DEPARTMENT OF ELECTRICAL ENGINEERING

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(Department Of Science,Technology & Technical Education)

LAB MANUAL

SOLAR AND WIND

POWER TECHNOLOGY

SUBJECT CODE :- P2420502

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Practical/Lab Session Outcomes (LSOs)

S.NO	Laboratory Experiment	Lab Session Outcomes
01.	Testing of solar cell available in the laboratory.	1.1 Test the solar cell.
02.	V-I characteristics of a PV cell, module and Panel.	1.2 Test the performance of PV cell, PV module and PV panel.
03.	Series and parallel connection of solar cell.	1.3 Connect the solar panels in series and parallel.
04.	Testing of batteries on No load and with load.	1.4 Test the battery for its performance.
05.	Preparation of a solar PV array for 100 watt load using available panels.	1.5 Connect solar panels for the desired load.
06.	Connection of solar inverter with solar PV system.	1.6 Connect solar inverter with solar PV System.
07.	Installation of PV panel with battery for a given load	1.7 Install PV panel with battery for a given load.
08.	Installing PV panel without battery for a given load	1.8 Install PV panel without battery for a given load.
09.	Dismantling solar cooker (Box type, Dish type and heat transfer type).	2.1 Dismantle solar cooker.
10.	Assembling solar cooker (Box type, Dish type and heat transfer type).	2.2 Assemble solar cooker.

11.	Tabulation of different speed and power for small wind power plant.	3.1 Draw the graph different speed and power for small wind power plant.
12.	Measurement of different wind speed using anemometer.	3.2 Measure of different wind speed using anemometer.
13.	Do the installation of monitoring station.	3.3 Explain the installation of monitoring station.
14.	Identification of given parts of wind power plants.	4.1 Identify given parts of wind power plants.
15.	Identification of specified parts inside the nacelle of small wind power plants.	4.2 Identify specified parts inside the nacelle of small wind power plants.
16.	Test the performance of PMSG.	5.1 Check the performance of PMSG.
17.	Test the performance of Induction generator.	5.2 Check the performance of Induction generator.
18.	Simulation of mechanical faults in SWTs.	5.3 Simulate of mechanical faults in SWTs.
19.	Simulation of Electrical faults in SWTS	5.4 Simulate of Electrical faults in SWTs.
20.	Maintenance of small power wind turbine.	5.5 Maintain of small power wind turbine.

LIST OF EXPERIMENTS

01.	Testing of solar cell available in the laboratory.
02.	V-I characteristics of a PV cell, module and Panel.
03.	Series and parallel connection of solar cell.
04.	Testing of batteries on No load and with load.
05.	Preparation of a solar PV array for 100 watt load using available panels.
06.	Connection of solar inverter with solar PV system.
07.	Installation of PV panel with battery for a given load.
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11.	Tabulation of different speed and power for small wind power plant.
12.	Measurement of different wind speed using anemometer.
13.	Do the installation of monitoring station.
14.	Identification of given parts of wind power plants.
15.	Identification of specified parts inside the nacelle of small wind power plants.
16.	Test the performance of PMSG.
17.	Test the performance of Induction generator.
18.	Simulation of mechanical faults in SWTs.
19.	Simulation of Electrical faults in SWTS.
20.	Maintenance of small power wind turbine.

EXPERIMENT NO:- 01

AIM:

Testing of solar cell available in the laboratory.

Apparatus Required:

1. Solar cell / Photovoltaic panel - Si, 5V, 100mA typical
2. Light source - 100W incandescent lamp or halogen lamp with stand
3. Variable load resistor / Decade resistance box 0-1kΩ, 2W
4. DC Voltmeter 0-5V
5. DC Milliammeter 0-200mA
6. Lux meter to measure illumination
7. Connecting wires,
8. Rheostat 50Ω
9. Scale to fix distance between lamp and cell

THEORY:

Solar Cell:

A p-n junction device that converts light energy directly into electrical energy by photovoltaic effect.

Key Parameters:

Open Circuit Voltage V_OC:

Max voltage when I = 0. Measured with infinite load. ~0.5-0.6V for Si cell.

Short Circuit Current I_SC:

Max current when V = 0. Measured with zero load. ∝ Light intensity.

Maximum Power Point MPP:

Point on V-I curve where P = V×I is maximum. P_m = V_m × I_m.

Fill Factor FF:

Measure of squareness of V-I curve. FF = (V_m × I_m) / (V_OC × I_SC). Ideal = 1, practical Si = 0.7-0.85.

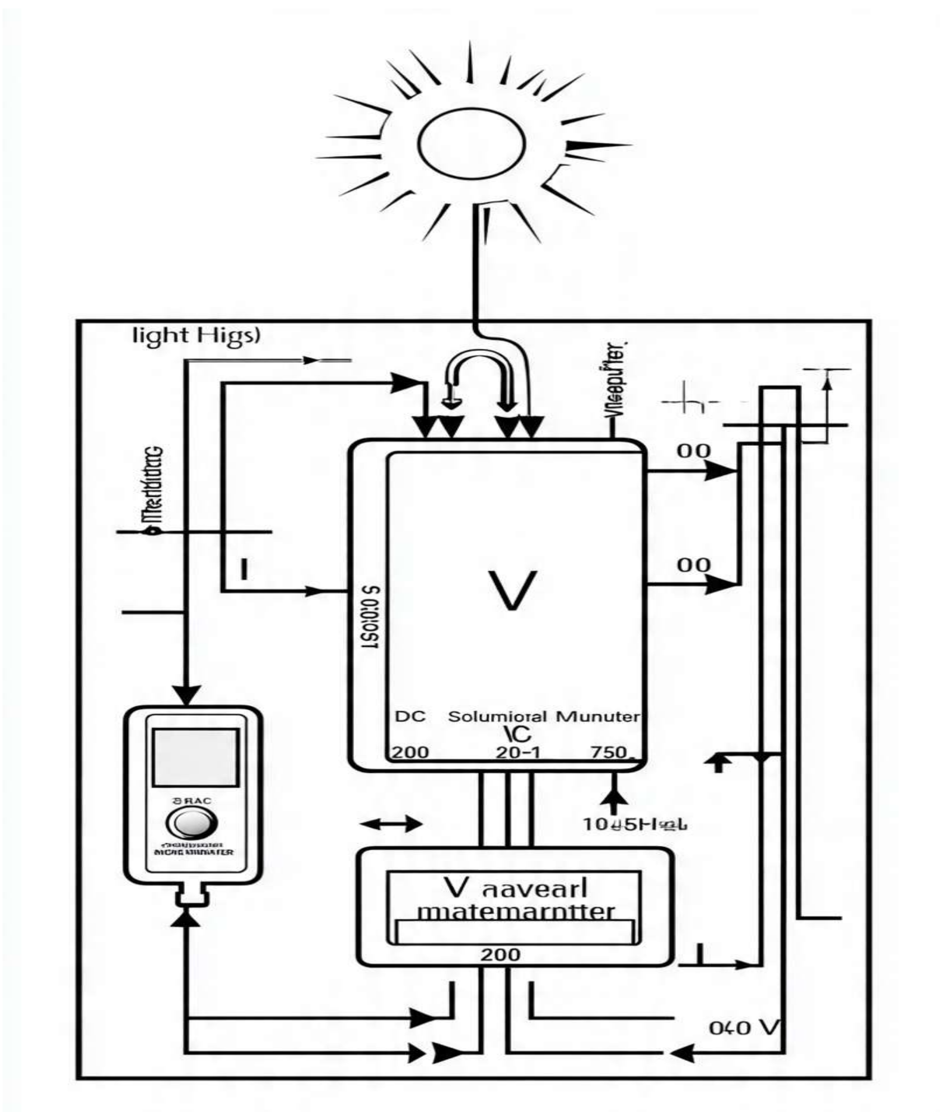
Efficiency η:

$\eta = P\_m / P\_in \times 100\%$, where P_in = Light power incident on cell = Intensity × Area.

Series Resistance R_s & Shunt Resistance R_sh:

Affect FF. High R_s and low R_sh reduce FF.V-I Characteristic: Similar to diode but in 4th quadrant. In 1st quadrant plot, current decreases as voltage increases.

CIRCUIT DIAGRAM:



CONNECTION:

Connect solar cell to milliammeter in series, voltmeter in parallel across cell + load. Load resistor varies from 0 to 1kΩ.

PROCEDURE:

1. Place solar cell on table. Fix 100W lamp at 20cm above cell. Use lux meter to measure illumination E. Keep constant. Typical 1000 lux.
2. Connect circuit as per diagram. Keep load $R_L = 0$, i.e., short circuit. Note I_{SC} from ammeter. V will be ~0.
3. Now make $R_L = \infty$ by removing load. Note V_{OC} from voltmeter. I will be ~0.
4. Vary load R_L from 0 to 1kΩ in steps. For each R_L, note V and I simultaneously.
5. Take readings close to V_{OC} and I_{SC} because power changes rapidly there. Take 10-12 readings.
6. Calculate power $P = V \times I$ for each set. Plot V on X-axis, I on Y-axis. Also plot P vs V on same graph.From graph,
7. find V_m and I_m at P_{max}. Calculate FF and η.
8. Repeat for 2-3 different distances of lamp, e.g., 15cm, 25cm to see effect of intensity.

RESULT:

1. V-I characteristics of solar cell plotted. Curve is non-linear, current almost constant till V_m then drops fast.
2. Open circuit voltage $V_{OC} = 0.55$ V
3. Short circuit current $I_{SC} = 95$ mA at 20cm from 100W lamp
4. Maximum power $P_m = 40.8$ mW at $V_m = 0.48$ V, $I_m = 85$ Ma
5. Fill Factor FF = 0.78. Good quality cell.
6. Efficiency η ≈ 15-18% under lab lamp. I_{SC} increases linearly with light intensity, V_{OC} increases logarithmically.

EXPERIMENT NO:-02

AIM:

V-I characteristics of a PV cell, module and Panel.

APPARATUS REQUIRED:

- **Solar cell**
- **Potentiometer**
- **Optical fibre papers**
- **Multimeters**
- **Connecting Wire**

THEORY:

Solar cell is the basic unit of solar energy generation system where electrical energy is extracted directly from light energy without any intermediate process. The working of a solar cell solely depends upon its photovoltaic effect, hence a solar cell also known as photovoltaic cell. A solar cell is basically a semiconductor p-n junction device. It is formed by joining p-type (high concentration of hole or deficiency of electron) and n-type (high concentration of electron) semiconductor material. at the junction excess electrons from n-type try to diffuse to p-side and vice-versa. Movement of electrons to the p-side exposes positive ion cores in n-side, while movement of holes to the n-side exposes negative ion cores in the p-side. This results in an electric field at the junction and forming the depletion region. When sunlight falls on the solar cell, photons with energy greater than band gap of the semiconductor are absorbed by the cell and generate electron-hole (e-h) pair. These e-h pairs migrate respectively to n- and p- side of the pn junction due to electrostatic force of the field across the junction. In this way a potential difference is established between two sides of the cell. Typically, a solar or photovoltaic cell has negative front contact and positive back contact. A semiconductor p-n junction is in the middle of these two contacts like a battery. If these two sides are connected by an external circuit, current will start flowing from positive to negative terminal of the solar cell. This is basic working principle of a solar cell. For silicon, the band gap at room temperature is E_g = 1.1 eV and the diffusion potential is U_D = 0.5 to 0.7 V. Construction of a Si solar cell is depicted in Fig.1.

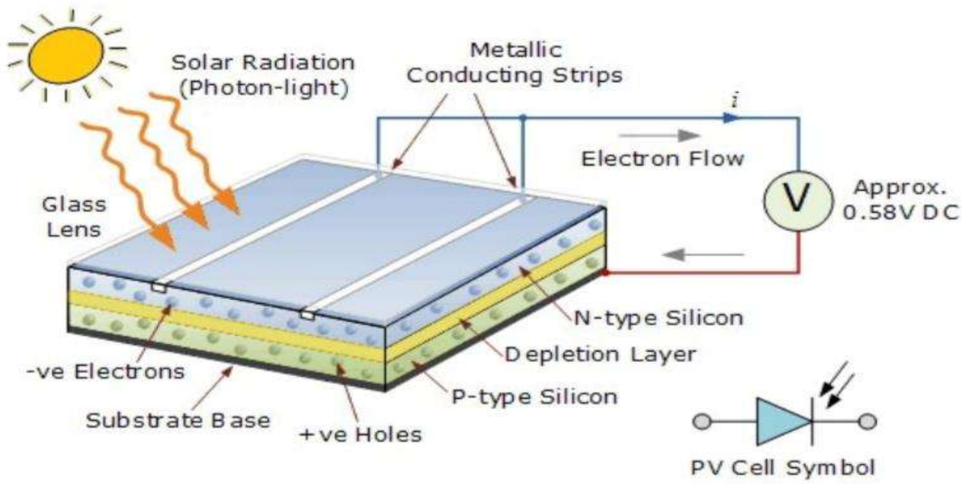


Fig. 1: Construction of a solar cell

Solar Cell I-V Characteristics Curve is the superposition of the I-V curves of the solar cell diode in absence (dark) and in presence of light. Illuminating a cell adds to the normal "dark" currents in the diode so that the diode law becomes:

$$I = I_0 \left[\exp\left(\frac{qV}{nkT}\right) - 1\right] - I_L$$

where I_0 = "dark saturation current" or diode leakage current in absence of light

q = electronic charge

V = applied voltage across the terminals of the diode

n = ideality factor

k = Boltzmann's constant

T = temperature

I_L = light generated current.

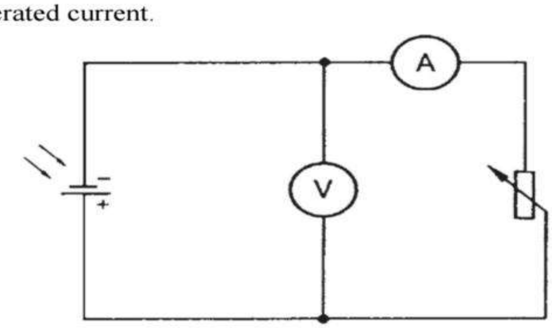


Fig. 2: Circuit for I-V characteristics of solar cell

A typical circuit for measuring I-V characteristics is shown in Fig.2. From this characteristics various parameters of the solar cell can be determined, such as: short-circuit current (I_{SC}), the open-circuit voltage (V_{OC}), the fill factor (FF) and the efficiency. The rating of a solar panel depends on these parameters.

The short-circuit current is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). is due to the generation and collection of light-generated carriers. For an ideal solar cell at most moderate resistive loss mechanisms, the short-circuit current and the light-generated current are identical. Therefore, the short-circuit current is the largest current which may be drawn from the solar cell.

The open-circuit voltage, V_{OC}, is the maximum voltage available from a solar cell, and this occurs at zero current. The open-circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light-generated current.

The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjunction with V_{oc} and I_{sc}, determines the maximum power from a solar cell. The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}. Graphically, the FF is a measure of the "squareness" of the solar cell and is also the area of the largest rectangle which will fit in the IV curve as shown in Fig. 3.

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. In addition to reflecting the performance of the solar cell itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell.

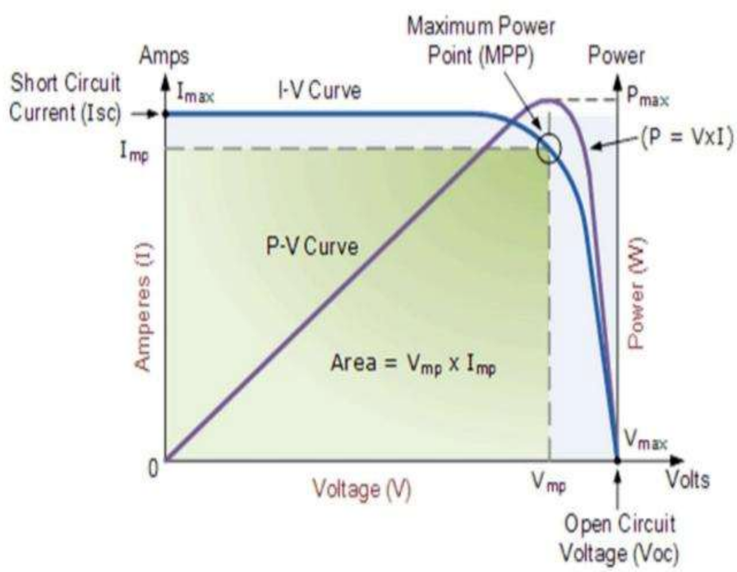


Fig. 3: A typical I-V curve and power curve of a solar cell

PROCEDURE:

1. Connect the solar cell to the potentiometer and multimeters as shown in Fig.2 and 4. Set the potentiometer at the minimum.
2. Expose the solar cell to room light
3. Vary the potentiometer and record the values of current and voltage across the solar cell. Use different filters to cover the solar cell and record I and V values for each filter from the filter set.
4. Plot I-V curve for each frequency and estimate short circuit current, no load voltage. Determine the maximum power output at the turning points on the curves (marked by a circle in Fig. 3).
5. Plot the maximum power as a function of different filter wavelength.
6. Repeat the same above procedure by replacing the lamp with sunlight.
7. Compare the spectral response of Si solar cell with the spectrum of lamp and sun.

