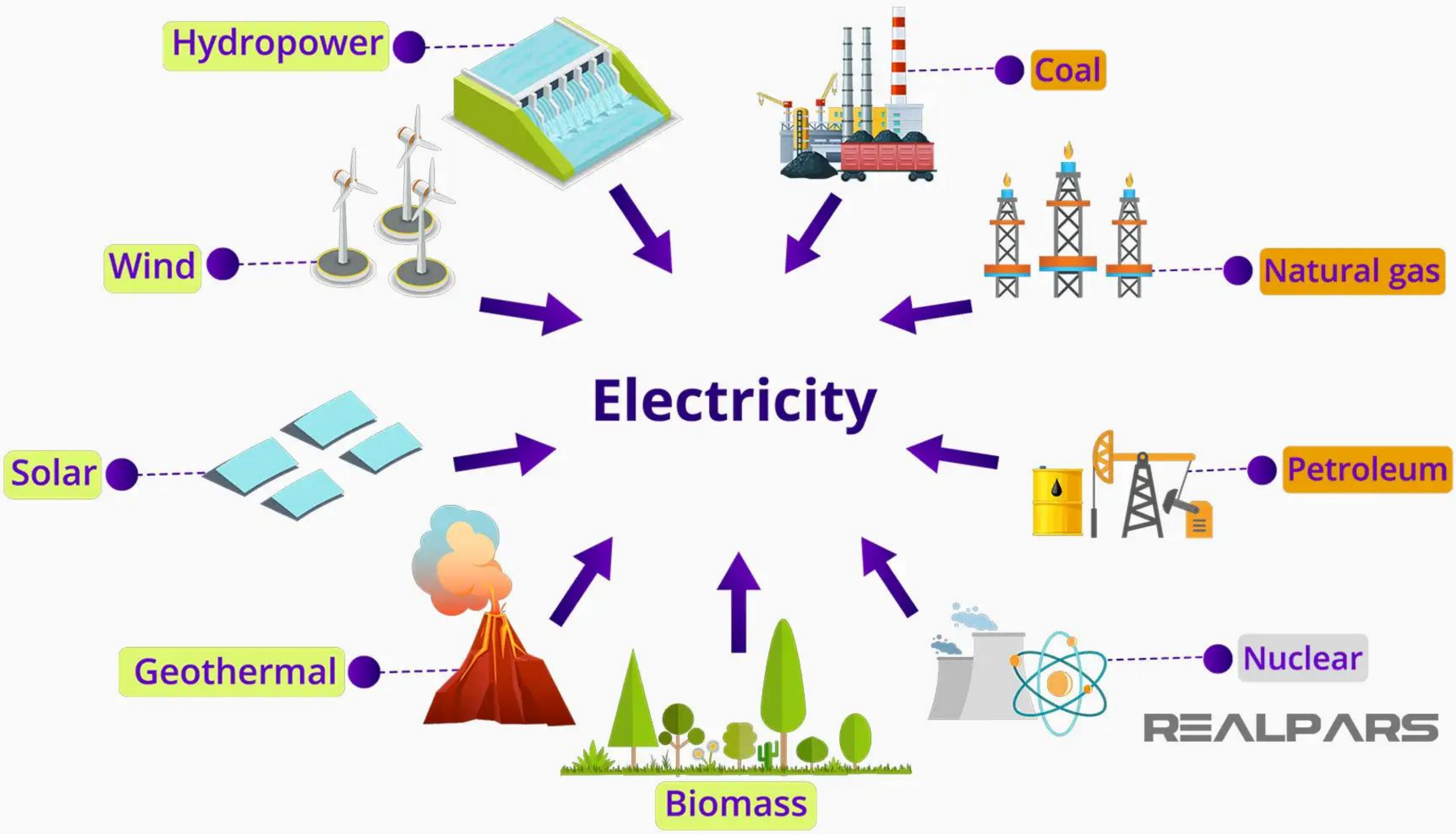

Hydropower
Coal
Wind
Natural gas
Electricity
Solar
Petroleum
Geothermal
Nuclear
REALPARS
Biomass

Structure of Electrical Power System

- Electricity is generated at central power stations and then transferred to loads (i.e, Domestic, Commercial and Industrial) through the transmission and distribution system. A combination of all these systems is collectively known as an Electric Power System.

- A power system is a combination of central generating stations, electric power transmission system, Distribution and utilization system.

