Subject Code: DI03009021 DI03009021

Previous Year Question Papers Solutions Complete Bilingual Solutions (English & Gujarati)

Generated by Gemini June 18, 2026

Contents

S2026

[3] Explain site selection of Thermal Power Station.

Site Selection for Thermal Power Station

The selection of a site for a thermal power station is crucial for its economic and efficient operation.

The main factors to be considered for the site selection of a thermal power station are:

- **Availability of Coal:** A thermal power station consumes a huge amount of coal. Hence, it should be located near coal mines to minimize the transportation cost of fuel.
- **Availability of Water:** Huge amounts of water are required for the condenser, boiler feed, and cooling purposes. Thus, the site must be located on the bank of a river or near a large water reservoir.
- **Transportation Facilities:** A well-connected rail and road network is essential for the continuous transportation of heavy machinery, coal, and ash.
- **Nearness to Load Centre:** To minimize transmission line costs and power losses, the power station should be located as close to the load centre as possible.
- **Availability of Land:** A large area of land is required for the plant, coal storage, ash disposal, and staff colony. The land should be cheap and have good bearing capacity to support heavy machinery.
- **Ash Disposal Facilities:** The combustion of coal produces a large amount of ash. Sufficient space and facilities must be available for its proper disposal without causing environmental pollution.
- **Away from Populated Areas:** To avoid the harmful effects of smoke, fly ash, and noise pollution, the plant should be situated away from densely populated areas.

[4] Explain Nuclear Fusion, Nuclear Fission and Chain reaction.

Nuclear Reactions

Nuclear reactions involve changes in the nucleus of an atom, releasing a tremendous amount of energy according to Einstein's mass-energy equivalence principle, $E = mc^2$.

1. **Nuclear Fission:**
   - The process in which a heavy nucleus (like Uranium-235) is split into two or more lighter nuclei when bombarded with a slow-moving neutron is called nuclear fission.
   - This process is accompanied by the release of a huge amount of energy and 2 to 3 additional neutrons.
   - Example: $\mathrm{U}_{92}^{235} + \mathrm{n}_0^1 \rightarrow \mathrm{Ba}_{56}^{141} + \mathrm{Kr}_{36}^{92} + 3\mathrm{n}_0^1 + \mathrm{Energy}$
2. **Nuclear Fusion:**
   - The process in which two light nuclei combine to form a single, heavier nucleus is called nuclear fusion.
   - This process also releases a massive amount of energy, even greater than nuclear fission, and occurs at extremely high temperatures (like in the sun).

- Example: $H_1^2 + H_1^2 \rightarrow He_2^4 + \text{Energy}$

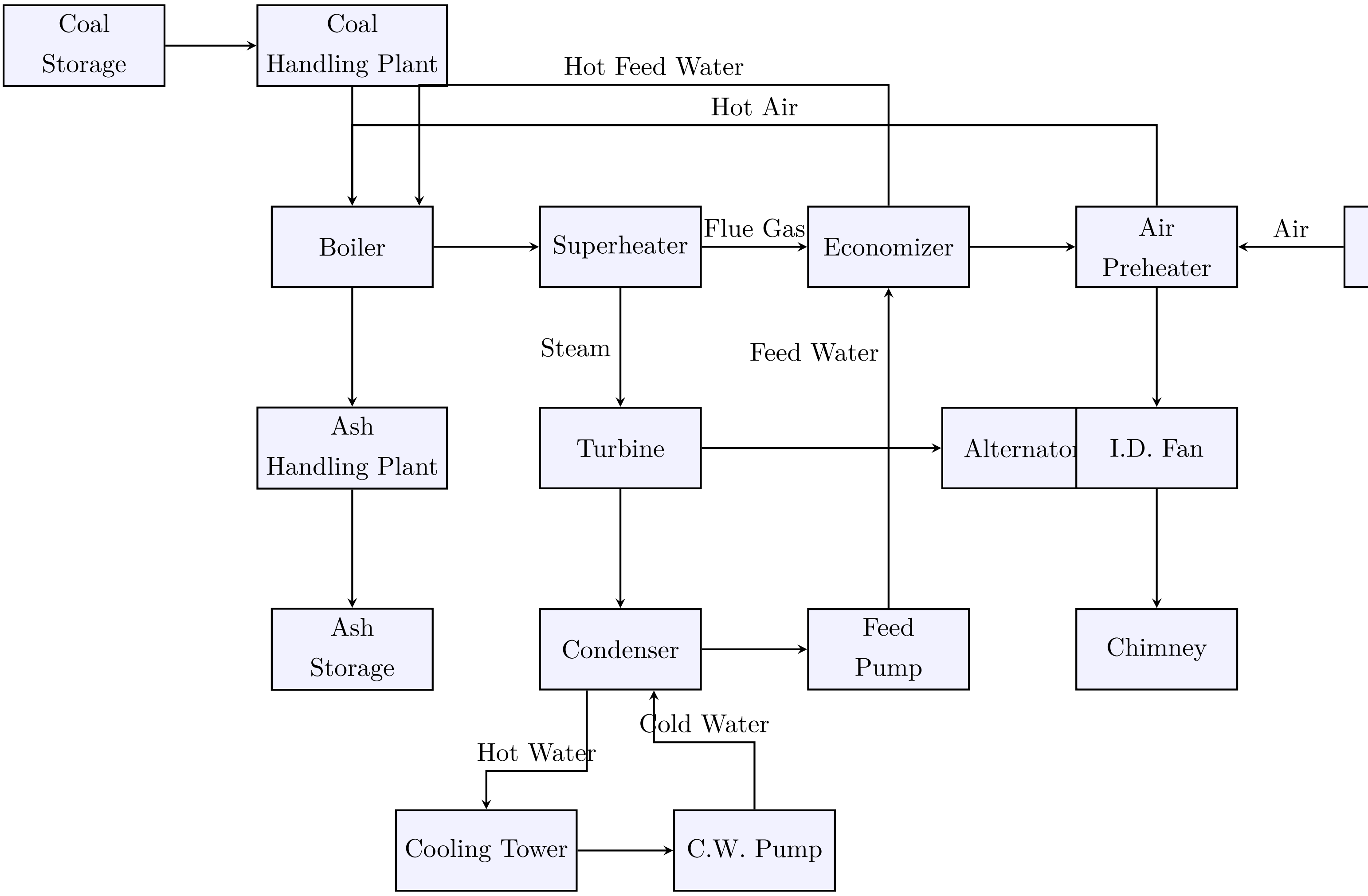
3. **Chain Reaction:**

- During the nuclear fission of U-235, 2 or 3 secondary neutrons are released. If these neutrons are allowed to strike other U-235 nuclei, further fission occurs, producing more neutrons.
- This continuous, self-sustaining sequence of fission reactions is called a chain reaction.
- A chain reaction can be *controlled* (as in a nuclear power reactor to produce electricity) or *uncontrolled* (as in an atomic bomb).

[7] Draw Schematic Diagram of Thermal Power Station.

Thermal Power Station Layout

A thermal power station converts the chemical energy of coal into electrical energy. It mainly consists of a coal and ash circuit, air and gas circuit, feed water and steam circuit, and cooling water circuit.



OR [7] Explain the function of following auxiliaries of Thermal Power Station : (1) Boiler (2) Economizer (3) F. D. Fan (4) Air Preheater (5) Condenser (6) Turbine (7) Cooling Tower

Thermal Power Plant Auxiliaries

The efficiency and proper functioning of a thermal power station depend on various auxiliary components that support the main process of steam generation and power conversion.

The functions of the given auxiliaries are as follows:

1. **Boiler:** It is a closed vessel in which water is heated and converted into high-pressure and high-temperature steam by utilizing the heat generated from the combustion of coal.

2. **Economizer:** It is a heat exchanger that recovers heat from the outgoing flue gases to preheat the feed water before it enters the boiler. This reduces coal consumption and improves boiler efficiency.

3. **F. D. Fan (Forced Draft Fan):** It draws fresh atmospheric air and forces it into the air preheater and then into the boiler furnace. It maintains a positive pressure in the furnace to supply the necessary oxygen for proper combustion of coal.

4. **Air Preheater:** It extracts the remaining heat from the hot flue gases (leaving the economizer) to heat the incoming fresh air from the F.D. fan. Supplying hot air to the furnace accelerates combustion and increases the thermal efficiency of the plant.

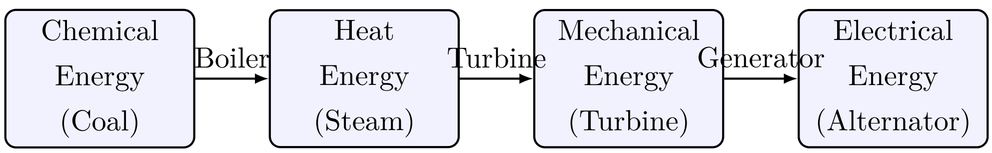
5. **Condenser:** It receives the exhaust steam from the turbine and condenses it back into water by cooling it. This creates a vacuum at the turbine exhaust, increasing the turbine's work output, and provides pure feed water to be reused in the boiler.

6. **Turbine:** It acts as the prime mover. It converts the thermal energy (heat and pressure) of the high-pressure steam from the boiler into mechanical rotational energy. The turbine shaft is coupled to the generator.

7. **Cooling Tower:** It cools the warm water coming from the condenser by spraying it downwards against an upward flow of atmospheric air. The cooled water is then pumped back to the condenser, enabling the continuous reuse of cooling water.

Question 2(a) [3 marks]

Draw & Explain Energy conversion Process in thermal power station.



