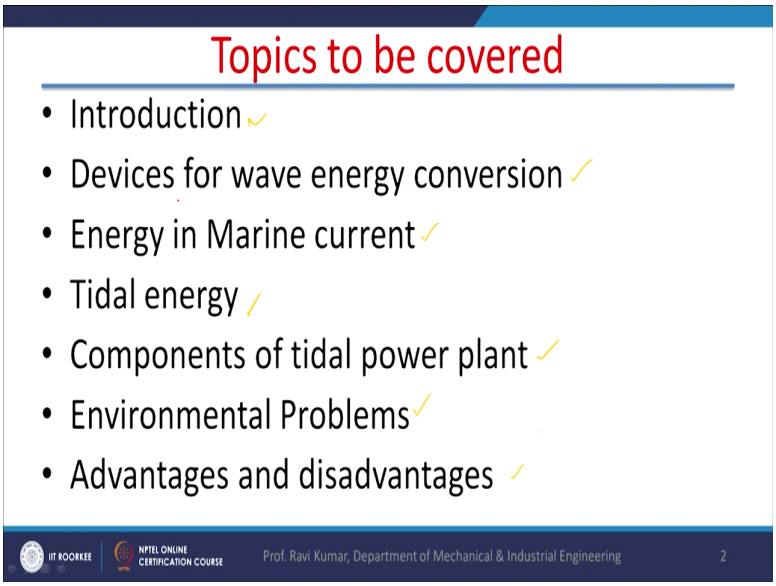
Power Plant Engineering
Prof. Ravi Kumar
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture – 33
Wave and Geothermal Energy

I welcome you all in this course on Power Plant Engineering and today we will discuss some more nonconventional energy sources like, Wave and Geothermal Energy, both are nonconventional type of energy sources.

(Refer Slide Time: 00:41)

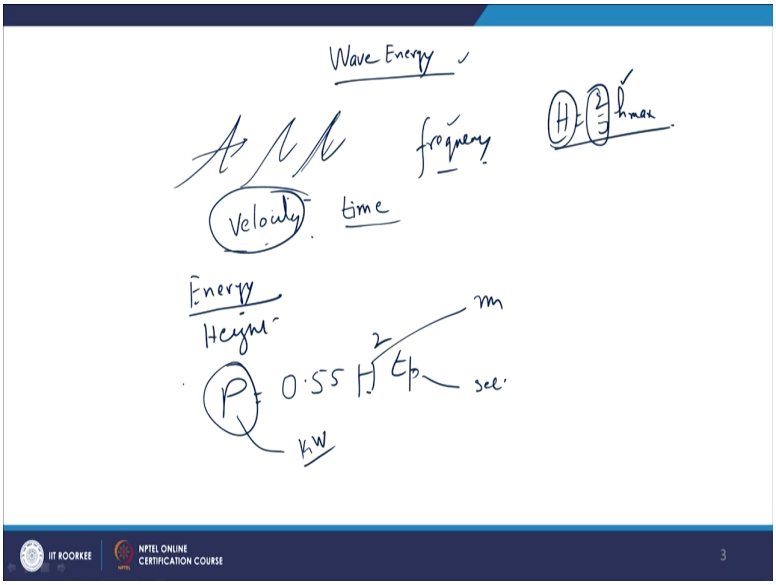


In today's lecture first of all I will start with the introduction of the lecture, then devices for wave energy conversion, what are the different devices which are used for wave energy conversion. Energy marine current, there is a marine current also which with the current which is below the surface of the sea, so that is known as marine current, so, we will discuss about

the marine current as well. Tidal energy, components of tidal power plants also we will be discussed in this lecture.

Now environmental problems with the geothermal energy, we will also we are because we are also discussing geothermal energy in this lecture. So, environmental problems with the geothermal energies, and advantages and disadvantages of geothermal energy, so, wave energy; first of all we will start with the wave energy.

(Refer Slide Time: 01:23)



In a sea on a seabed when there is a interaction between air and the seawater, air boost with the very high velocity and this very high velocity causes the wave in the sea right. So, higher the velocity higher is the wave. So, these waves contains enormous energy and this energy can also be trapped by some means through some devices. So, higher if the velocity higher the wave, if the duration, so the height of the wave depends upon the velocity and time is also

