MEC 3102 – PRODUCTION ENGINEERING I AND ELECTRICITY & ELECTRONICS II

Department of Mechanical Engineering
The University of Zambia

Name: Mr. Munkombwe Boyd,

Old School of Engineering Blg.,
Cell: 0968315273/0950435239
Email: boyd.munkombwe@unza.zm

2nd Series Lecture 1[2]

Electric Power System

2.1 Comparison of source of power

- While selecting a method of generating electricity, the following factors are taken into account for purposes of comparison:

i. Initial cost:- For a given rating of a unit (in the minds of planners), investment must be known. Naturally, lower the initial cost, better it is.

ii. Running Cost:- To produce a given amount of electrical energy, the cost of conversion process (including proportional cost of maintenance/repairs of the system) has to be known.

iii. Limitations:- Whether a particular resource is available, whether a unit size of required rating is available from a single unit or from an array of large number of units, and whether a particular method of generation is techno-economically viable and is time-proven, are typical queries related to the limitations of the concerned method.

iv. (1) perpetuity, (2) efficiency, (3) reliability, (4) cleanliness and (5) simplicity. It is naturally desirable that the source must have perpetuity (= be of endless duration), high conversion efficiency, and reliability (in terms of availability in appropriate quantity). The energy conversion must be throughly a cleaner process (specially from the view- points of toxicity, pollution or any other hazardous side effects). Further, a simpler overall system is always preferred with regards to maintenance/repairs problems and is supposed to be more reliable.

2.2 Sources for Generation of Electricity

A. Conventional methods

Thermal (coal, gas, nuclear) and hydro-generations are the main conventional methods of generation of Electrical Energy. These enjoy the advantages of reaching perfections in technologies for these processes. Single units rated at large power-outputs can be manufactured along with main components, auxiliaries and switch- gear due to vast experiences during the past century. These units are efficient and economical.

1) Thermal: Thermal energy (from fossil fuels) or Nuclear Energy used for producing steam for turbines which drive the alternators (= rotating a.c. generators).

   I. Steam power station (coal-fired)

      - Chemical energy stored within the coal is finally transformed into Electrical energy through the process of these stations.
      - Heat released by the combustion of coal produces steam in a boiler at elevated temperatures and pressures.
      - It is then passed through steam turbines, which drive the alternator, the output of which is the electrical energy.