Energy Conversion Process in Thermal Power Station

The overall energy conversion in a thermal power station occurs in three main stages:

- **Chemical Energy to Heat Energy:** In the boiler, coal is burnt. The chemical energy of coal is converted into heat energy. This heat converts feed water into high-pressure and high-temperature steam.

- **Heat Energy to Mechanical Energy:** The high-pressure steam is passed through the steam turbine. As the steam expands, its heat energy is converted into mechanical energy, which rotates the turbine shaft.

- **Mechanical Energy to Electrical Energy:** The turbine shaft is coupled with an alternator (generator). When the turbine rotates, the alternator converts the mechanical energy into electrical energy.

Question 2(b) [4 marks]

Draw and explain feed water and steam cycle of thermal power station.

closes the turbine gates. This sudden reduction in water flow causes a severe increase in pressure inside the penstock, known as the "water hammer" effect. The surge tank absorbs this sudden pressure surge by allowing water to rise into it, preventing penstock burst.

- **Supply of Additional Water:** When the load on the turbine suddenly increases, additional water is instantly required. The surge tank provides this extra water to the turbine until the flow from the main reservoir accelerates, preventing a vacuum in the penstock.

Function of Pen-Stock

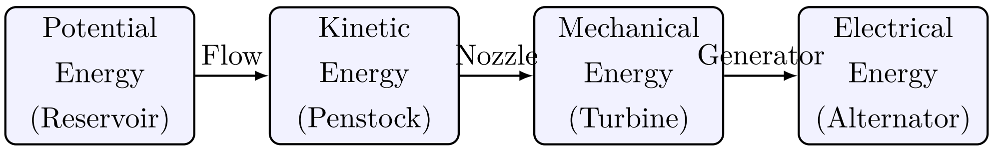
- A penstock is a large pipe or conduit made of steel or reinforced concrete.
- Its primary function is to carry water under high pressure from the main reservoir or surge tank to the hydraulic turbine.

Difference Between Catchment Area and Reservoir

- **Catchment Area:** It is the entire natural geographical land area from which rainwater drains and flows into a river or a particular basin. It is a naturally occurring topographical feature.
- **Reservoir:** It is an artificial lake or storage basin created by constructing a dam across a river. Its main purpose is to store water during the rainy season to ensure a continuous and reliable water supply to the power plant throughout the year.

Question 2(a) OR [3 marks]

Draw and explain energy conversion process in Hydro Power Plant.



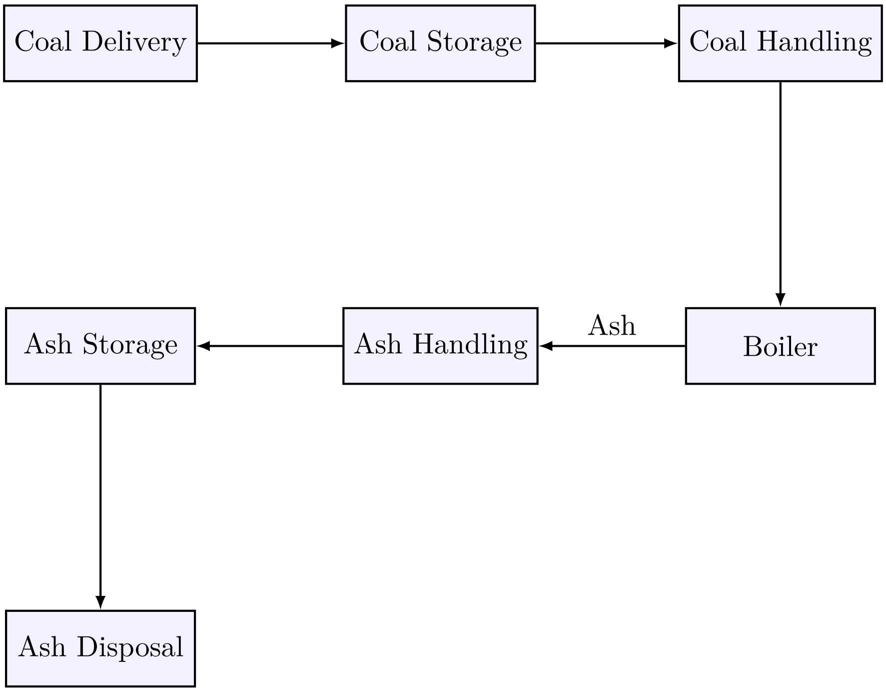
Energy Conversion Process in Hydro Power Plant

The energy conversion in a hydro power plant occurs in three main stages:

- **Potential Energy to Kinetic Energy:** Water stored in the reservoir at a certain height possesses potential energy. When this water is allowed to flow down through the penstock, its potential energy is converted into kinetic energy due to high velocity.
- **Kinetic Energy to Mechanical Energy:** The high-velocity water strikes the blades of the hydraulic turbine, forcing the turbine runner to rotate. Thus, the kinetic energy of water is converted into mechanical energy.
- **Mechanical Energy to Electrical Energy:** The turbine is mechanically coupled to an alternator. As the turbine rotates, it drives the alternator, which converts the mechanical energy into electrical energy.

Question 2(b) OR [4 marks]

Explain fuel and ash cycle with diagram for thermal power station.



Fuel and Ash Cycle

- **Coal Delivery and Storage:** Coal is transported to the power plant via trains or ships and is stored in the coal storage yard.
- **Coal Handling:** From the storage yard, coal is transferred to the coal handling plant, where it is crushed and pulverized (ground into fine powder) to increase its surface area for better and faster combustion.
- **Combustion in Boiler:** The pulverized coal is fed into the boiler furnace, where it burns to generate heat.
- **Ash Handling:** The combustion of coal produces a large amount of ash. Bottom ash falls to the bottom of the furnace, while fly ash is carried away with flue gases and collected by Electrostatic Precipitators (ESPs).
- **Ash Storage and Disposal:** The ash handling system transports this collected ash to the ash storage area. Finally, the ash is disposed of in ash ponds or sold to industries for making cement and bricks.

Question 2(c) OR [7 marks]

Give the classification of Hydro Power Station. State the different schemes used in Hydro Power Station.

Classification of Hydro Power Station

Hydro power stations can be classified based on various factors:

- **Based on the Availability of Water Head:**

  - High head power plants (Head $>$ 100 meters, e.g., Pelton wheel turbine)
  - Medium head power plants (Head between 30 to 100 meters, e.g., Francis turbine)
  - Low head power plants (Head $<$ 30 meters, e.g., Kaplan turbine)

- **Based on the Nature of Load:**
  - Base load power plants (run continuously to supply constant power)
  - Peak load power plants (run only during peak demand hours)

- **Based on Quantity of Water / Operational Concept:**
  - Run-off river plants without pondage
  - Run-off river plants with pondage
  - Reservoir (Storage) power plants
  - Pumped storage power plants

- **Based on Capacity:**
  - Micro, Mini, Small, and Large hydro plants.

Different Schemes Used in Hydro Power Station

The main schemes (arrangements) used for generating hydro power are:

- **Run-off River Scheme:** In this scheme, electricity is generated from the natural flow of a river. It does not have a large reservoir to store water. A small pondage may be provided to handle daily load variations.
- **Storage (Reservoir) Scheme:** A dam is constructed across a river to create a large reservoir. Water is stored during the rainy season and utilized throughout the year to generate electricity at a constant rate.
- **Pumped Storage Scheme:** This scheme utilizes two reservoirs: an upper reservoir and a lower reservoir. During off-peak hours (when electricity demand is low), excess power from the grid is used to pump water from the lower reservoir back to the upper reservoir. During peak hours, this stored water is released to generate electricity.

Question 3(a)

What are the points to be considered while selecting site for hydro power station?

Site Selection for Hydro Power Station

The selection of an appropriate site for a hydro power station depends on several geographical, hydrological, and economic factors to ensure efficient and continuous power generation.

The main points to be considered are:

1. **Availability of Water:** There should be a huge quantity of water available throughout the year. Hence, the plant is usually constructed on a perennial river.
2. **Storage of Water:** Water storage capacity must be available to run the plant continuously during dry seasons. A dam is constructed for this purpose, which requires a large catchment area.
3. **Water Head:** A high head (height) of water increases power generation and reduces the physical size of the turbine. Therefore, mountainous regions are highly preferred.
4. **Topography and Geological Conditions:** The foundation rock at the site must be strong and stable enough to withstand the immense stress transmitted by the dam structure and water pressure.
5. **Distance from Load Center:** Since hydro power plants are generally located far from load centers, long transmission lines are required. The site should be selected such that the transmission cost and line losses are minimized.
6. **Transportation Facilities:** The site should have adequate rail and road transportation facilities for moving heavy machinery, equipment, and construction materials.

Question 3(b)

Define the following terms: (1) Solar Cell (2) Solar Module (3) Solar Panel (4) Solar Array.

1. **Solar Cell:** It is the basic fundamental unit of a solar photovoltaic system. It is a semiconductor P-N junction device that converts sunlight directly into electrical energy via the photovoltaic effect. A typical solar cell produces an output of about 0.5 to 0.6 Volts.
2. **Solar Module:** A series or parallel combination of multiple interconnected solar cells, encapsulated in a single protective frame to achieve a practical and higher voltage and current rating, is called a solar module.
3. **Solar Panel:** A solar panel is formed when one or more solar modules are assembled together mechanically and electrically on a single supporting structure.
4. **Solar Array:** A complete power-generating system consisting of multiple solar panels interconnected in series and parallel combinations to meet a specific high-power demand of a load or a utility grid.

