

Session 1

Conventional power plants and non-conventional (or alternative) power plants differ in terms of the energy sources they use, their environmental impact, and their level of resource depletion. Here are some key differences between the two types:

Energy Sources:

Conventional Power Plants: Conventional power plants rely on traditional sources of energy, such as fossil fuels (coal, oil, natural gas) or nuclear fuel, for electricity generation.

Non-Conventional Power Plants: Non-conventional power plants utilize renewable energy sources, including solar energy, wind energy, hydropower, geothermal energy, biomass, tidal energy, and wave energy, for electricity generation.

Environmental Impact:

Conventional Power Plants: Conventional power plants, especially those using fossil fuels, often emit significant amounts of greenhouse gases, including carbon dioxide (CO₂), which contribute to climate change. They also release other pollutants such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter, which can cause air pollution and have adverse health effects. Nuclear power plants generate radioactive waste that requires careful disposal.

Non-Conventional Power Plants: Non-conventional power plants have a lower environmental impact compared to conventional ones. They typically produce little to no greenhouse gas emissions during operation, helping to mitigate climate change. However, there may be environmental considerations associated with non-conventional plants, such as the impact on wildlife habitats (e.g., wind farms and solar farms) or changes in river ecosystems (e.g., hydropower).

Resource Depletion:

Conventional Power Plants: Conventional power plants rely on finite resources such as coal, oil, and natural gas, which are non-renewable and will eventually deplete. The extraction, transportation, and combustion of these resources have associated environmental and social challenges, including pollution and habitat destruction.

Non-Conventional Power Plants: Non-conventional power plants utilize renewable energy sources that are naturally replenished and practically inexhaustible, such as sunlight, wind, water, and heat from the Earth's core. While there may be limitations on resource availability in specific locations, overall, renewable energy sources offer a sustainable and long-term solution to energy generation.

Technology and Infrastructure:

Conventional Power Plants: Conventional power plants have well-established technologies and infrastructure for electricity generation, transmission, and distribution. The infrastructure often includes fossil fuel extraction and transportation facilities, as well as complex systems for managing nuclear fuel.

Non-Conventional Power Plants: Non-conventional power plants require specific technologies and infrastructure to harness renewable energy sources efficiently. This may involve solar panels, wind turbines, hydropower dams, geothermal wells, or tidal/wave energy converters. The integration of these technologies into the existing energy infrastructure may require additional investments and grid modifications.

In summary, conventional power plants rely on traditional and finite energy sources, often have higher environmental impacts, and contribute to resource depletion. Non-conventional power plants, on the other hand, utilize renewable energy sources, have lower environmental impacts, and offer long-term sustainability. The transition to non-conventional power plants is essential for mitigating climate change, reducing pollution, and ensuring a secure and sustainable energy future.

Conventional types of generation typically refer to traditional methods of generating electrical power. These methods have been widely used for many years and rely on various energy sources. Here are some common examples of conventional generation types:

- A. **Fossil Fuel-Based Generation:** This involves the combustion of fossil fuels, such as coal, natural gas, or oil, to produce steam that drives a turbine connected to a generator. The steam can be produced by burning the fuel directly or by utilizing the heat generated from the fuel to create steam. Fossil fuel-based generation is widely used but contributes to carbon dioxide emissions and environmental concerns.

A fossil fuel-based generation system typically consists of the following components:

1. **Fuel Source:** The system relies on a fossil fuel, such as coal, natural gas, or oil, as the primary energy source.
2. **Combustion Chamber:** The fuel is burned in a combustion chamber, where it reacts with oxygen to produce high temperatures and combustion gases.
3. **Boiler:** The heat generated from the combustion process is transferred to water, which circulates through a network of pipes in a boiler. The water absorbs the heat and is converted into steam.
4. **Steam Turbine:** The high-pressure steam is directed into a steam turbine, which consists of multiple stages of blades mounted on a shaft. As the steam passes over the blades, its pressure and temperature decrease, causing the blades to rotate.
5. **Generator:** The rotating shaft of the steam turbine is connected to a generator. The rotational motion of the turbine shaft drives the generator, which converts mechanical energy into electrical energy.
6. **Cooling System:** Heat generated during the combustion and steam turbine processes must be dissipated to prevent damage to the system. Cooling systems, such as cooling towers or water bodies, are used to remove excess heat from the system.
7. **Electrical Grid:** The generated electricity is transmitted through power lines and integrated into the electrical grid, where it can be distributed to homes, businesses, and industries.

A fossil fuel-based generation plant typically consists of several key components arranged in a layout optimized for efficient operation and maintenance. While the exact layout may vary depending on factors such as the type of fuel used and plant capacity, here is a generalized description of a typical fossil fuel-based generation plant layout:

Fuel Storage: The plant usually has storage facilities to store the fossil fuel, such as coal or oil, before it is used for power generation. These storage facilities can include coal yards, oil tanks, or gas storage facilities, depending on the fuel type.

Fuel Handling and Preparation: The fuel is transported from the storage facilities to the power plant through conveyors, trucks, or pipelines. It then undergoes various processes to prepare it for combustion, such as crushing and pulverizing coal or filtering and treating oil or gas.

Boiler House: The boiler house is where the combustion of the fuel takes place. It typically contains the boilers, combustion chambers, and other equipment necessary for burning the

fuel and generating heat. In coal-fired power plants, this area may include coal bunkers, pulverizers, and stoker or fluidized bed boilers.

Steam Turbine Hall: This area houses the steam turbines, which convert the heat energy from the combustion process into mechanical energy. It includes multiple stages of steam turbines and associated control systems, valves, and piping. The turbines are connected to the generators, which produce electricity.

Cooling Systems: Fossil fuel-based power plants require cooling systems to dissipate excess heat generated during the combustion and power generation processes. Common cooling systems include cooling towers, which use evaporation to cool the water used in the plant, or once-through cooling systems that use water from nearby rivers or lakes.

Electrical Generation and Transformers: The electrical generation area consists of generators that convert the mechanical energy from the steam turbines into electrical energy. Transformers are used to step up the generated voltage for efficient transmission and distribution through power lines.

Control Room and Control Systems: The plant's control room serves as the central command center where operators monitor and control various plant operations, including fuel supply, combustion, power generation, and safety systems. Advanced control systems and instrumentation are used to ensure the plant operates safely and efficiently.

Environmental Systems: Fossil fuel-based generation plants have environmental control systems to mitigate emissions and comply with regulatory standards. These systems may include pollution control devices such as electrostatic precipitators, scrubbers, or selective catalytic reduction (SCR) systems to reduce particulate matter, sulfur dioxide, nitrogen oxide, and other pollutants.

Administration and Support Facilities: The plant layout includes administrative buildings, maintenance workshops, storage areas, and other facilities necessary for the plant's operation and maintenance staff.

