Energy Resources and Technology
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Lecture - 32
Tidal Energy (Contd.)

So, in the last class we were talking about the tidal power generation and we had come to the extent where we completed the sections on the one way turbine, the two way turbine and the single basin single tide and the double tide scheme and we had also seen that as you introduce the pumping, then that increases the total energy output by about 20%. Well, still as you have seen that in all the power generations schemes through tidal power, the output is not continuous. It generates power only during a specific period, something like 4 hours and then there will be gap, again 4 hours, then there will be gap, something like that and if the plant is large, then obviously that leads to a lot of problems.

Why because, how do you utilize that intermittent power? If you want to utilize it for domestic purposes, then obviously during the other periods you have to switch everything off, that is very inconvenient. So, one way people have tried to overcome this problem was by means of introducing specific industries. Specific industries means industries which are given incentives to utilize the power only during the period when it is available and there can be easily such industries; industries that switch on during that period, do their production and then when it is not available simply go for lunch. So, it is like that. But of course, if the tidal power plant is large, even larger than the capability of a few industries, then that also leads to problems. There either has to be additional hydroelectric power plants in the power system which can switch on and switch off depending on the availability of power from the hydroelectric plants or do you understand now, why I sometimes get angry about this? Coming some more than 10 minutes late; so, please settle down, please, no sounds please. So, this is one possible way of countering the problem, but people definitely look for other ways of generating continuous power.

Now, why was the power discontinuous or intermittent?

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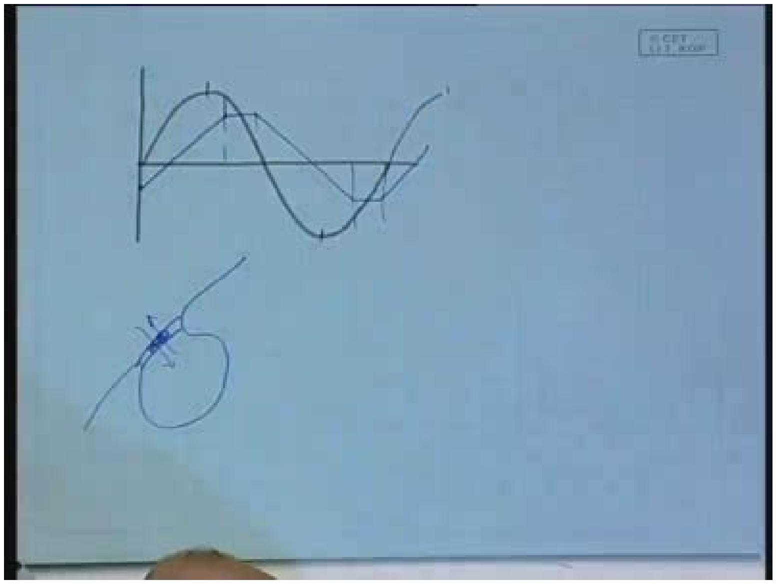

That is because as the tidal variation takes place, by the way which part is the high tide, which part is the low tide in this sinusoidal wave form? This is the high tide and this is the low tide, is it? Wrong. From here to here it is a low tide and from here to here it is a high tide. So, remember the timing. This part is when the water is going out and this is the part when the water is going in. So, this part is called the high tide and this part is called the low tide, not the positive and the negative parts of the wave form.

Now, it was intermittent because, if you have the scheme something like this, you have and you have the turbine here and suppose it is a two way turbine which means that during the high tide period, it will go up and till a certain time when the head is no longer sufficient and when it is closed, so this is the period when, these are the periods when it will be, it will not be generating any power and obviously these times will come how many times per day?

No; this is one cycle which occurs approximately in 12 hours. So, 4 times per day such periods will come when there will be no power generation. So, if there is sufficient amount of hydroelectric power capacity in the power system, please, no, you are too late, okay, come in. I do not understand this and things are getting recorded. So, there has to be some other means in order to produce continuous power and indeed there have been such proposals and installations where continuous power production is possible. One idea out of many that are available, I will illustrate here.

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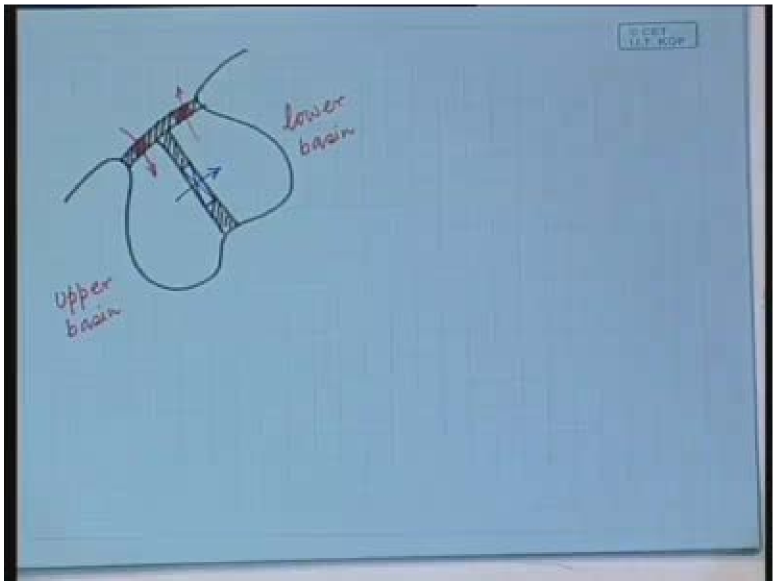

That is if say, you have some kind of topography, something like this, so that you construct a dam here and suppose you construct another dam here, so that the actual basin is divided into two basins. So, this is one dam and this is another one and the turbine is installed not there, but here, a one way turbine which means it is relatively less expensive and one way turbine means it either goes this way or that way. Suppose it goes this way and in these two parts of the dam there are two sluice gates like this. Is it visible, yeah, which means it can either be opened or closed depending on the time of the day.

