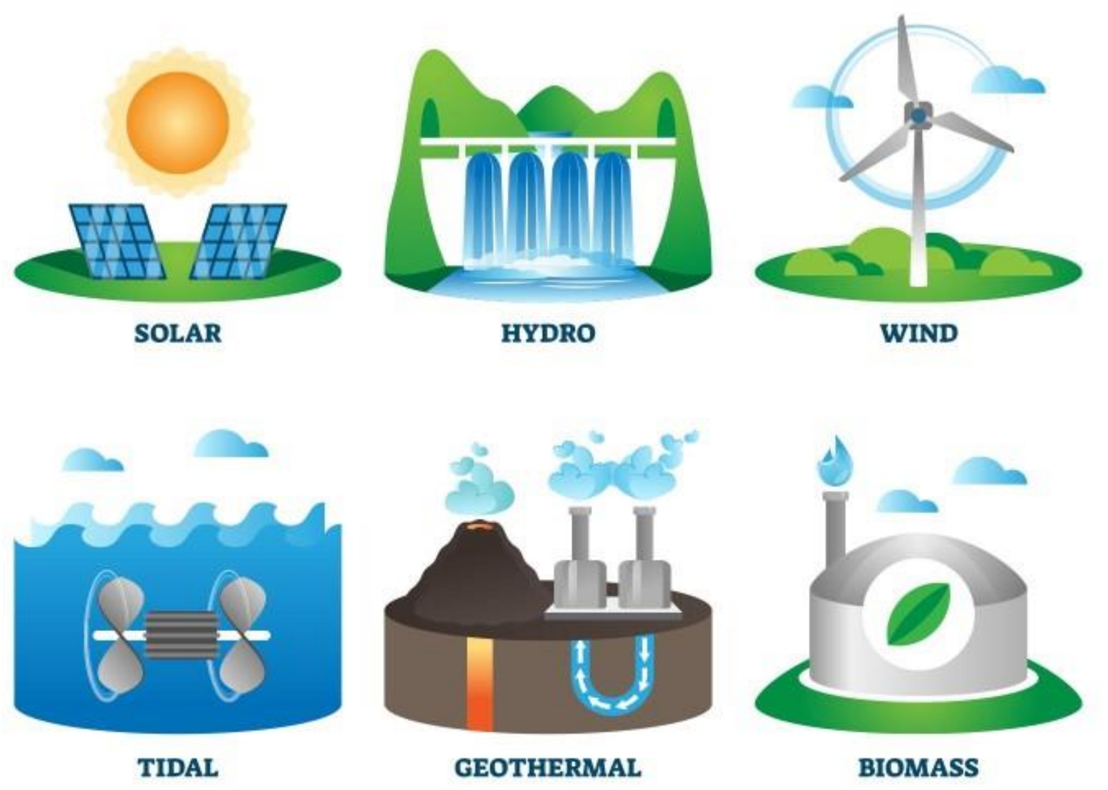
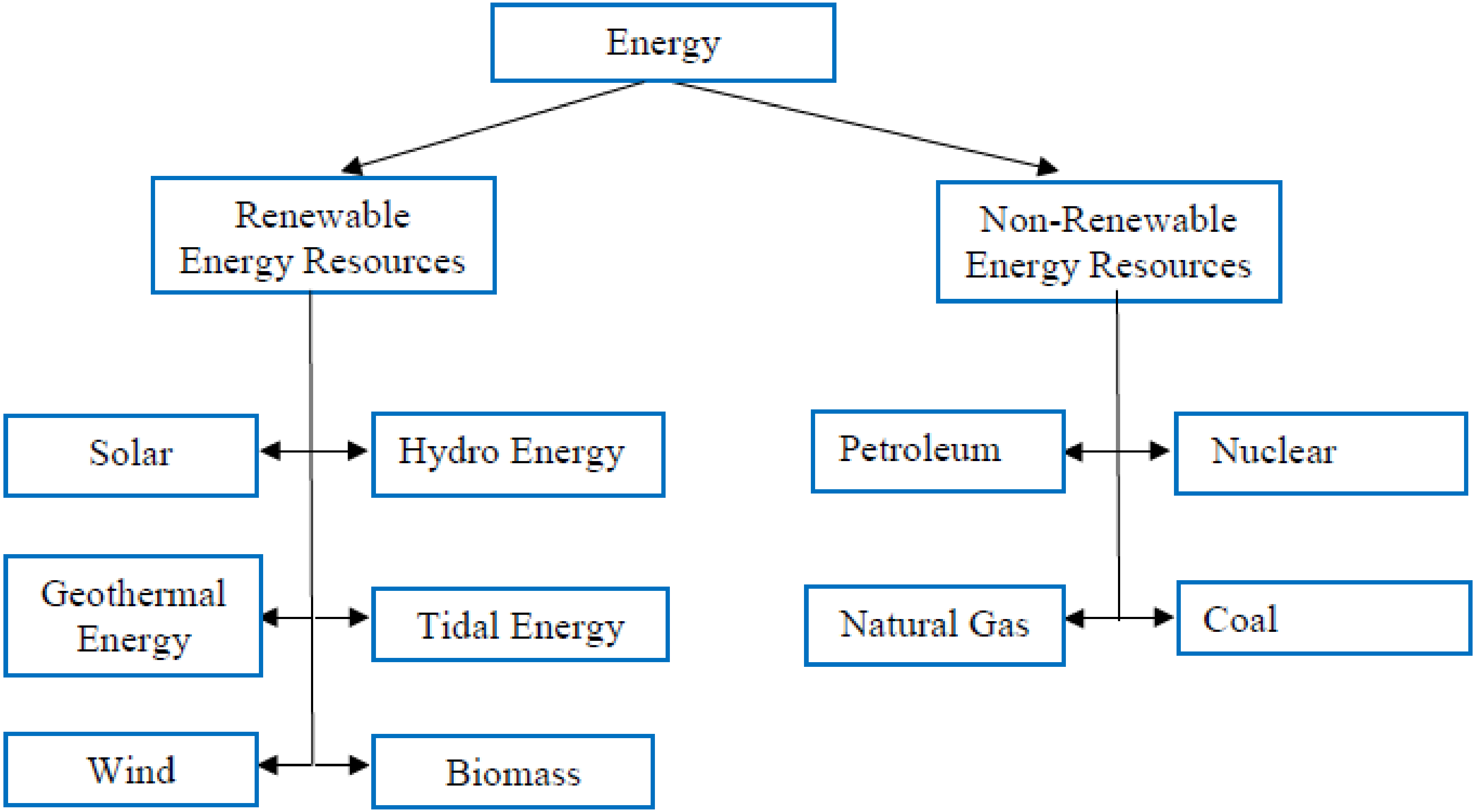
Renewable Energy Resources:

Nowadays, increasing energy demand and dependence on fossil fuel become an important issue facing the world. Therefore, there is a big trend for the use of renewable energy sources to address electricity generation.




Energy
Renewable Energy Resources
Non-Renewable Energy Resources
Solar
Hydro Energy
Geothermal Energy
Tidal Energy
Wind
Biomass
Petroleum
Nuclear
Natural Gas
Coal

Power Sector at a Glance ALL INDIA

Updated on 12-04-2023
Source: OM SECTION

***1.Total Installed Capacity (As on 31.03.2023)* -** Source : Central Electricity Authority (CEA)

INSTALLED GENERATION CAPACITY (SECTOR WISE) AS ON 31.03.2023

Sector	MW	% of Total
Central Sector	1,00,055	24%
State Sector	1,05,726	25.4%
Private Sector	2,10,278	50.5%
Total	**4,16,059**	

Reference: https://powermin.gov.in/en/content/power-sector-glance-all-india

Installed GENERATION CAPACITY(FUELWISE) AS ON 31.03.2023		
CATAGORY	**INSTALLED GENERATION CAPACITY(MW)**	**% of SHARE IN Total**
Fossil Fuel		
Coal	205,235	49.3%
Lignite	6,620	1.6%
Gas	24,824	6%
Diesel	589	0.1%
Total Fossil Fuel	**2,37,269**	**57.7 %**

Reference: https://powermin.gov.in/en/content/power-sector-glance-all-india

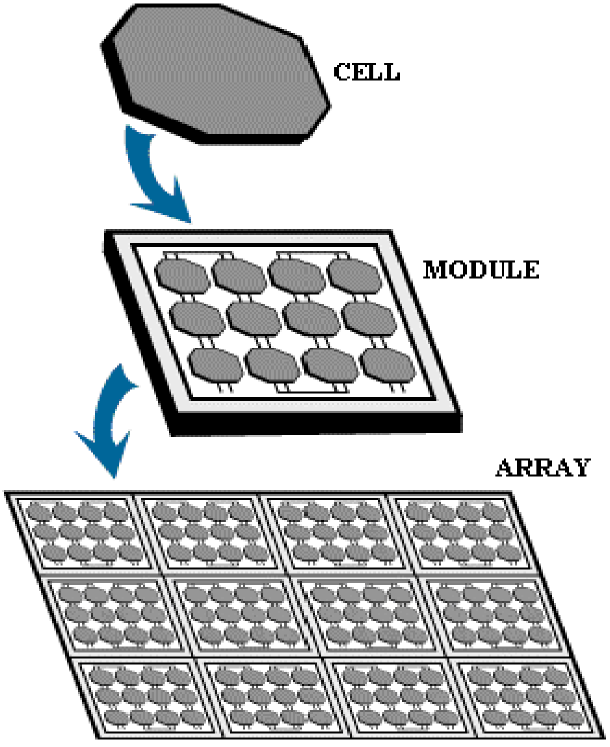
Non-Fossil Fuel		
RES (Incl. Hydro)	**172,010**	41.3%
Hydro	**46,850**	**11.3 %**
Wind, Solar & Other RE	125,160	30.1 %
Wind	42,633	10.2 %
Solar	66,780	16.1 %
BM Power/Cogen	10,248	2.5 %
Waste to Energy	554	0.1 %
Small Hydro Power	4,944	1.2 %
Nuclear	6,780	1.6%
Total Non-Fossil Fuel	**178,790**	43%

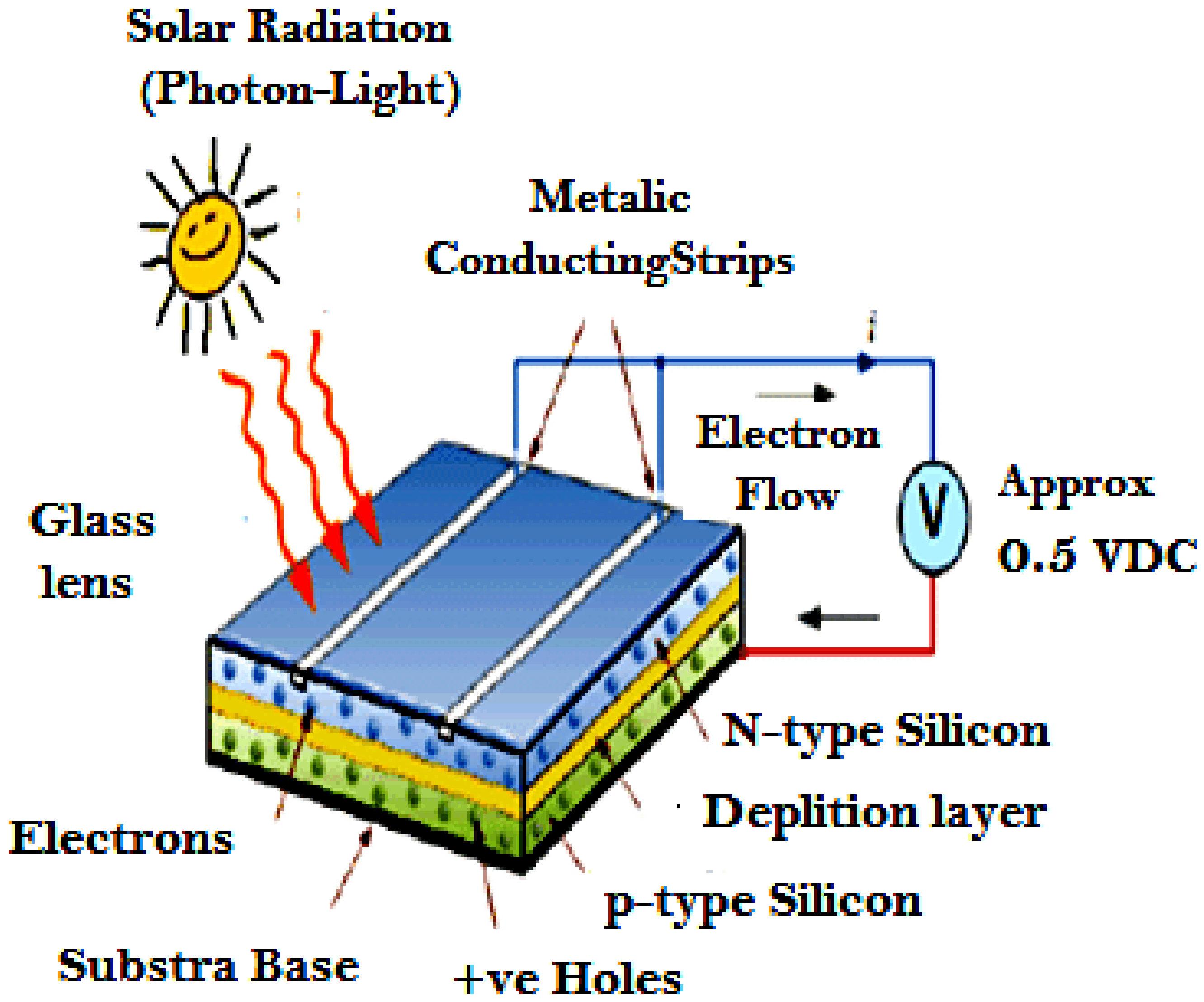
Reference: https://powermin.gov.in/en/content/power-sector-glance-all-india

Solar photovoltaic generation :

Solar photovoltaic (PV) systems directly convert solar energy into electricity.