It's important to note that different fossil fuel-based generation systems may have variations in their configurations and specific technologies used. Additionally, newer technologies, such as combined-cycle gas turbines, incorporate additional components to increase efficiency and reduce emissions.

Almost two third of electricity requirement of the world is fulfilled by **thermal power plants** (or **thermal power stations**). In these [power stations](#), steam is produced by burning some fossil fuel (e.g. coal) and then used to run a steam turbine. Thus, a thermal power station may sometimes called as a **Steam Power Station**. After the steam passes through the steam turbine, it is condensed in a condenser and again fed back into the boiler to become steam. This is known as **Ranking cycle**. This article explains **how electricity is generated in thermal power plants**. As majority of thermal power plants use coal as their primary fuel, this article is focused on a **coal fired thermal power plant**. **Typical Layout And Working Of A Thermal Power Plant**. A simplified **layout of a thermal power station** is shown below.

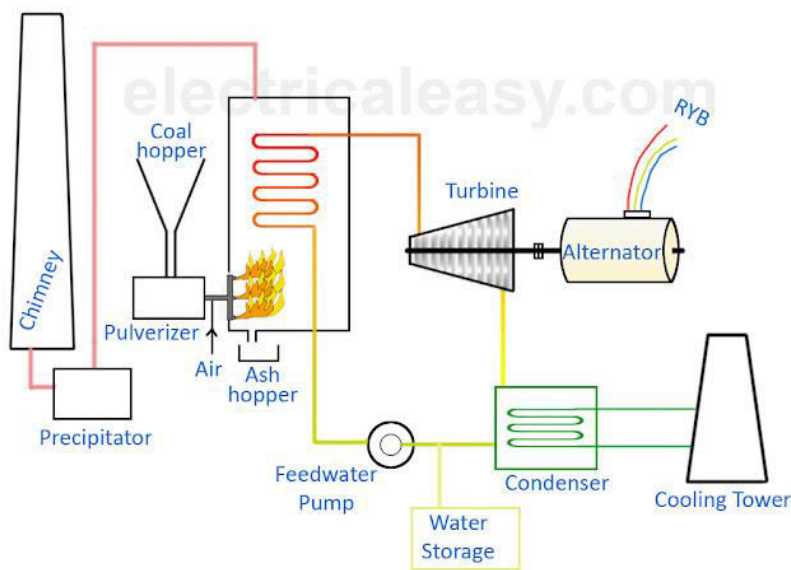


Figure 1 A layout of Thermal Power Plant

Coal: In a coal based thermal power plant, coal is transported from coal mines to the generating station. Generally, bituminous coal or brown coal is used as fuel. The coal is stored in either 'dead storage' or in 'live storage'. Dead storage is generally 40 days backup coal storage which is used when coal supply is unavailable. Live storage is a raw coal bunker in boiler house. The coal is cleaned in a magnetic cleaner to filter out if any iron particles are present which may cause wear and tear in the equipment. The coal from live storage is first crushed in small particles and then taken into pulverizer to make it in powdered form. Fine powdered coal undergoes complete combustion, and thus pulverized coal improves efficiency of the boiler. The ash produced after the combustion of coal is taken out of the boiler furnace and then properly disposed. Periodic removal of ash from the boiler furnace is necessary for the proper combustion.

Boiler: The mixture of pulverized coal and air (usually preheated air) is taken into boiler and then burnt in the combustion zone. On ignition of fuel a large fireball is formed at the center of the boiler and large amount of heat energy is radiated from it. The heat energy is utilized to convert the water into steam at high temperature and pressure. Steel tubes run along the boiler walls in which water is converted in steam. The flue gases from the boiler make their way through superheater, economizer, air preheater and finally get exhausted to the atmosphere from the chimney.

- **Superheater:** The superheater tubes are hanged at the hottest part of the boiler. The saturated steam produced in the boiler tubes is superheated to about 540 °C in the superheater. The superheated high pressure steam is then fed to the steam turbine.
- **Economizer:** An economizer is essentially a feed water heater which heats the water before supplying to the boiler.
- **Air pre-heater:** The primary air fan takes air from the atmosphere and it is then warmed in the air pre-heater. Pre-heated air is injected with coal in the boiler. The advantage of pre-heating the air is that it improves the coal combustion.

Steam turbine: High pressure super heated steam is fed to the steam turbine which causes turbine blades to rotate. Energy in the steam is converted into mechanical energy in the steam turbine which acts as the prime mover. The pressure and temperature of the steam falls to a lower value and it expands in volume as it passes through the turbine. The expanded low pressure steam is exhausted in the condenser.

Condenser: The exhausted steam is condensed in the condenser by means of cold water circulation. Here, the steam loses it's pressure as well as temperature and it is converted back into water. Condensing is essential because, compressing a fluid which is in gaseous state requires a huge amount of energy with respect to the energy required in compressing liquid. Thus, condensing increases efficiency of the cycle.

Alternator: The steam turbine is coupled to an alternator. When the turbine rotates the alternator, electrical energy is generated. This generated electrical voltage is then stepped up with the help of a [transformer](#) and then transmitted where it is to be utilized.

Feed water pump: The condensed water is again fed to the boiler by a feed water pump. Some water may be lost during the cycle, which is suitably supplied from an external water source.

This was the **basic working principle of a thermal power station** and its typical components. A practical thermal plant possess more complicated design and multiple stages of turbine such as High Pressure Turbine (HPT), Intermediate Pressure Turbine (IPT) and Low Pressure Turbine (LPT).

Advantages And Disadvantages Of A Thermal Power Plant

Advantages:

- Less initial cost as compared to other generating stations.
- It requires less land as compared to hydro power plant.
- The fuel (i.e. coal) is cheaper.
- The cost of generation is lesser than that of diesel power plants.

Disadvantages:

- It pollutes the atmosphere due to the production of large amount of smoke. This is one of the causes of global warming.
- The overall efficiency of a thermal power station is low (less than 30%).

Efficiency Of A Thermal Power Station

A huge amount of heat is lost in various stages of the plant. Major part of heat is lost in the condenser. That is why the efficiency of thermal plants is quite low.

1. **Thermal Efficiency:** The ratio of 'heat equivalent of mechanical energy transmitted to the turbine shaft' to the 'heat of coal combustion' is called as thermal efficiency.

$$\text{Thermal Efficiency} = \frac{\text{Heat equivalent of mech. energy transmitted to the turbine shaft}}{\text{Heat produced by coal combustion}}$$

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Thermal efficiency of modern thermal power stations is about 30%. It means, if 100 calories of heat are produced by coal combustion, the mechanical energy equivalent of 30 calories will be available at the turbine shaft.

