

Power Plant Engineering (315374)

Model Question Paper — Set B · Model Answers

Q.1**a) Types of conventional power plants.**

2 M

1. Steam (thermal / coal-fired) power plant
2. Hydro-electric power plant
3. Nuclear power plant
4. Diesel power plant
5. Gas turbine power plant

*(Any four, ½ M each)***b) Types of FBC boilers.**

2 M

- **Atmospheric FBC (AFBC):** (i) Bubbling FBC (BFBC) — low air velocity, dense bed; (ii) Circulating FBC (CFBC) — high velocity, solids carried up and returned by cyclone.
- **Pressurised FBC (PFBC):** bed works at 6–16 bar; hot pressurised flue gas also drives a gas turbine (combined cycle).

*(2 M)***c) Functions of superheater and economiser.**

2 M

- **Superheater:** Increases the temperature of saturated steam from the drum above its saturation temperature (superheated steam) without raising pressure; this raises turbine work and efficiency and reduces moisture in the turbine.
- **Economiser:** Heats the boiler feed water using heat of outgoing flue gases before it enters the drum; saves fuel (about 1 % saving for every 6 °C rise of feed water temperature).

*(1 M each)***d) Fissile and fertile nuclear fuels.**

2 M

- **Fissile fuels** (split by slow neutrons): Uranium-235 (0.7 % in natural uranium), Plutonium-239 and Uranium-233 (artificial).
- **Fertile materials** (convert to fissile fuel in a reactor): Uranium-238 → Pu-239, Thorium-232 → U-233.

*(1 M each)***e) Plant capacity factor and plant use factor.**

2 M

Plant capacity factor: Ratio of actual energy produced to the maximum possible energy that could have been produced if the plant ran at full rated capacity for the whole period.

$$\text{Capacity factor} = \frac{\text{Actual energy produced}}{(\text{Plant capacity} \times \text{Hours in the period})} = \frac{\text{Average load}}{\text{Plant capacity}}$$

Plant use factor: Ratio of actual energy produced to the energy that could have been produced at full capacity during the hours the plant actually operated.

$$\text{Plant use factor} = \text{Actual energy produced} / (\text{Plant capacity} \times \text{Hours of actual operation})$$

(1 M each)

f) Trigeneneration.

2 M

Trigeneneration (combined cooling, heating and power — CCHP) is the simultaneous production of electricity, useful heat and cooling (chilled water) from a single fuel source.

Example: a gas-engine plant in a hospital giving electricity, hot water and air-conditioning (through a vapour absorption chiller).

(Definition 2 M)

g) In-plant coal handling equipment.

2 M

1. Belt conveyors
2. Screw conveyors
3. Bucket elevators
4. Coal bunkers with chutes and feeders
5. Belt weighers / coal meters
6. Skip hoists, grab-bucket cranes

(Any four, ½ M each)

Q.2

a) Importance of power plants.

4 M

1. Electricity is the basic input for industry, agriculture (irrigation pumps), transport, communication and domestic use; power plants convert the energy of fuels and water into this useful form.
2. Per-capita electricity consumption is an index of standard of living and economic development of a country; more power plants → more industries → more employment.
3. Reliable, low-cost power is essential for "Make in India", railway electrification, electric vehicles and digital services.
4. Power plants supply base load and peak load to the grid continuously, maintaining frequency and voltage of the national grid.
5. Captive and cogeneration plants give cheap, reliable power to industries such as sugar, steel, cement and paper.

(Any four points, 1 M each)

b) Three-element boiler feed water control.