Question 3(c)

Draw and explain schematic diagram of Nuclear Power Station. Draw nuclear reactor diagram showing its major elements.

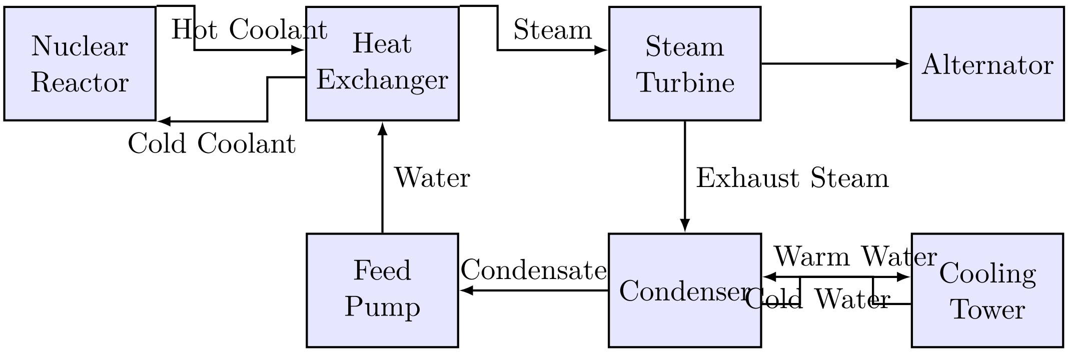


Figure 1: Schematic Diagram of Nuclear Power Station

Explanation of Nuclear Power Station Elements:

- **Nuclear Reactor:** It is the heart of the power station where a controlled nuclear fission chain reaction takes place (usually using Uranium-235). The immense heat generated is absorbed by a coolant circulated through the core.
- **Heat Exchanger (Steam Generator):** The hot primary coolant from the reactor transfers its heat to the secondary loop containing water, boiling it into high-pressure, high-temperature steam.
- **Steam Turbine:** The high-pressure steam expands through the blades of the steam turbine, converting the thermal energy of the steam into mechanical rotational energy.
- **Alternator:** Coupled directly to the turbine shaft, the alternator converts the mechanical rotational energy into electrical energy.
- **Condenser:** The exhaust steam leaving the turbine is cooled and condensed back into liquid water.
- **Feed Pump:** It pumps the condensed water back into the heat exchanger to continue the cycle.

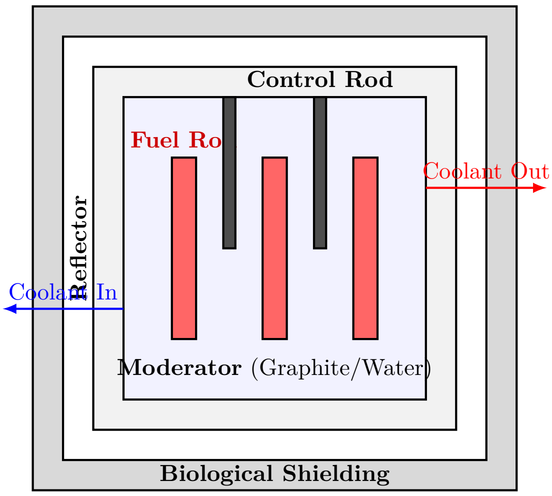


Figure 2: Major Elements of a Nuclear Reactor

Major Elements of a Nuclear Reactor:

- **Fuel Rods:** Contain the fissile materials like U-235 or Pu-239 where the fission reaction actually occurs.

- **Moderator:** A material (such as graphite or heavy water) used to slow down fast-moving neutrons to increase the probability of successful fission.
- **Control Rods:** Made of neutron-absorbing materials (like cadmium or boron) and are inserted into the core to control the rate of the chain reaction by absorbing excess neutrons.
- **Coolant:** A fluid (water, liquid sodium, or gas) circulated through the reactor core to carry away the generated heat.
- **Reflector:** Surrounds the core to bounce escaping neutrons back into the core, improving efficiency.
- **Biological Shielding:** Thick walls made of concrete and lead designed to absorb radiation and protect operating personnel.

Question 3(a) OR

Explain site selection of Nuclear Power Station.

Site Selection for Nuclear Power Station

Nuclear power plants require stringent safety, cooling, and geographical considerations compared to conventional thermal plants.

The major factors considered for the site selection are:

1. **Availability of Cooling Water:** A nuclear power plant requires a vast amount of cooling water for its condenser. Therefore, the plant must be located near a natural and large water body such as a river, lake, or sea.
2. **Distance from Populated Areas:** To minimize the catastrophic danger to human life from potential radioactive hazards or accidental leakages, the site should be located far away from densely populated areas.
3. **Transportation Facilities:** Strong and adequate transportation networks (railways or heavy-duty roads) are required for bringing in heavy reactor equipment, shielding materials, and transporting nuclear fuel safely.
4. **Disposal of Radioactive Waste:** The plant generates highly radioactive waste. The site should have proper geological provisions and isolated space for the safe and deep underground disposal or storage of this waste.
5. **Geological Conditions:** The foundation land should be incredibly stable, strong, and not prone to earthquakes or fault lines, as it needs to support the massive, heavy structures of the reactor and its thick biological shielding.

Question 3(b) OR

Draw and explain the characteristics of solar cell.

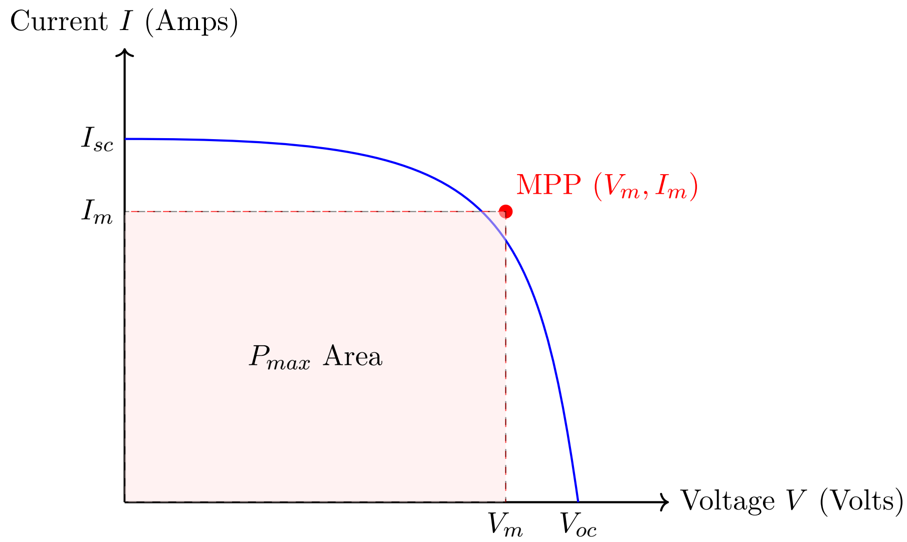


Figure 3: V-I Characteristics of a Solar Cell

Explanation: The Voltage-Current (V-I) characteristic curve illustrates the relationship between the voltage and current produced by a solar cell under a constant level of solar irradiance (light intensity).

- **Short Circuit Current (I_{sc}):** This is the maximum current that the solar cell can produce. It occurs when the terminals of the solar cell are short-circuited, meaning the voltage across it is zero ($V = 0$).
- **Open Circuit Voltage (V_{oc}):** This is the maximum voltage available across the solar cell terminals when they are left open, meaning no current is flowing through an external load ($I = 0$).
- **Maximum Power Point (MPP):** The distinct point on the curve where the product of voltage and current ($V_m \times I_m$) reaches its maximum value. This is the optimal operating point at which the solar cell delivers maximum electrical power.
- **Maximum Power (P_{max}):** It is represented by the rectangular area enclosed by the dashed lines extending from the MPP to the axes. $P_{max} = V_m \times I_m$.

Question 3(c) OR

Explain Rooftop Solar PV Power System: Grid connected and standalone with diagram.

1. **Grid-Connected (Grid-Tied) Rooftop Solar PV System:**

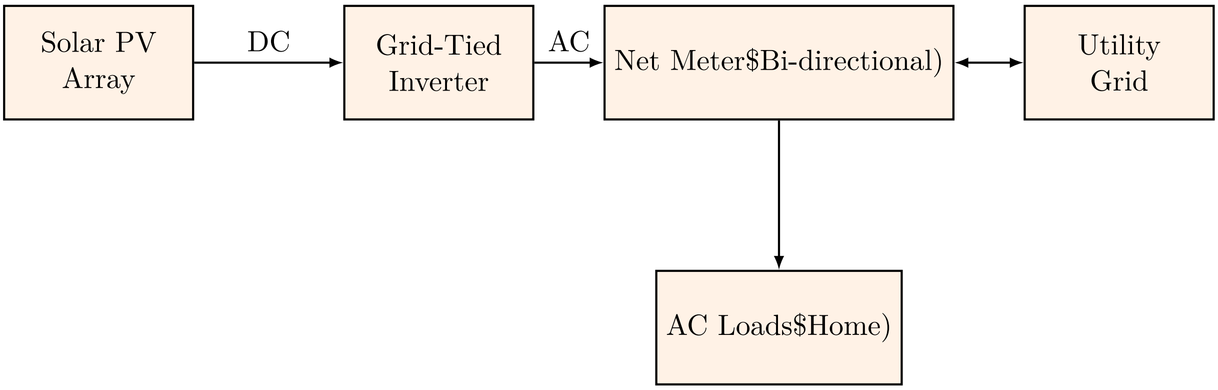


Figure 4: Grid-Connected Rooftop Solar PV System

- In this system, the rooftop solar PV array is directly connected to the utility power grid through a grid-tied inverter.
- **Working:** The DC power generated by the solar panels is converted into standard AC power by the grid-tied inverter. This AC power feeds the household appliances (AC Loads) directly.
- **Net Metering:** A bi-directional meter (Net Meter) is installed. If the solar system produces more power than the house needs, the excess is exported (sold) to the utility grid. If power generation is insufficient (e.g., at night), the extra power is imported seamlessly from the grid.
- **Advantage:** It does not require batteries, making it cheaper and highly efficient with minimal maintenance.

