UNIT-3

Basics of power Systems

Layout of Hydro Electric power plants:-

Layout of hydro power plants are classified in three categories based on availability of water head,

a) low-head plants - less than 30m, kaplan turbines.
b) medium-head plants - In b/w 30m-100m, Francis "
c) High-head plants - More than 100m, pelton turbines.

parts of layout of Hydro Electric power plant:-

The hydro power plants consists of mainly six parts:

1. Dam and Reservoir
2. control Gate
3. Penstock
4. Water turbine
5. Generator
6. Surge tank.

1. Dam and Reservoir:-

* when we hearing the word Dam that means sufficient water storage at some height.

(Because when the water from some height release so the velocity increase and which is further used for the generation of Electricity with the use of turbine).

* The dam forms a large reservoir behind it. The height of the water level (called a water head) in the reservoir determines how much potential Energy is stored in it.

2. Control Gate:

* In simple words, this is like controlling the flow of water.

(First water from the reservoir is allowed to flow through the penstock and to the turbine).

* The amount of water that is to be released in the penstock can be controlled by a control gate.

* When the control gate is fully opened, the maximum amount of water is released through the penstock.

3. Penstock:-

* The potential Energy of the water is converted into kinetic energy as it flows down through the penstock due to gravity.

4. Water turbine or Hydraulic Turbine:-

* The flow of water from the penstock is taken into the water turbine.

* The turbine is mechanically coupled to an electric generator.

* The kinetic Energy of the water drives the turbine and consequently the generator gets driven.

5. Generator :-

* A generator is mounted on the powerhouse and it is mechanically coupled to the turbine shaft.
* When the turbine blades are rotated, it drives the generator, the Electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

6. Surge Tank :-

* The surge tanks are usually provided in high or medium head power plants when considerably long penstock is required.
* A surge tank is a small reservoir or tank which is open at the top.
* It is fitted between the reservoir and the powerhouse.
* The water level in the surge tank rises or falls to reduce the pressure swings in the penstock.

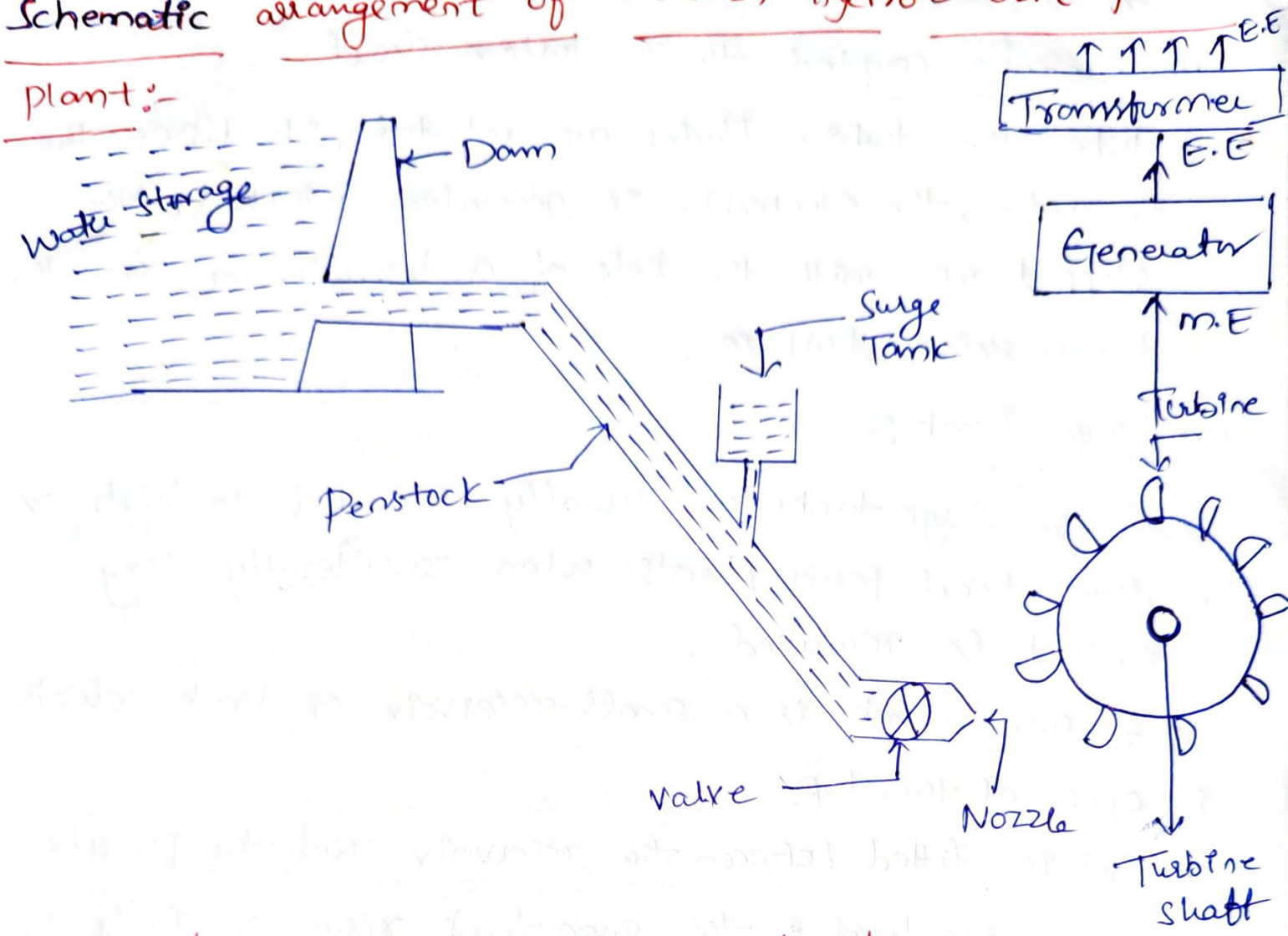
Introduction to Hydro Electricity :-

· Hydro power:

* Hydro power is considered as one of the most economic and non polluting sources of Energy.
* Power generated from water is known as Hydro Electricity.
* Hydro Electricity means Electricity generated by hydro power or from the use of the gravitational force

force of falling of flowing water.