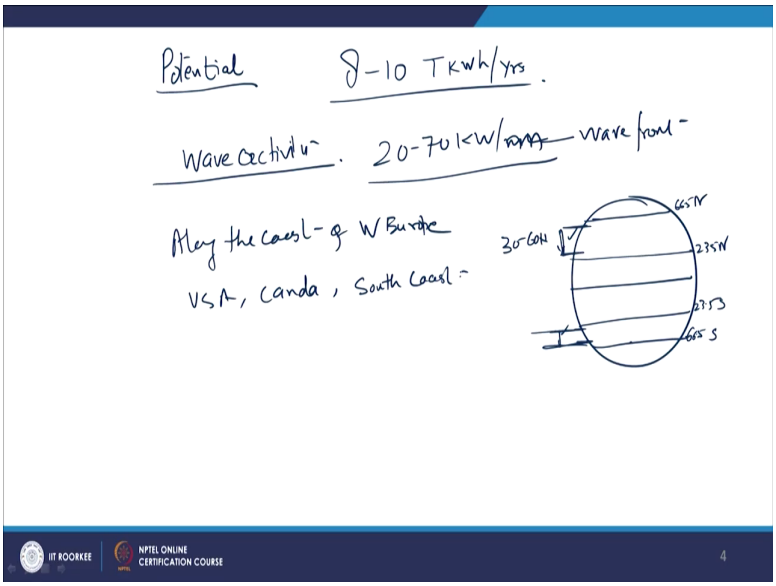
important. Duration of that velocity because velocity also keeps on changing velocity of air also keeps on changing.

So, a particular velocity is flowing over the seabed and for a particular time duration that will decide the energy in the wave and the height of the wave as well. So, energy (Refer Time: 02:28) the velocity the kinetic energy of air it is obvious. The kinetic energy of the air will transmit energy to the waves, right and duration also will decide how much energy is being transmitted to the waves. So, the velocity and time duration is important in order to find energy and height of the wave.

Height of the wave is also important and the second thing is in addition to the height of the wave or amplitude of the wave frequency of the waves. So, all these aspects have to be taken into account while we work on developing power with the wave energy. In fact, the wave energy is also manifestation of solar energy because due to the solar heat only the temperature differential is created on different parts of the world. And due to this temperature difference density difference is there and density difference causes the moment of the air and this moment of the air is causing the waves. So, it is indirect use of solar energy right and it is still a nonconventional power system.

Now the power from the wave, as I said the power varies with amplitude and frequency, but there is a empirical relation. Power is equal to 0.55 H square t p. H is the height of the wave, t p is the time in seconds. So, it is the height of the wave normal height of the wave in meters, t p in seconds and power in kilo Watt. So, we can have a rough idea how much power will be developed with the wave. Now wave height is another issue, because it keeps on changing with time. So, which height we should take in at for H. So, H is normally two-third of maximum height.

(Refer Slide Time: 04:51)

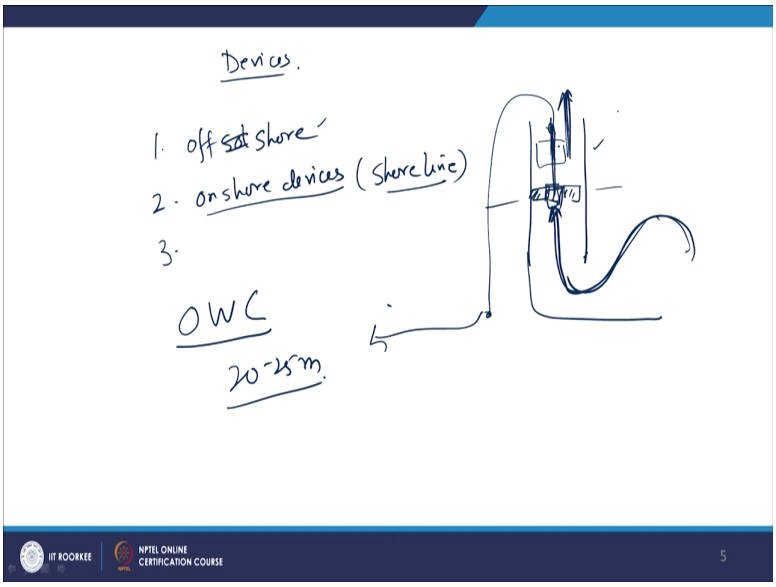


If we capture the image of the wave and we take the image of the wave and we take that in that case two-third height of the wave is considered as the nominal height of the wave which can be taken into account while calculating the power of the wave through this equation. Now potential, what is the potential of wave energy? What is the potential of wave energy? The wave energy potential throughout the world is between 8 to 10 trillion kilo Watt hours per year; it is quite high if it is properly trapped and this potential is universally distributed right.

Highest activity wave activity highest level of wave activity with annual average power potential is 2 to 70 kilo Watt per meter square sorry meter not meter square per meter wavefront per meter of wavefront or the wave height. And as you know if you look globally this is Tropic of Cancer, this is Tropic of Capricorn, this is Arctic Circle, this is Antarctic Circle. This is 66.5, this is 23.5 south, 23.5 north, 66.5 north, so, this is Arctic Circle this is Antarctic Circle.

So, between 30 and 60 north, 30 to 60 north, and 30 to 60 south as well; so, 30 to 60 south this band and this band mainly there is water right. So, this part of the globe it has very high potential for trapping the wave energy. Highest resources are available along the coast of Western Europe, USA, Canada, South Coast and Australia also South Coast and Australia. So, there are number of places in the world where we can trap the wave energy.

