for further reading:

1. "Solar PV Training Manual" – Published by GIZ or MNRE Includes step-by-step instructions on measuring parameters like voltage, current, and power.
2. You tube link video How to measure parameters of solar module complete practical guide.

Suggested Assessment Scheme:

Performance Indicators		Weightage
Process related :(15 Marks)		**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
Product related (10 Marks)		**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 2: Effect of load and inclination angle on solar panel output.

I **Practical Significance**:

In this experiment demonstrates the key factors that affect the performance of solar photovoltaic (PV) systems. By analysing the effect of varying electrical loads and panel inclination angles, students gain hands-on understanding of how to:

- Optimize power output from solar panels.
- Evaluate and select appropriate load types for solar-powered systems.
- Adjust panel installation angles for maximum sunlight exposure based on geographic location and time of year.

II **Industry/Employer Expected Outcome(s)**

Employers expect students and professionals in renewable energy or electrical fields to:

- Be capable of installing and adjusting solar panels at optimal angles to maximize energy harvest.
- Analyze solar system performance under different environmental and operational conditions.
- Apply knowledge in designing and troubleshooting solar power systems in residential, commercial, or industrial setups.

III **Course Level Learning Outcome(s)**

Test the performance of the solar panels.

IV **Laboratory Learning Outcome(s)**

LLO 2.1 Measure the current, voltage and power output of the solar panel connected to variable resistive/inductive load.

LLO 2.2 Locate the maximum power generation point by analyzing the graph of power verses load resistance.

LLO 2.3 Measure power output of the solar panel at different inclination angles.

LLO 2.4 Locate the maximum power generation point by analyzing the graph of power verses inclination angle.

V **Relevant Affective Domain related outcome(s)**

Awareness and appreciation of the importance of optimizing solar energy systems for sustainable development.

VI **Relevant Theoretical Background (With diagrams if required)**

The performance of a solar panel depends heavily on two key factors: the inclination angle of the panel and the electrical load connected to it. The inclination angle refers to the tilt of the panel relative to the horizontal ground. This angle significantly affects how much solar radiation is captured by the panel surface. When the panel is tilted at an optimal angle typically close to the latitude of the installation location it receives maximum sunlight throughout the day, improving overall energy output. A deviation from this optimal angle reduces the intensity of sunlight hitting the panel, thereby decreasing the power generated.

Similarly, the electrical load influences the operating point of the panel on its current-voltage

(I-V) curve. The load determines the amount of current drawn from the panel at a given voltage. If the load is too high or too low relative to the panel's maximum power point (MPP), the panel operates inefficiently, resulting in lower power output. The ideal load allows the panel to operate at or near its MPP, where the product of voltage and current and therefore power is maximized.

Together, the inclination angle and load resistance play a crucial role in determining the actual electrical output of a solar panel. A mismatch in either parameter can significantly reduce system efficiency. Understanding the theoretical impact of these variables is essential for optimizing solar energy systems, especially in standalone or off-grid applications where maximizing output is critical.

Solar panels convert sunlight into electrical energy. Their output depends on:

- **Load Resistance**: Affects the current drawn, which in turn influences the power output.
- **Inclination Angle**: The angle between the solar panel surface and the ground. An optimal angle allows the panel to absorb the maximum sunlight.

The power output (P) is calculated using:

$$P=V\times I$$

Where:

- V = Voltage across the load
- I = Current through the load

VII Actual Circuit diagram used in laboratory with equipment Specifications:

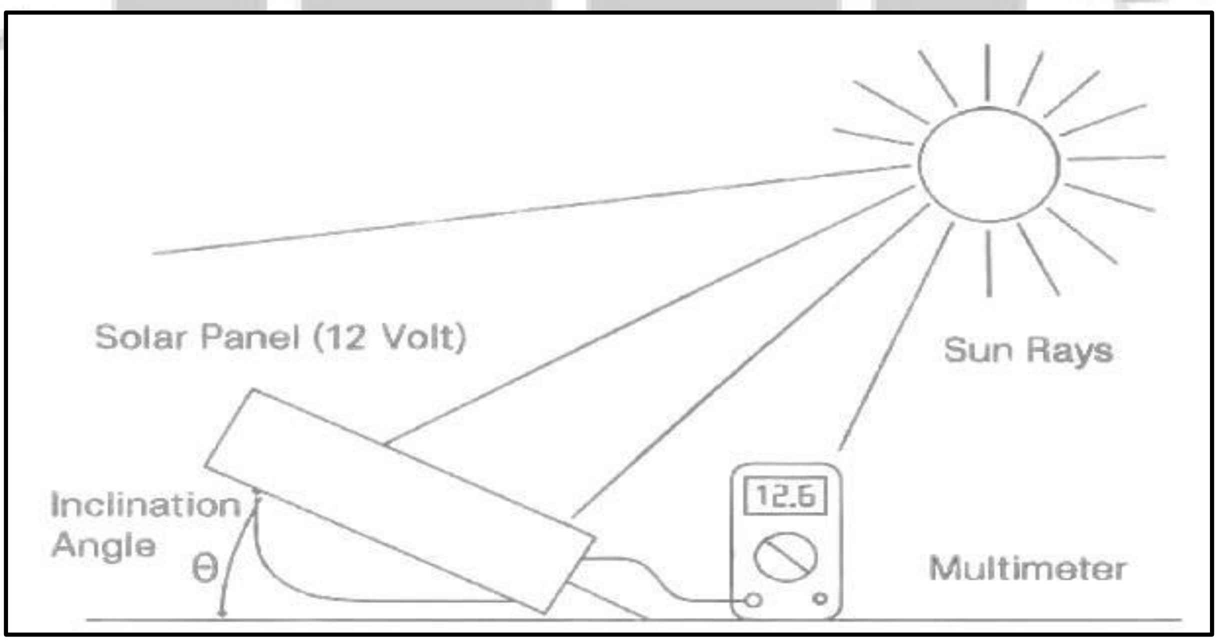

Figure 2.1 Circuit Diagram

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar Panel	(Typically 5V or 12V)	1
2	Variable electrical loads (e.g., resistors, DC motor, LED bulbs)	1KW Variable Resistor	1
3	Multimeter	500V, 20A,	2
4	Protractor	Semicircular (0^0 to 180^0) Dual Marking inner and outer scale.	1
5	Connecting wires and clips		As required
6	Stand or support frame to change inclination angle		As required

IX Precautions to be followed:

1. Perform the experiment in direct sunlight.
2. Ensure proper connections to avoid short circuits.
3. Avoid shadows on the solar panel during measurement.
4. Use the same load and same time of day when measuring inclination effects.

X Procedure

A. Effect of Load:

1. Connect the solar panel directly to a multimeter to measure open-circuit voltage (no load).
2. Connect different loads (e.g., 10Ω, 50Ω, 100Ω resistors) one by one across the solar panel.
3. For each load, measure and record the voltage and current.
4. Calculate the power for each load using P=V×I.

B. Effect of Inclination Angle:

1. Fix a medium load (e.g., 50Ω resistor) to the solar panel circuit.
2. Change the inclination angle of the solar panel in steps(e.g. 0°, 15°, 30°, 45°, 60°,75°, 90°).
3. At each angle, measure the output voltage and current.
4. Record observations and calculate power at each angle.

XI Observations and calculations

A. Effect of Load (fixed angle)

Sr No.	Load (Ω)	Voltage (V)	Current (A)	Power (W= V×I)
1.				
2.				
3.				
4.				

B. Effect of Inclination Angle (fixed load)

Sr No	Angle (°)	Voltage (V)	Current (A)	Power (W)
1.				
2.				
3.				
4.				

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is the effect of increasing load resistance on the current and power output of a solar panel?
2. Why is the inclination angle important for solar panel efficiency?
3. What factors, other than load and angle, can affect the output of a solar panel?
4. What safety precautions should be taken while connecting loads to the solar panel?

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Scale
X- axis -
Y- axis -

XVI References/Suggestions for further reading:

1. https://solar-energy.technology/photovoltaics/elements/photovoltaic-panel/location-of-solar-panels#google_vignette.
2. "Solar Radiation", "Inclination Angle Optimization", "Load Matching" Free access: https://nptel.ac.in/courses/.

Suggested Assessment Scheme :

	Performance Indicators	Weightage
	Process Related :15 Marks	**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
	Product Related : 10 Marks	**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 3: Series Parallel Connection of Solar Panels.

I Practical Significance:

To study and verify the voltage and current characteristics of solar panels connected in series, parallel, and series-parallel configurations, and understand how different arrangements affect the power output of the system.

II Industry/Employer Expected Outcome(s)

They should be able to measure, analyze, and optimize solar output based on load requirements and ensure safe, reliable installations.

III Course Level Learning Outcome(s)

Test the performance of the solar panels.

IV Laboratory Learning Outcome(s)

LLO 3.1 Connect solar panels in series and parallel combination.

LLO 3.2 Measure voltage and current of the solar array by connecting solar panels in series and parallel.

V Relevant Affective Domain related outcome(s)

Demonstrates responsibility, safety awareness, and a positive attitude toward the efficient use of solar systems.

VI Relevant Theoretical Background (With diagrams if required)

Solar panels produce DC (Direct Current) electricity. When designing solar energy systems, panels are often connected in different configurations to achieve the desired voltage and current to power specific loads or charge batteries.

A. Series Connection:

Panels are connected end-to-end (positive of one to negative of the next).

- **Voltage adds up**:

$$V_{total}=V1+V2+\cdots+Vn$$

- **Current remains the same**:

$$I_{Total}=I$$

- Used when higher voltage is required.

B. Parallel Connection:

- All positive terminals are connected together and all **B** are connected together.
- **Voltage remains the same**:

$$V_{Total} = V$$

- **Current adds up**:

$$I_{total} = I_1+I_2+\cdots+I_n$$

- Used when **higher current** is required.

C. Series-Parallel Connection:

- Combines both methods to get desired voltage and current.
- Suitable for **larger systems** where both high voltage and current are required.

Power Output:

$$P=V\times I$$

VII Actual Circuit diagram used in laboratory with equipment Specifications:

1.Series Connection:

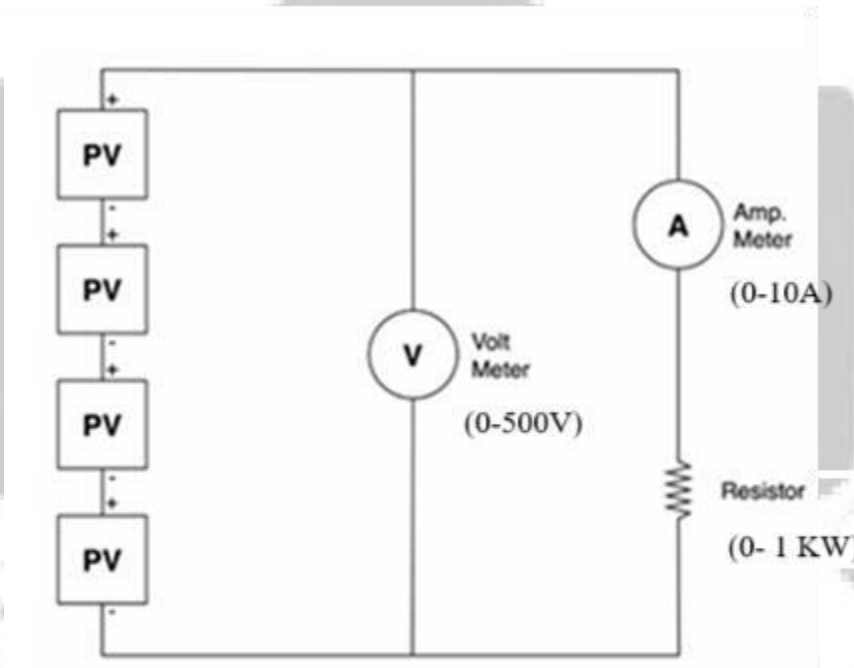

Figure: 3.1 Series Connection of Solar Cell

2.Parallel Connection:

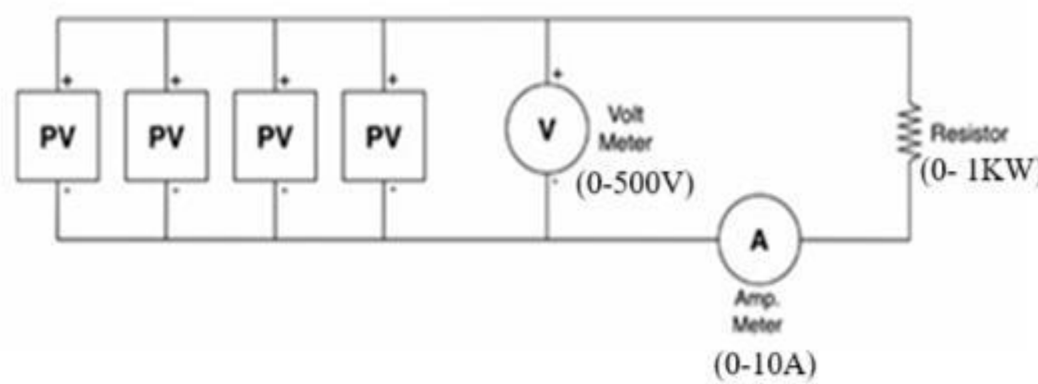

Figure 3.2 : Parallel Connection of Solar Cell

VIII. Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar panel	(Typically, 5V or 12V)	2 or More
2	Variable electrical loads (e.g., resistors, DC motor, LED bulbs)	1KW Variable Resistor	1
3	Voltmeter	500V	1
4	Ammeter	0-10 A	1
5	Connecting wires and clips		As required
6	Stand or support frame		As per required

IX Precautions to be followed:

1. Ensure all panels are identical in rating.
2. Avoid partial shading during the experiment.
3. Make firm and correct connections to prevent errors or damage.
4. Perform the test under direct sunlight or a consistent artificial light source.
5. Use a Multimeter correctly set to DC mode.