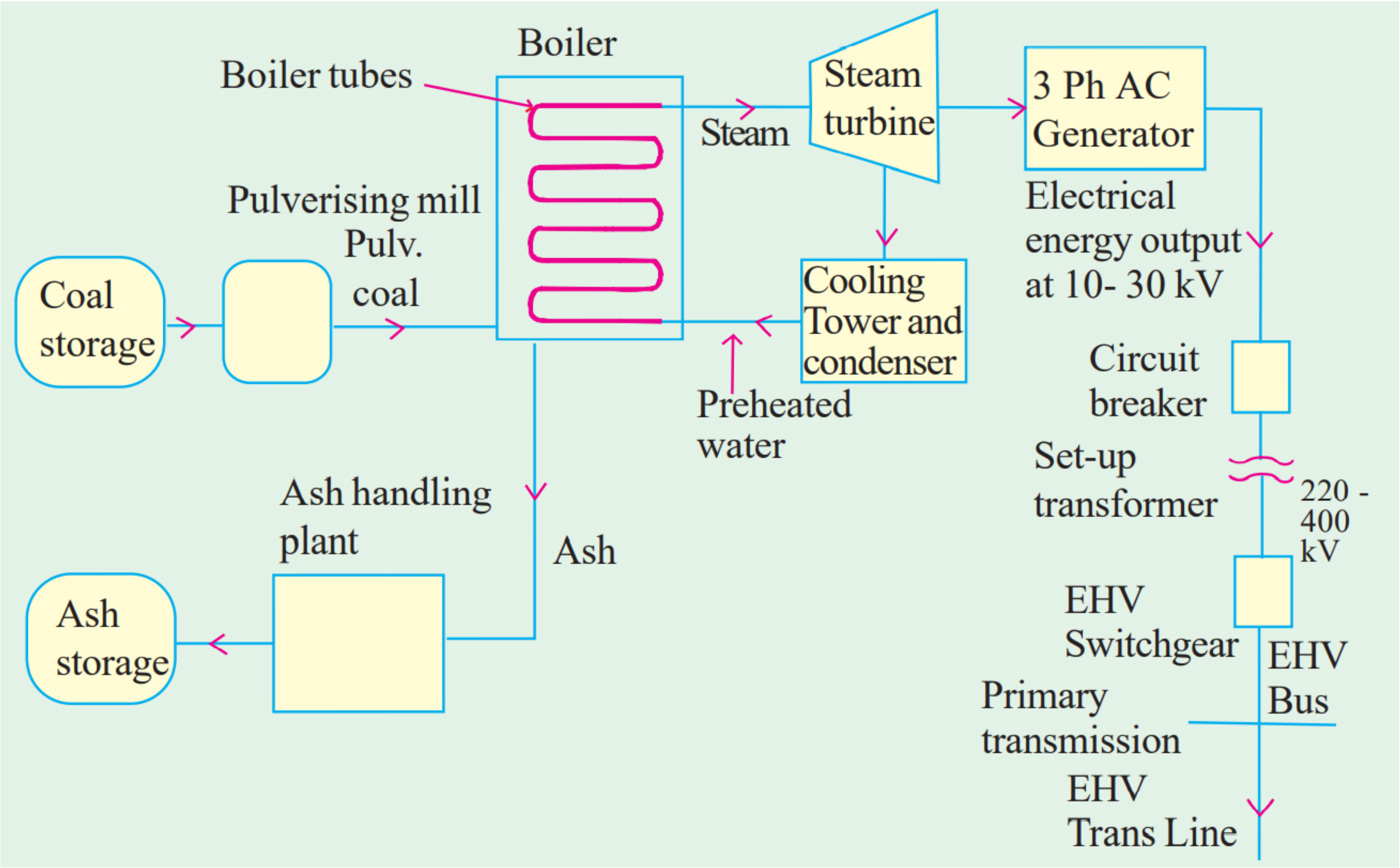

Fig. 3.1: Schematic representation of a coal-fired Thermal Station

- Coal is burnt in the boiler. This heat converts water into steam when passed through the boiler tubes.
- Modern plants have super heaters to raise the temperature and pressure of steam so that plant efficiency is increased.
- Condenser and cooling tower deal with steam coming out of turbine. Here, maximum heat is extracted from steam (which then takes the form of water) to pre-heat the incoming water and also to recycle the water for its best utilization.
- Steam-turbine receives controlled steam from boiler and converts its energy into mechanical energy which drives the 3-ph a.c. generator. The alternator delivers electrical energy, at its rated voltage (which may be between 11 to 30 kV).
- A modern coal-fired thermal power station consumes about 10% of its power for supplying to the Auxiliaries. These are mainly as follows.

a) Main-exciter for alternator.
b) Water pumps.
c) Fans: Forced draught and Induced draught fans for Pre-heaters and Chimney.
d) Coal handling plant including pulverising mill.
e) Ash handling plant including Electrolytic Precipitator.

So whenever such a station is to be brought into operation, the power required for the auxiliaries has to be supplied by the grid. Once the system is energized fully, it will look after supplying power to its own auxiliaries.

Merits

1. Fuel (= coal) is cheap.
2. Less initial cost is required.
3. It requires less space.
4. Combining all the above points, the cost of generating unit of electrical energy is less.

Demerits

1. Atmospheric pollution is considerable.
2. Coal may have to be transported over long distances, in some cases, after some years, and then the energy cost may be quite high.

II. Nuclear Power Stations

- Nuclear energy is available as a result of fission reaction. In a typical system, Uranium 235 is bombarded with neutrons and Heat energy is released. In chain-reaction, these release more neutrons, since more Uranium 235 atoms are fissioned.
- Speeds of Neutrons must be reduced to critical speeds for the chain reaction to take place. Moderators (speed-reducing agents like graphite, heavy water, etc). are used for this purpose.
- Nuclear fuel rods (of Uranium) must be embedded in speedreducing agents.
- Further, control rods (of cadmium) are required since they are strong neutron absorbers and help in finely regulating this reaction so that power control of the generator is precisely obtainable.
- When control rods are pulled out and are away from fuel rods, intensity of chain reaction increases, which increases the power output of the system. While if they are pushed in and closer to the fuel rods, the power-output decreases.

Thus, the electrical load demand on the generator decides (automatically) the control-rod positions through a very sophisticated control system.

