**Power Plant Engineering**
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**Lecture – 29**
**Combined Operations**

Hello, I welcome you all in this course on Power Plant Engineering.

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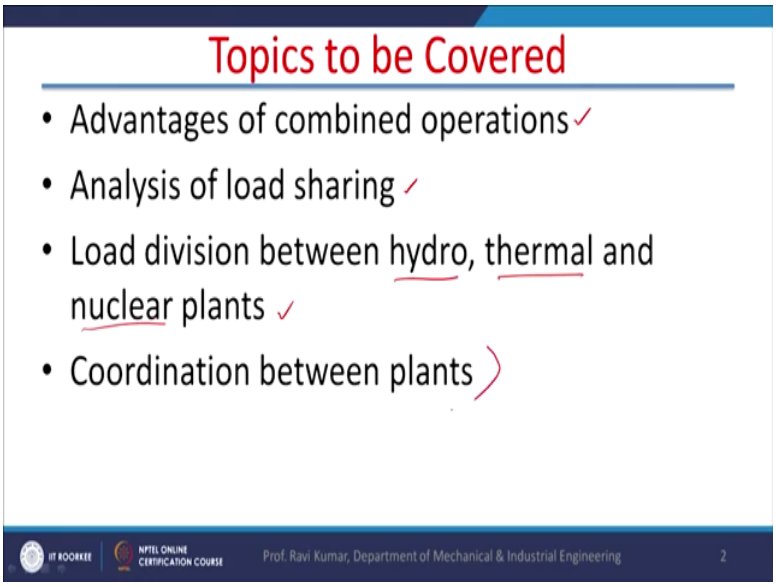


Today, we will discuss the combined operations. In combined operations, the topics to be covered are advantages of combined operations what first of all what are the advantages, analysis of load sharing – load division between hydro thermal and nuclear plants, because mainly we have hydroelectric power plants, thermal power plants and nuclear power plants, coordination between these three plants.

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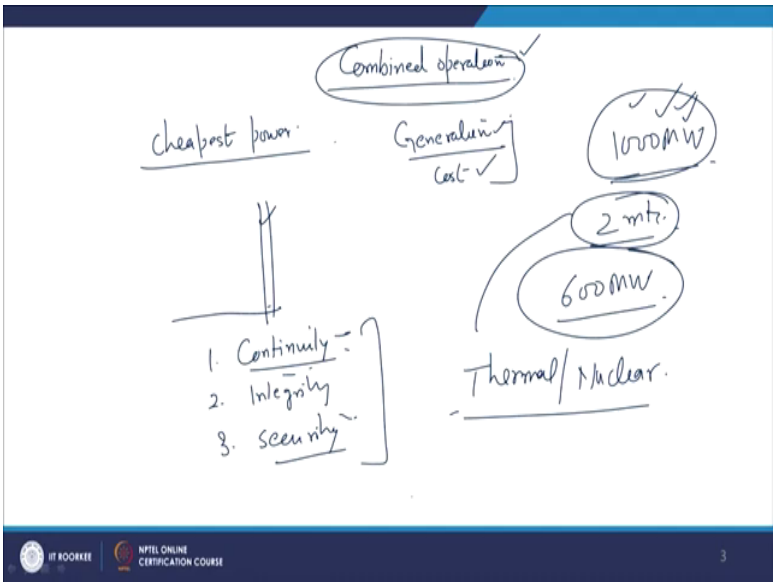


Now, what is combined operation? Now, combined operation, now why we choose combined operation the purpose of combined operation is to provide cheapest power, and to generate maximum power with available resource there are two things generation of maximum power and cost of the power. So, both the cost of the power has to be minimum, generation cost power has to be minimum that is why combined operations are done.

Now, what are combined operations? Combined operation means suppose in a area the requirement of power is 1000 megawatt. Now, if you go for the 1000 megawatt hydropower plants, suppose hydropower plant you want to use for this purpose, but this 1000 megawatt requirement is only for 2 months, remaining period the requirement is let us say 600 megawatt.

So, if I make 1000 megawatt hydro power plant then most of the time, it will be underutilized and you know in hydropower plants a dam has to be made. So, I will have to make a dam of higher capacity. So, the cost will increase. So, what I can do I can make a 600 megawatt plant and 400 megawatt for 2 months can be made with a thermal power plant or nuclear power plant right. So, this is known as combined operation right.