X Procedure:

A. Series Connection:

1. Connect the four cells in series by connecting the positive end of one cell to the negative of another as explained above.
2. Your multimeter is the final link in this chain. Using this assembly, and a variable resistor assemble this test circuit as in the single cell test above, leaving the positive lead at one end of your circuit disconnected.
3. Place your cells on the piece of cardboard. All cells should be at the same level, forming a 'module'. Tape a thermometer to the cardboard and place the cardboard unit so that the cells are in the optimum position both for tilt angle and the solar.
4. Connect the positive lead and collect your data in the same manner as you did with the single cell test and record your data below.
5. Using the data you plot a I-V curve on graph paper.

B. Parallel Connection:

1. Connect the four cells in a parallel circuit by connecting the positive ends together (clip one on top of the other) and all the negative ends together.
2. Using this assembly, and a variable resistor set up the test circuit as in the single cell test above, leaving the positive lead of your circuit disconnected.
3. Place your cells on the piece of cardboard.
4. All cells should be at the same level (or as close as possible with the wire length that you have), forming a 'module'.
5. Tape a thermometer to the cardboard and place the cardboard unit so that the cells are in the optimum position both for tilt angle and the solar.
6. Using the data you plot a I-V curve on graph paper.

XI Observations and calculations:

A.Series Connection:

Sr. No.	Voltage (V)	Current (A)	Power (W= V×I)
1.			
2.			
3.			
4.			

B. Parallel Connection:

Sr No.	Voltage (V)	Current (A)	Power (W= V×I)
1.			
2.			
3.			
4.			

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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Scale
X-axis-
Y-axis-

XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is the main purpose of connecting solar panels in series or parallel?
2. Explain the advantage of a series-parallel connection in solar systems.
3. Why is it important to use panels of equal ratings in series-parallel configuration?
4. Describe a real-life application where a series-parallel connection is used.

XVI References/Suggestions for further reading:

1. https://www.scribd.com/document/848438257/practical
2. https://onlinecourses.nptel.ac.in/noc24_ge51/preview
3. https://www.enpower.solutions/pdfs/Physics_Solar_Panels_in_Series_and_Parallel_PowerPoint(HighSchool).pdf.
4. Solar PV System Design for Beginners – Ministry of New and Renewable Energy (MNRE), Govt. of India
5. Solar Electricity Handbook (2024 Edition) – https://www.solarelectricityhandbook.com

Suggested Assessment Scheme:

	Performance Indicators	Weightage
	Process Related :15 Marks	**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
	Product Related : 10 Marks	**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 4: Sizing of Solar panels required for a residential house having 500 W electrical load.

I Practical Significance:

Understanding the sizing of solar panels is critically important in real-world applications of renewable energy systems. This practical helps diploma students in Electrical Engineering develop the skills needed to design and implement small-scale solar power systems tailored to specific energy requirements.

II Industry/Employer Expected Outcome(s)

Employers in the electrical and renewable energy sector expect diploma graduates to possess both theoretical knowledge and practical skills in designing basic solar power systems.

III Course Level Learning Outcome(s)

Test the performance of the solar panels.

IV Laboratory Learning Outcome(s)

LLO 4.1 Design solar panel for the residential unit based on annual consumption.
LLO 4.2 Prepare layout for the installation of solar panels.

V Relevant Affective Domain related outcome(s)

1. Demonstrates a responsible attitude toward sustainable energy practices and environmental conservation. Shows willingness to apply learned concepts of solar energy in real-life problem-solving scenarios.

2. Follow ethical practices.

VI Relevant Theoretical Background (With diagrams if required)

To determine the appropriate size of solar panels for a residential house with a 500W electrical load, several key theoretical concepts and factors need to be considered. These form the foundation for the practical sizing calculations.

1. **Electrical Load and Energy Consumption:**

- **Power (P):** The rate at which electrical energy is consumed or produced, measured in Watts (W). The given load is 500 W.
- **Energy (E):** The total amount of electrical work done over a period, measured in Watt-hours (Wh) or Kilowatt-hours (kWh). To size the solar panels, we need to estimate the daily energy consumption. This is calculated by:

$$\text{Energy (Wh/day)} = \text{P (W)} \times \text{Usage Time (hours/day)}.$$

2. **Solar Energy Fundamentals:**

- **Solar Irradiation (Insolation):** The amount of solar energy incident on a surface per unit area over a specific time, typically measured in $kWh/m^2/day$. This varies significantly based on geographical location (latitude), season, time of day, and weather conditions. Data for India is essential for accurate sizing.

3. **Solar Insolation:**

- Assume Average Sunlight Hours (Peak Sun Hours) = 5 hours/day (typical for India or similar tropical areas)

4. **System Losses and Efficiency:**

- **Inverter Efficiency:** The inverter converts DC power from the solar panels (and batteries, if used) to Alternating Current (AC) power for household appliances. This conversion process incurs losses (typically 5-15%).
- **Wiring Losses:** Energy is lost due to the resistance of the wires connecting the solar panels, charge controller, battery, and inverter. These losses depend on wire thickness and length.
- **Charge Controller Efficiency (if using batteries):** A charge controller regulates the flow of power between the solar panels and the batteries, minimizing losses and preventing overcharging or deep discharging.
- **Panel Degradation:** Solar panels gradually lose efficiency over their lifespan (typically 0.5-1% per year). This is usually covered by manufacturer warranties but is a long-term factor.
- **Environmental Factors:** Dust, shading, and the angle of incidence of sunlight on the panels can reduce their output.

5. **Mathematical Relationships:**

The core of solar panel sizing involves these fundamental relationships:

- Daily Energy Needed (Watt-hours) = Load Power (W) × Daily Usage (hours)
- Solar Energy Generated (Wh/day) ≈ Total Solar Panel Wp × Peak Sun Hours × System Efficiency (where system efficiency accounts for losses)
- Number of Panels ≈ Total Wp Required / Watt-peak per Panel.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

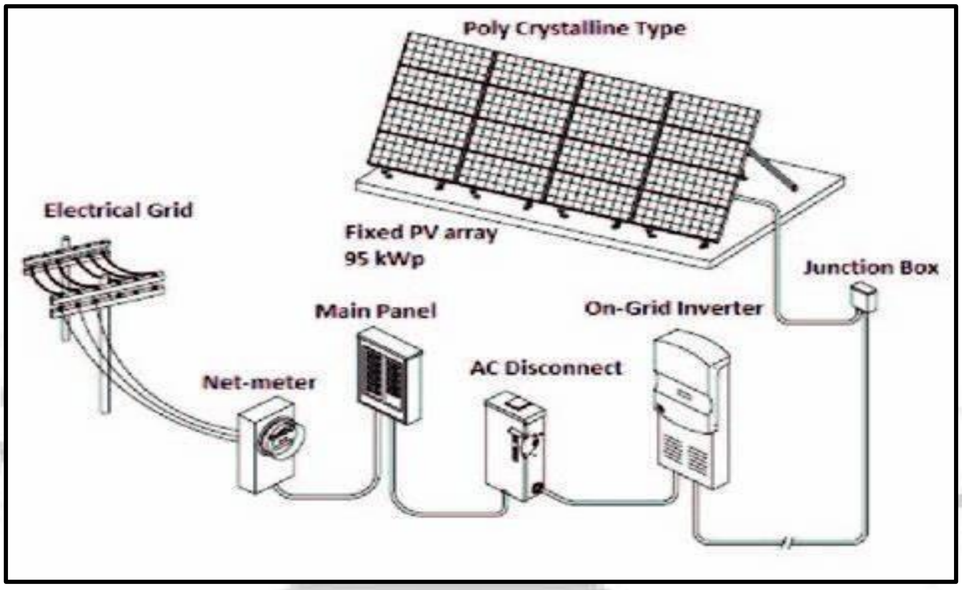

Figure:4.1 Solar Pannel Connection with Electrical Grid

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Solar Panel	250 W, 12V or 24V, Poly/Mono-crystalline	1
2	Electrical Load	500 W (bulbs, fans, or resistive load bank)	1
3	Voltmeter	0–600V	1
4	Ammeter	0–10A	1

IX Precautions to be followed:

1. Calculate your energy needs accurately (in kWh).

2 Ensure the panel design matches your load (number of appliances, usage hours, etc.)

3. Avoid shaded areas or plan for shade-tolerant designs (like micro-inverters).

4. Choose between Monocrystalline, Polycrystalline, or Thin-film:

- Monocrystalline: High efficiency, expensive.

- Polycrystalline: Moderate efficiency, cheaper.
- Thin-film: Less efficient, lightweight, flexible.

5. Higher efficiency panels generate more power per area.

X Procedure:

Step 1: Determine the Electrical Load

- Identify the total electrical power consumption of the household.
- Given: Load power = 500 W
- Determine the number of hours the load runs per day (e.g., 24 hours if continuous).

Step 2: Calculate Daily Energy Requirement

- Calculate total daily energy consumption using:

Energy (Wh/day) =Power (W)×Operating hours (h/day)

For 500 W running 24 hours:

$$500 \times 24 = 12{,}000 \text{ Wh/day} = 12 \text{ kWh/day}.$$

Step 3: Determine Peak Sun Hours (PSH)

- Obtain average peak sun hours for the location (typically 4 to 6 hours/day depending on region).
- For example, assume **5 hours/day** of peak sunlight.

Step 4: Calculate Required Solar Panel Capacity

- Calculate the solar panel capacity needed to generate the required energy in available sun hours:
- Panel Power (W) = Daily Energy Requirement (Wh) / Peak Sun Hours

Step 5: Consider System Losses

- Include losses due to inverter inefficiency, temperature, dust, wiring, etc. (typically 15-20%)
- Using 20% loss:
- Required Capacity = 2,400 W / 0.8 = 3,000 W = 3 kW.

Step 6: Select Number and Size of Panels

- Decide on the size of each solar panel (e.g., 300 W panels).
- Calculate the number of panels needed:
- Number of Panels=Adjusted Capacity / Panel Wattage
- Example:
- Number of Panels = 3,000 W / 300 W per panel = 10 panels.

Step 7: Determine Battery Storage (Optional for Off-Grid)

- Calculate battery capacity based on daily energy and battery voltage.
- If the system is off-grid, battery storage is needed.
- Battery capacity (in Ah) for 12 V system = 12,000 Wh / 12 V = 1,000 Ah

- For a 48 V system:
- Ah required = 12,000 Wh / 48 V = 250 Ah
- Suggested: 4 × 12 V, 250 Ah batteries connected in series
- Select battery bank accordingly (e.g., 4 × 12 V, 250 Ah batteries in series for 48 V system).

Step 8: Select Other Components

- Choose an inverter rated for at least 20-30% higher than load (e.g., 700 W - 1 kW inverter for 500 W load).
- Select appropriate charge controller compatible with the system voltage and panel current.

Step 9: Finalize System Design and Installation

- Arrange panels, batteries, and components according to design.
- Install and test the system ensuring proper safety and performance.

XI Calculations:

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. How do you calculate the total power output from a solar panel array?
2. What precautions must be taken while handling solar panels during installation?
3. Draw & Explain the wiring connection between solar panels, batteries, and inverters.
4. Determine the Sizing of Solar panels required for a residential house having 1000W electrical load.

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XVI References/Suggestions for further reading:

1. Solar PV Schematic Diagram wiringdraw.com
2. Solar Electricity Handbook – Michael Boxwell https://www.solarelectricityhandbook.com
3. MNRE (Ministry of New and Renewable Energy) – Govt. of India https://mnre.gov.in
4. NPTEL Online Course – Solar Photovoltaics https://nptel.ac.in/courses/115107117

Suggested Assessment Scheme:

	Performance Indicators	Weightage
	Process Related :15 Marks	**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
	Product Related : 10 Marks	**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 5: Measurement of Wind Speed at Different Heights and Locations.

I Practical Significance:

Measuring wind speed at different heights and locations is crucial for optimizing wind energy generation, ensuring aviation safety, and improving weather forecasting. It helps in understanding wind behavior for efficient planning in construction, agriculture, and environmental monitoring.

II Industry/Employer Expected Outcome(s)

Accurate wind speed data for selecting optimal sites for wind turbines and infrastructure projects. Improved safety and efficiency in sectors like aviation, construction, and agriculture. Enhanced decision making through reliable environmental and weather data for planning and operations.