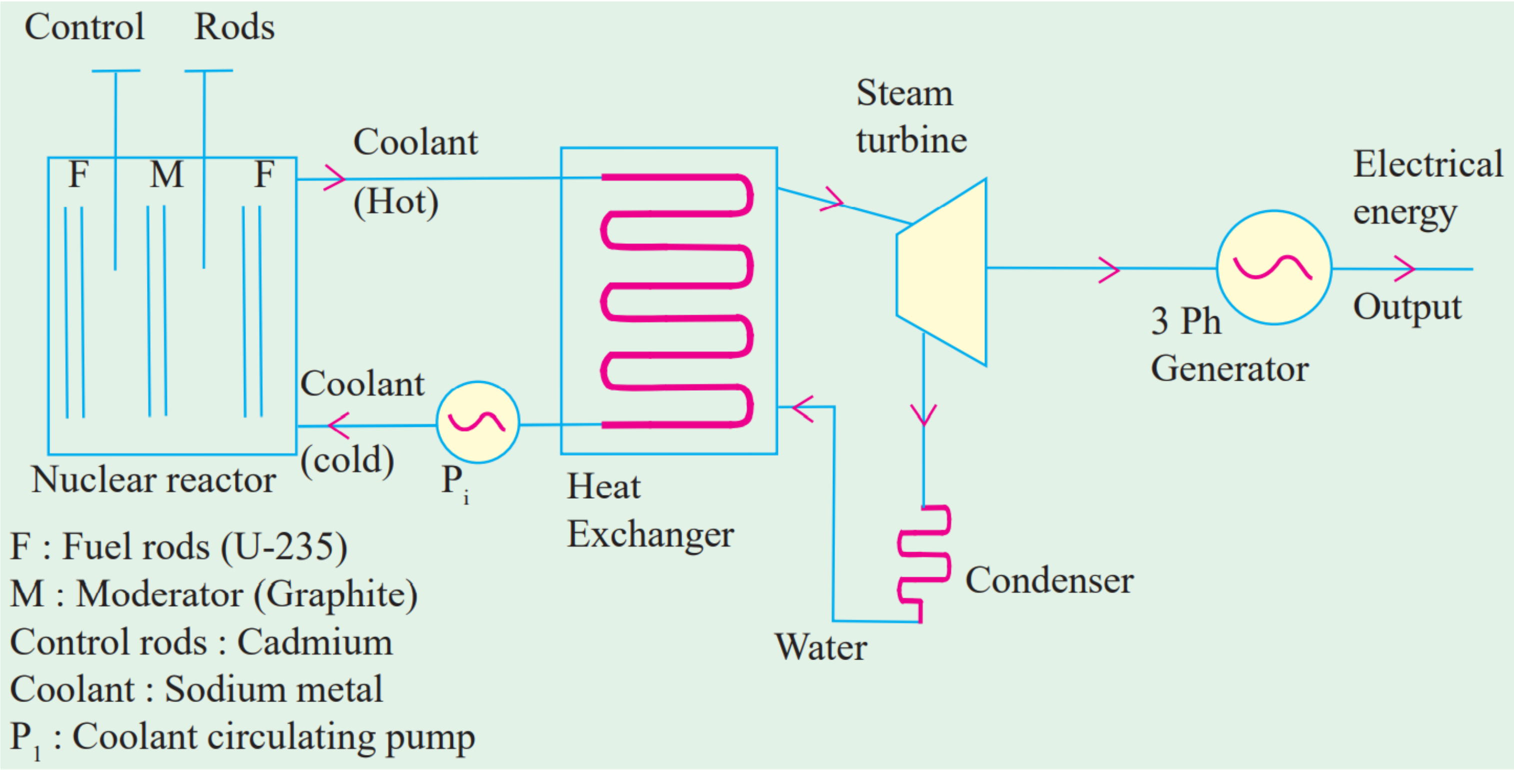

Fig. 3.2: Basic scheme of such a Nuclear power-station.

Advantages of Nuclear Generation

1. Quantity of fuel required is small for generating a given amount of electrical energy, compared to that with other fuels.
2. It is more reliable, cheaper for running cost, and is efficient when operated at rated capacity.

Disadvantages

1. Fuel is expensive and not abundantly available everywhere.
2. It has high capital cost.
3. Maintenance charges are high.
4. Nuclear waste disposal is a problem.

2. Hydro-electric: Potential of water stored at higher altitudes is utilized as it is passed through water-turbines which drive the alternators.