So, the combined operation also ensures the continuous power. Suppose, this hydro power plant fails, we have 400 megawatts of thermal power plants at least we can continue to supply some of the powers power, but suppose solely I am dependent on the hydropower plant something goes wrong with the hydropower plant then there will be no power at all. So, the combined operations, they ensure first of all continuity, continuity of the power supply, integrity of power supply, and third is security of power supply. These three things are ensured by a combined power system.

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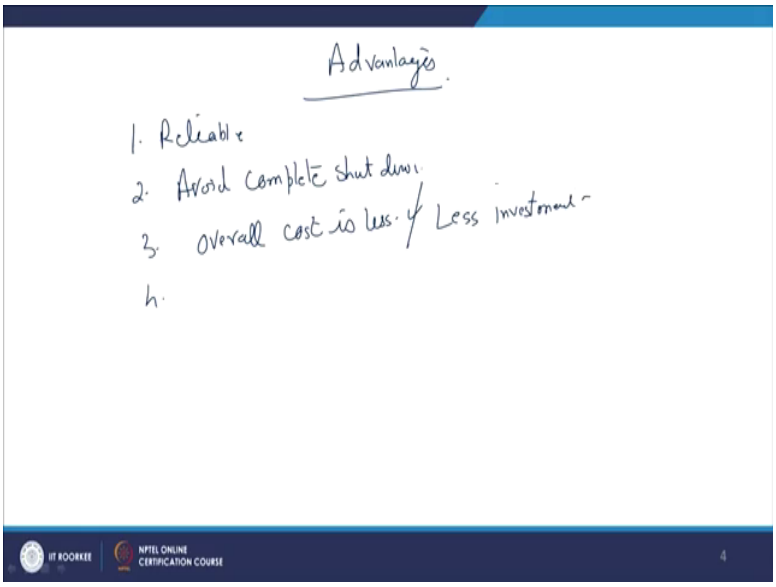


Now, combined operation system. Now, the what are the advantages? So, some of the advantages I have already discussed with you. Now, advantages of first of all it is reliable; second it avoids complete shutdown as I said earlier, so avoid complete shutdown; number 3 – overall cost is less because we are taking combination instead of going 1000 megawatt of hydro we are doing only 600, because hydro power plants the fixed cost is very high. I mean the installation cost is very high. Once the plant is installed then running cost is very because no fuel is required only water is required, so running cost is, so the power is cheap, but initial cost is high, so overall cost is less in case of combinations. Number 4 or we can say less capital investment more the same thing, and supervision and maintenance this cost is also reduce. So, there are so many advantages of combined operations.

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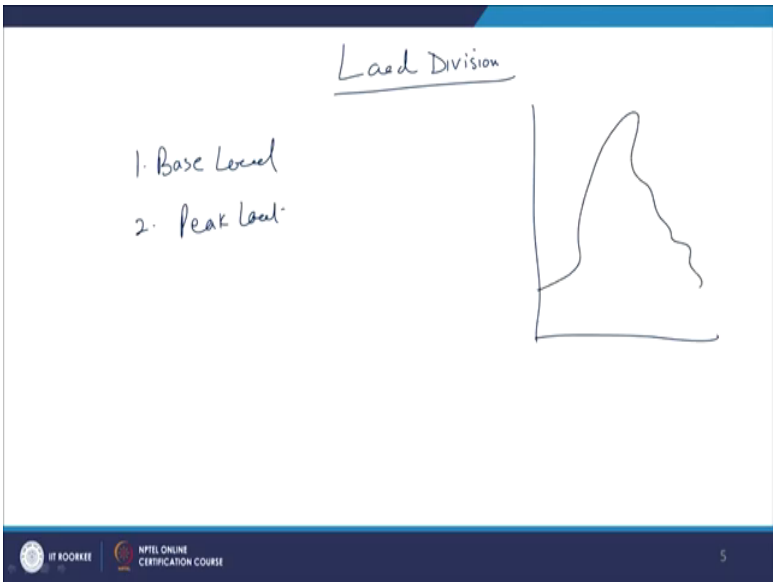


Now, load division, how we will share the load, load, load division between the power plants. So, there are two type of loads one is base load, another is peak load right. Suppose, month wise power consumption energy consumption is suppose is not like this.

