Renewable Energy Technology (315337)

Model Question Paper — Set C · Model Answers

Q.1

a) Solar declination and hour angle. 2 M

i) Declination (δ): The angle between the line joining the centres of the sun and the earth and its projection on the earth's equatorial plane. It varies from +23.45° (21 June) to −23.45° (22 December); $\delta = 23.45° \sin[360(284 + n)/365]$.

ii) Hour angle (ω): The angle through which the earth must rotate to bring the meridian of a place directly under the sun. It is zero at solar noon, changes by 15° per hour, negative in the morning and positive in the afternoon: $\omega = 15\ (ST - 12)$.

(1 M each)

b) Principle of pyrheliometer. 2 M

Principle: Beam radiation coming through a collimating tube (narrow aperture, ≈ 5.7° field of view) falls on a blackened absorbing surface; the rise in its temperature (or the electrical energy needed to produce the same heating, in the compensation type) is measured by a thermopile/thermocouple and is proportional to the radiation intensity.

Radiation measured: beam (direct normal) radiation.

(Principle 1 M, radiation 1 M)

c) Solar module and solar array. 2 M

Solar module (panel): A number of solar cells (e.g. 36, 60 or 72) electrically connected in series/parallel and encapsulated in a weather-proof frame with glass cover, to give a usable voltage and power (e.g. 12 V, 150 Wp).

Solar array: A group of modules connected in series (strings) and parallel to obtain the required system voltage, current and power (e.g. a 3 kWp rooftop array).

(1 M each)

d) Cut-in wind speed and tip speed ratio. 2 M

i) Cut-in wind speed: The minimum wind speed (about 3–4 m/s) at which the turbine starts to rotate and produce useful power.

ii) Tip speed ratio (λ): The ratio of the linear speed of the blade tip to the free wind speed: $\lambda = \omega R/V = \pi DN/(60V)$. Its optimum value is about 6–8 for three-blade turbines.

(1 M each)

e) Advantages of hydrogen as a fuel. 2 M

1. Highest energy per unit mass (about 120 MJ/kg — nearly three times petrol).
2. Clean burning — product is only water; no CO_2, CO, HC or smoke (only some NOx in engines).

3. Can be produced from water using renewable electricity; inexhaustible.
4. Can be used in fuel cells to produce electricity with high efficiency, and in IC engines.
5. Can be stored and transported (pipelines, cylinders) — useful for storing surplus renewable energy.

(Any four, ½ M each)

f) Advantages of fixed dome over floating drum. 2 M

1. Lower construction cost — no costly steel gas holder; no rusting, painting or replacement of drum.
2. Longer life (20+ years) and no moving parts, so low maintenance.
3. Fully underground — saves space and keeps the slurry warm in winter.

(Any two, 1 M each)

g) Classification of small hydro by capacity. 2 M

Class	Installed capacity (India, MNRE)
Micro hydro	up to 100 kW
Mini hydro	101 kW to 2 MW
Small hydro	2 MW to 25 MW

(Some books also use 'pico hydro' for plants below 5 kW.)

(2 M)

Q.2

a) Pyranometer. 4 M

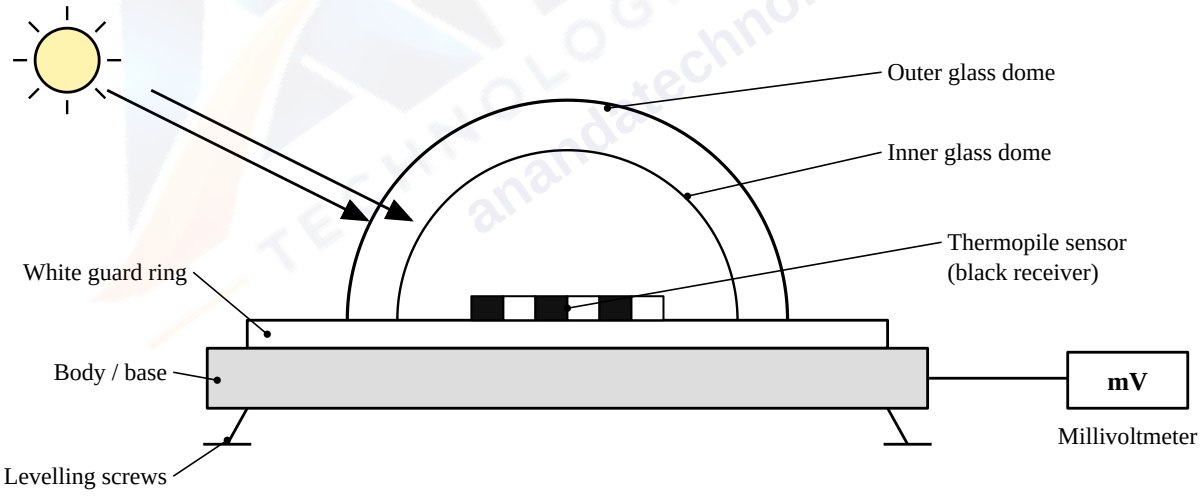


Fig.: Pyranometer (thermopile type)

Use: measures **global (beam + diffuse) radiation** on a horizontal surface; with a shading ring it measures diffuse radiation.

Construction: A thermopile sensor (black receiving surface; in some types alternate black and white segments) is mounted on a base and covered by **two concentric hemispherical glass domes** which allow radiation from the whole sky (2π field of view) and protect the sensor from wind and

rain. A white **guard ring** shields the body from heating; the instrument is levelled by levelling screws.

Working: The black surface absorbs radiation and becomes hotter than the reference (white surface / body). The hot junctions of the thermopile are on the black surface and cold junctions on the white/body, so an EMF proportional to the temperature difference — and hence to the radiation — is produced. It is read on a millivoltmeter or data logger and converted to W/m² using the calibration constant (e.g. Eppley pyranometer).

(Sketch 2 M, explanation 2 M)

b) I-V, P-V characteristics; fill factor and efficiency. 4 M

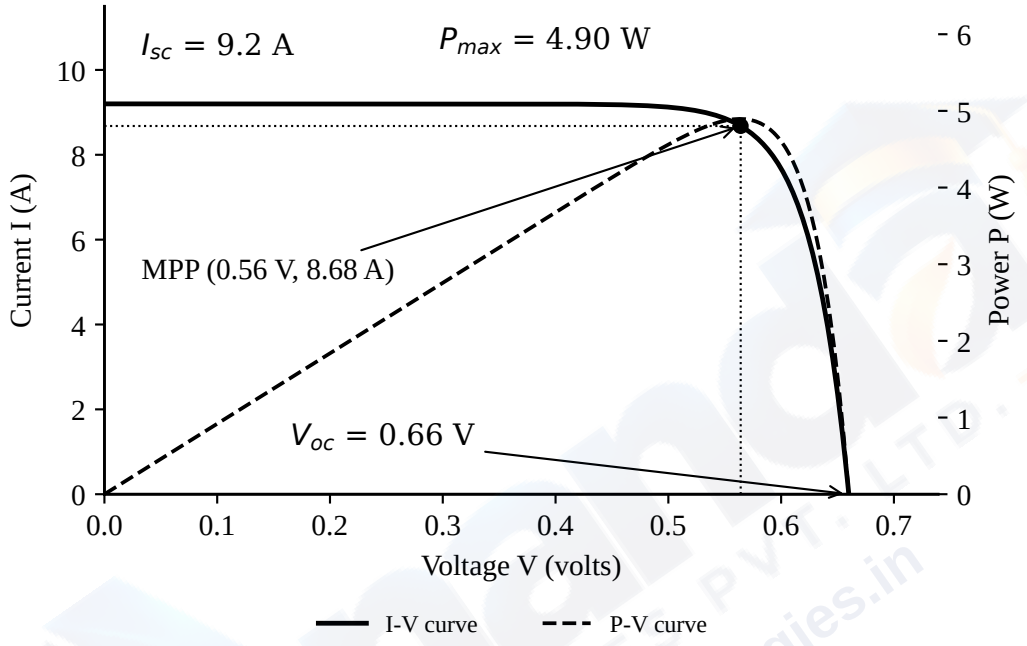


Fig.: I-V and P-V curves (single-diode model for Isc = 9.2 A, Voc = 0.66 V)

The I-V curve shows nearly constant current (≈ I_{sc}) at low voltage and a sharp fall near V_{oc}; the P-V curve rises from zero, reaches a peak at the **maximum power point** and falls to zero at V_{oc}.