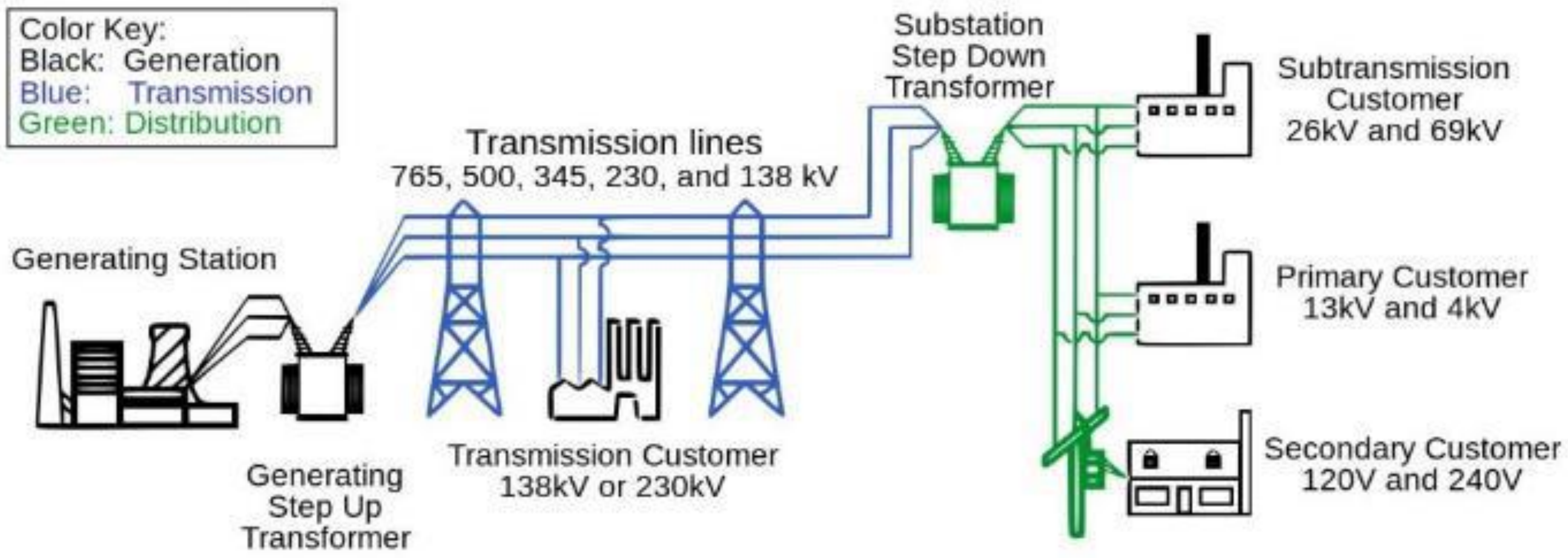


Fig. 1: Basic Structure of an Electric Power System (Energy Supply System)

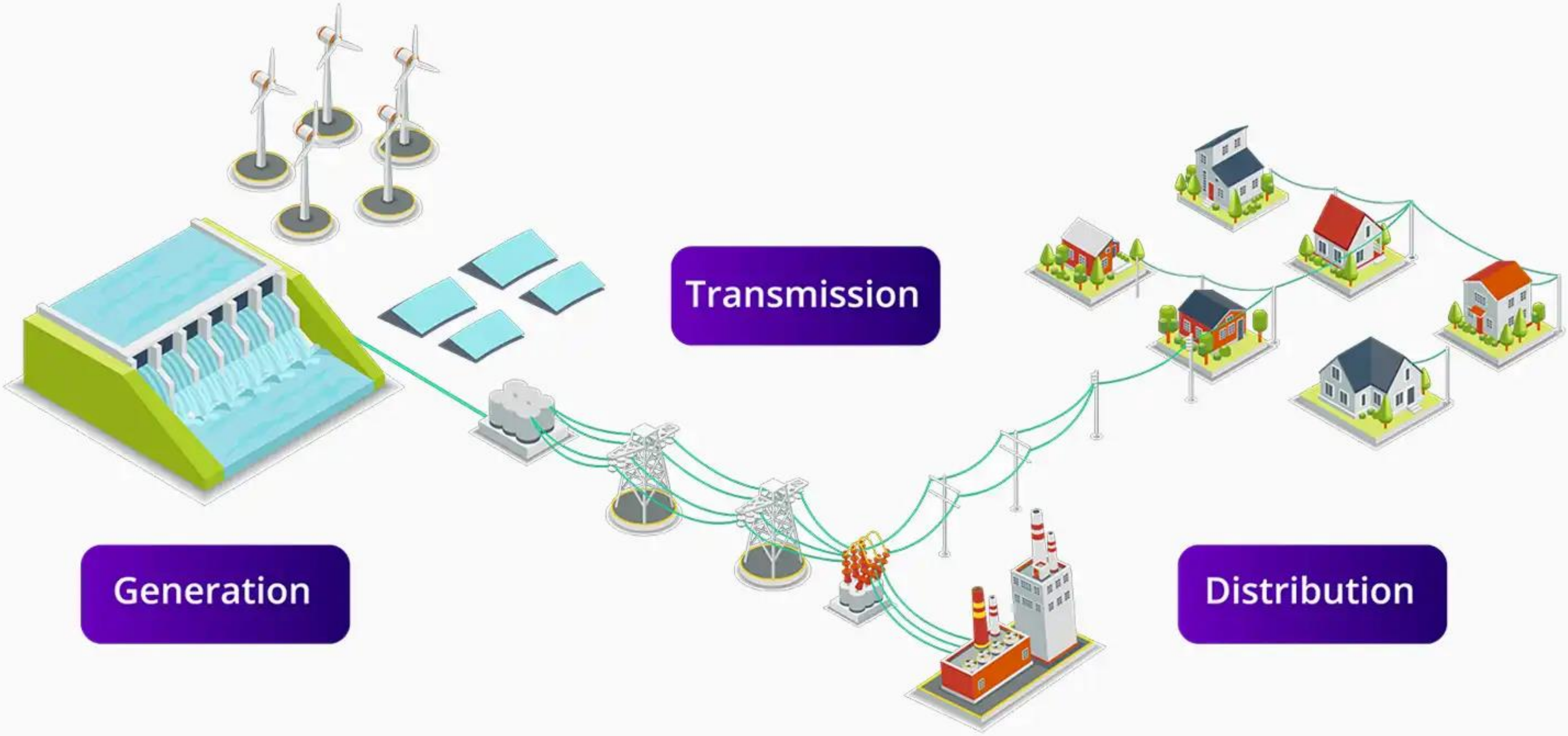
- An electric supply system consists of three principal components *viz*., the power station, the transmission lines and the distribution system.

- Electric power is produced at the power stations which are located at favourable places, generally quite away from the consumers. It is then transmitted over large distances to load centres with the help of conductors known as transmission lines.

- Finally, it is distributed to a large number of small and big consumers through a distribution network, supply system can be broadly classified into (*i*) d.c. or a.c. system (*ii*) overhead or underground system.

- Nowadays, 3-phase, 3-wire AC system is universally adopted for generation and transmission of electric power as an economical proposition. However, distribution of electric power is done by 3-phase, 4-wire AC system.

- The underground system is more expensive than the overhead system. Therefore, the overhead system is mostly adopted for transmission and distribution of electric power.


Transmission
Generation
Distribution

Generation
Demand
Stability

REALPARS

Typical AC Power Supply in a Power System

The large network of conductors between the power station and the consumers can be broadly divided into two parts *viz.,* transmission system and distribution system.

Each part can be further sub-divided into two—primary transmission and secondary transmission and primary distribution and secondary distribution.

It may be noted that it is not necessary that all power schemes include all the stages shown in the figure.