The basic building block of a PV system is the PV cell which converts solar energy into direct-current electricity.




Solar Radiation
(Photon-Light)
Metalic
ConductingStrips
Electron
Flow
V
Approx
0.5 VDC
Glass
lens
N-type Silicon
Deplition layer
Electrons
p-type Silicon
Substra Base
+ve Holes

Solar Cell Type	Efficiency-Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; Lightweight Portable & flexible	Lowest efficiency/performance shorter warranties & lifespan
Concentrated PV *Cell (CVP)*	*~41%*	*Very high performance & efficiency rate*	*Solar tracker & cooling system needed (to reach high efficiency rate)*

Advantages of Solar PV:

I. Can be used as a centralized or distributed power generation

II. PV Systems have no Moving Part

III. Energy independence and environmental compatible

IV. The sunlight is free and no noise or pollution is created from operating PV systems

V. Minimal maintenance and have long service lifetime.

Disadvantages of Solar PV:

I. High cost

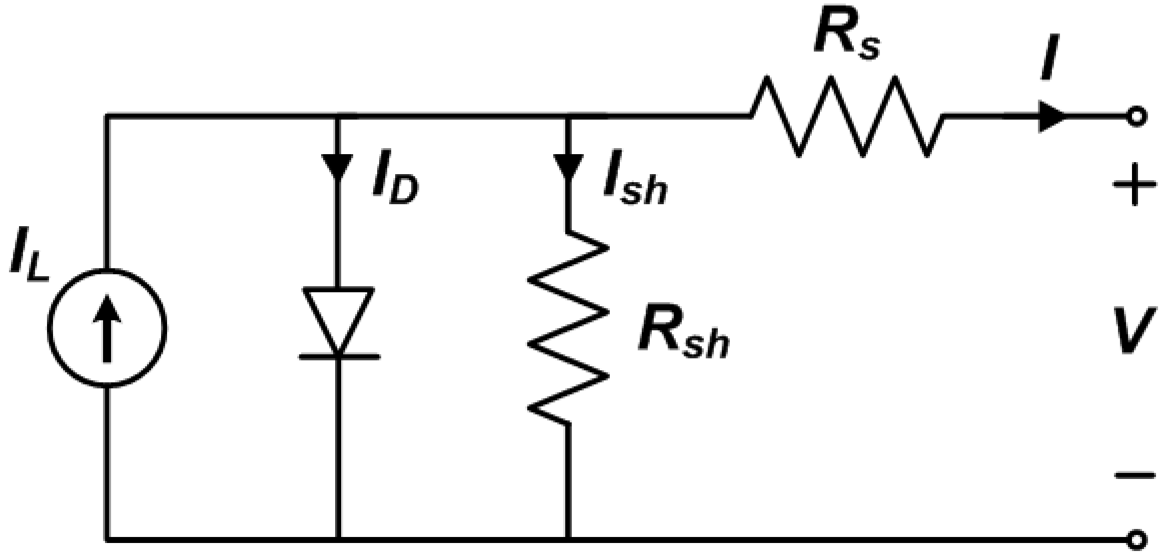
II. More surface area requirement

III. Efficiency depends upon availability of sunlight

IV. Batteries are required during the low sunshine period

V. Efficiency is very low

Equivalent Circuit Model:



$$i_L = i_d + i_{Rsh} + i$$

$$i = i_L - i_d - \left(\frac{v + iR_s}{R_{sh}} \right)$$

Diode current from the P-n junction Theory

$$i_d = I_o\left(e^{\frac{v+iR_S}{\eta V_T}} - 1\right)$$

$$\eta - ideality \quad factor$$

$$I_o - \mathrm{Re}\, verse \quad saturation \quad current$$

$$V_T = \frac{kT}{q}$$

$$k - Boltsmann \quad cons\tan t = 1.38\times 10^{-23}\ j/k$$

$$q - electronic \quad ch\arg e = 1.6\times 10^{-19}\, c$$

$$i = i_L - i_d - \left(\frac{v + iR_s}{R_{sh}} \right)$$

$$i = i_L - I_o \left(e^{\frac{v+iR_s}{\eta V_T}} - 1 \right) - \left(\frac{v + iR_s}{R_{sh}} \right)$$

When terminals of PV cell is short circuited

$$v = 0$$

$$i = I_{sc}$$

$$I_{sc} = i_L - I_o \left(e^{\frac{0+iR_s}{\eta V_T}} - 1 \right) - \left(\frac{0 + iR_s}{R_{sh}} \right)$$

$$R_s \ll R_{Sh}$$

$$I_{sc} = i_L$$

When terminals of PV cell is open circuited

$$v = v_{oc}$$

$$i = 0$$

$$0 = i_L - I_o\left(e^{\frac{v_{oc}}{\eta V_T}} - 1\right) - \left(\frac{v_{oc}}{R_{sh}}\right)$$

$$R_{sh} \gg v_{oc}$$

$$v_{oc} = \quad \eta V_T \, l_n\left(\frac{i_p + I_o}{I_o}\right)$$

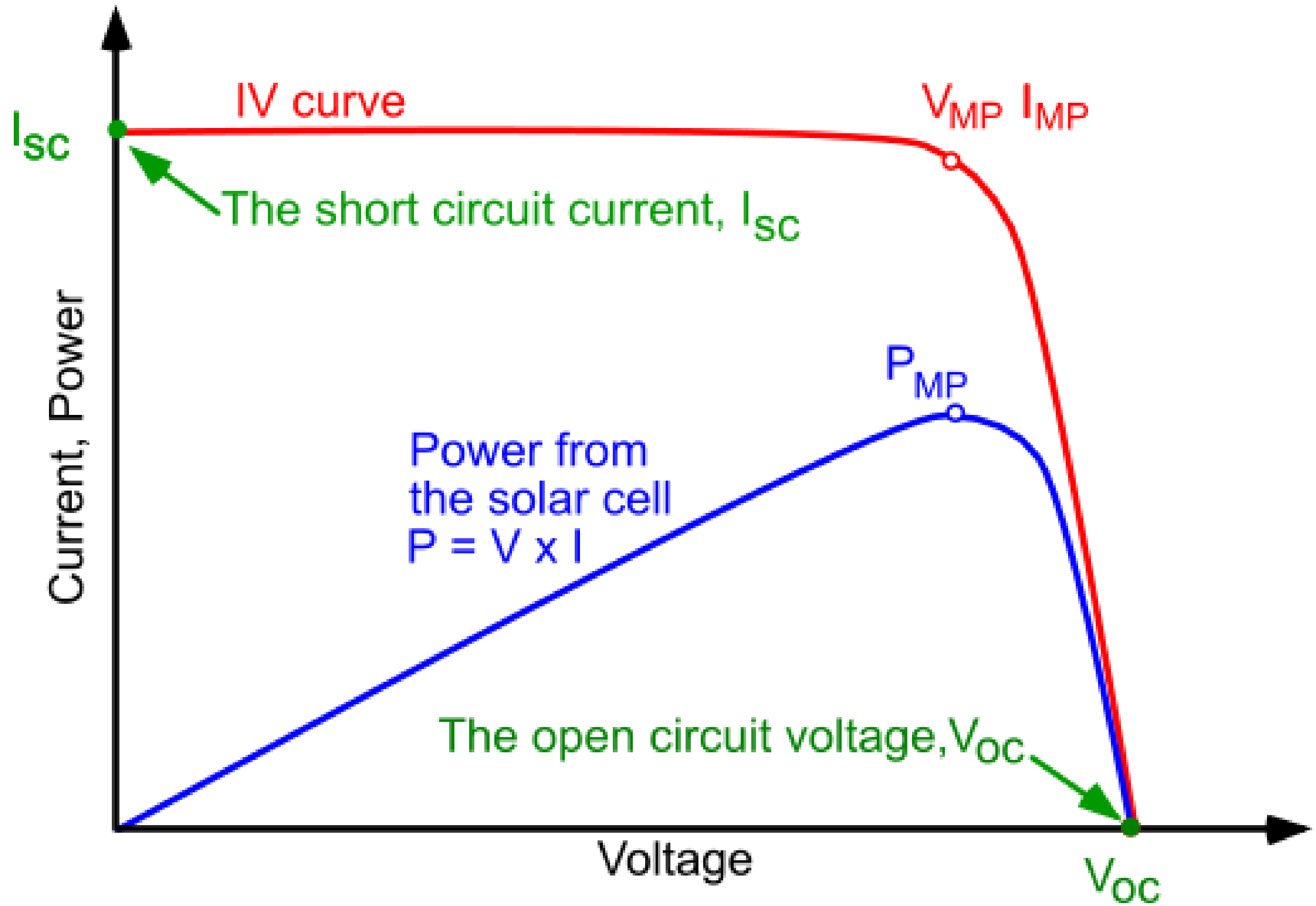
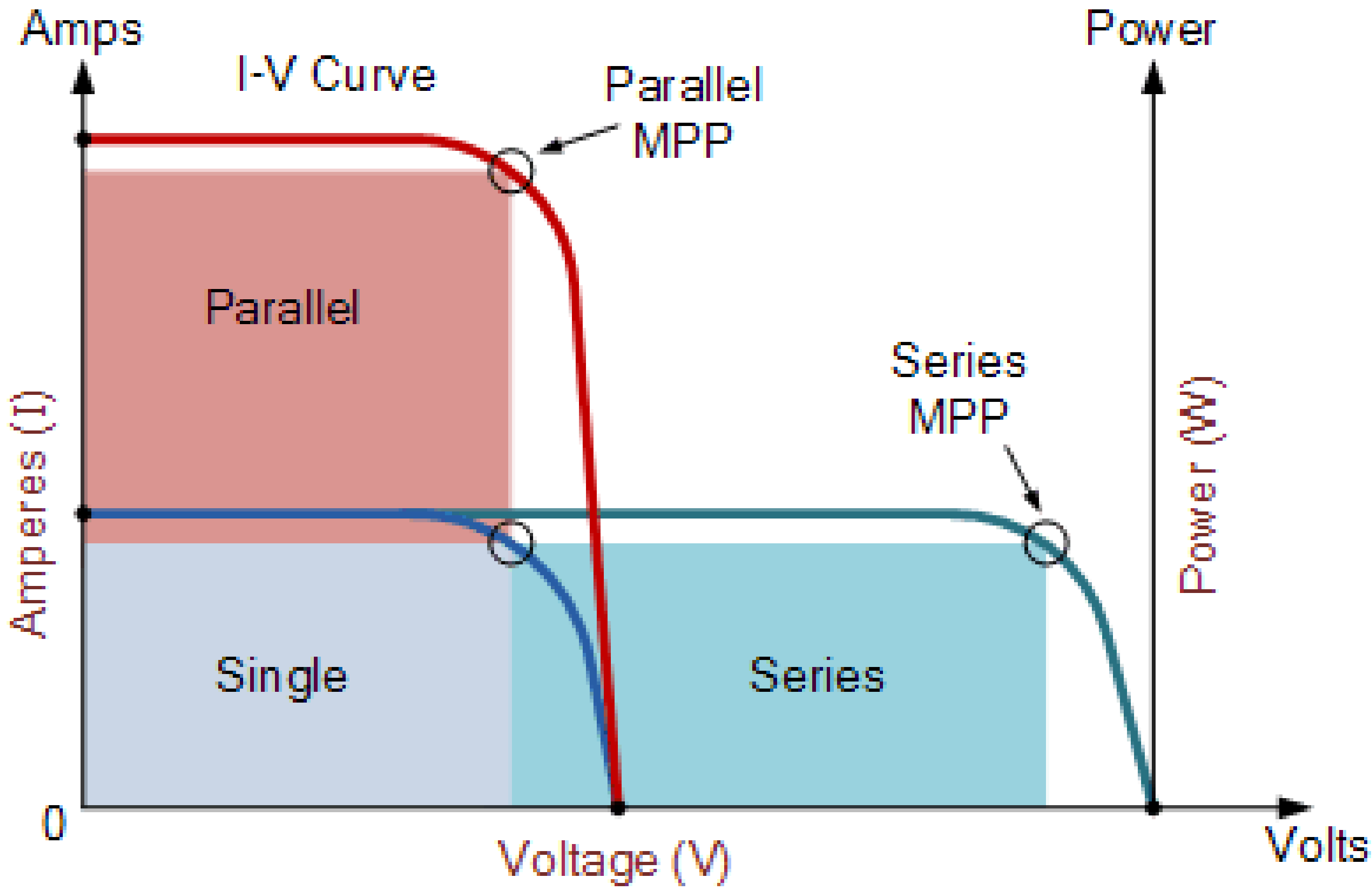
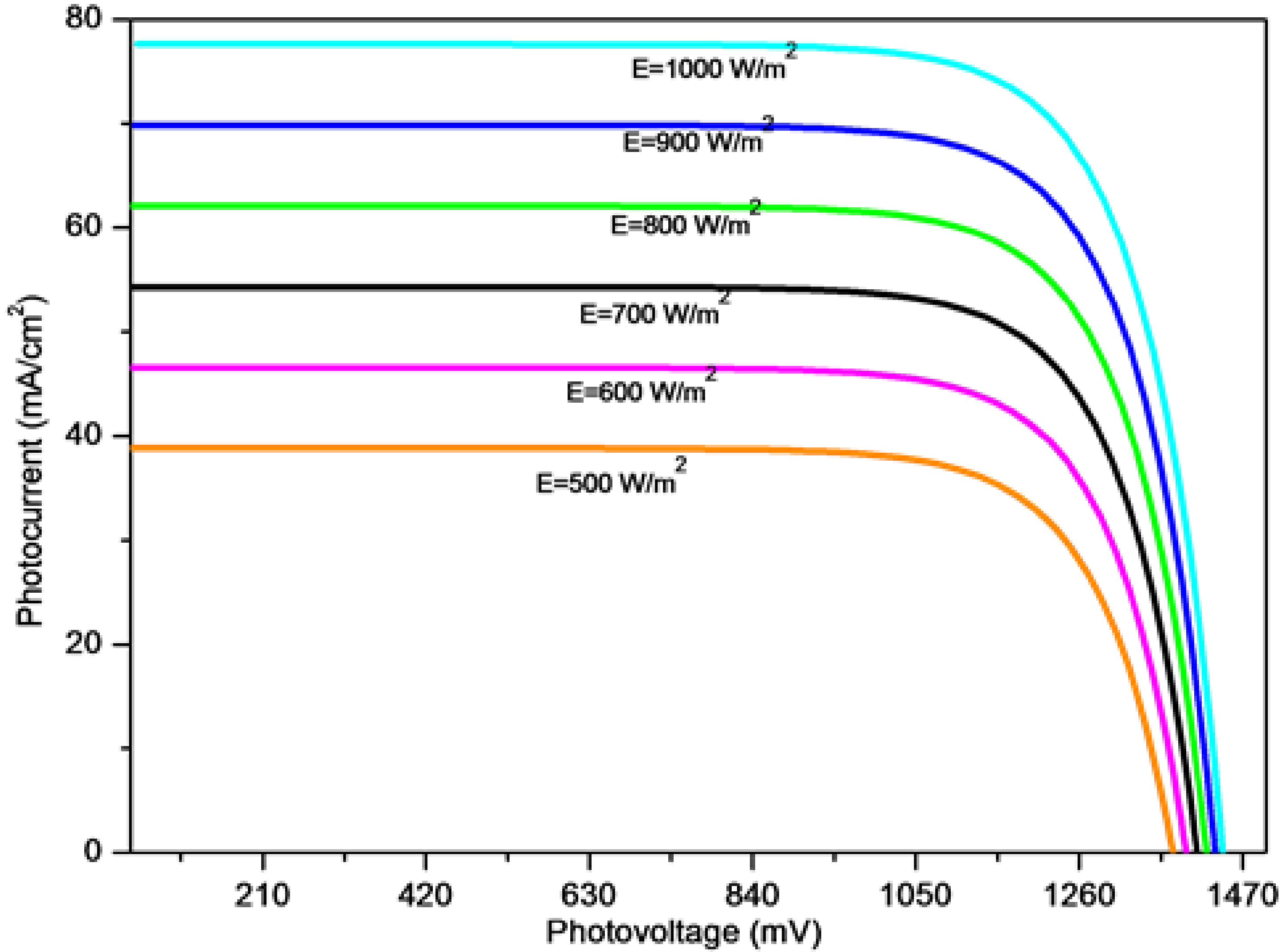
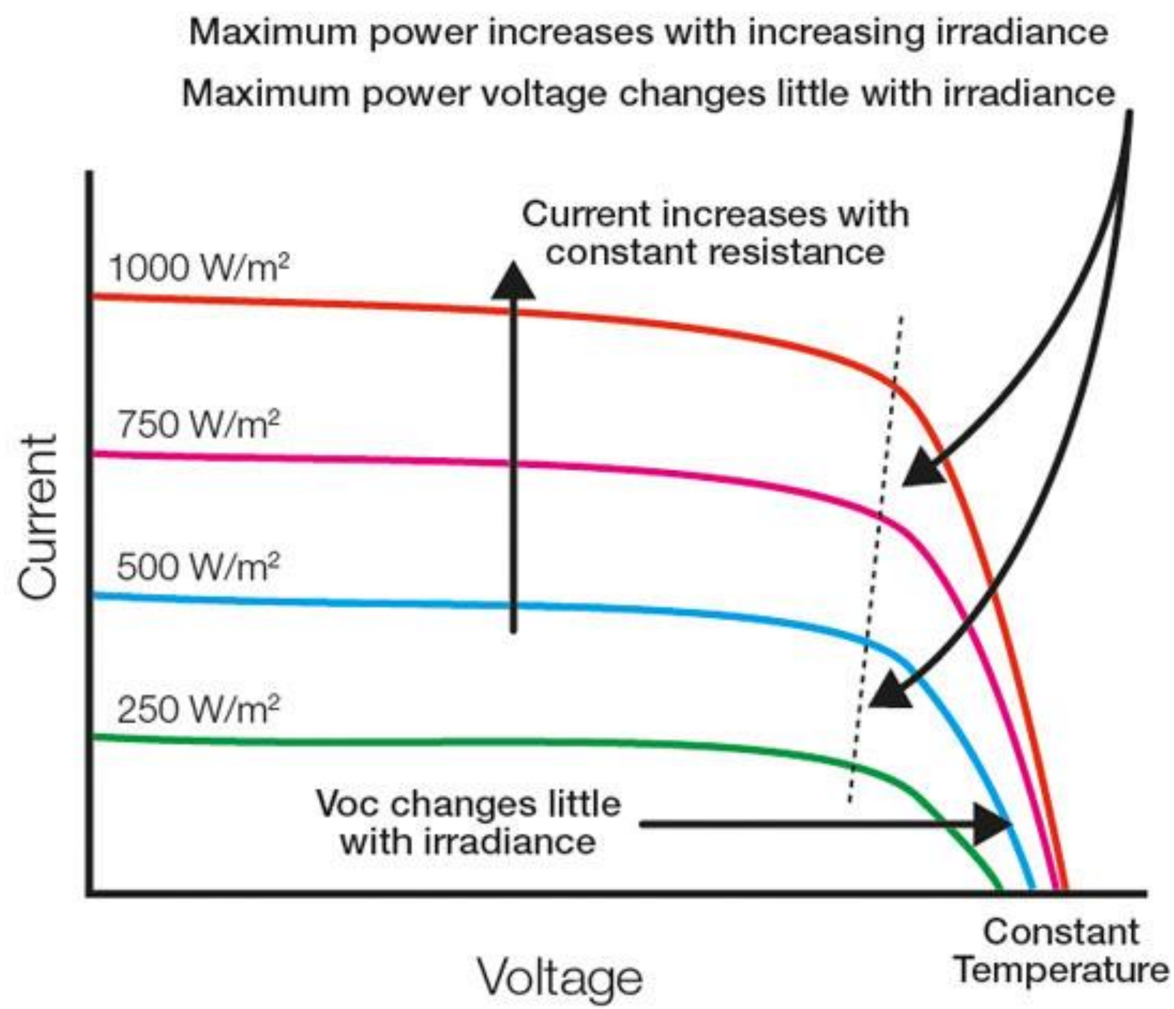