Given: area A = 15.6 × 15.6 = 243.36 cm², I_{sc} = 9.2 A, V_{oc} = 0.66 V, V_m = 0.56 V, I_m = 8.68 A, G = 1000 W/m².

Maximum power $P_m = V_m \times I_m = 0.56 \times 8.68 =$ **4.861 W**

Fill factor $FF = P_m / (V_{oc} \times I_{sc}) = 4.861 / (0.66 \times 9.2) = 4.861 / 6.072 =$ **0.801 (80.1 %)**

Input power $P_{in} = G \times A = 1000\ W/m^2 \times 243.36 \times 10^{-4}\ m^2 = 24.336$ W

Efficiency $\eta = P_m/P_{in} = 4.861 / 24.336 =$ **19.97 %**

(Curves 2 M, FF 1 M, efficiency 1 M)

c) Wind energy conversion system. 4 M

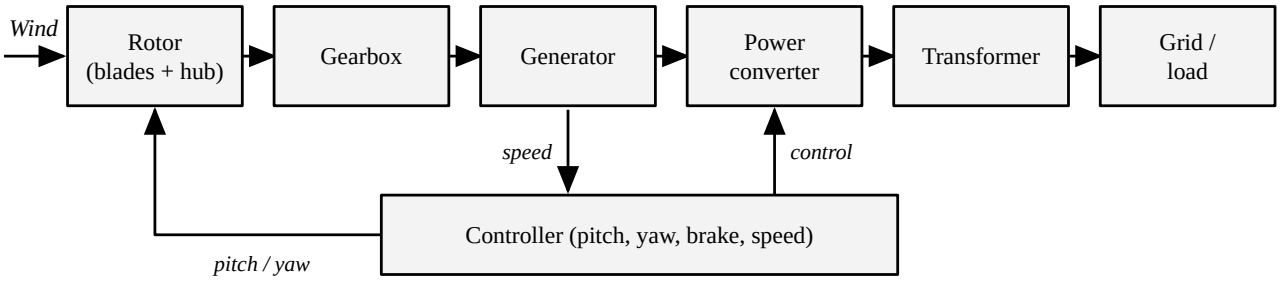


Fig.: Block diagram of a wind energy conversion system (WECS)

- **Rotor (blades + hub):** converts kinetic energy of wind into mechanical (rotational) energy.
- **Gearbox:** increases the low rotor speed (15–40 rpm) to generator speed (≈ 1500 rpm).
- **Generator:** converts mechanical energy to electrical energy (SCIG, DFIG or PMSG).
- **Power converter:** converts variable-frequency output to grid frequency and controls power (variable speed systems).
- **Transformer and grid/load:** steps up voltage for connection to the grid or supplies local loads.
- **Controller:** uses wind speed and direction sensors (anemometer, wind vane) to control pitch, yaw, brake and generator so as to get maximum power and protect the turbine.

(Block diagram 2 M, explanation 2 M)

d) Resistance (ohmic) polarization in fuel cell. 4 M

Resistance (ohmic) polarization is the voltage loss caused by the internal resistance of the fuel cell to the flow of charge:

- resistance of the **electrolyte** to the flow of ions (H^+ or OH^-) — usually the largest part,
- resistance of electrodes, bipolar plates and interconnects to electron flow,
- contact resistance between the components.

It obeys Ohm's law: $\mathbf{\Delta V_{ohm} = I \times R_{int}}$, so it increases linearly with current and appears as the straight middle portion of the polarization (V–I) curve.

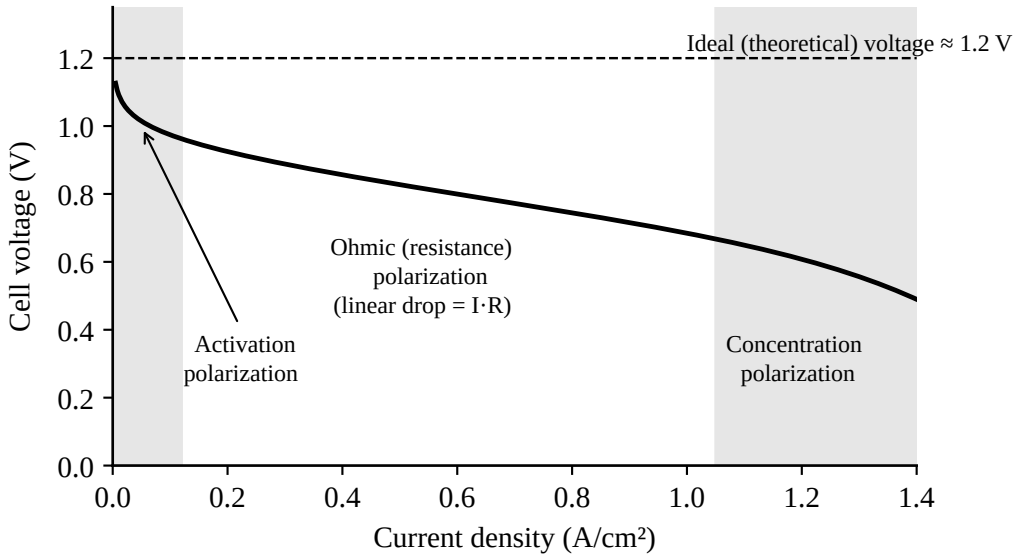


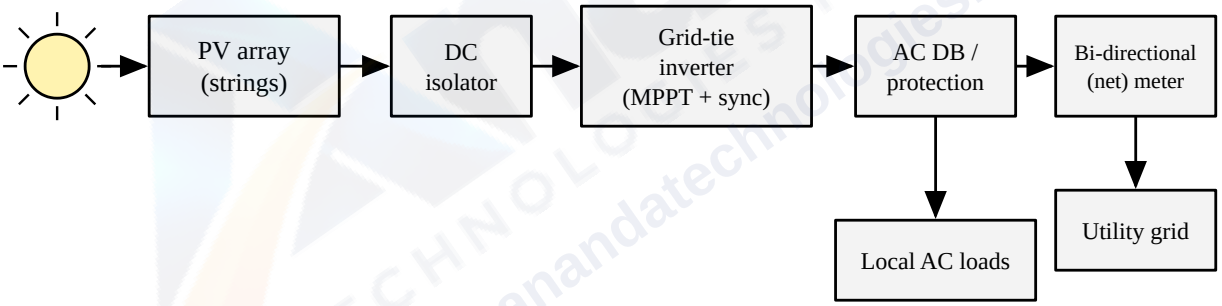
Fig.: Fuel cell polarization (V–I) curve showing three losses

Methods to reduce it: use thin electrolyte membranes of high ionic conductivity (keep PEM well humidified); use electrodes and bipolar plates of high electrical conductivity; good, tight contacts (proper clamping pressure); operate at suitable higher temperature to increase conductivity.