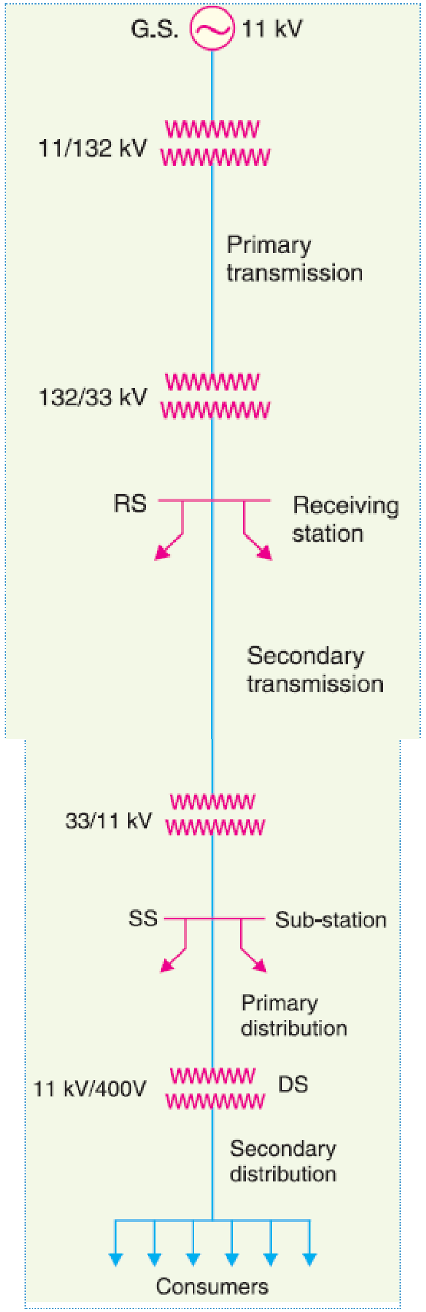


Fig. 2: AC Power Supply in a Power System

Generating Stations

Energy is generated (transformed from one to another) at the generating stations. Generating stations are of different type, for example, thermal, hydel, solar, nuclear power stations. The generated electricity is stepped up through the transformer and then transferred over transmission lines to the load centres.

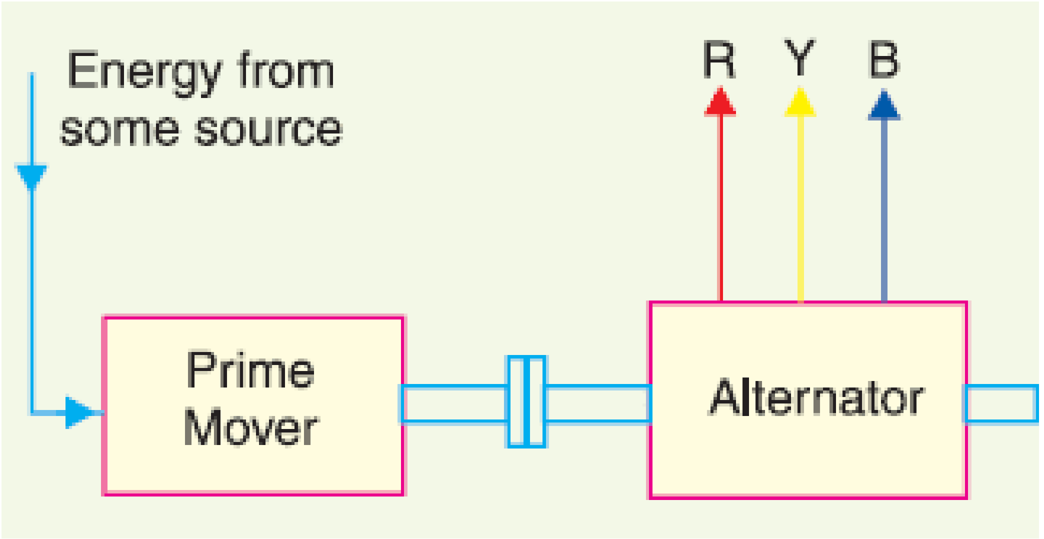


Fig. 3: Energy Conversion Process

Primary transmission.

- The electric power at 132 kV is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. This forms the primary transmission.

Secondary transmission

- The primary transmission line terminates at the receiving station (*RS*) which usually lies at the outskirts of the city. At the receiving station, the voltage is reduced to 33kV by step-down transformers. From this station, electric power is transmitted at 33kV by 3-phase, 3-wire overhead system to various sub-stations (*SS*) located at the strategic points in the city. This forms the secondary transmission.

Primary distribution

- The secondary transmission line terminates at the sub-station (*SS*) where voltage is reduced from 33 kV to 11kV, 3-phase, 3-wire. The 11 kV lines run along the important road sides of the city. This forms the primary distribution. It may be noted that big consumers (having demand more than 50 kW) are generally supplied power at 11 kV for further handling with their own sub-stations.

Secondary distribution

- In the last stage in a Power System, the electric power from primary distribution line (11 kV) is delivered to distribution sub-stations (*DS*) or Distribution Transformer. A typical pole mounted distribution transformer is shown in Fig. 5. These sub-stations are located near the consumers' localities and step down the voltage to 400 V, 3-phase, 4-wire for secondary distribution. The voltage between any two phases is 400 V and between any phase and neutral is 230 V. The single-phase residential lighting load is connected between any one phase and neutral, whereas 3-phase, 400 V motor load is connected across 3-phase lines directly. It may be worthwhile to mention here that secondary distribution system consists of *feeders*, *distributors and service mains*.