2. **Overall Efficiency:** The ratio of 'heat equivalent of electrical output' to the 'heat of coal combustion' is called as overall efficiency.

$$\text{Overall Efficiency} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat produced by coal combustion}}$$

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The overall efficiency of a thermal plant is about 29% (slightly less than the thermal efficiency).

Table 1. List of Thermal Power Plant in India

Sr. No.	Power Plant	State	Operator	Capacity
1	Vedanta Jharsuguda Captive Power Plant	Odisha	Vedanta Resources	1,215 MW
2	Sterlite Jharsuguda Power Station	Odisha	Sterlite Energy	2,400 MW
3	KSK Mahanadi Power Project	Chhattisgarh	KSK Energy Ventures Pvt Limited	1,800MW
4	Jindal Tamnar Thermal Power Plant	Chhattisgarh	Jindal Power Limited	3,400 MW
5	Sipat Thermal Power Plant	Chhattisgarh	NTPC	2,980 MW
6	Talcher Super Thermal Power Station	Odisha	NTPC	3,000 MW

Sr. No.	Power Plant	State	Operator	Capacity
7	Satpura Thermal Power Station	Madhya Pradesh	Madhya Pradesh Power Generation Company Limited	1,392.5 MW
8	Rihand Thermal Power Station	Uttar Pradesh	NTPC	3,000 MW
9	Singrauli Super Thermal Power Station	Uttar Pradesh	NTPC	2,050 MW
10	Rosa Thermal Power Plant	Uttar Pradesh	Reliance Power Limited	1,200 MW
11	Vindhyachal Thermal Power Station	Madhya Pradesh	NTPC	4,760 MW
12	JSW Barmer Power Station	Rajasthan	JSW Energy Limited	1,080 MW
13	Kota Super Thermal Power Plant	Rajasthan	Rajasthan Rajya Vidyut Utpadan Nigam Limited	1,240 MW
14	Suratgarh Super Thermal Power Plant	Rajasthan	Rajasthan Rajya Vidyut Utpadan Nigam Limited	2,820 MW

Sr. No.	Power Plant	State	Operator	Capacity
15	Neyveli Thermal Power Station II	Tamil Nadu	Neyveli Lignite Corp. Limited	1,470 MW
16	Vallur Thermal Power Project	Tamil Nadu	NTPC Tamil Nadu Energy	1,500 MW
17	Kahalgaon Super Thermal Power Station	Bihar	NTPC	2,340 MW
18	Dr Narla Tata Rao Thermal Power Station	Andhra pradesh	Andhra Pradesh Power Generation Corporation	1,760 MW
19	NTPC Ramagundam	Telangana	NTPC	2,600 MW
20	Simhadri Super Thermal Power Plant	Andhra Pradesh	NTPC	2,000 MW
21	Essar Salaya Power Plant	Gujarat	Essar Power Limited	1,200 MW
22	Wanakbori Thermal Power Station	Gujarat	Gujarat Urja Vikas Nigam Limited	1,470 MW
23	Raichur Thermal Power Station	Karnataka	Karnataka Power Corporation Limited	1,470 MW

Sr. No.	Power Plant	State	Operator	Capacity
24	JSW Ratnagiri Power Station	Maharashtra	JSW Energy Limited	1,200 MW
25	Udupi Power Plant	Karnataka	Adani Power Limited	1,200 MW
26	Bakreshwar Thermal Power Station	West Bengal	West Bengal Power Development Corporation Limited	1,050 MW
27	Kolaghat Thermal Power Station	West bengal	West Bengal Power Development Corporation Limited	1,260 MW
28	Mejia Thermal Power Station	West Bengal	Damodar Valley Corporation	2,340 MW
31	Indiabulls Amravati Thermal Power Project	Maharashtra	Indiabulls Power Limited	1,350 MW
32	Chandrapur Super Thermal Power Station	Maharashtra	Maharashtra State Power Generation Limited	3,340 MW
33	Indiabulls Nashik Thermal Power Station	Maharashtra	Indiabulls Power Limited	1,350 MW

Sr. No.	Power Plant	State	Operator	Capacity
34	Tiroda Thermal Power Station	Maharashtra	Adani Power Limited	3,300 MW
35	Indira Gandhi Super Thermal Power Project	Haryana	Aravali Power Company Private Limited	1,500 MW
36	Mahatma Gandhi Super Thermal Power Project	Haryana	CLP Power India Limited	1,320 MW
37	Essar Mahan Power Plant	Madhya Pradesh	Essar Power Limited	1,200 MW
38	Rajiv Gandhi TPS Hissar	Haryana	Haryana Power Generation Corporation	1,200 MW
38	Panipat Thermal Power Station	Haryana	Haryana Power Generation Corporation	1,367.8 MW
40	Mundra Thermal Power Station	Gujarat	Adani Power Limited	4,620 MW
41	Mundra Ultra Mega Power Plant	Gujarat	Tata Power Corporation Limited	4,150 MW
42	Barh Super Thermal	Bihar	NTPC	1,320 MW

Sr. No.	Power Plant	State	Operator	Capacity
	Power Station			
43	Kothagudem Thermal Power Station	Telangana	Telangana Power Generation Corporation	1,720 MW
44	Korba Super Thermal Power Plant	Chhattisgarh	NTPC	2,600 MW
45	Sanjay Gandhi TPS Birsinghpur	Madhya Pradesh	Madhya Pradesh Power Generation Company Limited	1,340 MW
46	Koradi Thermal Power Station	Maharashtra	Maharashtra State Power Generation Limited	1,080 MW
47	Mauda Super Thermal Power Station	Maharashtra	NTPC	1,000 MW
48	Khaparkheda Thermal Power Station	Maharashtra	Maharashtra State Power Generation Limited	1,340 MW
49	Bhusawal Thermal Power Station	Maharashtra	Maharashtra State Power Generation Limited	1,420 MW
50	Parli Thermal Power	Maharashtra	Maharashtra State Power	1,130 MW

Sr. No.	Power Plant	State	Operator	Capacity
	Station		Generation Limited	
51	Mettur Thermal Power Station	Tamil Nadu	TANGEDCO	1,440 MW
52	Tuticorin Thermal Power Station	Tamil Nadu	TANGEDCO	1,050 MW
53	North Chennai Thermal Power Station	Tamil Nadu	TANGEDCO	1,830 MW
54	Feroze Gandhi Unchahar Thermal Power Plant	Uttar Pradesh	NTPC	1,050 MW
55	NTPC Dadri	Uttar Pradesh	NTPC	2,637 MW
56	Anpara Thermal Power Station	Uttar Pradesh	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited	1,630 MW
57	Obra Thermal Power Station	Uttar Pradesh	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited	1,382 MW
58	Parichha Thermal Power Station	Uttar Pradesh	Uttar Pradesh Rajya Vidyut Utpadan Nigam Limited	1,140 MW