III Course Level Learning Outcome(s)

Maintain working of small wind turbines.

IV Laboratory Learning Outcome(s)

LLO 5.1 Measure wind speed using given meters at different heights and locations.

V Relevant Affective Domain related outcome(s)

Develops awareness and appreciation for environmental factors affecting engineering and industrial decisions. Demonstrates responsibility in collecting and analyzing data that influences public safety and sustainability. Shows commitment to applying scientific knowledge for solving real world problems and supporting green energy solutions.

VI Relevant Theoretical Background (With diagrams if required)

Wind energy is a significant renewable energy source. The power available from the wind is proportional to the cube of the wind speed. Therefore, understanding wind speed characteristics at different heights and locations is crucial for the effective design and deployment of wind turbines.

- **Wind Profile and Height:** Near the Earth's surface, friction from obstacles and the ground creates a wind gradient. Wind speed generally increases with height as the influence of surface friction decreases. This relationship can often be approximated by a power law:

$$\frac{V1}{V2} = \left(\frac{h1}{h2} \right)^{\alpha}$$

where:
  - V1) is the wind speed at height (h1)
  - (V2) is the wind speed at height (h2)
  - (α) is the power law exponent, which depends on surface roughness and atmospheric stability (typically ranges from 0.1 to 0.4).

- **Location and Obstructions:** The local environment significantly impacts wind speed. Obstacles like buildings, trees, and terrain features can create turbulence, reduce wind speed in their downwind side, and channel wind flow in other areas. Open and unobstructed locations generally experience higher and more consistent wind speeds.
- **Implications for Wind Energy:** Higher wind speeds at greater heights translate to significantly more power generation potential. Selecting locations with consistently high wind speeds and minimizing the impact of obstructions are critical for maximizing the efficiency and economic viability of wind energy systems.

VII Actual Circuit diagram used with equipment Specifications:

1.Wind Mill

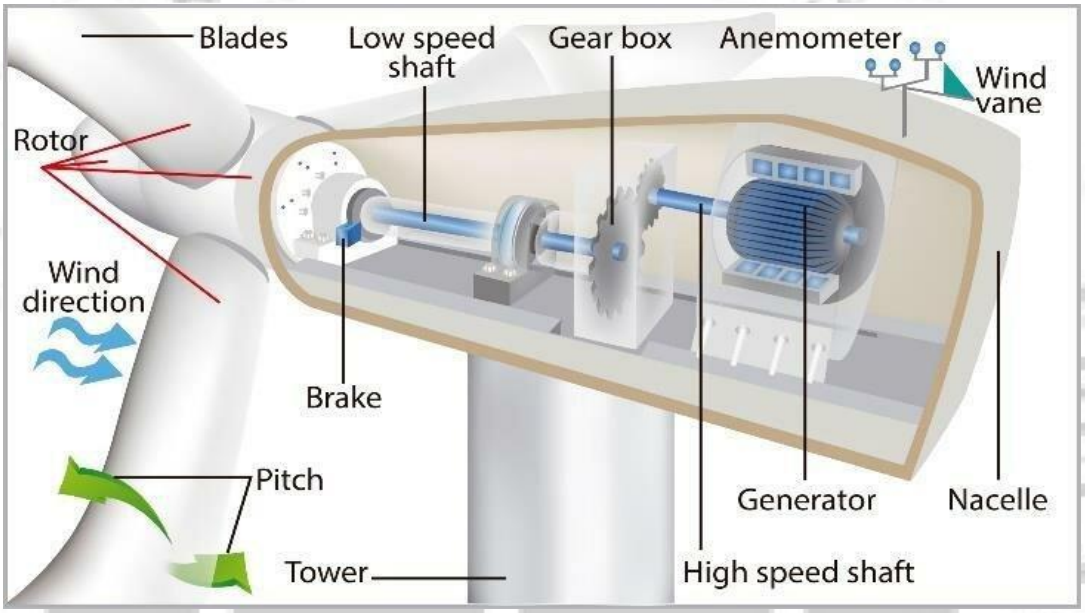

Figure 5.1 Parts of Winds Mill

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Anemometers	Digital or Cup Type	1
2	Measuring Tape.	At least 5 meters	1
3	Tripod or Stable Base	For mounting anemometer	1
4	Compass	Magnetic/Analog or Digital	1
5	Stopwatch	Digital or Analog	As required

IX Precautions to be followed:

1. Handle the anemometers and measurement equipment with care to avoid damage.
2. Ensure the mast is erected securely and stabilized with guy wires to prevent it from falling. Maintain a safe distance during setup and measurement.
3. Be aware of overhead power lines and maintain a safe distance from them.
4. Conduct the experiment in suitable weather conditions. Avoid strong winds, lightning, or heavy rain.
5. Wear appropriate safety gear (hard hats, safety shoes, high-visibility vests, gloves) at all times during the experiment.
6. Work in groups and ensure proper supervision by the instruction.

X Procedure:

Part I: Wind Speed Variation with Height at a Fixed Location)

1. **Site Selection:** Choose an open area with minimal surrounding obstructions (e.g., a field, a rooftop with safe access) for this part of the experiment. Record the GPS coordinates of this location.
2. **Practical Setup:** Carefully assemble and secure the telescopic mast or poles to achieve the desired measurement heights (e.g., 1m, 3m, 5m). Use guy wires to ensure stability, especially at higher elevations.
3. **Anemometer Mounting:** Mount the cup anemometer at the lowest chosen height on the mast. Ensure it is free to rotate without any obstruction.
4. **Wind Speed Measurement:**
    - Allow the anemometer to adjust to the wind flow for approximately 1 minute.
    - Start the stopwatch and count the number of rotations of the anemometer cups for a fixed time interval (e.g., 60 seconds).
    - Record the number of rotations and the time interval.
    - Note down the wind direction using the compass or wind vane.
    - Repeat the measurement 2-3 times at the same height to obtain an average.
5. **Repeat for Different Heights:** Carefully raise the anemometer to the next chosen height on the mast and repeat step 4. Continue this process for all selected heights.
6. **Data Recording:** Ensure all measurements (height, number of rotations, time, wind direction) are recorded systematically in the observation table.

Part II: Wind Speed Variation with Location at a Fixed Height)

1. **Location Selection:** Choose at least four different locations within the accessible area. These locations should represent varying degrees of exposure to wind (e.g., open ground, near a low building, in a slightly sheltered area).
2. **Fixed Height Measurement:** Decide on a fixed measurement height (e.g., 1.5m or 2m) that is easily achievable and consistent across all selected locations.
3. **Anemometer Usage:** Use the handheld digital anemometer for this part due to its portability.
4. **Wind Speed Measurement at Each Location:**
    - At the first selected location, hold the anemometer at the fixed height, ensuring it is held steadily and facing the prevailing wind direction.

- Allow the wind speed reading on the digital anemometer to stabilize for a few seconds.
- Record the instantaneous wind speed reading (in m/s or km/h) at regular intervals (e.g., every 10 seconds) for a duration of 1 minute.
- Note down the wind direction at this location.
- Repeat the measurements 2-3 times at the same location to obtain an average.

5. **Repeat for Different Locations:** Move to the next selected location and repeat step 4. Continue this for all chosen locations.
6. **Data Recording:** Record the location coordinates, measured wind speeds (and the time intervals), fixed height, and wind direction for each location in the observation table.

XI Observations and calculations

Part 1: Variation with Height (at fix Location: ______________)

Sr No.	Height (m)	Time Interval (s)	Number of Rotations	Wind Speed (rotations/s)	Average Wind Speed (rotations/s)	Wind Direction
1.						
2.						
3.						
4.						

Part 2: Variation with Location (at fix Height in meter: __________)

Sr No.	Location	Time Interval (s)	Number of Rotations	Wind Speed (rotations/s)	Average Wind Speed (rotations/s)	Wind Direction
1.	Rooftop					
2.	Play Ground					
3.	Between Building					
4.	Under the roof					

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is the purpose of measuring wind speed at different heights?
2. Why does wind speed generally increase with height?
3. List three applications where accurate wind speed measurement is essential.
4. What precautions should be taken while performing outdoor wind measurements?

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XVI References/Suggestions for further reading:

1. https://www.researchgate.net/publication/330435789/figure/fig1/AS:715894246359040@1547693897163/Parts-of-a-wind-turbine.jpg
2. A textbook of Joshua Earnest, Tore Wizelius Wind Power Plants and Project Development.

Suggested Assessment Scheme:

Performance Indicators		Weightage
Process Related :15 Marks		**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
Product Related : 10 Marks		**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 6: Components of Small Wind Turbine (Horizontal Axis / Vertical Axis).

I. Practical Significance:

Each component like blades, generator, and tower plays a critical role in efficiently converting wind energy into electricity. Their design and placement (horizontal or vertical) affect performance, energy output, and suitability for specific environments such as open fields (HAWT) or urban areas (VAWT).

II Industry/Employer Expected Outcome(s)

Employers expect small wind turbine systems to deliver reliable, cost effective, and sustainable power solutions. They also look for technicians and engineers with skills in installation, maintenance, and troubleshooting of HAWT and VAWT systems, ensuring optimized energy output and system longevity.

III Course Level Learning Outcome(s)

Maintain working of small wind turbines.

IV Laboratory Learning Outcome(s)

LLO 6.1 Dismantle small wind turbine.
LLO 6.2 Identify different parts of small wind turbine.

V Relevant Affective Domain related outcome(s)

Students are knowing the role of each component in sustainable energy systems, show respect for clean energy technologies, and develop a positive attitude toward the implementation and maintenance of wind turbine systems for environmental benefit.

VI Relevant Theoretical Background (With diagrams if required)

Wind energy is a clean and renewable power source that helps reduce greenhouse gas emissions and reliance on fossil fuels. Wind turbines convert wind's kinetic energy into electrical energy. There are two main types of wind turbines: horizontal axis and vertical axis.

Horizontal Axis Wind Turbine:

A horizontal axis wind turbine (HAWT) is defined as a wind turbine with a horizontal rotation axis parallel to the ground. HAWTs are the most common type used for large-scale electricity generation. They usually have three blades like airplane propellers, though some have two or one blade.

The main components of a HAWT are:

The rotor, which consists of the blades and the hub that connects them to the shaft.

The nacelle houses the generator, gearbox, brake, yaw system, and other mechanical and electrical components.

The tower supports the nacelle and the rotor and elevates them above the ground to capture more wind.

The foundation anchors the tower to the ground and transfers the loads from the wind turbine.

The working principle of a HAWT is based on lift, a force that pushes an object upward when air flows over its surface. The blades are shaped like airfoils, creating a pressure difference between their upper and lower surfaces when wind blows. This pressure difference makes the blades rotate around the horizontal axis, driving the shaft and generator to produce electricity.

Vertical Axis Wind Turbine:
A vertical axis wind turbine (VAWT) is defined as a wind turbine with a vertical rotation axis perpendicular to the ground. VAWTs are less common than HAWTs but offer advantages for small-scale and urban use. They typically have two or three straight or curved blades.
The main components of a VAWT are:
The rotor, which consists of the blades and the vertical shaft that connects them to the generator.
The generator, which converts the mechanical energy of the rotor into electrical energy.
The base, which supports the rotor and the generator and connects them to the ground.
The working principle of a VAWT is based on drag, a force that opposes an object's motion when air flows over it. The blades, whether symmetrical or asymmetrical, create varying drag when facing or opposing the wind. This difference in drag makes the blades rotate around the vertical axis, driving the generator to produce electricity.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