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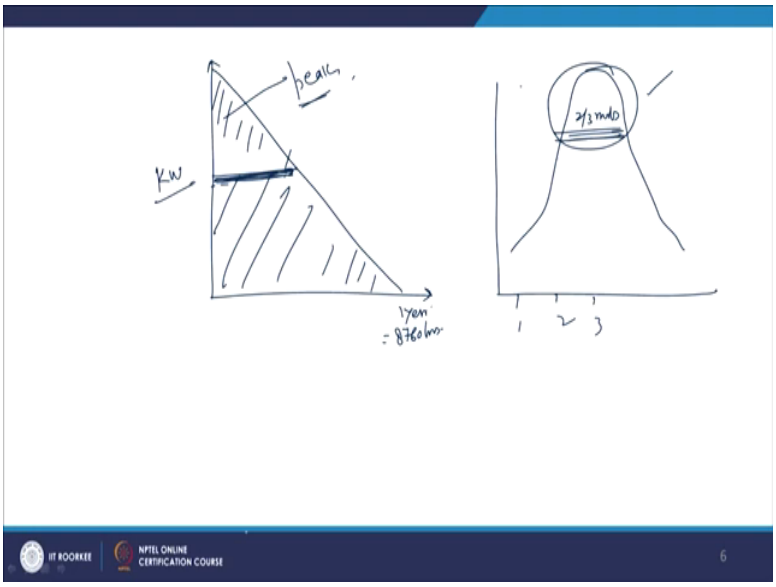


Next, month wise, suppose month wise energy consumption first month second month third month it is like this. So, this is the peak period maybe for 2 to 3 months right. So, this peak period we can go for instead of going for the hydro, we can go for some other power generation method, so that the cost is reduced, but it is not depicted normally in power plant when we depict the data it is always a cumulative frequency for 1 year. In 1 year how many hours are there in 1 year, 8760, 8760 hours, right.

So, we go by cumulative frequency and now we can see say for example, this one this is the base load, this is the base load, this is kilowatt. So, area will give you the new unit kilowatt hours. So, this is the base load and this is the peak load. For this duration for this duration of for this which of hour we require additional power or over an hour power of the base load.

Now, what are the requirement what is the basic requirement of a plant to supply power in the base load right.

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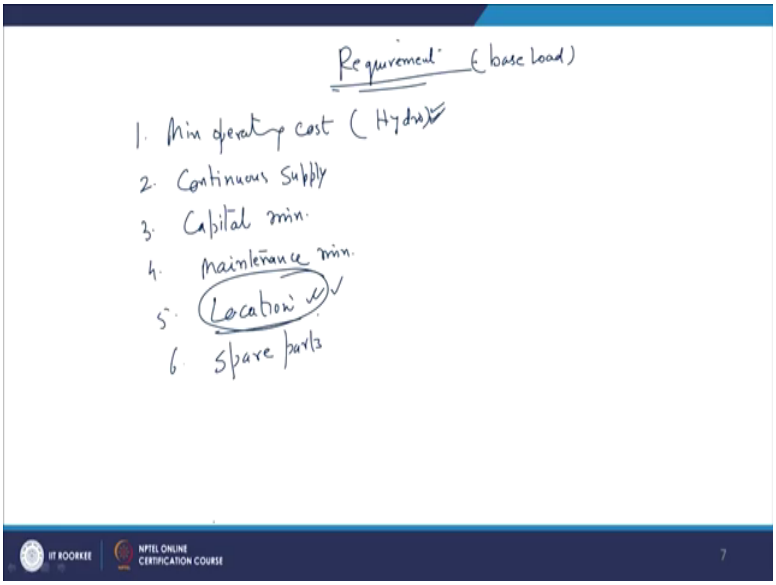


So, requirement for requirements of a plant for base load. First of all as I said earlier minimum operating cost hydro in hydropower plants, the operating cost is minimum, fixed cost is high, but the operating cost is minimum. Continue supply off load that is the it is a continuous supply, capital minimum, they all go in favor of hydro, capital cost minimum maintenance is minimum, hydropower plants have minimum maintenance. Thermal power plants have maintenance cost is high, because it works on high pressure steam is there, steam is causes erosion and corrosion, walls are there walls to be have to be replaced frequent and not frequently after a certain interval of time. So, the maintenance and the boiler has to be maintained. So, the maintenance cost of thermal power plants are higher than the hydropower plants. So, this also goes in the favor of hydropower plants.