4 M

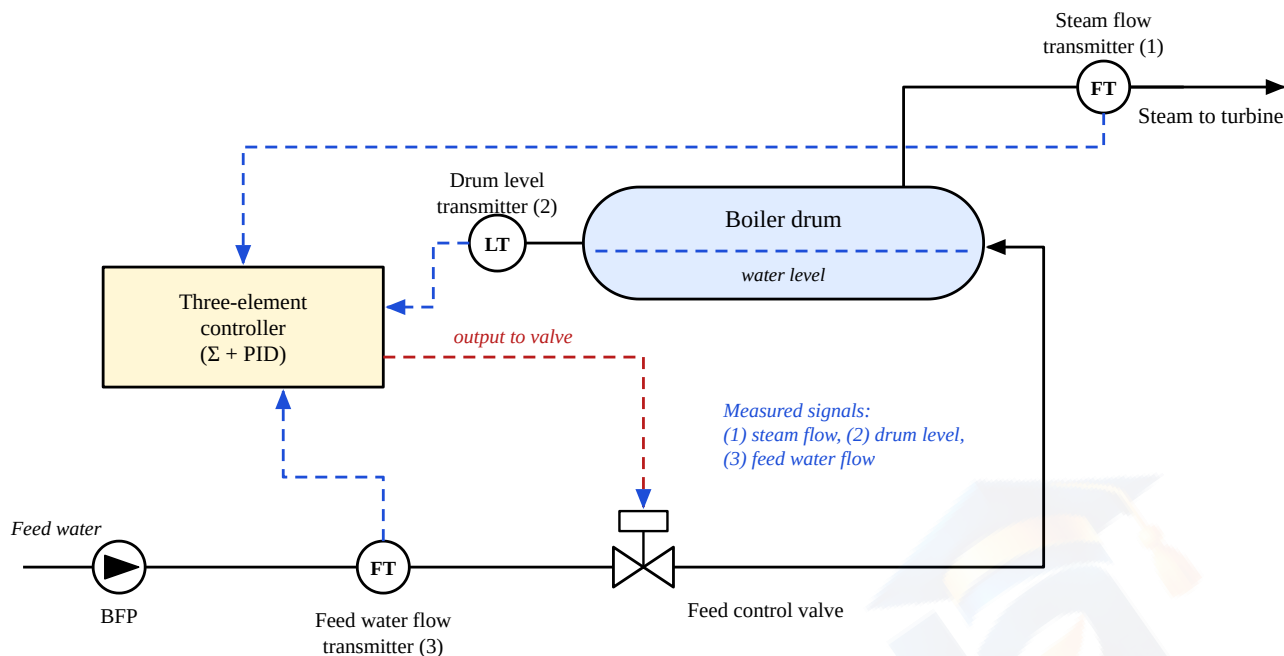


Fig.: Three-element boiler drum level (feed water) control

- Element 1 – Drum level:** the level transmitter (LT) measures the water level in the drum and sends it to the controller; this is the main controlled variable.
- Element 2 – Steam flow:** the steam-flow transmitter measures the steam drawn by the turbine. A change in load is sensed immediately, so feed water is changed in advance (feed-forward).
- Element 3 – Feed water flow:** measures actual feed water entering; the controller compares feed flow with steam flow and corrects the mismatch.
- The controller combines the three signals and adjusts the **feed control valve** (or feed pump speed) so that feed flow = steam flow and the drum level remains at its set value even during sudden load change (no error due to "swell and shrink").

Importance: Low drum level may expose water-wall tubes → overheating and tube burst. High level causes carry-over of water with steam → damage to superheater and turbine blades.

(Diagram 2 M, explanation 2 M)

c) Open cycle vs closed cycle gas turbine.

4 M

Point	Open cycle	Closed cycle
Working fluid	Air from atmosphere; exhaust thrown out	Same fluid (air / helium) recirculated
Combustion	Internal — fuel burnt in combustion chamber	External — heat given in a heater
Pre-cooler	Not required	Required
Fuel	Clean fuel (gas, oil) only	Any fuel, even coal or nuclear heat
Size for same output	Larger	Smaller (higher pressure)

Blade erosion	Possible (combustion products)	No (clean fluid)
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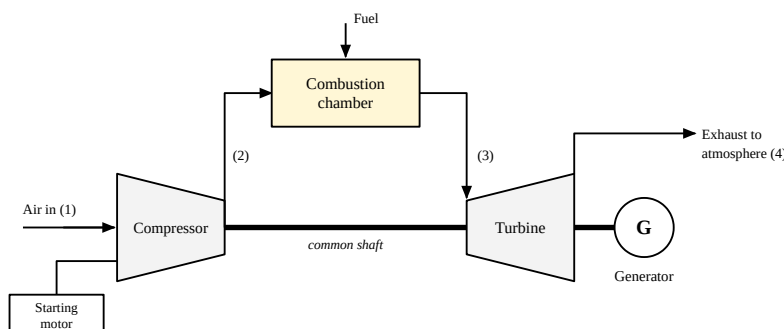


Fig.: Open cycle constant-pressure gas turbine power plant

(Any four points, 1 M each)

d) Functions of AERB.

4 M

AERB (Atomic Energy Regulatory Board) was constituted on 15 November 1983 under the Atomic Energy Act, 1962, to carry out regulatory and safety functions.

1. Develops safety codes, standards and guides for siting, design, construction, operation and decommissioning of nuclear plants.
2. Reviews safety and grants consents / licences at each stage (siting, construction, commissioning, operation).
3. Carries out regulatory inspections and enforces safety requirements; can order shutdown of unsafe units.
4. Prescribes radiation dose limits for workers and public; monitors radiation protection and waste management.
5. Reviews emergency preparedness plans; investigates incidents and informs the public.

(Any four, 1 M each)

Q.3

a) Ash handling system.