Hydel Power Generation

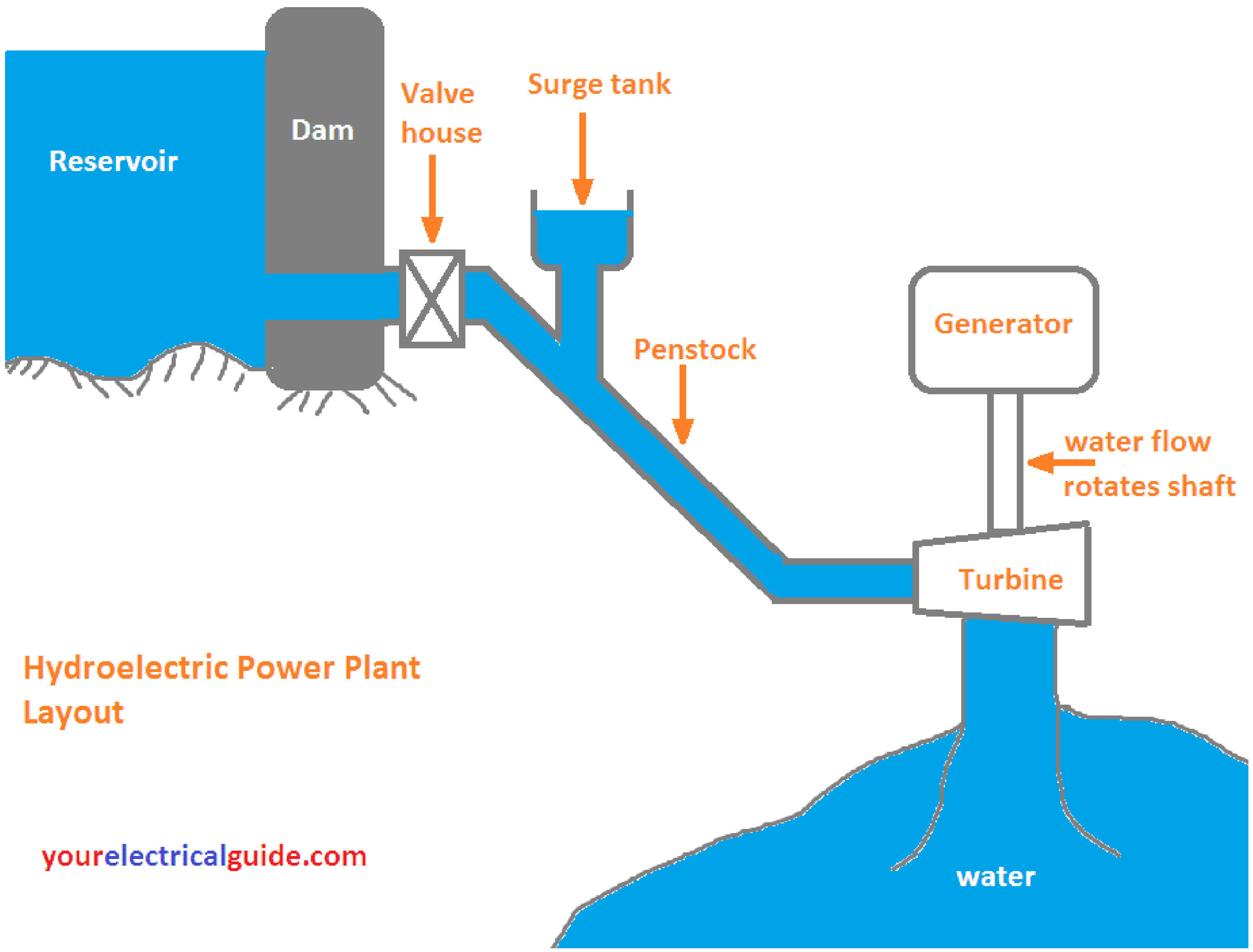
Working Principle of Hydroelectric Power Plant

- A power plant that utilizes the potential energy of water for the generation of electrical energy is known as a hydroelectric power plant.

- Hydroelectric power plants are generally located in hilly areas where dams can be built easily, and large water reservoirs can be made. In a hydropower plant, a water head is created by building a dam across a river or lake. From the dam, water is fed to a water turbine.

- The water turbine changes the kinetic energy of the falling water into mechanical energy at the turbine shaft. In simple words, falling water spins the water turbine. The turbine drives the alternator coupled with it and converts mechanical energy into electrical energy. This is the basic "working principle of hydroelectric power plant."

- Hydroelectric power plants are very popular because the stores of fuels (i.e., oil and coal) are exhausting day by day. They are also beneficial for irrigation and flood control purposes.


Reservoir
Dam
Valve
house
Surge tank
Penstock
Generator
water flow
rotates shaft
Turbine
water
Hydroelectric Power Plant
Layout
yourelectricalguide.com

Elements of Hydroelectric Power Plant

The main elements of a hydroelectric power plant are as follows:

- **Catchment area**: The total area behind the dam in which water is collected and stream-flow is obtained is known as the catchment area.
- **Reservoir**: It is an integral part of the power plant, where water is stored and supplied to a water turbine continuously.
- **Dam**: A dam is a barrier that stores water and creates a water head.
- **Spil-way**: Due to heavy rainfall in the catchment area, the water level may exceed the storage capacity of the reservoir. It may affect the stability of the reservoir. A structure is formed around the reservoir to remove this excess water. This structure is known as spil-way. Spil-way provides stability to the reservoir and reduces the level of water in the time of the flood.
- **Surge Tank**: It is a small tank (open at the top). It is provided to reduce the pressure surges in the conduit. It is located near the beginning of the conduit.
- **Penstocks**: Penstocks are open or closed conduits that carry water to the turbines. They are generally made of RCC or steel. The RCC penstocks are suitable for low water heads (< 30 m). The steel penstocks are ideal for any head, as they can be designed according to water head or working pressure.
- **Water turbines**: It works as an energy conversion device. It is a machine through which the potential energy of water is converted into the mechanical energy of shaft.
- **Generator:** A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

Nuclear Power Generation

Nuclear Power Plant Working Principle

Nuclear power plants consist of a nuclear reactor in place of a furnace, in which heat is generated by splitting atoms of radioactive material under controlled conditions.

The heat energy thus produced is used in generating steam at high temperature and pressure. This steam drives the steam turbine, which converts steam energy into mechanical energy.