2. Standalone (Off-Grid) Rooftop Solar PV System:

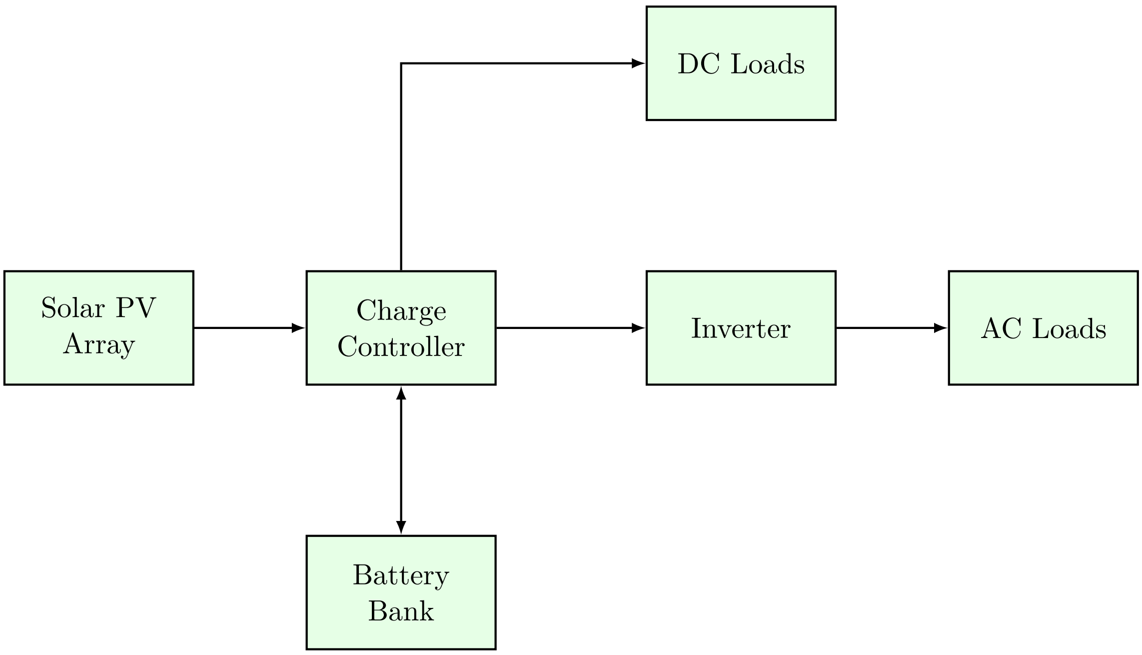


Figure 5: Standalone Rooftop Solar PV System

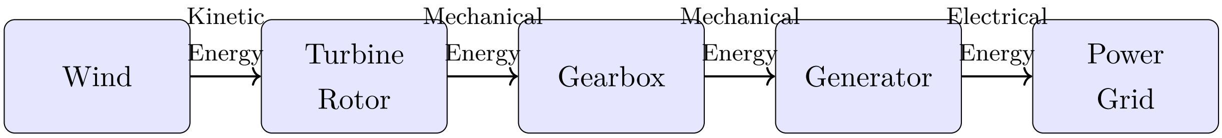
- This system is completely independent and operates disconnected from the utility grid. It requires a battery bank to store generated solar energy for use during nighttime or cloudy weather.

- **Working:** The DC power from the solar PV array flows into a Charge Controller. The controller regulates the voltage and current to safely charge the battery bank, preventing overcharging or deep discharging. DC loads can be powered directly from the charge controller. For standard AC appliances, a standalone inverter is used to convert the stored battery DC voltage into usable AC voltage.
- **Application:** It is essential for remote or rural locations where utility grid access is unavailable or unreliable. However, it requires a higher initial investment and periodic battery replacement.

(a) **Draw and explain energy conversion process in wind power plant.**

Energy Conversion Process

A wind power plant converts the kinetic energy of moving air (wind) into electrical energy in multiple stages. The key principle is that the wind's velocity applies an aerodynamic force on the turbine blades, creating rotational motion.



Explanation of the Process:

(a) **Kinetic to Mechanical Energy:** The wind blows towards the wind turbine, possessing kinetic energy. The aerodynamic design of the rotor blades captures this energy and converts it into rotational mechanical energy as the blades turn.

(b) **Mechanical Energy Transmission:** The rotor is connected to a low-speed shaft. A gearbox is typically used to step up the low rotational speed of the rotor shaft to a higher rotational speed suitable for generating electricity.

(c) **Mechanical to Electrical Energy:** The high-speed shaft drives an electrical generator. The generator converts the mechanical energy into electrical energy using the principle of electromagnetic induction.

(d) **Power Grid Integration:** The generated electrical energy is then conditioned, stepped up in voltage via transformers, and fed into the power grid for distribution.

(b) **Compare between HAWT and VAWT.**

Parameter	Horizontal Axis Wind Turbine (HAWT)	Vertical Axis Wind Turbine (VAWT)
Axis of Rotation	Horizontal (parallel to the ground).	Vertical (perpendicular to the ground).
Generator Location	Top of the tower (in the nacelle).	At the base or ground level.
Yaw Mechanism	Required to face the rotor towards the wind direction.	Not required; it is omni-directional and accepts wind from any direction.
Efficiency	Higher energy conversion efficiency.	Relatively lower efficiency.
Maintenance	Difficult, as heavy machinery is located high off the ground.	Easier, as all main components are accessible at ground level.
Self-Starting	Usually self-starting.	Often not self-starting (e.g., Darrieus rotor).

(c) **State advantages, disadvantages and limitations of solar power plant and wind power plant.**

Solar Power Plant:

- **Advantages:**
  - Abundant and freely available renewable energy source.
  - Environmentally friendly with zero operational emissions.
  - Low maintenance requirements since there are no moving parts (in PV systems).
- **Disadvantages and Limitations:**
  - Power generation is intermittent; it only works during the daytime and depends on clear weather.
  - Requires a large surface area for installation to generate significant power.
  - High initial capital cost and requires expensive energy storage solutions (batteries).

Wind Power Plant:

- **Advantages:**
  - Clean and renewable energy source with zero fuel costs.
  - Land beneath the wind turbines can simultaneously be used for agriculture or farming.
  - Highly cost-effective in areas with strong, consistent wind profiles.
- **Disadvantages and Limitations:**
  - Highly dependent on geographical locations with continuous wind availability.
  - Turbines produce noise pollution and visual impact on the landscape.
  - Can pose a threat to flying wildlife, such as birds and bats.

OR

(a) **Explain Captive Power Plant.**

Captive Power Plant

A Captive Power Plant (CPP) is a localized electricity generation facility set up by an industry or commercial enterprise primarily for its own consumption, rather than selling power to the public grid.

Key Features and Explanations:

- **Purpose:** The main goal is to ensure a continuous, uninterrupted, and reliable power supply, protecting the industry from grid outages, voltage fluctuations, and load shedding.
- **Applications:** Commonly installed by energy-intensive industries such as cement factories, steel plants, chemical manufacturing, and textile mills.
- **Economic Benefits:** It significantly reduces transmission and distribution (T&D) losses since the power is consumed near the point of generation. It also shields the industry from fluctuating grid electricity tariffs.
- **Cogeneration (CHP):** Many captive power plants utilize waste heat from the industrial process to generate electricity (Combined Heat and Power), dramatically improving overall energy efficiency.

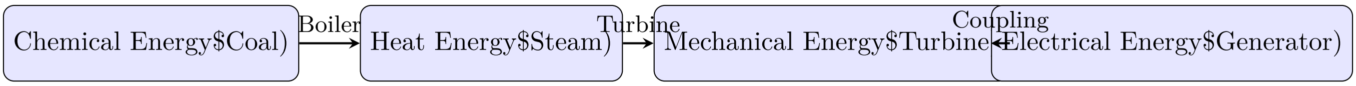
Summer 2026

W2025

- **Question 1(a) [3 marks]**
  Explain energy conversion in thermal power station.

A thermal power station converts the chemical energy of fossil fuels (like coal) into electrical energy through a series of stages:

1. **Chemical Energy to Heat Energy:** Coal is burnt in the boiler furnace. The chemical energy of coal is converted into heat energy.
2. **Heat Energy to Kinetic/Pressure Energy:** The heat generated is used to boil water and convert it into high-pressure, high-temperature steam.
3. **Kinetic/Pressure Energy to Mechanical Energy:** This steam expands in the steam turbine, causing its rotor to spin. Here, the thermal energy of steam is converted into mechanical energy.
4. **Mechanical Energy to Electrical Energy:** The turbine is coupled to an alternator (generator). The rotation of the alternator's rotor within a magnetic field generates electrical energy.



