# Non-Conventional Energy Resources
# Unit-IV

**Thermo-electrical and thermionic conversions:** Principle of working, performance and limitations.
**Wind energy:** Wind power and its sources, site selection, momentum theory, classification of rotors, concentrations and augments, wind characteristics, performance and limitations of energy conversion systems.

## THERMO-ELECTRICAL AND THERMIONIC CONVERSION

**Principle of Thermo-Electrical Energy Generation:** The thermo electrical devices are those solid-state devices which work on ***Seebeck effect*** and converts thermal energy into electrical energy.

**Seebeck Effect:** German Scientist (in 1821) Seebeck discovered, that when two dissimilar metals are used to form a closed circuit (loop) and two junctions are maintained at different temperature then and e.m.f is set up between the junctions, called thermo-electric e.m.f. Due to this e.m.f and closed circuit a current start to flow which depends on both the materials and the temperature difference between the junctions. The magnitude of open circuit may be calculated by: $V = \alpha \cdot \Delta T$

Where $\alpha$ → Seebeck coefficient (V/K).
$\Delta T$→Temperature difference between hot and cold junction (Kelvin).
This arrangement is known as ***thermocouple***

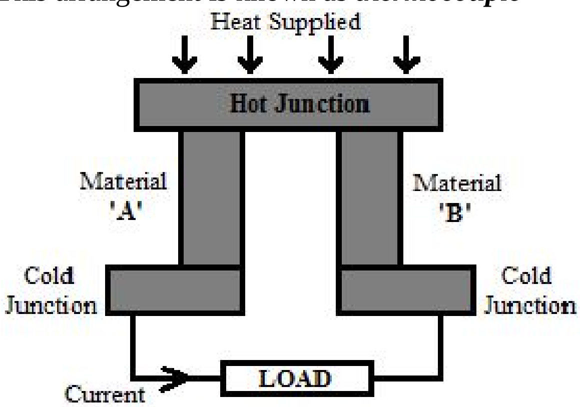


Fig. Thermo-electric Converter

**Peltier Effect:** The reverse effect of Seebeck effect *i.e.* when two dissimilar metals are used to made a closed circuit and current passes through it, then one junction becomes hot and other becomes cold. This effect is called ***Peltire effect.*** This effect is used for development of thermoelectric refrigerators and calculation of efficiency of thermoelectric generator.

**Thomson Effect:** According to William Thomson, "Any current carrying conductor with a temperature difference between two points, will either absorb or emit heat, depends on the type of materials used".

**Thermoelectric Material Selection:** The efficiency of the thermoelectric generator depends on material used and temperature difference between the junctions. The material used for thermoelectric generator should have following characteristics:

1. The metal should have high Seebeck coefficient.
2. They should have low thermal conductivity, helps to maintain large temperature gradient.
3. Should be stable in high temperature region.
4. The material should have low electrical resistivity.
5. The material should have high resistance to corrosion.

Generally semiconductor materials are used for thermoelectric generator.

**Thermoelectric Power Generator:** The efficiency of a single stage generator has low output. To improve the power output a number of generators are grouped in: (1) Series and (2) Parallel.
In such connections the efficiency of cascade system is sum of the efficiency of each generator.

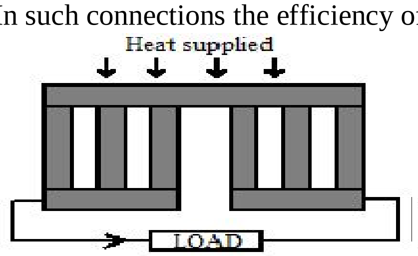


Fig. Parallel connection

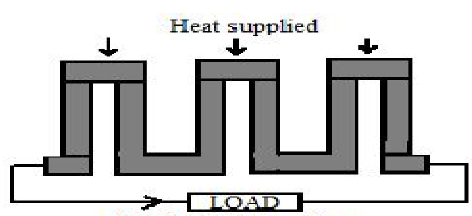


Fig. Series connection

**Thermionic Converter:** Thermoelectric generators are devices that convert heat directly into electrical energy, using a phenomenon called the Seebeck effect. These are also called Seebeck generators.