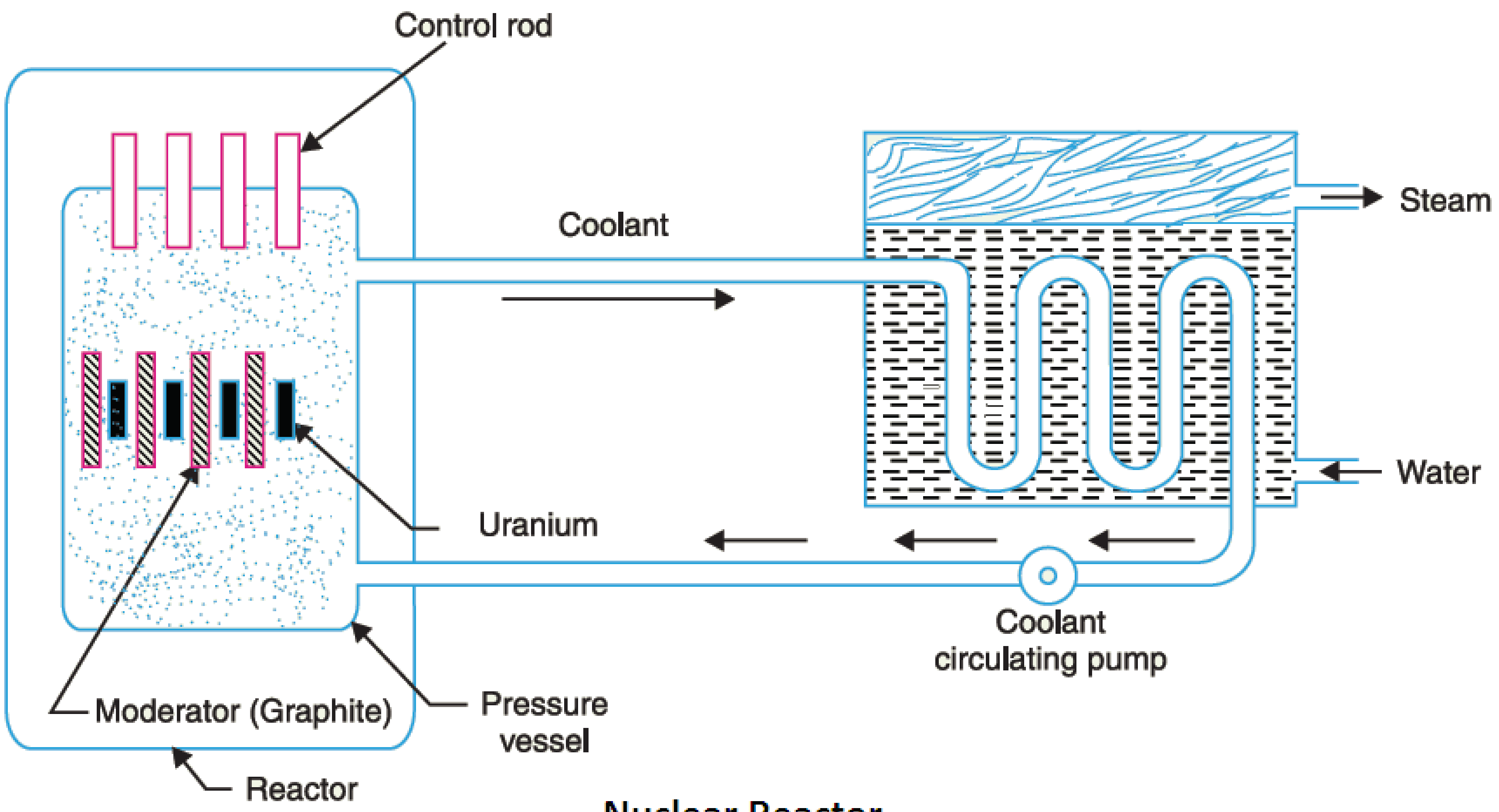
The turbine spins the alternator, which converts mechanical energy into electrical energy. This is the basic “nuclear power plant working principle”.

The most amazing feature of a nuclear power plant is that huge amount of electrical energy can be produced from a small amount of nuclear fuel.

Elements of Nuclear Power Plant

- Nuclear Reactor,
- Coolant and Coolant pump,
- Heat Exchanger,
- Steam Turbine, Condenser, Generator.

Nuclear Reactor: It is the apparatus in which controlled nuclear fission chain reaction is carried out for practical utilization of the released energy. It is constructed in the form of a cylinder or sphere from 10 to 15 cm thick steel plate and contains the fuel elements, the neutron control devices and a coolant.



Nuclear Reactor

One type of nuclear reactor is shown in Figure. It consists of a large number of uranium rods placed in a calculated geometrical lattice between the layers of pure graphite (moderator) blocks. The rods are covered by close-fitting aluminium cylinders to prevent oxidation of uranium. The control rods are so inserted in the lattice that they can be raised or lowered between the uranium rods whenever necessary. A concrete shield surrounds the whole reactor. A modern reactor has the following essential parts:

Fuel: The fissionable material, known as fuel, plays a vital role in the operation of a reactor. Uranium enriched with the isotope U^{235} of Pu^{239} is used as fuel.