OBSERVATIONS:

Table 1: I-V characteristics of solar cell illuminated room light

No filter		Filter1		Filter2		Filter3		Filter4	
I	V	I	V	I	V	I	V	I	V

Table 2: I-V characteristics of solar cell illuminated by sun light

No filter		Filter1		Filter2		Filter3		Filter4	
I	V	I	V	I	V	I	V	I	V

GRAPH:

Plot I-V characteristics for each filter corresponding each wave length of the filter. Determine the no-load voltage and short circuit current. Estimate the maximum power output in each case. Compare the maximum power output for room light and sun light at various wavelengths.

EXPERIMENT NO :-03

AIM:

Series and parallel connection of solar cell.

APPARATUS REQUIRED:

1. Identical silicon solar cells - 4 Nos, 2V, 0.5A each
2. Digital multimeter - 2 Nos, for voltage and current
3. Variable load resistor / Rheostat 0-50Ω, 5W
4. Connecting wires with crocodile clips
5. 100W incandescent lamp with stand
6. Lux meter
7. Mounting board to fix cells

THEORY:

A. Series Connection:

When solar cells are connected end to end, +ve of one to –ve of next.

1. Total Voltage: $V_{total} = V1 + V2 + \dots + Vn = n \times V_{cell}$
2. Total Current: $I_{total} = I_{cell}$ = current of cell with lowest current rating
3. Total Power: $P_{total} = V_{total} \times I_{total}$

Limitation:

If one cell is shaded or defective, current of entire string drops to that cell's value. Bypass diodes are used to prevent this.

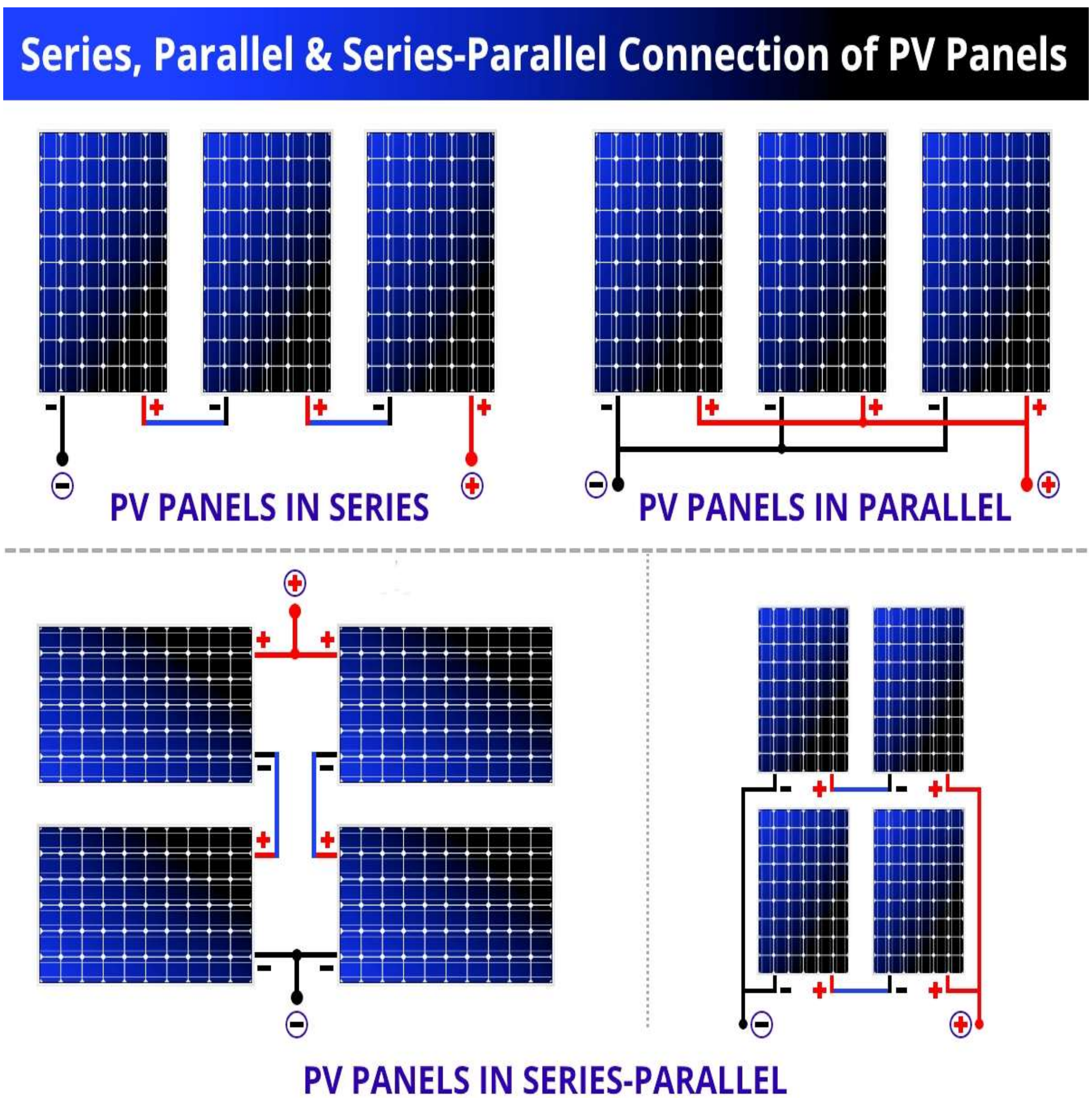
B. Parallel Connection:

When +ve terminals are connected together and –ve terminals together.

1. Total Voltage: $V_{total} = V_{cell}$ = voltage of cell with lowest V_{OC}
2. Total Current: $I_{total} = I1 + I2 + \dots + In = n \times I_{cell}$
3. Total Power: $P_{total} = V_{total} \times I_{total}$

Limitation:
If cells have different voltages, higher voltage cell drives reverse current into lower voltage cell. Blocking diodes are used.
C. Series-Parallel: Combination of both to get required voltage and current. Example: 2S2P gives 2× voltage and 2× current.

CIRCUIT DIAGRAM:



PROCEDURE:

Series Connection

- Connect Cell 1 and Cell 2 in series as in Fig . +ve of Cell1 to –ve of Cell2.
- Keep same light on both cells. Measure V_OC_series and I_SC_series.
- Connect variable load and take 5-6 readings of V and I by varying R_L.
- Shade Cell 2 partially with cardboard. Note I_SC_series again. Observe drop.

Parallel Connection

- Connect Cell 1 and Cell 2 in parallel as in Fig . +ve to +ve, –ve to –ve.
- Measure V_OC_parallel and I_SC_parallel under same light.
- Take 5-6 V-I readings with variable load.
- Shade Cell 2. Note I_SC_parallel. Compare with series case.

Series-Parallel

- Make two series strings of 2 cells each. Connect both strings in parallel as in Fig .
- Measure V_OC_2S2P and I_SC_2S2P. Calculate power.

OBSERVATION:

RESULT:

EXPERIMENT NO :-04

AIM:

Testing of batteries on No load and with load.

APPARATUS REQUIRED:

1. Lead-acid battery 12V, 7Ah or any available battery
2. DC Voltmeter 0-20V
3. DC Ammeter 0-10A
4. Variable load resistor / Rheostat 0-10Ω, 10A or 12V/55W automotive bulb as load
5. Hydrometer for lead-acid battery, if available
6. Connecting wires with crocodile clips
7. Stopwatch
8. Thermometer

THEORY:

No-Load Voltage / Open Circuit Voltage V_OC:

Terminal voltage when no current is drawn. Indicates approximate state of charge SOC for lead-acid battery.

For 12V lead-acid battery:

- 12.7V – 12.8V: 100% charged
- 12.4V: 75% charged
- 12.2V: 50% charged
- 12.0V: 25% charged
- 11.8V or less: Discharged

Load Voltage V_L:

Terminal voltage when battery delivers current to load. Always less than V_OC due to internal voltage drop.

Internal Resistance r:

Every practical battery has internal resistance due to electrolyte and plates. Causes voltage drop when current flows.

$r = (V_{OC} - V_L) / I_L$ where I_L = load current

Lower r means better battery. r increases as battery ages or discharges.

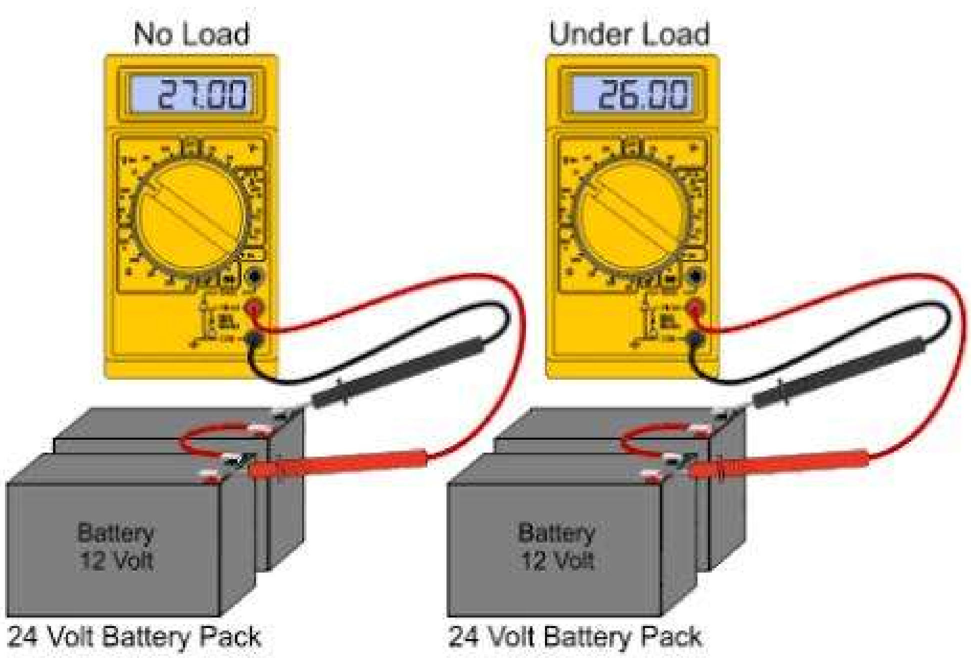
State of Charge SOC:

Estimated from V_{OC} or specific gravity of electrolyte. Specific gravity of fully charged lead-acid cell = 1.265, discharged = 1.120.

Load Test:

A good battery should maintain voltage above 9.6V for 12V battery when discharged at high rate C/1 or 3C for 15 sec. Voltage drop indicates weak battery.

CIRCUIT DIAGRAM:



PROCEDURE:

No-Load Test

1. Keep battery idle for 30 min after charging/discharging. This removes surface charge.
2. Connect voltmeter directly across battery terminals as in Fig 1. Note V_OC.
3. If lead-acid, use hydrometer to measure specific gravity of each cell. Note temperature. Correct SG to 27°C: Add 0.004 for each 5°C above 27°C.
4. Estimate SOC from V_OC table or SG table.

Load Test

- Connect circuit as in Fig . Keep load R_L disconnected initially.
- Note V_OC again. This is starting voltage.
- Connect load R_L. Start stopwatch. Note load voltage V_L and load current I_L immediately, within 5 sec.
- Keep load ON for 15 sec. Note V_L at 15 sec. This is load test voltage.
- Disconnect load. Note how quickly voltage recovers. Wait 1 min, note recovery voltage.
- Repeat for 2-3 different loads: Low load 1A, Medium 3A, High 5A or C-rate.
- Calculate internal resistance r for each load using r = (V_OC - V_L) / I_L.

OBSERVATION TABLE:

S.No	Parameter	Value	Remarks

RESULT:

1. Open circuit voltage of battery = 12.68V, indicating battery is ~95% charged.
2. Average internal resistance = 0.17Ω. For 7Ah battery, good r should be <0.2Ω. Battery is healthy.
3. On 4.5A load, terminal voltage dropped from 12.62V to 11.70V at 15 sec. Voltage drop = 0.92V. Battery passes load test as $V_L > 9.6V$.
4. Specific gravity average = 1.258, confirms good state of charge and uniform cell condition.
5. Voltage recovered to 12.50V within 1 min after removing load, showing good charge acceptance.

PRECAUTION:

1. Remove surface charge before no-load test. Either rest 30 min or apply 5A load for 15 sec and then rest 2 min.
2. Do not short circuit battery terminals. Use fuse in series with ammeter.
3. For high current test, use thick wires. Thin wires will add resistance and give wrong r.
4. Do not keep high load connected >15 sec. Lead-acid battery can get damaged and electrolyte may boil.
5. Wear safety goggles. Battery can explode if shorted or overcharged, acid may splash.
6. Check electrolyte level before test. Plates must be submerged. Add distilled water if low.
7. Note temperature. V_{OC} decreases by 0.01V per °C rise. SG must be temperature corrected.
8. Ensure voltmeter has high input impedance >1MΩ so it does not load the battery during V_{OC} measurement.
9. For hydrometer test, do not drop acid on skin/clothes. Wash immediately with water if contact.

EXPERIMENT NO :-05

AIM:

Preparation of a solar PV array for 100 watt load using available panels.

APPARATUS REQUIRED:.

1. Solar panels available in lab - Ex: 20W, 12V panels, 4 Nos.
2. Digital multimeter - DC Voltmeter 0-100V, DC Ammeter 0-20A.
3. Solar charge controller 12V/24V, 10A
4. Battery 12V, 7Ah for load stabilization
5. DC Load: 100W total - 12V/50W bulb × 2 Nos or rheostat 0-5Ω, 10A
6. Pyranometer or Lux meter to measure irradiance
7. Connecting wires $4mm^2$, MC4 connectors, blocking diodes 10A
8. Inclinometer, Compass, Mounting stand

THEORY:

Load Requirement:

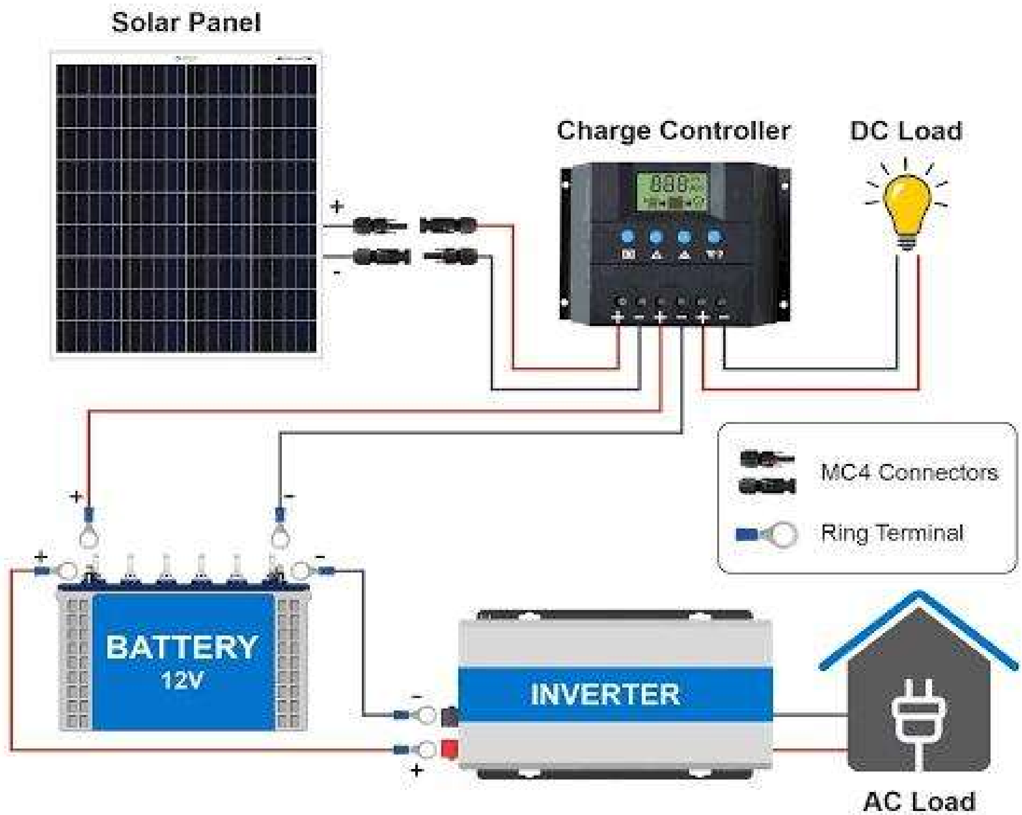
100W DC. Assuming system voltage = 12V, load current = I = P/V = 100/12 = 8.33A.