(Refer Slide Time: 07:23)



Now devices, now how to convert the wave energy devices? So, this technology is the most advanced technology for trapping the energy and it is costly also that is many of the companies could not survive when we developed the this wave energy when we are tried to wave trap the wave energy because this technology is quite advance and the energy produced by wave energy is also costly.

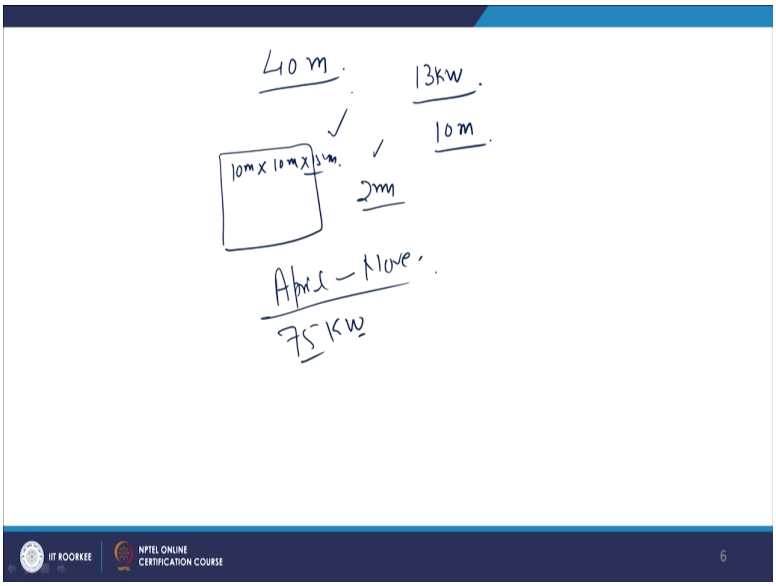
So, wave energy plant cannot be used as a base load plant it is obvious. So, it cannot be used as a base load plant. So, the devices which are used are classified as number 1 off shore devices, number 2 on shore devices and or off shore on shore or shore line near the shore right. 1 is off shore and another is number 3 is deep sea devices, quite in the deep sea where the depth is 40 meters or I mean 40 meters or 60 meters.

So, shore on shore devices they are placed on the shore itself, they are easy to install they are easy to install and fabrication is I mean transportation is also easy because you do not have to transport part into the deep sea. When the installation in the is in the deep sea, in that case the cost of the plant automatically shoots up. Now one of the examples of this devices wave energy devices is OWS Oscillating Water Column.

So, oscillating water column has been developed for I mean it is it is pleased in the deep sea where the where the depth is not very high it is approximately 20 to 25 meters. And it is a vertical cylinder it is a vertical cylinder having a piston type of arrangement, piston type of arrangement piston is fixed here and water is wave is coming from here. So, when the wave water is entering in pushing the piston is moving in upward direction.

So, wave energy is trapped in form of a linear mechanical linear motion which has momentum as well because momentum from these waves is transferred to this piston and that is how these a number of these type of cylinders are put on the seabed they are half submerged right and output of these OWC's right OWC's is connected is electricity is produced here itself by running a motor right. And the through the cable it is transmitted to the shore and you will find a number of OWC's are placed where the power is generated. A number of OWC's are because individual unit cannot produce much power.

(Refer Slide Time: 11:13)



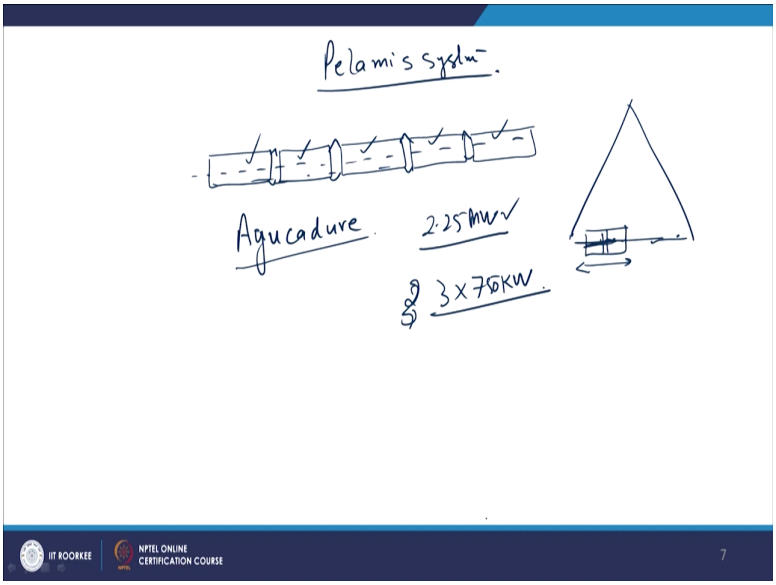
So, depending upon the power requirement number of OWC's are put on the seabed and power is trapped, but these type of plants they cause hindrance I mean the near the movement near the coast. So, that is the main drawback of these types of devices they can go up to 40 meter water also, but sometimes they restrict the movement of the ship as well. So, we cannot go for a large extent we cannot put such type of columns everywhere on the sea right.