4 M

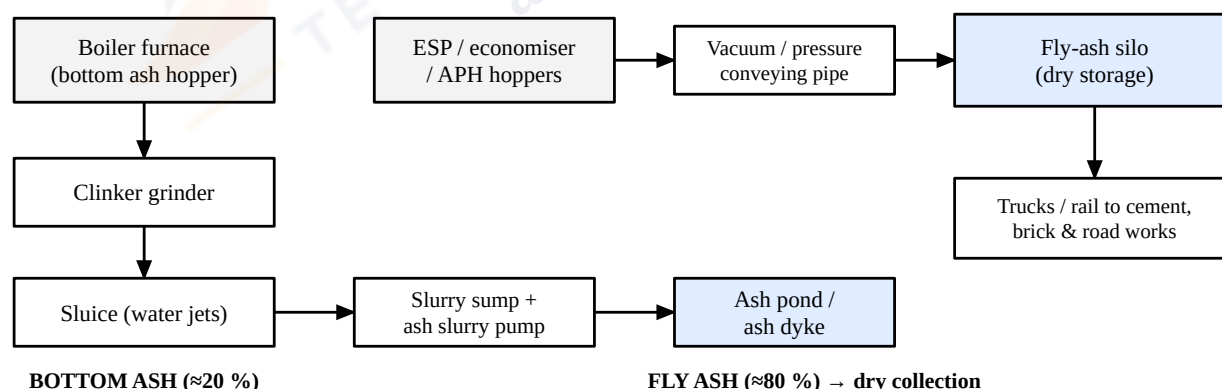


Fig.: Ash handling system (bottom ash: hydraulic; fly ash: pneumatic)

1. **Bottom ash (about 20 %)** falls into the water-filled bottom-ash hopper below the furnace; a **clinker grinder** crushes large clinkers.

- High-pressure water jets (**sluice**) carry the ash through channels to a slurry sump; **ash slurry pumps** pump it to the **ash pond / dyke** (hydraulic system).
- Fly ash (about 80 %)** is collected in ESP, economiser and air-preheater hoppers. It is conveyed dry by vacuum or pressure **pneumatic conveying** to **fly-ash silos**.
- From silos, dry fly ash is loaded into closed trucks or rail wagons for cement, brick and road works; the remaining is sent as slurry to the ash pond.
- Methods of ash handling:** hydraulic, pneumatic, mechanical (belt / scraper conveyor) and steam-jet systems.

(Layout 2 M, explanation 2 M)

b) Regeneration in open cycle gas turbine.

4 M

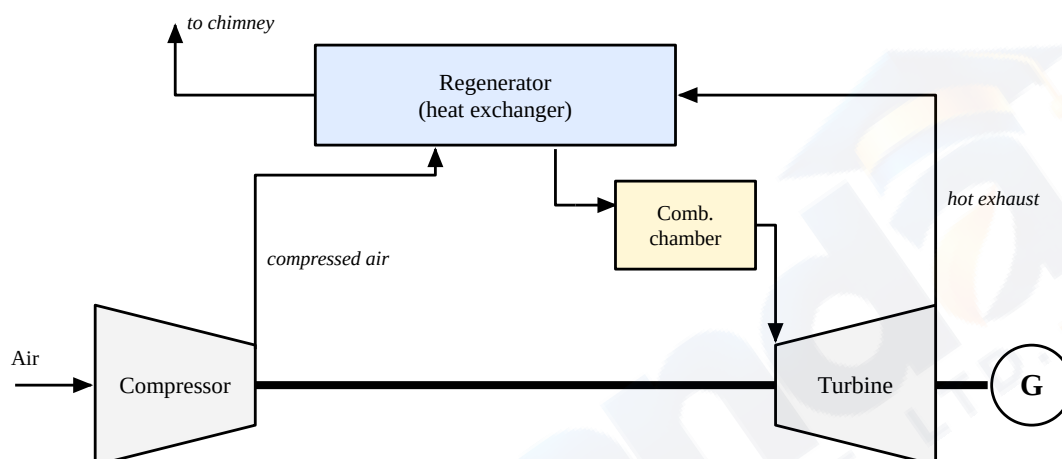


Fig.: Open cycle gas turbine with regenerator (heat exchanger)

- The hot exhaust gases leaving the turbine (400–550 °C) still contain a lot of heat.
- In a **regenerator** (heat exchanger) this exhaust heat is used to preheat the compressed air before it enters the combustion chamber.
- Less fuel is needed to raise the air to the turbine inlet temperature, while turbine work remains the same; hence **thermal efficiency increases**.
- Regeneration is useful only when the turbine exhaust temperature is higher than the compressor delivery temperature (low pressure ratio).

Advantage: fuel saving, higher efficiency. **Disadvantages:** bulky and costly heat exchanger, pressure loss in it.

(Sketch 2 M, explanation 2 M)

c) Nuclear power plants in India.

4 M

Nuclear power station	Installed capacity (operator: NPCIL)
Tarapur (TAPS), Maharashtra	$2 \times 160 \text{ MW (BWR)} + 2 \times 540 \text{ MW (PHWR)} = 1400 \text{ MW}$
Kudankulam (KKNPP), Tamil Nadu	$2 \times 1000 \text{ MW (VVER – PWR)} = 2000 \text{ MW}$
Rawatbhata (RAPS), Rajasthan	$1 \times 100 + 1 \times 200 + 4 \times 220 \text{ MW (PHWR)} + 700 \text{ MW (RAPP-7)}$
Kakrapar (KAPS), Gujarat	$2 \times 220 + 2 \times 700 \text{ MW (PHWR)} = 1840 \text{ MW}$

Kaiga (KGS), Karnataka	$4 \times 220 \text{ MW (PHWR)} = 880 \text{ MW}$
Narora (NAPS), Uttar Pradesh	$2 \times 220 \text{ MW (PHWR)} = 440 \text{ MW}$
Madras (MAPS), Kalpakkam, Tamil Nadu	$2 \times 220 \text{ MW (PHWR)} = 440 \text{ MW}$

Total installed nuclear capacity of India is about 8.8 GW (2025).

