Ncse unit 4 - NON conventional source of energy

Non-Conventional Energy Sources (Jawaharlal Nehru Technological University, Hyderabad)

NCSE

Geothermal energy: Resources, types of wells, method of harnessing the energy, potential in india.

Ocean energy- OTEC, principles, utilization, setting of OTEC plants, thermodynamic cycles, Tidal & wave energy; potential and conversion technique, mini-hydel plants, their economics.

Geothermal energy:-

Geothermal energy is the heat that comes from inside the earth. We can use this heat to make electricity, warm our homes, and even heat water for various uses. It's a clean and renewable source of energy that's always available.

Geothermal energy is heat transported from the interior of the earth. It is recovarable in some form such as stream or hot water.

Geothermal steam is of two kinds;-

1. Magnetic stream: Originating from the magma itself.
2. Meteoritic stream: obtained from ground water heated by the magma. It is the largest source of geothermal stream.

Factors that decide the Usage of geothermal energy in power generation:-

1. More flexible to use
2. Low cost
3. High energy content
4. High capacity factor
5. High energy density
6. Highly responsive & easily controllable

Advantages and disadvantages of geothermal energy:-

Advantages:-

i] It is a renewable source of energy

ii] The cost of the energy is less

iii] It causes less pollution

iv] Unlike other energies it is independent of weather conditions.

v] High energy content can be obtained

Disadvantages:-

i] Harmful gases are released during extraction of energy, which causes air pollution.

ii] The extraction of energy creates noise pollution due to drilling operation.

iii] The availability of geothermal resources are very less i.e. only in certain places. Therefore, power plants are installed only in few places.

iv) It may cause surface instability, due to the continuous extraction of energy.

How is geothermal energy generated inside the earth crust :-

The geothermal field consists of magma, rocks, reservoir, geysers, springs, fissures, wells etc.

The lower most portion of the field is 'magma' i.e hot molten rock. Above magma there are igneous rocks which were formed due to the solidification of magma. The water from the surface reaches to the underground through fissures and gets heated due to the high temperature of igneous rocks and converts into hot stream. This hot water is protected by the hard layer of rock. The heat water is utilized for geothermal power plant by digging the wells into the underground geothermal field.

Geothermal provinces of india :-

In india, there are 400 geothermal springs of medium and high. Most of them are liquid dominated systems. Among them one of two consists of both liquid and gas dominated systems. All these systems are located in seven provinces in the country.

1. The Himalayan province
2. Cambay province
3. West cost province

4. Sonata province

5. Sohana province

6. Godavari province

7. The Mahanadi province

Nature of geothermal fields :-

Geothermal field may be classified based on the following parameters.

1. Temperature gradient

(i) Non thermal Area :-

The area where temperature gradient is 10°C to 40°C depth.

(ii) semi thermal Area :-

The area where temperature gradient is 70°C per km depth.

(iii) Hyper-thermal Area :-

The area where temperature gradient is very high compared to non-thermal areas.

2. pressure and Temperature :-

(i) Hyper-thermal field

(a) wet field

(b) Dry field

(ii) Semi thermal field

Methods of harnessing the energy :-

Geothermal resources are classified into four types. As per the resources, there are is the method of extracting the energy.

Geothermal sources can be classified as;

1. Hydrothermal systems
   i) Vapour-dominated system
   ii) Liquid-dominated system
   iii) Hot water Fields
2. Geo-pressured systems / Geo-pressurised systems
3. petro-thermal systems
4. Magma resources

1: Hydrothermal systems :-

Due to the magma magma's heat, water on the surface of the magma gets heated. These can be vapour dominated and liquid dominated systems

i) Vapour dominated system:-

In this type of system steam is generated, as the water gets heated due to the heat of magma.

ii) Liquid dominated system:-

The water temperature in the reservoirs is about 100°c. but water does not boil as it is under pressure.

iii) Hot water fields :

It is similar to the liquid-dominated systems.

2. Geo pressurised systems:

Geo pressurised system is hot water in which substantial amount of methane ale dissolved. Electricity is generated by the combination of methane as well as heat from the thermal content of wates.

3. petro thermal systems :

when there is no availability of water at normal depths this is used. Though water is not available there will be hot rocks at normal depths. so the cold water is pumped into hot rocks by which water gets heated and should be get back out of the surface, this electricity is produced. These temperatures of hot dry rocks can be called as petro thermal energy.

4. Magma Resources:

These consist of partially or completely molten rocks with temperature in excess of 650°c, which may be available at moderate depths.