So, that will I mean that will create the obstruction in the moments of the vessels right, but there are there are certain power generation units like one Thiruvananthapuram it is producing 13 kilo Watt unit ok. And it is placed in the backwater breakwater of the depth of 10 meters, chamber where the power is generated is 10 meter by 10 meter and 15 meter height right and diameter of the turbine rotor is approximately 2 meters.

So, you can see the size of the plant and this escalates the cost of the plant as well that is why this type of energy is not I mean cheap energy it is a costly energy, but it can meet certain energy costal energy requirement near the coast because, running cost is not very high right.

So, this system delivers 8 months power for the 8 months from April to November right. And approximately 75 kilo Watt of power is delivered by this systems and this system is used for example, for Thiruvananthapuram this system is used for the deceleration of water because for the deceleration of water energy is required. So, this system was is used this system is used for the deceleration of water.

(Refer Slide Time: 12:55)



Now, another device is Pelamis system actually Pelamis is was a company which introduce this system and this system is very interesting there are number of drums the number of drums right. So, it is also called cc sneak and by several names it is called it appears to be like a big snake floating on the seabed and these drums are hinged together.

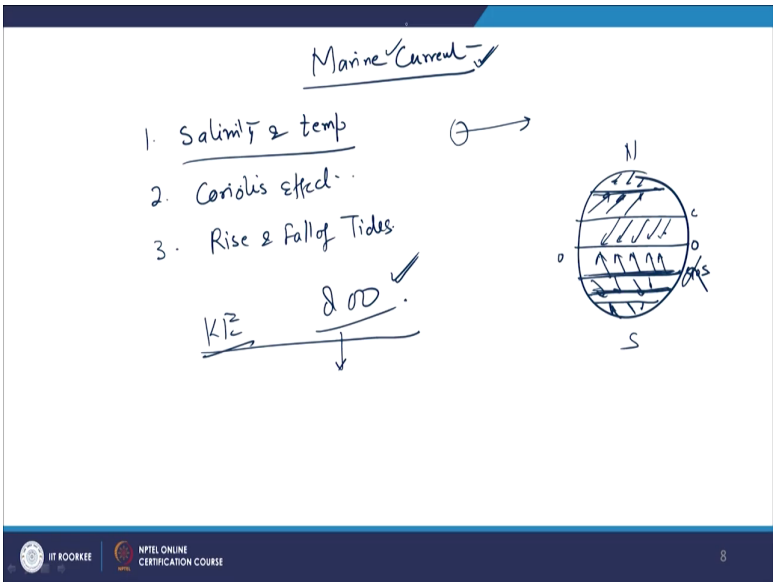
So, on a sea seabed there are drums and they are hinged together due to waves this hinges either they will stretch or they will contract they will move like this right. When they are

moving like this a pistons cylinder type of arrangement can be made right. So, when the hinge is moving then we can provide a piston cylinder type of arrangement here. So the piston will move in to and fro direction or in a linear direction.

Once this mechanical movement is attained this can be easily converted because electronics and technology is very high this is a high tech energy generation. I think it uses a sophistic sophisticated technology and the best technology in the world. So, this two and four movement of the piston ultimately it is converted into the energy electrical energy. So, but if you look at the sea you will find a sort of because these drums are just for the maintaining the inertia of the system right. And they are half they are often seen half floating on the sea floor. So, it appears that a snake is floating on the its not sea floor seabed.

Now this kind of system was first plant was started in Portugal Agucadoura. So the first plant started in the Portugal in Agucadoura this plant is producing 2.25 mega Watt. In fact, there are 3 type of systems and they are producing 75 sorry 750 kilo Watt each. 750 kilowatt each they are 3 systems together they are producing 2.25 mega Watt.

(Refer Slide Time: 15:25)



Now, energy in Marine Current marine current: So, marine current energy is different from the wave energy right. In marine current they are for different reasons first of all difference in salinity and temperature in the water. Because, under the sea if there is a differential in temperature and salinity then both of them will cause difference in the density, due to density difference there will be a movement of the bulk of the fluid from one part to the another part that the first cause on the marine current, second is coriolis component.

Now the when the coriolis force is caused on the moment on the earth because right when it is moving on it excess suppose this is 0 this is Tropic of Cancer, this is Tropic of Capricorn. The wind which is coming north to south will not move to north to south it will move in this direction due to coriolis force. And this wind which is going from south to north will go move in this direction. Sailors know this very well you know ancient time the sailors knew it very