Sr. No.	Power Plant	State	Operator	Capacity
59	Koderma Thermal Power Station	Jharkhand	Damodar Valley Corporation	1,000 MW
60	Durgapur Steel Thermal Power Station	West Bengal	Damodar Valley Corporation	1,000 MW
61	Guru Gobind Singh Super Thermal Power Plant	Punjab	Punjab State Power Corporation	1,260 MW
62	Maithon Power Plant	Jharkhand	Maithon Power Limited	1,050 MW
63	Trombay Thermal Power Station	Maharashtra	Tata Power	1,580 MW
64	Angul Thermal Power Station	Odisha	Jindal Steel and Power	1,200 MW
65	Shree Singaji Thermal Power Station	Madhya Pradesh	Madhya Pradesh Power Generating Company Limited	2,520 MW
66	Kamalanga Thermal Power Plant	Odisha	GMR Group	1,050 MW

Sr. No.	Power Plant	State	Operator	Capacity
67	Farakka Super Thermal Power Station	West Bengal	NTPC	2,100 MW

B. **Nuclear Power Generation:** Nuclear power plants generate electricity through nuclear fission, where the nucleus of an atom is split, releasing a significant amount of energy. This energy is used to heat water and produce steam, which drives a turbine connected to a generator. Nuclear power is known for its high energy density and low greenhouse gas emissions, but it raises concerns about waste disposal and safety.

Nuclear power generation harnesses the energy released from nuclear reactions to produce electricity. It involves the use of nuclear reactors, which contain radioactive materials that undergo controlled nuclear fission. Here is a general description of the process and components involved in nuclear power generation:

1. **Nuclear Reactor:** The heart of a nuclear power plant is the nuclear reactor. It contains a core made up of fuel rods, typically enriched uranium or plutonium. These fuel rods are arranged in a controlled configuration, and the reactor is designed to sustain a controlled chain reaction.
2. **Control Rods:** Control rods made of materials like boron or cadmium are inserted or withdrawn from the reactor core to regulate the rate of the chain reaction. These control rods absorb neutrons, which helps maintain a stable and controlled level of nuclear fission.
3. **Nuclear Fission:** Within the reactor core, nuclear fission takes place. During fission, the nucleus of a radioactive atom is split into two smaller nuclei, releasing a significant amount of energy in the form of heat. This heat is generated due to the conversion of a small fraction of the fuel mass into energy, as described by Einstein's equation $E=mc^2$.
4. **Coolant:** A coolant, such as water, heavy water (deuterium oxide), or liquid sodium, circulates through the reactor core. It absorbs the heat generated from nuclear fission and carries it away from the core.

5. **Steam Generation:** The heat transferred from the reactor core to the coolant is used to produce steam. The coolant, heated by the nuclear fission process, passes through a heat exchanger where it transfers its thermal energy to a secondary water loop. This secondary loop then turns into steam.
6. **Steam Turbine:** The high-pressure steam drives a turbine, which is connected to a generator. As the steam passes through the turbine, it causes the blades to rotate, converting the steam's thermal energy into mechanical energy.
7. **Generator:** The rotating turbine shaft is connected to a generator, which converts the mechanical energy from the turbine into electrical energy. The generator produces alternating current (AC) electricity.
8. **Condenser and Cooling System:** After passing through the turbine, the steam is condensed back into liquid form in a condenser. This condensation process releases the heat to a cooling system, typically using water from a nearby water source, such as a river or ocean. The cooled water is then recirculated back to the steam generator to repeat the cycle.
9. **Electrical Grid:** The electricity generated in the generator is stepped up to higher voltages using transformers. It is then transmitted through power lines and integrated into the electrical grid for distribution to consumers.
10. **Safety Systems:** Nuclear power plants incorporate multiple safety systems to ensure safe operation and prevent accidents. These systems include emergency shutdown mechanisms, containment structures, and backup cooling systems to manage any unexpected events.

It's worth noting that nuclear power generation is subject to stringent safety regulations and monitoring to prevent the release of radioactive materials and ensure the safe handling and disposal of nuclear waste.

A nuclear power plant typically consists of various components arranged in a layout optimized for safety, efficiency, and maintenance. Here is a general description of the layout of a nuclear power plant:

1. **Reactor Building:** The reactor building houses the nuclear reactor, including the reactor core, control systems, and associated equipment. It is designed to contain and shield radiation from the reactor.

2. **Turbine Hall:** The turbine hall contains the steam turbines, generators, and other equipment necessary for power generation. It is usually separate from the reactor building to minimize the risk of radiation exposure.
3. **Cooling Systems:** Nuclear power plants require efficient cooling systems to manage the heat generated during the power generation process. There are typically two types of cooling systems used:
 - a. **Primary Cooling System:** The primary cooling system circulates water or another coolant through the reactor core to absorb heat. This system includes pumps, heat exchangers, and piping to maintain proper temperature and pressure levels within the reactor.
 - b. **Secondary Cooling System:** The secondary cooling system, also known as the steam cycle, uses water from an external source to convert the heat absorbed by the primary coolant into steam. This steam is then used to drive the turbine and generate electricity.
4. **Fuel Storage and Handling:** Nuclear power plants have facilities for storing and handling nuclear fuel, typically in the form of fuel assemblies. These storage areas are designed to ensure the safe storage of fuel before it is loaded into the reactor.
5. **Control Room:** The control room serves as the nerve center of the power plant. Operators monitor and control various plant operations, including reactor control, power generation, safety systems, and plant parameters. Advanced control systems and instrumentation are used to ensure safe and efficient operation.
6. **Emergency Systems:** Nuclear power plants have multiple safety systems to manage any unexpected events or emergencies. These include emergency shutdown mechanisms, backup power supply systems (such as diesel generators), and containment structures designed to prevent the release of radioactive materials.
7. **Radiation Shielding:** Nuclear power plants incorporate extensive radiation shielding measures to protect workers and the environment from radiation exposure. This includes thick concrete walls, shielding materials, and appropriate design features to minimize radiation levels.
8. **Waste Management Facilities:** Nuclear power plants generate radioactive waste during operation. These plants typically have facilities for the safe storage, treatment, and disposal of

both low-level and high-level radioactive waste produced during the operation and maintenance of the plant.

9. Administrative and Support Facilities: Nuclear power plants include administrative buildings, maintenance workshops, warehouses, and other facilities to support the operation and maintenance staff.

It is important to note that the layout and specific design features of nuclear power plants may vary based on factors such as reactor type, capacity, and safety regulations in different countries. Safety considerations and adherence to strict regulations are paramount in the design and operation of nuclear power plants.