Now, imagine that during the high tide period, during the high tide period you allow this gate to be opened, so that water goes in like this and during the low tide period you open this gate and allow the water to go out through that. Again, the definition of the high tide and the low tide periods would be as I illustrated just now. That means this period is the low tide, this period is the high tide. In that case this basin will be a, will be maintaining a relatively high water level and this basin will be maintaining a relatively low water level, because during the high tide you are allowing water to come in and during the low tide you are allowing water to go out from here. So, perpetually there will be a head difference between these two and this turbine works utilizing that conditions. So, the turbine does not work utilizing the head difference between the sea and the basin, but rather the upper basin and the lower basin. So, this is the upper basin and this is the lower basin. Is that concept clear? Now in that case what would be the wave forms like?

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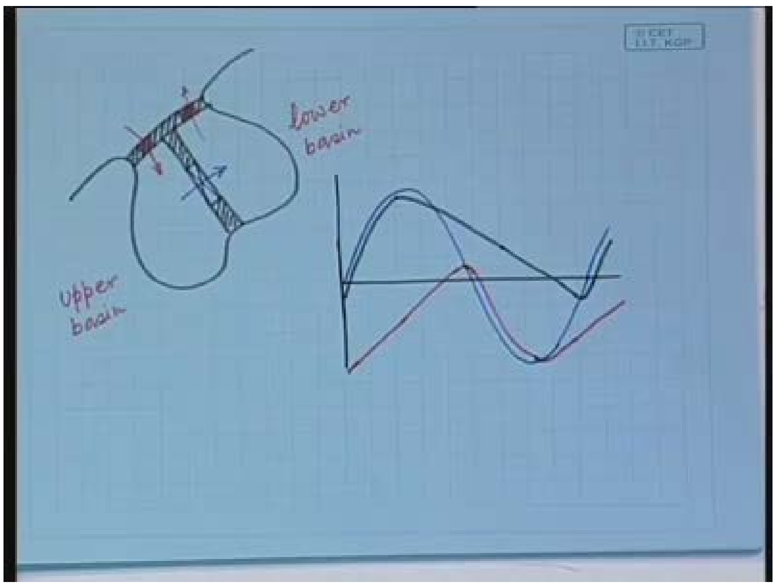

The sea water level let it vary like this. Now, the basin water level, there will be two basins and I will have to draw with different colours. So, what I will do is, I will draw one with black another with red, say I am talking about the upper basin. So, during the high tide period, the upper basin is open to the sea, right and therefore, it should filled up, it should be filled up and the difference between the sea level and the upper basin level would be very small. So, we can assume it to go up like this.

Now, when it is filled up, when this level is reached, very close to this level is reached, then obviously the gate is closed and therefore it will fall, right. Why does it fall? Because, the water is going from this basin to that basin and therefore, the water level falls. Now, let us say what happens to the lower basin. The lower basin was, actually this gate was actually closed during the high tide period up to this point. So, it was only rising. Why rising, because water was coming in from this period. So, even though this gate is closed, it was rising slowly, like so, say it comes to this point and at this point what will you do?

You will open this sluice gate, right. If this sluice gate is opened, then the water level falls. It will be slightly greater than the water level in the sea, but nevertheless it falls like this and this fellow continues, continues till what time? Till this time. At this time it again becomes equal to the sea level and then the sea level would be increasing. So, this sea level is increasing, it goes like this and it comes here. So if I continue to draw, it will be like this, the way it was rising here. What happens to the lower basin? At this point it is enclosed and then the lower basin’s sluice gates is closed. So it again keeps on rising like this.

Student: Sir, at any time lower basin and upper basin will be …

No, because all the time there is a level difference maintained between the, black one is the upper basin level and the red one is the lower basin level, you can always see there is always a head difference between the two that is maintained.

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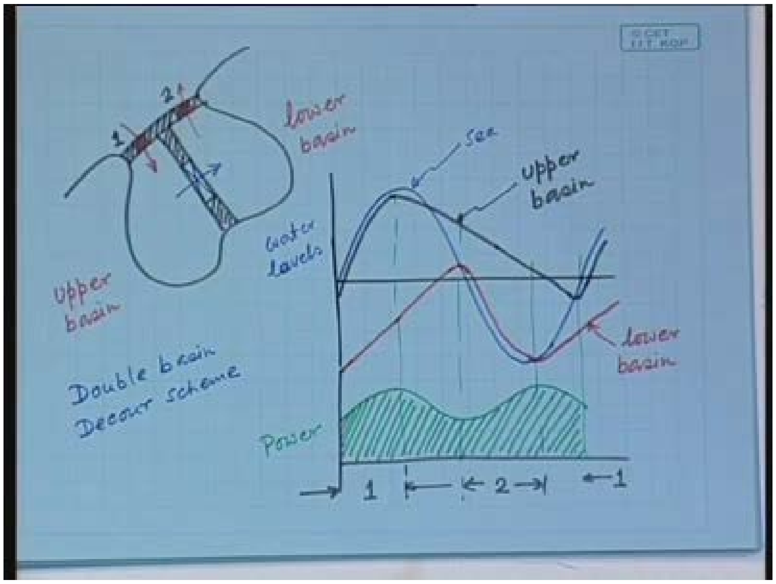

So, if you draw the curve for the power generation,

Student: Sir, when the water in the upper basin has been filled up in the first half, sir, will not there be water leaked into the lower basin, because we have a turbine?