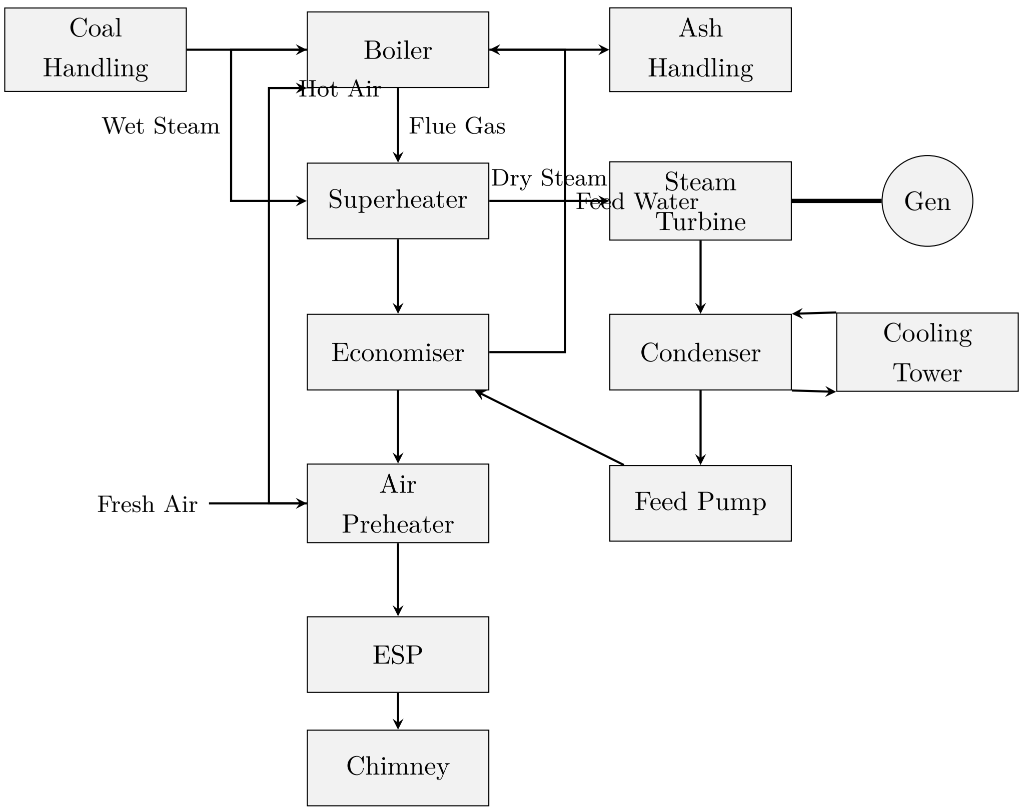
- **Question 1(b) [4 marks]**
  State the function of Superheater, Air preheater, Boiler & Turbine.

The functions of the major components in a thermal power station are as follows:

1. **Boiler:** It is a closed vessel in which water is heated and converted into steam by burning fuel (coal) in the furnace. It transfers heat from the combustion gases to the water.
2. **Superheater:** It receives wet steam from the boiler and further heats it above its saturation temperature using the hot flue gases. This converts it into dry, superheated steam, which increases the efficiency of the power plant and protects the turbine blades from moisture corrosion.
3. **Turbine:** It converts the heat energy of high-pressure, high-temperature superheated steam into mechanical energy. The steam expands over the turbine blades, causing the rotor to spin.
4. **Air Preheater:** It recovers heat from the exhaust flue gases leaving the economiser and uses it to preheat the fresh air entering the furnace for combustion. Preheated air accelerates the combustion process and increases the overall boiler efficiency.

- **Question 1(c) [7 marks]**
  Explain the line diagram of Thermal Power Station with sketch.

A thermal power station fundamentally operates on the Rankine cycle. The main components and their interconnections are represented in the line diagram:



The operation of a thermal power station can be understood through its four main circuits:

1. **Coal and Ash Circuit:** Coal is transported from the storage area to the boiler furnace, where it is burnt. After combustion, the resulting ash (both bottom ash and fly ash) is collected and transferred to the ash handling plant for proper disposal.

2. **Air and Gas Circuit:** Atmospheric air is forced into the system, preheated by an air preheater, and fed into the boiler for combustion. The hot flue gases produced from combustion pass through the superheater, economiser, and air preheater to transfer maximum heat before being exhausted into the atmosphere through the chimney via an Electrostatic Precipitator (ESP).

3. **Feed Water and Steam Circuit:** Water in the boiler is heated to form steam. The steam passes through a superheater to become dry and then enters the turbine, where it expands to do mechanical work. The exhaust steam from the turbine is condensed back to water in the condenser. This condensate is pumped back to the boiler through an economiser by the boiler feed pump.

4. **Cooling Water Circuit:** Cold water is circulated through the condenser to absorb heat and condense the exhaust steam. The warm water leaving the condenser is cooled in a cooling tower or discharged to a river/lake, and the cooled water is recirculated.

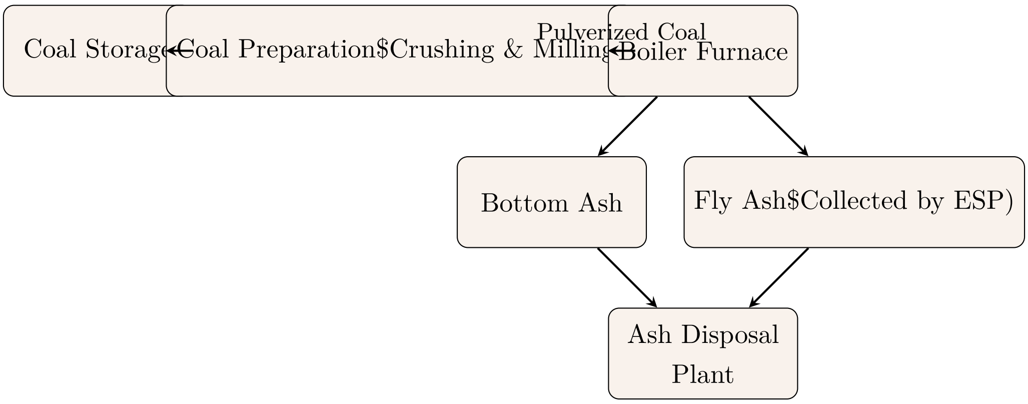
- **Question 1(c) OR [7 marks]**
  State different cycles of Thermal power station and explain any one cycle with neat sketch.

A thermal power station consists of four major interrelated cycles (or circuits):

1. Coal and Ash circuit

2. Air and Gas circuit
3. Feed water and Steam circuit
4. Cooling water circuit

Explanation of Coal and Ash Circuit: The primary function of this circuit is to feed fuel to the boiler and remove the residue (ash) after combustion.

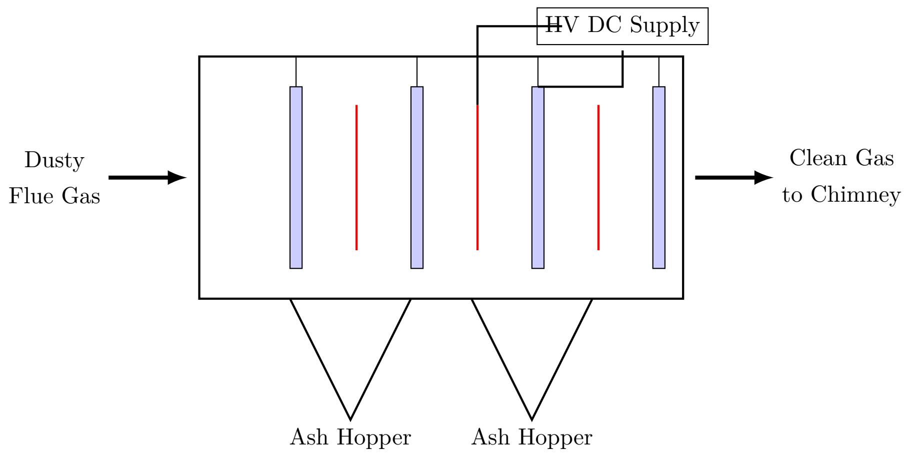


- **Coal Delivery and Storage:** Coal received at the power plant via trains or ships is unloaded and stored in the coal storage yard.
- **Coal Preparation:** The coal is transported to the coal handling plant, where it is passed through crushers to break it into smaller pieces. It is then fed to pulverisers (mills) where it is ground into a fine powder. Pulverisation increases the surface area for efficient and complete combustion.
- **Combustion:** The pulverised coal is blown into the boiler furnace where it mixes with preheated air and burns to produce intense heat.
- **Ash Handling:** The burning of coal results in two types of ash:
  - **Bottom Ash:** Heavier ash particles that fall to the bottom of the furnace.
  - **Fly Ash:** Lighter ash particles that are carried away with the flue gases.
- **Ash Disposal:** Fly ash is collected from the flue gases by electrostatic precipitators (ESPs). Both bottom ash and fly ash are collected in hoppers and transported to the ash disposal yard or sold for cement manufacturing.

(a) **Draw diagram of ESP for Thermal power plant.**

Answer:

An Electrostatic Precipitator (ESP) is an emission control unit used in thermal power plants to remove fine particulate matter, such as dust and fly ash, from the flowing exhaust flue gas before it is released into the atmosphere through the chimney.



Electrostatic Precipitator (ESP)

(b) **State the advantages & disadvantages of Thermal power station.**

Answer:

Advantages of Thermal Power Station:

- The fuel (coal) is relatively cheap and easily available.
- Initial cost is less compared to other generating stations like hydro or nuclear.
- It requires less space compared to a hydro power station.
- It can be installed at any location, not necessarily near the coal mine, as fuel can be transported.
- The generation cost is less compared to a diesel power station.