(Explanation 2 M, curve 1 M, methods 1 M)

Q.3

a) Grid-connected PV system. 4 M



No battery: surplus energy is exported to the grid; at night power is imported from the grid.

Fig.: Block diagram of a grid-connected (on-grid) PV system

- **PV array** produces DC power; strings are connected through a **DC isolator** / junction box with fuses and surge protection.
- **Grid-tie inverter** with MPPT converts DC into AC synchronised with the grid voltage and frequency, and has anti-islanding protection (it shuts down when the grid fails).
- **AC distribution board** feeds local loads; the **bi-directional (net) meter** records energy exported to and imported from the grid.

Point	On-grid system	Off-grid system
Battery	No battery needed (grid acts as storage).	Battery bank essential.
Cost	Lower cost and maintenance.	Higher cost (battery replacement).

Supply at grid failure	Shuts down during grid failure.	Works independently of grid.

(Block diagram 2 M, explanation 1 M, differences 1 M)

b) Parabolic trough vs heliostat field collector.

4 M

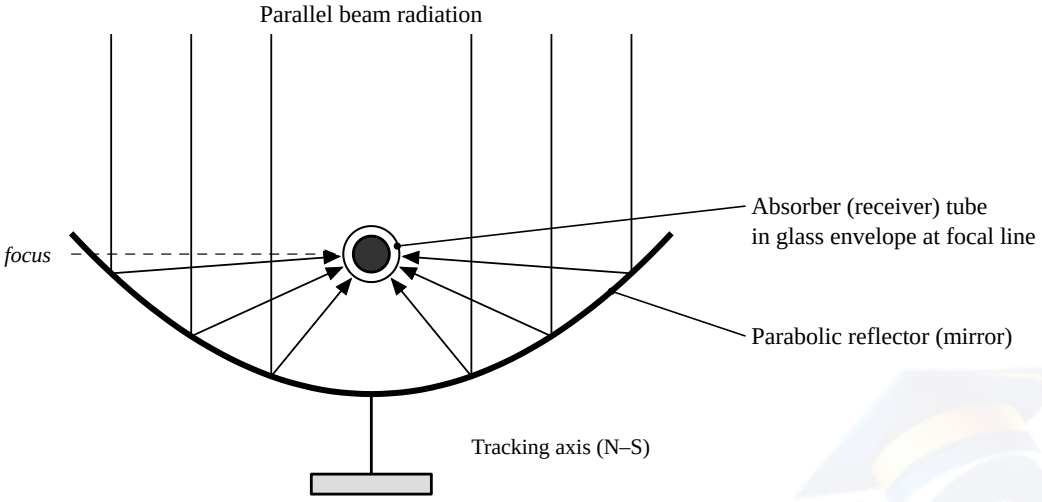


Fig.: Parabolic trough collector (focusing, line focus)

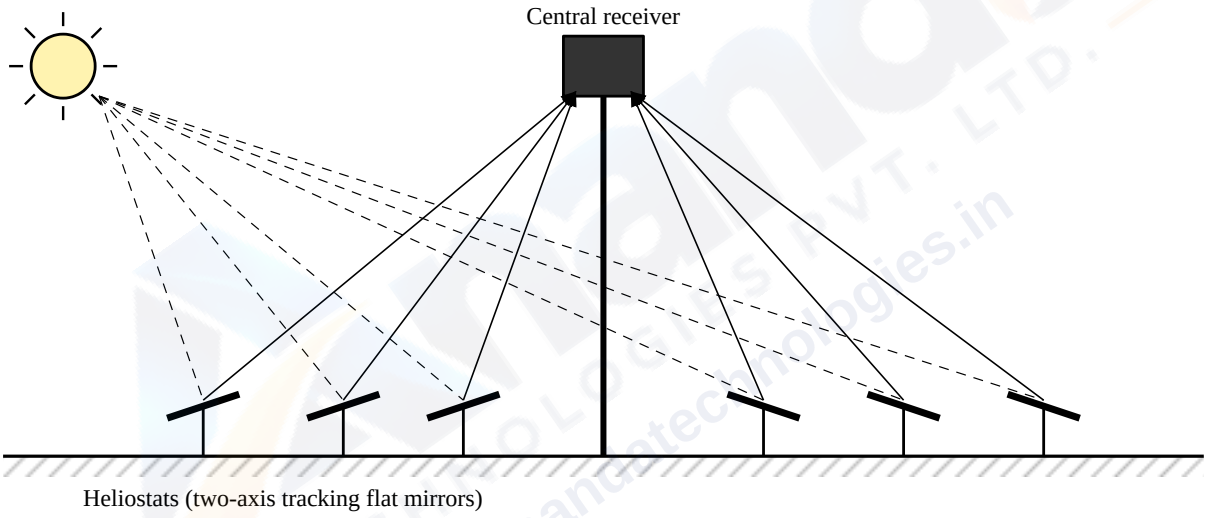


Fig.: Heliostat field with central receiver (power tower)

Point	Parabolic trough collector	Heliostat field (central receiver / power tower)
i) Efficiency	Line focus; concentration ratio ≈ 30–100; operating temperature ≈ 300–400 °C; solar-to-electric efficiency ≈ 14–16 %.	Point focus; concentration ratio ≈ 300–1500; temperature 500–1000 °C; higher thermodynamic efficiency (≈ 15–20 %).
ii) Scalability	Modular — rows of troughs can be added easily from kW to large MW plants.	Economical only in large sizes (tens to hundreds of MW); one tower per field.

iii) Storage capability	Thermal storage possible with synthetic oil / molten salt, but limited by lower temperature.	Excellent — molten salt at high temperature gives large, efficient storage (many hours of night operation).
iv) Applications	Power plants, industrial process heat and steam, solar cooling.	Large utility-scale power generation, high-temperature processes, hydrogen production research.

(1 M each)

c) Biomass conversion process for agricultural waste — gasification. 4 M

Suggested process: thermochemical gasification in a downdraft gasifier. Dry crop residues (stalks, husk, cobs) have low moisture and high lignin, so they do not digest well in a biogas plant but are excellent for gasification. The producer gas can run an engine–generator for village electricity or be used for heating; the process is fast and needs small space.