- Water-reservoir at higher altitudes is a pre-requisite for this purpose. Power-house is located at a lower level. The difference in these two levels is known as "Head".
  - ✓ Based on the "Heads", the Hydroelectric stations are categorized below:
    1. Low head up to 60 metres.
    2. Medium head between 60 and 300 metres.
    3. High heads above 300 metres.

- For this method, water from higher height is passed through penstock as controlled in the valve-house, into the water turbine.
- Thus, potential energy of water stored at higher altitudes is first converted into Kinetic energy.
- As the water reaches the turbine, it gains speed after losing the Potential energy.
- Kinetic energy of this speedy water drives the water turbine, converting it into mechanical output. It drives the coupled generator, which gives Electrical energy output.

- The valve house has a controlling valve (= main sluice valve) and a protecting valve (= an automatic, isolating, “butterfly” type valve).
- Power control is done by the main sluice valve, while “butterfly” valve comes into action if water flows in opposite direction as a result of a sudden drop in load on the generator.

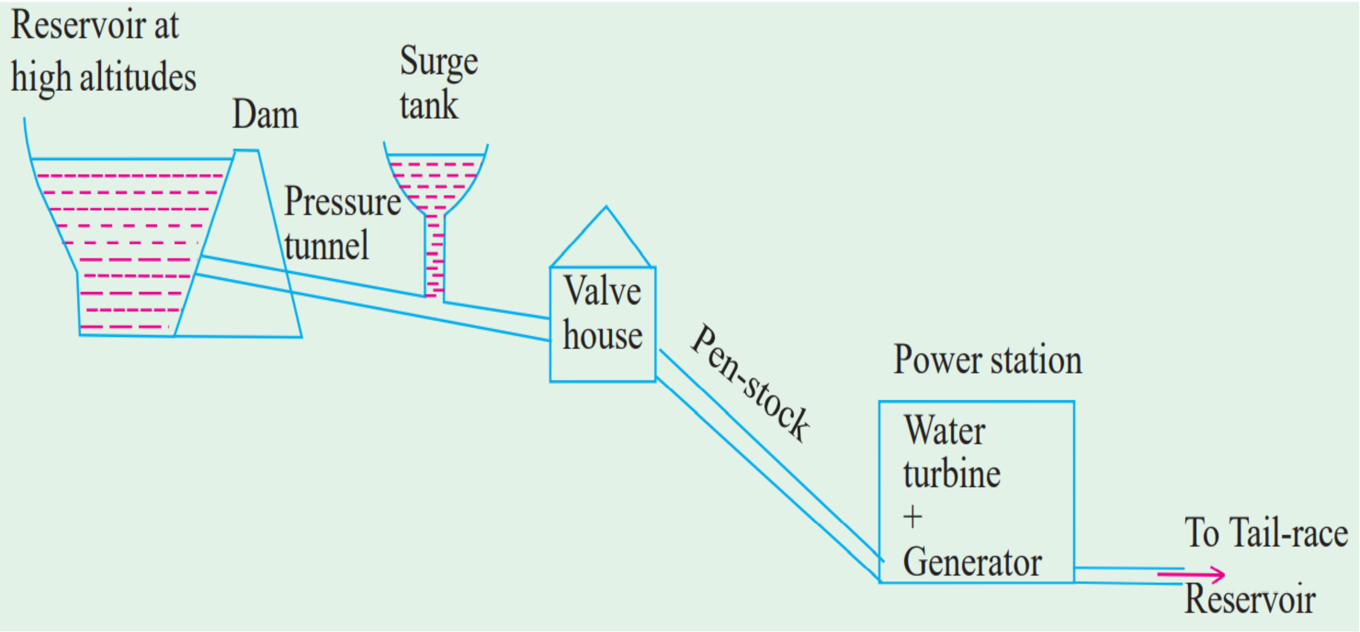

Fig. 3.3: Schematic of a typical Hydroelectric station

- After doing the work (of imparting its energy to the water turbine), the water is allowed to pass into the tail-race reservoir.
- The water turbines are essentially low-speed prime movers. In that, the best operating speed is dependent on the head. Alternators are coupled to water turbines thus have large number of poles (since P= 120 f/N). Such alternators have the Salient-Pole type rotor

Disadvantages of conventional methods of power generation

i. The fuels are likely to be depleted in near future, forcing us to conserve them and find alternative resources.

ii. Toxic, hazardous fumes and residues pollute the environment.

iii. Overall conversion efficiency is poor.

iv. Generally, these are located at remote places with respect to main load centres, increasing the transmission costs and reducing the system efficiency.

v. Maintenance costs are high.