Schematic arrangement of modern Hydroelectric power plant:-



Working of Hydroelectric power plant:-

* A dam is constructed across a water body.
* Water from the catchment area collects at the back of the dam to form reservoir.
* water is brought to valve house at the start of penstock.
* The valve house contains main sluice valves and automatic isolating valves.
* water is taken to water turbine through a huge steel pipe known as 'penstock'.

* The water house contains water
* The water turbine converts hydraulic Energy in to mechanical Energy.
* The turbine drives the alternator which converts mechanical Energy in to Electrical Energy.

Advantages:-

* More reliable power plant.
* low operating cost
* low starting time
* High production rate capacity.
* The fuel cost is zero.
* Pollution - free
* Renewable source of energy
* Life of the power plant is more.
* They are also used for flood control and irrigation.

Disadvantages:-

* capital cost is high.
* output depends upon the availability of water.
* commonly found in hill-areas.
* Apparatus needs corrosion protection.
* Require long Transmission lines.
* Skilled and experience hands are required to build the plant.

Conclusion: Hydro electric power plants should be promoted since they donot pose any threat to the environment.

Layout and working of a thermal power plant :-

* Almost two third of Electricity requirement of the world is fulfilled by thermal power plants.
* It is also known as "steam power plant".

Components of Thermal power plant :-

coal: Generally, bituminous coal or brown coal is used as fuel. The coal is stored in either 'dead storage' or in 'live storage'.

* The coal from live storage is first crushed in small particles and then taken into pulverizer to make it in powered 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.

Boiler:-

* The mixture of pulverized coal and air is taken into boiler and then burnt in the combustion zone.
* On ignition of fuel a large fireball is formed at the centre 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 super heater, economizer, air pre heater and finally get exhausted to the atmosphere from the chimney.

Steam turbine:-

* High pressure super heated steam is fed to the steam turbine which causes turbine blades to rotate.
* Energy in the steam turbine which acts as prime mover.
* Here mechanical energy in the steam is converted into mech Electrical energy.

Condenser:-

* The exhausted steam is condensed in the condenser by means of cold water circulation.
* Here the steam is converted back in to water.

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.