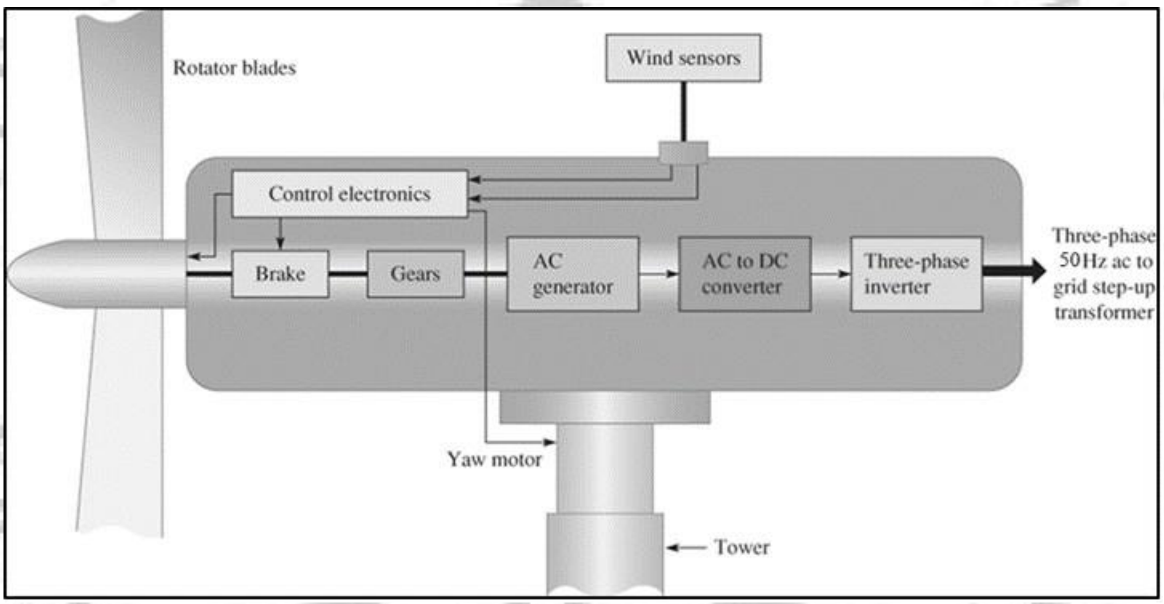

Figure 6.1: Horizontal-Axis Wind Turbine

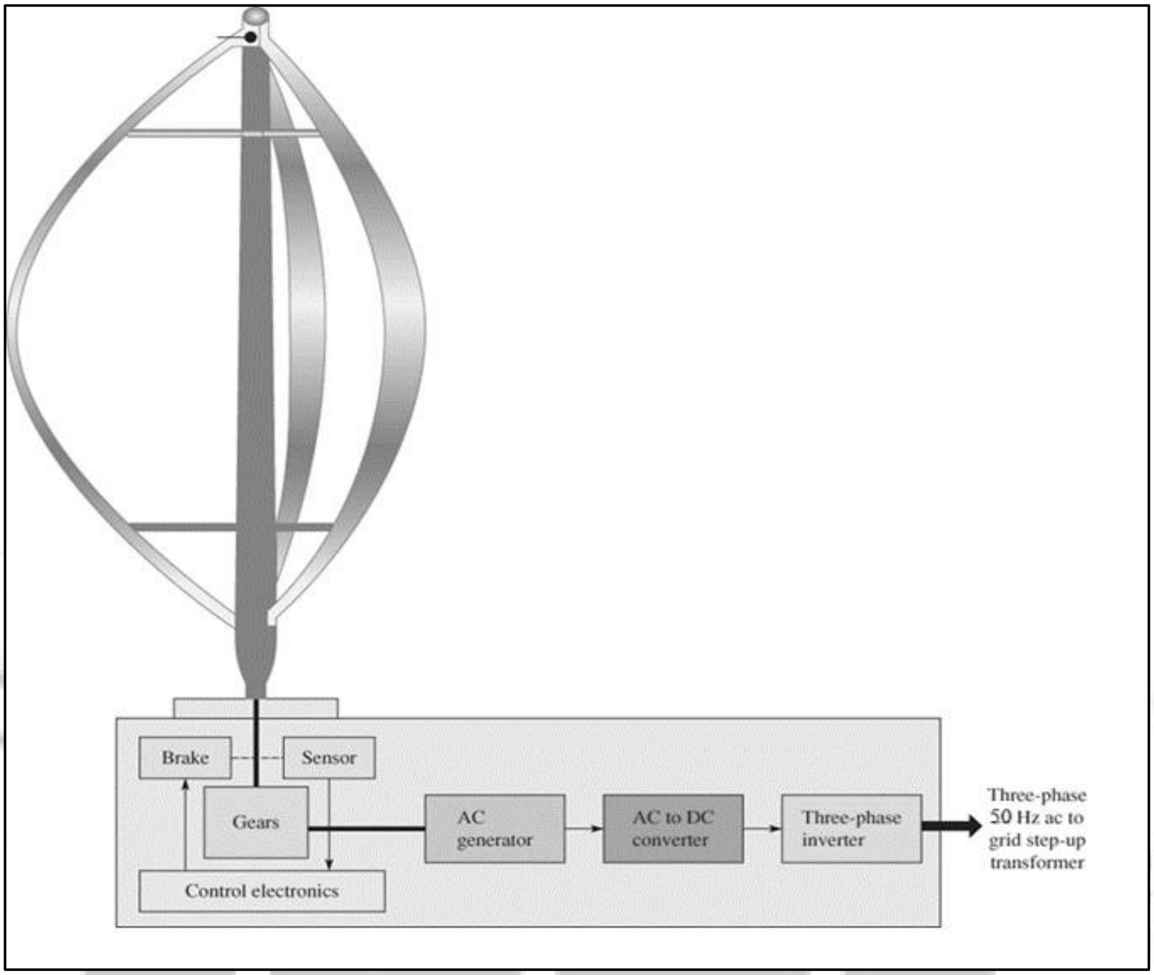

Figure 6.2: Vertical Axis Wind Turbine

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1	Horizontal-Axis Wind Turbine	Experimental kit, Output 20W/50W/75W/100W	01
2	Vertical Axis Wind Turbine	Experimental kit, Output-20W/50W/75W/100W/	01
3	Screw driver	Suitable set	01
4	Plier	Suitable	01
5	Spanner	Suitable	01
6	Hammer	Suitable	01

IX Precautions to be followed:

1. Avoid loose clothing that may get caught in rotating parts.
2. Perform the practical under the supervision of a lab instructor.
3. Ensure the power supply is turned off before connecting or disconnecting any electrical components.
4. Turbine blades should be handled carefully to avoid injury or damage.
5. Do not touch blades when the turbine is in motion.
6. Do not test turbines during high winds or storms.

X Procedure

1. Wear appropriate safety gear (gloves, goggles, closed shoes, etc.).
2. Collect and inspect all components required for the practical (blades, shaft, generator, tower, wires, etc.).
3. Identify each component of the wind turbine (HAWT/VAWT) and understand its function.
4. Assemble the turbine structure according to the model or lab manual instructions.
5. Mount the rotor blades properly with correct orientation and balance.
6. Secure the tower/base to ensure the setup is stable and does not tip over during operation.
7. Make all electrical connections carefully from the generator to the measuring device/load (e.g., battery, multimeter).
8. Check that all connections are tight, insulated, and grounded for safety.
9. Simulate wind flow using a fan (if indoors) or ensure suitable wind conditions (if outdoors).
10. Start the turbine slowly and observe the rotation of blades.
11. Measure electrical output (voltage and current) using appropriate instruments.
12. Note down the function of each component in the below observation table.

XI Observations:

1. Horizontal-Axis Wind Turbine : ________________________

Specification/ Name plate details of given wind turbine: ____________________

Sr. No.	Name of the Part	Material used	Function of the part
1.			
2.			
3.			
4.			
5.			
6.			
7.			

2. Vertical Axis Wind Turbine : ______________________

Specification/ Name plate details of given wind turbine: ______________________

Sr. No.	Name of the Part	Material used	Function of the part
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2.			
3.			
4.			
5.			
6.			
7.			

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is the function of the generator in a wind turbine system?
2. What are the main components of a small wind turbine?
3. What are the advantages of HAWTs & VAWTs
4. Compare between horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT)?

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XVI References/Suggestions for further reading:

1. https://niwe.res.in
2. https://electricalacademia.com/wp-content/uploads/2018/08/Figure-5.png
3. https://electricalacademia.com/renewable-energy/vertical-axis-wind-turbine-vawt-working-types-advantages-disadvantages/
4. https://onlinecourses.nptel.ac.in/noc25_ae12/preview
5. https://www.electrical4u.com/wind-turbine-introduction/

Suggested Assessment Scheme:

Performance Indicators		Weightage
Process Related :15 Marks		**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
Product Related : 10 Marks		**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			Dated signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 7: Performance of Induction Generator.

I Practical Significance:

This experiment helps students understand how an induction motor can function as a generator by converting mechanical energy into electrical energy. It demonstrates the importance of reactive power and is widely applicable in renewable energy systems like wind turbines.

II Industry/Employer Expected Outcome(s)

Students can identify and operate induction generators used in renewable energy and industrial applications. They understand the need for reactive power management and basic load handling in generator systems.

III Course Level Learning Outcome(s)

Maintain working of small wind turbines.

IV Laboratory Learning Outcome(s)

LLO 7.1 Measure output voltage and current of given type of induction generator for different wind speeds.

V Relevant Affective Domain related outcome(s)

Follow safety electrical rules for safe practices, Follow ethical practices.

VI Relevant Theoretical Background (With diagrams if required):

Induction Generator Definition: An induction generator (also known as an asynchronous generator) is defined as an induction machine used to generate electricity.

An induction machine will behave as an induction generator when: Slip becomes negative due to this the rotor current and rotor emf attains negative value. The prime mover torque becomes opposite to electric torque. Now let us discuss how we can achieve these conditions. Suppose that an induction machine is coupled with the prime mover whose speed can be controlled. If the speed of the prime mover is increased such that the slip becomes negative (i.e. speed of the prime mover becomes greater than the synchronous speed). This setup allows the machine to function as an induction generator. If the prime mover's speed increases too much, the generator's efficiency drops. Since the speed during operation isn't synchronous, it's also known as a synchronous generator.

An induction generator isn't self-excited and needs magnetizing current and reactive power to create a rotating magnetic field. This power usually comes from supply mains or another generator.

Induction generators are used in regenerative braking systems and windmills for converting wind energy into electrical energy.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

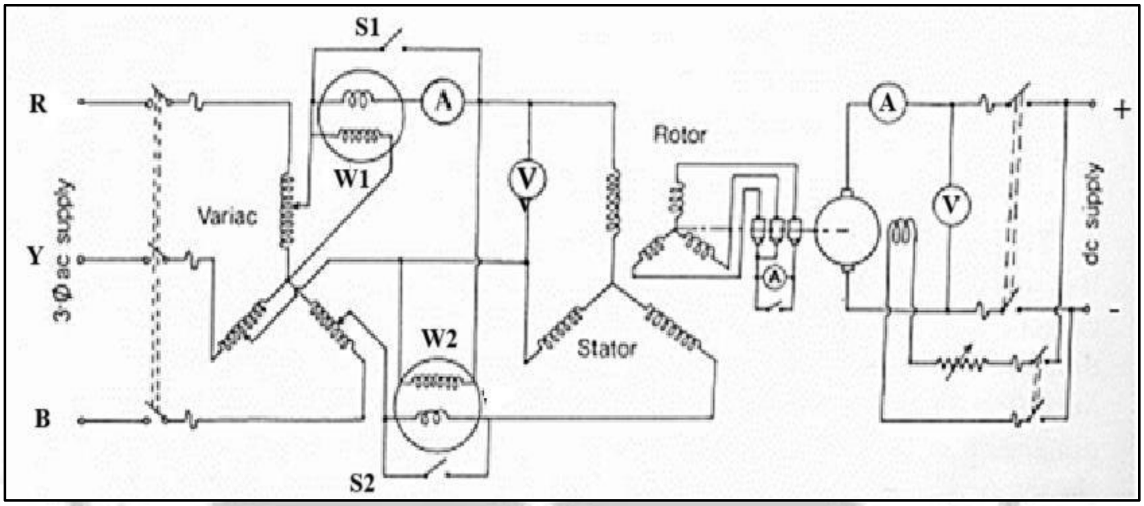

Figure 7.1: Circuit Diagram

VIII Required Resources/apparatus/equipment with specification:

Sr. No.	Name of Resource	Suggested Broad Specification	Quantity
1.	3-phase Induction Motor (used as generator)	3HP/ 5HP,415 V ,50 Hz	01
2.	Prime Mover (DC motor or engine)	DC Shunt Motor, 3 HP,220V	01
3.	Voltmeter	(0–600V AC)	01
4.	Ammeter	(0–10A AC)	01
5.	Wattmeter	(0-1500 Watt)	01
6.	Tachometer		01
7.	Rheostat / Load Bank	440v,10A,	01
8.	Connecting Wires		01

IX Precautions to be followed:

1. Ensure all connections are correct and tight.
2. Don't start the experiment without connecting the capacitor bank.
3. Avoid over-speeding the machine.

X Procedure:

1. Connect the circuit as per the diagram. Supply the stator through an autotransformer.

2. Start the induction motor using the autotransformer. When it reaches near rated speed, open the shorting switch on the ammeter and wattmeter.

3. Excite the coupled DC machine separately. Use separate switches for the field and armature.
4. Build up the DC armature voltage and match it with the supply voltage by adjusting field resistance. Check polarity and close the armature switch.
5. Slowly increase the speed by reducing the field current of the DC machine.
6. Use a stroboscope or tachometer to measure the speed and calculate the slip.
7. Use two wattmeter's for active power (assuming balanced load).Use another wattmeter with line current and phase-to-phase voltage for reactive power (√3 × reading).
8. Reduce the DC machine field current further until the rotor slip is zero (oscillation stops), indicating synchronous speed and open-circuit condition.

XI Observations:

Sr. No.	Voltage (V)	Current (A)	Wattmeter Reading (W)	Wattmeter Reading * Multiplying Factor =W *M.F.	Speed (RPM)	Slip
1.						
2.						
3.						
4.						
5.						

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical Related Questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What is an induction generator?
2. What are the conditions required for an induction machine to operate as a generator?
3. How does an induction generator differ from an induction motor?
4. Why is an external reactive power source (capacitor bank or grid) required for an induction generator?

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XVI References/Suggestions for further reading:

1. https://ee.iitkgp.ac.in/assets/file/TeachingLabs/MachineLab/Induction1.pdf.