(Any four with capacity, 1 M each)

d) MPCB / CPCB norms for thermal power plants.

4 M

MPCB (Maharashtra Pollution Control Board) enforces in Maharashtra the norms laid down by MoEF&CC / CPCB (Environment Protection Rules, notification of Dec 2015) for coal-based thermal power plants:

Parameter	Units installed before 31-12-2003	Units installed 2003–2016	Units installed from 01-01-2017
Particulate matter (PM)	100 mg/Nm ³	50 mg/Nm ³	30 mg/Nm ³
Sulphur dioxide (SO ₂)	600 mg/Nm ³ (<500 MW) 200 mg/Nm ³ (≥500 MW)	600 / 200 mg/Nm ³	100 mg/Nm ³
Oxides of nitrogen (NO _x)	600 mg/Nm ³	300 mg/Nm ³	100 mg/Nm ³
Mercury (Hg)	0.03 mg/Nm ³ (≥500 MW)	0.03 mg/Nm ³	0.03 mg/Nm ³

- **Water:** specific water consumption max. 3.5 m³/MWh for existing cooling-tower plants and 2.5 m³/MWh for plants installed after 1-1-2017; zero liquid discharge is encouraged; effluent pH 6.5–8.5.
- **Stack height:** 220 m for 200–500 MW units and 275 m for units of 500 MW and above.
- **Fly ash:** 100 % utilisation of fly ash as per MoEF&CC notification; ash ponds must be lined.
- **Consent:** Consent to Establish and Consent to Operate from MPCB are compulsory; online continuous emission monitoring (CEMS) connected to MPCB/CPCB servers.
- **Noise:** ambient noise limits for industrial areas 75 dB(A) day / 70 dB(A) night.

(Emission norms 2 M, water / ash / stack norms 2 M)

Q.4

a) Site selection for thermal power plant.

4 M

1. **Availability of fuel (coal):** Plant should be near coal mines (pit-head) or near a railway line so that transport cost of coal is low (a 500 MW unit burns about 6000–7000 t of coal per day).
2. **Availability of water:** Large quantity of water is needed for condenser cooling and boiler feed make-up, so the site should be near a river, lake or sea.
3. **Transport facilities:** Rail and road connections are needed for coal, heavy machinery and staff.
4. **Nature of land / soil:** Land should be cheap, level and have good bearing capacity to carry heavy foundations of boiler and turbo-generator.

5. **Ash disposal:** Enough space should be available for ash pond / ash dyke and for fly-ash utilisation units.

6. **Nearness to load centre:** Transmission cost and losses are less if the plant is near the load centre.

(Any four factors, 1 M each)

b) Layout of diesel power plant.

4 M

A diesel power plant is widely used as a **captive / standby** plant in hospitals, industries, hotels and telecom sites, and for peak load in small isolated systems.