Hydrothermal resources :-

These are the natural and commonly used sources of geothermal energy. The surface water enters into the earth crust and the deeper layers of 2 to 15 km. The water reaches a reservoir which is covered by solid impervious rocks. When the water comes in contact with the hot rocks above the magma, it gets heated by the heat generated from the magma upto a temperature of 350°C and its pressure increases.

Based on the o/p obtained, hydrothermal resources are classified into two types:

i) Vapour dominated system :-

In this system, the energy is obtained in the form of steam with no or less ~~e~~ water.

ii) Liquid dominated system:

In this system, the energy obtained is a mixture of steam & hot water.

Mini hydel power plant :-

Economic aspects of small/mini hydel power point:

In india, by employing skills and materials which are available locally; it is possible to design and manufacture components such as floating mills, Himalaya mills and hydraulic rams. Turbines for different small hydro power plants are shown in the

table below can be manufactured in Bhopal and Haridwar plants of BHEL (Bharat Heavy Electricals LTD), and Jyothi Ltd, Baroda plant. Purpose of setting up the independent small hydel power plants is an important economic consideration. If an independent plant is installed for power development alone, then construction costs involved will high. Cost of such plants per kW installed will be around Rs. 18000. Therefore, for these plants to be economically successful, they should be setup as multi-purpose plants which can be used for irrigation and other purposes in addition to power generation. Geographical location of the plant also affects the cost of the plant. Because the equipment cost, operation cost and maintenance cost are less and cost involved in pumping the water is eliminated. Following table indicates the range of operation of various hydraulic turbines.

Turbine type	Range of power generation (kW)	Range of operation Head (m)
Pelton	50-6000	100-400
Francis	50-3000	20-200
Turgo impulse	25-3000	50-200
Kaplan	10-6000	2-30
Horizontal tubular	10-6000	2-25

Types of wells :-

self-discharging wells :-

These wells are the most effective wells and generate high energy. The circular pump and the boiler are reused by these wells. Most of the production wells, 2-phase and vapour dominated wells are self-discharging. These wells have lower reservoir pressure. The wells which self discharge are changed into either monitoring wells or reinjection wells or even abandoned. These wells are designed based on the casing design. There are diff types of casings used in diff. sizes of wells. They are;

1. conductor casing
2. Anchor casing
3. Surface casing
4. production casing

Different wells are drilled to various depths ie, conventional wells are drilled upto 1000 to 2500 m, Enhanced Geothermal system (EGS) wells are drilled to more than 3000m The construction of a self-discharging well consists of various parts as shown in fig.

i) Casing Head Flange :- It is the valve which connects the master valve to the casing.

ii) single skin Assembly :-

If the wellhead assembly is connected to production casing, it is termed as single skin assembly.

iii] Double skin Assembly:-

If the wellhead assembly is connected to anchor casing through an expansion spool, then it is known as double skin Assembly.

iv] Expansion Spool:-

It makes the production casing to expand or contract thermally with less movement of wellhead assembly.

v] permanent Thrust Frame:-

when the well expands thermally in vertical direction, this frame supports the wellhead assembly in the axial direction.

Pumped wells:-

pumped wells are the geothermal wells which use pumps, The wells which cannot self-discharge. ale made to function using down-hole pumps. For hot water systems wells are drilled to more than 600m and for warm water systems, wells are drilled to more than 2000m. Pumped wells are also used for direct applications.

The down-hole pumps can function at a temperature less than 240°C. The factors which affect the

selection and installation of these are:

1. Well design
2. Fluid chemistry
3. Reservoir pressure
4. production flow rate
5. permeability

The pump is generally placed within the cased part of the well to ensure that the pump does not collapse. Generally, the initial cost and maintenance of pumped wells are more. The life span of the pump is also comparatively less.

Airlifted wells :-

These wells are mostly used for small and medium rates domestic uses such as bathing, space heating etc. In these wells, air from a compressor is blown into a shallow well. The air mixes with the hot water below the water level and reached the earth's surface due to the gradual decrease of the mixed fluids.

Disadvantages :-

1. As air is blown into the well, it can cause corrosion.
2. Deposition of minerals on the parts.
3. Less power o/p, therefore they are not used as power generation.
4. Not suitable for large [illegible]

Reinjection wells :-

Geothermal fluids are sent back into the reservoir after extracting the energy from them. This process is called reinjection and it has many advantages. It also protects the environment from further pollution. The wells used for such purposes are known as reinjections wells. Their design and drilling is similar to the production wells.