2. https://www.electrical4u.com/induction-generator/

Suggested Assessment Scheme:

Performance Indicators		Weightage
Process Related :15 Marks		**60%**
1	Handling of the components	10 %
2	Identification of component	20 %
3	Measuring value using suitable instrument	20 %
4	Working in team	10 %
Product Related : 10 Marks		**40%**
5	Identify theoretical values of given component from datasheets	10 %
6	Interpretation of result	05 %
7	Conclusions	05 %
8	Practical related questions	15 %
9	Submitting the journal in time	05%
Total (25 Marks)		**100 %**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 08 Demonstration of Hydrogen fuel cell.

I Practical Significance

In the industry Electrical Engineering diploma graduate are expected to maintain the functioning and operation of Hydrogen fuel cell troubleshoot the components of Hydrogen fuel cell. Therefore, this practical will help you to acquire necessary skills.

II Industry/Employer Expected Outcome(s)

Maintain the functioning and operation of the electrical power generation, from Hydrogen fuel cell.

III Course Level Learning Outcome(s)

Utilize small-capacity hydrogen fuel cell systems for various applications.

IV Learning Outcome(s)

LLO 8.1 Identify different components of fuel cell by dismantling experimental kit.
LLO 8.2 Assemble the fuel cell kit and operate fuel cell on load.

V Relevant Affective Domain related outcome(s)

a. Follow safety practices.
b. Maintain tools and equipment.
c. Maintain tools and measuring instruments.
d. Follow ethical practices.

VI Relevant Theoretical Background

Hydrogen fuel cell:

Hydrogen fuel cells are electrochemical devices that directly convert chemical energy into electrical energy. They operate on the principle of electrochemical oxidation, where hydrogen is reacted with oxygen to produce electricity, water, and heat. Unlike traditional combustion engines, fuel cells offer higher efficiency, lower emissions, and potentially zero-carbon emissions when using green hydrogen.

Electrochemical Reaction:

The core of a fuel cell involves the electrochemical oxidation of hydrogen (fuel) and reduction of oxygen (oxidant).

Anode and Cathode:

The fuel cell has an anode where hydrogen is oxidized, and a cathode where oxygen is reduced.

Electrolyte:

An electrolyte, such as an acidic or alkaline solution, facilitates the movement of ions (protons) between the anode and cathode.

Catalysts:

Catalysts, such as platinum or palladium, are used on the electrodes to accelerate the electrochemical reactions.

Overall reaction: $2 H_2(gas) + O_2(gas) \rightarrow 2 H_2O$ + energy

VII Practical set-up / Circuit diagram / Work Situation.

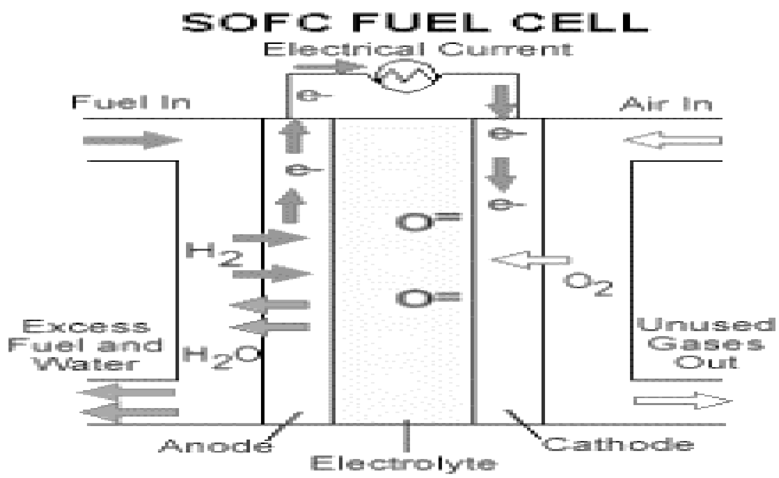

Figure 8.1 Hydrogen fuel cell plant

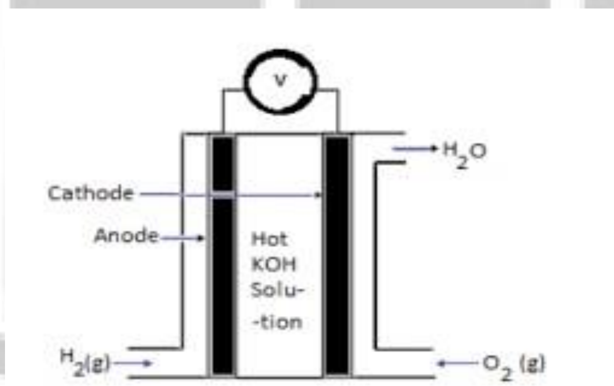

Figure 8.2 Block diagram of Hydrogen fuel cell

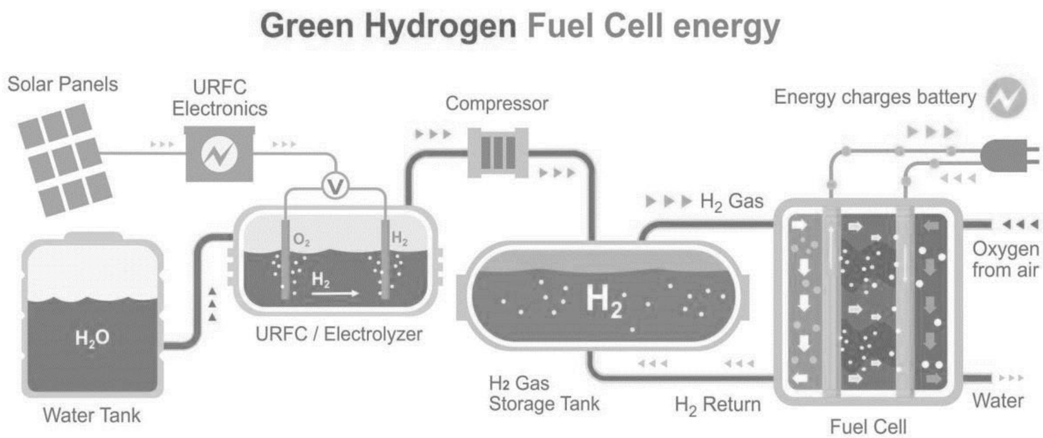

Figure 8.3 Layout of Hydrogen fuel cell

VIII Required Resources/apparatus/equipment with specification

1.Anode,
2.Chathode
3. Hydrogen,

IX Precautions to be followed

1. Watch authentic videos of Hydrogen fuel cell.
2. learn the function of Hydrogen fuel cell devices very well and their significance in.
3. Identify different components of fuel cell by dismantling experimental kit
4. assemble the fuel cell kit and operate fuel cell on load.
5. Learn the function of fuel cell.

X Procedure

1. Watch readings of Hydrogen fuel cell.
2. Students will observe Hydrogen fuel cell under the guidance of the teacher.
3. Observe the operation of various components of Hydrogen fuel cell.

XI Collect the following information about Hydrogen fuel cell:

1. Name of the power station…………………………………………………………………………
2. Specifications ……………………………………………………………………………......
3. No. of Units ………………………………………………………………………………......
4. Capacity of each unit ……………………………………………………………………...
5. Total installed capacity …………………………………………………………………....
6. Type of power station……………………………………………………………….…...
7. Rating of generator…………………………………………………………………………...

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Write the operation of Hydrogen fuel cell in brief.
2. Name the factors on which the generating capacity of Hydrogen fuel celldepends.
3. List the Hydrogen fuel cell (with capacity) in Maharashtra.
4. State the advantages of Hydrogen fuel cell compared to Thermal power stations.
5. Write the difference between Hydrogen fuel cell and water turbine.

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XVI References/Suggestions for further reading

1. https://youtu.be/8q0Zi55qNqU
2. https://en.wikipedia.org/wiki/Fuel_cell
3. https://vajiramandravi.com/upsc-exam/hydrogen-fuel-cell/
4. https://www.3mindia.in/3M/en_IN/hydrogen-technology-in/applications/fuel-cells/
5. https://www.researchgate.net/publication/349531500/figure/fig1/AS:1010701585903619@1617981444677/Schematic-of-a-PEM-fuel-cell.jpg
6. https://www.vedantu.com/question-sets/4071e0b8-78a1-429a-a21a-aafcbbd993e2240805035377972O649.png
7. https://totalshield.com/wp-content/uploads/2023/03/green-energy-system-clear-enclosures-1-1024x476.png

Suggested Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Identification of the components of Hydrogen fuel cell	10%
2	Drawing of layout/preparation of plan and elevation diagram	20%
3	Interpretation of normal operation of the Hydrogen fuel cell	20%
4	Understanding the importance of team work in Hydrogen fuel cell	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	5%
7	Conclusions	5%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100 %**

Marks Obtained			**Dated signature of teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 09: Demonstration of biogas operated plant. OR Visit to biogas operated plant.

I Practical Significance

In the industry Electrical Engineering diploma graduate are expected to maintain the functioning and operation of biogas operated plant and troubleshoot the components of biogas operated. Therefore, this practical will help you to acquire necessary skills.

II Industry/Employer Expected Outcome(s)

Maintain the functioning and operation of the renewable energy technology

III Course Level Learning Outcome(s)

Maintain basic components of biogas plant.

IV Laboratory Learning Outcome(s)

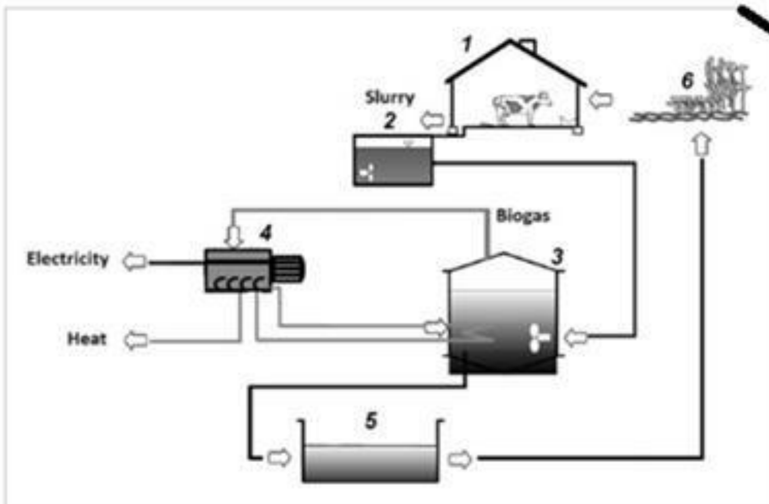
LLO 9.1 Identify different components of biogas operated plant.
LLO 9.2 Observe the output of biogas plant OR prepare a report on biogas operated Plant.

V Relevant Affective Domain related outcome(s)

a. Follow safety practices.
b. Maintain tools and equipment.
c. Maintain tools and measuring instruments.
d. Follow ethical practices.

VI Relevant Theoretical Background

Biogas Production: Biogas is produced through anaerobic digestion of organic matter, such as agricultural waste, food waste, or sewage sludge. The biogas is primarily composed of methane (CH_4) and carbon dioxide (CO_2). Biogas can be used as a fuel for internal combustion engines or gas turbines to generate electricity. Biogas is collected from the digester and purified to remove impurities. The purified biogas is used as fuel for an internal combustion engine or gas turbine. The engine or turbine drives a generator to produce electricity.
Biogas-operated electricity generation offers several benefits, including, Renewable energy source: Biogas is a renewable energy source, reducing dependence on fossil fuels.Waste management: Biogas production can help manage organic waste, reducing environmental impacts. Energy self-sufficiency: Biogas-operated electricity generation can provide energy self-sufficiency for farms, industries, or communities. By understanding the theoretical background of biogas operated plants for electrical energy generation, operators can optimize plant design and operation, ensuring efficient and reliable electricity generation.



Technological diagram of the analysed agricultural biogas plant [own elaboration]. 1—livestock facility, 2—slurry tank, 3—digester with biogas tank, 4—cogeneration unit, 5—digestate tank, 6—agricultural field.

Figure 9.1 Alternator coupled to biogas power plant

Block diagram given below gives-the inter connection of biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity. The design of an electric generator is similar to the design of an electric motor.