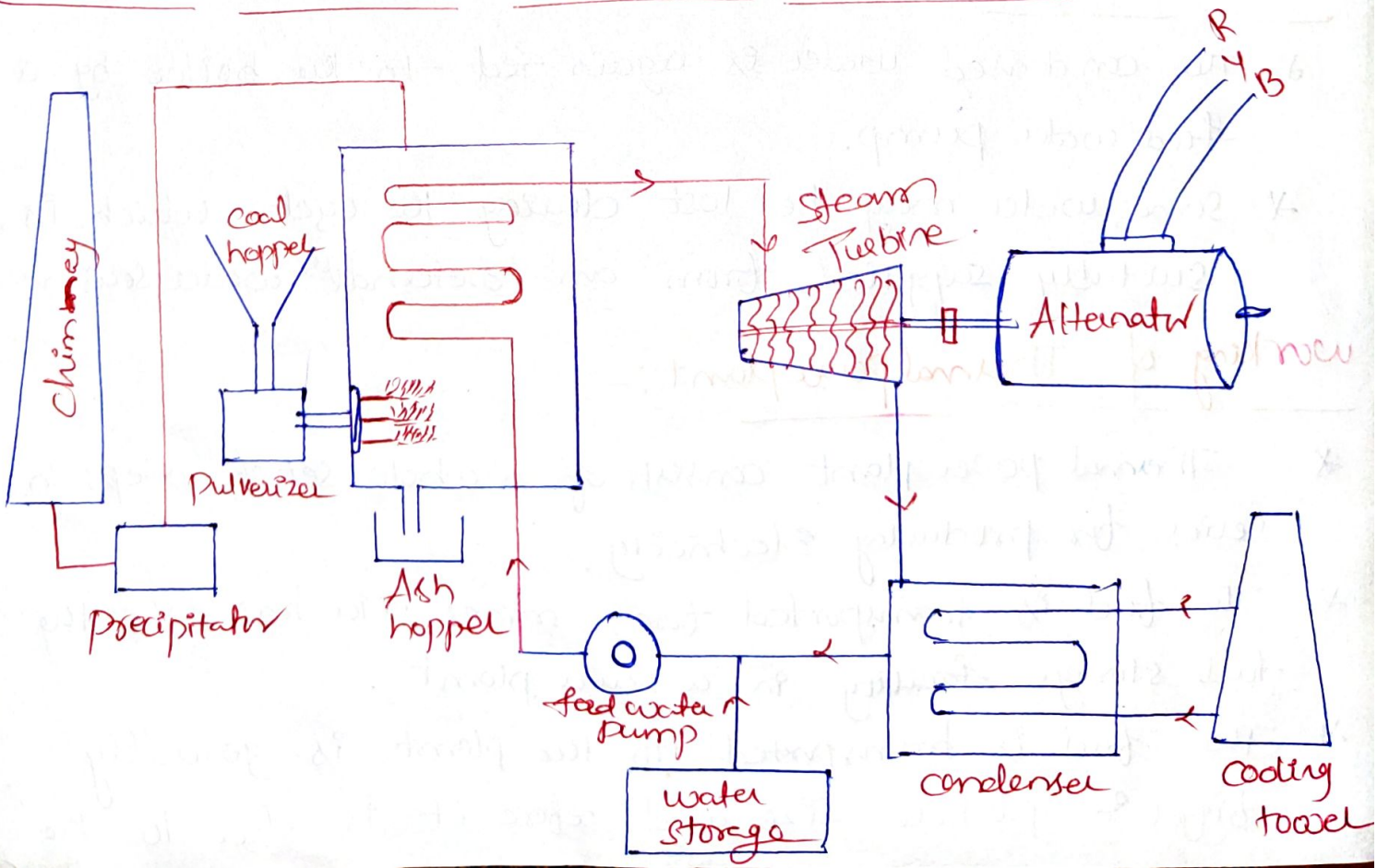
working of Thermal power plant:-

* Thermal power plant consists of a whole set of steps in series for producing Electricity.
* The fuel is transported from mines via trains to the fuel storage facility in a power plant.
* The fuel is transported to the plant is generally bigger in particle size and before it is fed to the

the boiler furnace it is broken down into smaller pieces using crushers.

* The fuel is then fed to the boiler generating a large amount of combustion heat.
* on the other hand treated water free from impurities and air is fed to the boiler drum where the combustion heat from the fuel is transferred to water to convert it into high pressure and temperature steam.
* A turbine is a mechanical device which converts the kinetic and pressure energy of steam into useful work.
* From the superheater steam goes to the turbine where it expands and loses its kinetic and pressure energy and rotates the turbine blade which in turn rotates and turbine shaft connected to its blades.
* The shaft then rotates the generator which converts this kinetic energy into electrical energy.

Schematic arrangement of 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 (ie., coal) is cheaper.
* The cost of generation is lesser than that of diesel power plants.

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Dis advantages:-

* 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%).
* Its maintenance cost is high.
* A large water source is required to convert water into steam.

Layout and Working of a nuclear power plant:-

* 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.

Basic components of a Nuclear power plant:-

Nuclear Reactor:-

* A nuclear reactor is a special apparatus used to perform nuclear fission.
* The nuclear fission is radio active, 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.

Heat exchanger:-

* In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water).
* Water from the secondary loop is converted into steam.

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.

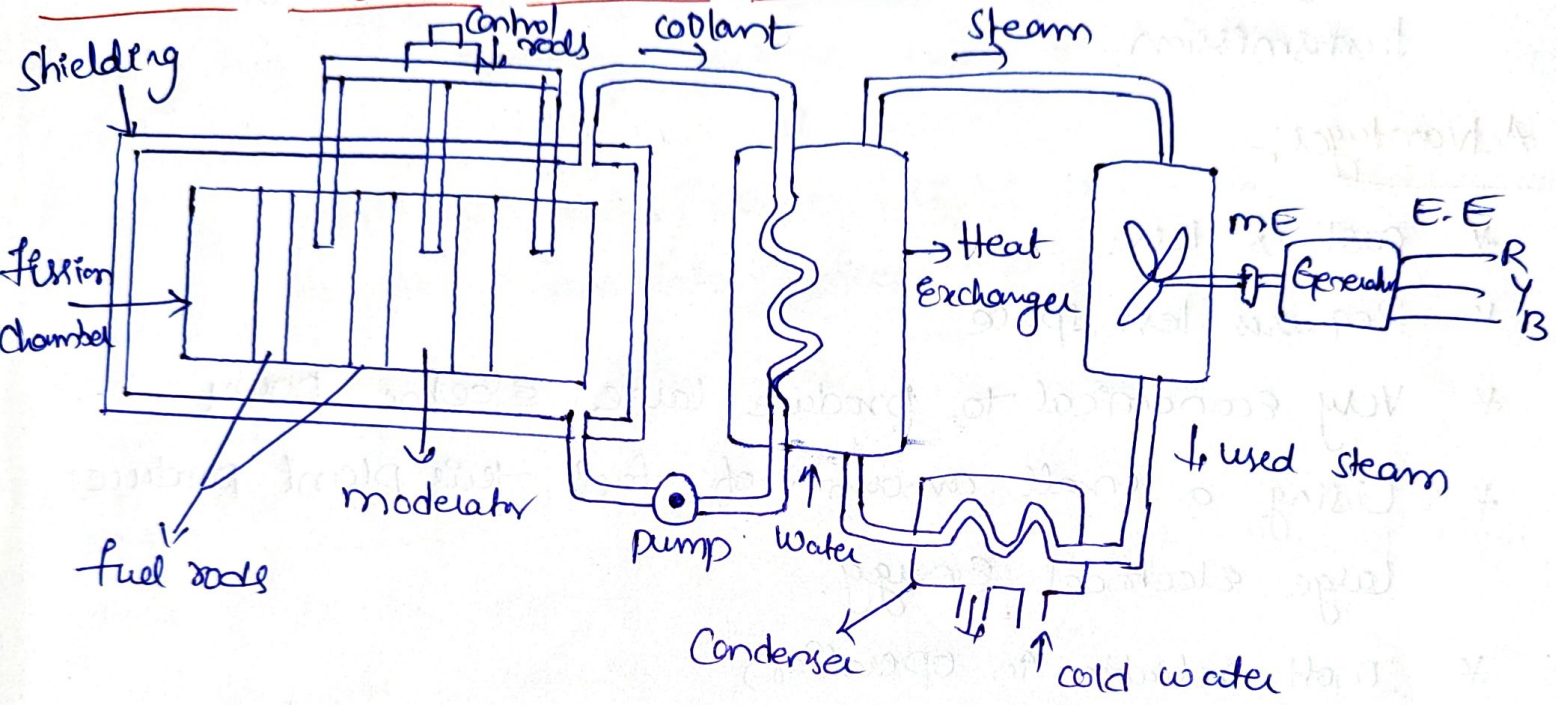
Alternator:-

* The steam turbine rotates the shaft of an alternator thus generating Electrical Energy.