5 – location, now base load plant should be close to the load, so that is I mean that goes against the hydropower plants, because the hydropower plants have restriction that there has to be a continuous flow of water. So, the base load plant should be close to the otherwise transmission losses will be there in our country transmission losses are already 30 percent, 30 to 40 percent. So, the location is very important right, and that restricts the use of the hydropower plants in many of the locations. And number of the operations required it should be minimum, so hydropower plants. So, number of operations because in if you go for a thermal or the nuclear plant the number of operations are very high right if you compared with the hydropower plants.

Spare parts, availability of spare parts, I think everything goes in favor of hydro except the location, because hydro power plants are restricted by that because we cannot install hydropower plants anywhere until unless they can be installed only on those locations where flowing water is available right, because the power is generated with a water. So, rain water can also be used in I mean for hydro generation, but not for the high capacity, for very low capacity rain water can be stored in a pond and the hydropower can be generated, but that is for a short duration of time, not for long duration of time.

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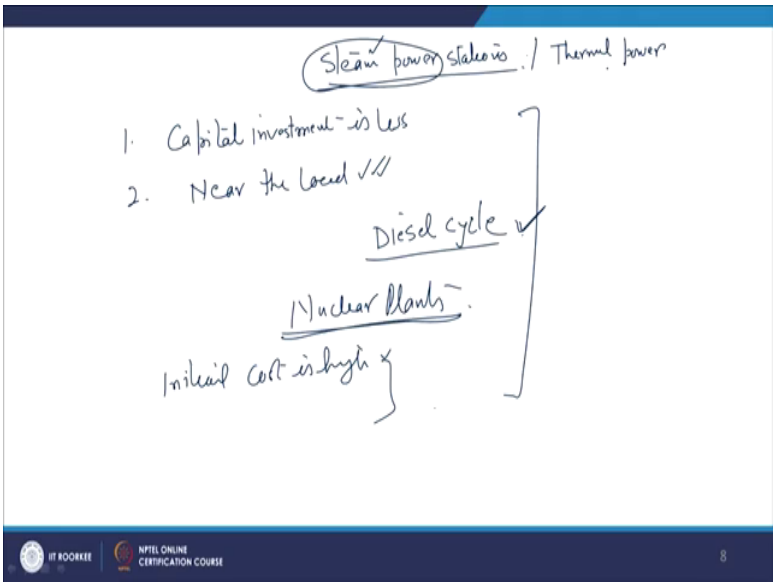


Steam power stations, now steam power station the best that is thermal power station, thermal power, steam or thermal power right, capital investment is less right, but operating cost is high right. So, capital investment is less, can be located near the load, steam power plant can be located near the load. There is no there are no issues only availability of coal is concerned and coal can be transferred transported by the railroad.

So, it can so location is and gestation period is also less. I mean if you compare with the hydropower plants, hydropower plants rehabilitation has to be done, the construction period is quite high if you compare with the thermal power plants. They can be easily fabricate I mean install near the load and the power can be generated. Running cost is high that is true and maintenance, is slightly higher. As I said earlier the thermal power plants periodic maintenance is required, so that is the additional financial burden in case of thermal power plants.

Now, there, there are other type of a steam power I am talking about a thermal power plant where steam is used as a working fluid or the power plant at what typical thermal power plant which works on the Rankine cycle. Now, there thermal power plants which work on Diesel cycle also or Diesel power plants. First of all their generation capacity is not very high, we cannot go for high capacity Diesel power plants. And if you go for high capacity Diesel power plants, the maintenance will shoot up, so that is not desire. So, they are not suitable as a base load plant at all. We can go for the peak load for certain duration of time, we need certain power, in that case we can go for the diesel cycle or diesel power plant, but not as a base load power plant right.

Another is nuclear power plants, its initial cost is very high. Nuclear power plants is a high technology plants, initial cost is high and running cost can be compared with a thermal power plant, but initial cost of that is why the cost of the energy generated in a nuclear power plant, I mean the cost plus kilowatt hour is slightly higher than the normal thermal power plant in case of a nuclear power plant.

And second is limited availability of the fuel. Fuel availability is the main issue in a nuclear power fuel availability and disposition of used fuel, these are two bore limitation in case of a nuclear power plant as a base. So, so we will say that if the location permits, in that case the hydropower plants are the best option, it is the best option be used as a base load plant.