In a **nuclear power plant**, heat energy is generated by a nuclear reaction called as **nuclear fission**. Nuclear fission of heavy elements such as Uranium or Thorium is carried out in a special apparatus called as a **nuclear reactor**. A large amount of heat energy is generated due to nuclear fission. Rest parts of a nuclear power plant are very similar to conventional [thermal power plants](#). It is found that fission of only 1 Kg of Uranium produces as much heat energy as that can be produced by 4,500 tons of high grade coal. This considerably reduces the transportation cost of fuel, which is a major **advantage of nuclear power plants**. Also, there are large deposits of nuclear fuels available all over the world and, hence, nuclear power plants can ensure continued supply of electrical energy for thousands of years. About 10% of the total electricity of the world is generated in nuclear power plants.

How Does A Nuclear Power Plant Work?

Heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission reaction in a nuclear reactor. Due to fission, a large amount of heat energy is produced which is transferred to the reactor coolant. The coolant may be water, gas or a liquid metal. The heated coolant is made to flow through a heat exchanger where water is converted into high-temperature steam. The generated steam is then allowed to drive a steam turbine. The steam, after doing its work, is converted back into the water and recycled to the heat exchanger. The steam turbine is coupled to an alternator which generates electricity. The generated electrical voltage is then stepped up using a transformer for the purpose of long distance transmission.

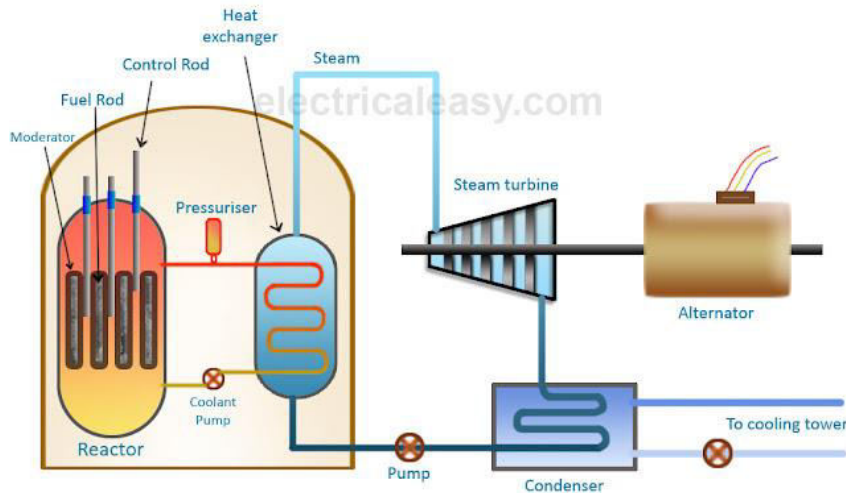


Figure 2 Nuclear Power Plant Layout

Basic Components Of A Nuclear Power Plant

Nuclear Reactor

A nuclear reactor is a special apparatus used to perform nuclear fission. Since the nuclear fission is radioactive, the reactor is covered by a protective shield. Splitting up of nuclei of heavy atoms is called as nuclear fission, during which huge amount of energy is released. Nuclear fission is done by bombarding slow moving neutrons on the nuclei of heavy element. As the nuclei break up, it releases energy as well as more neutrons which further cause fission of neighboring atoms. Hence, it is a chain reaction and it must be controlled, otherwise it may result in explosion. A nuclear reactor consists of fuel rods, control rods and moderator. A fuel rod contains small round fuel pellets (uranium pellets). Control rods are of cadmium which absorb neutrons. They are inserted into reactor and can be moved in or out to control the reaction. The moderator can be graphite rods or the coolant itself. Moderator slows down the neutrons before they bombard on the fuel rods.

Two types of nuclear reactors that are widely used -

1. Pressurised Water Reactor (PWR) -

This type of reactor uses regular water as coolant. The coolant (water) is kept at very high pressure so that it does not boil. The heated water is transferred through heat exchanger where water from secondary coolant loop is converted into steam. Thus the secondary loop is completely free from radioactive stuff. In a PWR, the coolant water itself acts as a moderator. Due to these advantages, pressurised water reactors are most commonly used.

2. **Boiling Water Reactor (BWR) -**

In this type of reactor only one coolant loop is present. The water is allowed to boil in the reactor. The steam is generated as it heads out of the reactor and then flows through the steam turbine. One major disadvantage of a BWR is that, the coolant water comes in direct contact with fuel rods as well as the turbine. So, there is a possibility that radioactive material could be placed on the turbine.

Heat Exchanger

In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

Steam Turbine

Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.

Alternator

The steam turbine rotates the shaft of an alternator thus generating electrical energy. Electrical output of the alternator is the delivered to a step up [transformer](#) to transfer it over distances.

Condenser

The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

- C. **Hydroelectric Power Generation:** Hydroelectric power utilizes the energy of flowing or falling water to generate electricity. Dams are constructed to capture water, which is then released in controlled amounts to turn turbines connected to generators. Hydroelectric power is a renewable energy source and does not emit greenhouse gases, but it can have significant environmental impacts due to the alteration of rivers and ecosystems.

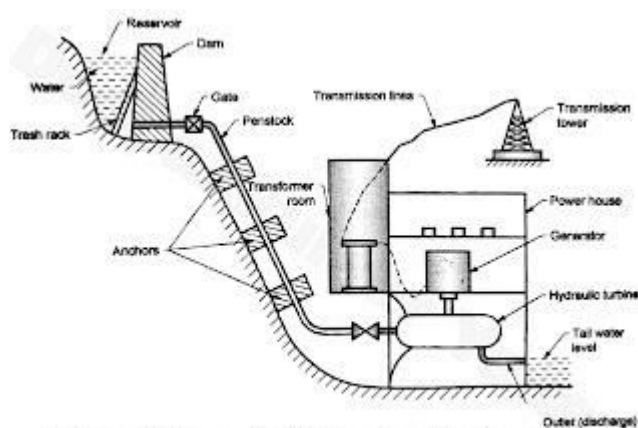
Hydroelectric power generation harnesses the energy of flowing or falling water to produce electricity. It is a renewable and clean energy source that has been widely used for many years. Here is a general description of the process and components involved in hydroelectric power generation:

1. **Dam and Reservoir:** A hydroelectric power plant typically requires the construction of a dam across a river or a water source to create a reservoir. The dam is built to store water and control its flow. The size of the reservoir depends on factors such as the water flow, power demand, and environmental considerations.
2. **Intake Structure:** The intake structure is located at the base of the dam and is designed to control the flow of water into the power plant. It includes gates or valves that can be opened or closed to regulate the amount of water entering the plant.
3. **Penstock:** The penstock is a large pipe or conduit that carries the water from the reservoir to the turbines. It is designed to withstand high pressure and directs the water flow towards the turbines.
4. **Turbines:** The water from the penstock is directed onto the blades of a turbine, causing it to rotate. There are different types of turbines used in hydroelectric power plants, including Francis, Kaplan, and Pelton turbines, depending on the specific water flow and head (the height difference between the water source and the turbine).
5. **Generator:** The rotating shaft of the turbine is connected to a generator. As the turbine spins, it drives the generator, converting the mechanical energy from the rotating turbine into electrical energy. The generator produces alternating current (AC) electricity.
6. **Transformer:** The electricity generated by the generator is stepped up to higher voltages using transformers. This higher voltage electricity reduces transmission losses and makes it suitable for long-distance transmission.
7. **Transmission Lines:** The electricity generated in the power plant is transmitted through high-voltage transmission lines to distribution networks, where it can be distributed to homes, businesses, and industries.