In order to avoid the risk of vertical reverse flowing of the fluid, the process of reinjection should be done under gravity and with no pressure during the process.

Monitoring wells :-

As the name represents these wells are used to measure & monitor the variation of various parameters such as temperature, pressure, water level, fluid chemistry etc. They give a warning symbol if there is any reverse flow of hot fluid during the injection process. They are shallow wells of less than 100m depth because depth of the well increases its cost.

The unused production and reinjection wells are converted into deep monitoring wells to observe the changes in the deep reservoirs. In some places, dedicated deep monitoring wells are drilled upto a depth of 400m to 1500m with similar casing of production wells. But in order to decrease the cost, these deeper wells are made of small diameter.

other types of wells & about two wells :-

certain wells are drilled for a few purposes by industries and departments such as mining. They are,

1. Mining exploration wells
2. petroleum wells
3. coal bed methane wells
4. Waste water disposal wells
5. Ground water wells

Petroleum wells :-

These wells are used to extract petroleum from the deep reservoirs. Based on the production targets, they can be either vertical or horizontal. These wells have relatively smaller diameters of 5.5 to 7 inches. They have limited output and less operating temperatures. Therefore, they are not used for production of geothermal energy. A permanent tubing or down hole pump is installed down the well. Some wells are also installed with petroleum down hole pump and a shaft to drive them.

Ground water wells :-

These are used for the extraction of water for domestic and industrial purposes. A well dug by the village people is also an example of ground-water well. It has concrete or stone lining and has a large diameter. Also, it is of less cost

To drill deeper wells, rotary bodrilling is employed. It depends on drilling conditions and depth of the well. Non metallic castings are widely used for such wells.

when excess water is available in the winter season, these wells are used for storing them so that they can be used in drought conditions. slug test is conducted by sending the air of high pressure to airlift the water from the bore well. It is done before the pump installation.

CBM (Coal Bed Methane wells):-

These wells are used to extract the methane gas which occurs in coal naturally. In the middle stage of coal formation, coal acts as a source of gas and reservoir. CBM reservoirs are better and environment friendly resources when compared to coal and oil. Their reservoirs are available within the coal range of sub-bituminous to low volatile bituminous. They are described based on the following factors

1. High permeability
2. High reservoir pressure
3. High gas content
4. Large thickness of coal bed

The down hole pumps are used in CBM wells for the following purposes

1. Remove water from the coal
2. Decrease the reservoir pressure
3. To desorb the gas from the coal

Waste-water Disposal Wells:-

These wells are used to dispose of the waste fluid into the ground. These wells are mostly drilled by the industries's where water is also reinjected into the ground and it was first started in the year 1865 by a petroleum industry. The field operators are instructed to provide best designs for such wells to protect the environment as the waste waters consists of harmful chemicals such as boron, chloride and selenium.

How does harnessing of geothermal energy works:-

Geothermal energy is harnessed from the earth's crust, where hot magma and water is present in the deeper regions. The heat of the magma is reaches the surface of the earth by convection process through the vents. This heat produced can be used directly in buildings or can be used to drive turbines to generate electricity.

Heat from the magma and water is brought onto the earth's surface in following ways:-

1. From Natural Geysers:-

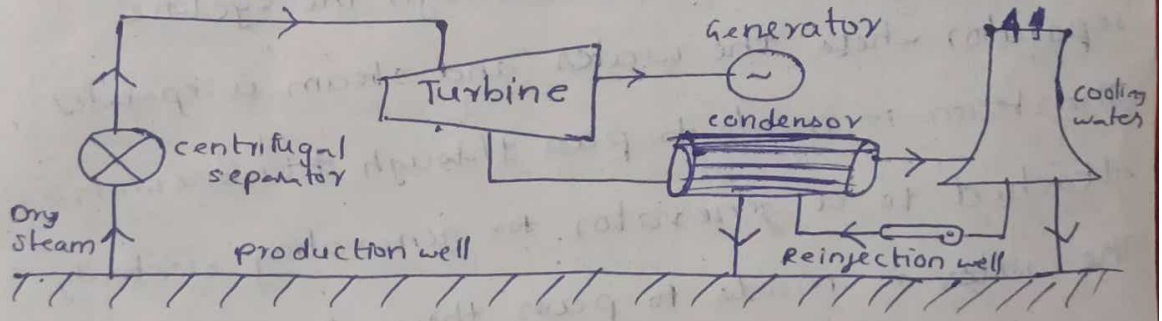
The heat from the magma converts the water in the underground reservoir into steam. This steam and hot water gets trapped in the space b/w the rocks present above the hot magma and escapes through the earth's surface in the form of fountains called geysers.