Yes, all the time water is going into that, but I am assuming that more water is coming in through the sluice gate, because sluice gate does not offer much of a resistance. So, we can logically assume that it would be more or less closely following the sea water level. Yes, all the time water is going, not leaking in. It is going from this side to that side. This by design it will go, but nevertheless more water is coming in from the sea side, so we can logically assume, though it may not be as closely following as I have drawn, it is just in order to illustrate, it may be slightly less.

So, what will be the wave form for the power generation like? Notice that even though all the time there is a head maintained, all the time there is a head maintained, the power generation is definitely not constant, because the head is not constant all the time. The head is large during this period, small during this period, again large during this period. So, you will see that if I, during this period, I expect it to be large and then it will fall and it will, it can, it will be large then it will fall, but nevertheless all the time you have power generation. So, the power curve is this, the water levels here. So, this is the sea, this is the upper basin and this is the lower basin.

Student: Sir, when does this sluice gate open and close?

I am coming to that. So, this is the curve of the power generation. So, his question is when does the, when do the two sluice gates open and close? Can you specify those periods? Let us see. This is sluice gate one and this is sluice gate two, say. Is it visible this side? Yes, it is visible. So, 1 is open during this period, till this point. Then at this period both are closed. The sluice gate 2 opens from this period to this period. So, 2 is from, again both are closed, again at this time 1 opens, right. So, this is called the double basin. That is way I had earlier mentioned single basin, because there are all also double basin schemes. It goes by the name of the engineer who designed it. Now, this is for example in use in La Rance in France, clear.

Now, similarly we can easily imagine that there can be more. You might possibly argue that why not install turbines here also. There can be those possibilities, turbines installed in those places, yes. You might argue why not use pumps in those places to increase the water level here and decrease the water level here. Yes, that is also possible. In addition there are also schemes where in this part there is a very complicated enclosure created with one turbine, so that the same instrument can be used both as a turbine and as a pump with various directions of gate opening and gate closing. All those schemes are available and installed in various places and these schemes normally go by the name of the people or the engineers who designed them.

For example, you would hear of Defour scheme. There is another French engineer who designed a similar thing, the Bernstein scheme who designed the Russian installations and stuff like that. But in essence, whatever we have learnt so far, those things are only combinations, various types of combinations of essentially the same ideas. So, one normally tries to generate continuous power, one normally tries to maximize the amount of power generation and in order to do that, you might say that okay, I will install one turbine here, but no turbine there, because each additional turbine would mean that there is some additional initial expenditure. So, one turbine here which means if it is a turbine, then obviously the water level will not go up as fast as it did if it were sluice gates. So, the head difference available for this one will be lower, but often that can be offset by additional pumping by the, by whatever is here. So, all these schemes are now in use in various places and as I told you, major installations are in France, La Rance; in UK there is one Severn river, on that there is a tidal power plant, in Russia there are a few and in Canada the big one. Is that clear, what I have told so far?

As I have told you that the tidal power plants normally require low head turbines. Why because, the head available is normally of the order of 2 meters, 1.5 meters, 2 meters, something like that. Only in very rare cases we have a head larger than that. So, 2 meter head is reasonably low head, but at the same time it is true that in river based hydel power plants, river based means normal hydel power plants, the ones that are in the upper reaches of the river in the mountains, they have quite large head, but small flow. The ones that are in the intermediate range, they have medium head, medium flow, but the ones that are in the lower range they normally have large flow, but low heads. So, the low head turbines are normally available, designed for use in the rivers.

So, the turbine is, remember in any alternative energy resource the cost actually is because these, the components that we use, these are not commercial products. Each one has to be designed for that particular purpose. As a result, the cost goes up, but the advantage of tidal power plant is that, mostly the turbines are industrial products which are available for regular use in river based plants. So, what are the things available? The ones that are most commonly available low head plants. The high head plants, when I was talking about the hydel power plant, I told that these are, what kind of turbines? Impulse turbines, ……., they are called. The intermediate head francis turbines, the low head, normally these are the Kaplan turbines, something like this.

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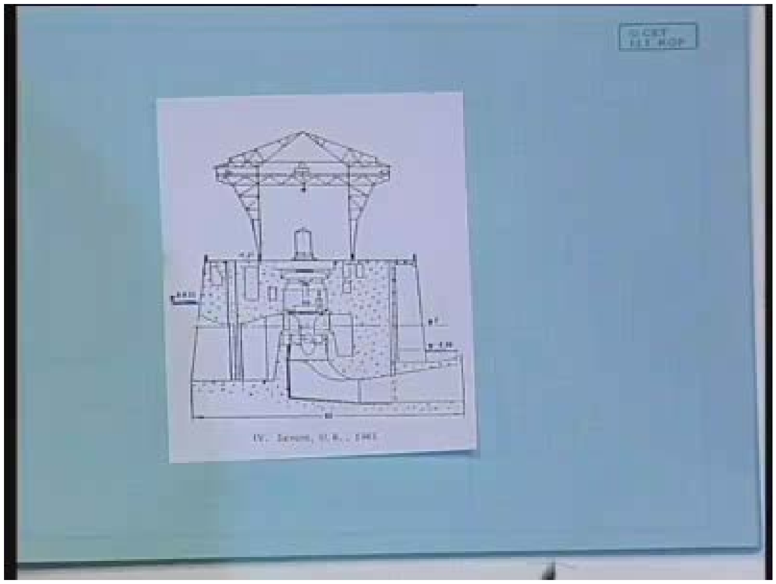