8. **Control Room and Control Systems:** The power plant has a control room where operators monitor and control various aspects of plant operations, including water flow, turbine speed, and electrical output. Advanced control systems and automation are used to optimize power generation and ensure safe and efficient operation.
9. **Environmental Considerations:** Hydroelectric power plants need to consider environmental factors, such as fish passage systems, environmental flow requirements, and habitat preservation, to minimize impacts on the ecosystem and comply with environmental regulations.

It's worth noting that there are variations in hydroelectric power plants, such as run-of-river systems that do not require large reservoirs and pumped storage systems that can store and release water to generate power during peak demand periods. The specific design and layout of a hydroelectric power plant depend on factors such as the site characteristics, available water resources, and power generation requirements.

A schematic layout of hydro-electric power plant is shown in Figure A large amount of water is collected during rainy season in a reservoir behind a dam. In case the rainfall is low in a particular year the low head of the reservoir will not be able to meet the maximum load, therefore, the present trend is to use hydro-electric power plant with steam power plant an interconnected system.



Schematic Layout of Hydroelectric Power Plant

Figure 3 Hydroelectric Power Plant Layout

The main components of the hydro-electric power plant and their functions are as follows :

1. **Reservoir** : A reservoir is provided to store water during rainy season and supplies the same in dry season. The water from the reservoir is used to run the hydraulic turbine.
2. **Dam** : A dam is structure of considerable height built across the river. Its function is to provide working head of water for power plant and to increase the storage capacity of reservoir.
3. **Trash rack** : These are made up of steel bars. Trash rack is provided to prevent entry of debris into the intakes from dam or from the forebays. Any debris into the intake water pipe may damage the turbine runners or choke the nozzles of an impulse turbine.
4. **Gate** : The gate is provided for controlling of flow of water from reservoir to hydraulic turbine through penstock . It is closed when maintenance of system is required.
5. **Forebays** : It is small water reservoir at the end of water passage from the reservoir and before the water is fed to the turbine to the penstock as shown in Figure B.

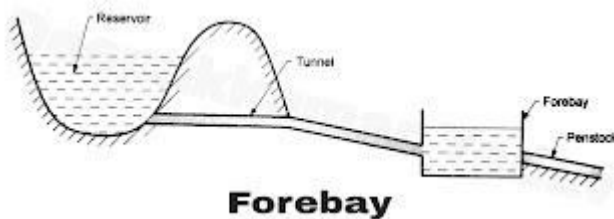


Figure B

It acts as a temporary regulating reservoir. It stores water when the load on the plant reduces and the same water is supplied to the turbine at the time of increasing load in the initial stages. It helps in absorbing the flow variations.

6. Surge tank :

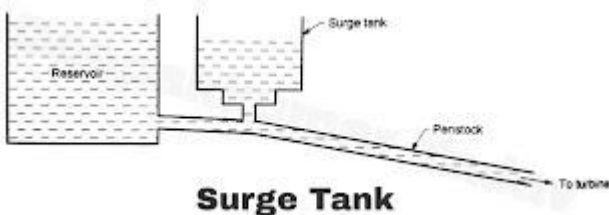


Figure C

In case the load on the turbine suddenly decreases, the gates admitting water to the turbine are suddenly closed due to governor action. As a result it reduces the water flow with sudden increase of pressures in the penstock. This sudden rise of pressure in penstock is called "**Water Hammer**".

On the other hand, due to sudden increased load on the turbine, the gates admitting water to the turbine are suddenly opened. It causes water to rush from penstock into the turbine and it creates a vacuum in the penstock.

Therefore, penstock is subjected to positive pressure (water hammer) due to sudden decrease in load on the turbine and to negative pressure due to sudden increase in load on the turbine.

In order to provide better regulation of water pressure in the system, a surge tank is used which is located near the power house on high ground. When the turbine gates are closed and water flow to the turbine reduces, the water rises into the surge tank. It produces a retarding head with reduced velocity of water in the penstock. As soon as the velocity of water in the penstock is reduced to a value corresponding to the level of the turbine, the level of water in the surge tank starts falling and fluctuates up and down until its motion is damped out by friction.

Similarly, during the increase load on the turbine, additional water flows from the surge tank to the turbine. It produces an accelerating head which increases the velocity of flow of water in the penstock . Therefore, a surge tank helps in establishing the velocity and pressure in the penstock and it reduces the water hammer effect.

7. Waterway and penstock : A waterway is used to carry water from the dam to the power house. It includes canal and penstock (closed pipe) or a tunnel. The penstock are made up of steel or reinforced concrete which are designed to withstand high pressures. Penstock are supported by anchors. Sharp bends in penstocks are avoided in order to reduce the hydraulic losses.

8. Spillway : A spillway is provided to discharge the flood water and to keep the level of water below the designed maximum level in the reservoir . Thus a spillway saves the dam from damage during floods.

9. Power house : A power house consists of hydraulic and electric equipments where the water energy is converted into electrical energy. Usually the power house is located underground whenever possible e.g. as in case of Koyana power house in Maharashtra state.

10. Hydraulic turbines : These are used to convert the kinetic energy of water into mechanical energy.

11. Draft tube : A draft tube is a passage which connects the exit from the turbine runner down to tail race water level. It supplements the action of runner of **the reaction turbine** by utilising the remainder K.E. of the water at discharge end of the runner. Another purpose of the draft tube is to permit the setting of the runner of the reaction turbine wheel at a level above that of water in the tail race under high water and flood conditions of the river.

12. Tail race : A tail race is a water way to lead the water discharged from the turbine to the river.

Operation of hydro-electric power plant :

Water from reservoir flows through penstocks to hydraulic turbine and during the passage its potential energy (water head) is converted into kinetic energy. This high velocity jet of water strikes the hydraulic turbine vanes where its K.E. is converted into mechanical energy.

A generator coupled to hydraulic turbine converts the available mechanical energy into electrical energy. The speed of the turbine and generator depends on the head, specific speed and the power.

The electrical power generated is controlled by the governing mechanism attached to hydraulic turbine which controls the quantity of water to be supplied to the turbine according to the load on the system.