2. By drilling pipes :-

It is the alternative method in which the pipes are inserted into the deeper regions of the earth. The steam which is trapped inside rocks is pumped out through these pipes with high pressure. This steam is used for driving turbines and generate electricity.

Vapour dominated system:-

These systems extracts dry steam of 200°c and pressure limited to 8 bar i.e, similar to the steam used in turboelectric power plants. Hence, they are also known as dry steam fields. The cost of power generation is less, but adverse effects caused by corrosive gases and crosive material. There are only few vapour dominated systems in the world.



It consists of a centrifugal separator, turbine, condenser, generator & a cooling wates.

During its working, dry steam is extracted from the reservoir and passed into the centrifugal separator through the production well. In centrifugal separator, the solid particles and impurities present in steam are removed. Then, this steam enters the turbine, where it expands over the turbine blades to run the generator coupled to it. The exhaust steam from the turbine

is supplied to the condenses where the wet steam get condensed by means of cooling wates. The excess wates is again supplied into the reservoir through a reinjection well. The warm wates leaving the condenses is supplied to the cooling ~~wates~~ tower, where it is cooled and directed back to the condenses.

Liquid dominated systems:-

In a liquid-dominated system, the temperature of the underground water is slightly highes than its boiling point temperature. But the liquid does not boil because of the under pressure in the reservoir. As the wates reaches to the surface there will be pressure drop & rapid boiling of wates takes place which flushes into a mixture of hot wates and steam. The mixture is made to pass through the cyclone separator where the wates and steam is separated The steam is made to pass through the turbine which is attached to a generator for generating electricity. The wates is made to pass through condenses & then again into the geothermal wells.

The liquid-dominated system is classified into following types. They are -

(a) The flash steam system

(b) The binary system

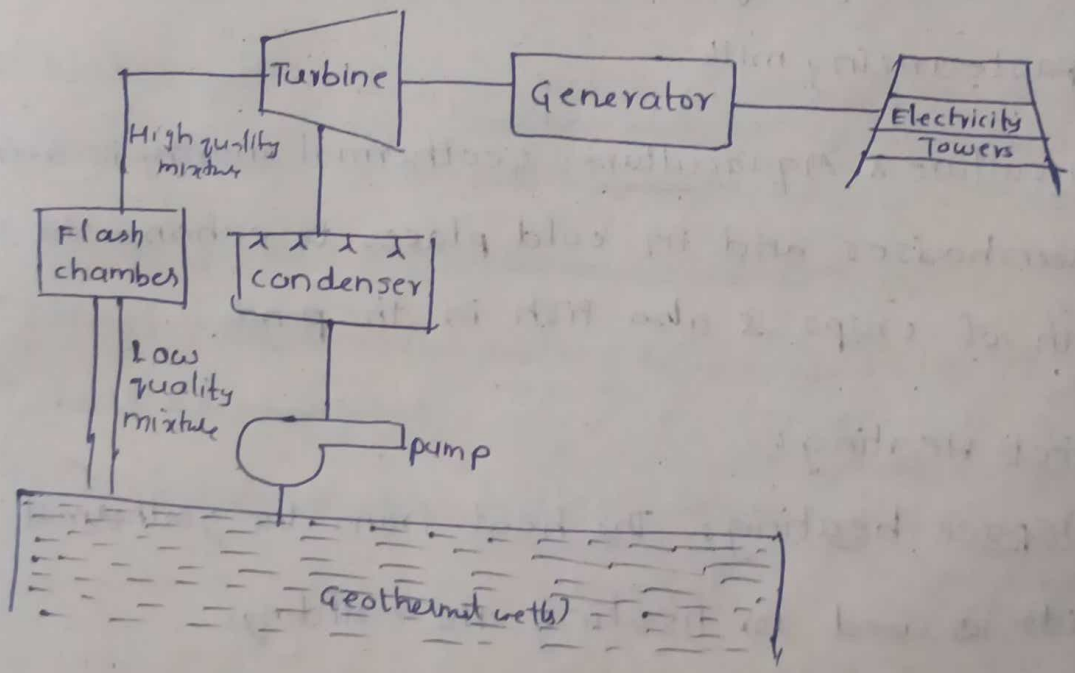
(c) The total flow system

Flash system :-

The flash system consists of a flash chamber, turbine, generator, condenser, pump etc., as shown in fig. There are three types of flash systems. They are :-

(i) Single-flash system
(ii) Double-flash system
(iii) Multiple-flash system

In these systems, the hot brine solution i.e, mixture of salt water and steam is made to pass over the flash chamber using throttling process. In flash chamber the low quality mixture of steam and water is separated and high quality mixture is passed into the steam turbine.