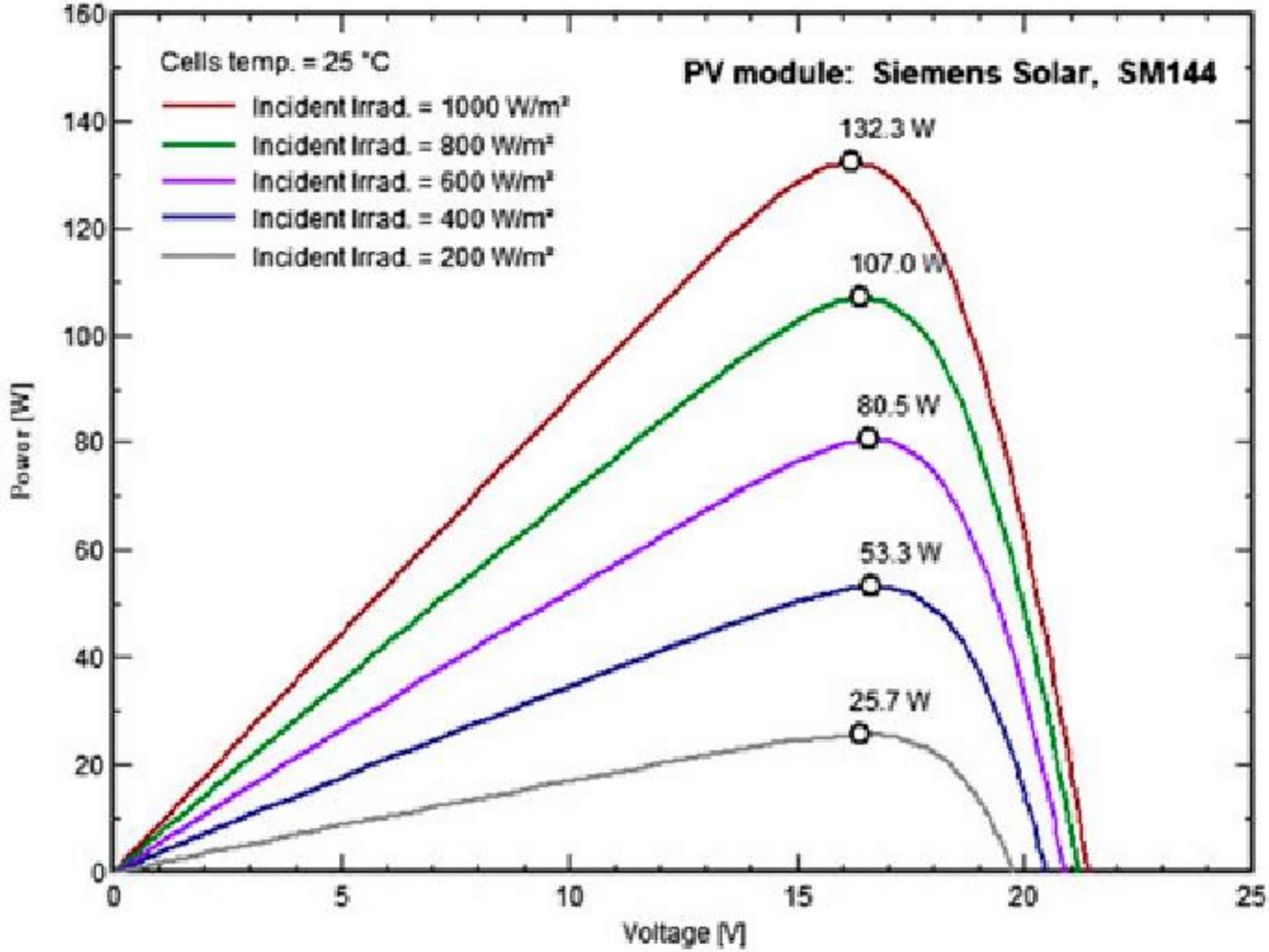
Fig: i-v characteristic of solar cell


Amps
I-V Curve
Parallel
MPP
Power
Parallel
Series
MPP
Amperes (I)
Power (W)
Single
Series
0
Voltage (V)
Volts

Effect of solar irradiance variation:

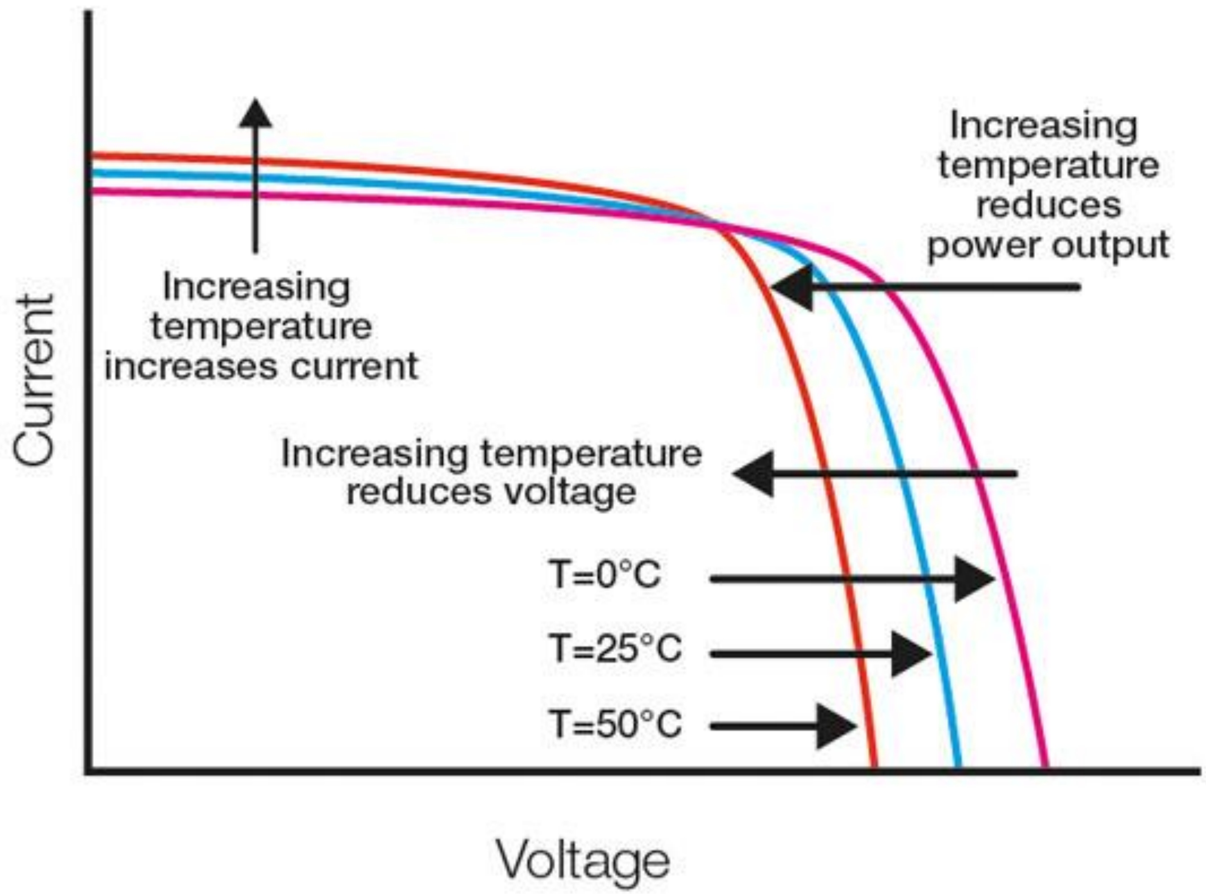



Maximum power increases with increasing irradiance
Maximum power voltage changes little with irradiance
Current increases with constant resistance
1000 W/m²
750 W/m²
500 W/m²
250 W/m²
Current
Voc changes little with irradiance
Voltage
Constant Temperature