Can you see? Here this is the turbine that has been installed in the Severn scheme in UK. Remember, it was installed in 1945, quite long back. You would notice that here is the path of the water to come and go, can you see, it is somewhat small, but probably you can see, like this and here is the turbine and the turbine is vertical axis turbine with the generator stationed here and this is the civil engineering construction that are shown with the, with the doted thing meaning these are concrete constructions. So, here is the vertical axis turbine, the generator is here, the turbine is here, basically a propeller type turbine, simple construction and the water flow, notice the water flow passage. It goes like this.

These are the standard available ones for the low head installation in the river based plants, river based hydel plants, where these are installed in the lower reaches of the river. Now, notice that if this is to happen, then there has to be some area, some height that must be available in this part, because it has to accommodate the vertical axis propeller. Not only that, before it comes to the propeller there has to be a turn. The water has to turn. There is a bend and naturally, at the bend we have to ensure that the water does not get turbulent, else the power production will go down and there will be vibration around. So, there has to be some range available before it touches the turbine. That also increases the amount of head.

After it, again there is a bend and you have to avoid creating turbulence in this part. So, there has to be some head that must be available here. So, the head actually that the turbine works against is this head, this to this, this difference; say, it is here, one level is here and in the outside it is say, somewhere here. So, this is the actual head difference. So, the turbine works against that head difference, all right, but in order to have this kind of a turbine you must have some minimum head available, so that it can, it can accommodate these two bends. But this is a very convenient construction, why because you can directly situate the generator above the water level.

Now, as I told you, there are some improvements over these designs, specifically meant for very low head hydel power plants. Again, these are commercially available. One is the one that is very popular for relatively low head plants that is the bulb turbine.

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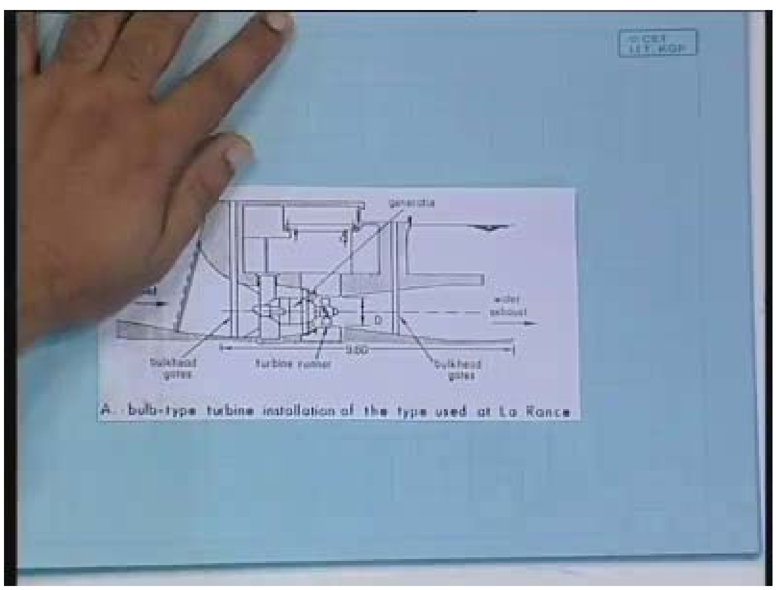

In this case, this is the water inlet. Can you see? This is the water inlet and here is the bulb. So, water flows like this, water flows like this and here is the turbine. The bulb is a metal casing, water tight, that houses the turbine. So, the turbine is housed inside the water, but by means of this water type bulb, you have, you make it free of any water intrusion. So, here notice that you have either a straight flow or a slightly bent flow, but not a complete S-type construction with two big bends. So, naturally the head that you can work against is very low. So, these are very standard constructions for the low head plants. There are obviously a few advantages as well as disadvantages in any construction. One, because the bulb has to accommodate the whole generator and the gearbox, therefore the water passage has to go around the bulb and so, the whole construction has to be such that it does not create a turbulence when it enters the blade. That is one problem.

The other problem is that because the bulb, for this reason, must be relatively small, so the generator size and the gearbox size also necessarily needs to be small. So, you need very efficient generators for this purpose. But nevertheless, these are very useful constructions and installed in many places. For example, here you can see the La Rance is the place where this was installed in France. Is that clear? So, water actually does not flow this way, water flows this way.