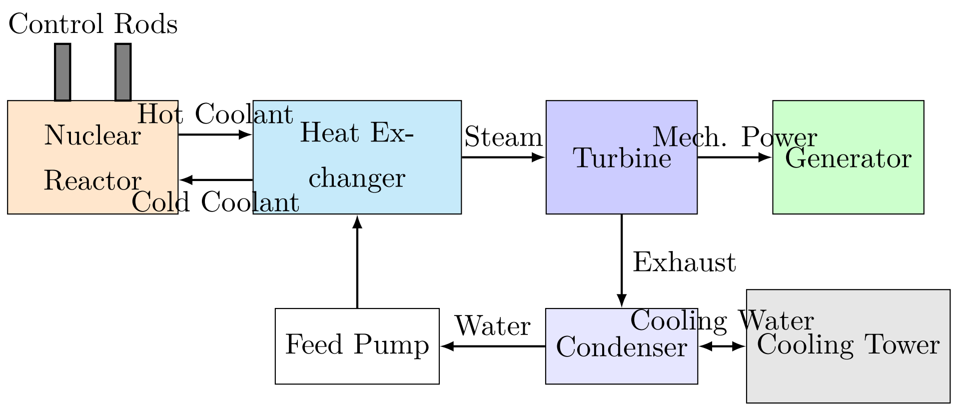
Disadvantages of Thermal Power Station:

- High running and maintenance costs due to continuous fuel consumption.
- It pollutes the atmosphere by producing a large amount of smoke, fly ash, and toxic gases.
- Requires a massive quantity of water for the condenser and cooling purposes.
- Overall efficiency is quite low (around 30% to 40%) because a large amount of heat is lost in the condenser and exhaust gases.
- Transportation of fuel (coal) and disposal of ash are major logistical challenges.

(c) **Draw & explain line diagram of Nuclear power station.**

Answer:

A nuclear power station generates electrical energy from the massive amount of heat released during the nuclear fission of radioactive elements like Uranium ($U - 235$).



Main Components of Nuclear Power Station:

(a) **Nuclear Reactor:** It is the heart of the plant where the nuclear fission chain reaction takes place, releasing a huge amount of heat energy. It contains fuel rods (Uranium), control rods (Cadmium or Boron to control the reaction rate), and a moderator (Graphite or Heavy water to slow down neutrons).

(b) **Heat Exchanger (Steam Generator):** The primary coolant (like liquid sodium or pressurized water) carries the heat from the reactor to the heat exchanger. Here, the heat is transferred to water, converting it into high-pressure steam.

(c) **Steam Turbine:** The high-pressure steam from the heat exchanger is directed onto the turbine blades. The steam expands and rotates the turbine, converting heat energy into mechanical energy.

(d) **Alternator (Generator):** The turbine is coupled to the alternator. As the turbine rotates, the alternator converts the mechanical energy into electrical energy.

(e) **Condenser:** The exhaust steam from the turbine enters the condenser, where it is cooled by cold water from a cooling tower and condenses back into water. This feed water is pumped back to the heat exchanger by a feed pump, completing the cycle.

OR

(a) **Explain Thermal Efficiency and Overall Efficiency for Thermal power station.**

Answer:

Thermal Efficiency ($\eta_{thermal}$)

It is defined as the ratio of the heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of the combustion of coal.

$$\eta_{thermal} = \frac{\text{Heat equivalent of mechanical energy at turbine shaft}}{\text{Heat of combustion of coal}}$$

The thermal efficiency of a modern steam power station is generally about 30% to 40%. Most of the heat is lost in the condenser and exhaust gases.

Overall Efficiency ($\eta_{overall}$)

It is defined as the ratio of the heat equivalent of the electrical output to the heat of the combustion of coal.

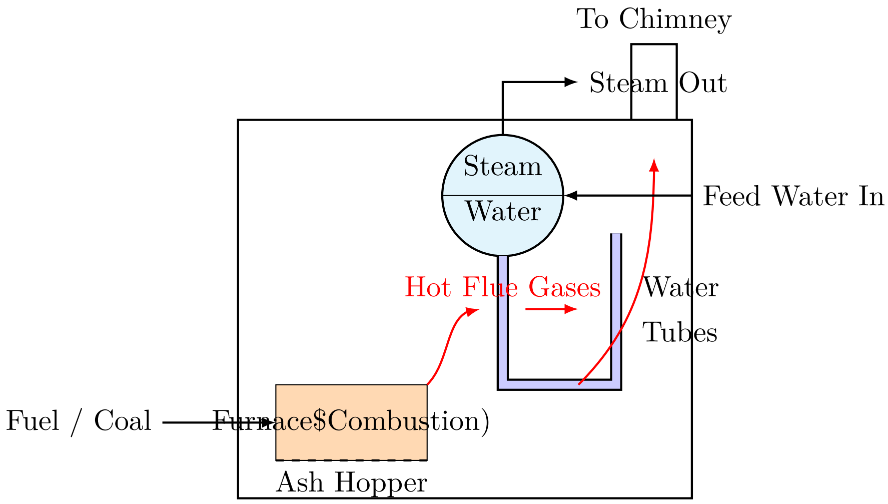
$$\eta_{overall} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat of combustion of coal}}$$

The overall efficiency is always less than the thermal efficiency because it also accounts for the alternator losses. It can also be expressed as: $\eta_{overall} = \eta_{thermal} \times \eta_{electrical}$

(b) **Explain Boiler with diagram.**

Answer:

A boiler (or steam generator) is a closed vessel in which water is heated and converted into high-pressure and high-temperature steam by burning fuel (like coal, oil, or gas) in a furnace. The steam generated is then used to drive a steam turbine.



Working and Components:

- **Furnace:** The combustion chamber where the fuel (coal) is burnt on a grate. The burning fuel produces hot flue gases.
- **Water Drum and Tubes:** In a water-tube boiler, water circulates inside the tubes. The hot flue gases pass over these tubes and transfer their heat to the water, converting it into steam. The steam collects in the upper part of the boiler drum.
- **Ash Pit:** The ash left after the combustion of coal falls into the ash pit, from where it is periodically removed.
- **Chimney:** The exhaust flue gases, after passing through the boiler and transferring their heat, are released into the atmosphere through a tall chimney to disperse pollutants safely.

(c) **Explain energy conversion in Hydro power station and state advantages & disadvantages of Hydro power station.**

Answer:

Energy Conversion in Hydro Power Station: A hydro power station generates electricity by utilizing the potential energy of water stored at a high head in a reservoir. The energy conversion takes place in the following steps:

(a) **Potential Energy:** Water stored in the dam at a certain height possesses potential energy.

(b) **Kinetic Energy:** As water flows down through the penstock (large pipe), its potential energy is converted into kinetic energy due to its high velocity.

(c) **Mechanical Energy:** This high-velocity water strikes the blades of the water turbine, causing the turbine runner to rotate, converting kinetic energy into mechanical energy.

(d) **Electrical Energy:** The turbine is mechanically coupled to an alternator. As the turbine rotates, the alternator converts mechanical energy into electrical energy.

Advantages of Hydro Power Station:

- No fuel is required since water is the source of energy, making the running cost very low.
- It is a clean source of energy and does not cause environmental pollution.
- The equipment is robust and has a much longer life compared to thermal power stations.
- Very few operating staff are required, and the maintenance cost is low.
- It can be started up and synchronized to the grid very quickly.
- Overall efficiency is high (around 80% to 90%).

Disadvantages of Hydro Power Station:

- Extremely high initial capital cost due to the construction of a massive dam and civil structures.
- Depends heavily on natural rainfall and water availability, which may decrease during dry seasons.
- Usually located in hilly, remote areas, requiring long and expensive transmission lines to bring power to load centers.
- Takes a very long time (long gestation period) for construction and commissioning.
- Requires a large area of land, which often leads to the displacement of local communities and ecological disturbances.

(a) **Give functions of Forebay, Penstock & Dam** **[3]**

- **Forebay:** A forebay is a temporary water storage reservoir located at the end of the headrace and just before the penstock. Its primary function is to act as a regulating reservoir by temporarily storing water to meet the sudden increased demand by the turbine, and absorbing excess water when the turbine load suddenly decreases.
- **Penstock:** A penstock is a large conduit or pipe, usually made of steel or reinforced concrete, that carries water under high pressure from the forebay or surge tank directly to the hydraulic turbine.
- **Dam:** A dam is a massive barrier constructed across a river or stream. Its main functions are to store a large quantity of water (creating a reservoir) for continuous power generation throughout the year and to increase the hydraulic head (potential energy) of the water.

(b) **Explain stand alone PV System.** **[4]**

A stand-alone Photovoltaic (PV) system is an off-grid solar power system that operates independently of the main utility grid. It is primarily designed to supply electricity to a local load, making it highly suitable for remote areas where extending the grid is unfeasible.

Major Components of a Stand-alone PV System:

(a) **PV Array:** Consists of interconnected solar panels that convert sunlight (solar irradiance) directly into DC electricity.

(b) **Charge Controller:** Regulates the voltage and current flowing from the PV array to the battery bank. It protects the battery from being overcharged by the panels and deep-discharged by the loads.

(c) **Battery Bank:** Stores the electrical energy generated during the day so it can be used during the night or on cloudy days, ensuring a continuous power supply.

(d) **Inverter:** Converts the DC electricity stored in the batteries into AC electricity, which is required by most standard household appliances.

(e) **Loads:** The electrical devices and appliances (DC or AC) that consume the power.