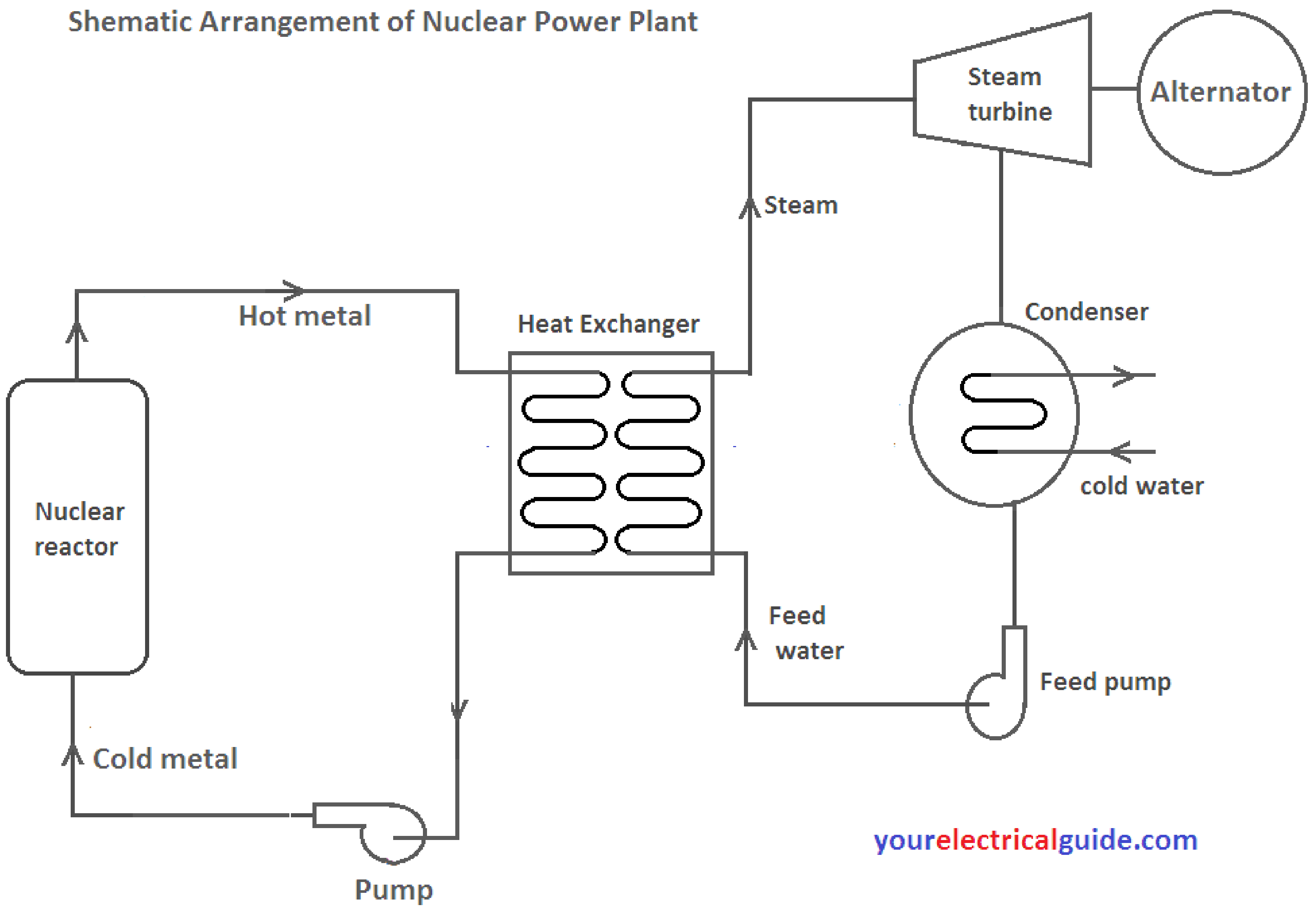
Moderators: They are substances which, when introduced into radioactive fuel mass, are capable of slowing down the neutrons. The slow neutrons are more effective in triggering fission in natural uranium than the fast neutrons. Heavy water, light water, beryllium and graphite are generally used as the moderator.

Control Rods: The control rods are made of cadmium and are inserted into the reactor. Cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission. The intensity of chain reaction and hence heat production can be controlled with the help of control rods.

Coolant: It is the medium through which the heat produced in the reactor is transferred to the heat exchanger for production of steam.
•Gas Coolants — Air, helium and CO_2,
•Liquid Coolants – Light and Heavy water,
•Metal Coolants – Molten sodium and Lithium.

Shield: Various types of intense rays are emitted from the reactor, which may be harmful to the people working near the reactor. Thick concrete walls are erected around the reactor to protect them from this radiation.

Safety Devices: In case of an accident or any other emergency, a special set of control rods, known as ‘shut-off rods’ enter the reactor automatically. They immediately absorb the neutrons so that the chain reaction stops entirely.


Shematic Arrangement of Nuclear Power Plant
Steam
turbine
Alternator
Steam
Hot metal
Heat Exchanger
Condenser
Nuclear
reactor
cold water
Feed
water
Feed pump
Cold metal
Pump
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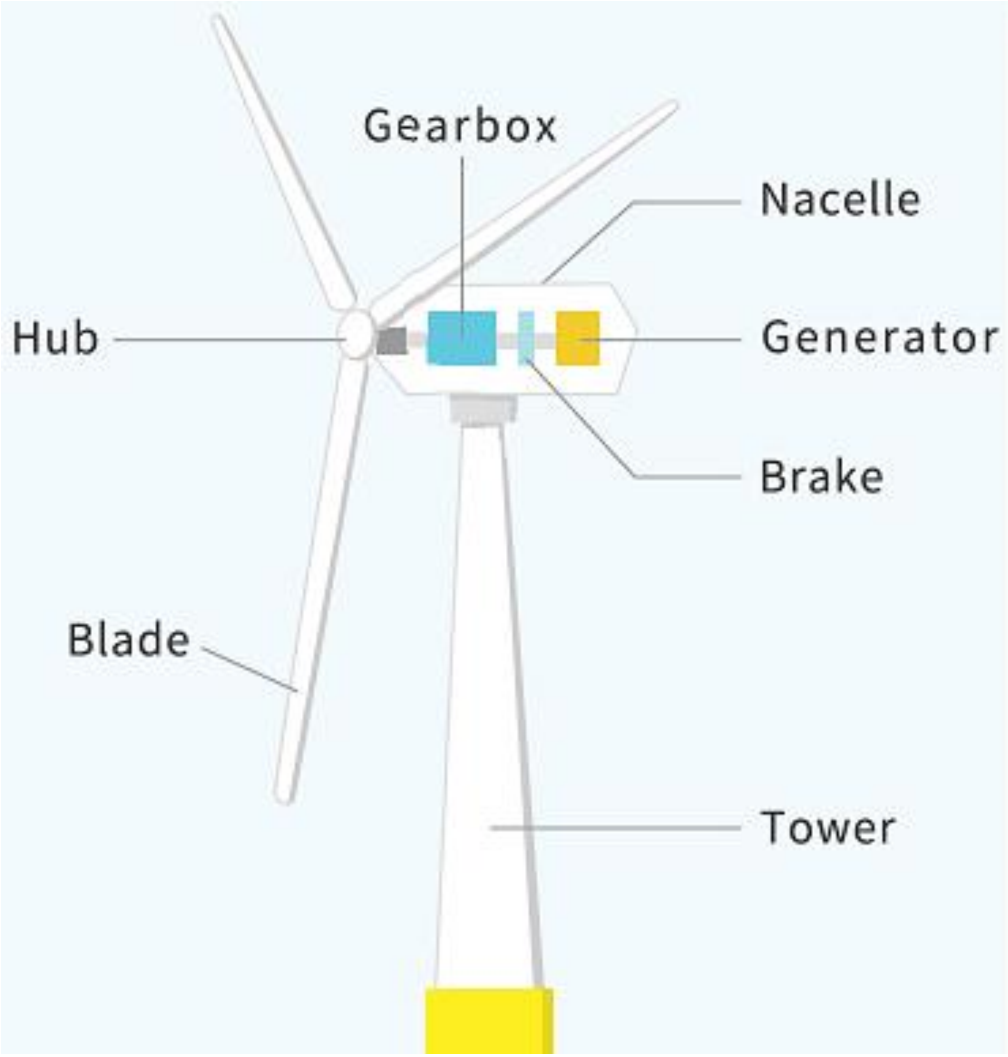
Wind Power Generation

Wind Power Plant Working Principle

As the free wind stream interacts with turbine rotor, it transfers a part of the kinetic energy to the rotor due to which its speed decreases. This difference in kinetic energy is converted into mechanical power.