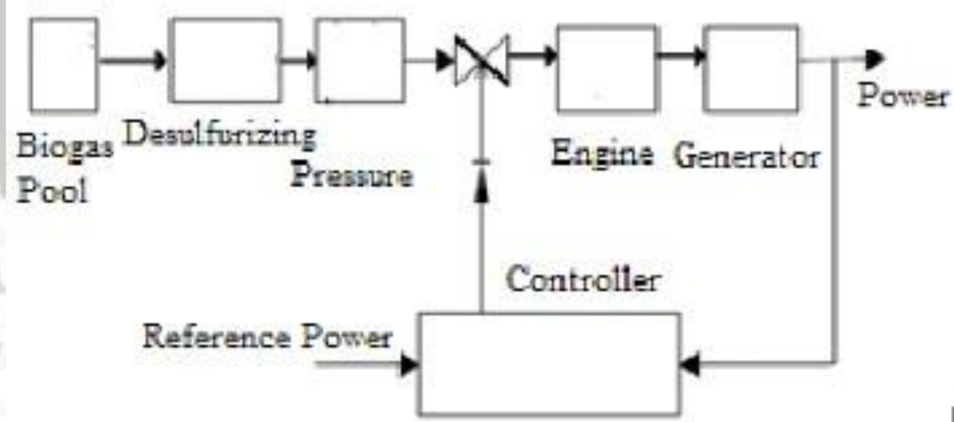


Figure 9.2 Block diagram of biogas operator power plant

VII Actual Circuit diagram used in laboratory with equipment Specifications:

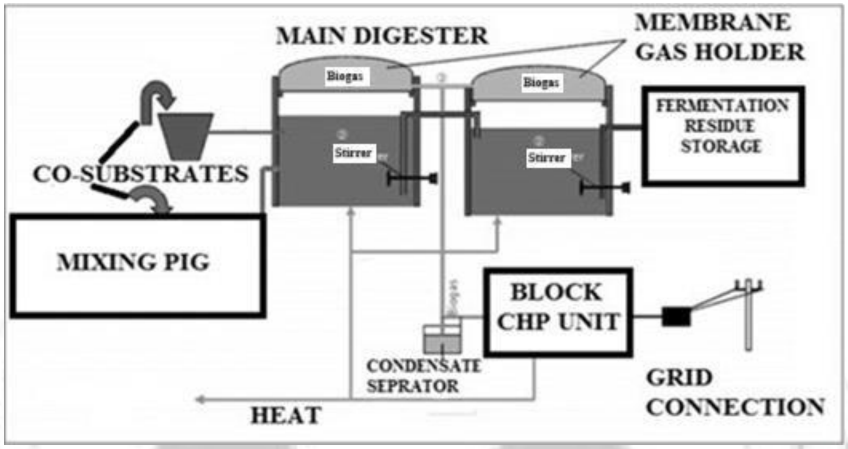


Figure 9.3 Layout of biogas operator Power Plant

VIII Required Resources/apparatus/equipment with specification:

1. Drawing tools
2. Half Imperial drawing sheet
3. Videos on biogas operator station

IX Precautions to be followed:

1. Watch authentic videos and learn layout of biogas operator plant.
2. Use proper symbols while drawing the layout on the imperial half-sheet.

X Procedure:

1. Watch videos of biogas operator plant/ visit biogas operator station.
2. Students will draw this layout on the drawing sheet under the guidance of the teacher.
3. Observe the operation of various components of biogas operator station.

XI Collect the following information about Hydro Power plant:

1. Name of the power station: …………………………………………………………………….

2.Specifications:……………………………………………………………………………………

3.No. of Units :……………………………………………………………………………………

4. Capacity of each unit:…………………………………………………………………………….

5. Total installed capacity:…………………………………………………………………………..

6. Type of turbine:………………………………………………………………………………..

7. Type of cooling system:……………………………………………………………………….

8 .Rating of generator:……………………………………………………………………………

XII Observation table (use blank sheet provided if space not sufficient)

Sr. No.	List of Component	Function	Specification
1	Inlet		
2	Digester		
3	Gas purification unit		
4	Gas flow controller		
5	Engine		
6	Generator		
7			
8			

Note: If any addition equipment then students add some list of component

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Write the operation of biogas operator station in brief.
2. Name the factors on which the generating capacity of biogas operator station depends.
3. List the biogas operator station (with capacity) in Maharashtra.
4. State the advantages of-biogas operator stations compared to Thermal power stations.
5. Write the difference between steam turbine and biogas operator power plant.

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XVI References/Suggestions for further reading

1. https://www.electrical4u.com/hydro-power-plant-construction-working-and-history-ofhydro-power-plant/ ttps://www.britannica.com/science/hydroelectric-power
2. https://www.energy.gov/eere/water/types-hydropower-plants
3.https://www.researchgate.net/publication/308704133/figure/fig2/AS:677176869408774@1538462955804/Block-Diagram-of-Bio-gas-power-plant.png
4. https://www.mdpi.com/applsci/applsci-14-04200/article_deploy/html/images/applsci-14-04200-g001-550.jpg
5. https://ars.els-cdn.com/content/image/3-s2.0-B9780128227183000046-f04-12-9780128227183.jpg

Suggested Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Identification of the components of-biogas operator power plant	10%
2	Drawing of layout/preparation of plan.	20%
3	Interpretation of normal operation of the plant	20%
4	Understanding the importance of team work in various power plants.	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusions	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process related (15)	**Product related (10)**	**Total (25)**	

Practical No.10: Demonstration of geothermal power plant using video/animation.

I Practical Significance:

In this experiment demonstrates a geothermal power plant converts heat from the Earth's interior into electricity. A video/animation can visually demonstrate this process, including the drilling of wells, extraction of hot water or steam, and the use of a turbine and generator to produce electricity Optimize power output from solar panels.

II Industry/Employer Expected Outcome(s)

1. Ability to install and operate geothermal power plants, ensuring stable and clean energy generation.
2. Competence in analyzing system performance under various environmental and operational conditions.
3. Contribution to energy independence, local economic development, and technological advancement in renewable energy.

III Course Level Learning Outcome(s)

Identify major components of the geothermal, ocean and small hydro power plants.

IV Laboratory Learning Outcome(s)

LLO 10.1 Identify different components of geothermal power plant

V Relevant Affective Domain related outcome(s)

1.Follow safety practices.
2.Maintain tools and equipment.
3.Maintain tools and measuring instruments.
4.Folow ethical Practices

VI Relevant Theoretical Background (With diagrams if required)

Geothermal power plants use Earth's internal heat to generate electricity. They tap into high-temperature, underground reservoirs of hot water or steam, which then drives turbines to produce electricity. This process involves several key steps: drilling into the Earth's crust, extracting hot fluids, converting them into steam, spinning a turbine, and ultimately generating electricity

Drilling and Extraction:

Deep wells are drilled into the Earth to access geothermal reservoirs, requiring specialized drilling technologies and materials.

Turbine and Generator Technology:

Steam or hot water is used to power turbines, which are connected to generators to produce electricity.

Waste Heat Management:

Condensate, which is the cooled steam, is often reinjected back into the reservoir to maintain the resource and minimize environmental impact.

Environmental Considerations:

Geothermal power plants have a relatively low environmental impact compared to fossil fuel plants, but concerns about potential emissions and seismic activity need to be addressed.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

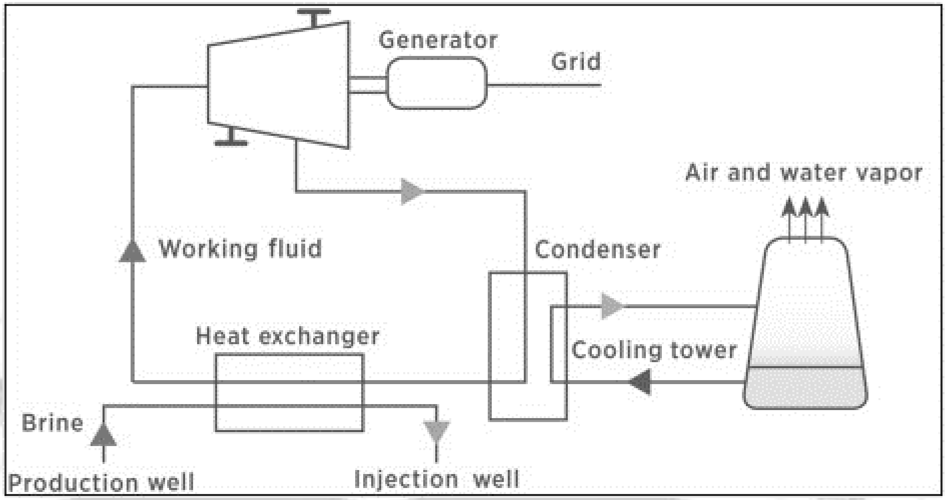

Figure: 10.1 Working and construction of geothermal power plant

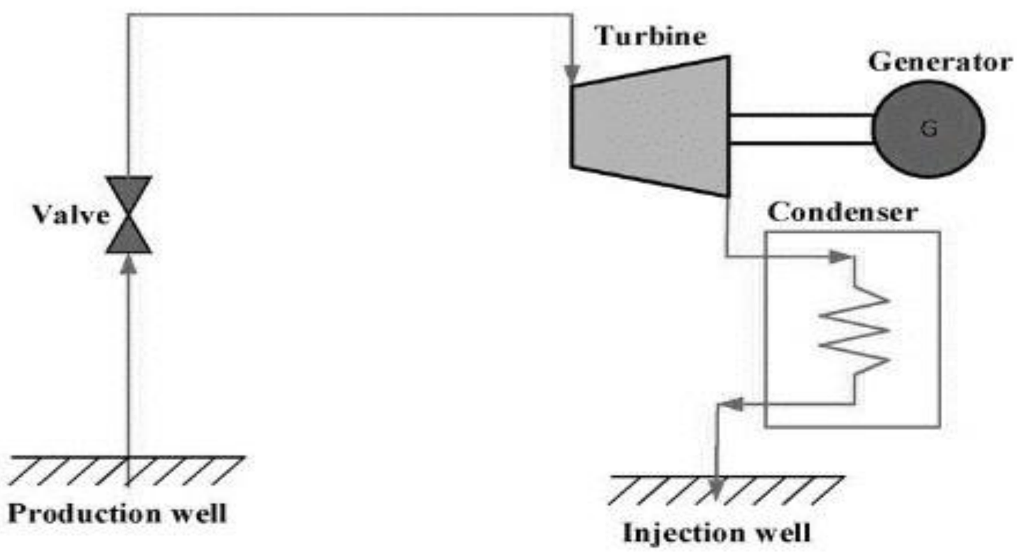

Figure: 10.2 Block diagram of geothermal power plant

VIII Required Resources/apparatus/equipment with specification:

1. Geothermal Reservoirs:

- Type: Hydrothermal resources (hot water or steam).
- Temperature: 300°F to 700°F.
- Depth: Wells can be as deep as 2 miles.

2. Wells:

- Type: Drilled into the earth to access geothermal reservoirs.
- Depth: Varies depending on reservoir depth and location.
- Pumps: Down hole pumps to extract water or steam from the wells.

3. Piping Systems:
- Type: Pipes to transport steam or hot water from wells to the surface.
- Material: Typically made of corrosion-resistant materials suitable for geothermal fluids.

4. Turbines:
- Type: Steam turbine (for dry steam and flash steam plants) or organic Rankine cycle (ORC) turbine (for binary cycle plants).
- Power Output: Designed to generate the required amount of power.

5. Generators:
- Type: Electric generators powered by the turbines.
- Output: Produces electricity for distribution to the grid.

6. Heat Exchangers:
- Type: Used in binary cycle plants to transfer heat from geothermal water to another fluid with lower boiling point.
- Materials: Designed to withstand high temperatures and pressures.

7. Pumps:
- Type: Condensate pumps, cooling water circulation pumps, brine injection pumps, etc.
- Specifications: Chosen based on flow rate, pressure, and material requirements.

8. Control Systems:
- Type: Automated control systems to monitor and manage plant operations.
- Features: Include pressure transmitters, temperature transmitters, and flow meters.

9. Other Equipment:
- Silencers: To reduce noise from steam and gas.
- Separators: To remove sand and particulate matter from steam and brine.
- Flash vessels: To separate steam from hot water in flash steam plants.
- Cooling Towers: To dissipate heat from the power plant.
- No condensable Gas Removal System: To remove non-condensable gases like hydrogen sulfide.

IX Precautions to be followed:
1. Hazard Identification and Training.
2. Equipment Maintenance and Monitoring:
3. Environmental Considerations:
4. Emergency Preparedness:
5. Community Safety.

X Procedure
1. Watch videos of geothermal power plant / visit geothermal power plant operator station.
2. Students will draw this layout on the drawing sheet under the guidance of the teacher.
3. Observe the operation of various components of geothermal power plant.

XI Observations table:

Sr. No.	Geothermal Power Plants Equipment	Function
1.	Geothermal Reservoirs	
2	Turbines	
3	Generators	
4	Heat Exchangers	

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What are the biggest problems with geothermal energy?
2. Which type of geothermal power plant system is the most common?
3. What is the temperature of a geothermal well?
4. What is the future of geothermal energy?

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XVI References/Suggestions for further reading:

1. https://en.wikipedia.org/wiki/Geothermal_power
2. https://en.wikipedia.org/wiki/Electric_power
3. https://youtu.be/mCRDf7QxjDk
4. https://cdnintech.com/media/chapter/76368/1512345123/media/F1.png
5. https://ars.els-cdn.com/content/image/1-s2.0-S1364032121001465-gr18.jpg

Suggested Assessment Scheme:

	Performance Indications	Weightage
	Process Related: 15 Marks	**60%**
1	Identification of the component of geothermal power plant	10%
2	Drawing of layout of the geothermal power plant	20%
3	Interruption of normal operation of the plant	20%
4	Understanding the importance of term work in various power plant	10%
	Product Related :10 Marks	**40%**
5	Calculate theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusions	05%
8	Practical related question	15%
9	Submitting the journal in time	05%
	Total (25)	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 11: Demonstration of Tidal and Wave Power Plant Using Video/Animation.