Similarly, the process is called as double & multiple flash ~~system~~ steam where high efficient quality of steam is pumped into the turbine.

Applications of Geothermal energy:-

1. Electricity generation:- It can be used for power generation if the temperatures ale above 150°C. In countries such as the US, italy, New zealand the energy is used for generating electricity. The energy can be used for generation of base load power.

2. Industrial process applications:-
   a) Drying of crops
   b) chemical & textile industries
   c) Food dehydration
   d) Drying of cement slabs in cement industry
   e) paper manufacturing
   f) coal drying & gasification
   g) pasteurizing milk

3. Agriculture & Aquaculture:- Geothermal energy is used in greenhouses and in cold places to enhance the growth of crops & also fish in the ponds.

4. Direct Heating:-
   (a) space heating:- The heat from the geothermal fluids is used for heating the buildings.
   (b) In cold countries, it is also used for cooking, bathing and keeping their houses warm.

Benefits of Geothermal energy storage:-

1. Wastewater is recycled
2. There is no effect on the minerals in the soil & they are preserved.
3. Less utility costs
4. Less emission of carbon dioxide

Disadvantages of geothermal energy storage:-

1. Greatly affected by the surrounding environment.
2. The underground heat impacts the storage system

3. Possible sources of geothermal pollution & how to avoid them:-

1. solid particles & Non-condensable Gases
2. Water pollution (reinjection of geothermal fluid into the reservoir minimizes the surface pollution)
3. Land erosion (controlled by planting trees on large scale)
4. Noise pollution (can be minimized by installing silencers)
5. Heat pollution (be avoided by generating additional power by binary fluid cycle)
6. Water borne poisons (can be prevented from mixing & polluting by re-injection)
7. Air borne poisons (by discharging in a controlled direction)

Open cycle OTEC system:

An open OTEC system have the following impact on the environment.

1. In this system, when the warm water containing CO_2 particles is discharged into the atmosphere, it effects the surrounding environment.
2. Due to the circulation of water during operation, living organisms in the ocean are effected and can be killed.
3. Ecosystem surroundings the power plant will have adverse effects as the temperature of the water changes.
4. It also effects the ocean currents & weather

potential of geothermal energy in india:-

In india, about 340 thermal areas, in the form of hot springs have been discovered and there are 93 systems which are considered as the total stored heat potential. The total heat potential of these systems is 36.87×10^{17} calories. This is nearly equal to the energy released by burning 5160 million tonnes of coal or 25440 million containers of oil. Among these 93 systems 38 are used in electrical power generation, as they posses high temperatures For 100 years the power generated by these systems is

estimated to be about 500MW and for 30 years, it is 1650 MW. The other remaining systems are used in applications other than power generation due to their intermediate and low temperatures.

The geological survey of india have discovered nearly 50 geothermal fields of steam in puga valley of Ladakh, which are capable of operating a 5MW power generation plant.

Working of an OTEC system:-

The concept of Ocean Thermal Energy Conversion (OTEC) was first introduced by a French physicist J.D. Arsonval. It is based on ocean thermal gradient principle of thermodynamics. It states that "If a heat source is available at a higher temperature and a heat sink at lower temperature, then it is possible to utilize the temperature difference to operate a machine such as turbine, which can convert a part of heat taken from the source into mechanical energy & hence into electrical energy by using a generator. The remaining heat is discharged to the sink at lower temperature. The surface of sea water acts as a solar heat collector. The surface of the sea will have high temperature, and is considered as heat source. The water at deeper levels at the sea are at relatively lower temperature, and is considered as 'heat sink'. This temp. gradient can be utilized to run heat engine to generate power. This is known

Difference b/w tidal energy & wave energy:-

Tidal energy	Wave energy
It refers to the hydro energy in ocean tides.	It refers to the waves of water from ocean to the shore.
Tides occur due to the gravitational attractive forces from the sun & the moon.	Waves occur due to the rotation of the earth and the winds over ocean surface
The water level in ocean rises periodically during high tides and drops during low tides.	Wave have an interval of 4 to 12 seconds. Usually the cost of a wave varies from few centimetres to about 10m
The difference in water heads during high tide & low tide is used for rotating hydroturbine generator.	The wave energy rotates the rotor of the wave machine