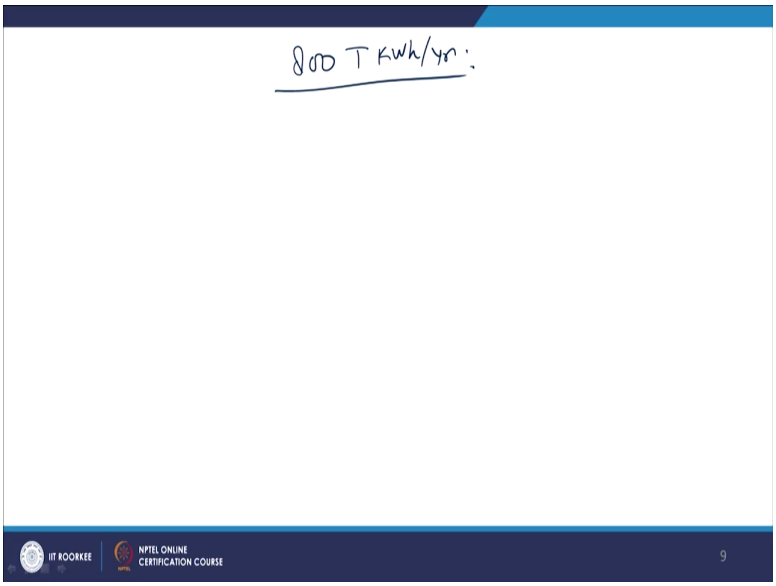
well and that is how they used to manure their ship in a particular season when they wanted to go in a particular direction right.

Now, if you go for this Tropic of Cancers to Tropic of Capricorns this is north Arctic Circle and this is Antarctic Circle. So, in Arctic Circle and Antarctic Circle also the direction is like this and here it is like this. So, they are converging here also they are converging and if you go this 40 south there is hardly any there is land mass, but land mass is not much. And this region is known as the region of sea calm there is not much moment of the air in 40 south, 40 south will not come here it will come somewhere here.

ok So, salinity and temperature 2 is Coriolis effect, number 3 is a rise and fall of tides. Due to rise and fall of tides also the marine currents are formed. Now these marine current they have high kinetic energy because the density of the water is approximately 800 times the density of air right. So, in order to generate the same power we need a very small I mean the size of the machine is comparatively small or with the same volume of water as for air we can generate much more power right.

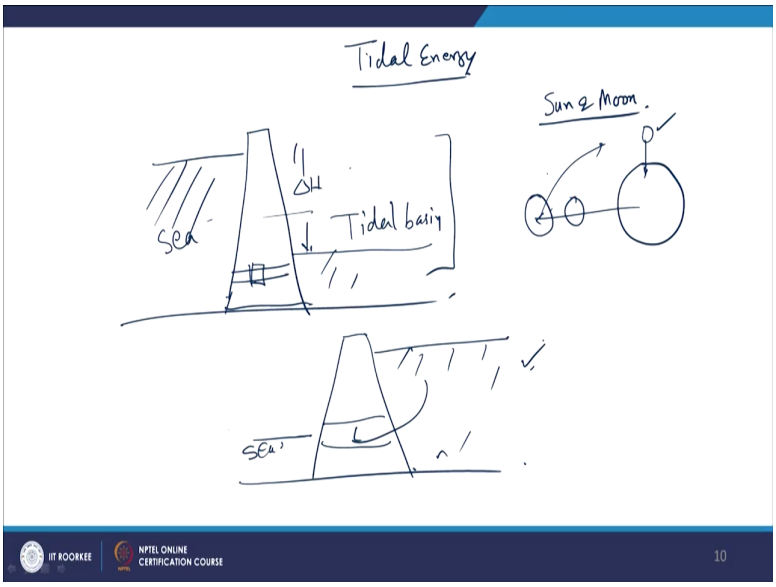
So, the rest of the systems which are used for the marine current are seen as those are for the wind turbines only there is a design change due to density change in the fluid. So, definitely the size of the power generating unit is reduced because the density of the fluid is very high. Rpm is also reduced to a certain extent because if we go for the higher rpm than higher viscous forces will be applied on the blades. So life of the blades will be reduced.

(Refer Slide Time: 19:29)



So, so the using this sub marine turbines you can harness the marine energy also. Now for this energy the global resources now for every energy resource estimation is done. So, for the marine energy the global estimate is 800 trillion kilowatt hour per year, this much energy can be trapped. And at many places like USA, UK, Canada, Italy, Greek Island. Though so many places in the world where this type of energy can be harnessed.

(Refer Slide Time: 19:57)



Now, after this the energy from the sea can be trapped with the form of tidal energy they are tides in the sea. And tides are nothing but, the change in the level of the sea and the level of the sea changes due to gravity from sun and moon. And after every 6 hours the level of the sea changes it will rise for 6 hours, then it will fall it will rise and it will fall it happens 4 times. And during new moon and full moon because new moon and full moon the sun and the moon are aligned. So, both the forces work in the same direction.