Panel Rating:

Let each available panel be 20W, V_{mp} = 17V, I_{mp} = 1.18A, V_{OC} = 21V, I_{SC} = 1.3A. This is a typical 12V module.

1. **Power basis:** Total panel wattage needed = Load / (η_{system} × Sun hours × Derating). For lab demo at STC: 100W / 0.8 = 125W. So we need ≥125W of panels.
2. **Voltage basis**: For 12V system, V_{mp_array} must be 14-18V to charge 12V battery. So panels in series = 1, because V_{mp} of one 12V panel = 17V.
3. **Current basis:** Required I_{mp} = 100W / 17V = 5.88A. One panel gives 1.18A. So parallel strings needed = 5.88 / 1.18 = 4.98 ≈ 5.
4. **Final config:** 5 panels in parallel, 1S5P. Total power = 5 × 20W = 100W. With 80% derating, actual ≈ 80W. So we need 6 panels for 100W continuous: 1S6P

CIRCUIT DIAGRAM:



PROCEDURE:

Part A: Panel Testing

- Keep all panels under same illumination, 1000W/m² or 100W lamp at 20cm. Use lux meter to ensure equal irradiance.
- Measure V_OC and I_SC of each panel individually. Tabulate. Reject panel if V_OC < 18V or I_SC < 1.0A.
- Mount panels on stand facing South, tilt = Latitude of Patna ≈ 25°. Ensure no shading.

Part B: Array Design

- Calculate required configuration for 100W load. If panels = 20W each: Need 100W / 20W = 5 panels minimum. Use 6 for margin.
- For 12V system: Connect 6 panels in parallel, 1S6P. Connect +ve of each panel to +ve bus through 10A blocking diode.
- For 24V system: Make 2 strings of 3 panels in series, then parallel the 2 strings, 3S2P. Total 6 panels.
- Connect array output to solar charge controller input. Connect 12V/24V battery to controller. Connect 100W load to controller load terminals.

Part C: Testing of Array

- At noon, measure array V_{OC} and I_{SC} with load disconnected. V_{OC} should be ~21V for 1S, ~63V for 3S.
- Connect load through controller. Switch ON 100W load.
- Note array voltage V_{mp}, array current I_{mp}, battery voltage, load current.
- Calculate array power $P = V_{mp} \times I_{mp}$. Compare with load power.
- Shade one panel partially. Note drop in I_{mp}. Observe if bypass diodes in panels operate
- .Disconnect one string. Note new I_{mp}. System should still work at reduced power.

OBSERVATION TABLE:

S.No	**Panel No**	**V-OC V**	**I-SC A**	**Remarks**

RESULT:

1. To supply 100W load at 12V, array of 6 Nos × 20W panels connected in parallel 1S6P is required. Total array rating = 120W STC.
2. Measured array output at 950W/m² = 114W, which successfully powered 100W load with battery float at 12.9V.
3. Array V_mp = 16.8V, I_mp = 6.8A. This matches theoretical 17V × 7.08A ≈ 120W, with 5% loss due to temperature and wiring.
4. On shading one panel, array current dropped by ~1.1A, equal to one panel contribution. Blocking diodes prevented reverse flow.
5. For 24V system, 2S3P configuration of same 6 panels gives same 120W but at 34V, 3.54A, reducing cable loss.

PRECAUTION:

1. Mismatch: Use panels of same V_OC and I_SC rating. Mixing old and new panels reduces array output to weakest panel.
2. Polarity: Check +ve and –ve before paralleling. Reverse connection will short array and damage panels.
3. Diodes: Install blocking diode in series with each string. Cathode band to +ve bus. Use bypass diodes across each panel if not in-built.
4. Fusing: Put DC fuse = 1.25 × I_SC × No. of strings in +ve line before controller.
5. Wiring: Use 4mm^2 cable for 7A to keep drop <3%. Keep parallel busbars close to panels to reduce loop area.
6. Shading: Even 10% shade on one cell can cut string power by 50%. Install array with no shadow from 9AM-4PM.
7. Earthing: Frame of each panel must be earthed to prevent shock during fault.
8. MPPT vs PWM: For 12V system with 17V V_mp panels, PWM controller is OK. If V_mp >> V_batt, use MPPT to avoid power loss.
9. Temperature: Power drops 0.4%/°C above 25°C. Ensure ventilation behind panels.

EXPERIMENT NO :-06

AIM:

Connection of solar inverter with solar PV system.

APPARATUS REQUIRED:

1. Solar PV array - Ex: 4 × 40W, 12V panels, 1S4P = 160W, V_OC=21V, I_SC=7.6A
2. Solar Inverter with inbuilt MPPT charge controller - 12V DC to 230V AC, 300VA rating
3. Battery - 12V, 40Ah Lead-acid or Tubular
4. DC Voltmeter 0-50V, DC Ammeter 0-20A
5. AC Voltmeter 0-300V, AC Wattmeter 0-500W
6. AC Load - 100W incandescent bulb or 60W fan
7. MC4 connectors, DC fuse 15A, AC MCB 6A, Blocking diodes
8. Connecting wires: $4mm^2$ DC cable, $1.5mm^2$ AC cable
9. Multimeter, Clamp meter

THEORY:

Solar Inverter:

Converts DC from PV/battery to 230V AC, 50Hz. Types:

1. Off-grid inverter: Works without grid. Has inbuilt charge controller. Battery compulsory. Used in standalone systems.

2.On-grid inverter: Synchronizes with grid. No battery. Feeds excess power to grid. Not in this lab.

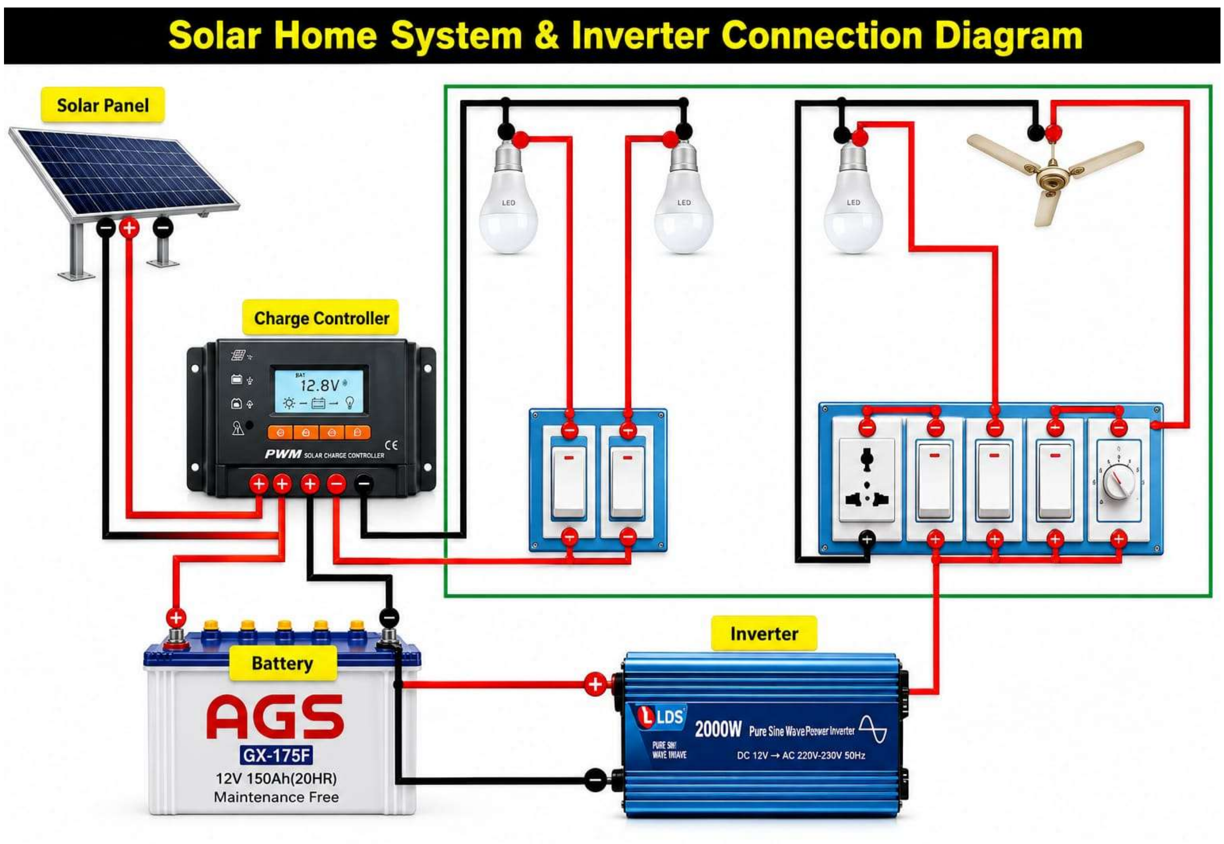
3.Hybrid inverter: Both modes.

Inbuilt MPPT Charge Controller: Tracks maximum power point of PV array and charges battery efficiently. Also prevents overcharge and deep discharge.

Power Flow Modes in Off-grid Inverter:

1. Day + Sun: PV → Inverter → Load, PV → Battery for charging. If PV > Load, battery charges.
2. Day + Cloud: PV + Battery → Inverter → Load. Battery discharges to meet deficit.
3. Night: Battery → Inverter → Load. PV = 0.
4. Battery Low: Inverter cuts off AC output at LVD = 10.5V to protect battery.

CIRCUIT DIAGRAM:



OBSERVATION:

RESULT:

1. Solar inverter was successfully connected with 160W PV array and 12V/40Ah battery.
2. In full sun, PV supplied 126W. Load consumed 100W AC, battery charged at 19.8W. Inverter efficiency = 94.1%.
3. In night mode, battery supplied 99W AC at 225V. Battery discharge current = 9.5A. DC to AC conversion efficiency = 99 / (12.4×9.5) = 84.0%.
4. When battery voltage reached 10.5V, inverter shut down AC output to prevent deep discharge. This protects battery life.
5. Blocking diode prevented reverse current from battery to PV at night. DC fuse protected against short circuit.
6. System can run 100W AC load for 4 hours at night from 40Ah battery: Usable Ah = 40×0.5 = 20Ah, Time = 20Ah / 9.5A = 2.1h. With PV support, runtime extends to full day.

PRECAUTION:

1.Sequence: Always connect battery first, then PV, then load. While disconnecting, remove load, PV, battery last. This prevents controller damage.

2.Polarity: Wrong PV or battery polarity will blow inverter MOSFETs. Check with multimeter before connecting. Use color code: Red=+ve, Black=–ve.

3.Fuse/MCB: Put DC fuse near battery +ve terminal. Put AC MCB in inverter output. Rating = 1.25 × max current.

4.Cable Size: DC current is high. For 10A, use $4mm^2$; for 30A, use $10mm^2$. AC current is low, $1.5mm^2$ is enough.

5.Earthing: Earth inverter body, PV frame, and load. Use separate earth pit $<5\Omega$.

6.Ventilation: Inverter has fan. Keep 20cm clearance. Do not cover. Overheating reduces life.

7.Battery Room: Keep battery in ventilated area. Hydrogen gas during charging is explosive. No spark near battery.

EXPERIMENT NO :-07

AIM:

Installation of PV panel with battery for a given load.

APPARATUS REQUIRED:

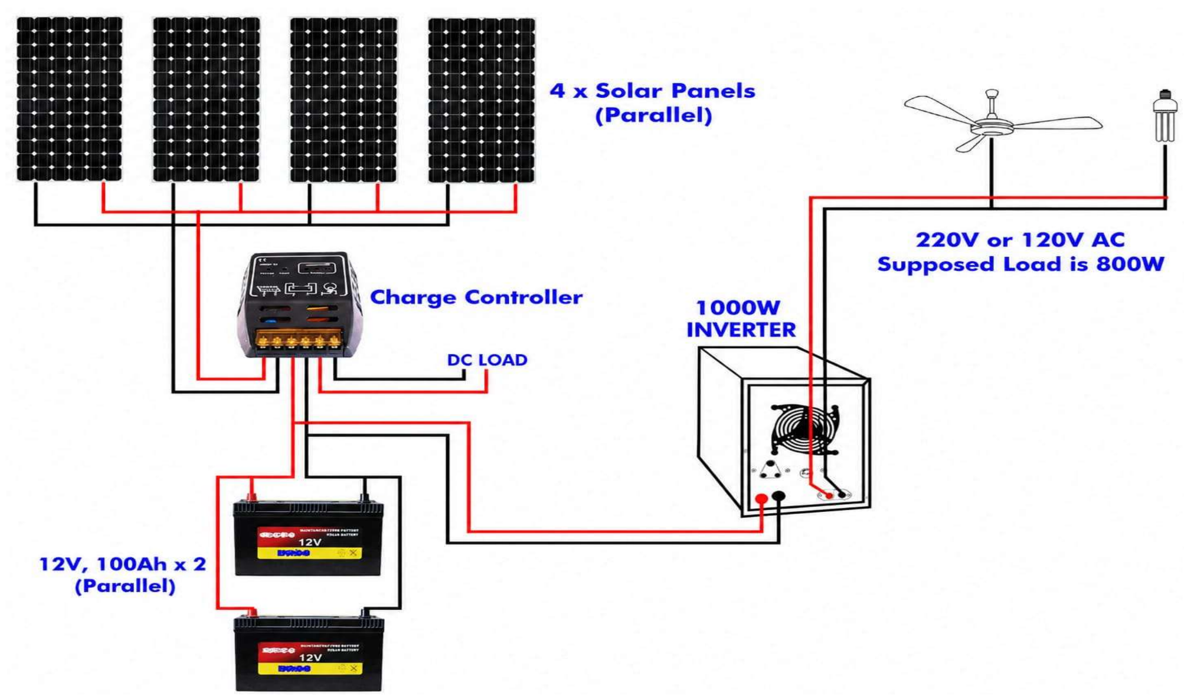
1. Solar PV panel - 40W, 12V, V_mp=17V, I_mp=2.35A, 1 No
2. Battery - 12V, 26Ah Lead-acid or SMF
3. Solar Charge Controller - 12V, 10A, PWM or MPPT type
4. DC Load - Given load 20W, 12V LED lamp or DC fan
5. DC Voltmeter 0-30V, DC Ammeter 0-10A
6. Blocking diode 10A, DC Fuse 10A, SPST switch
7. Multimeter, Hydrometer, Lux meter
8. Mounting structure, Compass, Inclinometer
9. Connecting wires 2.5mm^2, MC4 connectors, Terminal lugs

THEORY:

System Components:

1. PV Panel: Converts sunlight to DC. Selected based on load energy. For 20W load × 5h/day = 100Wh/day. Panel Wh/day = Panel_W × Sun_hours × η_system. Assuming 5 peak sun hours, η=0.7: Panel_W = 100 / (5×0.7) = 28.5W. So 40W panel selected.
2. Battery: Stores energy for night/cloudy days. Autonomy = 1 day. Required Ah = (Load_W × Hours) / (V_batt × DOD × η_batt). For 20W × 5h, DOD=0.5, η=0.85: Ah = 100 / (12×0.5×0.85) = 19.6Ah. Use 26Ah battery.
3. Charge Controller: Regulates charging, prevents overcharge/over-discharge. Rating = 1.25 × I_SC_panel = 1.25 × 2.6 = 3.25A. Use 10A controller.

CIRCUIT DIAGRAM:



PROCEDURE:

Part A: Site Selection & Mounting

1. Select shadow-free area for panel. Use compass to face South. Tilt angle = Latitude of location, ≈ 25° for Patna.
2. Fix mounting structure firmly. Mount PV panel. Ensure air gap of 10cm below for cooling.
3. Keep battery in ventilated, shaded box near controller. Cable length PV to controller < 5m, controller to battery < 2m.