Condenser:-

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

Schematic diagram of a Nuclear Power plant:-



Working of Nuclear power plant:-

* 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 in to high temperature steam.
* The generated steam is then allowed to drive a steam turbine.

* The steam, after doing its work, is converted back in to 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.

Advantages:-

* cost is less.
* Requires less space
* Very economical to produce large electric power.
* Using a small amount of fuel, this plant produces large electrical energy.
* most reliable in operation.
* It is very neat and clean as compared to a thermal power plant.
* Operating cost is low.

Disadvantages:-

* Initial installation cost is very high.
* Nuclear fuel is very much expensive and it is difficult to recover.
* Capital cost is high.
* There is a chance to spread of radio active pollution from this type of plant.
* cooling water requirement is more.

Solar Power generating System:-

* Solar power is the conversion of renewable energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination.
* Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam.
* Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Main components of Solar power:-

1. Solar panels:-

* It is the heart of the solar power plant. Solar panels consists a number of a solar cells.
* We have got around 35 solar cells in one panel.
* The energy produced by each cell is very small, but combining the energy of 35 of them we have got enough energy to charge a 12volt. battery.

2. Solar cells:-

* It is the energy generating unit, made up of P-type and n-type silicon semiconductor.
* It is the heart of solar power plant.

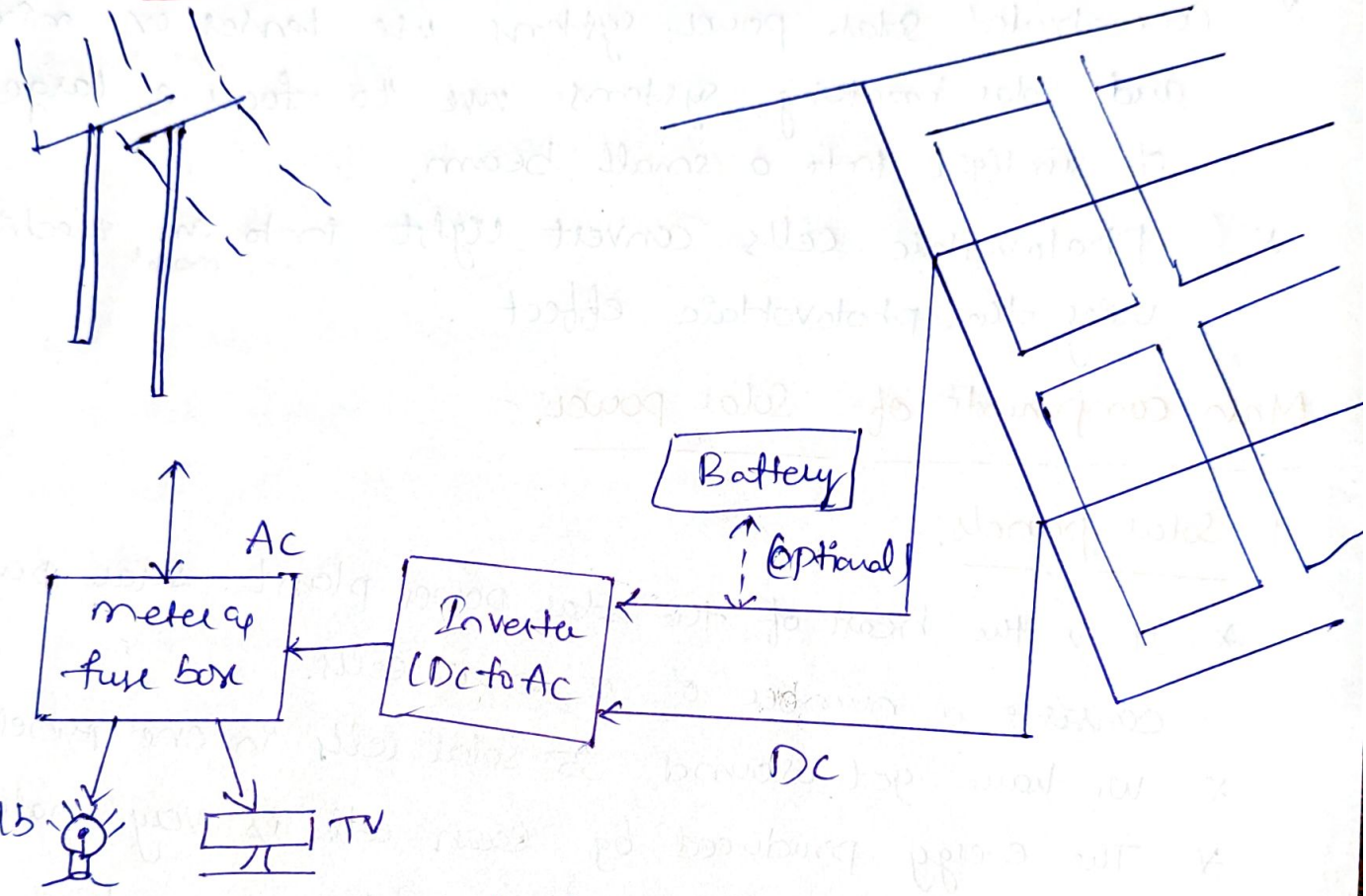
3. Battery:-

* Batteries are used to produce the power back or store the excess energy produced during day, to be supplied during night.