B. Alternative methods of electric generation

➢Photo Voltaic Cells (P.V. Cells or SOLAR Cells)

- When ionized solar radiation is incident on a semi-conductor diode, energy conversion can take place with a voltage of 0.5 to 1 volt (d.c.) and a current density of 20-40 mA/cm^2, depending on the materials used and the conditions of Sunlight.
- Area of these solar cells decides the current output.
- An array of large number of such diodes (i.e. Solar cells) results into higher d.c. output voltage.
- Since, the final form of electrical energy required is generally an alternating current, it is realized from d.c. using inverters.

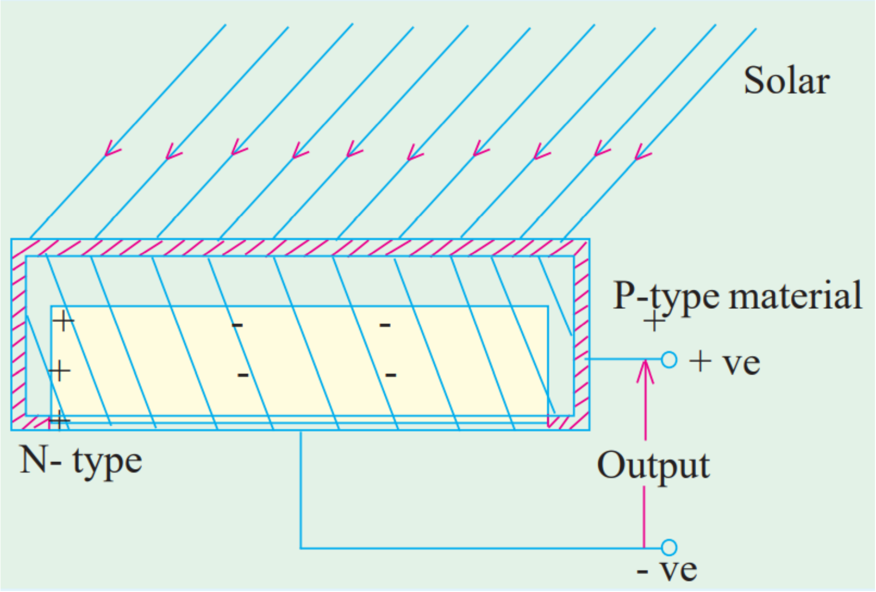

Fig. 3.4: Photo Voltaic (or Solar Cell)

➢Fuel Cells

- In Fuel cells, negative porous electrode is fed by hydrogen and the positive porous electrode is fed by oxygen.
- Both the electrodes are immersed in an electrolyte.
- The porous electrodes are made of such a conducting material that both the fuel (oxygen and hydrogen) and the electrolyte can pass through them. Such a material for electrodes is nickel.
- The electrolyte is a solution of sulphuric acid or potassium hydroxide.
- The electrodes have a catalyst (= platinum or sintered nickel) which break the fuel compound into more reactive atoms.

Chemical Process (with Acidic Electrolyte)