**Working:**

- A thermionic energy converter (or) thermionic power generator is a device consisting of two electrodes placed near one another in a vacuum.
- One electrode is normally called the cathode, or emitter, and the other is called the anode, or plate.
- Ordinarily, electrons in the cathode are prevented from escaping from the surface by a potential-energy barrier.
- When an electron starts to move away from the surface, it induces a corresponding positive charge in the material, which tends to pull it back into the surface.
- To escape, the electron must somehow acquire enough energy to overcome this energy barrier.
- At ordinary temperatures, almost none of the electrons can acquire enough energy to escape.
- However, when the cathode is very hot, the electron energies are greatly increased by thermal motion.
- At sufficiently high temperatures, a considerable number of electrons are able to escape.
- The liberation of electrons from a hot surface is called *thermionic emission.*

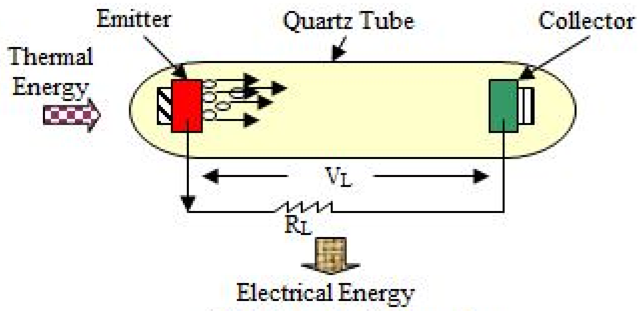


Fig. Thermionic Convertor

***Richardson law states that the emission current density is exponentially depend on work function and inversely depends upon the absolute temperature.***

According to Richardson, the emission current density 'J' can be expressed as,

$\mathbf{J = AT^2 \exp(-\Phi/KT)}$ Amperes/m$^3$

Where: A-Emission constant (A/m$^3$/K$^2$); Φ - Work function; T – absolute temperature (Kelvin)
K – Boltzmann constant; J - emission current density.

**Advantages, Disadvantages & Applications of Thermionic Converters:**

| **Advantages** | **Disadvantages** | **Applications** |
|---|---|---|
| Higher efficiency | There is a possibility of vaporization of emitter surface | They are used in space power application for spacecraft |
| High power density | Thermal breaking is possible during operation | They are used to power submarines and boats |
| Compact to use. | The sealing is often gets failure | They used in water pump for irrigation, |
| | | They used in power plant for industry and domestic purpose |

## WIND ENERGY

**Wind Energy and Its Sources:** Wind energy is an indirect form of solar energy. They are caused by the uneven heating of earth's surface and its rotation. The winds can be classified in two categories:

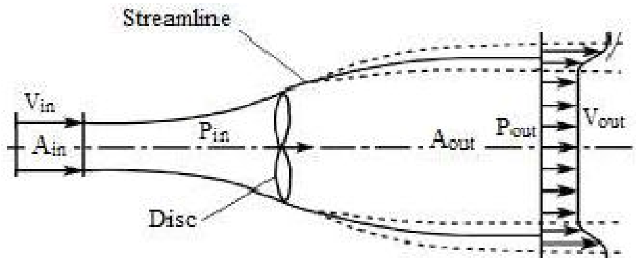
**(*i*) Local Winds:** Local wind is caused due to unequal heating and cooling of ground surface and water bodies at day and night. During day time land is hotter than sea due to which air near the surface becomes hot faster than the sea which creates a pressure difference between surface and sea shore and due to this difference in pressure cool air at high pressure zone (from sea) will move towards the land and these breeze are known as **sea breeze.** Its vice versa action is taken place at night and now air starts to move from surface to sea and such breeze are known as **land breeze.**

(*ii*) **Planetary Wind:** These are caused due to unequal heating of the earth's surface near the equator and the northern or southern poles. Because of this, warm air from tropical regions flows upward and moves towards the poles and cool air from poles moves towards the tropical region.

## Wind Power (Momentum Theory):

If *m* be the mass of the air moving with velocity *V*, per unit time, then
the power associated with it may be calculated by:
$P = 1/2\, mV^2$…………..(1)
If $A$ = cross sectional area of the wind stream ($m^2$)
$\rho$ = density of air ($kg/m^3$)
Then mass flow rate (kg/s) of air : $m = \rho AV$
$\therefore P = 1/2(\rho AV)\, V^2 = 1/2\, \rho AV^3$……… (2)
Now if the diameter of wind aero turbine be $D \Rightarrow A = (\pi/4)\, D^2$
The total wind power:

$$P = \tfrac{1}{2}\, \rho\, (\pi/4)\, D^2 V^3 = \frac{1}{8}\, \pi \rho D^2 V^3$$
…………………………(3)