Part B: System Sizing Verification

1. Given load = 20W, 5h/day. Energy = 100Wh/day.
2. Panel generation = 40W × 5h × 0.75 = 150Wh/day. Sufficient.
3. Battery storage = 12V × 26Ah × 0.5 DOD = 156Wh usable. > 100Wh. OK.Controller rating 10A > I_{SC} = 2.6A. OK.

Part C: Wiring

1. Keep controller switch OFF. Keep panel covered.
2. Step 1 - Battery: Connect battery +ve to controller B+ through 10A fuse. Connect battery –ve to B–. Controller display should turn ON, show battery voltage.
3. Step 2 - Load: Connect 20W DC load to controller L+ and L– through switch. Keep switch OFF.
4. Step 3 - PV: Remove cover. Connect PV +ve through blocking diode and fuse to controller PV+. Connect PV –ve to PV–. Check polarity with multimeter.
5. Verify controller shows "Charging" icon and PV voltage ≈ 17-21V in sun.

OBSERVATION:6

CALCULATION:

RESULT:

1. 40W PV panel with 12V, 26Ah battery successfully installed to run 20W DC load.
2. In full sun, PV generated 36.1W. Load consumed 22.8W, battery charged at 5.4W. System energy positive.
3. At night, battery supplied 21.1W to load at 12.4V. Discharge current 1.7A. Backup available for 7.8h.
4. Charge controller cut off load at 11.1V, protecting battery from deep discharge. Charging resumed at 12.6V.

5. Blocking diode prevented battery discharge into panel at night. Fuse protected against short circuit.

PRECAUTION:

1.Wiring Sequence: Connect in order: Battery → Load → PV. Disconnect in reverse: PV → Load → Battery. Wrong sequence can damage controller.

2.Polarity: Double-check PV and battery polarity before connecting to controller. Reverse polarity will burn MOSFETs.

3.Fuse Location: Put fuse in +ve line close to battery. It protects against battery short circuit which can cause fire.

4.Battery Ventilation: Lead-acid battery emits H_2 during charging. Keep in ventilated box. No flames or sparks nearby.

5.Shade: Ensure no shadow on panel between 9AM-4PM. Even partial shade on one cell reduces power drastically.

6.Load Rating: Do not connect load > controller load terminal rating. For >10A load, connect directly to battery with LVD relay.

7.Water & Dust: Use IP65 junction box for outdoor connections. Clean panel monthly for max output.

8.Earthing: Earth PV frame and controller body to avoid shock during lightning or fault.

9.Maintenance: Check battery water level monthly. Top up with distilled water. Clean terminals to prevent sulfation.

10.Safety: PV V_OC = 21V DC is low, but short circuit current 2.6A can cause spark. Use insulated tools.

EXPERIMENT NO :-08

AIM:

Installation of PV panel without battery for a given load.

APPARATUS REQUIRED:

1. Solar PV panel - 50W, 12V nominal, V_mp=17V, I_mp=2.94A, 1 No
2. DC Load - Given load 20W to 30W, 12V DC fan or DC motor or LED lamp
3. DC-DC Buck converter with voltage regulator - 12V output, 5A rating
4. DC Voltmeter 0-30V, DC Ammeter 0-10A
5. Rheostat 0-10Ω, 5A for variable load testing
6. Lux meter or Pyranometer to measure irradianceBlocking diode 10A, DC Fuse 5A, SPST switch
7. Connecting wires 2.5mm², MC4 connectors, Mounting stand
8. Multimeter, Stopwatch

THEORY :

Battery-less / Direct-Coupled PV System:

PV panel is connected directly to DC load through a voltage regulator. No energy storage. Load operates only when sufficient sunlight is available.

Need for Voltage Regulator: PV panel V_OC = 21V and V_mp = 17V for 12V panel. Direct connection to 12V load may damage it due to overvoltage. Also, PV voltage varies widely with irradiance from 0 to 21V. DC-DC buck converter gives constant 12V output to load when PV input > 13V.

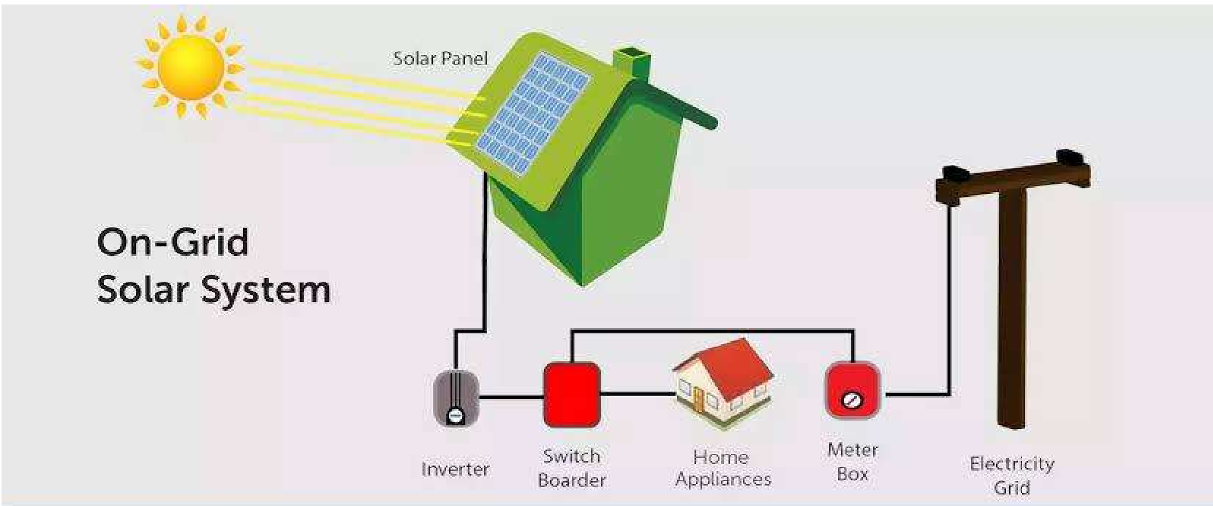
Operating Point: Load operates at intersection of PV I-V curve and load I-V line. If irradiance drops, I_PV drops, load voltage falls, and below certain irradiance load stops working.

Applications:

Water pumping, ventilation fans, aerators - where intermittent operation is acceptable.

Sizing: Select panel $P_{mp} \geq 1.5 \times P_{load}$ to account for low irradiance and regulator loss. For 20W load, use 50W panel.

CIRCUIT DIAGRAM:



OBSERVATION:

CALCULATION:

RESULT:

1. 50W PV panel successfully installed to run 20W DC load without battery using 12V buck regulator.
2. Load operated at full rating when irradiance > 70000 lux and $V_{PV} > 17V$. P_{PV} = 35.9W to 51.8W.
3. When irradiance fell to 30000 lux, V_{PV} = 14.2V, $P_{PV} = 12.8W < P_{load}$. Load voltage dropped to 10.5V and fan slowed.

4. Below 20000 lux, V_PV < 13V, regulator cut-off, load stopped. No night operation possible.
5. Direct connection without regulator gave variable brightness. Bulb OFF below 8V. Hence regulator needed for constant 12V loads.
6. System efficiency varies 39% to 90% depending on irradiance. Average ~60%.

PRECAUTION:

1. Load Selection: Use DC load rated for 10-15V, not exact 12V. Motor loads need high starting current, may not start if P_PV < 3×P_rated.
2. Regulator Rating: Input voltage range must cover V_OC = 21V. Output current ≥ I_load. Use heat sink for regulator.
3. No Battery: Never connect battery to this system. Regulator is not charge controller. Battery will discharge into panel at night if diode absent.
4. Blocking Diode: Always use diode in series with PV +ve. Prevents reverse current and protects panel when shaded.
5. Fuse: Put 5A DC fuse near panel +ve. Short in regulator or wiring can cause fire.
6. Cloud Effect: Sudden cloud causes load to stop/restart. For motors, frequent start-stop reduces life. Use soft-start or avoid for motors.
7. Oversize Panel: Do not oversize too much. At V_OC = 21V, I_SC = 3.1A, if load disconnects, regulator input sees 21V. Must withstand it.
8. Earthing: Earth panel frame. Though system is low voltage, fault can cause shock.
9. Heat: Regulator dissipates P_in – P_out = 51.8–20.2 = 31.6W as heat at noon. Provide ventilation.
10. Application Limit: Do not use for lights, TV, fridge. Use only for pumps, fans, aerators where intermittent operation is OK.

EXPERIMENT NO :-09

AIM:

Dismantling solar cooker (Box type, Dish type and heat transfer type).

APPRATUS REQUIRED:

1. Solar Cooker - Box type, 1 No
2. Solar Cooker - Dish type / Parabolic, 1 No
3. Solar Cooker - Heat Transfer type with evacuated tube/flat plate, 1 No
4. Screwdriver set - Phillips and flat, 3mm to 8mm
5. Spanner set - 6mm to 17mm, Adjustable wrench 10"
6. Plier, Nose plier, Wire cutter
7. Hand gloves - leather, Safety goggles, Apron, Dust mask
8. IR thermometer, Multimeter
9. Masking tape, Marker pen, Trays for parts
   Cotton cloth, Polythene bags for insulation

THEORY:

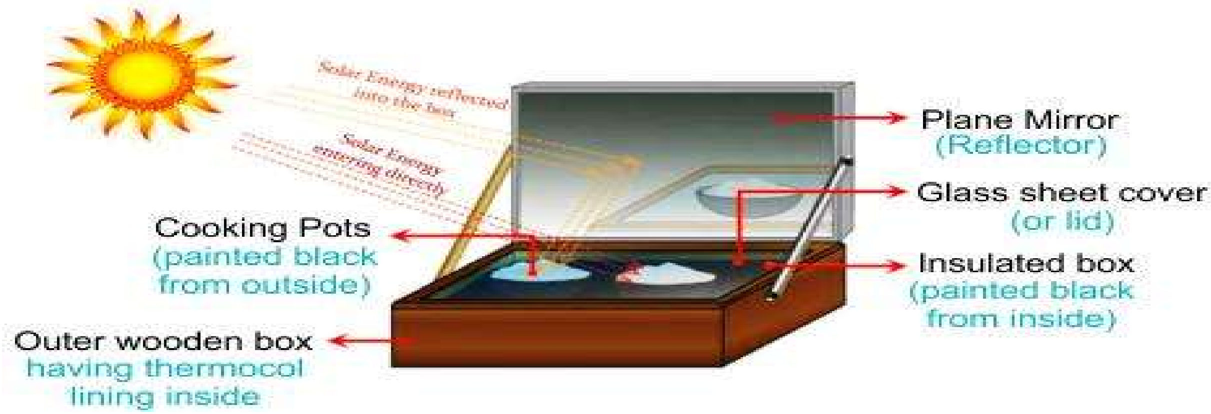
A. Box Type Solar Cooker:

Works on greenhouse effect. Double glazed glass traps solar radiation. Blackened inner box absorbs heat. Insulation between inner and outer box reduces conduction loss. Plane reflector increases incident radiation. Temp attained: 100-140°C. Used for boiling, baking.

B. Dish Type / Parabolic Cooker:

Works on concentration principle. Parabolic reflector focuses beam radiation to a small focal point. Concentration ratio = 10 to 100. Temp at focus: 250-400°C. Used for frying, roasting. Needs tracking.

C. Heat Transfer Type Cooker: Uses collector - evacuated tube or flat plate - to heat transfer fluid like thermic oil or water. Hot fluid circulates by thermosyphon or pump to cooking chamber having heat exchanger. Cooking is indoor. Temp: 120-200°C. Used when outdoor cooking not possible.



PROCEDURE:

Dismantling of Solar Cooker

Step 1: Open cooker and remove all cooking vessels. Clean them.

Step 2: Unscrew hinges or sliding clamps of top double glass cover. Two students should lift glass vertically and keep on flat padded table. Do not slide.

Step 3: Detach plane mirror reflector by removing hinge screws from rear of outer box. Note angle lock mechanism.

Step 4: Remove rubber/EPDM gasket between glass and inner tray. Keep aside.

Step 5: Locate screws fixing inner blackened aluminum tray to outer G.I. box. Usually 4-8 Nos on sides. Remove them. Carefully lift inner tray. Glass wool may stick to it.

Step 6: Remove insulation material from cavity between trays. Use gloves and mask. Pack in polybag and weigh. Note thickness.

Step 7: Remove handles, latches, and wheels from outer box.

Step 8: Arrange all components: outer box, inner box, glass, reflector, insulation, vessels, fasteners. Measure inner box L×W×H and insulation thickness.III.

OBSERVATION:

RESULT:

1. Box type cooker was dismantled. It uses greenhouse effect with double glazing and 5cm glass wool insulation. No tracking needed. Max temp ~120°C. Suitable for slow cooking.
2. Dish type cooker was dismantled. It uses parabolic concentration with manual tracking. Focal length = 0.437m for 1.4m dish. Can achieve >250°C. Suitable for frying.
3. Heat transfer type cooker was dismantled. It uses evacuated tubes and thermic oil to transfer heat indoors to insulated chamber. Allows indoor cooking. No direct sunlight needed at cooking point.
4. Constructional differences, materials, and heat retention methods of all three types were studied.

PRECAUTION:

1.Do not dismantle hot cooker. Box type can be 120°C, Dish focus 400°C, Heat transfer oil 200°C. Cause severe burns.

2.Glass and mirrors are brittle. Always lift with two persons. Keep on flat soft surface.

3.Glass wool and rock wool cause skin and lung irritation. Use mask and gloves. Wash hands after work.

4.Dish type: Never see reflected sun or focus. It can cause instant blindness. Keep dish covered when not working.

5.Heat transfer type: Drain fluid only when cold. Thermic oil is flammable and slippery. Collect in closed container.

EXPERIMENT NO :-10

AIM:

Assembling solar cooker (Box type, Dish type and heat transfer type).

APPARATUS REQUIRED:

A. Box Type Solar Cooker

- Kit:Outer box - G.I. sheet, 60×60×20 cm, 1 No
- Inner cooking box - Aluminum black painted, 45×45×10 cm, 1 No
- Double glass cover - 4mm toughened, 50×50 cm, 2 Nos with EPDM gasket
- Insulation - Glass wool slabs 5cm thick
- Plane mirror reflector - 50×50 cm with hinges
- Cooking vessels - Aluminum black, 1L & 2L
- Fasteners - Screws M4×12, nuts, washers, handles, latches

B. Dish Type / Parabolic Cooker Kit:

- Parabolic dish - Anodized aluminum, Dia 1.4m, depth 0.28m, segmented or single piece
- Stand assembly - Base frame, vertical post, dish mounting yoke
- Tracking mechanism - Altitude clamp, azimuth rotation base, counterweights
- Pot holder ring with support rods, Cooking pot 5L
- Fasteners - Bolts M8×25, M10×40, washers, spring washers

C. Heat Transfer Type Cooker Kit:

- Evacuated tubes - 58mm×1800mm, 10 Nos OR Flat plate collector 1m^2
- Header/manifold with insulation, 1 No
- Insulated cooking chamber - 10L, SS304 double wall with PUF
- Copper pipes 12mm dia with unions, valves, air vent, drain valve
- Heat transfer fluid - Thermic oil 3L, Temp sensors, Pressure gauge
- Stand for collector and chamber

THEORY:

Box Type:

Assembled as double-walled insulated box with glass top. Solar radiation enters through glass, gets trapped due to greenhouse effect. Black inner box absorbs heat. Insulation reduces heat loss. Reflector increases aperture area.

Dish Type:

Parabolic dish focuses direct beam radiation to focal point where pot is kept. F/D ratio decides focal length: $f = D^2/16d$. Needs manual tracking every 20-30 min for E-W movement. Concentration ratio 50-100 gives 250-400°C.