So, we get high tides the level of the sea were go goes up to highest level and then it comes down. Similarly, when it is middle of this maybe 8 days after the new moon or the full moon they are on the spring tides. The tides are not very high they are I mean highest tide is minimum highest tide is minimum. So, that is known as the is that is known as the that is

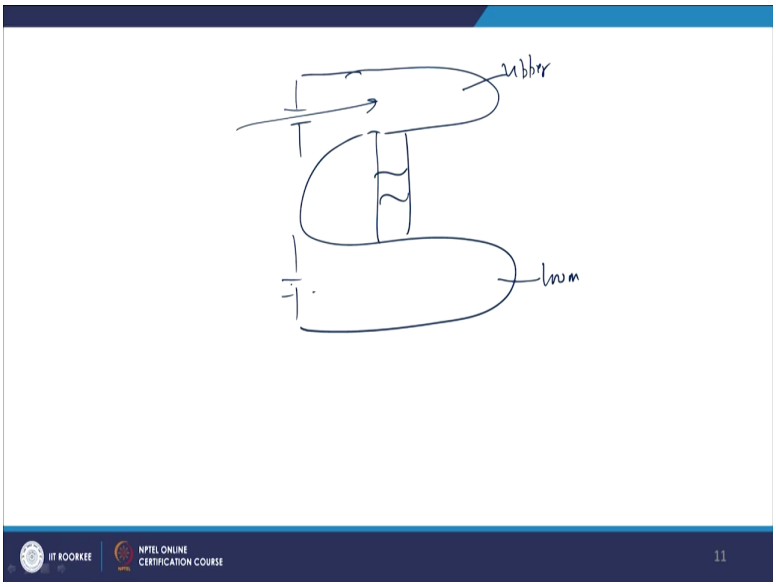
known as the spring tide. So, this difference in tides level of the sea can be used for generating the power.

Now for generating the power simply we need a dam like right this side it is sea this side this is tidal basin. So a basin is perform. So during the high tide the water will be filled with the basin, the when the water will come down. Because sea say sea is suppose there is a low tide sea is on this level basin water is at this level and here there is a passage where we have fixed the turbine. So, when the sea rises it had differential will be develop and this differential will cause the turbine to move.

Though the power will not be constant because at some part of time the both the level will become same. Then what will happen after 6 hours after when there is the low tide, when there is the low tide the sea level will go down and this level will is filled with the water due to high tide and then this is sea level. Then reverse flow will take place and again turbine will continue. So, turbine will continuously producing energy may not be the constant energy because the energy will depend upon the head.

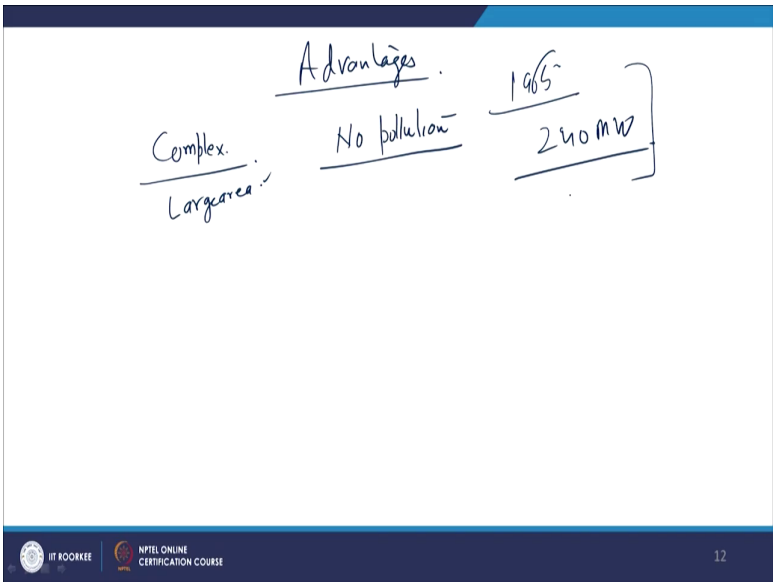
So, nowadays we have sophisticated instrument and electronics right. And. so that which can be used for the purpose of getting the constant power from these turbines. So, excess energy has to be stored and when the energy is not available the stored energy will be used for used in the grid so there is the constant supply of energy.

(Refer Slide Time: 23:15)



So, this is a single basin type and there are 2 basin types of system also where there are 2 basins. Upper basin and there is lower basin upper basin upper basin and there is lower basin and there are sluice gates here through which the water enters and here we have turbines. In 2 basin system also it is a relatively stable to be if you go for the 2 basin system it is relatively stable. And because during the high tide this basin will be filled with the water and water will become stable in the both sides and we get relatively more uniform power from this type of system.