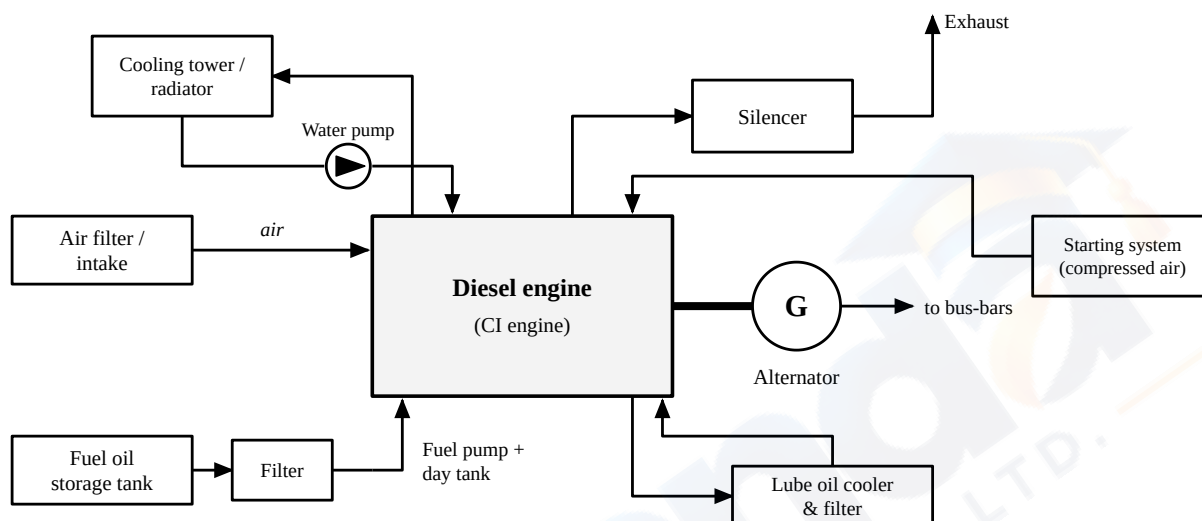


Fig.: Layout of a diesel power plant

1. **Engine and alternator:** the CI engine drives the alternator directly.
2. **Fuel system:** storage tank → filter → day tank → fuel pump → injectors.
3. **Air intake system:** air filter (and supercharger) supply clean air to the engine.
4. **Exhaust system:** silencer and exhaust pipe (waste heat may be recovered).
5. **Cooling system:** water pump circulates jacket water through radiator / cooling tower.
6. **Lubrication and starting systems:** lube-oil pump, cooler, filter; compressed-air or electric (battery) starting.

(Layout 2 M, systems 2 M)

c) MTEE and FEEED under NMEEE.

4 M

NMEEE (National Mission for Enhanced Energy Efficiency) is one of the eight missions of the National Action Plan on Climate Change (NAPCC, 2008); it is implemented by the Bureau of Energy Efficiency (BEE) under the Energy Conservation Act, 2001.

MTEE — accelerates the shift to energy-efficient appliances in designated sectors through innovative measures that make them affordable: e.g. Bachat Lamp Yojana (CFLs), UJALA LED bulb programme and Super-Efficient Equipment Programme (fans, ACs), standards & labelling (star rating) and demand-side management.

FEEED — develops fiscal instruments to promote energy efficiency: **Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)** that gives partial guarantee to banks lending to EE

projects (ESCO projects), and **Venture Capital Fund for Energy Efficiency (VCFEE)** that gives equity support; also public procurement of efficient equipment.

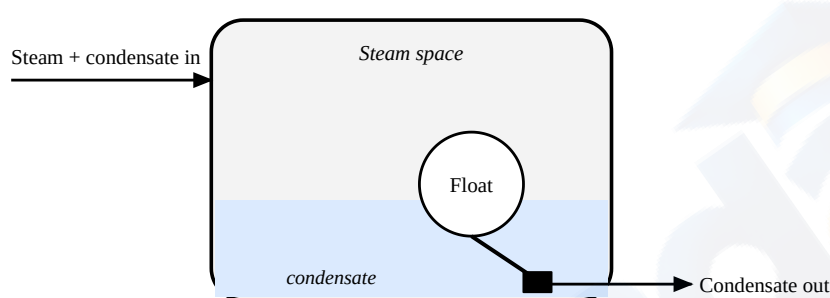
(MTEE 2 M, FEEED 2 M)

d) Need of steam traps; float trap.

4 M

Need: A steam trap is an automatic valve that discharges condensate (and air / non-condensable gases) from steam pipes and equipment **without allowing live steam to escape**. It prevents water hammer, keeps heat-transfer surfaces free of condensate, saves steam and allows condensate recovery.

Types: (i) Mechanical — float and inverted-bucket; (ii) Thermostatic — bimetallic and balanced pressure; (iii) Thermodynamic (disc) type.



Float rises with condensate level → valve opens → water drains; steam is held back

Fig.: Float type (mechanical) steam trap

Working of float trap: condensate collects in the trap body and lifts the float; the float, through a lever, opens the outlet valve and condensate is discharged. When the level falls, the float closes the valve. Since the valve is always below the water level, steam cannot escape. A thermostatic air vent is usually fitted at the top.

(Need 1 M, sketch 1 M, working 2 M)

e) Numerical: plant load factor and plant use factor.

4 M

Given: 2 units × 80 MW for 7200 h; 1 unit × 30 MW for 2500 h; energy $E = 1000 \times 10^6$ kWh = 10,00,000 MWh.

Quantity	Formula and substitution	Result
Installed capacity	$2 \times 80 + 30$	190 MW
Max. possible energy per year	190×8760	1,664,400 MWh
Plant load factor	$E / (\text{capacity} \times 8760) = 10,00,000 / 1,664,400$	60.08 %
Energy possible during running hours	$2 \times 80 \times 7200 + 30 \times 2500 = 11,52,000 + 75,000$	1,227,000 MWh
Plant use factor	$E / \Sigma(\text{capacity} \times \text{hours run}) = 10,00,000 / 1,227,000$	81.50 %

Note: Plant load factor (PLF) as used in Indian power sector = actual energy / (installed capacity × 8760 h); it is the same as the plant capacity factor.

Q.5

a) World and national energy scenario.