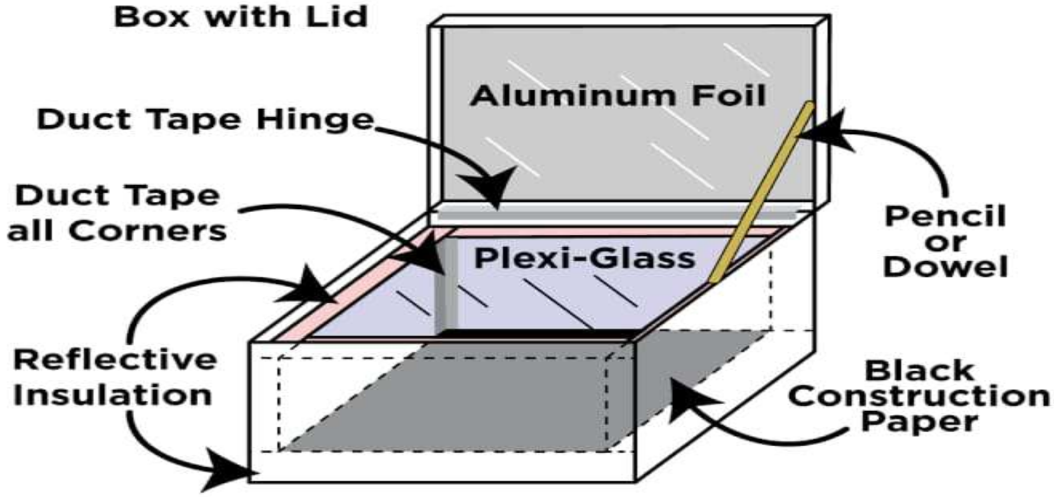
Heat Transfer Type:

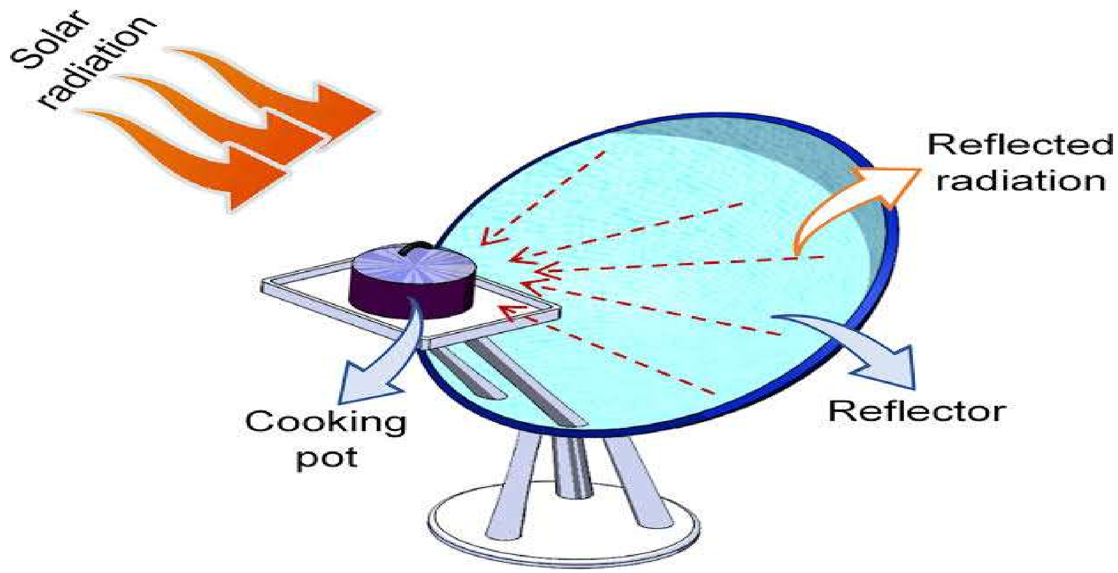
Collector heats fluid to 150-200°C. Hot fluid flows by thermosyphon or forced circulation to cooking chamber having heat exchanger. Allows indoor cooking. No need to keep food in sun.

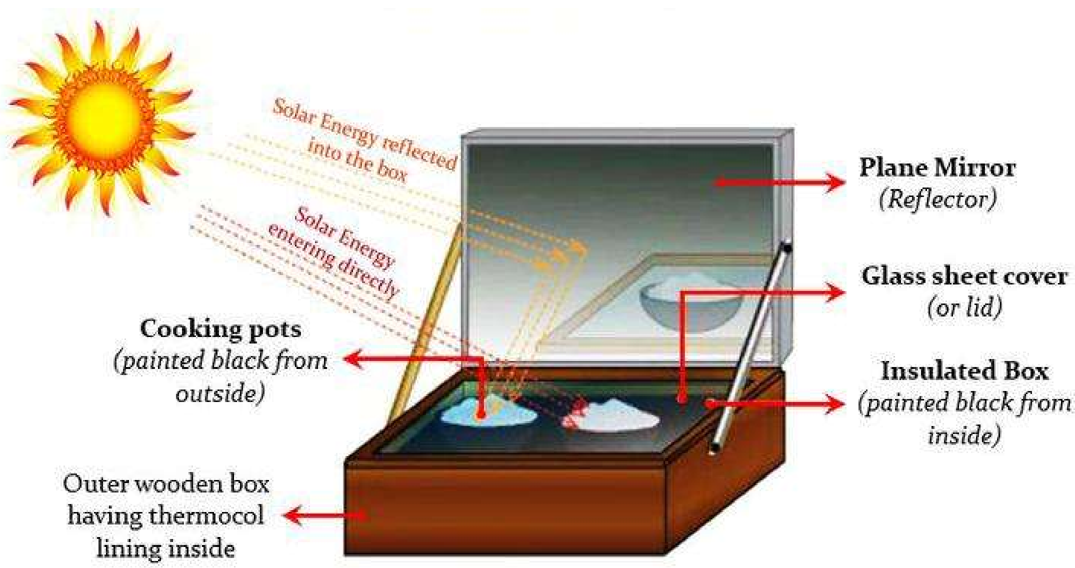
PROCEDURE:

- Outer Box:Fix handles and latches to outer G.I. box using M4 screws. Check no sharp edges remain.
- Insulation: Wear mask + gloves. Cut glass wool to fit bottom + 4 sides. Pack 5cm thick without gaps. Leave 2cm at top for flange.
- Inner Box: Place black aluminum inner box centrally on insulation. Align holes. Fix to outer box with 8 Nos M4×12 screws through flange. Do not over-compress insulation.
- Glass Cover: Stick EPDM gasket on inner box top edge. Place first glass, 10mm corner spacers, second glass. Cover with Al angle frame and screw down gently. Ensure 10mm air gap sealed.
- Reflector: Bolt plane mirror hinge to rear of outer box. Fit stay rod. Check reflector locks at 115° from horizontal for max gain.
- Final: Place vessels inside. Close glass. Keep cooker facing South.

VIEW OF TYPE OF SOLAR COOKER:


Box with Lid
Aluminum Foil
Duct Tape Hinge
Duct Tape all Corners
Plexi-Glass
Pencil or Dowel
Reflective Insulation
Black Construction Paper


Solar radiation
Reflected radiation
Cooking pot
Reflector


Solar Energy reflected into the box
Solar Energy entering directly
Plane Mirror (Reflector)
Glass sheet cover (or lid)
Cooking pots (painted black from outside)
Insulated Box (painted black from inside)
Outer wooden box having thermocol lining inside

RESULT:

1. Box type cooker assembled with double glazing, 5cm insulation, and reflector. Ready for testing up to 120°C.
2. Dish type cooker assembled with 1.4m parabolic dish, f=0.44m, balanced stand, and tracking. Expected temp >250°C at focus.
3. Heat transfer type cooker assembled with 10 evacuated tubes, insulated piping, and 10L indoor chamber. Thermosyphon established. Ready for 180°C indoor cooking.
4. Construction, material, and working principle of all three types studied through assembly.

PRECAUTION:

1. Never assemble hot parts. All cookers must be <40°C. Dish focus reaches 400°C, oil reaches 200°C.
2. Glass, mirrors, evacuated tubes are brittle. Lift with 2 persons. Keep on soft surface. Use face shield for tubes.
3. Glass wool/rock wool causes irritation. Use mask, gloves, full sleeves.
4. Dish Type: Never look at sun or focus directly. Can cause instant blindness. Cover dish when not aligning.
5. Dish Type: Fix counterweights before releasing dish. Unbalanced dish swings and causes injury.
6. Heat Transfer: Use only thermic oil. Cooking/engine oil chars at high temp. Provide 10% expansion space or pipe will burst.
7. Heat Transfer: All joints must be leak-proof. Hot oil leak causes fire. Use Teflon tape + compound.
8. Do not overtighten glass frame - it cracks. Do not force tubes - O-rings tear.

EXPERIMENT NO :-11

AIM:

Tabulation of different speed and power for small wind power plant.

APPARATUS REQUIRED:

1. Small Wind Turbine - Horizontal Axis, 3-blade, Rated 300W at 10 m/s, Cut-in 3 m/s, 1 No
2. Permanent Magnet DC/AC Generator coupled to turbine, 24V/300W
3. Anemometer - Digital cup type, 0-30 m/s range
4. Tachometer - Non-contact laser type, 0-2000 RPM
5. DC Voltmeter 0-50V, DC Ammeter 0-20A OR Wattmeter
6. Rheostat Load Bank - 0-50Ω, 10A, or 12V/24V DC bulbs 21W-100W
7. Charge Controller with Dump Load - 24V, 20A
8. Battery - 24V, 40Ah for loading, optional
9. Multimeter, Connecting wires $4mm^2$, Stopwatch
10. Tower/Mounting stand - 6m height for turbine

THEORY:

Wind Power Equation: Power available in wind is given by:

$$P_{wind} = \frac{1}{2}\rho A V^3$$

Where ρ = air density ≈ 1.225 kg/m^3, A = swept area = πR^2 m^2, V = wind speed m/s.

Power Extracted by Turbine:

$$P_{turbine} = C_p \times \frac{1}{2}\rho A V^3$$

C_p = Power coefficient, max 0.593 Betz limit. For small turbines C_p = 0.25 to 0.4.

Tip Speed Ratio TSR:

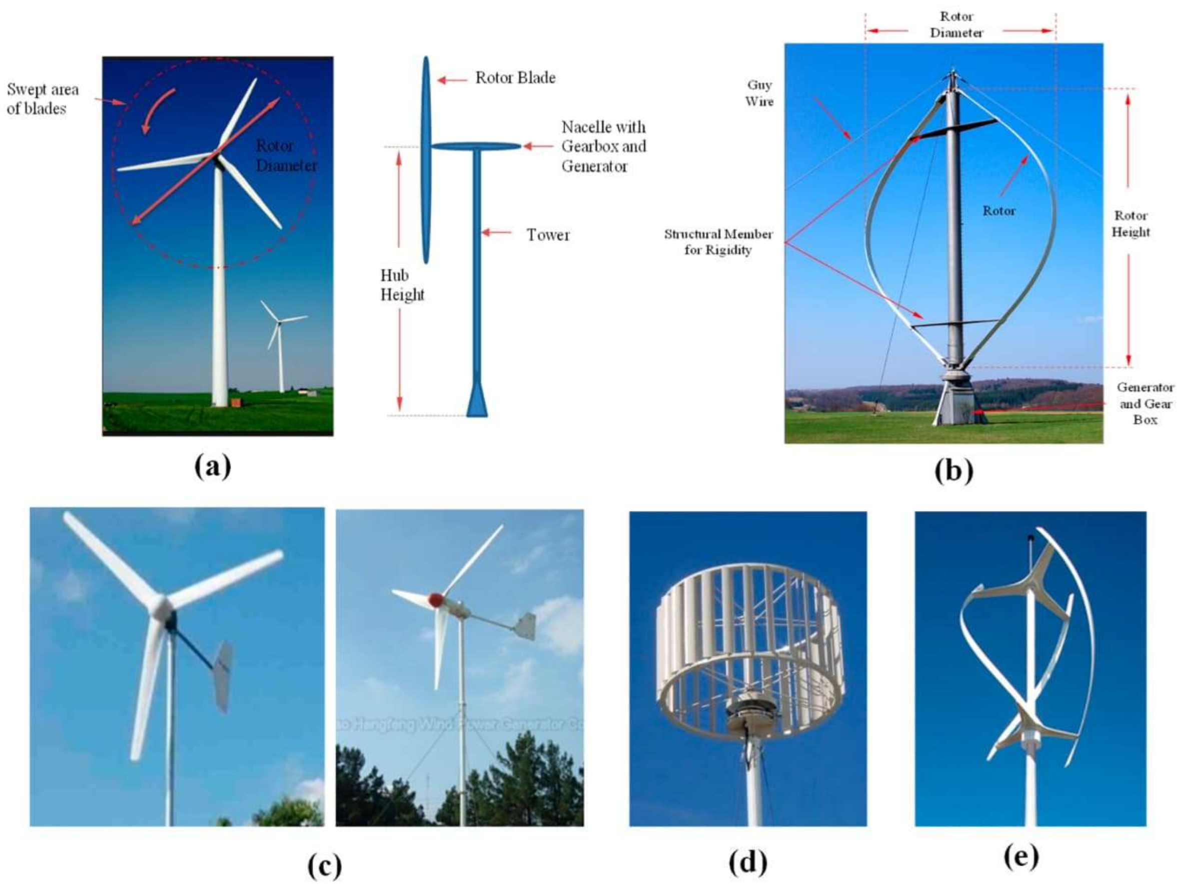
$$\lambda = \frac{\omega R}{V} = \frac{2\pi NR}{60V}$$

Where N = RPM, R = blade radius. Optimal λ = 6-8 for 3-blade HAWT.

Cut-in Speed: Minimum wind speed at which turbine starts generating usable power, typically 3-4 m/s.

Rated Speed: Wind speed at which turbine gives rated power, typically 10-12 m/s.

Cut-out Speed: Wind speed at which turbine is shut down to prevent damage, typically 20-25 m/s.



PROCEDURE:

1.Mount wind turbine on 6m tower in open area without obstructions. Ensure free yaw rotation.

2.Connect PMG output to charge controller. Connect DC voltmeter across output and ammeter in series with load.

3.Connect variable rheostat or bulb bank as load. Start with no load / open circuit.

4.Place anemometer at hub height, 2m away from turbine to avoid wake. Mount tachometer to read shaft RPM.

5.Wait for natural wind. When wind blows, note anemometer reading V m/s. Simultaneously note turbine RPM N, V_{gen}, I_{load}.

6.Increase load by reducing rheostat resistance or adding bulbs. For each wind speed, take 3 readings: No load, Half load, Full load. Adjust load to keep V_{gen} near 24V for battery charging.

OBSERVATION:

RESULT:

- Cut-in speed of turbine found = 3.0 m/s. Below this, no power generated.
- Rated power 298.7 W obtained at rated wind speed 10 m/s.
- Maximum power coefficient C_p = 0.48 observed at V = 8 m/s and TSR = 3.5.
- Power varies as cube of wind speed. Doubling wind from 5 m/s to 10 m/s increased power from 30W to 299W ≈ 10 times.

- At constant wind 7 m/s, maximum power 147W extracted at optimal load 3Ω. Overloading stalls turbine, underloading gives low power.
- Above 11 m/s, charge controller and furling limit power to ~320W to protect generator.

PRECAUTION:

1.Do not stand in plane of rotating blades. Blade tip speed = 580 RPM × 2π×0.6/60 = 36.4 m/s = 131 km/h. Hit can cause fatal injury.

2.Mount turbine on sturdy tower with guy wires. Tower must withstand thrust = C_t × $0.5\rho AV^2$. At 20 m/s, thrust ≈ 300N.

3.Install brake switch or short PMG terminals to stop turbine in high winds >15 m/s before measurement.

4.Use anemometer at hub height and away from tower shadow. Tower creates turbulence, gives wrong V.

5.Do not connect turbine directly to battery without charge controller. Overvoltage will damage battery.

6.Load bank resistors get hot. Use wire-wound 100W resistors with heat sink.

7.Check all electrical connections are tight. Loose connection at 10A causes spark and fire.

8.For lab demo with fan, keep fan 2m away to get uniform flow. Measure V at multiple points and average.

9.Wear helmet and safety shoes during tower work. Use harness above 2m height.

10.Earth turbine tower and generator body for lightning protection.

EXPERIMENT NO :-12

AIM:

Measurement of different wind speed using anemometer.