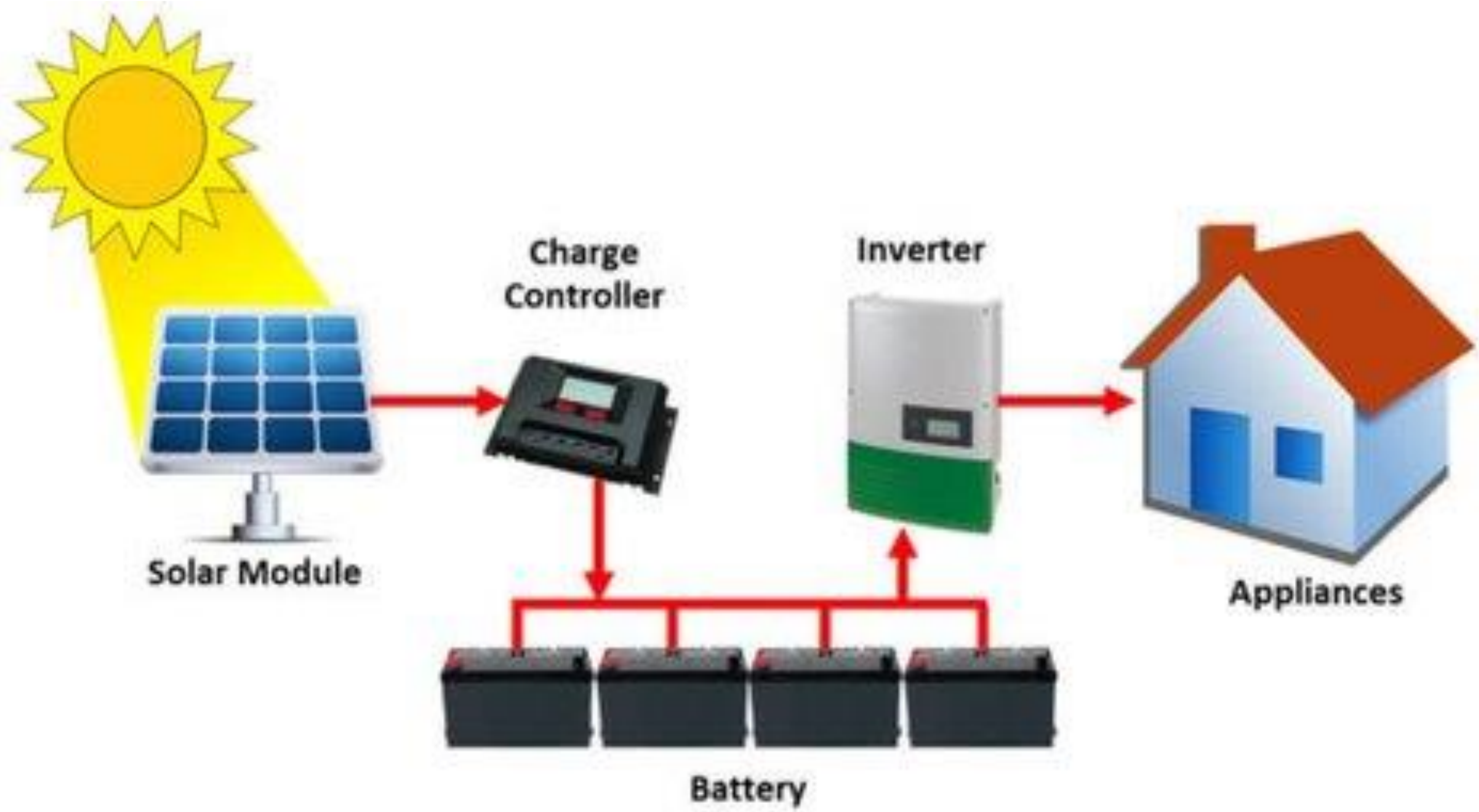
PV module: Siemens Solar, SM144
Cells temp. = 25 °C
Incident Irrad. = 1000 W/m²
Incident Irrad. = 800 W/m²
Incident Irrad. = 600 W/m²
Incident Irrad. = 400 W/m²
Incident Irrad. = 200 W/m²
132.3 W
107.0 W
80.5 W
53.3 W
25.7 W
Power [W]
Voltage [V]
0
20
40
60
80
100
120
140
160
0
5
10
15
20
25

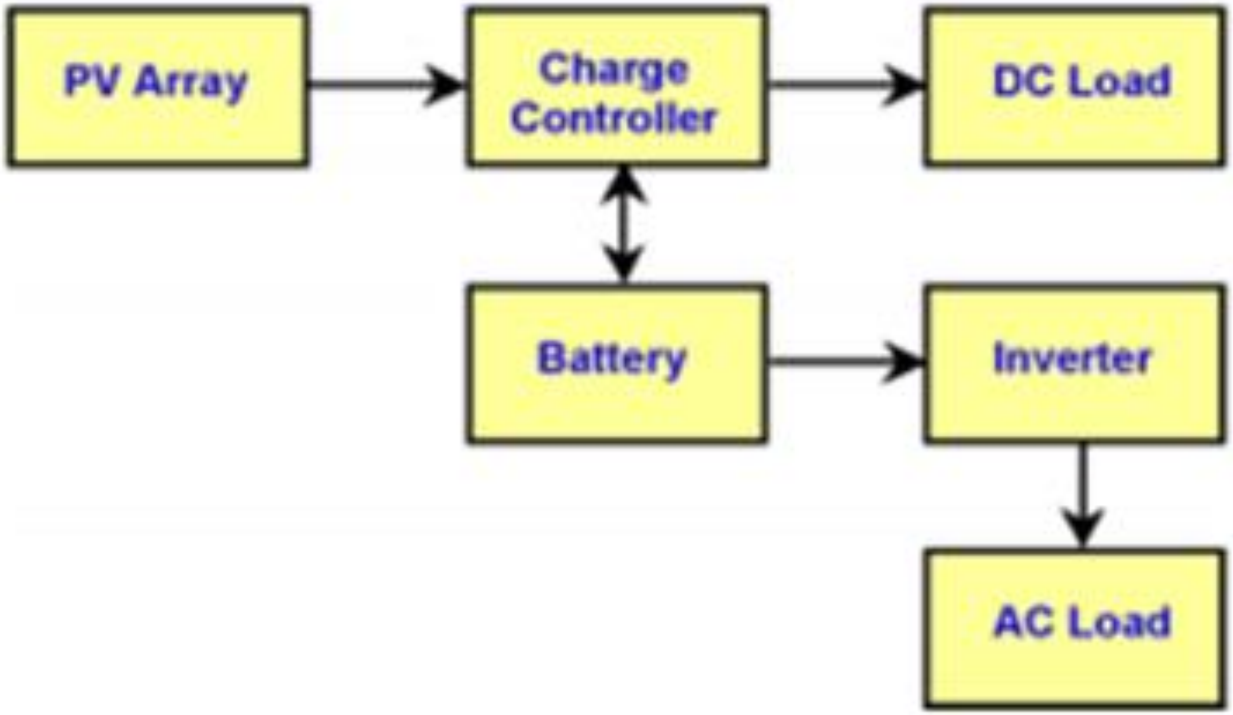
Effect of Temperature variation:



Types of Solar PV System:

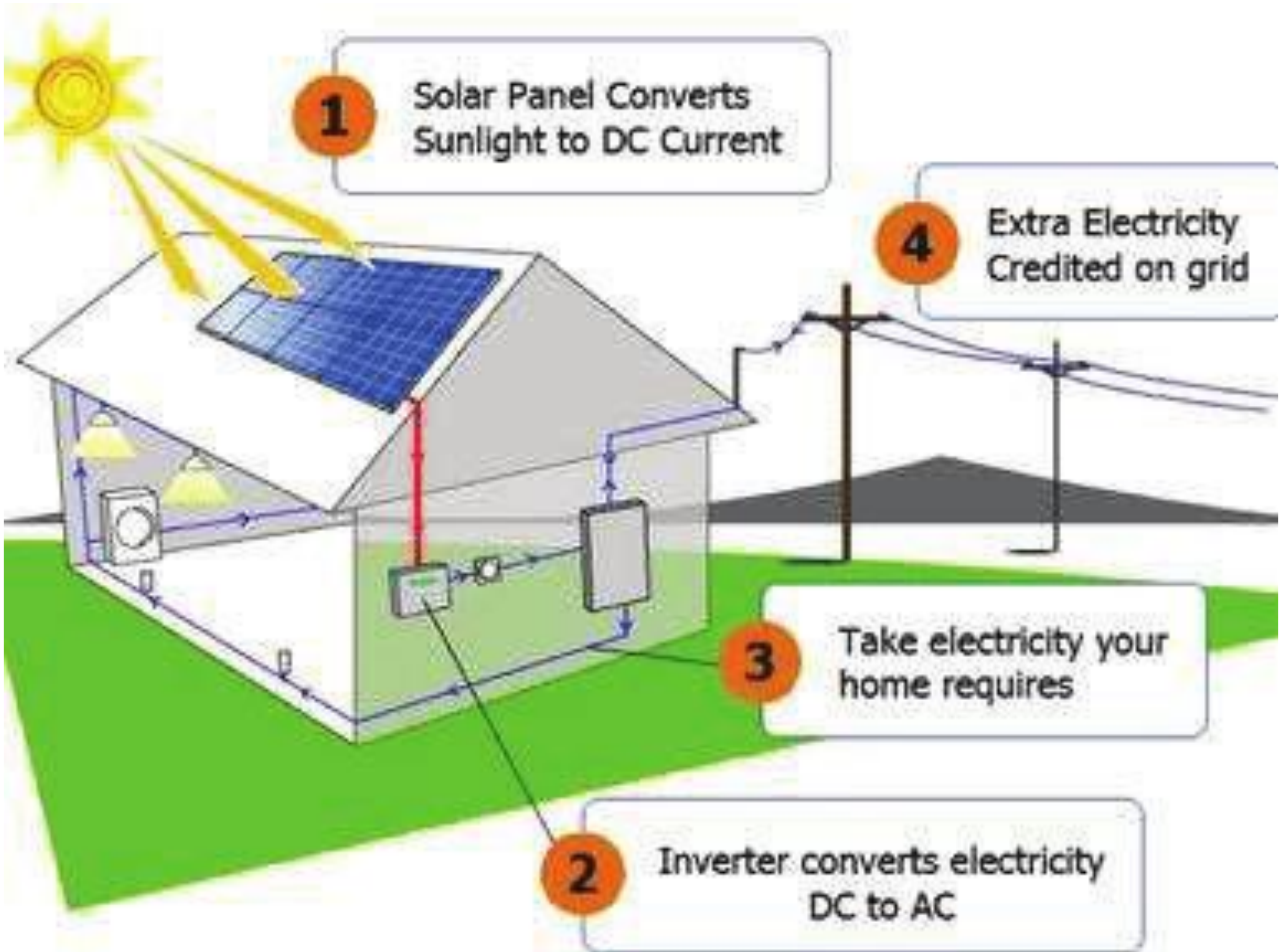
1) Off Grid Solar PV System:

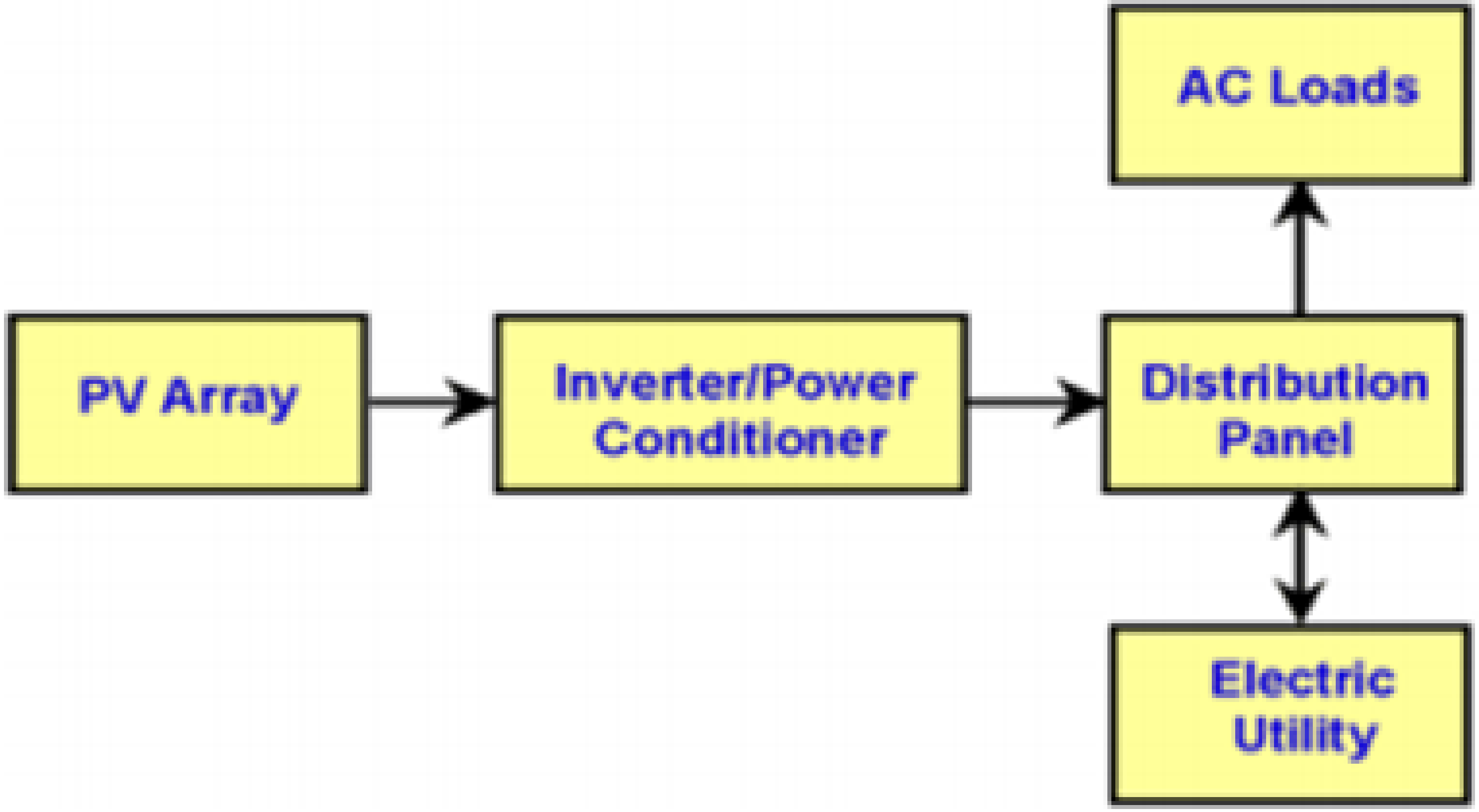




Stand-alone PV Power System

2) Grid connected solar PV system:





Grid-connected PV Power System

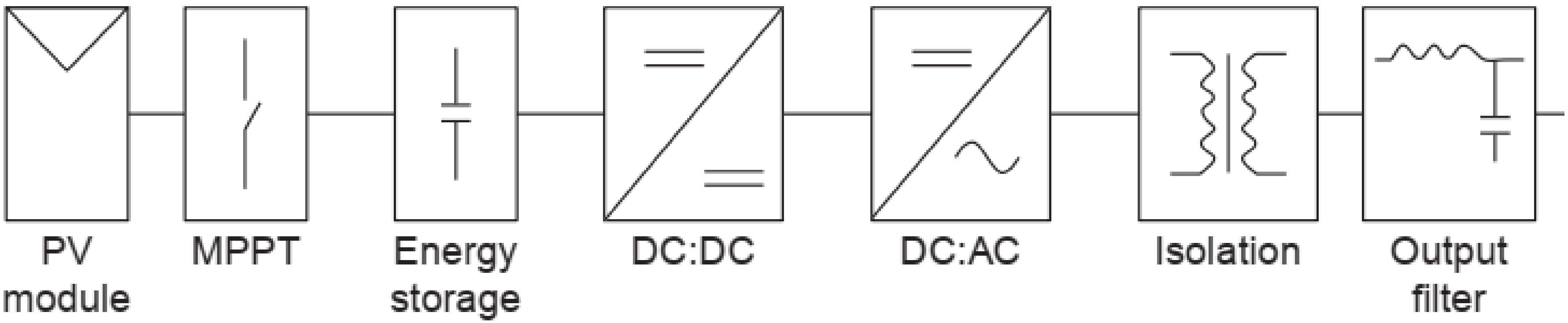


Figure: Schematic representation of a small PV inverter for ‘grid-connected’ operation

(1) MPPT circuit

(2) Energy storage

(3) DC:DC converter to increase the voltage,

(4) DC: AC inverter stage,

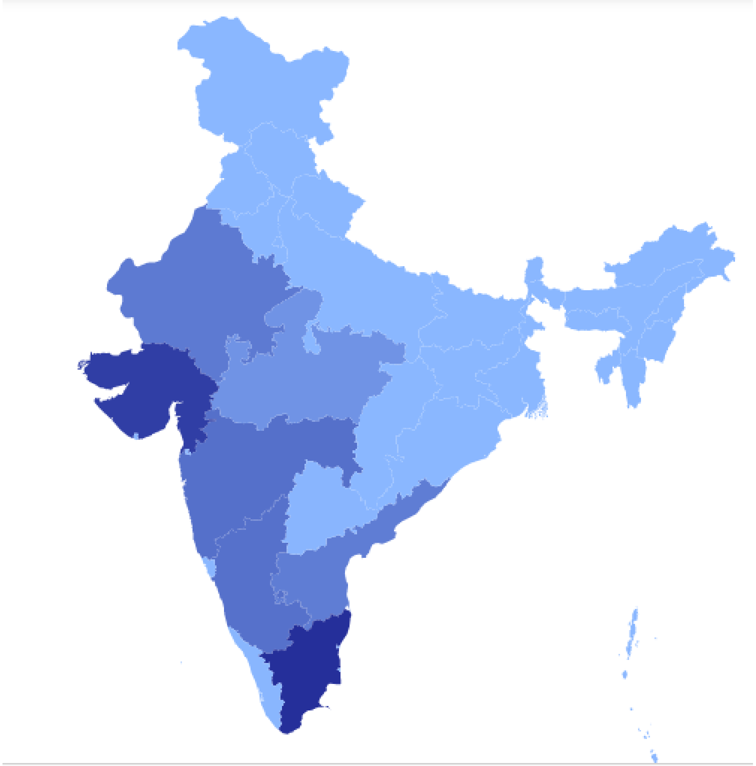
(5) Isolation transformer to ensure DC is not injected into the network

(6) Output filter to restrict the harmonic currents passed into the network

WIND ENERGY:

India’s wind energy sector is led by indigenous wind power industry and has shown consistent progress.

The country currently has the **fourth** highest wind installed capacity in the world with total installed capacity of **39.25 GW** (as on 31st March 2021)



https://mnre.gov.in/

Potential of Wind Energy in India:

An extensive Wind Resource Assessment is essential for the selection of potential sites.

The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 100m and 120m above ground level.

S. No.	State	Wind Potential at 100 m (GW)	Wind Potential at 120 m (GW)
1	Gujarat	84.43	142.56
2	Rajasthan	18.77	127.75
3	Maharashtra	45.39	98.21
4	Tamil Nadu	33.79	68.75
5	Madhya Pradesh	10.48	15.40
6	Karnataka	55.85	124.15
7	Andhra Pradesh	44.22	74.90
	Total 7 windy states	292.97	651.72
8	Others	9.28	43.78
	Total	**302.25**	**695.50**

Wind power plants:

A wind turbine operates by extracting kinetic energy from the wind passing through its rotor. The power developed by a wind turbine is given by:

$$P = \frac{1}{2} C_p \rho V^3 A$$

where Cp = power coefficient – a measure of the effectiveness of the aerodynamic rotor,

P = power (W),

V = wind velocity (m/s),

A = swept area of rotor disk (m2)

ρ = density of air (1.25 kg/m3).

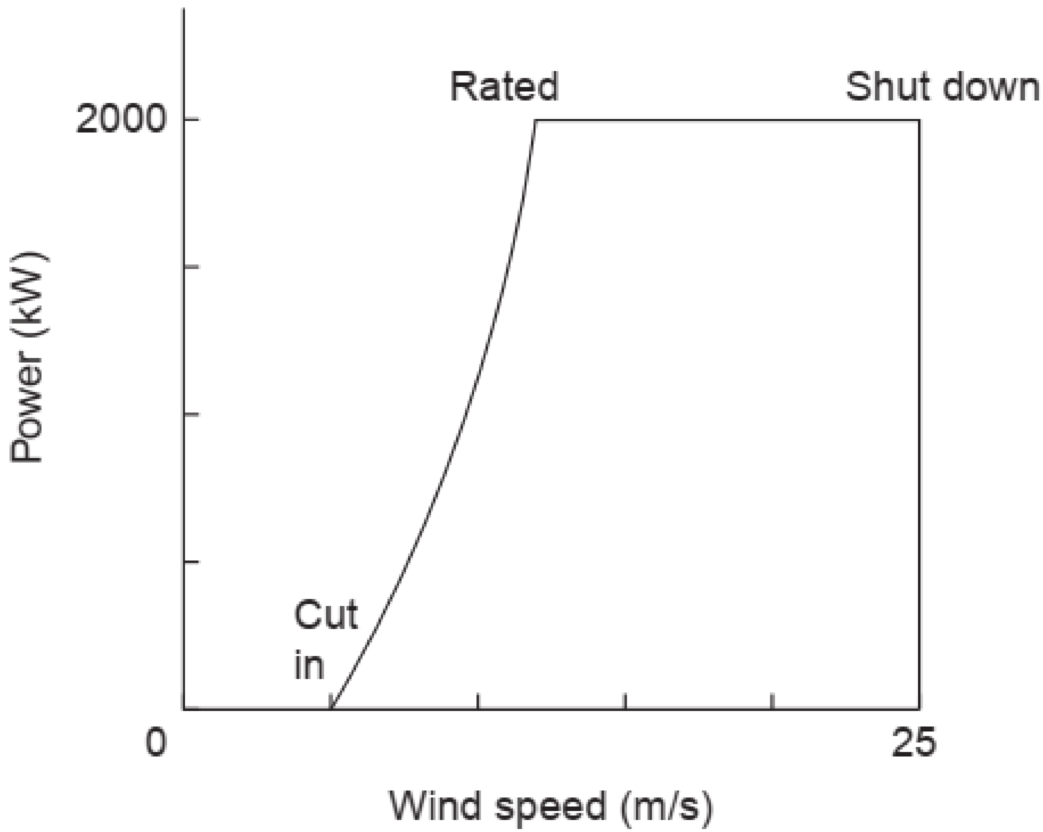
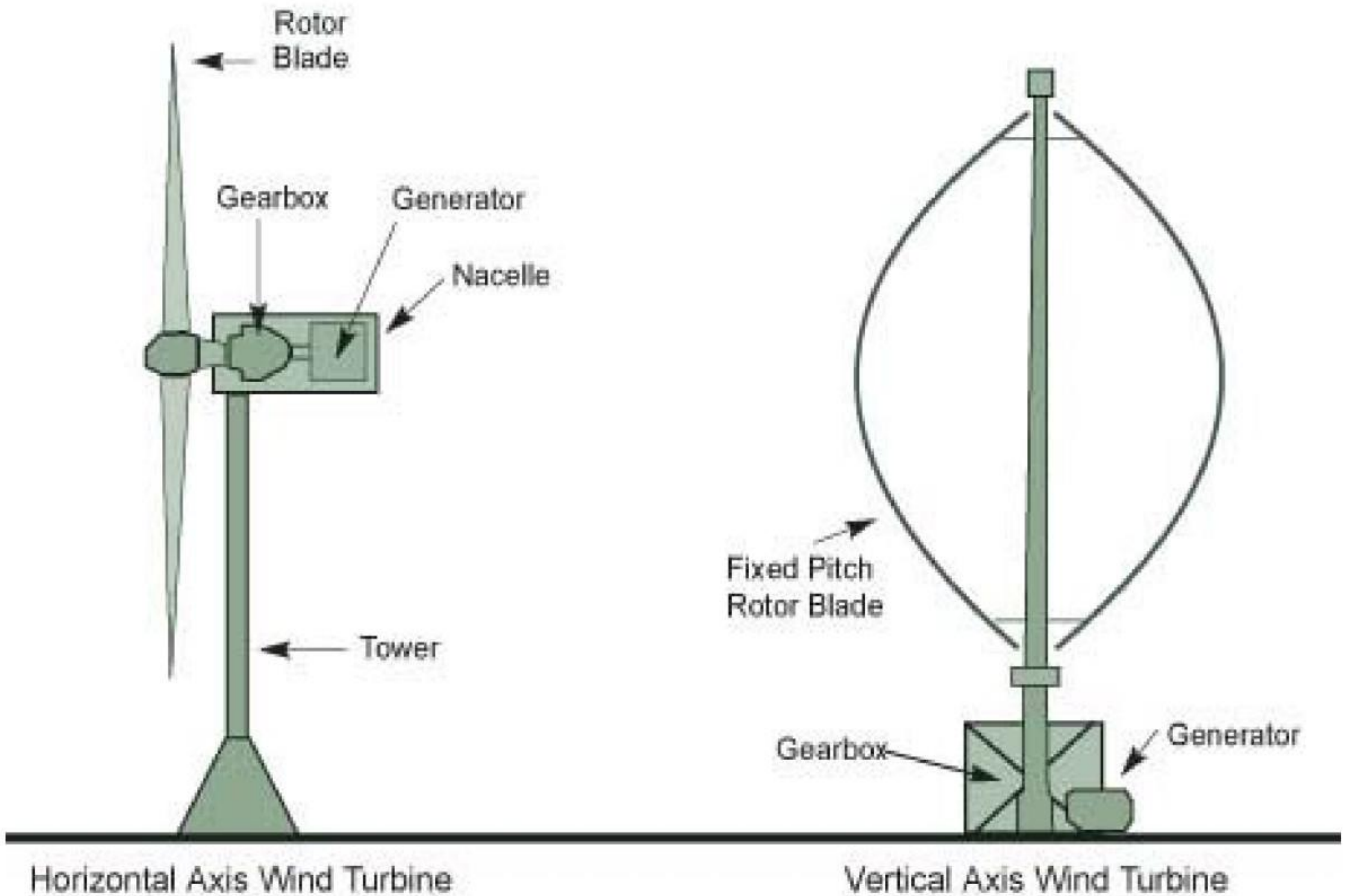