4. DC to AC Converter (Inverter):

* Solar panels produce direct current which is required to be converted into alternating current to be supplied to homes or power grid.

Schematic diagram of solar power plant:-



Working of solar power plant:-

* As sunlight falls over a solar cells, a large number of photons strike the p-type region of silicon.
* Electron and hole pair will get seperated after absorbing the energy of photon.
* The electron travels from p-type region to n-type region due to the action of electric field at PN junction.
* Further the diode is reversed biased to increase this electric field.

Energy Storage:-

* storage of the energy generated by the solar panels is a important issue.
* Some times the unused energy generated during daytime is used to pump water to some height, so that it could be used to generate electricity using its potential energy when required or mainly at night time.

Advantages:-

* most clean and renewable source of energy.
* It is available in abundance and endless.
* It provides electricity at low cost, as fuel is free.
* with new research in this sector we now have a good power storage solution.
* Keeping in mind the pollution and cost of fossil fuel, it's becoming the most reliable source of clean energy.

Disadvantages:-

* It requires a lot of land to be captured forever.
* Initial cost of installation is too high.
* The energy storage options are not efficient.
* Power production is quite low.
* There is a problem if it is cloudy for few days.
* Their production causes pollution.

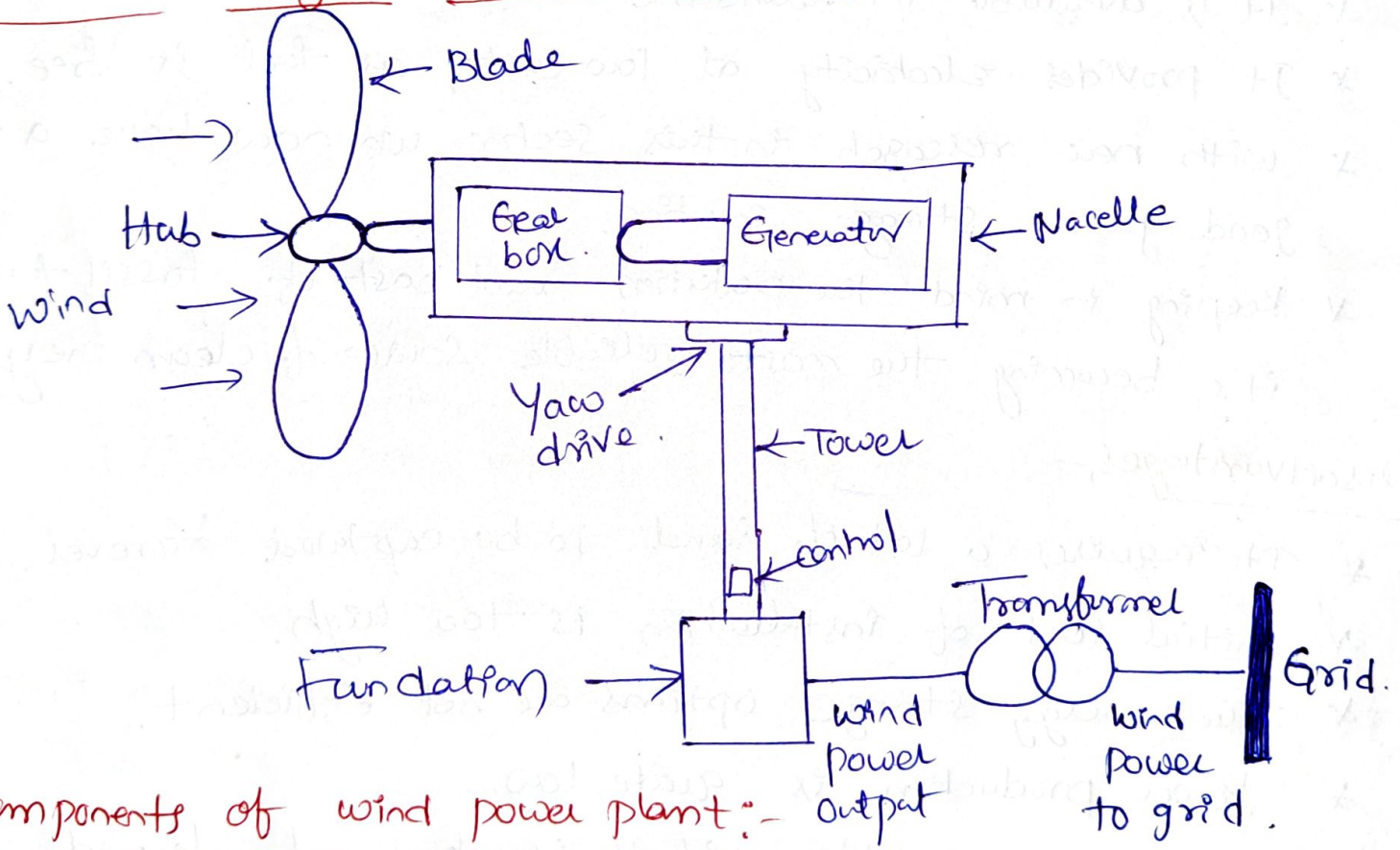
Application:-

* solar power plant is powering cities in most efficient manner.
* solar panels could be used to generate electricity individually for each house especially in remote areas.

Wind power plant :-

* There is an air turbine of large blades attached on the top of a supporting tower of sufficient height.
* when wind strikes on the turbine blades, the turbine rotates due to the design and alignment of rotor blades.
* The shaft of the turbine is coupled with an electrical generator.
* The output of the generator is collected through electric power cables.