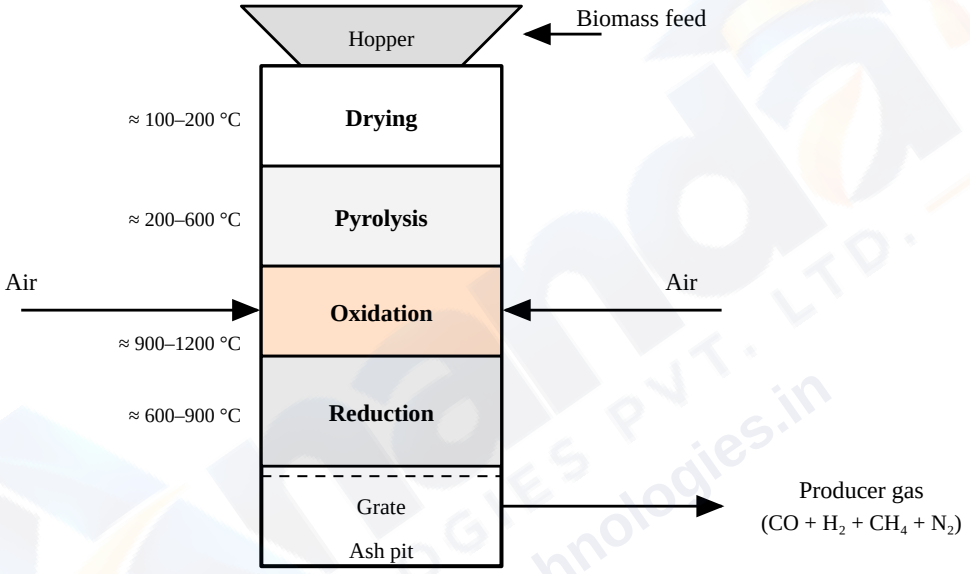


Fig.: Downdraft biomass gasifier showing reaction zones

Working: Gasification is partial combustion of biomass with a limited supply of air (about one-third of that needed for full combustion). Biomass fed at the top moves down through four zones:

1. **Drying zone** — moisture is removed.
2. **Pyrolysis zone** — biomass decomposes into charcoal, tar vapours and gases.
3. **Oxidation (combustion) zone** — air enters through nozzles; part of the char and volatiles burn ($C + O_2 \rightarrow CO_2$), producing the heat for the whole process.
4. **Reduction zone** — CO_2 and H_2O pass over hot charcoal and are reduced: $C + CO_2 \rightarrow 2CO$, $C + H_2O \rightarrow CO + H_2$.

The producer gas (CO ≈ 20 %, H_2 ≈ 15–20 %, CH_4 ≈ 2 %, rest N_2 and CO_2) leaves from the bottom, is cooled and cleaned, and used. Ash collects in the ash pit.

(Selection with justification 1 M, sketch 1 M, working 2 M)

d) Small hydro plant working and turbine for 60 m head. 4 M

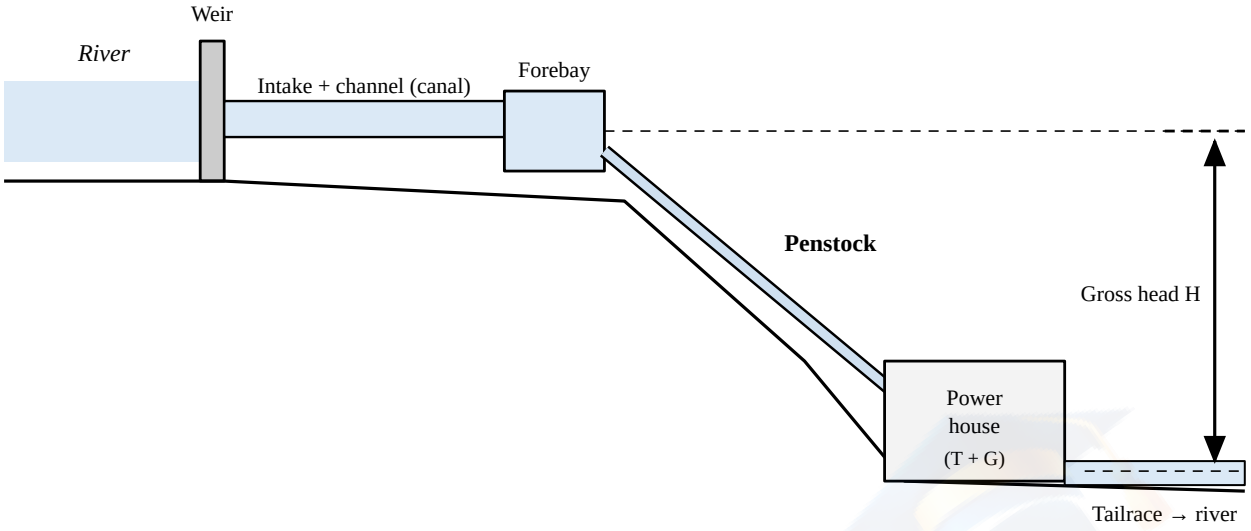


Fig.: General arrangement of a small hydroelectric power plant (run-of-river)

Working: A low **diversion weir** diverts part of the river flow into the **intake** (with trash rack) and **channel** to the **forebay** (desilting and small storage). From the forebay a **penstock** carries water down to the **powerhouse**, where its potential energy is converted into kinetic energy and then into mechanical energy by the **turbine**, which drives the **generator**. Water returns to the river through the **tailrace**. Power $P = \rho g Q H \eta$.

Recommended turbine for 60 m head, moderate flow: Francis turbine (medium head reaction turbine, suitable for about 30–300 m) — it has high efficiency at medium head and moderate discharge and a compact size. (For very small schemes, a cross-flow or Turgo turbine may also be used.)

(Layout 2 M, working 1 M, turbine 1 M)