Fig. Wind turbine Power Curve

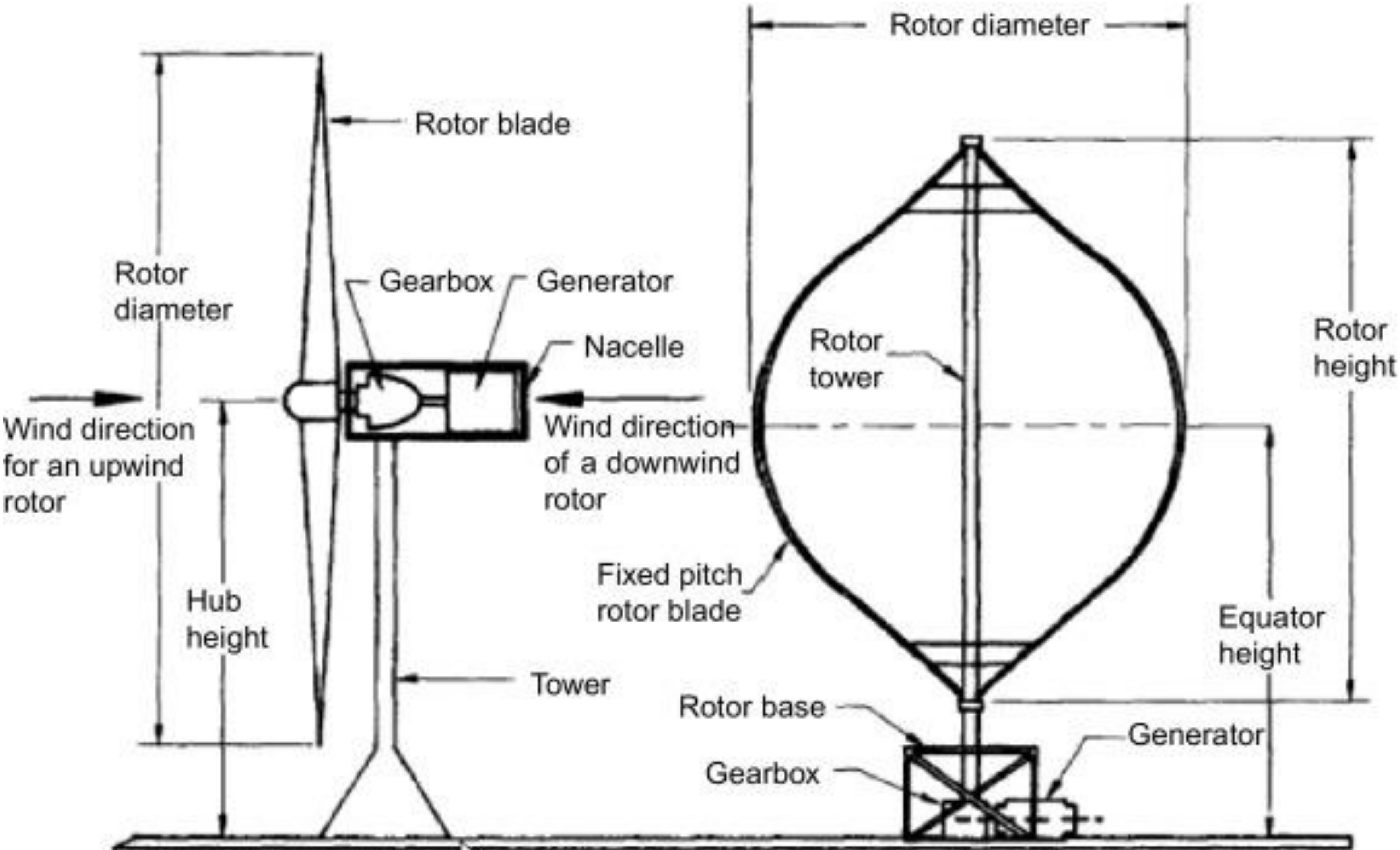
Configurations of Wind Turbine:

There are two types of wind turbines available

(i) Horizontal-axis wind turbines (HAWTs) (ii)Vertical-axis wind turbines (VAWTs)



Configurations of Wind Turbine:



Horizontal-axis wind turbine (HAWT)

Vertical-axis wind turbine (VAWT)

Vertical-axis wind turbines:

Vertical-axis wind turbines (VAWTs) have an axis of rotation that is vertical, and so, unlike the horizontal wind turbines, they can capture winds from any direction without the need to reposition the rotor when the wind direction changes

But there are some disadvantages such as smaller power coefficient than obtained in the horizontal-axis wind turbines, strong discontinuation of rotations due to periodic changes in the lift force.

Horizontal-axis wind turbines are, by far, the most common design. There are a large number of designs commercially available ranging from 50 W to 4.5 MW.

The mechanical and aerodynamic balance is better for three-bladed rotor

Comparison of wind turbines

Type of wind turbines		Yield	Strength of necessary wind	Violent winds resistance	Installation on the frame	Area
Horizontal axis		Good (between 100 W and 20 kW)	High	Low (Need installation of breaks and guyed mast	No (Except for small wind turbines) because it induces vibration	Open area
Vertical axis	Darrieus wind turbine	Medium (until 10 KW). Can be better with a Reduction gear	Medium (due to a heavy rotor)	Good	Yes	Open or Urban area
	Savonius wind turbine	Low. Need to add a reduction gear	Low	Good	Yes only if the roof can support the weight of the turbine	Open area, Urban area or lower installations

Onshore and Offshore winds :

- Onshore wind power refers to turbines located on land rather than over water.

- Offshore wind power refers to wind farms that are located over open water, usually in the ocean, where there are higher wind speeds.

- The motivations for developing offshore wind energy include: the higher-quality wind resources located at sea.

Fig.1

Fig.2

- Wind energy is one of the largest sources of renewable energy.

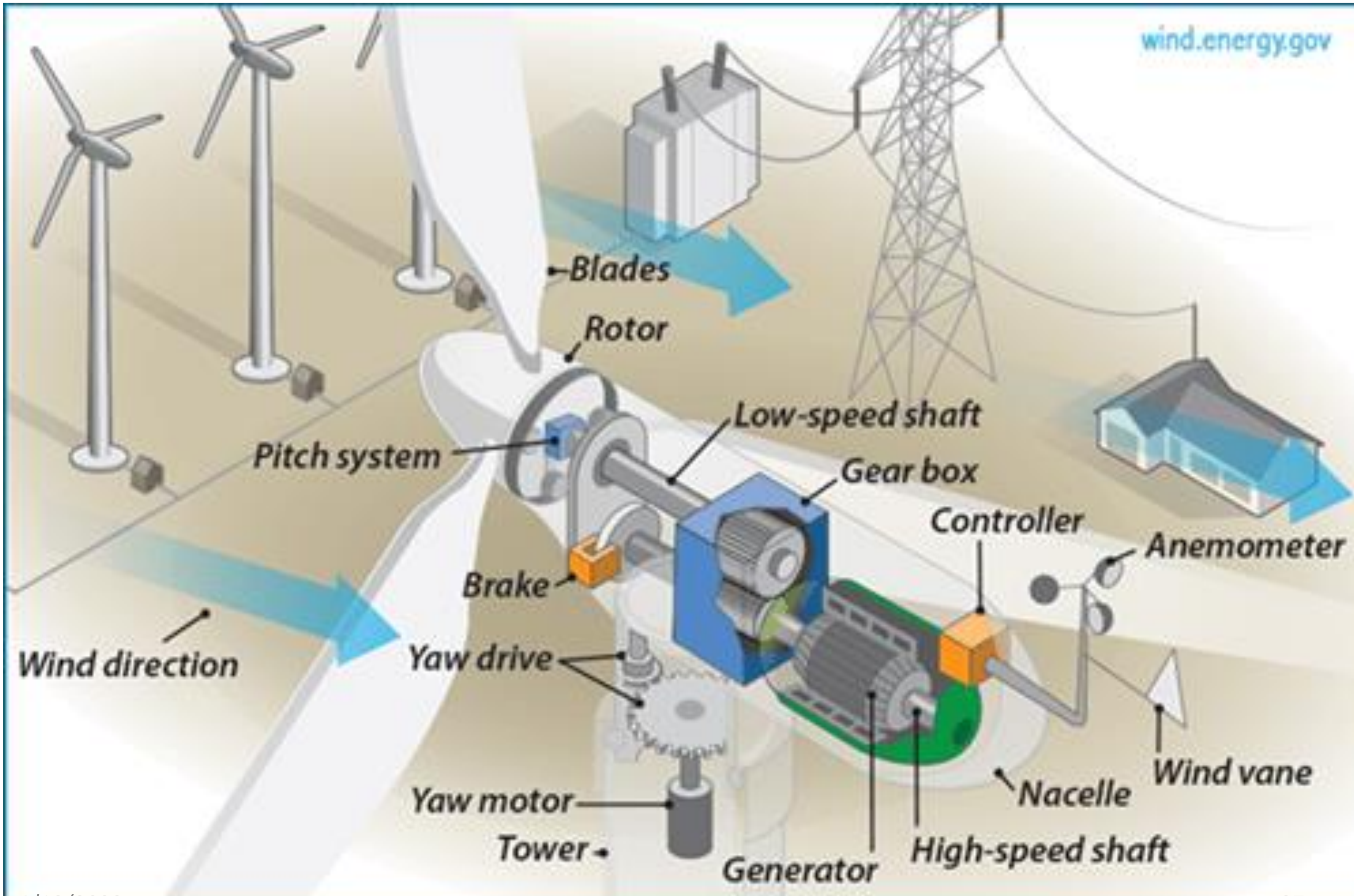
- Winds are caused by the uneven heating of atmosphere by the sun, the irregularities of the earths surface, and rotation of the earth.

- Wind energy is harnessed by wind turbines, which convert the energy of the wind into electricity.

- Wind speed generally increases with height, which is why wind turbines tend to be very tall

- Wind speed over the ocean tend to be faster and steady than on land.

Construction

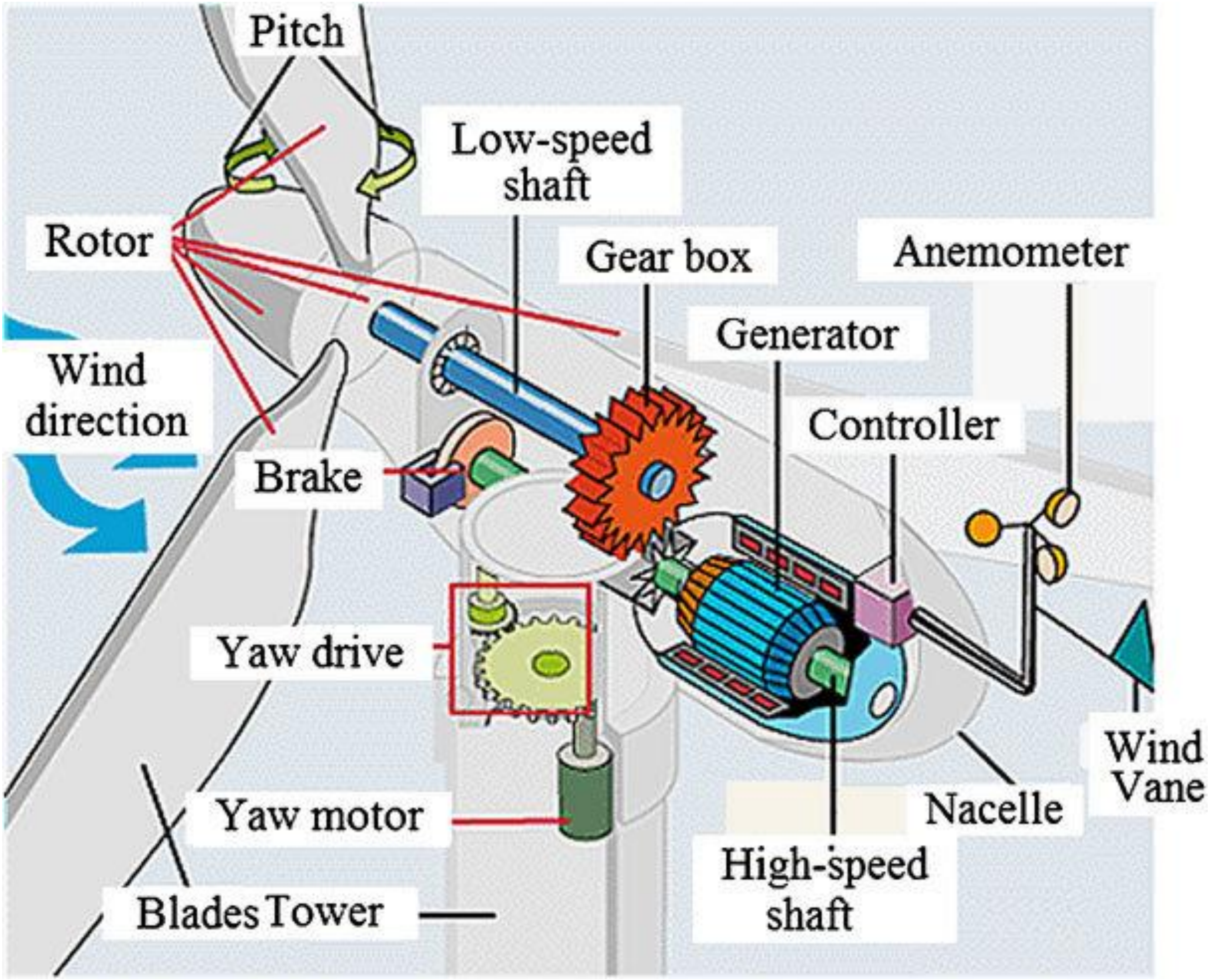


Blade: Blade is a rotating component designed aerodynamically to work on the principle of lift and drag to convert kinetic energy of wind into mechanical energy

Rotor: Blades and the hub together are called the rotor.

Necelle: It is a cover housing that houses all of the generating components in a wind turbine

Tower: A tower's height is crucial for turbines because wind speed increases with height.