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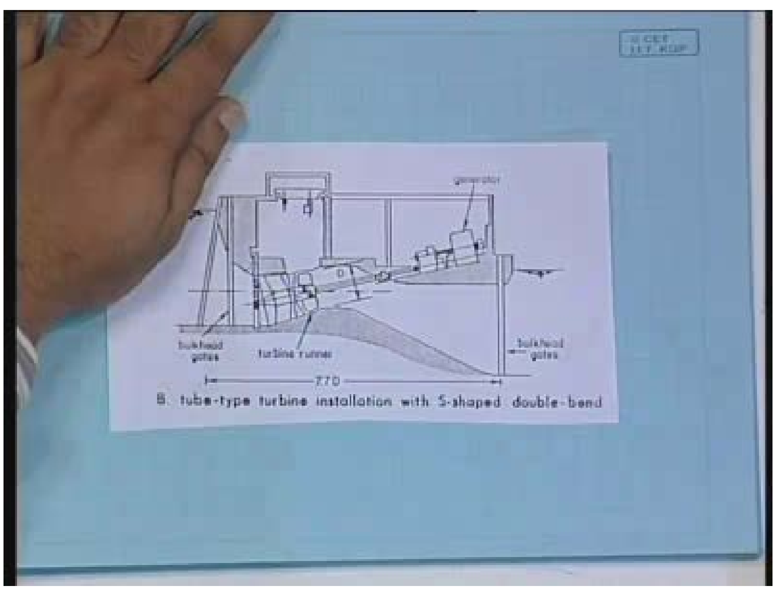

Now, an alternative construction is the tube turbine, where you have the water flow something like this. It has a slight bend. It is not as much as the complete S bend for the vertical axis turbine and the turbine is installed at an angle, not at a vertical angle or horizontal angle, at some angle something like 20 degrees and the shaft goes through and here is the water tight bearing point and it goes to the generator, which is also positioned in an inclined position and above the water level. Here, you can easily see that here also the water passage would be something like this; water passage will be something like this. Here also the head requirement will be rather small, but not as small as the bulb turbine. So, this is called the tube turbine, tubular construction, the whole thing has tubular construction, clear. This is also available, but more available commercially is the bulb turbine.

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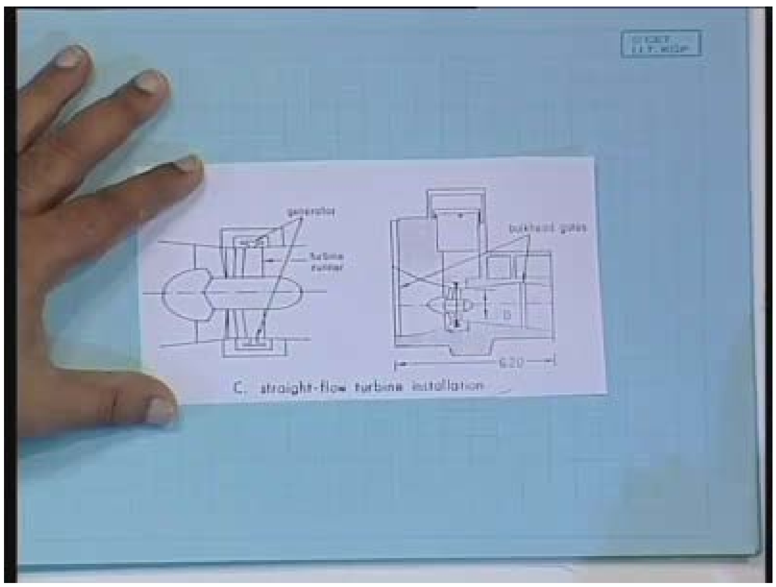

There is another construction that has been proposed, but I do not know whether it has been installed actually, where it is completely straight flow. The turbine, its blades, they are actually connected to the outer periphery. That means the blades extend out to the outer periphery and at the outer periphery, at the end of the blade you have the generator winding here. The stator is stator, static, while the generator rotor winding is mounted atop of the blade, so that as the blade rotates, the rotor windings also do so, clear. Obviously, here you would not have any scope of putting a gearbox. It is directly connected. So, naturally the number of poles have to be large so that you can still generate 50 hertz, but nevertheless the point is that here you have a completely straight flow and therefore, the head that you can work against is very low, it is the lowest. But, there are obviously problems in making such a rotating arrangement water tight, so I am not sure how many places this has really been installed. So, you can imagine the whole construction to be something like this. Here you can see the turbine and the generator here in this part, this part. So, that is how it is installed. Can you see that, right?

So, these are the different types of generators that are used in tidal power plants and naturally what type of scheme you would use, what type of generator you will use, what type of turbine you will use, all that depends on the specificity of the site. There is no general recommendation for that. What is the specificity of the site? One - is there a scope of having two basins? When will there be a scope of having two basins?

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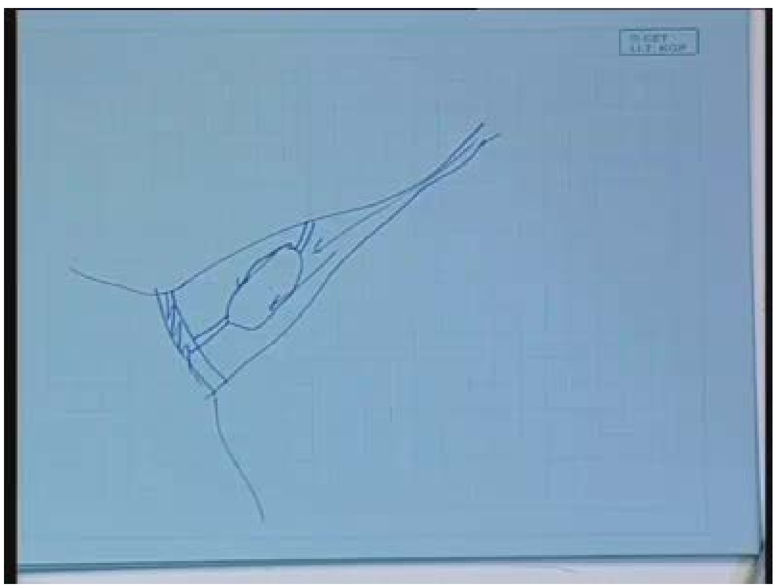