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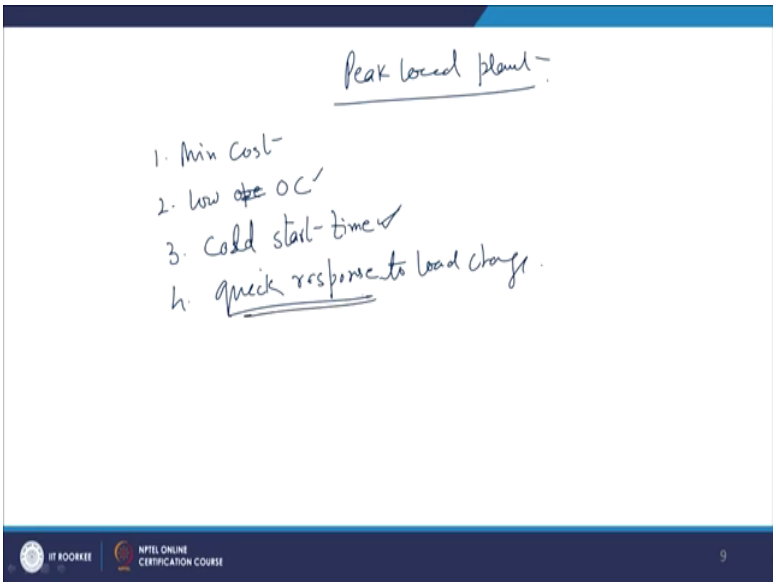


Now, regarding the peak load plant, minimum cost, the cost of the plant should be minimum because the peak load plant will work for a only certain duration of time in an year right. Low operating cost, operating cost, so operating costs for any machine of it is always desired that will it should have the minimum operating cost. So, is the case here, this is important – cold start time, I mean the moment of the power is required immediately the power plant should start producing the power. So, cold start power, if you look at then the Diesel power plants are the best. You just press the button and the power is generated, so if they have minimum cold start time.

And number 4 quick change response to load change, to peak load will keep on changing, base load will remain constant, but the peak load will keep on changing. So, there has to be quick response of the power generating machine for the change in the load.

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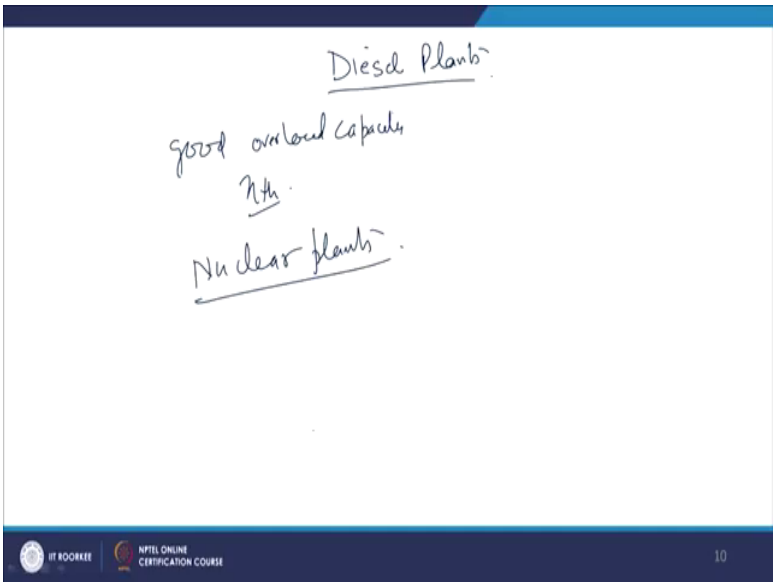


Now, in this case as I say diesel plants, diesel power plants. Easy to cold start I said that it is the best option if the if you have to consider only the cold start. Now, auxiliaries are limited reason is power say for normal steam power plant auxiliaries are required first of all you have to start the pump. So, a system is required to start the pump right, then you have to ignite the boiler, but here in this case just you press the switch and the and the power will be generated.

So, auxiliaries are not required. And it has good overload capacity, good overload capacity, and thermal efficiency is also good for a diesel power plant. So, but the limitation is that it cannot we cannot go for very high power with the diesel power plants.

And nuclear plants, they cannot go for the peak load plant because nuclear power plants, they produce constant power, so they cannot they have never recommended for the peak load plant, they are always recommended for the base load plant that is why you will find we have

nuclear power plants of very high capacity and this high capacity is used as the base load in any power combination.