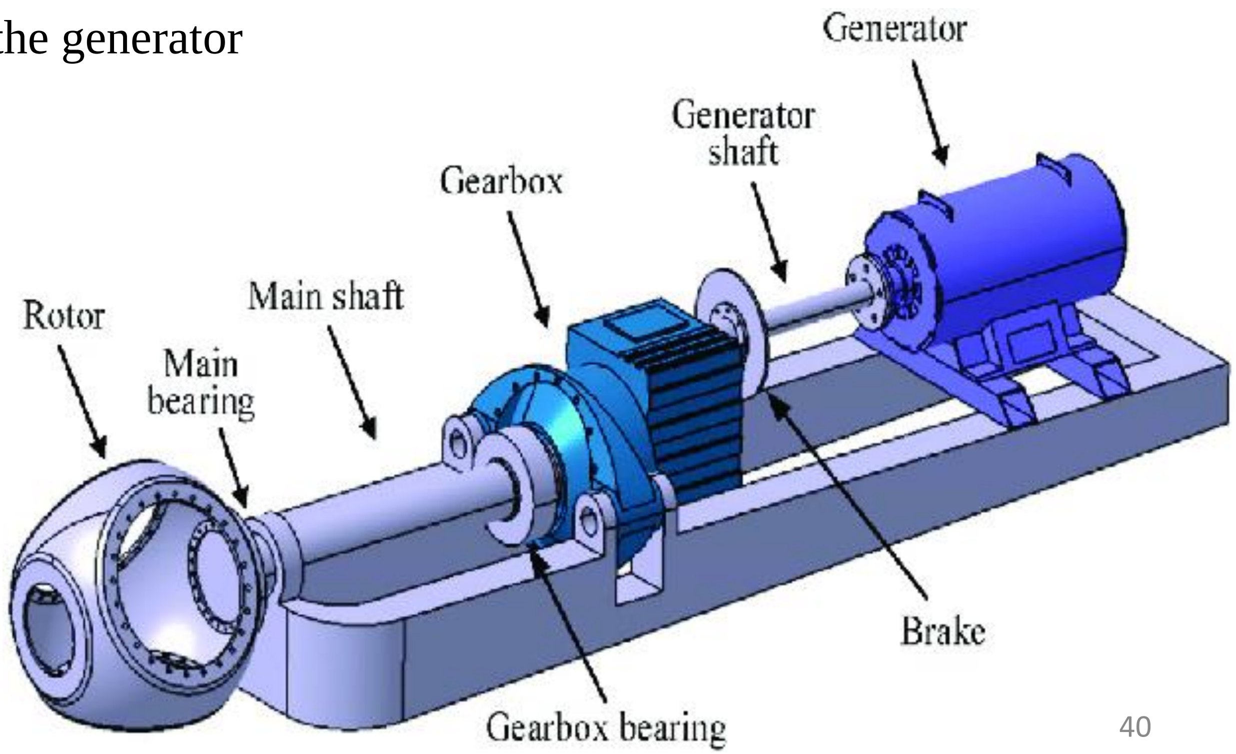

Pitch
Low-speed shaft
Rotor
Gear box
Anemometer
Generator
Wind direction
Controller
Brake
Yaw drive
Wind Vane
Yaw motor
Nacelle
High-speed shaft
Blades Tower

Low speed Shaft:

- Transfer torque from the rotor to the rest of the drive train
- It is connected to gearbox to increase the rpm.

Gear Box: Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds according to the requirement of electric generator

High Speed Shaft: Drives the generator



Brake: During the periods of extremely high winds and maintenance, brakes are used to stop the wind turbine for its safety

Generator: Generator converts rotational mechanical energy into electrical energy

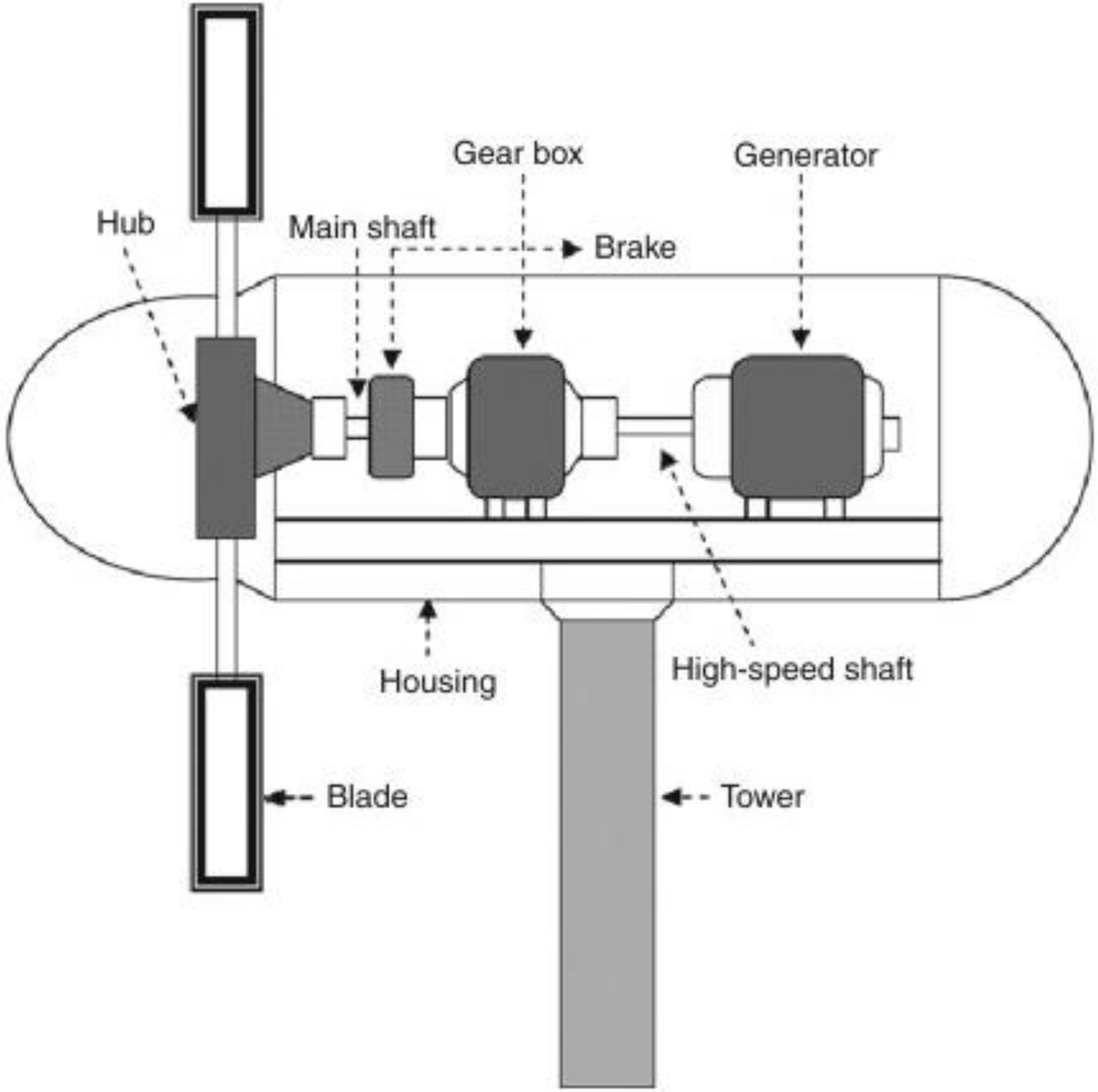
Controller: The controller measures and controls parameters like voltage, current, frequency, temperature inside nacelle, wind speed etc.

Anemometer: Measures the wind speed and transmits wind speed data to the controller for power regulation and breaking beyond the cut out and survival wind speed.

Wind vane: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind.

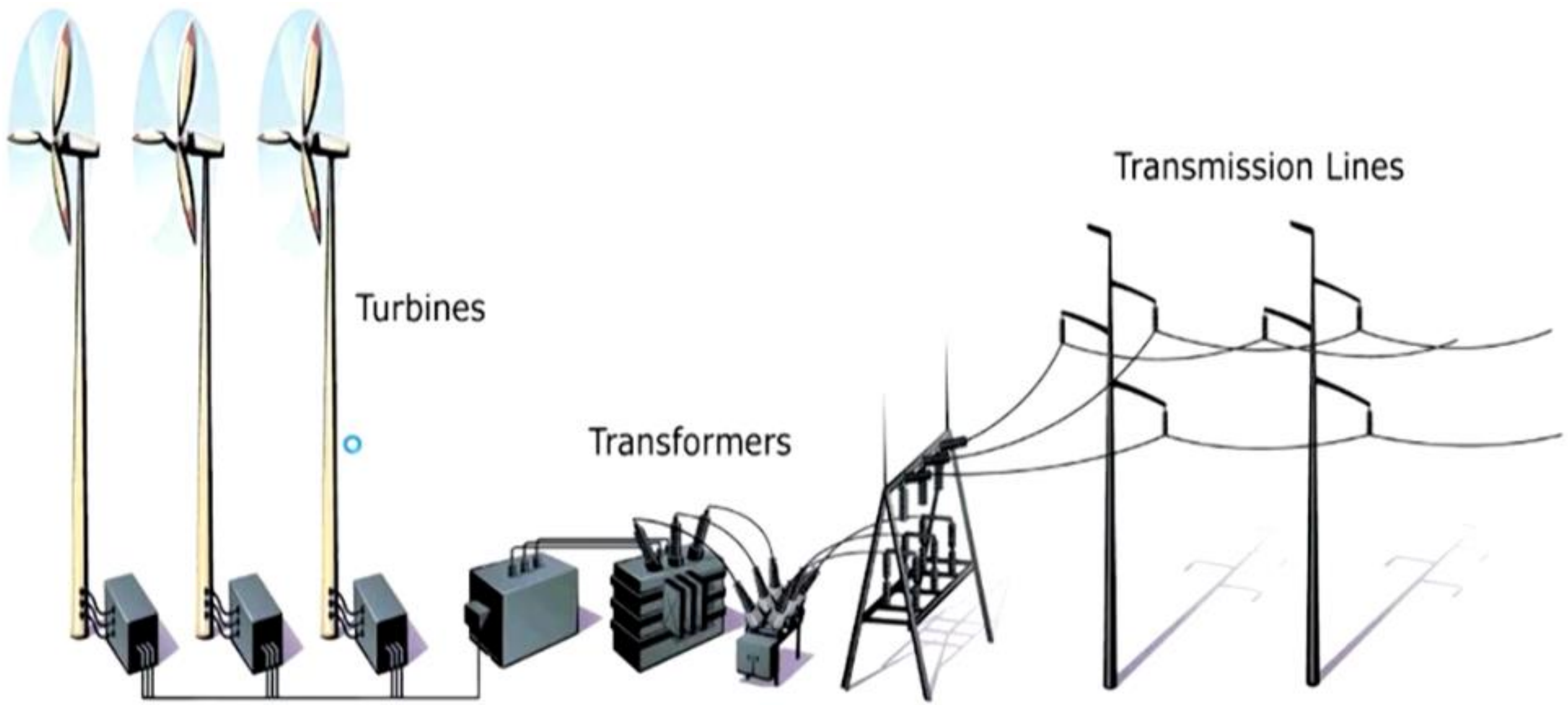
Yaw drive: Yaw drive turns the nacelle with rotor to the wind direction as the wind direction changes.

Yaw motor: Yaw motor is to power the Yaw drive.