Because, if the structure is something like this that you have got the tributary of a river, so the water go like this and it goes. How will you create the two basins? You can put a dam here and that is it. So, in such cases, it would be rather difficult to make two basins. However, in many cases you have deltas, you have islands, right here. So, if you have that, it is not difficult to have two basins like if you construct a dam like this. So, much of the dam requirement would be offset by the existence of a large island. In those cases, the creation of two basins might be economically viable, because the whole thing depends on the installation cost. Running cost is very small, there is no fuel requirement and so, the installation cost should be kept within an acceptable level and that all depends on the topography of that site.

So, whenever a particular site is considered, one first has to consider the aerial view and from there one has to identify what are the places. One has to find out from the ground how much is the water level that …. that goes on and that may be different from a point to another point. So, all that has to be taken into account, finally you have to decide on what kind of scheme you can install. But in general, it is always better to have the installation of various types of, installation of turbines as well as the pumps.

Now, you would notice that so far we have talked about the solar energy, we have talked about the wind energy, we have talked about tidal energy and we will, in course of time we will, talk about the geothermal energy, then the ocean thermal energy, those things will come. But, you notice that most of the things that we are talking about in terms of renewal power, these are all intermittent. Wind power cannot be generated unless there is wind and wind flow is somewhat varying all the time, unpredictable. Tidal power is very predictable, when it will come, when it will not come, very predictable, but nevertheless mostly intermittent, unless you have a scheme like this.

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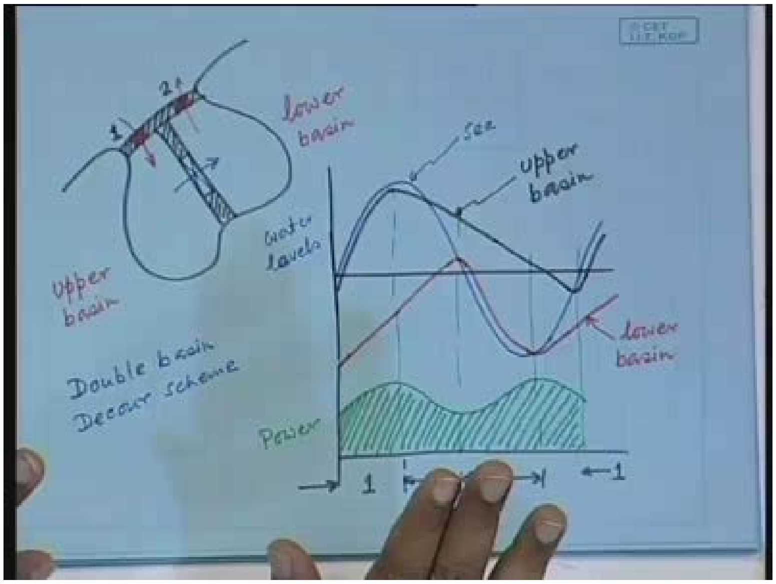

But then also the power production is not constant and therefore, there has to be some kind of a subsidiary arrangement for that. In case of solar energy, you know there is no solar energy during the night. So, there are, these are all schemes that produce and whenever energy is available you produce. So, in the whole power station, where do they come? They come in the base load part. So, I told know that the whole load is divided into a few parts. At the bottom there is the base load normally taken by very large, either thermal power plants or nuclear power plants or something like that. The intermediate load, smaller thermal power plants and if there are relatively large hydel power plants and the peak load almost totally by hydel power plants, because they can be started and stopped quickly.

That means the idea is that the base load plants will work round the clock, 24 hours at the same load. The intermediate load plants will vary their powers, but the peak load plants will start and switch off. Now, where in the whole scheme, well, in the whole picture do this renewable power sources come in? They have to go into the base load plant, because conceptually whenever energy is available use it, which means that the actual base load plants, the ones that are catered by very large thermal power plants, 2000 megawatt thermal power plants, their requirement now goes down.

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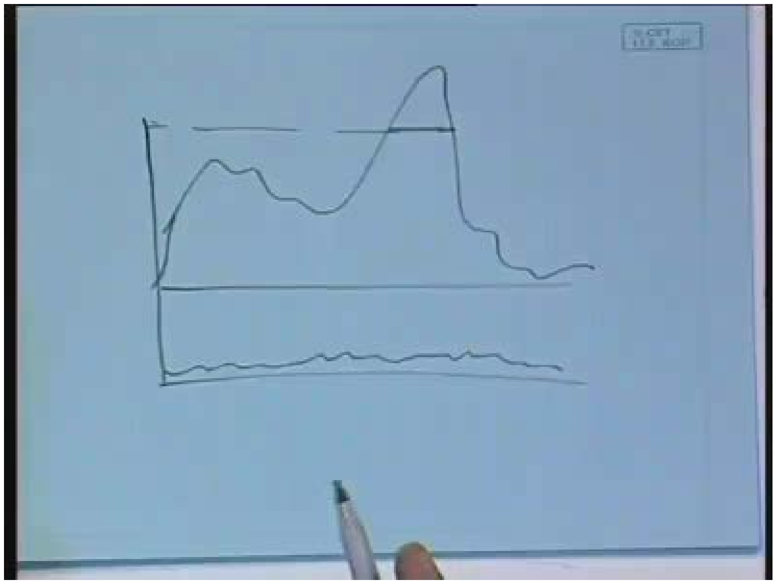