Different types of conversion techniques for tidal energy:-

There are three techniques available for conversion of tidal energy into electrical energy. They are:-

1) Tidal Barrages:-

Tidal Barrages are similar to that of dams employed in hydroelectric power plants, but tidal barrages are quite bigger than dams. Construction of tidal barrages

is carried out across an Bay. Minimum value of tidal range ie, diff b/w high & low tide should be by 5m, in order to generate power using the tidal barrage. During high tide period, ocean water enters into the basin through the barrage. The gates of the system gets closed when the tides become less intense.

Tidal lagoons :-

Working principle of tidal lagoons is same as that of tidal barrages but differ in construction and location. It is smaller in size and located away from the ocean. During high tide period, ocean water is allowed to flow into the lagoons through canal connecting ocean and lagoon.

Tidal Turbines :-

They resemble the windmills, but difference is that they are located underneath the water. Tidal turbine blades are shorter and of higher strength when compared to that of wind mills.

Tidal turbines are environmental friendly and their installation cost is high.

Sources of Tidal energy :-

Tides are periodic rise & fall of ocean water level, which occur generally twice in each lunar day. The gravitational pull of moon and to a lesser extent the sun, on the earth gives rise to a bulge in the ocean on side facing of moon. On the opposite side

of the earth a second bulge creates centrifugal force due to its rotation. The two bulges are high tides and the areas b/w the bulges are low tides.

Tides are driven by the moon's rotation around the earth and waves are driven by the wind blowing across the surface of the waters.

Minimum tidal Range :-

Minimum tidal Range is defined as the difference b/w the level of mean high tide and low tide.

For a tidal plant operating with conventional equipment, the value of min. tidal range is 5m. whereas, for a tidal plant with low-head equipment is about 2m.

Tidal power plants :-

The periodic rise and fall of the sea level relative to the land is called as tide. Attraction of sea by the moon results in tides. Tidal power is a renewable source of energy and is a form of hydro energy. The energy obtained from tides can be converted to mechanical energy using hydro turbines which in turn converted to electrical energy by generation. The energy generation from tides depends upon the heights of the tides. The height of the tide must be either below or above the level of tidal basin in order to operate the turbine unit.

The power or energy generation system of tidal energy includes the following elements.

1. Tidal Basin :-

A shallow bay that is used to store and discard the water as the tide rises and falls respectively is known as tidal basin.

2. Barrage or Dam :-

It is a wall constructed across the tidal path i.e in b/w sea and tidal basin to trap the waters from either going into basin during high tides or going out of basin during low tides.

3. power house :- It consists of turbines, generators & other auxiliaries.

4. Turbine :- It gets operated when flow occurs from sea to basin and vice versa, which converts the energy possessed by water into mechanical energy.

5. gates :- The flow of water to the basin is controlled by gates to avoid overflow.

6. Generator :- It is connected to o/p shaft of turbine so as to convert the mechanical energy from turbine to electrical energy.

Advantages of Tidal power generation:

1. It does not require large area of land.
2. power generation is free from pollution.
3. Tidal power does not depend on the rainfall. Thus, there is no uncertainity in tidal energy availability
4. It is inexhaustible and a renewable source of energy.
5. The net cost associated with the tidal plant is less

Limitations of Tidal power generation:

1. The construction of tidal plant in sea is difficult
2. The o/p tidal energy changes with the variation in the tidal range.
3. when compared to other renewable sources of energy, the tidal power plants are costly.
4. The machinery may get corroded bcoz of the sea water.
5. sedimentation of tidal basins is a common problem.

Utilization of tidal energy:

The following two arrangements are used for the utilization of tidal energy:

1. Single basin arrangement
2. Double basin arrangement

1. Single basin arrangement:-

It consists of a single basin and a dam that separates the basin with the sea. The flow b/w the sea and basin is regulated by sluice ways located on the dam. In this system, the power can be generated using any one of the following systems.

i) Single Basin Single effect:- There are 2 operation cycles

a) Ebb generation:- When there is a high tide in the sea, the water is allowed into the basin by opening the sluice gates. During this process, the turbines sets are closed. The water flows into the basin till it attains the max. tide level.

b) Flood or Tide generation:-

ii) Single Basin double effect:-

a) Double basin arrangement:-

Advantages & disadvanges of Wave energy:-