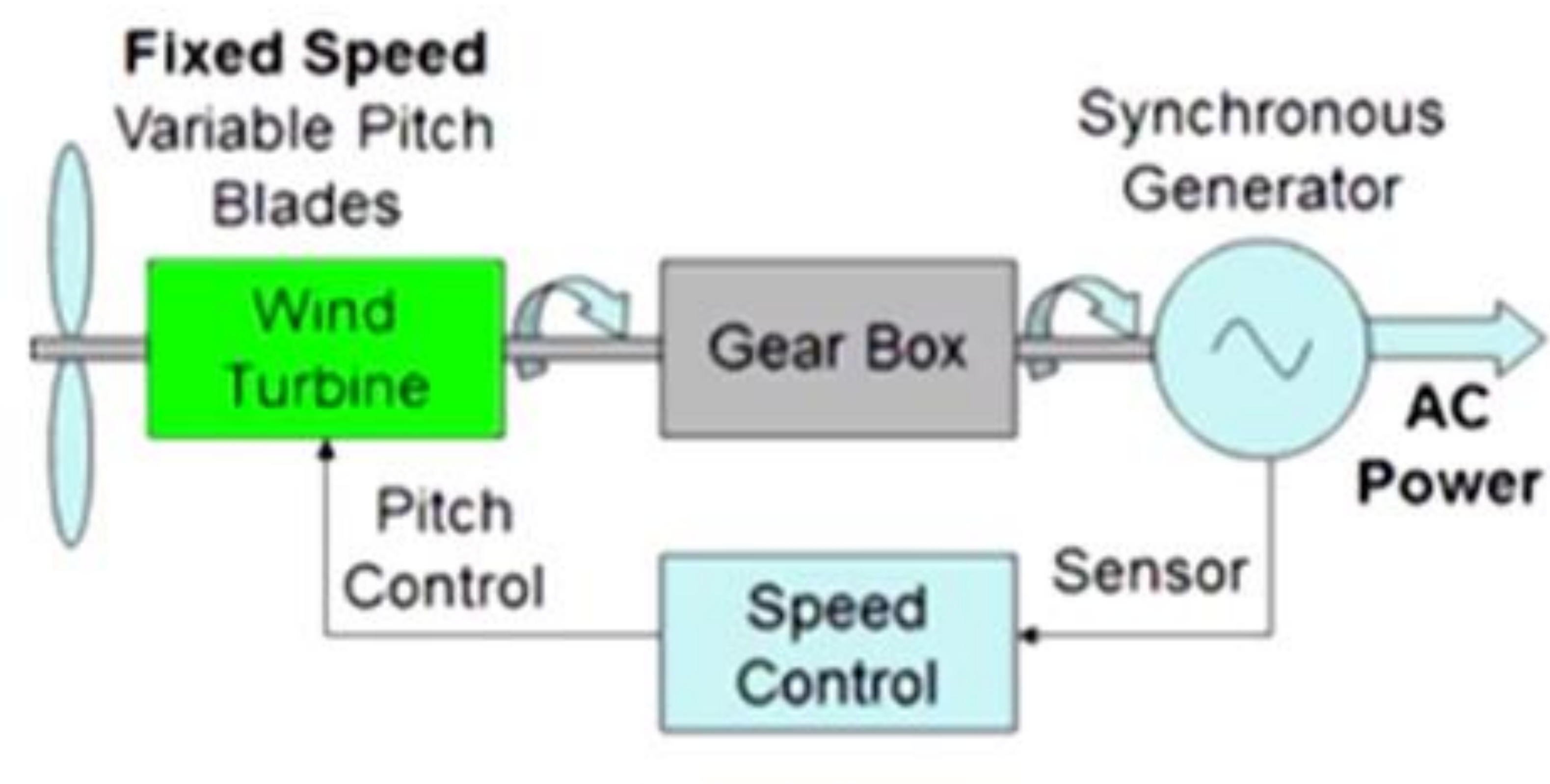


Sectional view of a HAWT

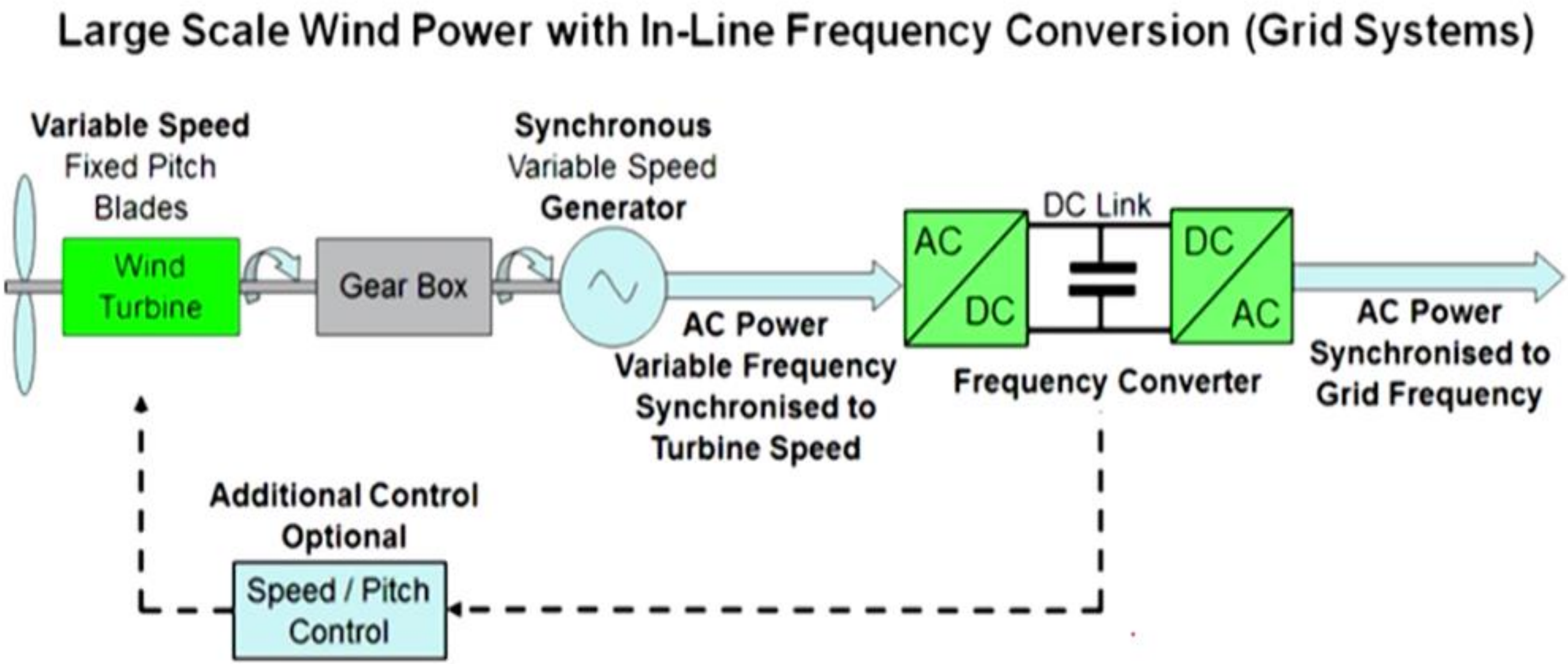
Wind Farms



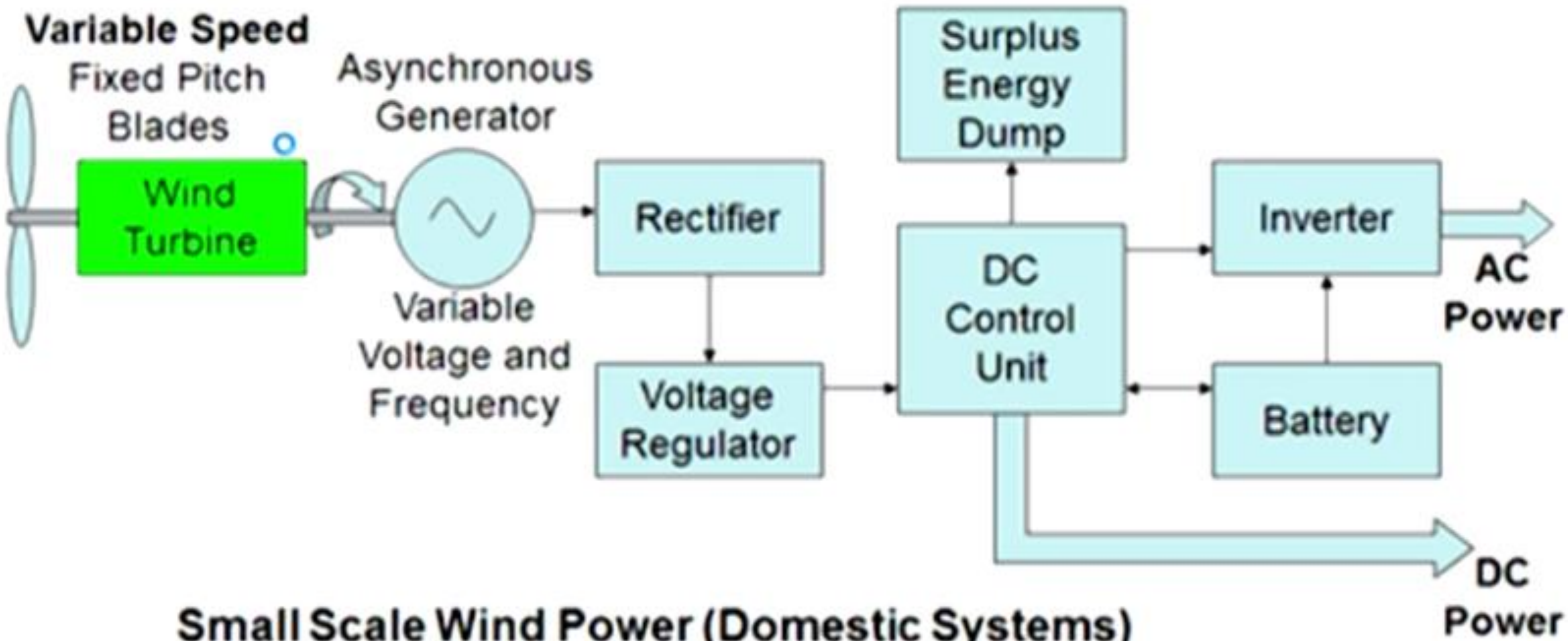
1) Fixed Speed Wind Turbine Generators:



Synchronous Generator with In-Line Frequency Control:

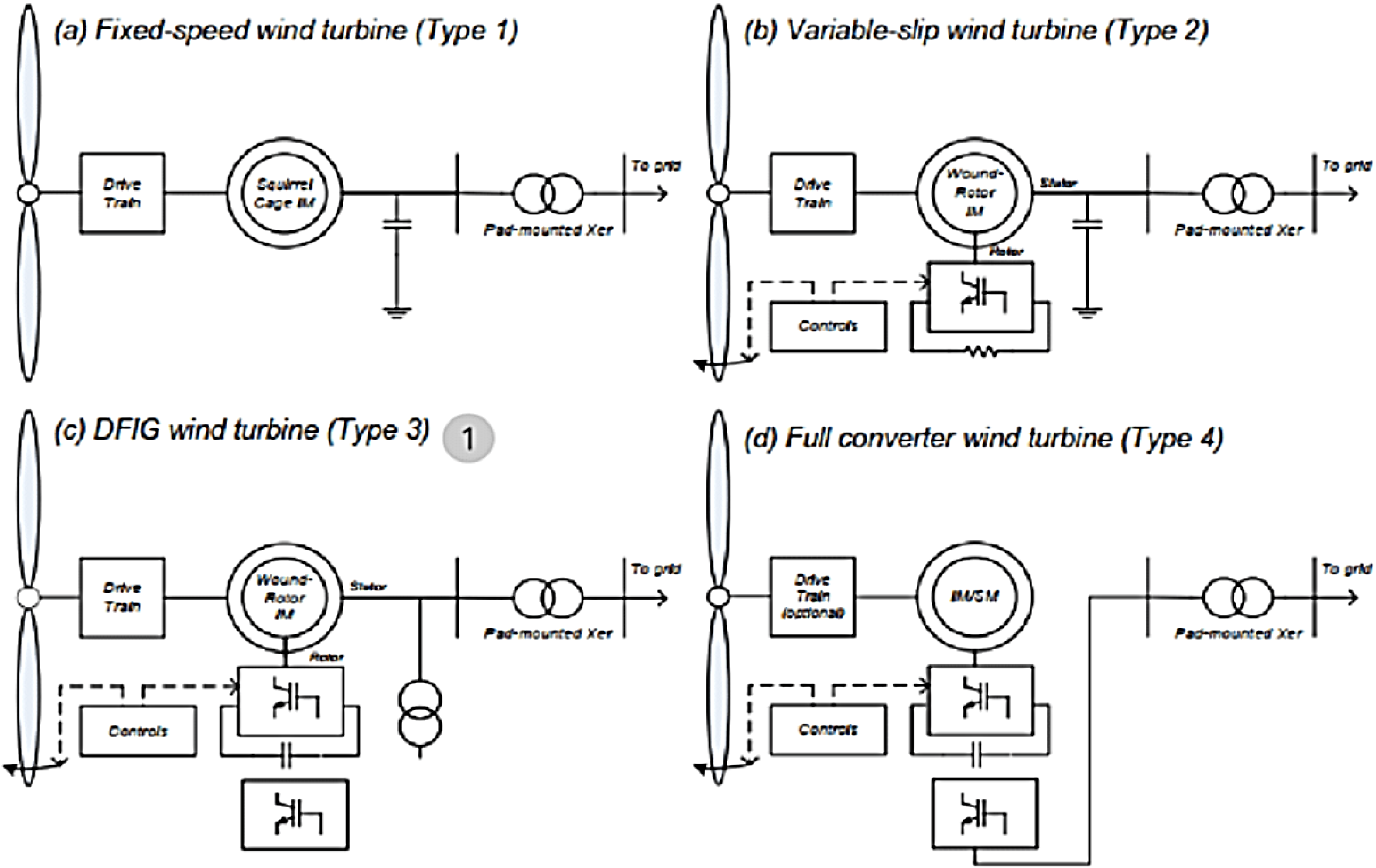


Domestic Wind Turbine Installation:



Small Scale Wind Power (Domestic Systems)

Types of wind turbine generators



Type 1 Fixed speed WTG

- Generator is an induction generator, which is directly interfaced with the host utility network.
- Rotor speed is determined by grid frequency, regardless of wind speed.
- Induction generator is equipped with an electronic starter and shunt capacitor bank for reactive power compensation.

✓ **Features:** Simplicity, robustness of components, and relatively low cost.

✓ Widely used in early 1990’s , not used for large size WTG.

o **Drawbacks:** Excessive mechanical stress, significant fluctuations in output quantities.

Type 2 Variable speed WTG (limited)

- Generator is a wound rotor induction generator.
- Generator is equipped with a rotor resistor adjustment device.
- It enables slip control, typically upto 10%.
- Shunt capacitor system for reactive power compensation.

✓ **Features:** As compared to Type 1 WTG, slightly aerodynamically more efficient has modestly lower drive train mechanical stress.

o **Drawbacks:** Not preferred choice for present day large size WTG.

Type 3 Variable speed WTG with DFIG

- WTG is composed of a pitch controlled wind turbine, a gear box and a doubly-fed induction generator.
- Stator of the DFIG is directly connected to the host power system.
- Three phase rotor circuit is connected to the grid through a back-to-back voltage sourced converter system.
- ➢ Applies the voltage across the rotor that is regulated by two rotor current controllers.
- Typically provides variable speed operation from 30% to 40% of the nominal power system frequency. Shunt capacitor system for reactive power compensation.
- ✓ **Features:** Aerodynamically more efficient, lower drive train mechanical stress, and lower power/voltage fluctuations.

Salient features of DFIG

- Wound rotor induction generator with slip-rings.
- Rotor is fed from three phase variable frequency source, thus allowing variable speed operation.
- The variable frequency supply to the rotor is attained through the use of two voltage source converters linked via capacitor.
- Since the converter system **handles only the rotor quantities**, its rating is significantly smaller (about 30%) than the generator rating.
- **Features:** Reduction of mechanical stress, higher overall efficiency, reduced acoustical noise.

Type 4 Variable speed WTG with front end converter system

- Generator is either a induction machine or synchronous machine.
- turbine, a gear box and a doubly-fed induction generator.
- Stator of the DFIG is directly connected to the host power system.
- Three phase rotor circuit is connected to the grid through a back-to-back voltage sourced converter system.

➢ Applies the voltage across the rotor that is regulated by two rotor current controllers.

✓ **Features:** Aerodynamically more efficient, lower drive train mechanical stress, and lower power/voltage fluctuations.

○ **Drawbacks:** Not preferred choice for present day large size WTG.