6 M

A) World scenario:

- World electricity demand is rising every year (about 2–4 % per year) due to population growth, industrialisation, electric vehicles, air-conditioning and data centres.
- Fossil fuels still dominate world generation: coal gives roughly one-third and natural gas about one-fifth of world electricity; hydro, nuclear, wind and solar supply the rest.
- Share of solar and wind is growing fastest; many countries have net-zero targets and are phasing down coal.
- Coal, oil and gas reserves are limited and unevenly distributed, so energy security and fuel price fluctuations are major concerns.

B) National (Indian) scenario:

- India is the third largest producer and consumer of electricity in the world. Total installed capacity is about **504 GW** (31 Oct 2025).
- Coal-based thermal plants are still the backbone: coal + lignite = 44.6 % of capacity, but they generate about three-fourths of the energy because they run as base-load plants.
- Non-fossil sources (RE + large hydro + nuclear) have crossed 50 % of installed capacity (51.3 %) in 2025; the target is 500 GW non-fossil capacity by 2030.
- Peak demand has crossed 250 GW (met on 30 May 2024) and keeps rising; per-capita consumption (about 1400 kWh/year) is still far below the world average, so demand will grow.
- Gaps: shortage of domestic coal of good quality (imports), low gas availability (gas plants under-utilised), T&D losses, and need of storage for solar/wind.

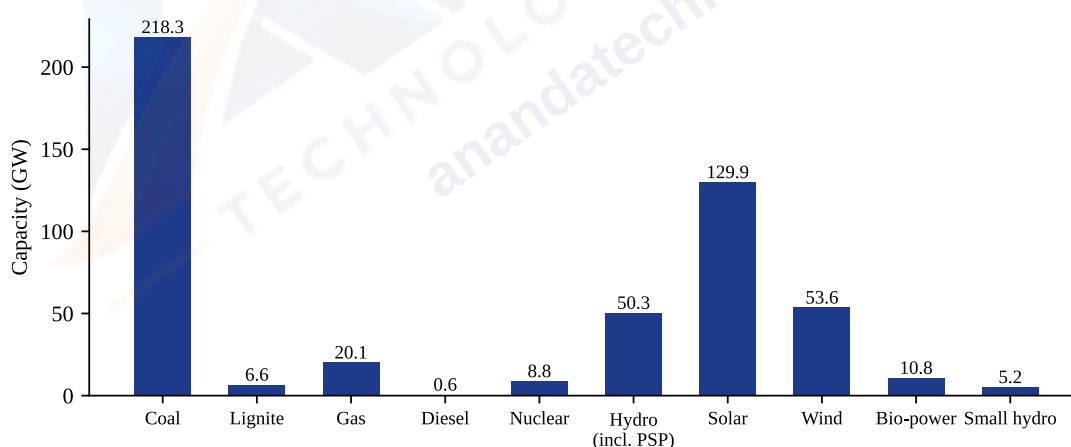


Fig.: Installed generating capacity of India by source, GW (as on 31 Oct 2025, Ministry of Power / CEA data)

(World scenario 2 M, Indian scenario 3 M, chart / data 1 M)

b) Pressurised Water Reactor (PWR).