Horizontal axis wind turbine generators are being used all over the world successfully. The main components of a propeller type wind generator are shown in Figure.



•Usually, it has two of three blades made of high-density glass fiber reinforced plastic. The diameter of rotor ranges from 2 to 25 m. Modern rotors may be up to 100 m in diameter. Rotor blades are assembled on a hub. The hub, brakes, gearbox, generator with electrical controls is accommodated in a box called nacelle.

•The whole system is mounted on a tower top. It is designed to bear up the wind loads during storms.

•A yaw control mechanism is also provided to adjust the nacelle around a vertical axis to keep it wind facing. A servomechanism operated by a wind direction sensor controls the nacelle so that the turbine blades are always oriented in the direction perpendicular to wind to have the maximum wind stream area.

•The pitch of the blade (0^o to 30^o) is controlled automatically so as to provide the feathering action. Thereby the power and speed of wind turbine shaft are adjusted to match with generator speed and its electrical output. The pitch control mechanism adjusts the pitch to obtain the optimum performance.

•The wind energy is converted into mechanical energy by an aero turbine. This mechanical power is transferred through gears to the generator to increase its speed. Since rotor speeds are low, a gear system is necessary to match the synchronous speed of the generator.

•Due to fluctuations in wind speed, it not possible to obtain a power supply of a fixed frequency from windmills. To overcome this problem, the output of 3 phase generator is rectified and converted into AC with the help of a PWM inverter operating at 50 or 60 Hz.

Solar Power Generation

Solar Panel Working Principle

A photovoltaic cell is also called a solar cell. It is a semiconductor device which converts sunlight into DC power using the photoelectric effect. Practically, all solar cells are photodiodes made of semiconductor material like silicon. A solar cell works in three steps:

- Photons in the sunlight hit the solar cell and are absorbed by the semiconductor material.
- Negatively-charged electrons are knocked off from their atoms and start flowing in the same direction to produce electric current.
- A typical silicon solar cell can produce up to 0.5 V and current up to 6 A. Thus, its maximum power is 3 W.

Since the output of a single solar cell is very small, **a large number of solar cells are interconnected to form a solar module, combination of solar modules is called panel and combination of panels is called solar array.** It is done to get the required power output from a PV system.

When the solar cells are connected in series their voltage increases as much as the number of cells connected in series. But the current remains the same.

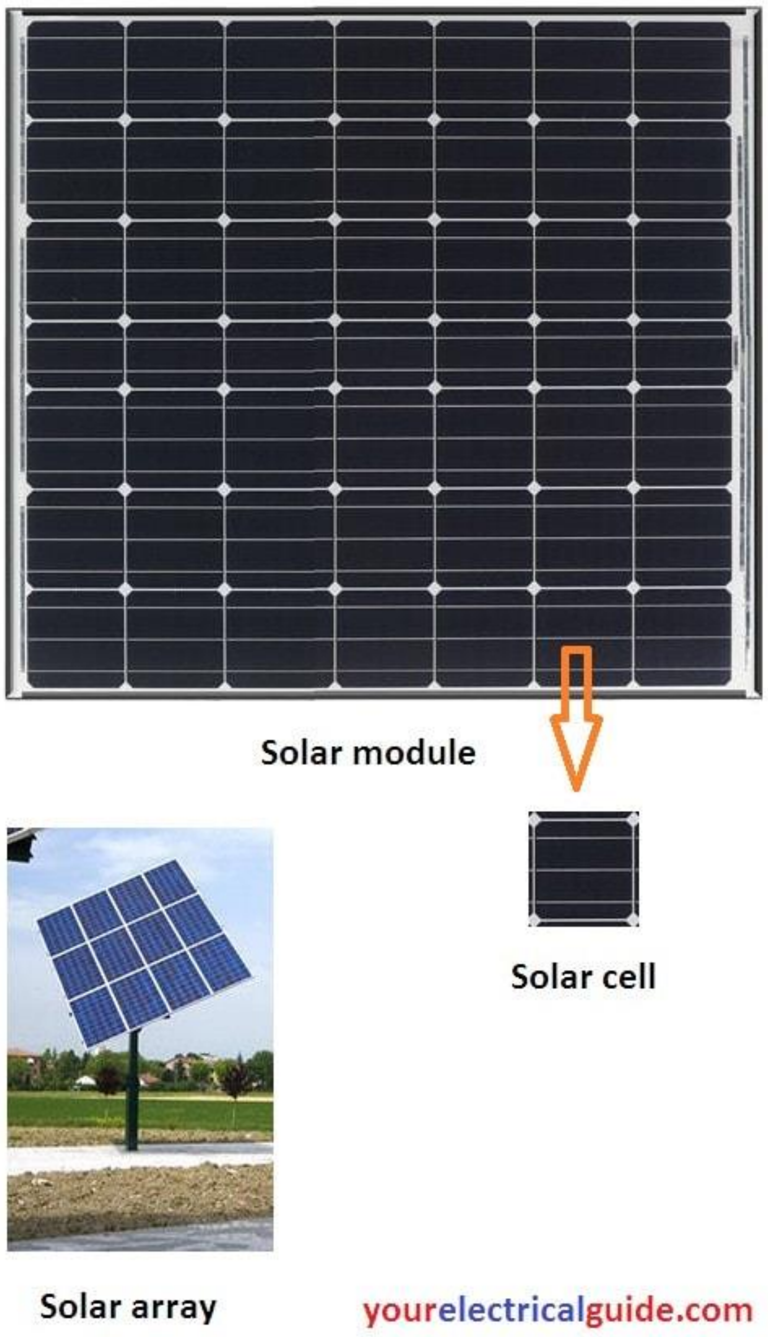
When cells are connected in parallel, voltage remains constant, same as that of one cell but current gets multiplied. The cells, modules or panels can be connected in parallel only if their voltages are the same. Main components of a solar PV system are as under:

Blocking Diodes

The SPV arrays are connected to the battery. During sunshine hours the panels generate electricity which charges the battery. But when there is no sunshine or during the night the current will try to flow in the reverse direction i.e. from the battery to the arrays. This can damage the arrays. So to avoid this reverse flow of current, blocking diodes are used.