Because, now within the, let me show, suppose you have this as the power curve, this is the day time may be, this is the evening time may be and this is the night time. So, you will have the base load somewhere here, you will have the intermediate load somewhere here and this is the peak load. So, this part is the intermediate load, this part is the base load, this part is the peak load. Normally, you catered these base loads by those big plants, this load by the smaller thermal power plants and this load by the hydroelectric plants or earlier we used to use gas turbines. But these days, gas turbines are somewhat going out of favour except for the regions where the natural gases are available.

In Calcutta, earlier there were gas turbines, but nowadays they do not function because the cost of running is too high, because they have to run on oil. So, this is mainly by hydel power plants, this is by hydel as well as smaller thermal and this is by larger thermal plants. When a power system has this renewable sources, they must be accommodated somewhere here and since these fellows are variable, therefore the amount that was earlier catered by the base load plants, they also must then vary or more amount of power goes then from the base load bigger plants to the intermediate load plants, because then the intermediate load plants can accommodate variation of the power.

So, one implication of in load of the renewable energy is that you have to have larger number of other plants that can vary their power, clear. But at the same time, these renewable energy sources are often complimentary, in the sense that when one is available the other is not available and so on and so forth. For example, wind is often, you will find since we have been in Kharagpur for quite some time, have you noticed that in the evening the wind speed goes up. So, the wind is relatively more available during the evenings and that is when solar energy is not available and so on and so forth.

So, one can imagine a combination of solar energy and wind energy, solar photovoltaic and wind energy, so that overall generation is more or less, more or less we should not say exactly constant, but more or less it is able to cater to a constant load. Such things are even more necessary in the islands. For example in the Sunderbans, there are quite many islands that normally has to run diesel in order to make electricity available. So, every evening for about 2 hours, a diesel plant runs and then at 10 o' clock you have to go to sleep that is it. So, from 7 to 10, 3 hours it runs. It is extremely expensive, because diesel is very expensive. So, the alternative proposals can be to have wind power plants, but wind is again very variable. So, in addition to that, some solar power plants and then the diesel can come in only as a supplementary when these are not available. These kinds of combinations are called hybrid power systems.

These kinds of combinations are called hybrid power systems. So, one might imagine in such places small wind power plants, solar photovoltaic plants and diesel plants connected together, so that the overall demands of the community can be catered to. Even in many cases, in some places these days you have biomass operated thermal power plants. That means you do not have to carry coal, rather the biomass, the biogas as well as the industrial products like bagasse and the remains of the paddy plants, those things can be used as the fuel of thermal power plants; all that can work together. So, nowadays you have these hybrid energy systems as the kind of things to install in these remote and isolated communities.

Have you studied about the synchronous generators, their requirements and stuff, the induction generators? No, probably not. So, a few things are in order in that case. For example if you use a normal diesel plant, diesel plants means the kind of thing that you that you have used, that you have seen being used as diesel generators. Have you seen? Most of the time when there is electricity shortage, you have diesel generators - small generators that make a lot of noise and make a lot of pollution, but nevertheless most of the places in India during the load shedding periods, they have this things, you have seen that.

What kind of generator do they use? Synchronous generators, because there you can keep, it is possible to keep the speed of rotation more or less, more or less constant. It is not exactly constant, but more or less close to 50 hertz, so that you can, you can give supply to the normal appliances. What kind of generators do we use in wind turbines? Induction generators, I talked about that know, induction generators. What is the essential difference between them? What is the essential difference between them?

The synchronous generators can not only convert the mechanical energy into electrical energy, but also it can generate or consume reactive power. Reactive power you have learnt of, learnt about. Reactive power is a very important component, something that we often do not understand. Whenever there is a power demand, power demand means there is a either a light or there is a fan or there is a motor running, it demands active power, because it demands energy. But at the same time, it demands reactive power depending on the character of the load. So, there are particular loads. For example, simple lighting loads will demand mostly active power and no reactive power. But, any motor will demand also reactive power, because their magnetizing circuit has to be energized. So, the magnetic field has to be set up and that requires reactive power.

Now, in induction machines, it cannot generate reactive power. Induction machines have to consume reactive power from the system; that I have talked about. Normally, that is provided by a capacitor bank. However, that can also be provided by the synchronous generator, because synchronous generator’s reactive power can be varied. You see there is a shaft which is being rotated by some mechanical means and that gives the active power into the generator which is converted into electrical energy. Where does the reactive power come from? A field; a field is strengthened that generates reactive power, weakened that consumes reactive power. So, if it is strengthened, then that can generate reactive power, we do not have anything additional to be done, being done and that can cater to the induction machine. Even when the diesel generator is not required to produce any active power, you can simply allow it to run, in order to generate the reactive power for the other systems.

So, since a hybrid power system will consist of both synchronous generator and induction generators, they can work in tandem, so that the all produced active power, whenever requirement, whenever required, but the synchronous generators provide the reactive power necessary for the induction generators. So, that is how the whole hybrid power system works. In addition to that, the overall demand has to be so controlled, so that the amount generated is equal to the amount consumed, because there is no storage of electricity unless there are batteries.