Q.4

a) Solar air heater for drying. 4 M

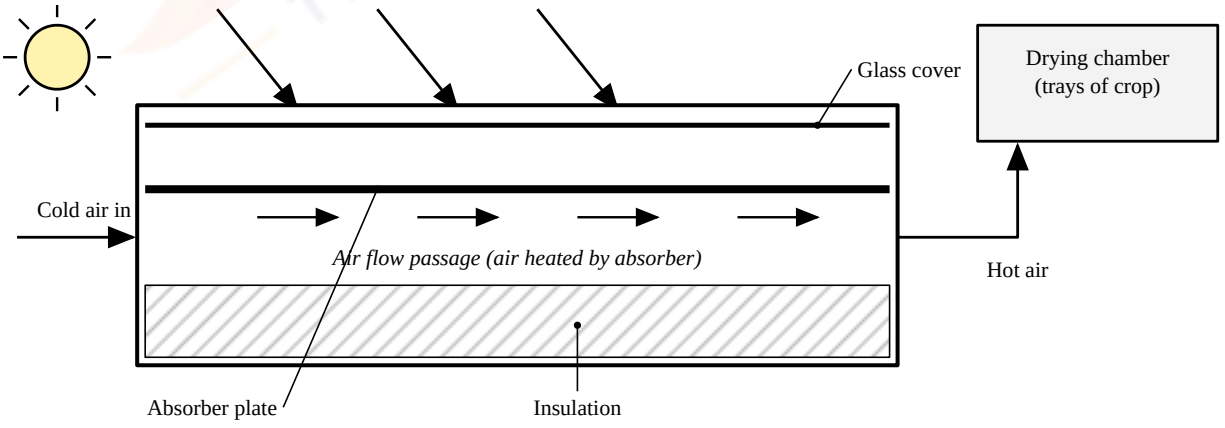


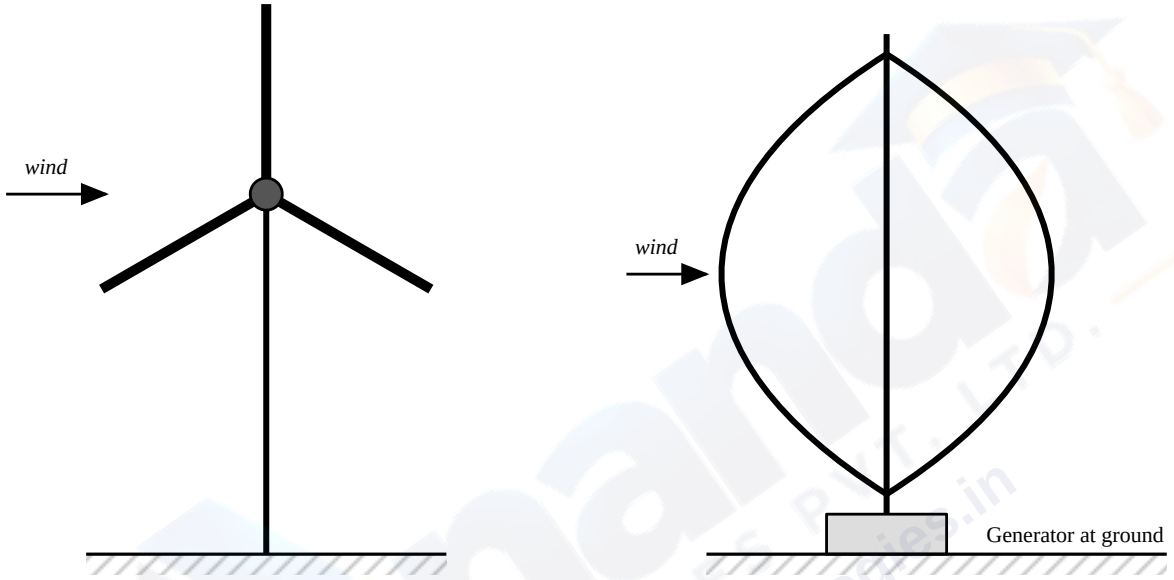
Fig.: Solar air heater (flat plate air collector) used for drying

Working: Solar radiation passes through the glass cover and is absorbed by the blackened absorber plate. Air is passed (by natural draught or a small fan) through the passage below (or above) the absorber, picks up heat and leaves at 40–70 °C. The hot air is ducted to the drying chamber where it passes over trays of crop, removes moisture and leaves through the chimney/vent. Fins or roughness on the plate improve heat transfer; insulation reduces back loss.

Advantages for drying: faster and more uniform drying than open sun drying; product is protected from dust, rain, birds and insects — better quality and colour; no fuel cost; no freezing or leakage problem as with water; simple and cheap construction.

(Sketch 2 M, working 1 M, advantages 1 M)

b) HAWT vs VAWT; rooftop choice. 4 M



(a) HAWT — axis parallel to wind (b) VAWT — axis perpendicular to wind

Fig.: (a) Horizontal axis (3-blade) and (b) vertical axis (Darrieus) wind turbines

Point	Horizontal axis wind turbine (HAWT)	Vertical axis wind turbine (VAWT)
Axis of rotation	Parallel to wind direction (horizontal).	Perpendicular to wind (vertical).
Yaw mechanism	Needed to face the wind.	Not needed — accepts wind from any direction.
Efficiency (Cp)	High, about 0.40–0.48.	Lower, about 0.30–0.35 (Savonius ≈ 0.15–0.2).
Generator / gearbox position	At tower top in nacelle — maintenance difficult.	At ground level — easy maintenance.
Starting	Self-starting.	Darrieus type is not self-starting.
Use	Large MW-scale wind farms.	Small, urban and rooftop installations.

For rooftop installation: VAWT is more suitable — wind on rooftops is turbulent and changes direction often, and VAWT accepts wind from all directions without yaw; it is compact, quieter, starts at low speeds (Savonius), and generator is at the base, so the load on the roof and maintenance are easier.

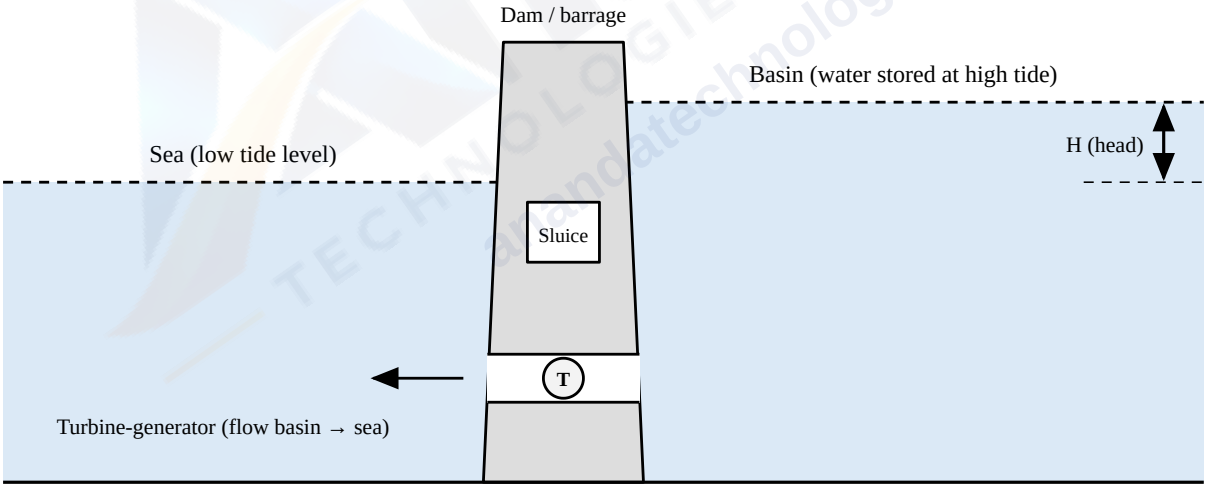
(Comparison 3 M, recommendation 1 M)

c) Comparison of hydrogen storage methods. 4 M

Point	Compressed gas	Liquid hydrogen	Metal hydride
Condition	200–700 bar at room temperature	−253 °C, near atmospheric pressure	Absorbed in alloy at low pressure (1–30 bar)
Volumetric density	Low (≈ 15–40 kg/m³)	High (≈ 71 kg/m³)	Very high (often > liquid H_2)
Energy needed	Compression ≈ 10–15 % of energy	Liquefaction ≈ 30 % of energy	Heat for release; cooling while filling
Weight	Heavy cylinders	Light, but bulky insulated tank	Very heavy (1.5–7 wt % H_2)
Safety	High-pressure burst/leak risk	Boil-off and cryogenic hazards	Safest — slow release, low pressure
Use	Vehicles, cylinders, industry	Rockets, bulk transport	Small/stationary storage, submarines

(Any four points, 1 M each)

d) Single basin tidal power plant. 4 M



Ebb generation: basin filled through sluices at high tide; at low tide water flows basin → sea through turbines.

Fig.: Single basin tidal power plant

Arrangement: A **dam (barrage)** is built across the mouth of a bay or estuary to form a **basin**. The dam houses low-head **bulb turbines** coupled to generators and **sluice gates** for filling/emptying the basin.

Working (ebb generation):

1. During the flood (rising) tide the sluice gates are opened and the basin fills up to high-tide level; then the gates are closed.
2. As the sea falls during ebb tide, a head (H) develops between basin and sea.
3. When the head is sufficient, water is allowed to flow from the basin to the sea **through the turbines**, generating power until the head becomes too small.
4. The cycle repeats about twice a day. Energy per cycle ≈ ½ ρ g A R^2 (A = basin area, R = tidal range). Double-effect plants generate on both flood and ebb tides.