**Power transferred by wind turbine:** The amount of power transferred by wind is directly proportional to the density of the air, wind speed and area of the opening as given in equation (3). If a basic layout of a wind turbine is as shown in figure having different parameters as shown in figure

The thrust on the turbine (*i.e.*) momentum: $F = m\,(V_{in} - V_{out})$ ……. (4)
The power extracted by turbine $P_T = m\,(V_{in} - V_{out})\, V_{rot}$…… (5)
We know that change in kinetic energy is converted into this extracted power, so:
$m\,(V_{in} - V_{out})\, V_{rot} = 1/2\, m(V_{in}^2 - V_{out}^2)$
$\Rightarrow V_{rot} = (V_{in} + V_{out})/2$
Now rate of flow of mass through turbine:
$m = \rho A_{out} V_{rot} = \rho A_{out}\, (V_{in} + V_{out})/2$……(6)
Hence from equation (5):
$P_T = \rho A_{out}(V_{in} + V_{out})/2\,(V_{in} - V_{out})\,(V_{in} + V_{out})/2$

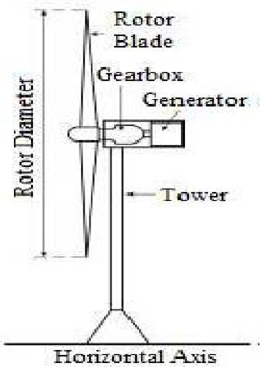
$$P_T = \tfrac{1}{4}\, \rho A\, (V_{in} + V_{out})\, (V_{in}^2 - V_{out}^2)$$

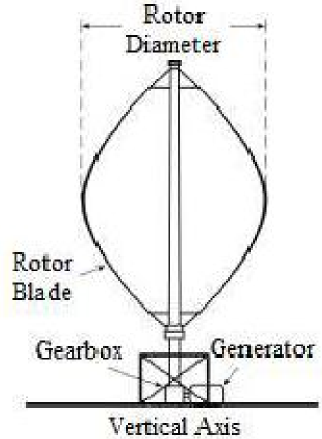
And from equation (4) & (6), Thrust on the turbine
$F = \rho A(V_{in} + V_{out})/2\,(V_{in} - V_{out})$

$$F = \frac{\pi}{8} \rho D^2\, (V_{in}^2 - V_{out}^2)$$

**Classifications of Wind Turbines:**

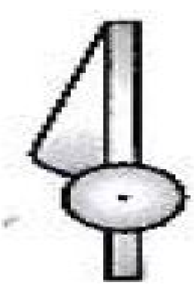
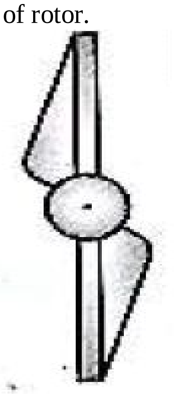
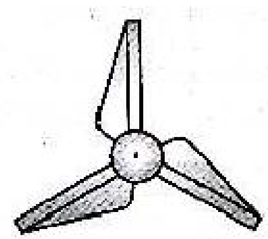
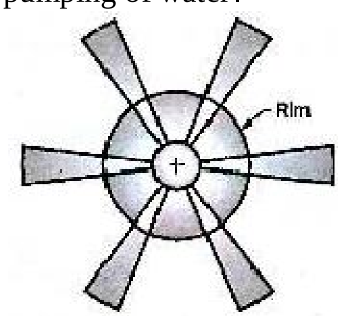
Wind turbines may be classified into two categories: **(1) Horizontal axis, (2) Vertical axis**.



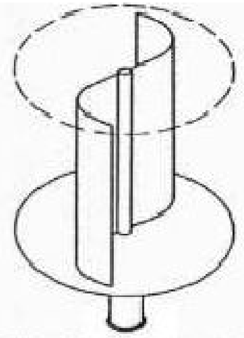
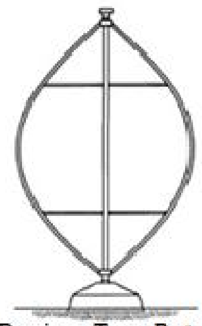