In larger sizes for example the size of a whole island, you cannot really have great battery storage. There are such batteries storages now installed in Sunderbans from photovoltaics, but that is also limited in quantity, because the batteries are not very large in size. So, there has to be some kind of a matching provided and this becomes a little bit of a problem in relatively smaller power, power systems. A large power system means large generators, large amount of buffer capacity available. Now, if you suddenly switch on something, just consider this. You switch on a light and immediately you find that power is coming, don't you? Where did the power come from? Where did the power come from? You might say that that comes from the generator.

Now, imagine that in order to give the excess amount of energy, then excess amount of steam had to be put in. That means the steam governor had to be controlled and it had to open and in order to, in order for the excess amount of steam to come in, excess amount of coal had to be given. So, all these are interconnected and obviously, the moment you switch on, that moment itself everything cannot happen. So, things are, naturally should be little slow, but you do get the power. Where do you get the power from? The moment you switch on, nobody tells that, wait, wait, wait, let me, let me increase the coal input; no, you cannot do that, you get the power. Where do you get the power from? You get the power from actually the kinetic energy of the generators. It is already rotating, so immediately you get the power and that is when the kinetic energy, even by a small amount that reduces which means the speed tends to fall, but then that is sensed by the, the frequency fluctuation is sensed by the feedback mechanism and the steam governor is put in, so that again makes it balanced, but that takes time.

So, whenever there is a load, you might imagine that I have switched on a single light, but often remember huge loads come in. In industry, having switched on right in the morning, huge amount of load suddenly have been coming. So, what happens? Even that immediately is catered to by the kinetic energy of the generator rotors.

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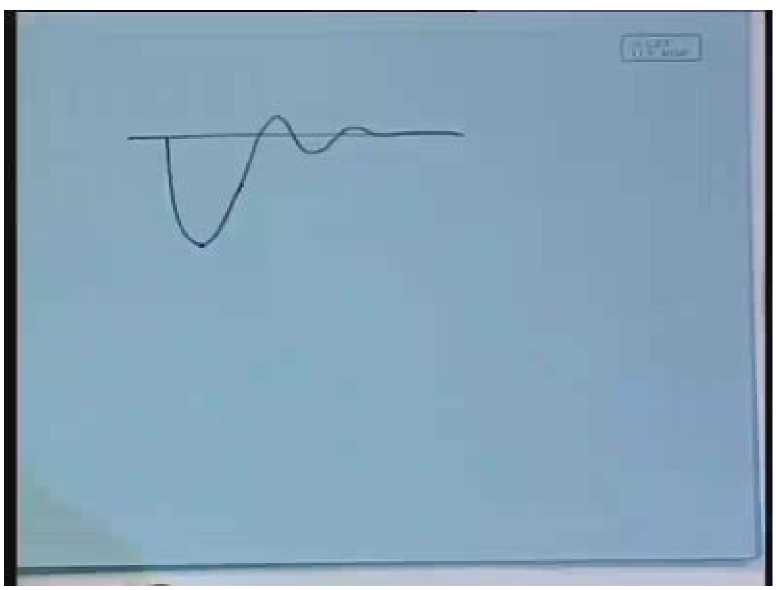

So, the kinetic energy would fall, this frequency would fall and the steam governor would react with by means of increase in the steam input. So, it will tend to go up, but then often that overshoots and it goes with some kind of oscillation to again the right speed. That is what happens even if you do not notice it, right and naturally the amount of fluctuation therefore depends on what? Depends on the amount of kinetic energy that is there in a generator rotor, namely depends on how big are the generator rotors, the amount of inertia it has.

In smaller power plants therefore, this has a problem. In smaller power plants, remember a wind generator working. Wind turbine therefore, its kinetic energy is that storage which can immediately supply some load. Similarly, if you have a tidal power plant, its generator is that kind of a storage which can immediately supply some load, till it can cater to. If a whole power system is controlled by only renewable energy sources, then we do not have any control like that, because in case of a normal power plant you have the control over the steam governor and you increase or decrease the amount of steam that goes in.

In a wind power plant, what do you control? You will say no, bhai, abi jyadha hawa lavo, aisa nahi chalega. So, you cannot, you cannot ask someone to put in more air, wind, no. In case of the tidal power plant also, whenever the energy is available you use it, can do nothing about the controls. In case of the photovoltaic power plant again, whenever it is there you use it; you cannot by wish increase it. So, there is a problem there and therefore the frequency is likely to fluctuate more in case of small power plants, small systems consisting of only renewable power plants and that is why, that is again why, you need to have some kind of a what is called spinning reserve; something spins and the diesel power plant can be that.

So, the diesel power plant may not really work all the time. You may not really run the diesel engine all the time, but because it is spinning, because it has some storage capacity, that can stabilize this kind of transient oscillations. These are also very important from the consideration. So, the essential message is that in case you have to design a whole system for a small contained community, it is better to have, better to do so by more than one source. One of them should preferably be a spinning type of, spinning means a hydel power plant is a spinning thing. It has a kinetic energy which can immediately cater that.

Yes, a wind power plant also is one, but a photovoltaic plant is not, it has no inertia. So, all these things need to be taken into account, in order to ensure a reliable supply to some system, however small it may be. So, that is all for today. In tomorrow's class, we will start with the ocean thermal energy conversion.

Thank you!