(c) **Explain major elements of nuclear reactor with diagram.** **[7]**

A nuclear reactor is a device used to initiate and control a self-sustained nuclear chain reaction. The major elements of a nuclear reactor are:

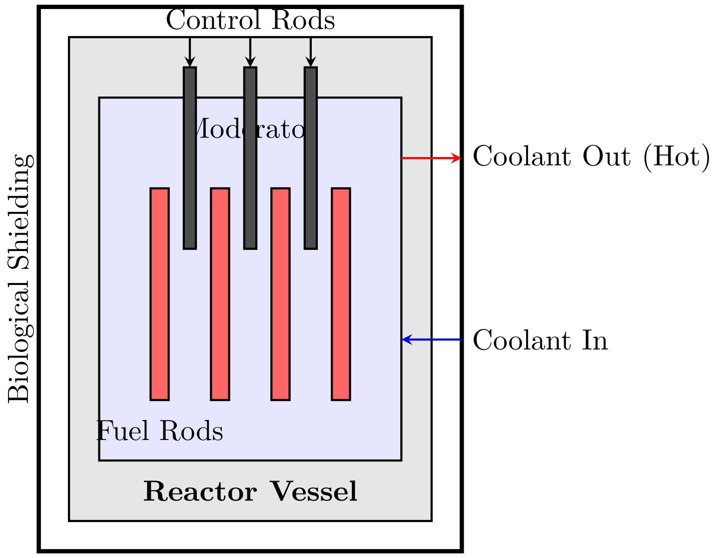


Figure 6: Major Elements of a Nuclear Reactor

(a) **Nuclear Fuel:** The fuel consists of fissionable material, commonly Uranium-235 (^{235}U), which undergoes nuclear fission to release tremendous heat. It is usually fabricated into small cylindrical pellets and packed into fuel rods.

(b) **Moderator:** During fission, fast-moving neutrons are emitted. The moderator is used to slow down these fast neutrons to thermal speeds so they can cause further fissions efficiently. Graphite, heavy water (D_2O), and ordinary water are common moderators.

(c) **Control Rods:** These are made of strong neutron-absorbing materials like Boron or Cadmium. By inserting or withdrawing these rods into the reactor core, the rate of the chain reaction can be controlled or stopped entirely.

(d) **Coolant:** A fluid (such as water, heavy water, liquid sodium, or gas like CO_2) circulated through the reactor core to absorb the heat generated by fission. It transfers this heat to a heat exchanger (steam generator) to produce steam.

(e) **Reflector:** A layer surrounding the reactor core that bounces escaping neutrons back into the core. This improves neutron economy and reduces the critical mass of fuel required.

(f) **Shielding:** It protects personnel and the environment from harmful radiation (gamma rays and fast neutrons). It typically consists of an inner thermal shield (steel) to absorb heat and an outer biological shield (thick concrete).

(g) **Reactor Vessel:** A robust, pressure-resistant steel vessel that encloses the reactor core, moderator, reflector, and coolant, withstanding the high internal pressures and temperatures.

OR

(a) **Explain Nuclear fission process.** **[3]**

Nuclear fission is a process in which the nucleus of a heavy, unstable atom (such as Uranium-235 or Plutonium-239) splits into two lighter nuclei (fission fragments) when bombarded by a slow-moving thermal neutron.

This splitting process is accompanied by the release of a massive amount of energy (primarily in the form of heat) and two or three additional fast neutrons.

Nuclear Fission Reaction

The typical fission equation for Uranium-235 is: ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\,\mathrm{n} \rightarrow {}^{236}_{92}\,\mathrm{U} \rightarrow {}^{141}_{56}\,\mathrm{Ba} + {}^{92}_{36}\,\mathrm{Kr} + 3\ {}^{1}_{0}\mathrm{n} + \mathrm{Energy}$

The newly released neutrons can then strike other nearby ${}^{235}\mathrm{U}$ nuclei, causing them to split and release even more neutrons and energy. This creates a self-sustaining **chain reaction**, which is the fundamental principle behind nuclear power generation.

(b) **Explain variable speed variable frequency schemes for wind power generation.** **[4]**

In variable speed wind power generation, the turbine rotor is allowed to operate at varying rotational speeds depending on the changing wind speed. This is essential to extract the maximum aerodynamic energy (Maximum Power Point Tracking) from the wind.

However, as the turbine speed changes, the frequency and voltage of the AC power generated by the electrical generator also vary continuously (variable frequency). Since the electrical utility grid strictly requires a constant frequency (e.g., 50 Hz) and stable voltage, this generated power cannot be directly fed to the grid.

The Scheme: To resolve this, a power electronic conversion system is used:

(a) **Rectification (AC to DC):** The variable voltage, variable frequency AC power from the generator is first passed through a rectifier to convert it into DC power.

(b) **DC Link:** The DC power passes through a DC link containing a capacitor, which smooths out voltage ripples and stabilizes the DC voltage.

(c) **Inversion (DC to AC):** Finally, an inverter converts this smoothed DC power back into AC power with a constant grid frequency (50 Hz) and matching voltage, which is safely injected into the grid.

This scheme reduces mechanical stress on the turbine and significantly improves the overall energy capture efficiency.

(c) **State different names of turbine used in Hydro power station and explain any one.** **[7]**

Different names of turbines used in Hydro power stations:

- Pelton Wheel Turbine (Impulse Turbine)
- Francis Turbine (Reaction Turbine)
- Kaplan Turbine (Reaction Turbine)
- Propeller Turbine (Reaction Turbine)

Explanation of Pelton Wheel Turbine:

The Pelton wheel is an **impulse turbine** typically used for high head (above 250 m) and low discharge hydropower plants.

Construction:

- **Runner and Buckets:** It consists of a circular disc known as the runner, mounted on a horizontal shaft. Along the periphery of the runner, a series of specially designed double-hemispherical cup-shaped buckets are attached.
- **Nozzle and Spear:** A nozzle is fitted at the end of the penstock, which directs the water jet tangentially onto the runner. A spear valve inside the nozzle regulates the amount of water flowing out.
- **Casing:** A casing is provided to prevent water from splashing and to direct the discharged water to the tailrace. It does not hold any pressure.

Working Principle:

(a) Water from the penstock enters the nozzle, where its entire pressure energy is converted into kinetic energy, emerging as a high-speed water jet.

(b) This high-velocity jet strikes the buckets tangentially. The splitter ridge inside the double-hemispherical bucket divides the jet into two equal halves, deflecting them backwards by approximately 160° to 165°.

(c) This change in momentum creates a massive impulsive force that pushes the buckets, causing the runner to rotate at high speed.

(d) The runner's shaft is coupled to an alternator, generating electricity. During the entire process, the water pressure remains atmospheric.

- **Question 4(a) [3 marks]**
- State advantages solar power plant.

Advantages of Solar Power Plant

The key advantages of a solar power plant include:

1. **Renewable and Sustainable:** Solar energy is an inexhaustible and renewable source of energy.
2. **Environmentally Friendly:** It generates clean power without emitting greenhouse gases or air pollutants, helping to reduce the carbon footprint.

3. **Low Maintenance Cost:** Solar power systems have no moving parts (except for some tracking systems), which minimizes wear and tear and results in very low maintenance costs.
4. **Reduction in Electricity Bills:** Generating power locally can offset consumption from the electrical grid, leading to significant savings on utility bills.
5. **Silent Operation:** Unlike conventional generators or turbines, solar panels produce electricity silently, avoiding noise pollution.
6. **Versatile Installation:** Can be installed in remote off-grid areas or integrated into buildings (rooftops).

- **Question 4(b) [4 marks]**
- State & explain various equipments used in Diesel power station.

Equipments Used in Diesel Power Station

A diesel power station uses a diesel engine as the prime mover for generating electrical energy. The main equipments include:

1. **Diesel Engine:** The primary component that burns diesel fuel to produce mechanical rotational energy.
2. **Alternator (Generator):** Coupled to the engine shaft, it converts the mechanical energy from the engine into electrical energy.
3. **Fuel Supply System:** Includes storage tanks, fuel pumps, strainers/filters, and a day tank. It ensures a continuous and clean supply of diesel fuel to the engine.
4. **Air Intake System:** Supplies clean and fresh air required for the combustion of fuel. It is equipped with air filters to remove dust and suspended particles.
5. **Exhaust System:** Safely discharges the hot exhaust gases from the engine to the atmosphere. It usually includes a silencer to reduce the noise caused by the engine exhaust.
6. **Cooling System:** Dissipates the immense heat generated during combustion to prevent engine overheating. It typically consists of a water pump, cooling jackets, and a radiator or cooling tower.
7. **Lubricating System:** Includes an oil pump, oil filter, and oil cooler. It circulates lubricating oil to the moving parts of the engine to reduce friction, wear, and tear.
8. **Starting System:** Provides the initial rotational force required to start the diesel engine. This is usually done using compressed air or an electric starter powered by a 12V or 24V battery.

- **Question 4(c) [7 marks]**
- Explain construction and working of Solar PV plant.