At Negative Electrode : $2H_2 \rightarrow 4H^+ + 4e^-$

At Positive Electrode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

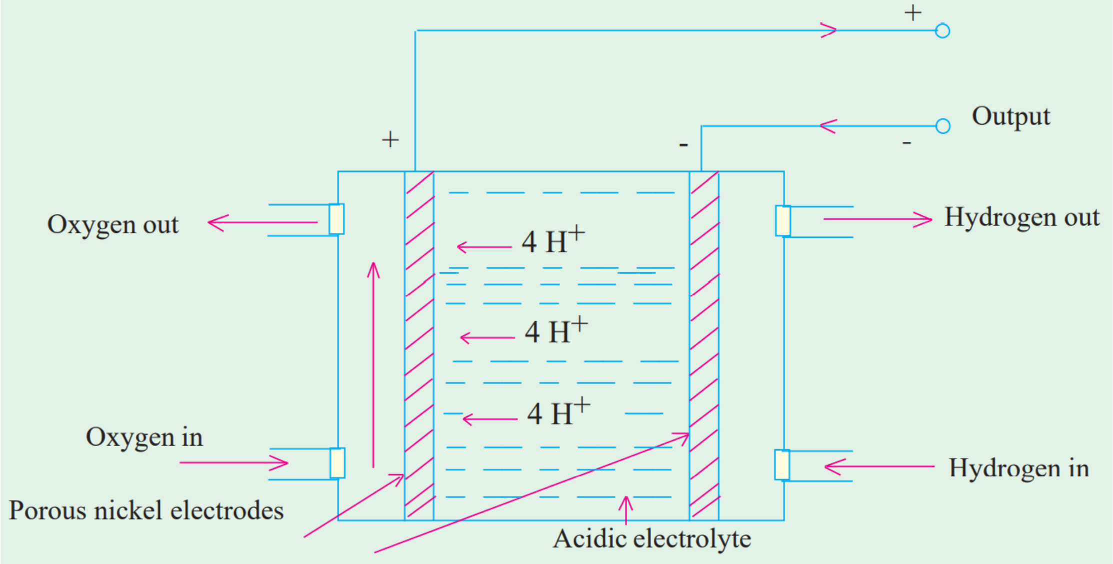

Fig. 3.5: Fuel cell

Advantages

- Pollution-free, noiseless.
- No outside source of energy is required.
- Efficient.
- No restriction on location

Disadvantages

- High initial cost.
- Working life is short.

➢Wind Power

- Wind power has been in use for serving the mankind, since centuries through what has been popularly known as “Wind-mills”.
- There is no “electrical” stage of energy in old-styled uses were wind-velocity is directly used for performing the jobs such as wheat-grinding, pumping water for irrigation, sailing vessels, etc.

Advantages:

- Being plentiful,
- Inexhaustible,
- Renewable and non-polluting, over and above being cheap for running costs.

Disadvantages:

- Unreliable, and being economically un-viable for large power generation.

- The speed of wind varies, as such turbine speed also varies so that output frequency and voltage of three-phase alternator vary over a wide range.
- To increase its utility, it is necessary to modulate (through proper power-control) in order to derive constant line-frequency and voltage output so that the available wind-energy can be pumped into the local grid.