(Refer Slide Time: 23:55)



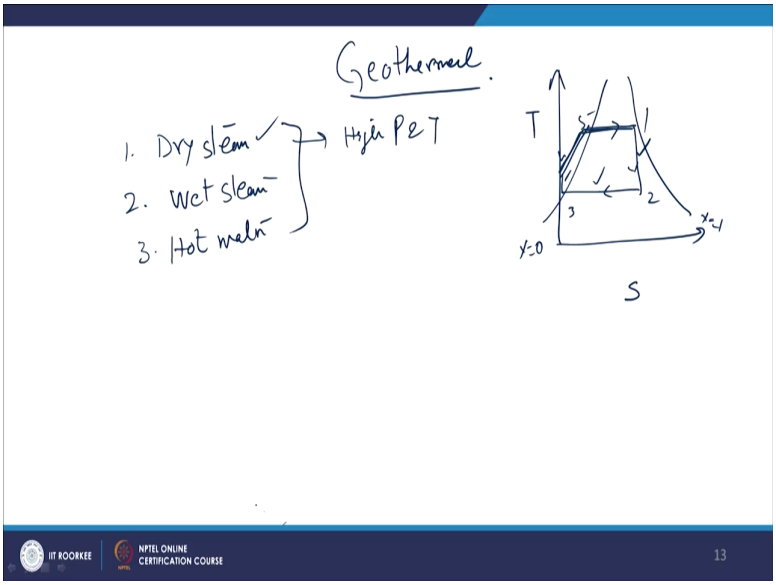
Now, there are certain advantages first of all it is a complex system this type of tidal system is a complex system. But the sources is in inexhaustible because in any type of water what energy we are extracting from the sea, the energy source does not exhaust right. That is that is the benefit of such type of the system, no fuel is required large area is also not required right.

So, it can be worked it can be used such type of systems can be used as a top of plant they cannot be used as a base load plant, but they can always be used as a top of plant they are free from pollution no pollution they are pollution absolutely I mean pollution free. But the construction work in the sea is difficult if you go for the sea basin the construction work in the sea is difficult and I said earlier due to variation in tides we do not get the constant power. So, for getting the constant power some arrangement has to be made. Second thing is siltation in basin take place if you go for the hydro dam also siltation takes place.

So, here also siltation takes place after certain period either you clear the basin or install your plants somewhere else because that basin will become not use less, but of less utility because with it will generating the less power and lastly, the power because the cables have to be laid right and a special type of cables are required when the power is transmitted through the sea. Because the sea is has saline water which is corrosive in nature.

So, the power transmission become costlier when we power is generate in any kind of power which is generated in the sea. So, this type of plant is also available first plant was started in the France in 1965 and it is generating 240 mega Watt power. So, all these non conventional sources are being used in some part of the world. Though their contribution is not significant, but they are using very high technology maybe in the future they may become the conventional power systems nobody knows.

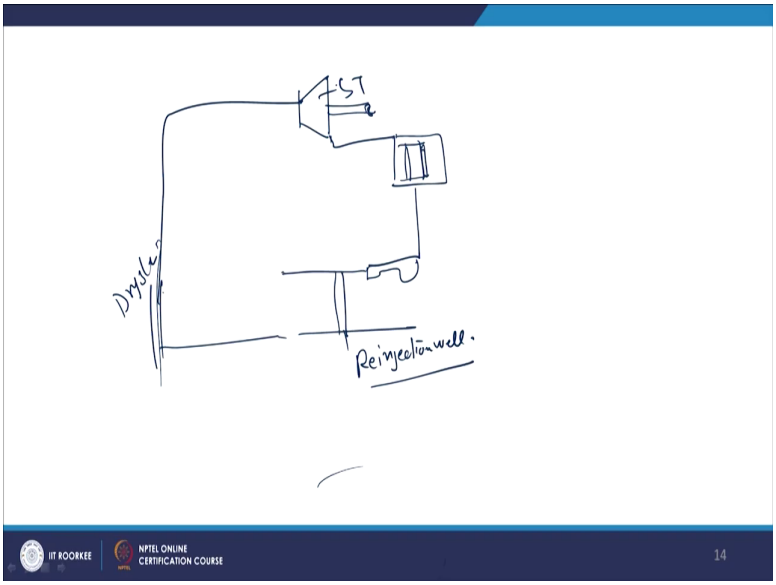
(Refer Slide Time: 26:21)



Now, the next is geothermal power geothermal plants. Now the plants power plants which are running with the geothermal energy when we talk about thermal energy it is something like converting work into the heat and for converting work into the heat we have very simple cycle which is known as Rankine cycle right. So, here also these plants will work on Rankine cycle this is 1 2 3 4 5.

So, geothermal plants have turbines they have condensers, they have pumps only thing is heat addition does not take place in any boiler, heat is extracted from geothermal energy right. So, in the earth you may have seen so there are different types of geothermal power plants 1 is dry steam based power plants where dry or super heated steam is available. So, dry steam is available the dry steam plant, 2ns is wet steam 3rd is hot water right. This steam is available at high pressure and temperature, temperature is around 150 140 150 degree centigrade.