Example: La Rance (France) 240 MW. Indian sites: Gulf of Kutch, Gulf of Khambhat, Sundarbans.

(Sketch 2 M, working 2 M)

e) Classification of biogas plants; batch and continuous. 4 M

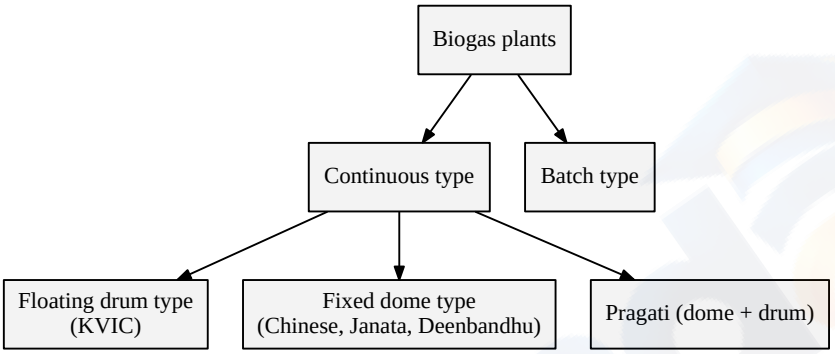


Fig.: Classification of biogas plants

Batch type: The digester is filled with a full charge of feed material (e.g. crop residues, dung), sealed and left for the complete digestion period (40–60 days). Gas production starts slowly, reaches a peak and then falls. After digestion the plant is emptied and recharged. Gas supply is intermittent, so two or more digesters are used in rotation. Suitable for solid, fibrous wastes.

Continuous type: A small quantity of slurry is fed daily and an equal quantity of digested slurry flows out. Gas is produced continuously at a nearly steady rate. Suitable for regular daily feed such as cattle dung. Types: floating drum (KVIC), fixed dome (Chinese, Janata, Deenbandhu) and Pragati.

(Classification 1 M, batch 1½ M, continuous 1½ M)

Q.5

a) Why variable speed; VSCF scheme. 6 M

Justification for variable speed operation:

- Power coefficient Cp is maximum only at one optimum tip speed ratio λ = ωR/V. If the rotor speed follows the wind speed, λ and hence Cp stay near maximum — about 10–20 % more energy per year.
- Gusts are absorbed as changes of rotor speed (flywheel effect) — lower torque peaks, less stress on blades, gearbox and tower; longer life.
- Smoother power output and better power quality; reactive power can be controlled by the converter.
- Lower speed and noise at low winds; easier grid-code compliance (fault ride-through).

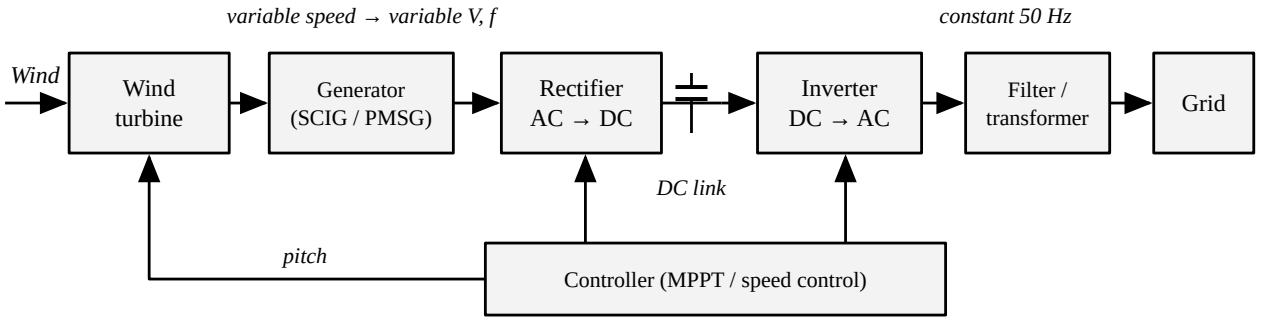


Fig.: Variable speed constant frequency (VSCF) scheme using AC–DC–AC link

VSCF scheme (AC–DC–AC link):

1. The turbine drives the generator (SCIG / PMSG) at variable speed, giving output of variable voltage and frequency.
2. A rectifier converts it to DC; the DC-link capacitor stores energy and decouples generator and grid.
3. A PWM inverter converts DC to AC at constant 50 Hz and grid voltage; a filter and transformer connect it to the grid.
4. The controller sets the generator speed/torque for maximum power point tracking below rated wind speed and uses pitch control above rated speed.

(Justification 2 M, block diagram 2 M, explanation 2 M)

b) Hydrogen vs petrol and CNG as vehicle fuel. 6 M

Property	Hydrogen	Petrol	CNG
Energy per kg (LHV)	≈ 120 MJ/kg (highest)	≈ 44 MJ/kg	≈ 47–50 MJ/kg
Energy per volume	Very low — needs 350–700 bar or liquefaction	High (liquid)	Low — stored at ≈ 200 bar
Exhaust emissions	Only water (fuel cell); some NOx in IC engine	CO_2, CO, HC, NOx, particulates	CO_2 (less than petrol), low CO/HC
Flammability range in air	4–75 % (very wide)	1.4–7.6 %	5–15 %
Ignition energy	≈ 0.02 mJ (very low)	≈ 0.2 mJ	≈ 0.3 mJ
Source	Renewable (water + green power) possible	Fossil (crude oil)	Fossil (natural gas)
Infrastructure / cost	Very limited stations; costly	Widely available	Moderate availability; cheap

Safety precautions for hydrogen vehicles: 1) Use certified high-pressure composite tanks with pressure-relief devices, and hydrogen leak sensors with automatic shut-off valves. 2) Provide good ventilation/venting upward, avoid sparks, and park in ventilated places; flame (UV) detectors because the flame is invisible.

(Six points 4 M, two precautions 2 M)

c) Chinese fixed dome biogas plant. 6 M

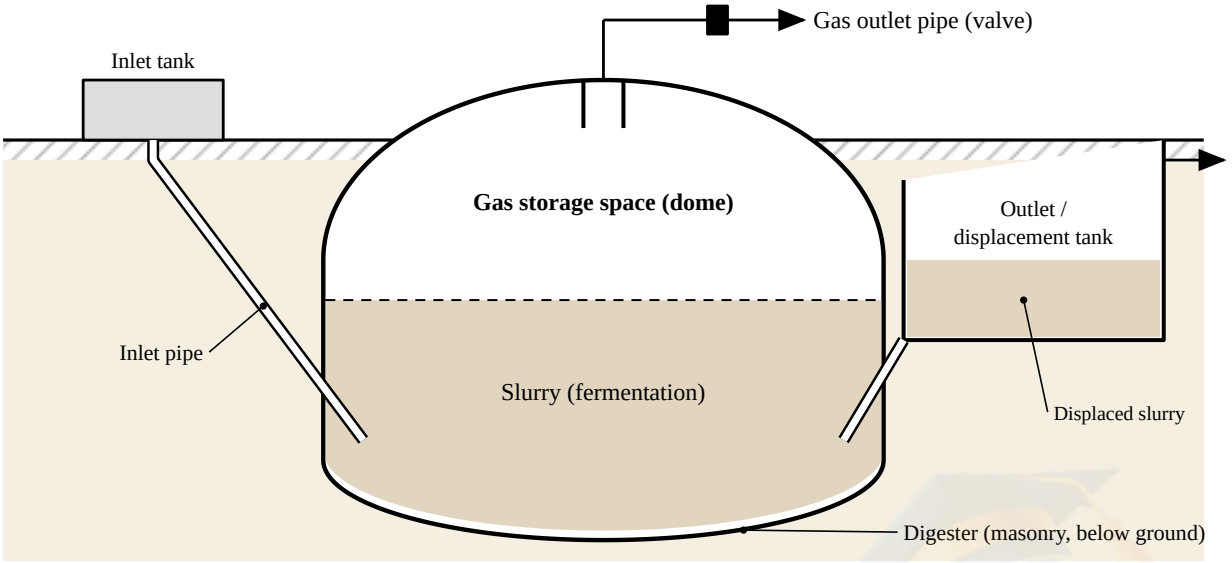


Fig.: Chinese fixed dome type biogas plant

Construction:

- **Digester:** underground brick/concrete chamber with curved bottom and a **fixed dome-shaped top**, made gas-tight with plaster.
- **Gas storage:** upper part of the dome; gas outlet pipe with valve at the crown.
- **Inlet tank and pipe:** to feed the dung–water slurry.
- **Outlet (displacement) tank:** receives slurry pushed out by gas pressure; overflow gives manure.

Working: The slurry is digested by anaerobic bacteria and biogas collects under the dome. Increasing gas pressure pushes slurry into the displacement tank, so the gas pressure varies with the stored volume (up to about 1 m of water column). When gas is used, slurry returns to the digester. Fresh feed added daily displaces spent slurry from the outlet.

Applications: cooking gas for households and community kitchens; lighting (gas mantle lamps); running dual-fuel engines for pumping water and small power generation; digested slurry as rich organic manure; sanitation (night-soil based plants).

(Sketch 2 M, construction and working 2 M, applications 2 M)

Q.6

a) Solar angles at Nagpur on 10 June, 2:30 PM. 6 M

Given: latitude $\varphi = 21.15°$ N, date: 10 June, solar time = 14:30 PM (14.5 h), collector tilt $\beta = 20°$, facing due south ($\gamma = 0°$).

Step 1 – Day number: n = 151 (days before June) + 10 = **161**

Step 2 – Declination (Cooper's equation): $\delta = 23.45° \times \sin[(360/365)(284 + n)] = 23.45 \times \sin(438.90°) = 23.45 \times (0.9813) =$ **23.01°**

Step 3 – Hour angle: $\omega = 15° \times$ (solar time − 12) $= 15 \times (14.5 - 12) =$ **37.5°** (positive after noon)

Step 4 – Zenith angle: $\cos\theta_z = \cos\varphi\cos\delta\cos\omega + \sin\varphi\sin\delta$
$= \cos 21.15° \times \cos(23.01°) \times \cos(37.5°) + \sin 21.15° \times \sin(23.01°)$
$= (0.9326)(0.9204)(0.7934) + (0.3608)(0.3909) = 0.6810 + (0.1410) =$ **0.8221**
$\theta_z = \cos^{-1}(0.8221) =$ **34.71°** ; solar altitude $\alpha = 90° - \theta_z =$ **55.29°**

Step 5 – Angle of incidence on the south-facing tilted collector:
$\cos\theta = \cos(\varphi - \beta)\cos\delta\cos\omega + \sin(\varphi - \beta)\sin\delta$
$\varphi - \beta = 21.15 - 20 = 1.15°$
$\cos\theta = (0.9998)(0.9204)(0.7934) + (0.0201)(0.3909) =$ **0.7379** $\rightarrow \theta =$ **42.45°**

Step 6 – Day length: sunset hour angle $\omega_s = \cos^{-1}(-\tan\varphi\tan\delta) = \cos^{-1}(-\tan 21.15° \times \tan 23.01°)$
$= \cos^{-1}(-0.1643) = 99.46°$
Day length $= 2\omega_s/15 = 2 \times 99.46/15 =$ **13.26 h ≈ 13 h 16 min**

Answers: i) $\delta = 23.01°$ ii) $\omega = +37.5°$ iii) $\theta_z = 34.71°$, $\alpha = 55.29°$ iv) $\theta = 42.45°$ v) day length ≈ 13.26 h

(δ 1 M, ω 1 M, θ_z and α 1 M, θ 2 M, day length 1 M)

b) Wind power, tip speed ratio and power curve. 6 M

i) At V = 6 m/s:

Given: rotor diameter D = 50 m, wind speed V = 6 m/s, air density $\rho = 1.225$ kg/m³, power coefficient Cp = 0.4.

Swept area $A = \pi D^2/4 = \pi \times 50^2 / 4 =$ **1,963.50 m²**

Power available in wind $P = \frac{1}{2}\rho A V^3 = 0.5 \times 1.225 \times 1{,}963.50 \times 6^3 = 0.5 \times 1.225 \times 1{,}963.50 \times 216 =$ **259,770.44 W ≈ 259.8 kW**

Power density $= P/A = \frac{1}{2}\rho V^3 =$ **132.3 W/m²**

Maximum extractable power (Betz limit, Cp,max = 16/27 = 0.593) = 0.593 × 259,770.44 = **153.9 kW**

Mechanical power at rotor = Cp × P = 0.4 × 259,770.44 = **103.9 kW**

At V = 10 m/s:

Given: rotor diameter D = 50 m, wind speed V = 10 m/s, air density $\rho = 1.225$ kg/m³, power coefficient Cp = 0.4.

Swept area $A = \pi D^2/4 = \pi \times 50^2 / 4 =$ **1,963.50 m²**

Power available in wind $P = \frac{1}{2}\rho A V^3 = 0.5 \times 1.225 \times 1{,}963.50 \times 10^3 = 0.5 \times 1.225 \times 1{,}963.50 \times 1000 =$ **1,202,640.94 W ≈ 1202.6 kW**

Power density $= P/A = \frac{1}{2}\rho V^3 =$ **612.5 W/m²**

Maximum extractable power (Betz limit, Cp,max = 16/27 = 0.593) = 0.593 × 1,202,640.94 = **712.7 kW**

Mechanical power at rotor = Cp × P = 0.4 × 1,202,640.94 = **481.1 kW**

ii) Tip speed ratio: tip speed $u = \pi DN/60 = \pi \times 50 \times 24 / 60 = 62.83$ m/s; $\lambda = u/V = 62.83/10 =$ **6.28** (close to the optimum range 6–8).

iii) Doubling the diameter: $P \propto A \propto D^2$, so power becomes $(2)^2 =$ **4 times** — at 10 m/s it rises from 481.1 kW to 1924.2 kW.