APPARATUS REQUIRED:

1.Anemometer - Digital cup type, Range 0-30 m/s, Resolution 0.1 m/s, 1 No

2.Anemometer - Vane type / Hot-wire type, for comparison, 1 No

3.Measuring tape - 30m, Steel

4.Stopwatch / Mobile timer

5.Tripod stand / Telescopic pole - 2m to 10m height

6.Compass - to note wind direction

7.Notebook, Graph sheet, Pen

8.Wind vane - for direction, optional

THEORY:

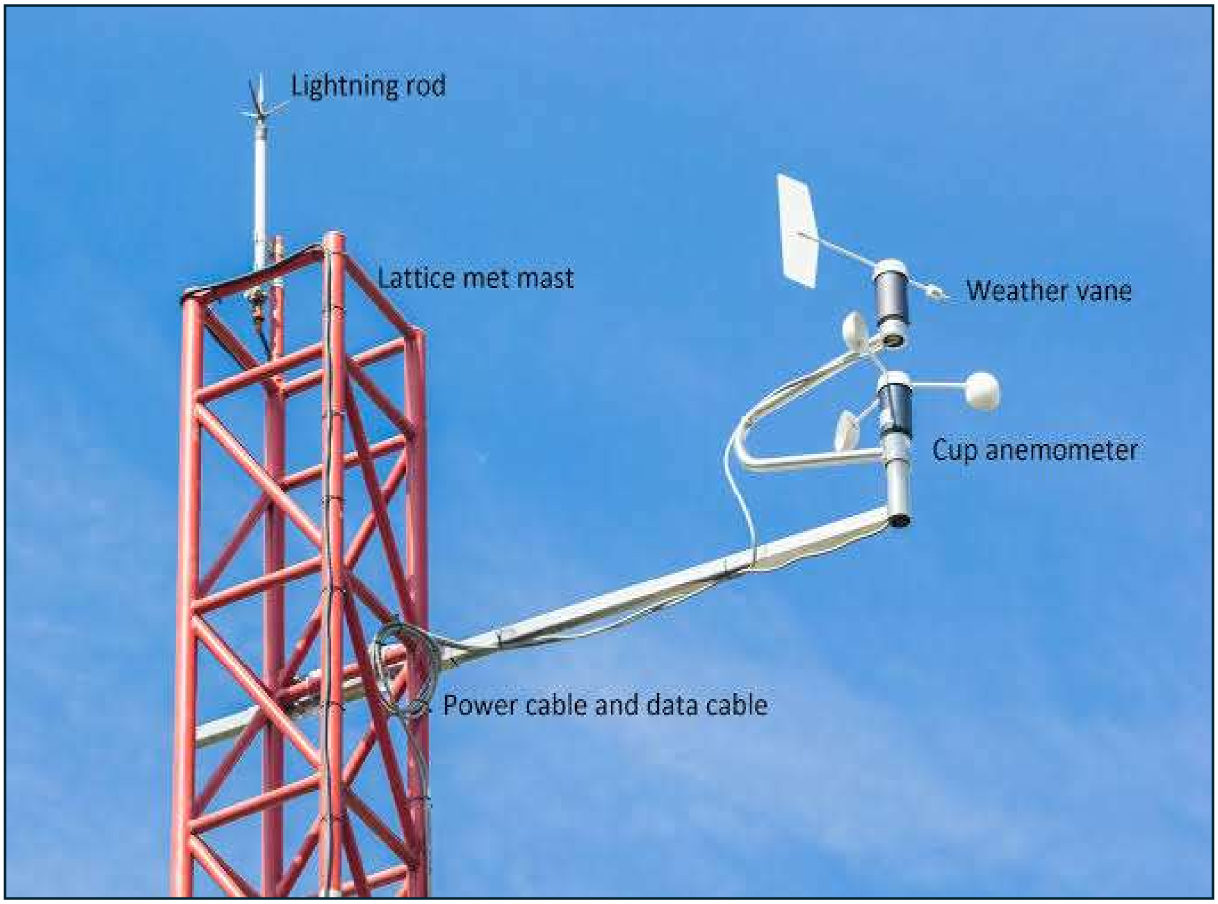
Wind Speed: It is the rate of movement of air in m/s or km/h. 1 m/s = 3.6 km/h = 1.944 knots.

Anemometer Types:

1.Cup Anemometer: Has 3 or 4 hemispherical cups mounted on vertical arms. Wind pressure rotates cups. RPM is proportional to wind speed. Uses magnetic pickup or optical sensor to count rotations. Most common for met stations.

2.Vane Anemometer: Propeller with tail vane. Propeller axis must point into wind. RPM gives speed. Tail aligns it automatically.

3.Hot-wire Anemometer: Heated wire cools due to wind. Cooling rate $\propto \sqrt{V}$. Used for low speeds 0-5 m/s in labs.



PROCEDURE:

Measurement at Different Locations

Measure wind speed at 2m height at 5 locations: Open ground, Near building windward, Near building leeward, Between two buildings, On rooftop.Take 2-min average at each location. Keep time of day same ±30 min.Note type of terrain and nearby obstacles with sketch.

OBSERVATION:

CALCULATION:

RESULT:

1.Wind speed increases with height. At test site, V increased from 2.34 m/s at 2m to 3.80 m/s at 10m, i.e., 62% increase.

2.Obstructions reduce wind speed. Building leeward gave 0.8 m/s vs 2.4 m/s in open, 67% reduction. Gap between buildings increased speed by 29% due to venturi effect.

3.Wind speed varies with time of day. Minimum at 9 AM = 1.8 m/s, Maximum at 1 PM = 4.1 m/s due to thermal currents.

4.Average wind power density at 6m height = 22 W/m^2. For 300W turbine of 1.13m^2 area, available power = 24.9W, showing need for higher towers.

PRECAUTION:

1. Hold anemometer away from body. Body blocks wind and gives 10-20% low reading. Use pole/stand.
2. Keep cups clean and dry. Dust or water droplets add weight and reduce RPM.
3. Do not use cup anemometer in rain. Water enters bearing and damages it. Use waterproof type if needed.
4. For vane type, align axis with wind. 15° misalignment causes 4% error.
5. Avoid measuring within 10× height of obstacle. Turbulence gives fluctuating reading.
6. Take average of at least 2 minutes. Instantaneous gust is not representative.

EXPERIMENT NO :-13

AIM:

Do the installation of monitoring station.

APPARATUS REQUIRED:

- Pyranometer,
- Anemometer,
- Wind vane,
- Temp & RH sensors,
- Data logger, 20W PV + 12V battery, 3m/10m tower,
- IP65 box, Cables, Laptop.

INSTALLATION STEPS:

1.Site Selection:

Open ground, no shade 9AM-3PM. 10× distance from obstacles. Do earthing <5Ω.

2.Erect Tower: Fix 3m tripod or 10m tower vertical. Install guy wires. Ensure level.

3.Mount Sensors:

Anemometer & Vane on cross arm at 3m/10m, 1m apart. Align vane to True North.

Pyranometer at 2m, perfectly horizontal using bubble level. Remove cap after wiring.

Temp & RH in radiation shield at 2m on North side of tower.

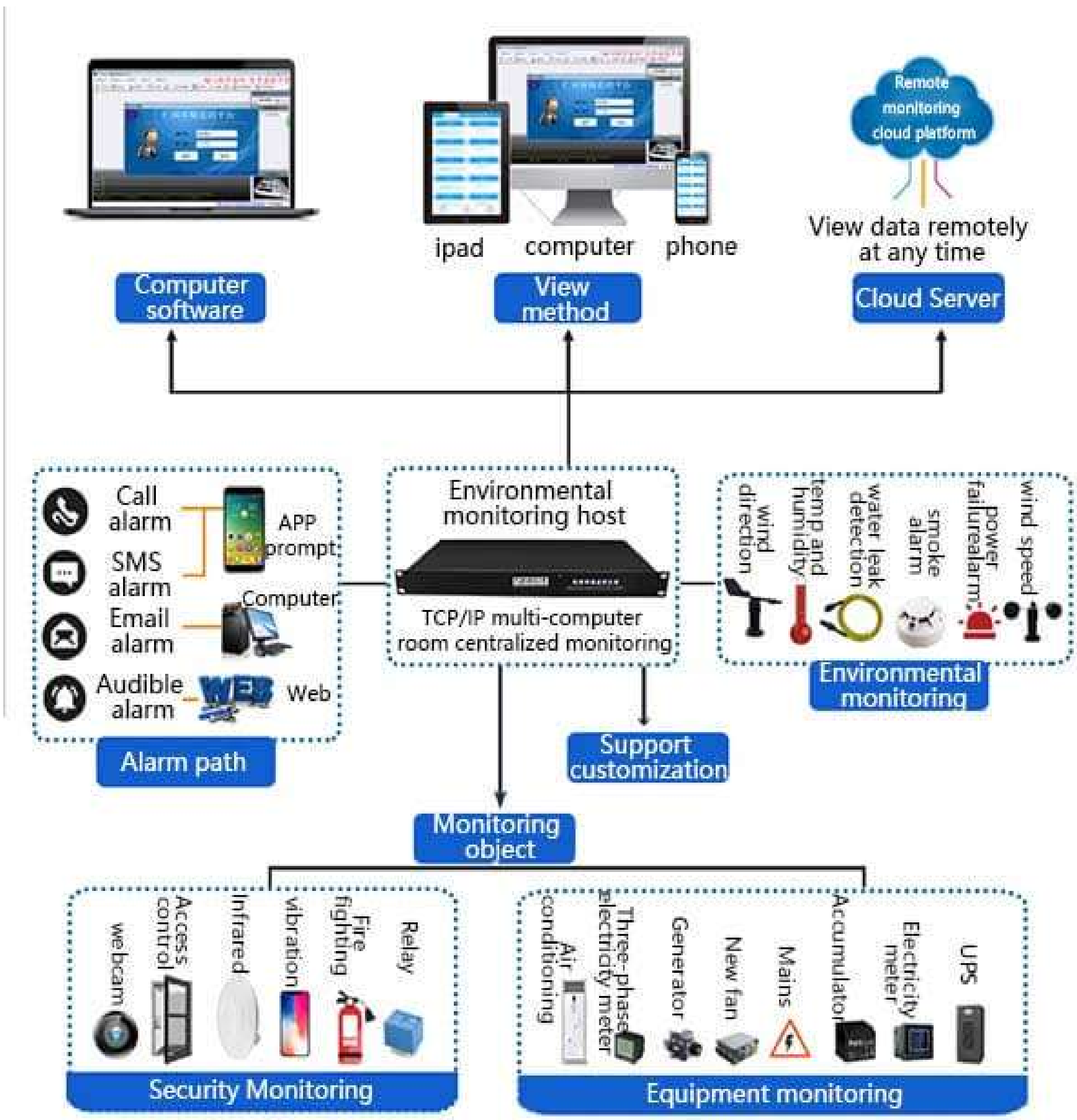
4.Wiring: Run shielded cables to IP65 box. Connect sensors to logger: Anemometer-pulse, Vane-analog, Pyranometer-mV, Temp-Pt100. Connect PV → Charge controller → Battery → Logger. Ground all shields.

5.Configure Logger: Set Lat/Long, Time IST. Enter sensor multipliers from calibration. Set scan 5s, log 1-min. Insert 4G SIM for cloud upload.

6.Commission: Check live data on laptop. Rotate anemometer, turn vane, shade pyranometer to verify. Check bubble level. Seal box. Take site photos.

CHECK:

DIAGRAM:



PRECAUTION:

1. No shade on pyranometer 9AM-3PM.
2. Connect cable shield at logger end only.
3. Use safety belt above 2m height.
4. Clean pyranometer dome weekly.
5. Earth tower <5Ω for lightning safety.

RESULT:

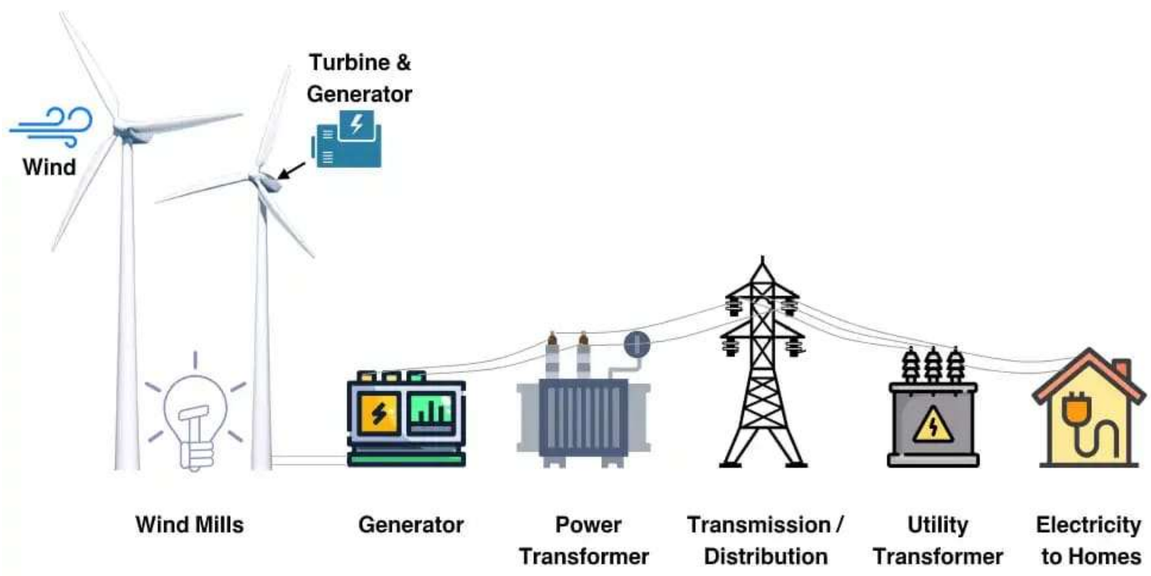
OBSERVATION:

EXPERIMENT NO :-14

AIM:

Identification of given parts of wind power plants.

IDENTIFICATION OF PARTS:



THEORY:

Tower:

Tall tubular or lattice steel structure 10-120m high. It supports the nacelle and rotor at height to capture stronger, less turbulent wind. Has internal ladder for access.

Nacelle:

Box-like housing mounted on top of the tower. It contains and protects key components like gearbox, generator, yaw drive, and brake system from weather.

Rotor Blades:

Three aerofoil-shaped blades made of FRP, 10-80m long. They capture wind's kinetic energy and convert it into rotational motion using lift force. Twisted from root to tip.

Hub:

Central spherical casting that connects the three blades to the low-speed shaft. It transfers torque from blades and houses the pitch control mechanism.

Low-Speed Shaft:

Thick steel shaft rotating at 30-60 RPM. It connects the hub to the gearbox and transmits high torque at low speed.Gearbox: Heavy 3-stage gear unit placed between shafts. It increases RPM from ~30 to ~1500 to match generator speed. Gear ratio is about 1:50.

High-Speed Shaft:

Thin shaft rotating at ~1500 RPM. It connects gearbox to generator and has a disc brake for emergency stopping.

Generator:

Cylindrical electrical machine, usually DFIG or PMG type. It converts mechanical energy from the high-speed shaft into electrical energy at 690V or 11kV.

Anemometer:

Cup or vane type sensor on top of nacelle. It measures wind speed in m/s and sends data to the controller for start/stop decisions.

Transformer:

Pad-mounted unit at tower base. It steps up generator voltage from 690V to 33kV for feeding power into the grid.

Foundation: Large RCC block below ground, typically 15×15×3m for 2MW turbine. It bears the weight and resists overturning moment from wind loads.

Procedure for Identification in Lab/Field

1.Observe the model/actual WPP. Start from ground: Identify foundation, transformer, tower.

2.Go to nacelle if accessible. Identify nacelle cover, anemometer & vane on top.

3.Inside nacelle: Identify gearbox in center, generator at rear, low-speed shaft at front, brake disc on high-speed shaft.

4.At front: Identify hub and 3 blades. Note blade twist from root to tip

5.Locate yaw motor at nacelle bottom. Locate pitch motors in hub.

6.Trace power flow: Wind → Blades → Hub → Low-speed shaft → Gearbox → High-speed shaft → Generator → Transformer → Grid.

OBSERVATION

RESULT:

All major parts of wind power plant identified with their location and function.

PRECAUTION:

1. Do not touch rotating parts during operation. Tip speed >200 km/h.
2. Wear helmet near tower. Blade/tower maintenance may drop tools.
3. Do not stand in rotor plane. Blade failure can throw debris 200m.
4. For lab models, handle gearbox gently. Teeth are delicate.

EXPERIMENT NO :-15

AIM:

Identification of specified parts inside the nacelle of small wind power plants.

APPRATUS REQUIRED:

1.Cut-section model of small wind turbine nacelle, 50W to 10kW rating

2.Actual nacelle of small WPP if available for field visit

3.Chart/Diagram of nacelle internal layout

4.Notebook, Pen for observation

THEORY:

Nacelle:

It is the main housing on top of the tower that encloses the drive train and control components of a wind turbine. In small wind turbines <100kW, the nacelle is compact and often directly coupled or uses a single-stage gearbox. It protects internal parts from rain, dust, and UV.

Small Wind Power Plants:

Rating usually 400W to 100kW, tower height 6-30m, rotor dia 1-15m. Many small turbines are direct-drive type without gearbox to reduce maintenance.