Schematic arrangement of wind generating power plant :-



Components of wind power plant :-

Gear box :-

A shaft connected to the hub directly goes in to the gear box and it increases its rpm to the required level. It is the heaviest part in the system.

Brakes:- Brakes are used when wind is blowing above critical level to same turbine from damage. Brakes is mounted just behind the gearbox.

Generator:- It converts the energy of fast rotating shaft in to electrical energy, and finally the high voltage transformer converts it to high voltage to be ready to go in transmission lines.

Tower:-

- It's the cylindrical structure on which system is mounted.
- For a sub megawatt turbine generating upto 400-600 watts of power its height may vary from 25m to 45 meters.
- The diameter of this cylinder reduces as we go up the tower.

Working of Wind power plant:-

- Blades of the wind turbine work as an airfoil of different cross sections all along the length.
- When fluid (air) moves over this airfoil of it generates a lift force thus making the blade to rotate at its axis.
- The generator is also connected to the rotor shaft starts rotating and produces Electricity.
- Now, we all know that rotating blades can get us electricity.
- But the wind speed keeps on changing with time so we get a fluctuation in power.
- To overcome this, threshold velocity is decided at which turbine will start rotating, below that brakes are used to prevent the blades from rotating.
- And for high wind velocity brakes are applied to prevent turbine from damage.

* motor and sensors are used to rotate the blades about their axis so that they can adjust according to the varying direction of wind.
* And to extract maximum power out of wind. Blades are also rotated to stop the turbine from rotating, means they are oriented in such a way that no left will be generated even with the blowing wind.
* In a wind powerplant, turbines are required to be interconnected to get the best out of them.
* They are connected to each other by a medium voltage power collection system usually around 35.5 kV along with a communication network, that helps them to communicate.

Advantages:-

* Air as fuel is free and inexhaustible.
* It is clean source of energy and doesn't not pollute the environment.
* The cost of electricity is too low and the wind turbine could be used over more than 20 years.
* It's cheap to installation and maintance cost.

Disadvantages:-

* It takes a lot of research and effort to decide the location
* Initical cost is high.
* Noise pollution is high
* Wind power plant is only useful to the countries with coastal or hilly areas.

Applications:-

* It is mostly used for electricity generation.
* It is also used for water pumping through multi blade turbine.

Typical AC power supply scheme :-

The lines network between Generating station (Power station) and consumer of electric power can be divided into two parts.

1) Transmission System.
2) Distribution System.

We can explore these systems in more categories such as primary transmission and secondary transmission. Similarly primary distribution and secondary distribution.

* This is shown in the below diagram called "single line diagram or one line diagram of typical AC power system scheme).
* It is not necessary that the entire steps which are shown in the above image must be included in the other power schemes.

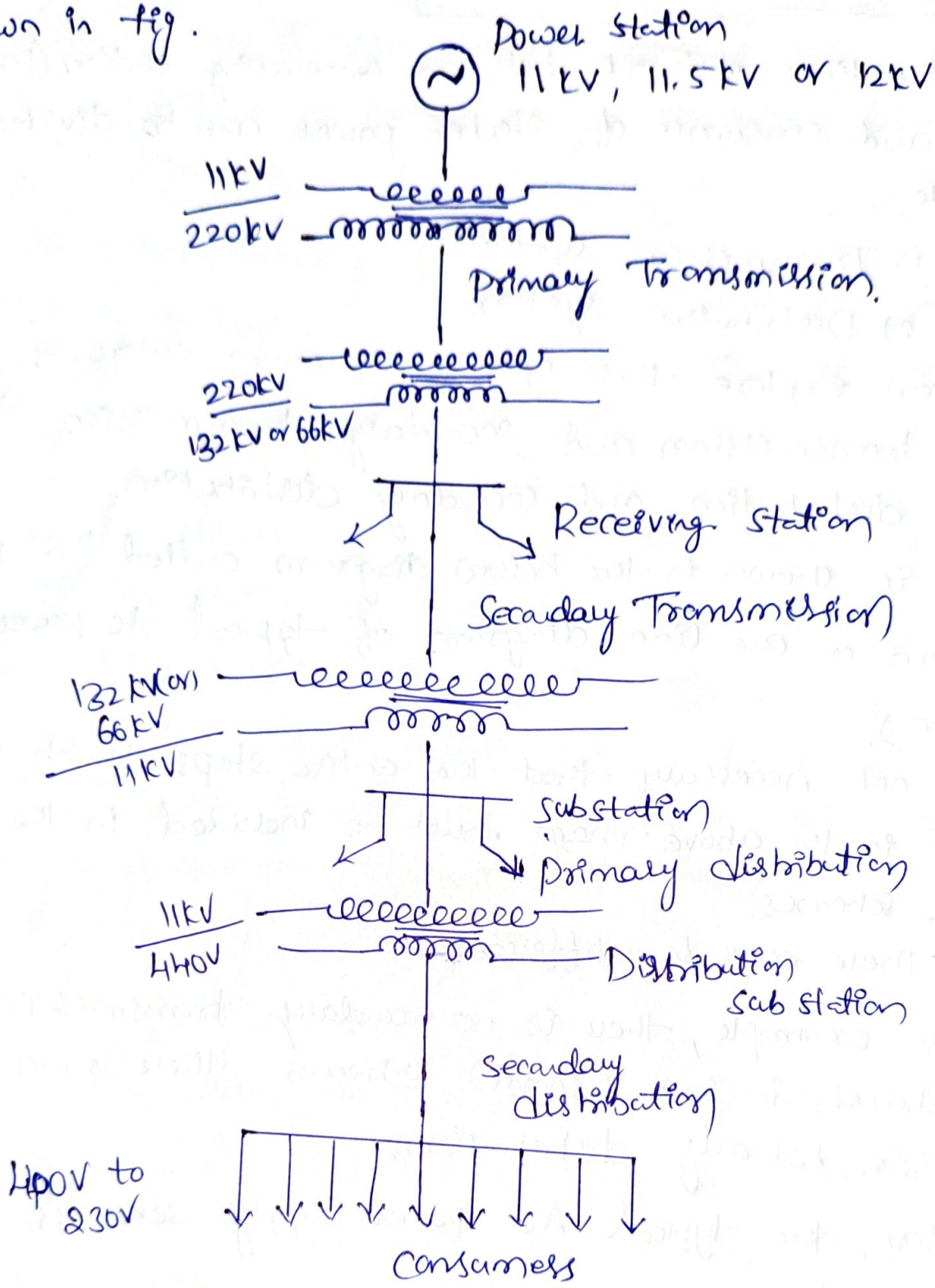
There may be difference.