6 M

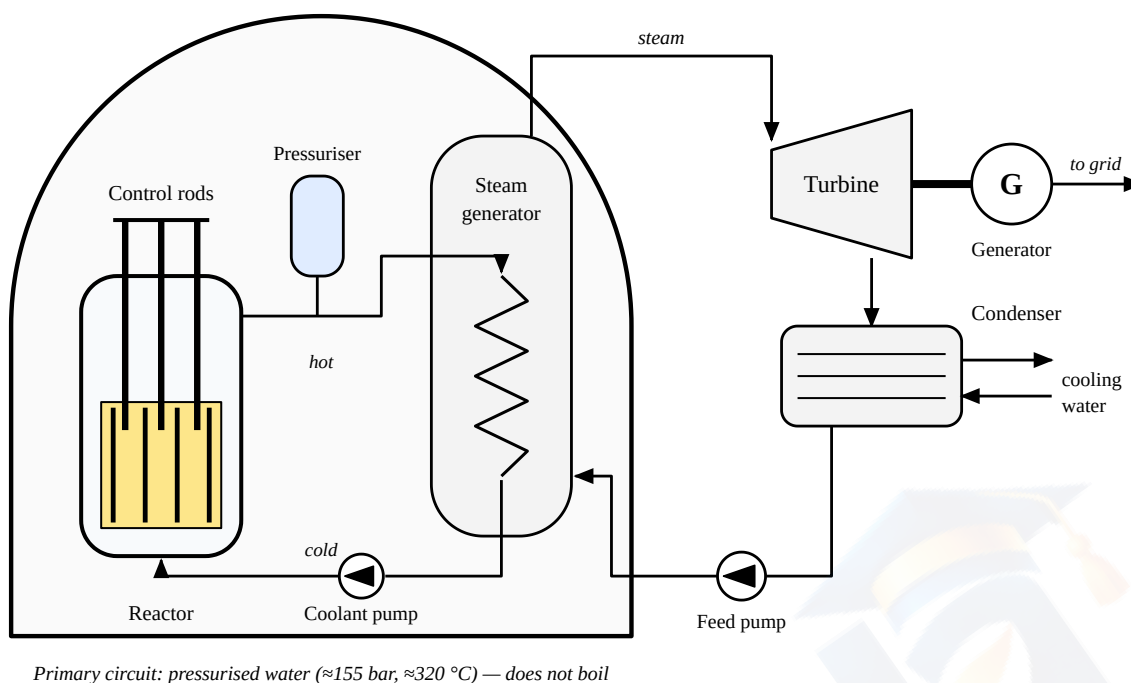


Fig.: Pressurised Water Reactor (PWR) nuclear power plant

1. A PWR has two separate circuits. In the **primary circuit** light water (coolant + moderator) is circulated through the core at about 155 bar; the high pressure (maintained by the **pressuriser**) prevents boiling, and the water leaves the reactor at about 320 °C.
2. The hot primary water flows through the tubes of the **steam generator** (heat exchanger) and gives its heat to the secondary water; it is then returned to the reactor by the coolant pump.
3. In the **secondary circuit** water boils in the steam generator; the steam drives the turbine–generator, is condensed in the condenser and pumped back by the feed pump.
4. Control rods are inserted from the **top**; boric acid in the coolant is also used for reactivity control.
5. The reactor, pressuriser and steam generators are housed in a strong **containment** building.
Example: Kudankulam (VVER).

Advantages: compact core, turbine side not radioactive, uses ordinary water. **Disadvantages:** high pressure vessel, needs enriched uranium, costly steam generators.

(Sketch 2 M, construction and working 3 M, advantages 1 M)

c) Electrostatic precipitator and advantages.

6 M

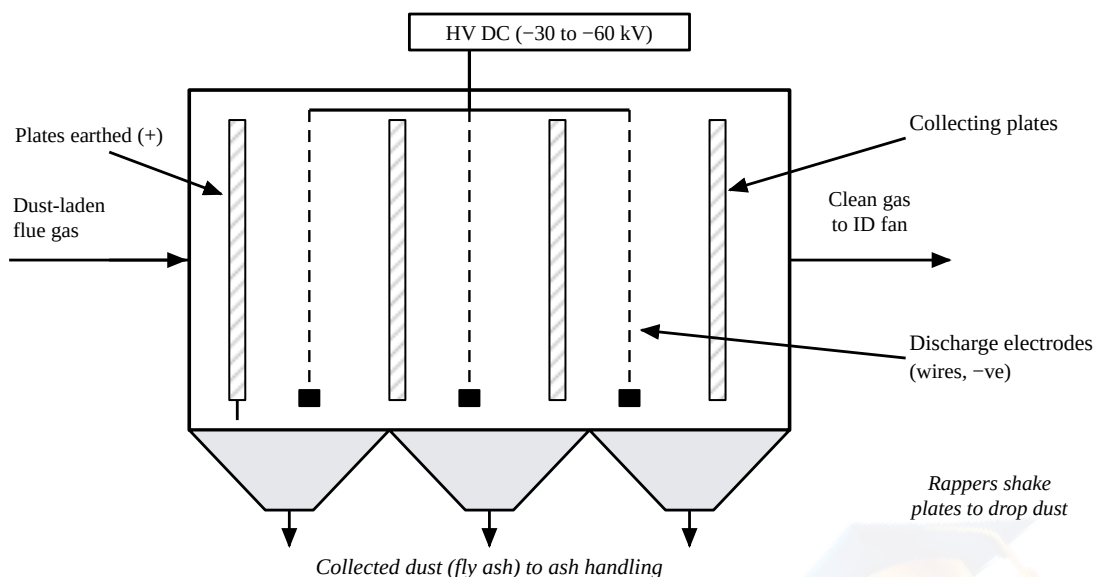


Fig.: Electrostatic precipitator (plate type)

- Construction:** an ESP is a large chamber in which vertical earthed **collecting plates** are placed parallel to each other with **discharge electrodes** (wires) hung midway between them. The wires are connected to a high-voltage DC supply (about -30 to -60 kV) and the plates are earthed. Hoppers are provided at the bottom and rapping hammers on the plates.
- Ionisation (corona):** the high voltage produces a strong electric field near the wires; the gas around them ionises (corona discharge) and produces a large number of negative ions.
- Charging:** as the dust-laden flue gas passes slowly between the plates, the negative ions attach to the dust particles, which become negatively charged.
- Collection:** the charged particles are attracted to the positively (earthed) collecting plates and stick to them; clean gas leaves the ESP and goes to the ID fan and chimney.
- Removal:** the plates are periodically rapped (shaken); the dust layer falls into the hoppers and is removed by the fly-ash handling system.

Advantages:

- Very high collection efficiency (99–99.9 %), even for fine particles below 1 micron.
- Low pressure drop, so low ID fan power.
- Can handle very large gas volumes at high temperature.
- Dry dust is collected, which can be sold for cement/brick making.

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

Q.6

a) Indian Boiler Regulations (IBR).