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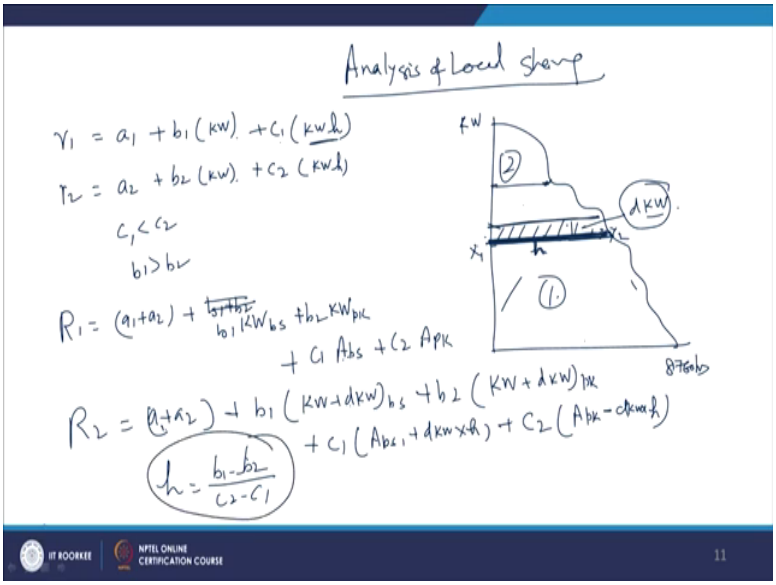


Now, load sharing, how to share the load? So, we have two types of power plants, base load power plants and peak load power plants, and load has to be shared between these two power plants right. Now, suppose in a year v 8760 hours right, and the variation of load is like this, there is certain variation in the load. This is the peak load, peak load may remain say for 1 hour or 2 hours right, this much load this much load will remain for this duration of time, this much load will remain this duration of time. So, duration and load curve we have drawn this is the power in kilowatts right, and this is the h hours per year, suppose this peak load this peak load this load this will remain h hours per year right.

So, we choose certain base load, suppose let us say this is base load somewhere we have to draw a line. You can take base load as this in that case during remaining period the plant will be under utilize. If you take base load this, in that case peak load has to work for a for a longer duration of time. So, some optimum value has to be realized right between peak load and base load. Now, annual cost r 1, suppose this is a base load line, above this it is peak load, and this one a b is or x y is or x 1, x 2 is base load line.

So, the cost, cost is something fixed cost, some fixed cost plus capacity wise if you increase the capacity the cost with so there has to be constant for the capacity. If you keep on increasing the capacity, the this cost will increase plus tariffs. So, they are three things. Firstly, fixed cost, another is cost dependent on the capacity of the plants in plant in kilowatts, and the third is cost as per the energy generated right.

Now, this is plant 1 this is from plant 1 and this is from plant 2. Suppose, this is hydro plant, this is thermal plant. So, plant 2 is again a 2 plus b 2 plus c 2 right. Now, for operation practically if you compare these two equations, the c 1 has to be less than c 2, unit cost in base plant has to be less than the unit cost in the top plant or the peak load plant. So, c 1 has to be less than c 2, I mean c 1 is say and b 1 has to be greater than total cost.

When you are operating at this point, what is the total cost? So, total cost R 1 is equal to a 1 plus a 2 plus b 1 plus b 2 sorry not b 1 plus b 2, it is b 1 kilowatt this is base plus b 2 kilowatt peak, they are different. Kilowatt, this is base kilowatt, this is peak kilowatt, because r 1 we are using 1 is we are using for the base plant, 2 is we are using as peak plant. So, b 1 kilowatt base plus b 2 kilowatt peak right plus c 1 plus c 2. Why I am taking area, this is kilowatt multiplied by, if you take the area of this, it will give kilowatt hours right, so area base load plus area c 2 area peak. Now, this is the cost.

Now, there is a change you increase d kilowatt as we do in mathematics you have changed the baseline, now the baseline is this. Now, when the baseline is this d kilowatt is added some differential of kilowatt is added. When some d kilowatt is added then R 2 is a 1 plus a 2 this is

going to remain same plus b 1 kilowatt plus d kilowatt base right plus b 2 kilowatt plus d kilowatt peak right plus c 1 d kilowatt into h where this is h.

So, we will take the area, d kilowatt into h. So, this area will be added and from here the this area will be subtracted. So, it is going to be c 2 a peak A peak minus A peak kilowatt into h right. We have what we have done, we have just added these two we got the total cost. We added r 1 and r 2, we got the total cost a 1 plus a 2 plus b 1 kilowatt b 1 plus b 2 plus c 1 plus c 2 ok, kilowatt hours we have taken the area of the graph.