For example, there is no secondary transmission in many schemes, in some (small) schemes there is no transmission, but only distribution.

Here, the typical AC power supply schemes are divided in to,

1. Generating station.
2. Primary transmission
3. Secondary transmission
4. Primary distribution
5. Secondary distribution.

The following parts of a typical power supply scheme are shown in fig.



1. Generating station:-

* The place where electric power produced by parallel connected three phase alternators / generators is called "Generating station".
* The ordinary generating voltage may be 11kV, 11.5kV, 12kV or 13kV.

* But economically, it is good to step up the produced voltage from (11kV, 11.5kV or 12kV) to 132kV, 220kV or 500kV or greater up to 1500kV by step up transformer.

2) Primary transmission:-

* The electric supply (in 132kV, 220kV, 500kV or greater) is transmit to load center by three phase three wire overhead transmission system.

3. Secondary Transmission:-

* Area far from city (outskirts) which have connected with receiving station by line is called "Secondary Transmission".
* At receiving station, the level of voltage reduced by step down transformer up to 132kV, 66kV or 33kV, and Electric power is transmit by three phase three wire overhead system to different sub stations.

So this is a secondary Transmission.

4. Primary distribution:-

* At a substation, the level of secondary transmission voltage (132kV, 66 or 33kV) reduced to 11kV by step down transformers.
* Generally, Electric supply is given to those heavy consumer which demands is 11kV, from these lines which carries 11kV (in 3-ϕ 3-wire overhead system) and they make a seperate substation to control and utilize this power.
* In other cases, for heavier consumer their demand is about 132kV or 33kV, 66kV or 33kV) and then step down the lvel of voltage by step down transformers in their own sub station for utilization (ie., for electric traction etc).

5. Secondary Distribution:-

* electric power is given to distribution sub station.
* This sub station is located near by consumers areas where the level of voltage reduced by step down transformers 440V
* These transformers are called "Distribution transformers".
* So there is 400 volts between any two phases and 230V between a single phase wires.
* Residential load (ie. fans, lights and TV etc) may be connected between any one phase and neutral wires, while three phase load may be connected directly to the three phase lines.

Elements of Distribution systems:-

Secondary distribution may be divided into three parts.

1. Feeders
2. Distributors
3. Service lines or Service mains.

Elements of Transmission line:-

* Electrical transmission lines are responsible for bulk transportation of electricity from one point to another.
* Various components of transmission lines play their role for the successful transmission of power from plants to utilities.

1. Phase Conductor:-

* A conductor is the main component which carries current from one point to another.
* Very often a single circuit pole contains three conductors
* Some poles are designed to carry two circuits, such poles contain six line conductors.

2. Transmission pole;-

* Transmission pole is the main structure which carries conductors and keeps them away from the ground.
* Due to economic reasons, the conductors used in transmission lines are kept bare.
* To keep them at an appropriate distance from earth a pylon (pole) of appropriate height is required.

3. Insulator;-

* The transmission line insulator is made of Porcelain.
* Its major objective is to insulate conductor from pole as well as to support it.
* The insulator is directly connected to cross arm of the pole.

4. Cross arms;-

Cross arms are used to support insulators.

5. Earth cable;- Besides phase conductor there is another cable that is connected at the top of pole.
* The Earth cable is used to provide protection against lighting strokes.

6. Spacer;-

* For low voltage transmission of electricity, one conductor pa phase is used.
* For High voltage transmission, multiple conductors per phase are employed.
* In such a case the spacer is used so as to keep the conductors apart from each other.

7. Danger plates;- Danger plates indicate the voltage level of transmission lines as well as it serves the purpose to warn

users for not touching the lines.

8. Anti-climbing fence;-

* Anti-climbing fence is used to restrict users from climbing the transmission line poles.
* They are installed near the base of transmission lines and their sole purpose is to provide safety to the general public.

9. Power line markers;-

* Power line markers are used to make transmission lines visible to pilots, drone operators and other machinery operating in area.
* Very often orange coloured balls are used on transmission lines for this purpose.

10. Vibration Dampers;-

* As the name indicates the vibration dampers are installed on transmission lines to control vibrations of overhead lines.
* A vibration dampers has two bell shaped metallic weights fastened to end of the metallic rod.

Types of Insulators;-

There are 5 types of insulators used in transmission lines as overhead insulation.

1. Pin insulator
2. Suspension Insulators } These are used in medium to high voltage systems.
3. Strain Insulators
4. Stay Insulators
5. Shackle Insulators. } Low voltage applications.