6 M

- Indian Boilers Act, 1923** and **Indian Boiler Regulations (IBR), 1950** govern design, material, manufacture, registration, inspection and safe operation of steam boilers and steam pipes in India. (The 1923 Act has now been replaced by the **Boilers Act, 2025**, in force from 1 May 2025, which keeps the same basic system of registration, inspection and certification.)

2. **Boiler** (as per the Act): any closed vessel exceeding 22.75 litres capacity used for generating steam under pressure, including mountings and fittings.
3. **Registration:** no boiler can be used unless it is registered with the Chief Inspector of Boilers of the State and has a registration number.
4. **Certificate of operation (fitness):** boiler must be inspected and a certificate issued; it is valid for a limited period (maximum 12 months) and renewed after inspection.
5. **Hydraulic test:** before registration and at periodic inspections, the boiler is tested hydraulically at about 1.5 times the maximum working pressure.
6. **Design and materials:** plates, tubes, welding, safety valves, water-level gauges, pressure gauges, fusible plug etc. must conform to IBR / approved standards; manufacturers and welders must be IBR-approved.
7. **Repairs and alterations** need prior approval of the Inspector; accidents must be reported within 24 hours.
8. **Competent persons:** boilers must be operated by persons holding a Boiler Attendant or Boiler Operation Engineer certificate.
9. **Penalties:** using an unregistered or uncertified boiler, or exceeding the permitted pressure, is punishable with fine.

(Any six provisions, 1 M each)

b) Trigeneration and its necessity.

6 M

- **Trigeneration** (combined cooling, heating and power — CCHP) is the simultaneous production of electricity, useful heat and cooling (chilled water) from a single fuel source.
- A prime mover (gas turbine / gas engine) drives the generator; heat from the exhaust is recovered in a heat-recovery boiler; part of this heat drives a **vapour absorption machine (VAM)** to produce chilled water.

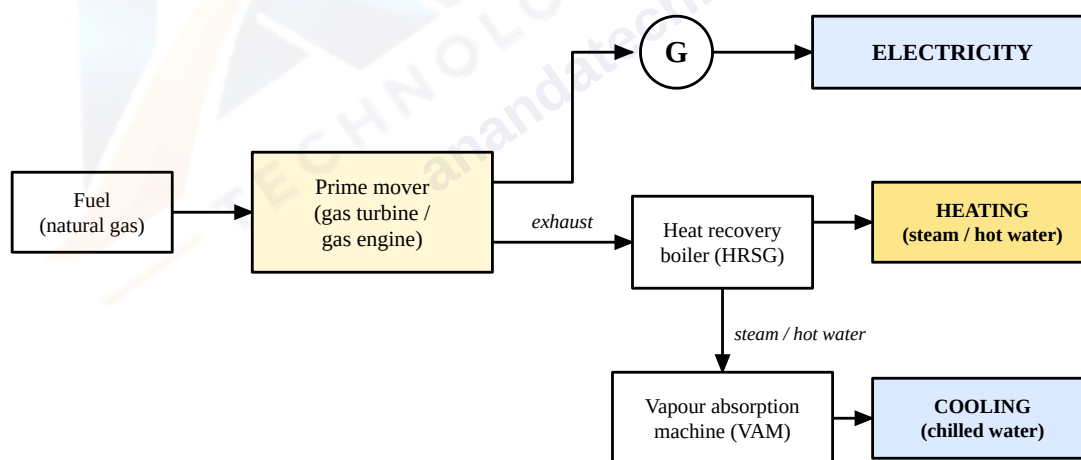


Fig.: Trigeneration (combined cooling, heat and power — CCHP)

Necessity:

- Overall fuel utilisation of 75–90 % against 30–40 % for separate generation.
- Air-conditioning load in summer can be met from waste heat — reduces electricity demand of compressors.

- Lower fuel cost and lower CO₂ emissions.
- Suitable for hospitals, hotels, malls, airports, IT parks, food and pharma industries where power, heat and cooling are all needed.

(Block diagram 2 M, explanation 2 M, necessity 2 M)

c) Numerical: daily energy, reserve capacity, use factor.

6 M

Given: Max. demand = 25 MW, load factor = 0.64, plant capacity factor = 0.50, plant use factor = 0.80.

Quantity	Formula and substitution	Result
Average load	Load factor $\times$ Max. demand = 0.64×25	16 MW
(i) Daily energy produced	Average load $\times 24 = 16 \times 24$	384 MWh
(ii) Installed capacity	Average load / Capacity factor = $16 / 0.5$	32 MW
Reserve capacity	Installed capacity – Max. demand = $32 - 25$	7 MW
(iii) Max. energy if fully loaded while running	Actual energy / Use factor = $384 / 0.8$	480 MWh/day
(iv) Hours of running per day	$480 \text{ MWh} / 32 \text{ MW}$	15 h

((i) 1 M, (ii) 2 M, (iii) 2 M, (iv) 1 M)

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