Construction and Working of Solar PV Plant

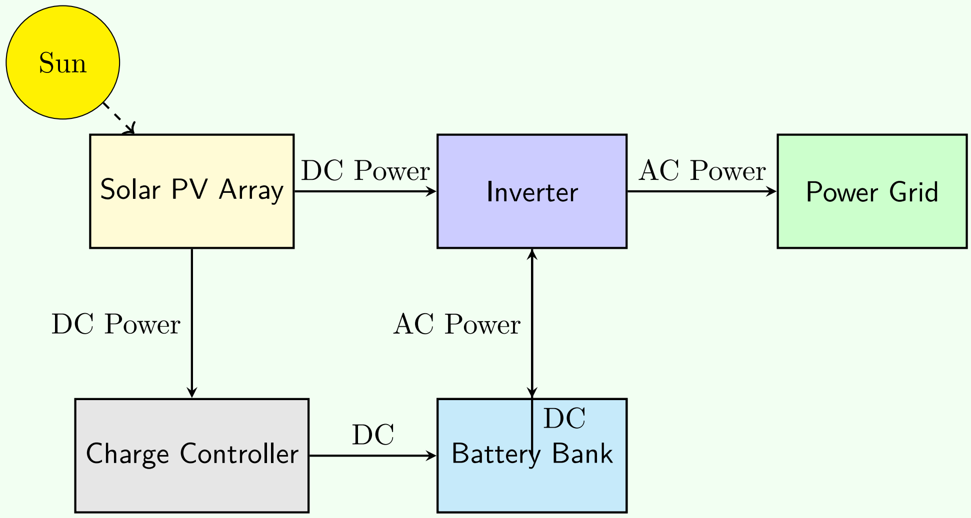
Construction: A Solar Photovoltaic (PV) plant consists of several key components that work together to convert sunlight into usable electricity:

1. **Solar PV Arrays:** Composed of multiple solar panels connected in series and parallel combinations. These panels are made of semiconductor materials (like silicon) and directly convert sunlight into DC electricity.
2. **Inverter:** A crucial electronic device that converts the variable Direct Current (DC) output from the solar panels into Alternating Current (AC) electricity, which is the standard form used by the grid and most home appliances.
3. **Charge Controller:** In systems that include batteries, a charge controller is used to regulate the voltage and current coming from the solar panels to prevent the batteries from overcharging and discharging deeply.
4. **Battery Bank (Optional):** Stores the electrical energy generated during the day for use during the night or periods of low sunlight (cloudy days).
5. **Balance of System (BoS):** Includes mounting structures to orient the panels at the optimal angle, wiring, switches, and a step-up transformer for grid-tied plants to transmit power to the electrical grid.

Working Principle:

- The fundamental working principle is based on the **photovoltaic effect**. When sunlight (which consists of tiny packets of energy called photons) strikes the semiconductor material of the solar cells, they absorb the energy.
- This absorbed energy knocks electrons loose from their atoms. The built-in electric field of the solar cell forces these free electrons to flow in a specific direction, creating a Direct Current (DC).
- The DC electricity generated by the solar array is collected and sent to the inverter.
- The inverter converts this DC electricity into Alternating Current (AC) electricity with the required voltage and frequency (230V, 50Hz).
- The AC power can then be used directly to power local electrical loads. In a grid-connected system, any excess power generated is fed into the main utility grid, whereas in a standalone system, it is stored in the battery bank.

Block Diagram:



- **Question 4(a) OR [3 marks]**
- State advantages of wind power plant.

Advantages of Wind Power Plant

The key advantages of a wind power plant are:

1. **Clean and Renewable Source:** Wind energy is a clean fuel source. It does not pollute the air like power plants that rely on combustion of fossil fuels, and it doesn't produce greenhouse gases.
2. **Cost-Effective and Free Fuel:** The fuel (wind) is absolutely free. Once the wind turbine is built, the operating costs are nearly zero, making it cost-effective in the long run.
3. **Space Efficiency (Multi-use Land):** Wind turbines can be built on existing farms or ranches. The footprint of the turbine itself is small, allowing the land below to still be used for farming or cattle grazing.
4. **Ideal for Remote Areas:** Wind power is highly suitable for providing electricity to remote or off-grid locations, especially in coastal or hilly areas where grid connectivity is difficult.

- **Question 4(b) OR [4 marks]**
- Explain Thermo-Chemical based power plant.

Thermo-Chemical Based Power Plant

A thermo-chemical based power plant generates electricity by converting biomass (such as agricultural waste, wood chips, and municipal solid waste) into heat or a combustible gas through thermal processes. The two most common types are **Biomass Gasification** and **Biomass Combustion** plants.

1. Biomass Gasification Power Plant:

- **Process:** Solid biomass is heated in a device called a gasifier under a limited supply of oxygen (sub-stoichiometric conditions) at very high temperatures (700°C to 1000°C).
- **Producer Gas Generation:** This thermo-chemical decomposition produces a combustible gas mixture known as **syngas** or **producer gas**, which mainly consists of Carbon Monoxide (CO), Hydrogen (H_2), and

Methane (CH_4).

- **Electricity Generation:** The generated gas is cleaned (to remove tar and dust), cooled, and then fed into an Internal Combustion (IC) engine or a gas turbine. The engine/turbine drives an alternator to produce electricity.

2. Biomass Combustion Power Plant:

- **Process:** In this simpler method, biomass is burned directly in a boiler in the presence of excess air.
- **Electricity Generation:** The heat released during combustion is used to convert water into high-pressure steam. This steam expands in a steam turbine, which drives an alternator to generate electrical power (similar to a conventional coal-fired thermal power plant).

- **Question 4(c) OR [7 marks]**
- Explain Horizontal Axis wind turbine with diagram.

Horizontal Axis Wind Turbine (HAWT)

A Horizontal Axis Wind Turbine (HAWT) is the most common type of wind turbine where the main rotor shaft is arranged horizontally, parallel to the ground.

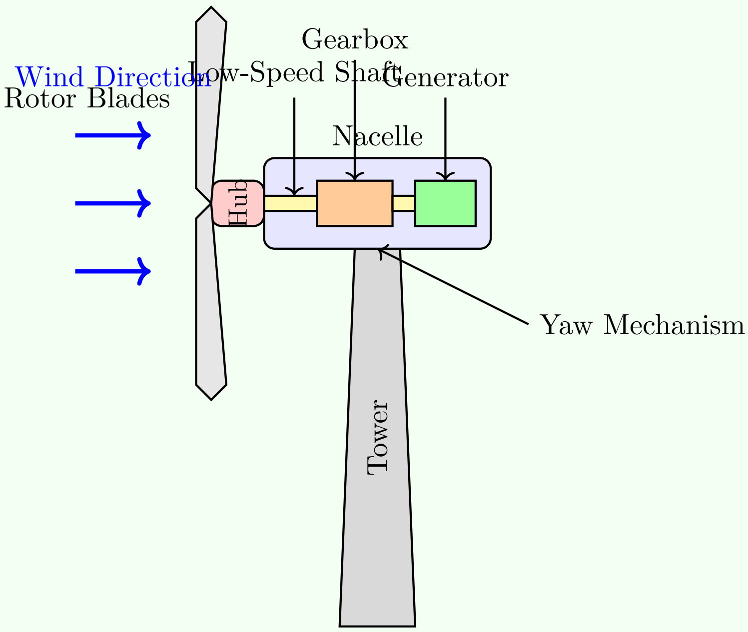
Main Components:

1. **Rotor Blades:** Aerodynamically designed to capture wind energy. They act like airplane wings, creating lift that causes the rotor to turn.
2. **Rotor Hub:** The central component to which the rotor blades are attached. It connects the blades to the low-speed main shaft.
3. **Nacelle:** A large housing positioned at the top of the tower. It protects and contains all the key generating components, including the gearbox, generator, brakes, and control systems.
4. **Low-Speed Shaft:** Connected directly to the rotor hub, it is turned by the blades at a relatively low speed (e.g., 10 to 30 rpm).
5. **Gearbox:** A heavy piece of equipment that connects the low-speed shaft to the high-speed shaft. It increases the rotational speed from the low-speed shaft to a much higher speed (e.g., 1500 rpm) required by the generator to produce electricity efficiently.
6. **Generator:** Converts the rotational mechanical energy from the high-speed shaft into electrical energy.
7. **Yaw Mechanism:** Consists of a yaw drive and a motor. It continuously rotates the nacelle on top of the tower to keep the rotor facing directly into the wind for maximum energy extraction.
8. **Tower:** A tall, strong structure (made of tubular steel or concrete) that supports the nacelle and rotor, elevating them to a height where wind speeds are higher and less turbulent.

Working Principle:

- When wind flows over the aerodynamically shaped rotor blades, it creates uneven air pressure (lift and drag forces), which causes the rotor to spin.
- The rotating blades turn the rotor hub, which in turn rotates the low-speed shaft.
- The low-speed shaft transfers this mechanical rotational energy to the gearbox. The gearbox steps up the rotational speed significantly.
- The fast-spinning high-speed shaft from the gearbox drives the generator, which produces electrical power.
- Simultaneously, an anemometer measures wind speed and direction, and the yaw mechanism automatically rotates the nacelle so that the blades always face the wind.

Diagram:



1] Connected Load:

- The **connected load** is defined as the sum of the continuous ratings of all the electrical equipment, apparatus, and appliances connected to the power supply system.
- It is typically expressed in kilowatts (kW) or megawatts (MW).

2] Load Factor:

- **Load factor** is defined as the ratio of the average load to the maximum demand during a specific period of time (e.g., a day, a month, or a year).
- It indicates how efficiently the electrical energy is being consumed. A higher load factor means the load is more constant.

Load Factor Formula

Load Factor $= \frac{\text{Average Load}}{\text{Maximum Demand}}$

3] Plant Utilization Factor:

- **Plant utilization factor** is the ratio of the maximum demand on the power station to its installed rated capacity.
- It indicates the extent to which the installed capacity of the plant is being utilized.

Plant Utilization Factor Formula

Plant Utilization Factor $= \frac{\text{Maximum Demand}}{\text{Plant Capacity}}$

Winter 2025