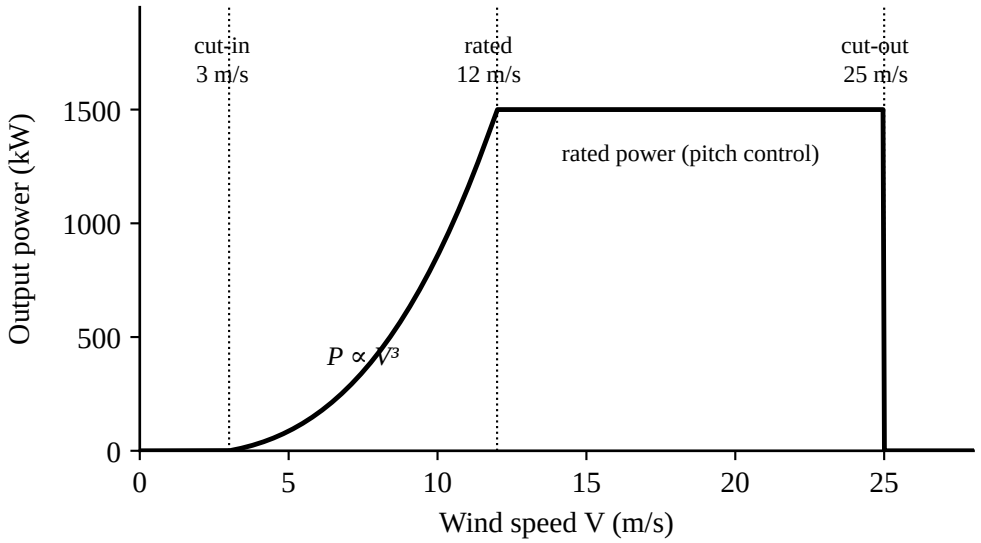


Fig.: Typical power curve (cut-in 3 m/s, rated 12 m/s, cut-out 25 m/s)

Below cut-in speed no power is produced; between cut-in and rated speed power rises roughly as V^3; between rated and cut-out speed output is held at rated value by pitch control; above cut-out speed the turbine is stopped for safety.

(Power at two speeds 2 M, TSR 1 M, doubling D 1 M, power curve 2 M)

c) Binary cycle and flash steam geothermal plants. 6 M

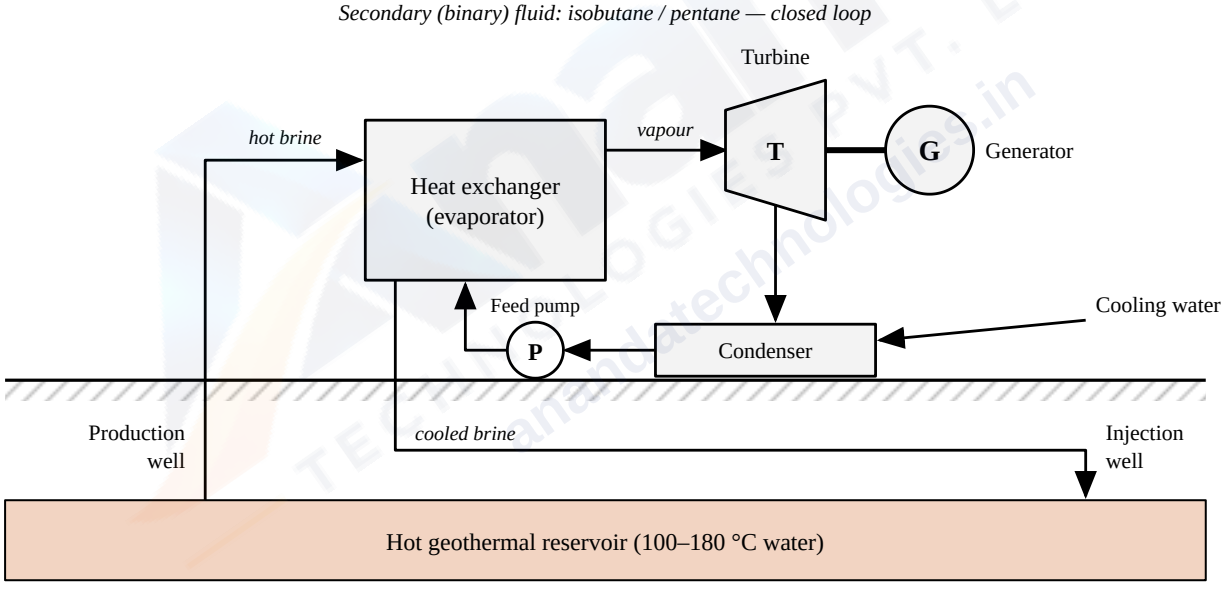


Fig.: Binary cycle geothermal power plant

Binary cycle plant: Hot brine from the production well passes through a heat exchanger where it vaporises a low-boiling organic working fluid (isobutane / pentane). The vapour drives the turbine–generator, is condensed and pumped back (closed organic Rankine cycle). The cooled brine is re-injected. Works with water at about 100–180 °C.

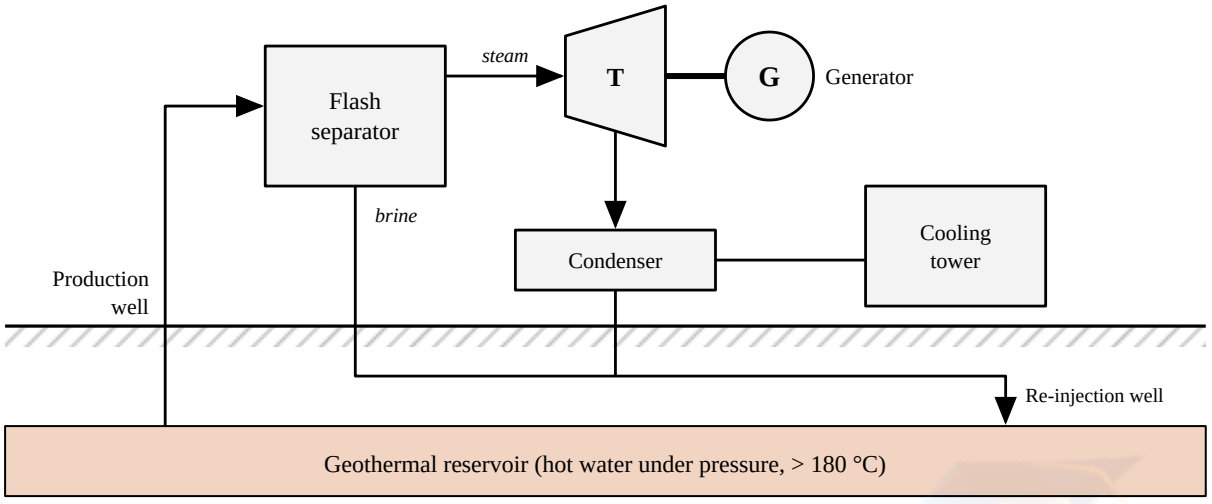


Fig.: Single flash steam geothermal power plant

Flash steam plant: High-pressure hot water (above about 180 °C) from the well enters a **flash separator** (low-pressure tank) where part of it suddenly boils (flashes) into steam. The steam drives the turbine–generator, is condensed (cooling tower) and, together with the separated brine, is re-injected into the reservoir. Double-flash plants flash the remaining brine again at lower pressure to get more steam.

For a 130 °C resource: binary cycle plant is suitable — water at 130 °C cannot flash enough steam at useful pressure for a steam turbine, whereas the organic fluid boils at a much lower temperature and gives high-pressure vapour. The closed loops also avoid scaling, corrosion and gas emissions.

(Binary 2½ M, flash 2½ M, justification 1 M)

Note: This is a **model question paper prepared by Ananda Technologies** only for practice and exam preparation, based on the pattern of previous MSBTE question papers and the K-scheme syllabus. It is **not an official MSBTE paper**, and it does **not** mean that these questions will come in the exam. Answers follow standard textbook points; marks shown are indicative. Free for students — anandatechnologies.in