Voltage Regulator

The voltage output from PV panels varies according to the intensity of sunlight. This would lead to the fluctuation of load current. The voltage regulators will ensure that the voltage fluctuations are kept within the prescribed limit.



Inverter

Since power produced by a PV array is DC, an inverter is used to convert it into AC power so that we can utilize it easily. The inverter unit installed with different protection devices ensures the safety of the system and performs automatic changeover of load and available power sources.

Storage Batteries

These are used storage of solar energy. They are the most vital components of the Solar PV system. The success of a Solar PV system depends upon battery storage system very much.

Battery Controllers

These are devices to ensure that the charging of batteries is done in a proper way. They control charging current and protect the battery from overcharging. This is done by constantly monitoring the battery current, voltage and temperature.

Types of Solar Photovoltaic System

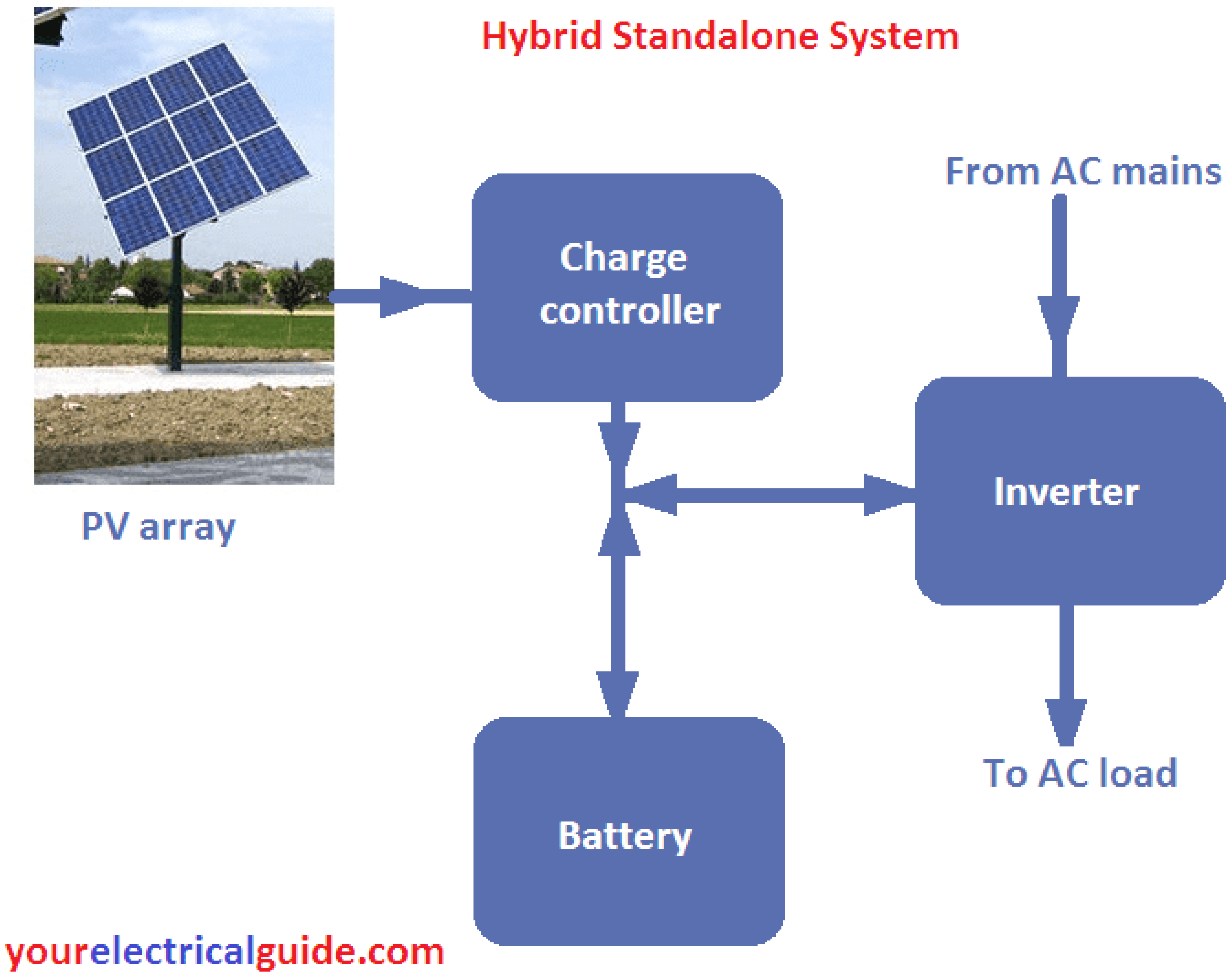
According to the method of utilization, there can be two configurations:

- Stand-alone system
- Grid-connected system

Stand-alone System

In this system, power is supplied to a load without the use of any common grid or connection to any other system and operates autonomously and independently. It is used for backup power where connecting to the grid is very costly. It can be used to power DC loads, also the AC loads using an inverter.

There are different types of standalone systems. But the *hybrid stand-alone system* is most commonly used.


Hybrid Standalone System
From AC mains
Charge
controller
Inverter
PV array
To AC load
Battery
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In a hybrid standalone system, one or more sources in addition to the PV panels are used. Sources like generators, fuel cells, AC mains etc. may be used in conjunction with PV arrays. Thus dependence on any single source is reduced. This also reduces battery storage capacity and size of PV arrays.

Grid-connected System

In this system, the power generated by the PV array is given to grid or to the AC loads directly. When power generation exceeds the requirement of the loads, it is supplied to a commercial grid. Thus the system becomes a part of a large network. In this system, when power produced by the PV array exceeds the local load requirement, is supplied to the grid. An energy meter is used to monitor the supplied energy.