**Horizontal Axis Wind Turbines:**

- The orientation of these turbines are kept along the horizontal axis and can be divided into:

| **(a) Mono-blade machine** | **(b) Twin-blade machine** | **(c) Three-blade machine** | **(d) Multi-blade machine** |
|---|---|---|---|
| ➢ These are simple in construction.<br>➢ Installation is easy and having low cost and easy maintenance.<br>➢ Can produce low power of 15kW – 50 kW.<br>➢ Generally used for pumping, battery charging and other agricultural purpose.<br> | ➢ These machines are rated from 1MW – 3MW.<br>➢ They are less costly than three blade machines but having large vibration during running.<br>➢ This vibration is caused due to unequal force at lower and vertical positions of rotor.<br> | ➢ These are high in cost but also more efficient.<br>➢ These machines are rated from low capacity 15kW to higher capacity of 3MW.<br> | ➢ Having high starting torque characteristics.<br>➢ These machines are used for pumping of water.<br><br> |

**Vertical Axis Wind Turbine:** These turbines are mounted on ground level and their blades go from top to bottom. These are basically of two designs:

| **(a) Savonious Type Rotor** | **(b) Darrieus Type Rotor** |
|---|---|
| ➢ In such turbines **'S'** shaped rotor (also called **S-rotor**) is supported at top and bottom by two circular plates.<br>➢ The A hollow cylinder is sliced into two pieces and each of these halves fixed to a vertical axis with a fixed gap.<br>➢ The air strikes on concave side, circulating through centre of rotor and glides over the convex surface of the other blade.<br>➢ The tip to speed ratio of turbine is 1-2 and efficiency 15-30%. | ➢ The turbine consists of a number of curved aerofoil blades mounted on a vertical rotating shaft or framework.<br>➢ The curvature of the blades allows the blade to be stressed only in tension at high rotating speeds.<br>➢ _When the Darrieus rotor is spinning, the aero-foils are moving forward through the air in a circular path.<br>➢ Relative to the blade, this oncoming airflow is added vector ally to the wind, so that the resultant airflow creates a |

| | |
|---|---|
| ➢ These rotors having low rpm (up to 100rpm).<br>➢ These are basically useful for agricultural purpose not for electricity generation.<br><br>Savonious Type Rotor | varying small positive angle of attack (AoA) to the blade.<br>➢ These turbines are available in size of 4 MW – 14 MW capacities with efficiency of 35 – 40%.<br><br>Darrieus Type Rotor |

## Advantages, Disadvantages and Environmental Impact of Wind Energy

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| Advantages | Disadvantages | Environmental Impact & Limitations |
|---|---|---|
| ➢ Pollution free and not release toxic gases<br>➢ It is renewable & free of cost<br>➢ Have low maintenance cost.<br>➢ Doesn't require any transportation<br>➢ Doesn't require consumption of water | ➢ High capital cost.<br>➢ Having low efficiency (10-45%).<br>➢ Depends on location, season and wind speed.<br>➢ Causes sound pollution<br>➢ Storage of wind is not possible | ➢ Wind Turbines can safely within the range of 5m/s to 24m/s wind speed.<br>➢ Proper land is required for installation of wind turbines, free from tall buildings, towers etc.<br>➢ Fatal collisions of birds caused by rotating turbine blades |

**Wind Energy in India:** India ranks fifth amongst the wind-energy-producing countries of the world after USA, China,Germany and Spain. As of 31 December 2013 the installed capacity of wind power in India was 20149 MW, mainly spread across Tamil Nadu (7154 MW), Gujarat (3,093 MW), Maharashtra (2976 MW), Karnataka (2113 MW), Rajasthan (2355 MW), Madhya Pradesh (386 MW), Andhra Pradesh (435 MW), Kerala (35.1 MW), Orissa (2MW), West Bengal (1.1 MW) and other states (3.20 MW). It is estimated that 6,000 MW of additional wind power capacity will be installed in India by 2014. Wind power accounts for 8.5% of India's total installed power capacity, and it generates 1.6% of the country's power.

**Site Selection:** Following factors are to be considered for selection of good site for wind power generation:

- High annual wind speed (should have an average wind speed in the range of 6 m/s to 30 m/s throughout the year).
- Historic data of wind mean speed must be collected for average velocities during the year to select the site for availability of wind velocities needed for installation of wind farms.
- Tower design must be adequate to withstand maximum wind speeds observed in the last few years in the installation area.

- No tall obstructions for a radius of 3 Km.
- Open plain or open shore
- Top of a smooth, well rounded hill with gentle slopes
- Mountain gap which produces wind funneling.