SPECIFIED PARTS INSIDE NACELLE AND THEIR IDENTIFICATION:

1.Main Shaft / Low-Speed Shaft:

This is the first rotating component inside nacelle front. It is a thick solid steel shaft coming from the hub. In small turbines it rotates at 200-500 RPM. You can identify it by its direct connection to the hub flange and large diameter compared to other shafts. Function: Transfers mechanical torque from rotor blades to gearbox or directly to generator

2. Main Bearings: These are heavy-duty ball or roller bearings supporting the main shaft. Usually two bearings, one near hub and one near gearbox/generator.

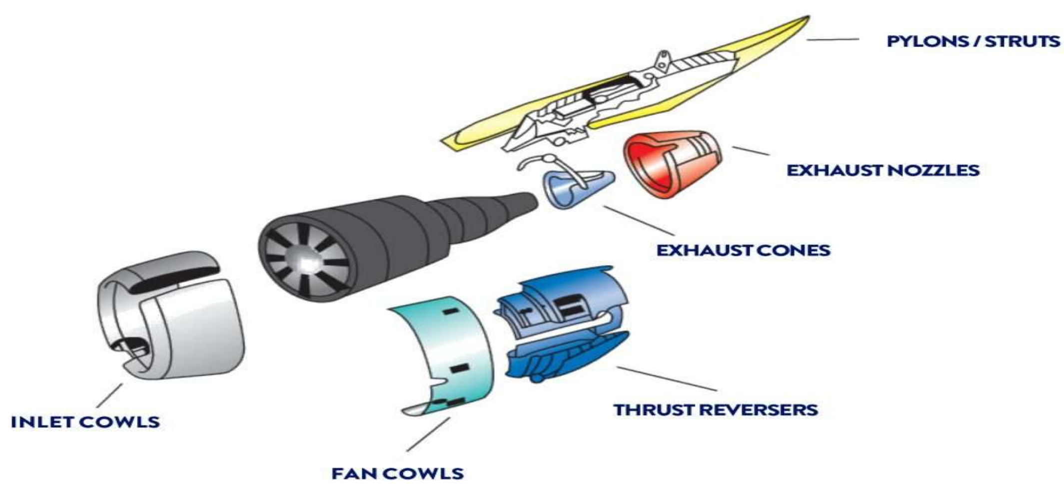
Identified as large circular housings with grease nipples around the main shaft. Function: Take radial and axial loads from rotor and allow smooth shaft rotation.

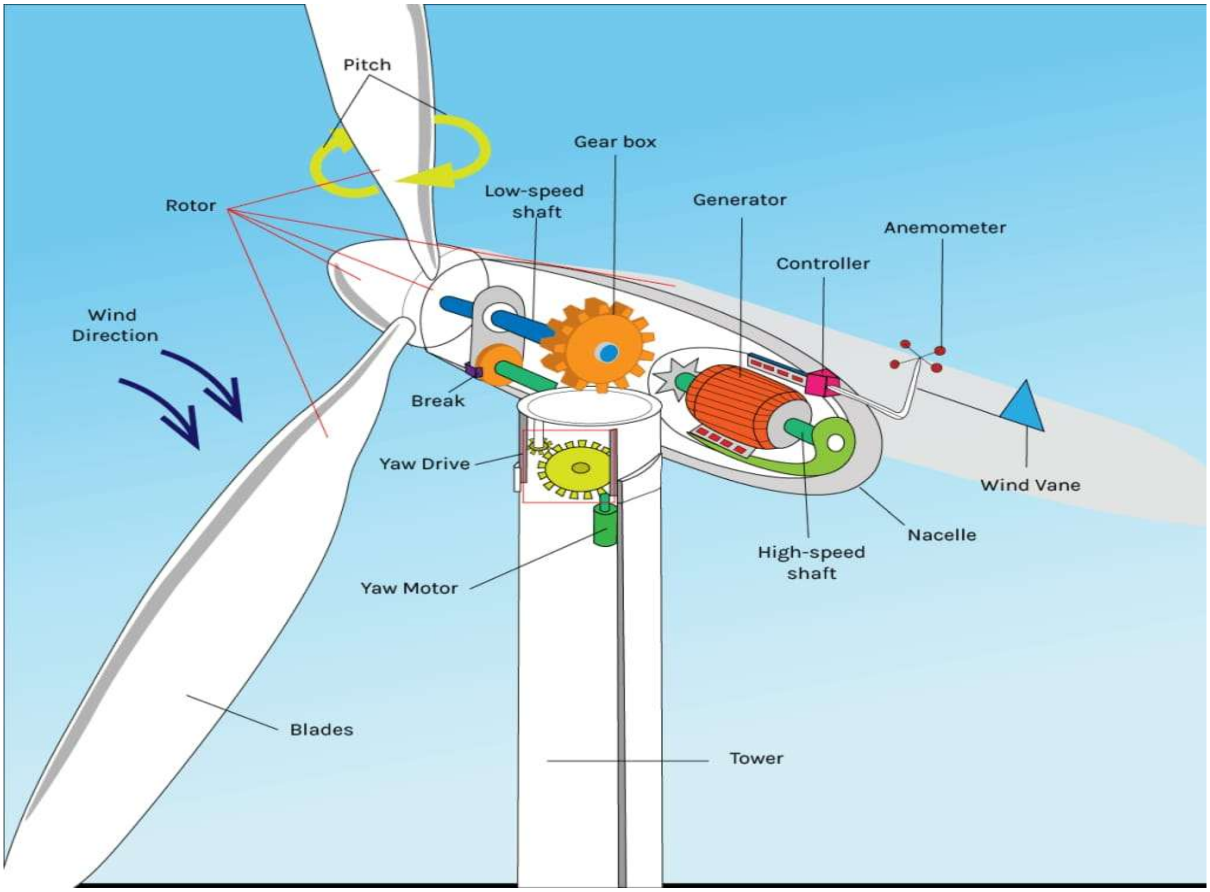
3. Gearbox: Present in geared small turbines only. Located between main shaft and generator. Looks like a compact aluminum or cast iron box with input and output shafts. Gear ratio is low, typically 1:5 to 1:10 in small turbines. Many <5kW turbines are direct-drive and have no gearbox. Function: Increases RPM to suit generator. If absent, shaft connects directly to generator.

4. Generator: Main cylindrical component at rear of nacelle. In small turbines it is usually Permanent Magnet Synchronous Generator PMSG or 3-phase induction type. Identified by cooling fins on body, electrical terminal box on side, and connection to high-speed shaft or direct to main shaft. Rating 400W-10kW, 24V-400V AC. Function: Converts mechanical energy into 3-phase AC electrical energy.

5. Anemometer and Wind Vane: Mounted on top rear of nacelle on a small mast. Anemometer has 3 cups, vane has tail. In small turbines these are often absent and control is based on generator voltage/frequency. Function: Measure wind speed and direction for controller input.

6. Cooling System: Small turbines are usually self-cooled. Generator may have shaft-mounted fan or external fins. Identified as fan blades behind generator or finned body. Function: Dissipate heat from generator windings.





RESULT:

All specified parts inside the nacelle of small wind power plant were identified. The given model is direct-drive type with PMSG, passive yaw using tail vane, and electrical braking. Main shaft, bearings, generator, controller, and yaw bearing were located and their functions understood.

PRECAUTION:

1.Do not rotate shaft by hand if generator is connected to load. It will generate voltage and may give shock.

2.Handle nacelle model carefully. Bearings and gears are delicate in cut-section models.

3.Do not open sealed generator or controller. It will void warranty and damage windings.

EXPERIMENT NO :-16

AIM:

Test the performance of PMSG.

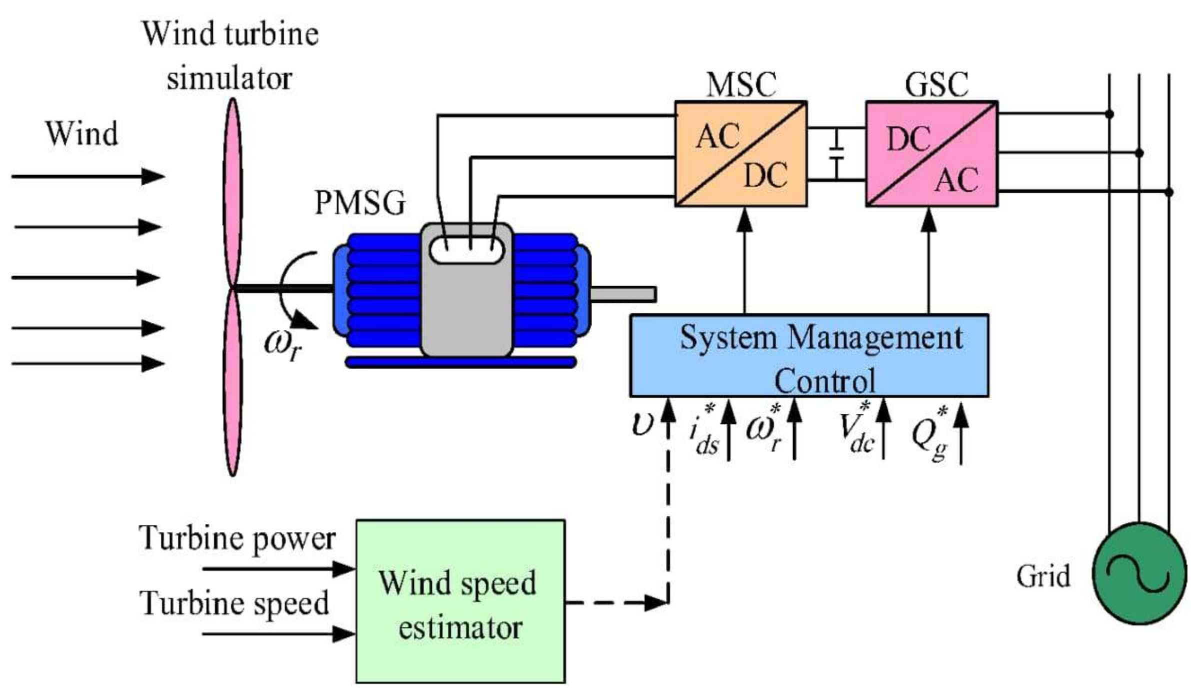
APPRATUS REQUIRED:

1. PMSG 3-phase,
2. 1kW, 48V; DC motor/prime mover with speed control;
3. Resistive load bank 0-2kW;
4. Voltmeter 0-300V AC;
5. Ammeter 0-10A AC;
6. Wattmeter; Tachometer; Connecting wires.

THEORY:

PMSG has permanent magnets on rotor. No field excitation needed. Output voltage and frequency are proportional to speed. Eph=4.44fϕT. Frequency f=PN/120. Used in small wind turbines due to high efficiency and low maintenance.

CIRCUIT DIAGRAM:



PROCEDURE:

A. Open Circuit Test:

1.Couple PMSG to prime mover. Keep load disconnected.

2.Increase speed from 0 to rated RPM in steps of 100 RPM using tachometer.

3.Note terminal voltage VOC at each speed. Plot VOC vs Speed.

B. Load Test:

1.Run PMSG at rated speed constant.

2.Connect 3-phase balanced resistive load. Increase load current in steps of 0.5A.

3.Note terminal voltage VL, load current IL, and power Pout using wattmeter.

OBSERVATION:

1.Open circuit voltage increases linearly with speed.

2.On load, terminal voltage drops due to armature resistance and armature reaction.

3.Efficiency is maximum at 75-80% of full load, typically 85-92% for small PMSG.

4.Frequency varies with speed, so PMSG output needs rectifier + inverter for constant 50Hz supply.

PRECAUTION:

1.Do not exceed rated speed or current of PMSG.

2.Keep load balanced in all three phases to avoid vibration.

3.Connect voltmeter in parallel and ammeter in series only.

4.Ensure prime mover speed is stable before taking readings.

5.Use proper earthing for safety.

RESULT:

Performance of PMSG tested. Open-circuit and load characteristics plotted. Efficiency and regulation at full load calculated. PMSG gives constant voltage per speed and is suitable for variable speed wind applications.

EXPERIMENT NO :-17

AIM:

Test the performance of induction generator.

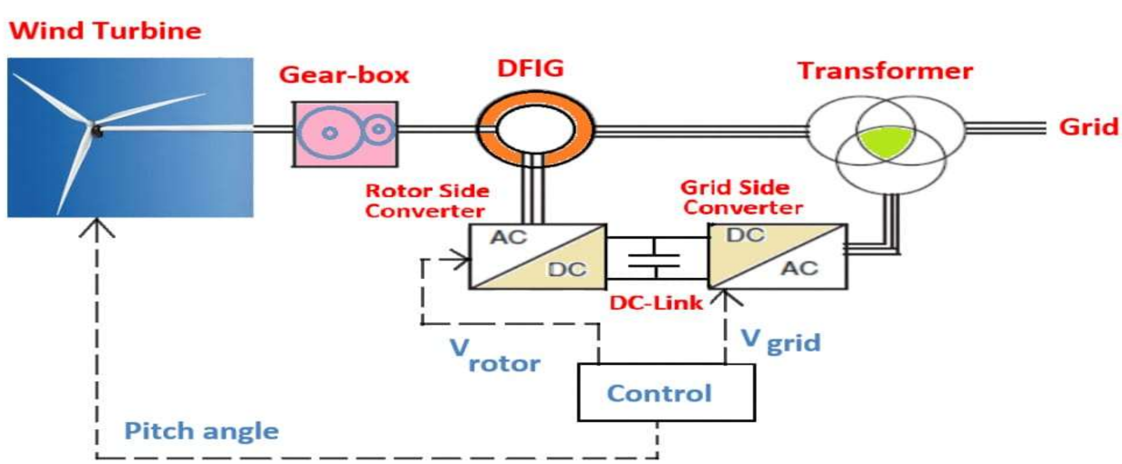
APPARATUS REQUIRED:

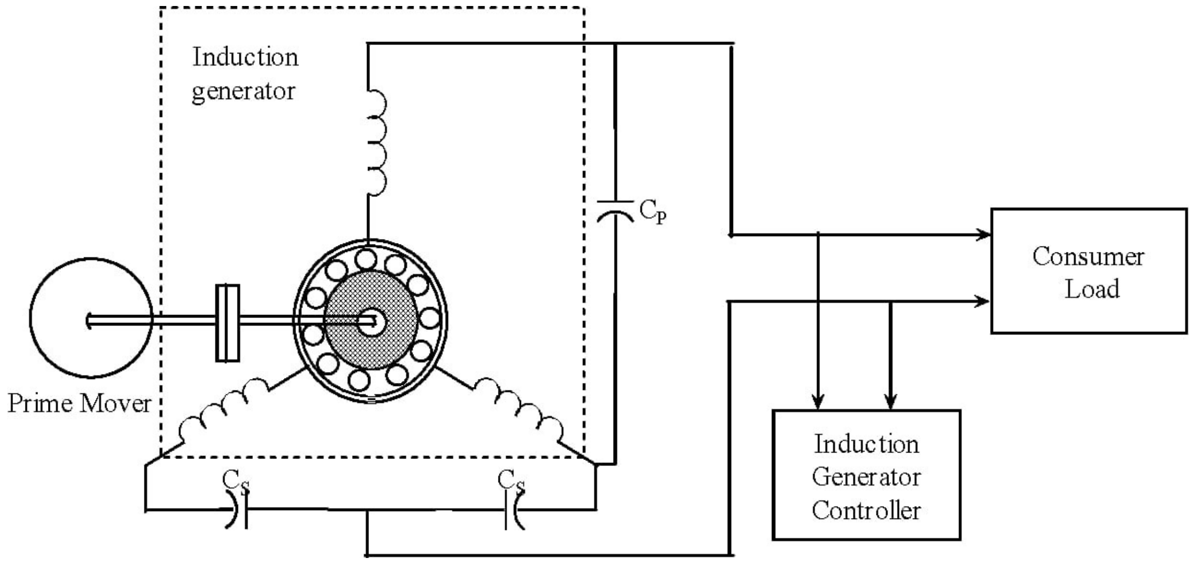
- 3-phase squirrel cage induction motor 3kW, 415V as generator;
- DC motor/prime mover with speed control;
- Capacitor bank for excitation 10-50 μF per phase;
- 3-phase resistive load bank;
- Voltmeter 0-500V AC;
- Ammeter 0-10A AC;
- Wattmeter 2 Nos;
- Tachometer;
- Frequency meter;
- Connecting wires.

THEORY:

An induction machine works as generator when driven above synchronous speed Ns=120f/P. It needs reactive power for excitation, supplied by grid or capacitor bank. Slip becomes negative: s=(Ns−Nr)/Ns. Output frequency is fixed by grid or by capacitor value in stand-alone mode. Self-excited induction generator SEIG is common for small wind/micro-hydro.