Classification of Distribution system:-

Classification based on the nature of current:

- Dc distribution system.
- Ac distribution system.

classification based on the type of construction:

- Over-head system.
- Under-ground system.

classification based on the scheme of connection.

- Radial systems.
- Ring-main systems.
- Inter-connected systems.

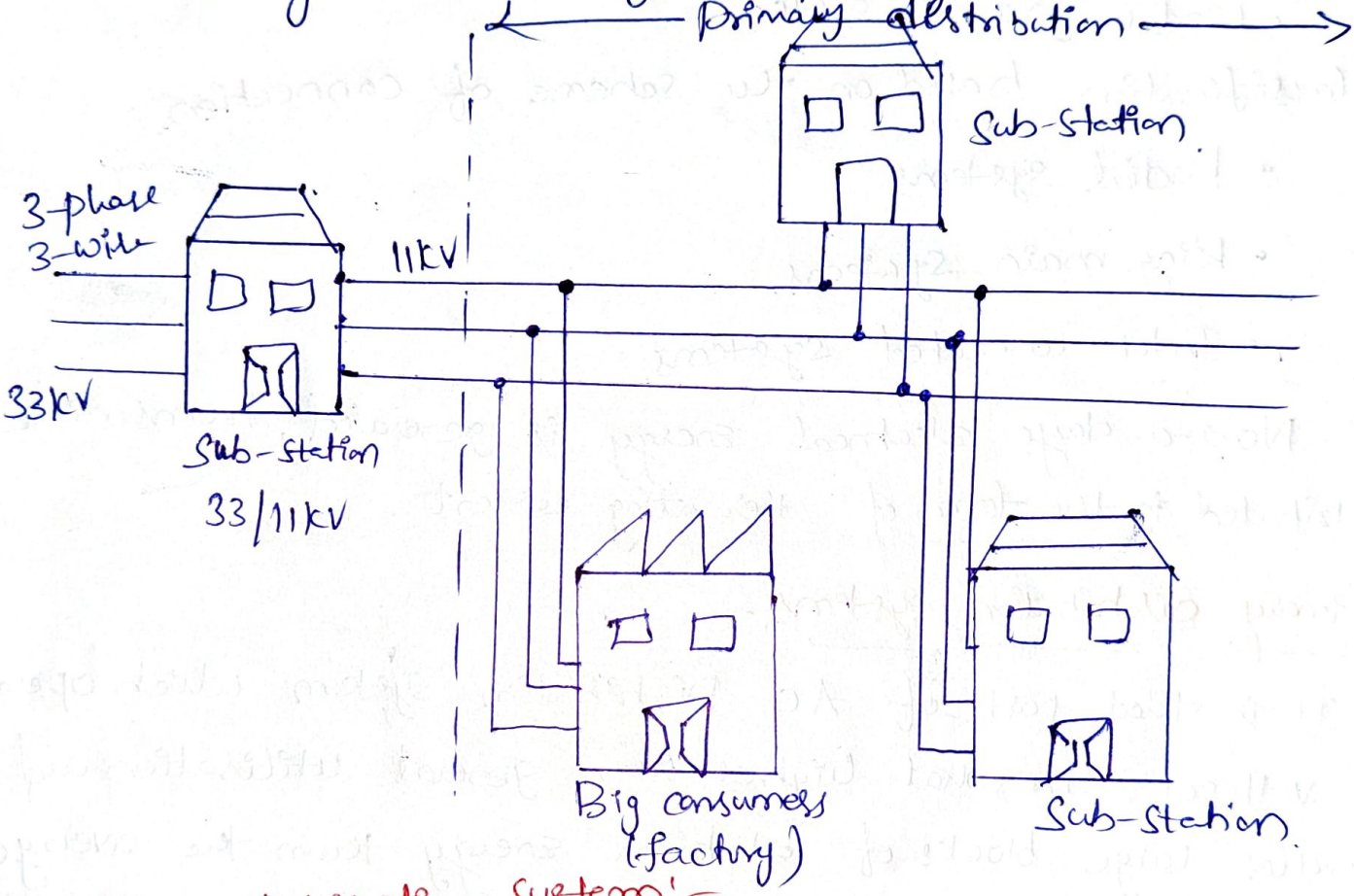
* Now-a-days electrical energy is generated, transmitted & distributed in the form of alternating current.

Primary distribution systems:-

* It is that part of Ac Distribution System which operates at voltages somewhat higher than general utilisation and handles large blocks of electrical energy than the average low-voltage consumer uses.
* The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed.
* The most commonly used primary distribution voltages are 11KV, 66KV and 3.3KV.
* Due to economic considerations, Primary distribution is carried out 3-phase, 3-wire systems.
* Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.

* At this substation, voltage is stepped down to 11kV with the help of step-down transformer.
* Power is supplied to various substations for distribution or to big consumers at this voltage.
* This forms the high voltage distribution or primary distribution.

The fig. shows a typical primary distribution system.



Secondary distribution system:-

* It is that part of AC distribution system which includes the range of voltages at which the ultimate consumer utilises the electrical energy delivered to him.
* The secondary distribution employs 400/230 V, 3-phase, 4-wire system.
* The primary distribution circuit delivers power to various substations, called "Distribution substations".
* The substations are situated near the consumers localities and contain step-down transformer.

* At each distribution substation, the voltage is stepped down to 400V and power is delivered by 3-phase, 4-wire a.c. system.
* The voltage between any two phases is 400V and between any phase and neutral is 230V.
* The single phase domestic loads are connected between any one phase and the neutral, where as 3-phase 400V motor loads are connected across 3-phase lines directly.

The below figure shows a typical secondary distribution system.