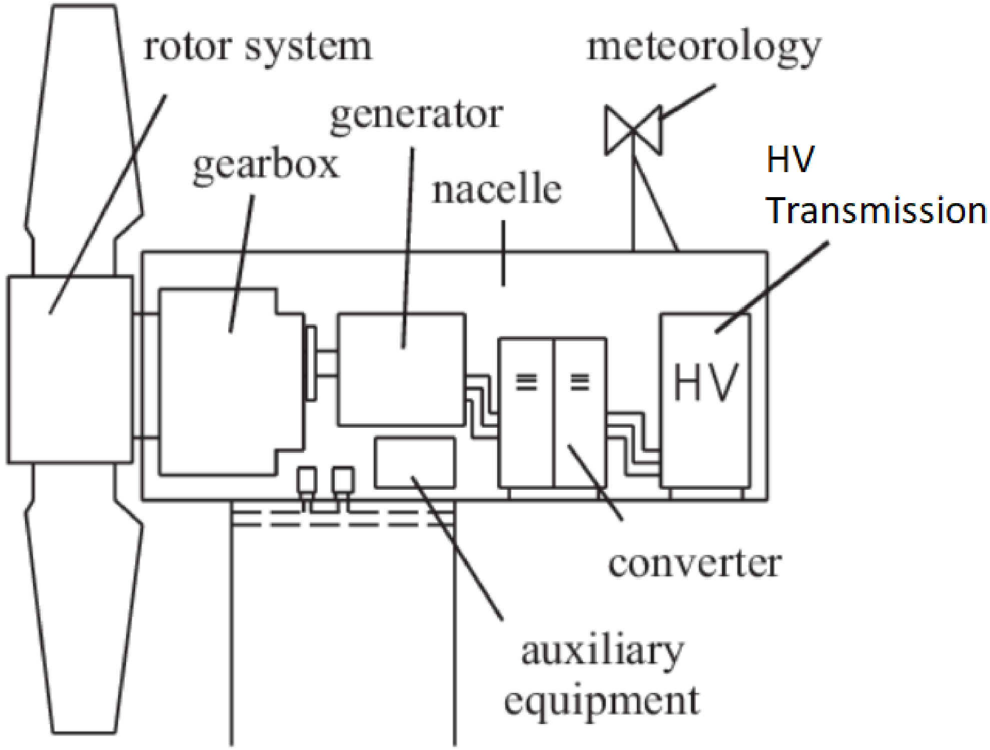

Fig. 3.6: Wind-generation, a Schematic view

2.3 Power system structure and components

Power System

- **Definition:** The power system is a network which consists generation, transmission system, and distribution. It uses the form of energy (like coal and diesel) and converts it into electrical energy.
- The power system includes the devices connected to the system like the synchronous generator, motor, transformer, circuit breaker, conductor, etc.
- The power plant, transformer, transmission line, substations, distribution line, and distribution transformer are the six main components of the power system.
- The power plant generates the power which is step-up or step-down through the transformer for transmission.
- The electric supply system can be broadly classified into (i) **d.c.** or **a.c.** system (ii) overhead or underground system.
- Nowadays, 3-phase 3-wire a.c. system is universally adopted for generation and transmission of electric power as an economical proposition.

- Distribution of electric power is done by 3-phase 4-wire a.c. system.
- The underground system is more expensive than the overhead system.
- Therefore, for a country like Zambia, overhead system is mostly adopted for transmission and distribution of electric power.

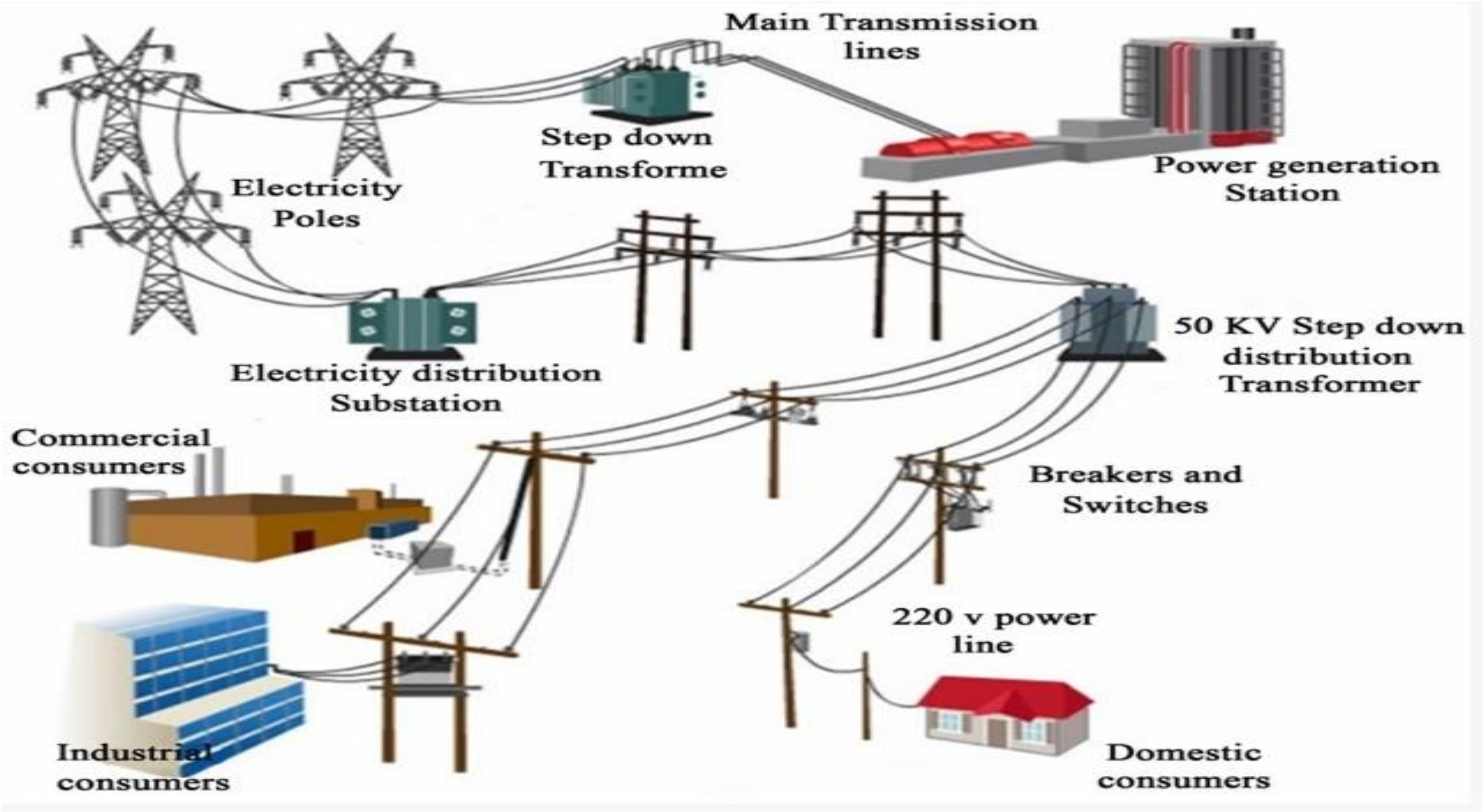

Fig. 3.7: Electric power system

Generating station:

- The generation of electrical energy is nothing but the conversions of various other forms of energy into an electrical energy.
- A Generating station which is usually located far/too far away from the cities and towns. It is generating electrical power at 11 kV and is increased to transmission levels (i.e. 66kV, 88kV, 132kV, 220kV and 330kV) using step up transformers.

Transmission of power:

- After generation, power is transferred to the load centres with the help of transmission lines and towers, transmitted over long distance.

  The scheme is divided into two sections, they are

  1. Primary transmission
  2. Secondary transmission

1. **Primary transmission:**

- Primary transmission is basically with help of overhead transmission lines for consumer load demands that use voltage levels up-to 132 kV, 220 kV or more. This type of transmission is high voltage transmission and uses a 3-phase 3-wire system.

2. **Secondary transmission:**

- The primary transmission line continues via transmission towers till the receiving station where it is stepped down to voltage levels of up to 22 kV or 33 kV with the help of step down transformers. There can be more than one receiving station and power can be transmitted to various substations using overhead 3-phase 3-wire system. This is secondary transmission.

Distribution of power:

- The distribution of power is, power distributed to the local distribution centers with the help of distribution lines. The scheme is divided into two sections, these are:

1. **Primary distribution:**

- In the distribution side is incoming voltage levels of about 22kV or 33 kV. So this voltage level is reduced to 6.6 kV, 3.3 kV as per the consumer needs with help of step down transformers. It uses the 3-phase 3-wire overhead/underground systems and power is transmitted to the local distribution centers. So primary distribution is called high voltage distribution.

2. **Secondary distribution:**

- At the local distribution centers, there are step down distribution transformers. The voltage level of 6.6 kV or 3.3 kV is reduced to 400 V, 230 V using distribution transformers. Then finally power can be distributed to consumers with help of distributors and service mains to the consumers. This system uses 3-phase 4-wire system. Hence, it is called secondary distribution or low voltage distribution.

3.4 Comparison of D.C. and A.C. Transmission

Advantages of D.C. transmission over A.C.

i. It requires only two conductors as compared to three for a.c. transmission.

ii. There is no inductance, capacitance, phase displacement and surge problems in d.c. transmission.

iii. Due to the absence of inductance, the voltage drop in a d.c. transmission line is less than the a.c. line for the same load and sending end voltage. For this reason, a d.c. transmission line has better voltage regulation.

iv. There is no skin effect in a d.c. system. Therefore, entire cross-section of the line conductor is utilised.

v. For the same working voltage, the potential stress on the insulation is less in case of d.c. system than that in a.c. system. Therefore, a d.c. line requires less insulation.

vi. A d.c. line has less corona loss and reduced interference with communication circuits.

vii. The high voltage d.c. transmission is free from the dielectric losses, particularly in the case of cables.

viii. In d.c. transmission, there are no stability problems and synchronising difficulties.

Disadvantages of D.C.

i. Electric power cannot be generated at high d.c. voltage due to commutation problems.
ii. The d.c. voltage cannot be stepped up for transmission of power at high voltages.
iii. The d.c. switches and circuit breakers have their own limitation.

Advantages of A.C. transmission over D.C.

i. The power can be generated at high voltages.
ii. The maintenance of a.c. sub-stations is easy and cheaper.
iii. The a.c. voltage can be stepped up or stepped down by transformers with ease and efficiency. This permits to transmit power at high voltages and distribute it at safe potentials.

Disadvantages of A.C.

i. An a.c. line requires more copper than a d.c. line.

ii. The construction of a.c. transmission line is more complicated than a d.c. transmission line.

iii. Due to skin effect in the a.c. system, the effective resistance of the line is increased.

iv. An a.c. line has capacitance. Therefore, there is a continuous loss of power due to charging current even when the line is open.

END OF LECTURE!