- D. **Wind Power Generation:** Wind turbines convert the kinetic energy of wind into electrical energy. When the wind blows, it turns the blades of a turbine, which is connected to a generator. Wind power is a renewable and clean energy source, but it is dependent on wind availability and requires suitable wind conditions for efficient generation.

Wind power generation harnesses the kinetic energy of the wind to generate electricity. It is a renewable and clean energy source that has seen significant growth in recent years. Here is a general description of the process and components involved in wind power generation:

1. **Wind Turbines:** Wind turbines are the primary components of a wind power generation system. These tall structures consist of three main parts:

a. Rotor Blades: The rotor blades are aerodynamically designed to capture the wind's kinetic energy. They rotate when the wind blows, converting the wind's energy into rotational mechanical energy.

b. Nacelle: The nacelle is located at the top of the tower and houses the components that generate electricity. It contains the gearbox, generator, control systems, and other equipment necessary for power generation.

c. Tower: The tower supports the rotor blades and the nacelle, elevating them to capture stronger winds at higher altitudes. Towers can vary in height depending on the wind resource and the turbine design.

2. Wind Monitoring and Control Systems: Wind power plants incorporate sophisticated monitoring and control systems to optimize power generation and ensure safe operation. These systems include anemometers and wind vanes to measure wind speed and direction, as well as control mechanisms to orient the rotor blades into the wind for optimal efficiency.

3. Generator: The rotation of the rotor blades drives a generator housed within the nacelle. The generator converts the mechanical energy from the rotating blades into electrical energy. Most wind turbines use synchronous generators or asynchronous generators, depending on the specific design and requirements.

4. Transformer: The electricity generated by the generator is stepped up to higher voltages using transformers. This higher voltage electricity reduces transmission losses and makes it suitable for long-distance transmission.

5. Power Collection System: Multiple wind turbines in a wind farm are connected through a power collection system. This system includes underground or overhead cables that collect the electricity from individual turbines and bring it to a central point within the wind farm.

6. Substation: The collected electricity from the wind farm is sent to a substation, where it is further transformed and integrated into the electrical grid. The substation contains transformers that step up the voltage for efficient transmission.

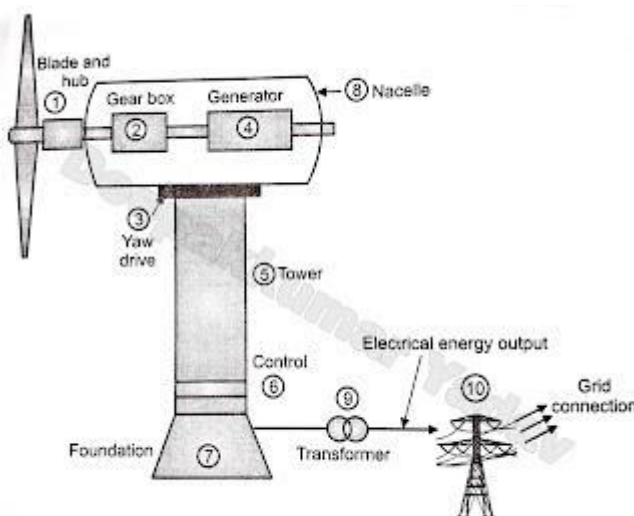
7. Transmission Lines: The electricity from the wind farm is transmitted through high-voltage transmission lines to distribution networks, where it can be distributed to homes, businesses, and industries.

8. Control Room and Monitoring: A control room is typically present in a wind power plant, where operators monitor and control various aspects of the plant's operations, including power output, turbine performance, and maintenance requirements. Advanced monitoring systems provide real-time data on turbine performance, wind conditions, and electrical output.

It's important to note that wind power generation requires suitable wind conditions for efficient operation. Wind farms are often located in areas with consistent and sufficient wind resources, such as coastal areas, open plains, or hilly regions. The specific layout and design of a wind power plant depend on factors such as wind resource assessment, turbine capacity, and site characteristics.

Main components of Gear Wind Power Plant :

1. Blades and hub
 2. Gear box
 3. Yaw drive
 4. Generator
 5. Tower
 6. Control
 7. Foundation
 8. Nacelle
 9. Transformer
 10. Grid connection
- Let us see how these components are assembled.



Geared Wind Power Plant

Figure 4. Wind Power Plant Layout

- This is the old and traditional type of plant requiring more maintenance and complex type of design.
- **Design of blades of turbine hub** is more important. Its design takes into account (1) wind speed, (2) desired output power. Accordingly number of blades, blade orientation, diameter tip speed ratio are designed. Lift-drag characteristics are taken into account.
- **Rotor** : Its blades are strong-durable, light weight and non-corrosive. Composites of reinforced plastic and fibre-glass is used for construction. Rotor design is aerodynamic.
- **Gear box** : It is located in between rotor of blades and the unit of generator. Its design is complicated. Rotor output is amplified by this gear box. It suffers highest stress. Gear box and generator act as a drive-train.
- **Generator** : Variety types of generators are suitable for such type of plant. Turbine rotor rotates the generator which converts rotational energy into electrical energy. Power electronic unit is provided which facilitates to feed power to grid system.

Working of Gear Wind Power Plant :

- Wind blow on the turbine blades of turbine starts its rotor, in turn, it drives the generator which produce electrical energy. (Kinetic energy is converted into mechanical energy which is then converted into electrical energy).
- Gear box helps in increasing the speed upto 1500 rpm.
- Gear box construction is complicated, its consists of many wheels and bearings and requires frequent maintenance.

Advantages and Disadvantages of Gear Wind Power Plant :

Advantages of Gear Wind Power Plant :

1. Light in weight.
2. Provides very high torque to turn.
3. It is cheaper in cost.
4. It is able to provide high speed operation which is very economical for the plant.

Disadvantages of Gear Wind Power Plant :

1. Its design is not so simple but is very complicated.
2. Reliability issues arise.
3. Serious damages may occur if any in case of misalignment.

4. So many moving parts, so maintenance work is critical and frequent which involves more cost.

E. **Solar Power Generation:** Solar energy is captured using photovoltaic (PV) cells, which convert sunlight directly into electricity. Solar power can be harnessed through large-scale solar farms or individual rooftop installations. It is a renewable and environmentally friendly energy source, but its efficiency is dependent on sunlight intensity and availability.