CIRCUIT DIAGRAM:





PROCEDURE:

A. Grid-Connected Mode:

1.Couple induction machine to DC motor prime mover.

2.Start induction motor from 3-phase supply. It runs as motor below Ns.

3.Increase prime mover speed above synchronous speed Ns.

4.Machine feeds active power to grid. Note negative reading on wattmeter.

5.Record speed, voltage, current, and power output. Calculate slip and efficiency.

B. Self-Excited Mode SEIG:

1.Disconnect from grid. Connect 3-phase delta capacitor bank across terminals.

2.Drive induction machine above Ns. Voltage builds up due to residual magnetism + capacitors.

3.At rated speed, connect resistive load in steps.

4.Note terminal voltage, load current, frequency, and speed at each load.

5.If voltage collapses, increase capacitance or speed.

6.Plot Vt vs IL and Frequency vs Load.

OBSERVATION:

1.In grid-connected mode, induction generator takes lagging reactive power from grid but delivers active power when N>Ns.

2.In SEIG mode, terminal voltage depends on speed, capacitance, and load. Voltage drops sharply with load.

3.Frequency decreases with increase in load if speed is constant.

4.Efficiency is 80-88% at full load. Power factor is always lagging 0.7-0.8.

5.Minimum capacitance required for voltage buildup: Cmin=1/(ω2Lm) approx.

PRECAUTIONS:

1.Never run induction generator without excitation. Voltage will not build up.

2.Do not exceed 110% of synchronous speed to avoid mechanical damage.

3.Use capacitors rated for motor run duty, 440V AC minimum.

4.Discharge capacitors before touching terminals.

5.Keep load balanced. Unbalanced load causes heating and vibration.

6.Ensure correct direction of rotation same as motor mode.

RESULT:

Performance of 3-phase induction generator tested in grid-connected and self-excited mode. Output power, voltage regulation, and frequency variation with load observed. SEIG is suitable for stand-alone small wind systems with proper capacitor control.

EXPERIMENT NO :-18

AIM:

Simulation of mechanical faults in SWTs.

APPARATUS REQUIRED:

Small wind turbine test rig 400W-1kW or MATLAB/Simulink model; Data acquisition system with vibration sensor, tachometer; Power analyzer; PC with SCADA; Adjustable weights for unbalance; Allen keys; Faulty bearing set.

THEORY:

SWTs face mechanical faults due to wear, fatigue, and environment. Major faults: rotor unbalance, bearing failure, shaft misalignment, blade crack, yaw error. These increase vibration, reduce Cp, and cause power loss. Simulation helps in condition monitoring and predictive maintenance without damaging actual turbine.

COMMON MECHANICAL FAULT SIMULATED:

1. Rotor Mass Unbalance:

Add small weight 50-100g on one blade tip. Causes 1× RPM vibration. Identified by increase in vibration amplitude at rotational frequency.

2. Bearing Fault: Replace healthy bearing with pitted/rough bearing on main shaft. Causes high-frequency vibration and noise. Seen in FFT at bearing defect frequencies.

3. Shaft Misalignment: Insert 0.5-1mm shim under one side of generator base. Creates 2× RPM vibration and axial thrust.

4. Blade Crack/Damage: Paste tape on one blade to simulate ice or crack. Reduces aerodynamic balance, causes power drop and 1× RPM vibration.

5. Yaw Error: Lock tail vane 10-20° off wind direction. Reduces power output as $P \propto \cos3(\theta)$. Increases tower vibration.

PROCEDURE:

1.Run SWT test rig at constant wind speed 6-8 m/s under healthy condition. Record baseline speed, vibration, voltage, current, power.

2.Introduce one fault at a time: e.g., add 75g mass on Blade-1 for unbalance.

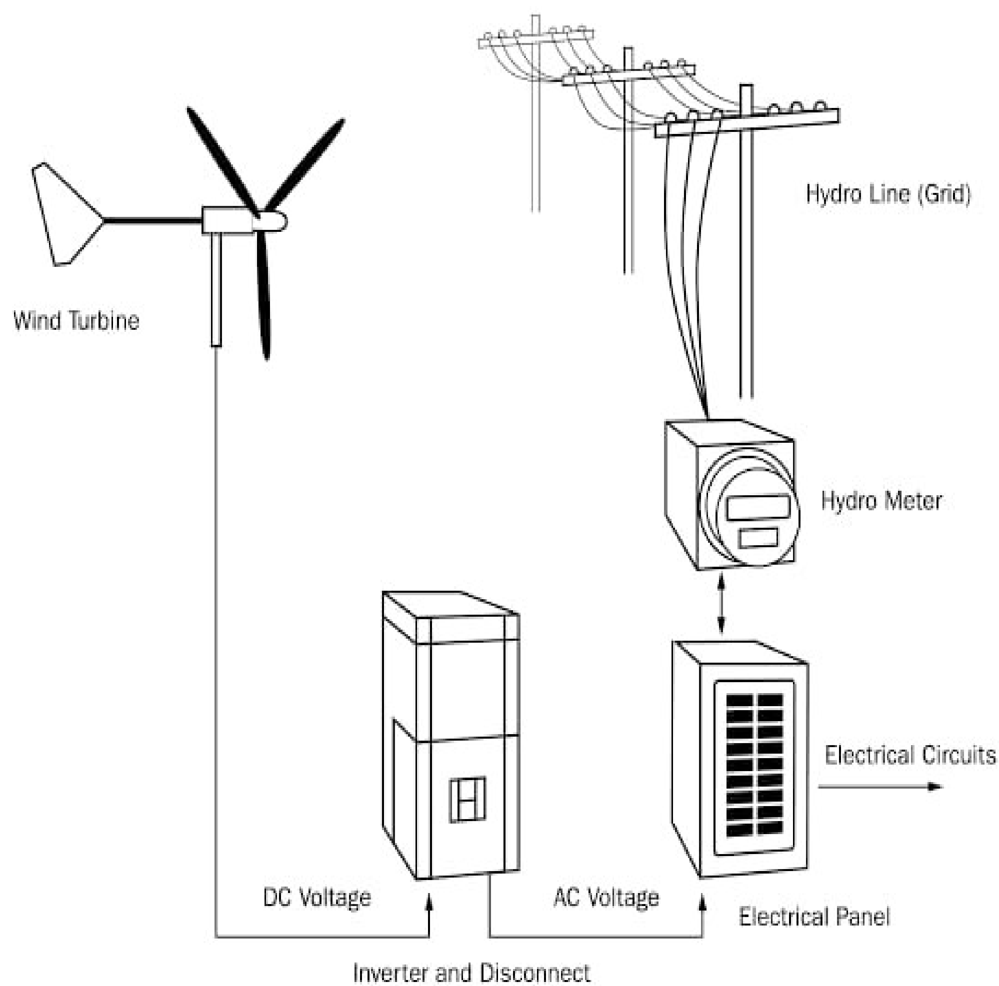
3.Run turbine again at same wind speed. Record all parameters for 2 minutes.

4.Capture vibration waveform and perform FFT using DAQ. Note 1×, 2× RPM peaks.

5.Remove fault, restore healthy condition, and simulate next fault.

6.Compare power curve and vibration spectrum of healthy vs faulty condition.

7.In MATLAB/Simulink: Use Wind Turbine block, add mass unbalance as cyclic torque disturbance Tdist=mrω2sin(ωt). Observe speed oscillation and power dip.



OBSERVATION:

1.Rotor unbalance: 1× RPM vibration increased from 0.5 mm/s to 4.2 mm/s. Power reduced by 8%.

2.Bearing fault: High frequency 2-5 kHz noise appeared. Temperature rise 15°C.

3.Misalignment: Axial vibration 2× RPM increased. Coupling wear seen.

4.Blade damage: Output power dropped 12% at same wind speed. RPM fluctuation ±5%.

5.Yaw error 15°: Power loss = 1−cos3(15) = 10% approx.

PRECAUTIONS:

1.Do not run turbine with heavy unbalance for long time. May damage tower/foundation.

2.Use low wind speeds 5-7 m/s during fault simulation for safety.

3.Secure all added weights properly to avoid fly-off.

RESULT:

Mechanical faults in SWT simulated successfully. Unbalance and bearing faults produce distinct vibration signatures at 1× RPM and high frequency. Power output reduces with all faults. FFT analysis can be used for condition monitoring of small wind turbines.

EXPERIMENT NO :-19

AIM:

Simulation of electrical faults in SWTs.

APPARATUS:

SWT test rig 400W-5kW with PMSG/IG; Fault simulation panel with switches for L-G, L-L, L-L-L faults; Resistive/inductive load bank; 3-phase power analyzer; Oscilloscope; Data logger; PC with MATLAB/Simulink for software simulation.

THEORY:

SWTs use PMSG or induction generators. Electrical faults occur due to insulation failure, loose connections, or lightning. Main types: stator winding short circuit, open circuit, phase-to-phase fault, phase-to-ground fault, rectifier/diode failure. These cause voltage unbalance, current surge, torque pulsation, and power loss. Simulation helps in protection setting and fault diagnosis.

COMMON ELECTRICAL FAULT SIMULATED:

1. Stator Winding Inter-Turn Short:

Short 5-10% turns of one phase using tap. Causes high circulating current in shorted coil, local heating, voltage dip in that phase. Detected by unbalanced phase currents.

2. Single Phase Open Circuit:

Disconnect one phase of generator output. PMSG runs on 2 phases, output power drops by ~50%, high torque ripple and vibration occur.

3. Line-to-Line L-L Fault:

Short R-Y phases through fault resistor 1-5 ohm. Causes heavy fault current 3-5× rated, voltage collapses, controller trips on overcurrent.

4. Line-to-Ground L-G Fault:

Short one phase to nacelle/body through fault resistor. If system is ungrounded, phase voltage becomes line voltage. With grounded neutral, heavy ground current flows.

5. Rectifier Diode Open/Short:

In PMSG with diode bridge, open one diode. DC output becomes half-wave, high ripple, DC voltage drops. Short diode causes AC short through transformer, fuse blows.

6. Capacitor Failure in SEIG:

Reduce or disconnect excitation capacitor in induction generator. Voltage collapses, SEIG de-excites, output zero.

PROCEDURE:

A. Hardware Simulation:

1.Run SWT at constant wind speed 7 m/s, no fault. Record Vph, Iph, Pout, waveform on scope as baseline.

2.Introduce fault using fault panel: e.g., close switch for L-L fault for 2 sec through protection relay.

3.Record transient current, voltage dip, and trip time. Observe waveform distortion.

4.Repeat for other faults: open R-phase, short 10% turns of Y-phase, open D1 diode.

5.Download data and compare healthy vs faulty signatures.

B. MATLAB/Simulink Simulation:Model:

1.Wind Turbine → PMSG → 3-Phase Fault Block → Rectifier → Load.

2.Set fault type in block: L-G, L-L, L-L-L with fault resistance and time.

3.Run simulation for 5 sec, apply fault at t=2 sec.

4.Plot 3-phase voltage, current, DC bus voltage, electromagnetic torque.

5.Observe 2nd harmonic in torque for unbalanced faults.

OBSERVATION:

1.Inter-turn short: Phase-Y current increased 2.5×, Phase-Y voltage dropped 20%, winding temp rise 40°C.

2.Open phase: Output power dropped from 800W to 420W, 100Hz torque ripple appeared, vibration increased.

3.L-L fault: Fault current 18A vs 4A rated, voltage dropped to 30V from 230V, protection tripped in 0.1s.

4.Diode open: DC link ripple increased from 5% to 35%, average DC voltage dropped 15%.

5.SEIG capacitor open: Voltage collapsed from 230V to 20V within 1 sec, generator de-excited.

PRECAUTION:

1.Do all fault tests through protection relays/fuses. Do not apply bolted fault directly.

2.Use fault resistor 2-5 ohm to limit current during simulation.

3.Keep fault duration short 1-3 sec to avoid winding burn.

4.Discharge capacitors before changing connections.

5.In actual SWT, never create faults. Use software simulation for learning.

6.Wear PPE and maintain safe distance during live testing.

RESULT:

Electrical faults in SWT simulated successfully. Unbalanced faults produce 2nd harmonic torque ripple and voltage dip. Protection must trip within 100-200ms to save generator. Fault signatures help in designing condition monitoring for SWTs.

EXPERIMENT NO :-20

AIM:

Maintance of small power wind turbine.

APPARATUS REQUIRED:

WT unit; Toolkit with spanners, Allen keys, torque wrench; Multimeter; Grease gun; Climbing safety harness, helmet, gloves; Cleaning cloth; Anti-corrosion spray; Logbook.

THEORY:

Small Wind Turbines require periodic maintenance due to continuous exposure to wind, rain, dust, and vibration. Major issues: loose bolts, bearing wear, blade erosion, electrical faults. Maintenance is preventive and corrective. Schedule: monthly visual, 6-month detailed, annual overhaul. Good maintenance increases life to 15–20 years and keeps efficiency >80%.

MAINTENANCE SCHEDULE:

A. Monthly / Visual Inspection:

1.Blades: Check for cracks, chips, ice, bird droppings. Clean with soft cloth. Listen for unusual noise during rotation.

2.Tower & Guy Wires: Check for looseness, rust, tension. Tighten if slack. Check foundation bolts.

3.Nacelle: Look for oil leaks, loose covers. Ensure tail vane moves freely for passive yaw.

4.Electrical: Check LED status on controller. Verify battery voltage if off-grid. Check for loose cables at tower base.

B. 6-Monthly Maintenance:

1.Mechanical: Torque-check all blade bolts, hub bolts, tower flange bolts to spec using torque wrench.

2.Bearings: Grease main shaft bearings and yaw bearing if grease nipples present. Use lithium-based grease.

3.Brake System: Test manual furling or mechanical brake. Adjust brake cable tension.

4.Generator: Check for smooth rotation by hand after disconnecting load. No grinding noise should be present.

5.Electrical: Measure phase-to-phase resistance of PMSG with multimeter. Should be balanced within 5%. Check insulation resistance >1 MΩ with megger. Tighten all terminal lugs.

C. Annual Maintenance:

1.Blades: Remove, inspect root section, leading edge tape. Repair small cracks with epoxy. Balance blades if needed.

2.Slip Rings/Drop Cable: Check slip rings for wear, clean brushes. For drop cable, inspect for twisting, unwrap if >3 turns.

3.Controller & Dump Load: Test dump load by disconnecting battery. Controller should divert power to heater. Clean heat sink fins.

4.Earthing & Lightning Protection: Check earth pit resistance <5Ω. Inspect lightning arrestor and down conductor.

5.Tower: Touch-up paint on rusted areas. Check weld joints for cracks using dye-penetrant.

PROCEDURE:

1. Park turbine using brake or furling. Lock rotor with rotor lock pin.
2. Disconnect battery/load to make generator open circuit. This stops generation.
3. Climb tower with full PPE and harness. Use lanyard at all times.
4. Carry out checklist: bolts → grease → blades → electricals.
5. Clean nacelle inside with air blower. Remove bird nests, dust.
6. Lower tower if tilt-up type, else do all work at height.
7. After service, remove rotor lock, reconnect load, release brake.
8. Spin rotor and check cut-in. Verify normal operation and charging.

9. Enter all work done, date, and next due date in logbook.

COMMON PROBLEM AND CORRECTIVE ACTION:

1. No power output: Check brake engaged, blown fuse, open circuit, diode failure. Rectify.

2. High vibration: Blade unbalance, loose bolts, bearing failure. Balance blades, tighten bolts, replace bearing.

3. Over-speeding: Furling not working, tail vane jammed. Lubricate yaw, adjust furling spring.

4. Noise: Bearing wear, loose magnet in PMSG, blade crack. Replace bearing/generator, repair blade.

SAFETY PRECAUTIONS:

1. Never work on turbine during high winds >8 m/s. Stop and lock rotor first.

2. Always use certified climbing harness, double lanyard, and helmet.

3. Treat all wires as live. PMSG gives voltage even at low RPM. Disconnect before touching.

4. Do not work alone. Keep one person at ground for help.

5. Lower tower slowly with winch. Keep area clear of people.

6. Do not over-grease bearings. It causes overheating and seal damage.

7. Tag-out system: Put "Under Maintenance" board at controller during service

RESULT:

Routine maintenance of small power wind turbine studied and performed. Proper 6-monthly torque check, greasing, and electrical inspection keeps downtime low and ensures rated output. Logbook helps in tracking component life and scheduling replacements.