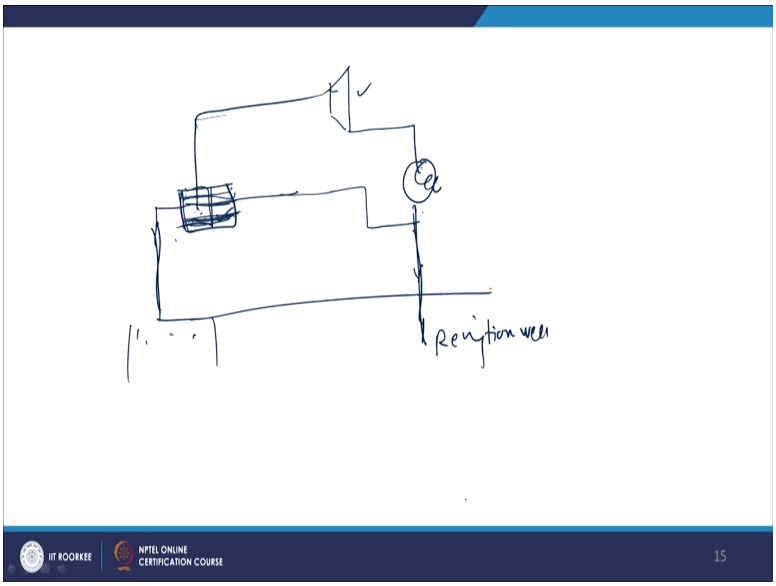
(Refer Slide Time: 28:13)



So, the schematic of this type of power plant is very simple they have a turbine. From turbine sorry the output of the turbine goes to a condenser goes to a condenser from condenser there is a pump and from pump it goes to the it goes to underground and from the ground dry steam is emerge this dry steam goes to the a steam turbine. And this go to the reinjection well.

So, simply there is a steam turbine condenser pump from pump the water is pumped to the reinjection well, from reinjection well we get the dry steam dry steam again its a simple Rankine cycle. Now when the steam is wet so we simply do not put the wet steam into the system because, it may contain some particles right and then we erode the turbine blade.

(Refer Slide Time: 29:21)



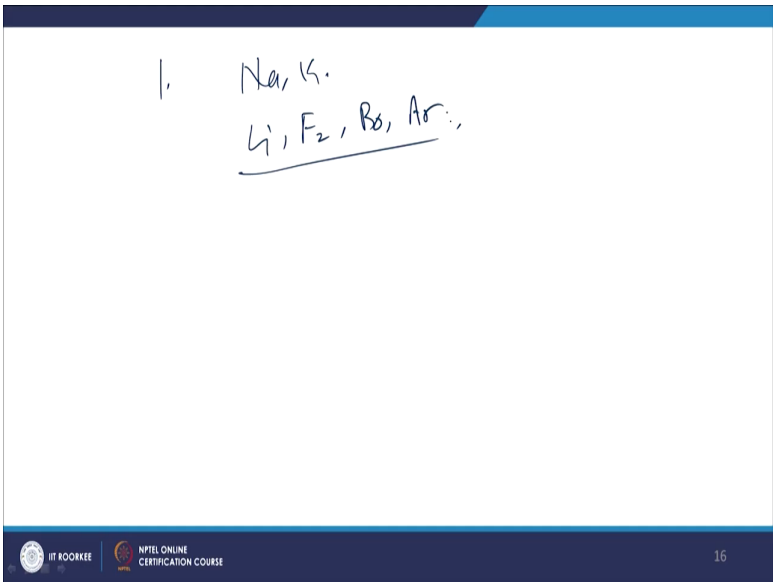
So, first we do what we do we make a close circle of turbine condenser and pump and pump sends this fluid is working fluid is brain. So, brain goes to reinjection well; reinjection well and from here the brain comes it is not water it is brain it goes to the flux chamber. Flux chamber

brain leaves and the flux chamber the steam which is leaving the flux chamber it goes to the turbine. And this again is connected to the exit of the pump and it goes to the reinjection well.

So, brain is our we include not the steam in this case when the steam is wet right. The steam coming from the source is wet so it is not directly used. So, that steam is we used for the heating the brain water and in the flux chamber the steam is removed from the brain and the remaining high concentration of brain is connected with the outlet of the pump and it goes to the reinjection well. Now same thing happens when there is water instead of steam there is hot water.

So, for hot water this is replaced by heat exchanger brain is used right and brain is and there is a heat exchanger, where exchange of heat takes place between this brain high temperature brain water and water coming here at the exit of the turbine and this water gets heated and its converted into the steam. Because brain is at high temperatures around one fifty degrees centigrade and pressure is also 4 to 5 bar right.

(Refer Slide Time: 31:25)



So, this brain transmit heat to the water and water is converted into the steam and steam goes to the turbine. This is how the geothermal power plants work, but the problem with the geothermal power plants is affluent is salty right and affluent contains sodium and potassium and other minerals and some of the compounds which are not environmental friendly. For example; lithium, fluorine, boron, arsenic, they come on the surface and they cause damage to the environment.

Application: geothermal energy can be used for the space heating also besides the power generation, it can be used for the space heating purposes also in it is available. Generating power is low for geothermal engineering, but definitely the heat which is available in addition to the power generation it can be used for process heating as well if there is a nearby industry right. So, this is all for today.

Thank you very much.