Solar power generation harnesses the energy from sunlight to generate electricity. It is a renewable and clean energy source that has gained significant popularity in recent years. Solar power can be generated through two primary technologies: photovoltaic (PV) systems and solar thermal systems. Here is a general description of the process and components involved in solar power generation:

1. Photovoltaic (PV) Systems:

a. **Solar Panels:** Solar panels, also known as photovoltaic modules, are the main components of PV systems. They consist of multiple solar cells made of semiconductor materials, typically silicon. When sunlight hits the solar cells, it excites the electrons, generating an electric current.

b. **Mounting Structures:** Solar panels are mounted on structures, such as rooftops or ground-mounted systems, to maximize their exposure to sunlight. The mounting structures provide support and allow for optimal placement and orientation of the panels.

c. **Inverters:** The direct current (DC) electricity generated by the solar panels is converted into alternating current (AC) electricity using inverters. Inverters are electronic devices that convert the DC electricity to AC electricity, making it compatible with the electrical grid and suitable for use in homes and businesses.

d. **Electrical Connections and Wiring:** The solar panels are connected in series or parallel configurations to form an array. Wiring and electrical connections are used to interconnect the panels, inverters, and other system components.

e. **Monitoring and Control Systems:** Solar power systems often include monitoring and control systems that provide real-time data on the performance of the panels, electricity

generation, and system health. These systems allow for efficient operation, troubleshooting, and optimization of the solar power generation.

2. Solar Thermal Systems:

a. Solar Collectors: Solar thermal systems use mirrors or reflective surfaces to concentrate sunlight onto a receiver. The receiver absorbs the sunlight and converts it into heat.

b. Heat Transfer Fluid: In solar thermal systems, a heat transfer fluid, such as water or oil, is circulated through the receiver to absorb the heat energy from the concentrated sunlight.

c. Heat Exchanger: The heat transfer fluid transfers the captured heat to a heat exchanger, which transfers the heat to water or another fluid to produce steam or hot water.

d. Steam Turbine and Generator: The steam or hot water produced by the heat exchanger is used to drive a steam turbine, which is connected to a generator. The generator converts the mechanical energy from the turbine into electrical energy.

e. Storage and Backup Systems: Some solar thermal systems include thermal storage systems or backup systems to store excess heat for use during periods of low sunlight or to provide continuous power supply.

3. Electrical Grid Connection: The electricity generated by solar power systems can be used on-site or connected to the electrical grid. Grid-connected systems allow for excess electricity to be fed back into the grid, earning credits or providing power to other consumers when the solar system is generating more electricity than is needed.

4. Control Room and Monitoring: Solar power systems may have control rooms where operators monitor and control various aspects of the system's performance, including electricity generation, system health, and maintenance requirements. Monitoring systems provide real-time data on the performance of the solar panels, inverters, and other system components.

It's important to note that the specific layout and design of solar power systems can vary based on factors such as available sunlight, system size, and application. Solar power can be deployed on rooftops, open spaces, or solar farms, and can be used for residential, commercial, or utility-scale applications.

How Solar Power Works?

Electrical energy can be harvested from solar power by means of either photovoltaics or concentrated solar power systems.

Photovoltaics (PV)

Photovoltaics directly convert **solar energy into electricity**. They work on the principle of the photovoltaic effect. When certain materials are exposed to light, they absorb photons and release free electrons. This phenomenon is called as the photoelectric effect. Photovoltaic effect is a method of producing direct current electricity based on the principle of the photoelectric effect.

Based on the principle of photovoltaic effect, solar cells or photovoltaic cells are made. They convert sunlight into direct current (DC) electricity. But, a single photovoltaic cell does not produce enough amount of electricity. Therefore, a number of photovoltaic cells are mounted on a supporting frame and are electrically connected to each other to form a photovoltaic module or **solar panel**. Commonly available solar panels range from several hundred watts (say 100 watts) up to few kilowatts (ever heard of a 5kW solar panel?). They are available in different sizes and different price ranges. Solar panels or modules are designed to supply electric power at a certain voltage (say 12v), but the current they produce is directly dependent on the incident light. As of now it is clear that photovoltaic modules produce DC electricity. But, for most of the times we require AC power and, hence, **solar power system** consists of an inverter too.

[Also read: [Power Plants or Electricity Generating Stations.](#)]

Photovoltaic Solar Power System

According to the requirement of power, multiple photovoltaic modules are electrically connected together to form a PV array and to achieve more power. There are different types of PV systems according to their implementation.

- PV direct systems: These systems supply the load only when the Sun is shining. There is no storage of power generated and, hence, batteries are absent. An inverter may or may not be used depending on the type of load.
- Off-grid systems: This type of system is commonly used at locations where power from the grid is not available or not reliable. An off-grid solar power system is not connected to any electric grid. It consists solar panel arrays, storage batteries and inverter circuits.

- Grid connected systems: These solar power systems are tied with grids so that the excess required power can be accessed from the grid. They may or may not be backed by batteries.

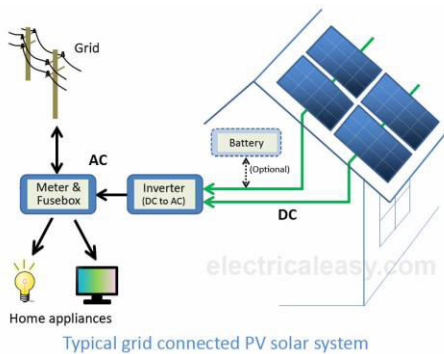
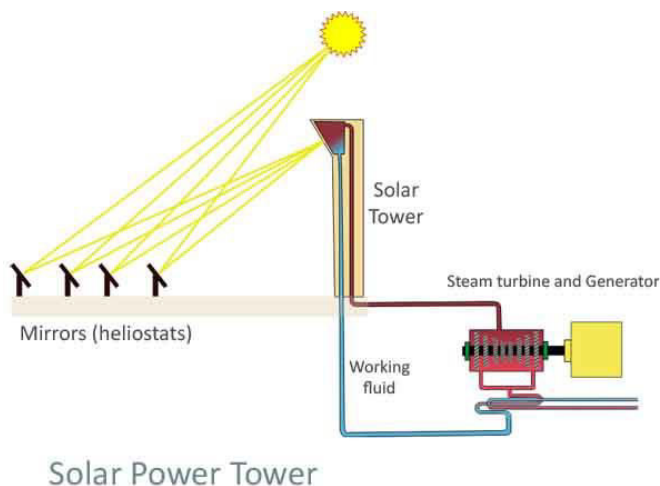


Figure 5 Solar Power Plant Layout

Concentrated Solar Power

As the name suggest, in this type of solar power system, sun rays are concentrated (focused) on a small area by placing mirrors or lenses over a large area. Due to this, a huge amount of heat is generated at the focused area. This heat can be used to heat up the working fluid which can further drive the steam turbine. There are different types of technologies that are based on the concentrated solar power to produce electricity. Some of them are - parabolic trough, Stirling dish, solar power tower etc. The following schematic shows how a solar power tower works.



These conventional generation types have been the backbone of the global electricity generation system for many years. However, there is an increasing shift toward renewable

and sustainable energy sources to reduce greenhouse gas emissions and mitigate the impacts of climate change.