I Practical Significance:

Tidal energy, harnessed from the natural rise and fall of tides, can be utilized through barrages or stream turbines to generate power. Wave power, derived from ocean waves, uses various technologies, including oscillating water columns and submerged devices, to convert wave motion into electricity.

II Industry/Employer Expected Outcome(s)

The market is expected to grow due to increasing demand for clean energy and government support, requiring collaborative efforts and cost reduction strategies to overcome the initial investment hurdle

III Course Level Learning Outcome(s)

Identify major components of the geothermal, ocean and small hydro power plants.

IV Laboratory Learning Outcome(s)

LLO11.1 Prepare a report on tidal and wave power plant.

V Relevant Affective Domain related outcome(s)

1. Follow safety practices.
2. Maintain tools and equipment.
3. Maintain tools and measuring instruments.
4. Follow ethical Practices

VI Relevant Theoretical Background (With diagrams if required):

Tidal Power:

Barrage Systems: Tidal barrages, similar to dams, are built across inlets or bays to create a tidal basin. During high tide, water flows into the basin, and when the tide recedes, the water flows back out, turning turbines to generate electricity.

Stream Turbines: These turbines, resembling underwater wind turbines, utilize the constant flow of tidal currents to generate electricity.

Predictability and Reliability:

Tidal energy is a predictable and reliable source compared to wind or solar, as it is driven by predictable lunar cycles.

Environmental Considerations:

Tidal barrages can have some environmental impacts, such as habitat destruction and changes in tidal levels, but these can be mitigated through careful design and site selection.

Wave Power:

Various Technologies:

Wave energy conversion (WEC) technologies include oscillating water columns, submerged devices, and surface devices.

Challenges:

Developing robust and efficient WEC devices that can withstand harsh ocean conditions is a major engineering challenge.

Potential for Growth:

As technology improves and environmental impacts are addressed, wave energy holds significant potential as a renewable energy source.

Electricity Generation:
Both tidal and wave power can contribute to the electricity grid, reducing reliance on fossil fuels and emissions.
Coastal Applications:
Tidal energy can be used to power coastal communities and support other industries like aquaculture and ocean research.
Sustainability:
These renewable energy sources offer a sustainable alternative to traditional energy sources, reducing the environmental impact of energy production.
Economic Benefits:
Development of tidal and wave power projects can create jobs and stimulate economic growth in coastal regions.

VII Actual Circuit diagram used in laboratory with equipment Specifications:

Figure : 11.1 Block diagram of tidal and wave power plant

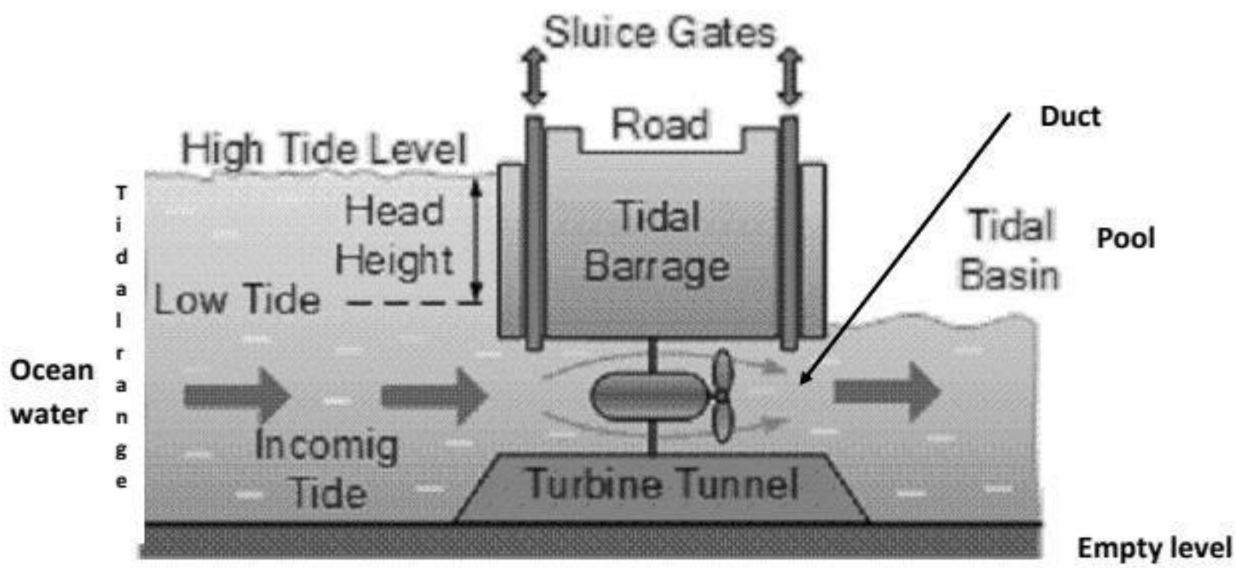

Figure : 11.2 Layout of Tidal And Wave Power Plant

VIII Required Resources/apparatus/equipment with specification:

Tidal Power Plant Resources and Equipment:
Dam or Barrage: A barrier constructed across a tidal channel to form a tidal basin or create a head of water.
Turbines: Rotating devices (typically horizontal or vertical axis turbines) that convert the kinetic energy of moving water into mechanical energy.
Generators: Convert mechanical energy into electricity.
Sluice Gates: Used to regulate the flow of water and control the level of the tidal basin.
Powerhouse: A structure housing the turbines, generators, and other electrical equipment.
Underwater Cables: Used to transmit electricity from the power plant to the grid.

IX Precautions to be followed:

1. Site Selection
2. Environmental Impact Assessment
3. Marine Life Protection
4. Long-term Sustainability

X Procedure:

1. Watch videos of tidal and wave power plant using video/animation.
2. Students will draw this layout on the drawing sheet under the guidance of the guidance of teacher.
3. Observe the operation of various compliments of tidal and wave power plant using video/animation.
4. How they work: Turbine placement, Tidal Barrages, Water flow, Two-way generation

XI Observation Table:

Sr. No.	Tidal and Wave Power Plants Equipment	Function
1	Sluice Gate	
2	Turbines	
3	Generators	
4	Tidal Barrage	

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical Related Questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. What are the limitations of tidal energy?
2. What method by which tidal waves are used to generate electricity?
3. Which country uses tidal energy the most?
4. What are the negative effects of tides?
5. How many tides per day?
6. What is the biggest problem with tidal power?

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XVI References/Suggestions for further reading:

1. https://youtu.be/kYCRO-yfRvc
2. https://en.wikipedia.org/wiki/Tidal_power
3. https://www.researchgate.net/publication/313799656/figure/fig2/AS:642460476784649@1530185922279/Flow-diagram-of-tidal-power-generation.png
4. https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcRh9Ap1ijGTW00G5vK-jK3BGxm9Rx0Tmrwn-Q&s

Suggested Assessment Scheme

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Identification of the components of tidal and wave power plant	10%
2	Drawing of layout/preparation of plan and elevation diagram/preparation of single line diagram	20%
3	Interpretation of normal operation of the tidal and wave power plant	20%
4	Understanding the importance of team work in various tidal and wave power plant	10%
	Product Related: 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusions	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 12: Demonstration of marine power plant and ocean thermal energy conversion (OTEC) plant using video/animation.

I Practical Significance:

It harnesses the temperature difference between surface and deep ocean waters to generate electricity, offering a stable and continuous renewable energy source. OTEC is particularly relevant for remote island communities and coastal areas where conventional energy sources may be scarce or expensive.

II Industry/Employer Expected Outcome(s)

Employers shift towards sustainable and reliable energy generation, reduced reliance on fossil fuels, and potential economic benefits.

III Course Level Learning Outcome(s)

Identify major components of the geothermal, ocean and small hydro power plants.

IV Laboratory Learning Outcome(s)

LLO12.1 Prepare a report on marine power plant and ocean thermal energy conversion (OTEC) plant.

V Relevant Affective Domain related outcome(s)

1. Follow safety practices.
2. Maintain tools and equipment.
3. Maintain tools and measuring instruments.
4. Follow ethical Practices.

VI Relevant Theoretical Background (With diagrams if required)

Temperature Gradient:
OTEC relies on the natural temperature difference between the surface and deep ocean, often 20°C (36°F) or more.

Heat Engine:
The temperature difference drives a heat engine, similar to a reverse air conditioner, which can be used to generate mechanical work (e.g., spinning a turbine).

Rankine Cycle:
A common cycle used in OTEC is the Rankine cycle, where a working fluid (like ammonia) is evaporated by the warm water, drives a turbine, and then condensed by the cold water, creating a continuous cycle.

Thermodynamics:
The principles of thermodynamics, particularly the first law (conservation of energy), are applied to model and analyze the performance of OTEC systems.

Working Fluid:
Various working fluids, such as ammonia, have been used in OTEC systems, each with its own properties and advantages

Efficiency:
OTEC systems have a limited efficiency compared to other power generation technologies due to the low temperature difference available.

Location:
OTEC is best suited for tropical regions with a stable temperature gradient.
Water Volume:

OTEC plants require large volumes of both warm and cold water, so access to these resources is crucial.
Cost:
The initial cost of building and operating an OTEC plant can be high, but the long-term benefits of clean, renewable energy are significant.

Environmental Impact:

OTEC has the potential to be a clean and sustainable energy source, unlike fossil fuel based power plants.

Challenges:

Some challenges include developing efficient and durable systems, addressing the cost of construction, and ensuring minimal environmental impact.

VII Actual Circuit diagram used in laboratory.

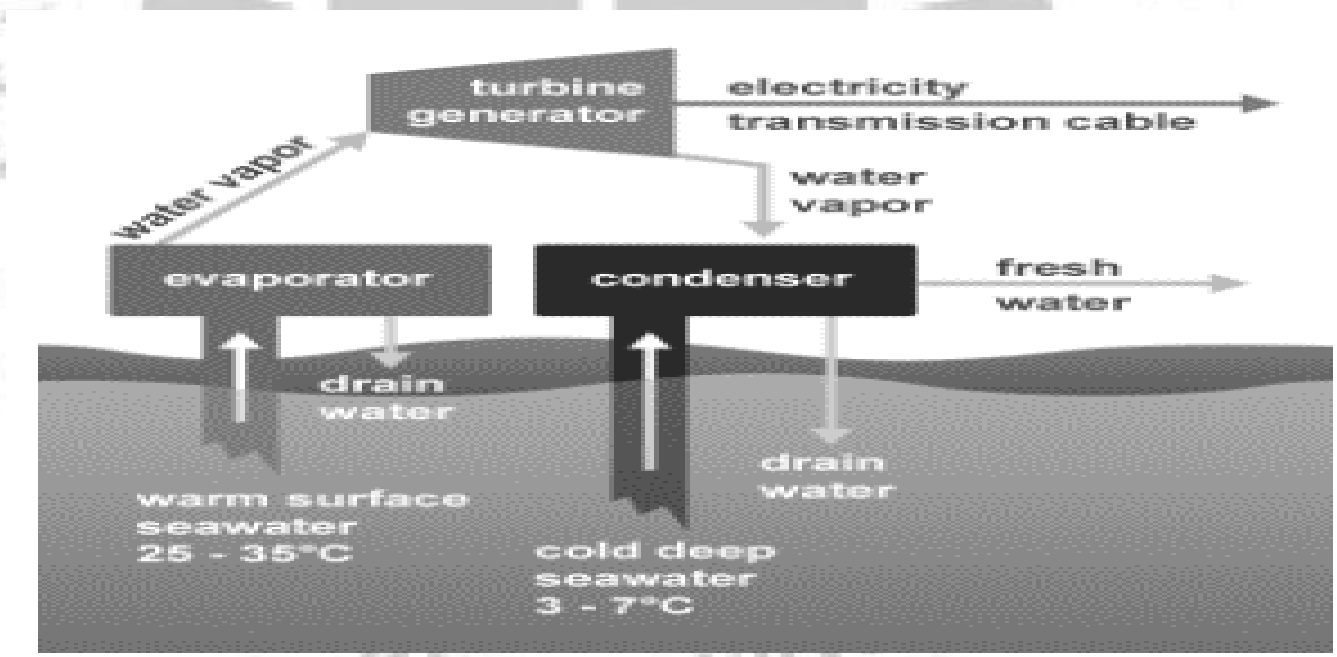

Figure 12.1 Layout of marine power plant and ocean thermal energy

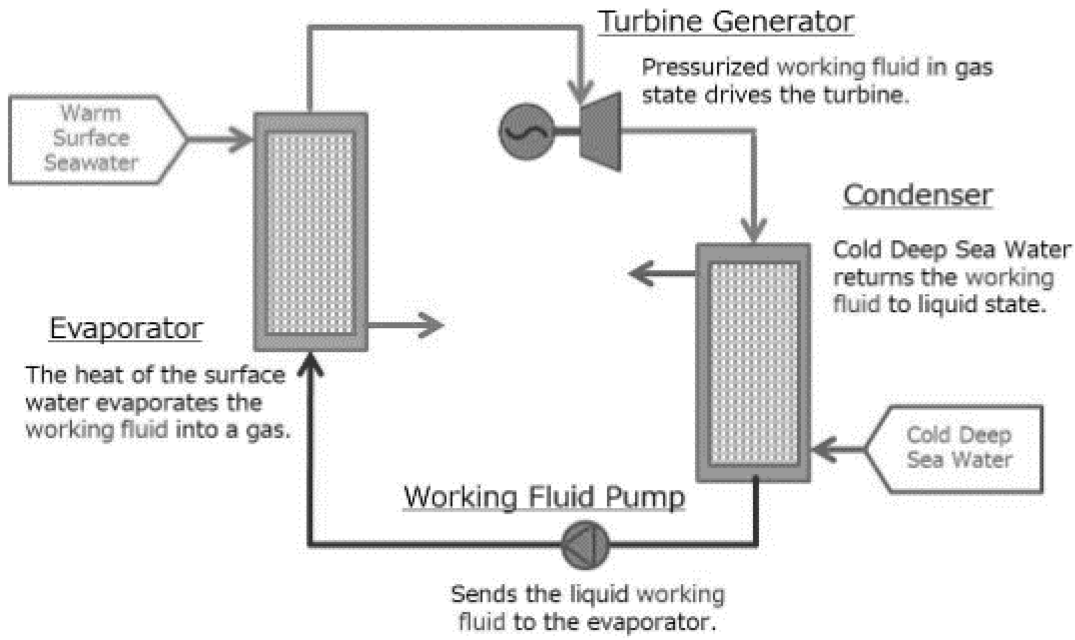

Figure 12.2 Block diagram marine power plant and ocean thermal energy

VIII Required Resources/apparatus/equipment with specification:

1. Drawing tools
2. A4 size drawing sheet
3. Videos on OTEC

IX Precautions to be followed:

1. Maintenance and Inspection:
2. High-Voltage Safety:
3. Fire Safety:
4. Emergency Procedures:

X Procedure

1. Watch videos of OTEC or visit OTEC
2. observe the operation of various components of OTEC

Collect the information about OTEC

Name of OTEC: ________________________________

XI Results:

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XII Interpretation of results:

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XIII Conclusion and recommendation:

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XVI Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. How can the efficiency of OTEC systems be improved to make them more viable for large-scale power generation?
2. What are the potential future applications of OTEC beyond electricity generation, such as desalination and hydrogen production?
3. What is a major limitation of ocean thermal energy conversion?
4. What is the temperature difference used in ocean thermal energy conversion?
5. Where is the world's only operating ocean thermal energy conversion plant located?
6. What are the environmental impacts of OTEC plants?

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XV References/Suggestions for further reading:

1. https://www.eia.gov/energyexplained/hydropower/ocean-thermal-energy-conversion.php
2. https://www.tandfonline.com/doi/full/10.1080/20464177.2017.1320839
3. https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2023.1115695/full
4. https://youtu.be/ala3ruvZMho
5. https://youtu.be/26e12fepJQs
6. https://www.eia.gov/energyexplained/hydropower/images/oceanthermal.png
7. https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQGynDX_hIeRdbvQGkKQ5vXRNJXIILraLLqD41y8q0_Jx5DKzk5

Suggested Assessment Scheme

	Performance Indicators	**Weightage**
	Process Related: 15 Marks	**60 %**
1	Identification of the components of marine power plant and ocean thermal energy	10%
2	Drawing of layout/preparation of plan and elevation diagram/preparation of marine power plant and ocean thermal energy	20%
3	Interpretation of normal operation of marine power plant and ocean thermal energy	20%
4	Understanding the importance of team work in various marine power plant and ocean thermal energy	10%
	Product Related 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusions	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100%**

Marks Obtained			**Dated Signature of Teacher**
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 13: Demonstration of small hydro power plant using video/animation. OR Visit to hydro power plant.

I Practical Significance

In the electrical engineering field, diploma graduates are expected to keep hydro power plants running smoothly and fix any problems with the plant's equipment. This practical experience will help you learn the important skills needed for this job.

II Industry/Employer Expected Outcome(s)

Maintain the functioning and operation of the electrical power generation, transmission and distribution systems.

III Course Level Learning Outcome(s)

Identify major components of the geothermal, ocean and small hydro power plants.

IV Laboratory Learning Outcome(s)

LLO 13.1 Identify different components of small hydro power. OR prepare a report on small hydro power

V Relevant Affective Domain related outcome(s)

a. Follow safety practices.
b. Maintain tools and equipment.
c. Maintain tools and measuring instruments.

VI Relevant Theoretical Background

A hydro power plant is a station that uses the stored water at a high level to generate electricity. The water is stored in large amounts and then flows through pipes called penstocks, where its potential energy changes into kinetic energy. This water flows to a turbine, which turns the kinetic energy into mechanical energy. The turbine is connected to an alternator, which then converts the mechanical energy into electrical energy.

Water Source:
Hydropower plants typically rely on a river or reservoir, often with a dam to create a water head (height difference).

Turbines:
The water flow through the penstock spins the blades of a turbine, converting the kinetic energy of the water into mechanical energy.

Generators:
The rotating turbine is connected to an electric generator (also called an alternator), which converts the mechanical energy into electrical energy.

Penstock:
A pipe that carries the water from the dam to the turbine, maximizing the pressure and flow of water for power generation.

Control and Regulation:
Systems monitor and adjust water flow to maintain a stable electricity supply and ensure efficient power generation.

Storage:
Some plants have reservoirs for storing water, allowing for energy generation during peak demand or when flow is low.

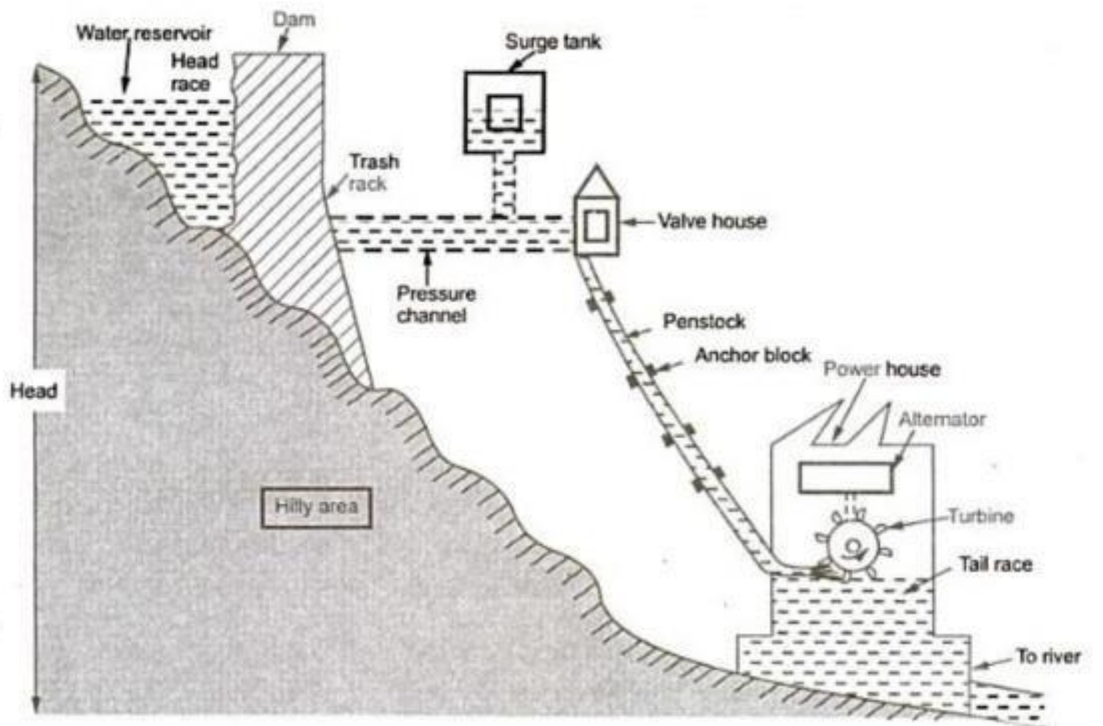

Figure 13.1 Alternator coupled to water turbine in Hydro power plant

Block diagram given below gives the interconnection of water body (intake or reservoir), penstock, water turbine, alternator and transformer at power house. The capacity of Hydro power plant depends upon the availability of water in that region. It may be a river, big pond or a reservoir with dam.

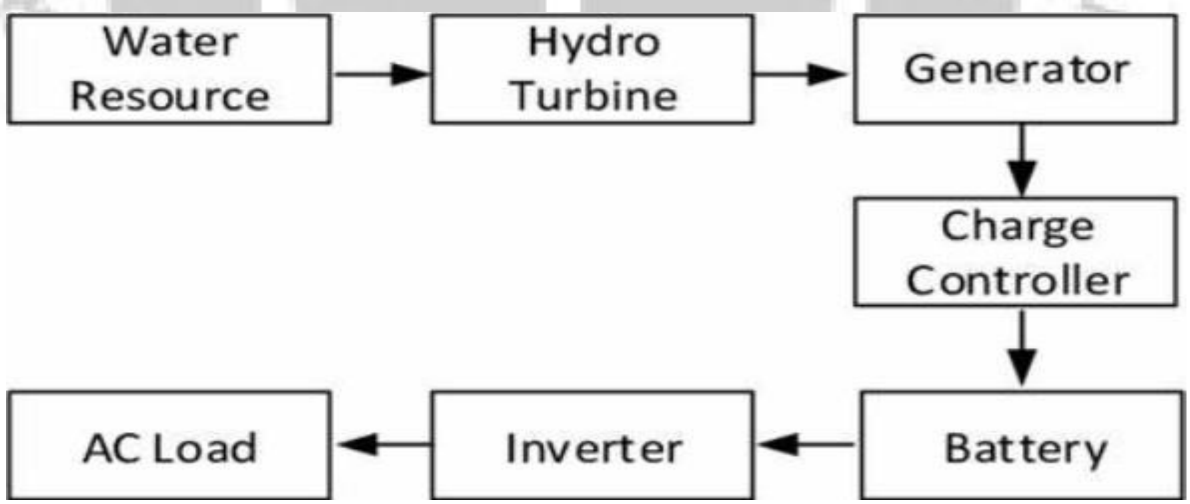

Figure 13.2 Block diagram of Hydro power

VII Required Resources/apparatus/equipment with specification

1. Drawing tools
2. A4 size paper
3. Videos on Hydro Power station

VIII Precautions to be followed

1. Watch authentic videos and learn layout of Hydro power plant.
2. Use proper symbols while drawing the layout on the imperial half-sheet.

IX Procedure

1. Watch videos of Hydro power plant/ visit hydro power station.
2. Students will draw this layout on the drawing sheet under the guidance of the teacher.
3. Observe the operation of various components of Hydro power station.

X Collect the following information about Hydro Power plant (Using Visit/Video Program /etc.):

1. Name of the power station: ____________________
2. Specifications: ____________________
3. No. of Units: ____________________
4. Capacity of each unit: ____________________
5. Total installed capacity: ____________________
6. Type of turbine: ____________________
7. Type of cooling system: ____________________
8. No. of penstock: ____________________
9. Type of power station: ____________________
10. Base/Peak load power station: ____________________
11. Low/Medium/high water head: ____________________
12. Rate of discharge of water: ____________________
13. Rating of generator: ____________________

XI Observation table (use blank sheet provided if space not sufficient)

Sr. No.	List of components	Function	Specification
1	Reservoir		
2	Penstock		
3	Trash-rack		
4	Surge tank		
5	Turbine		
6	Generator		
7	Power house		
8	Transformer		
9	Forebay		
10	Tailrace		
11	Spillway		

XII Results:

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XIII Interpretation of results:

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XIV Conclusion and recommendation:

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XV Practical related questions (Provide space for answers)

Note: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO.

1. Write the advantages and Disadvantages of Hydropower Plant
2. On what factors does the power output of a hydro power plant depend?
3. List the Hydro power station (with capacity) in Maharashtra.
4. Write the difference between steam turbine and water turbine.
5. What are the Different Types of Turbines used in Hydropower Plant

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XVI References/Suggestions for further reading:

1. https://www.electrical4u.com/hydro-power-plant-construction-working-and-history-ofhydro-power-plant/
2. ttps://www.britannica.com/science/hydroelectric-power
3. https://www.energy.gov/eere/water/types-hydropower-plants
4. https://study.madeeasy.in/wp-content/uploads/2024/07/hydro-electric-plant.jpg
5. https://www.researchgate.net/publication/349653883/figure/fig4/AS:1017824084504576@1619679580061/Block-diagram-of-Pico-hydro-power-plant.png

Suggested Assessment Scheme:

	Performance Indicators	Weightage
	Process Related: 15 Marks	**60 %**
1	Identification of the components of power plant/transmission system/Distribution system	10%
2	Drawing of layout/preparation of plan and elevation diagram/preparation of single line diagram	20%
3	Interpretation of normal operation of the plant/transmission system/Distribution system	20%
4	Understanding the importance of team work in various power plants & T& D systems	10%
	Product Related : 10 Marks	**40%**
5	Calculated theoretical values of given component	10%
6	Interpretation of result	05%
7	Conclusions	05%
8	Practical related questions	15%
9	Submitting the journal in time	05%
	Total (25 Marks)	**100%**

Marks Obtained			Dated Signature of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	