Now, next cost when there is the change in the d kilowatt right. Then the next cost a 1 plus a 2 will remain same fixed cost will increase. So, we have added running cost c 1 is going to be the this area plus this area, and c 2 this area minus this area. Now, if you take the difference and solve these two simultaneous equation and for optimum condition the h has to be b 1 minus b 2 by c 2 minus c 1. You just take the difference and make it 0, r 2 minus r 1 is 0. So, then you are going to get the value of this.

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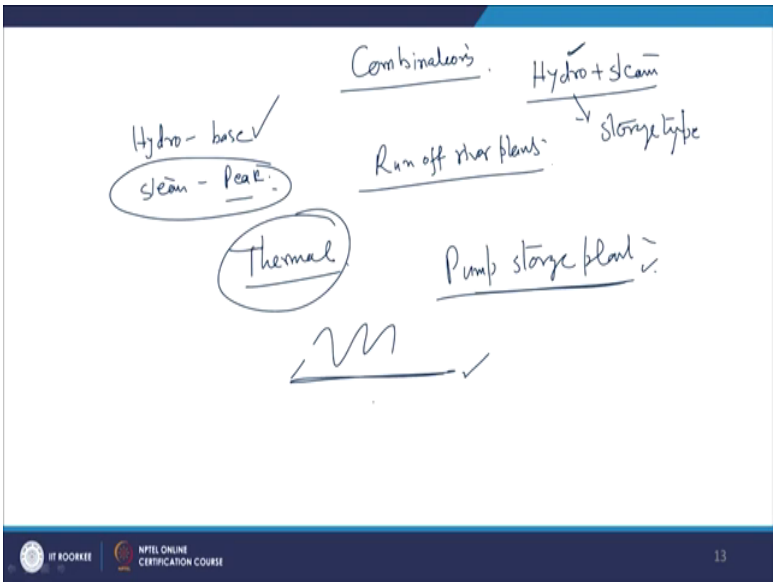


So, the value of h is b 1 minus b 2 divided by c 2 minus c 1. Now, regarding this now we will take combinations. Now, combination is, first combination we are going to take is hydro and steam. And hydro this is storage type a storage type of hydroelectric power plants means, there is the water reservoir, it is not a run off type of there are two types of hydroelectric power plants one is run of type another is a storage type.

In run of type of there is a continuous flow of water and power is generated, in that case it has to be ensured that throughout the year there is continuous for flow of water and there is not much variation in the flow of water. Another type of hydro plant that we store the water during rainy season and that stored water is used for the entire year as we do in our country you may find many of the hydropower plants, they are dam based power plants (Refer Time: 24:33) storage type of power plants.

So, hydro plus steam in hydro will be based, the steam will be peak right. during drought period, when there is no water the situation may reverse, the steam power plant will may become the base power plant and the hydro plant because it is genetic the less power, it will become the peak load power plant. But you should remember that thermal power plant are cost costly to run as a base load power plants right if you compare with the hydropower plant.

And if you were to have predominantly hydropower plants, then you have to go for run off type of runoff run off river plants. So, as I said earlier in runoff river plants, the flow of water continuous flow of water has to be maintained right. So, there scope is quite limited. So, and then we have predominantly thermal plants. Predominately thermal plants means thermal power plants they work as a base load plant.

So, in a geographical location where we cannot use hydro energy, naturally thermal power plants are going to be the base load plants or cost of is storage water is quite high or running cost or overall running cost of hydro plant become very high, in that case we have to go for the thermal power plant ok. We have to go for the thermal power plant as a base load plant.

There is a another system that is known as pump storage plant. Now, in pump storage what happens suppose in a thermal in a hydro plant, the requirement is suppose 200 megawatt and capacity is 300 megawatt. So, this difference of capacity is used for in a pumping station to pump back the water right. So, that when in future when the demand is remain constraint, but the supply of water is reduced in that case this energy can be used. So, these type of power plants are known as pump storage plant, and they can be used in combination of nuclear power plants.

Nuclear power plants are never a peak load plant, they are always base load plants because nuclear power plants has the power I mean the power generation is constant that does not change. So, in nuclear power plants we can we can go for the pump storage type of plant as a peak load plant, but not as a base load plant.

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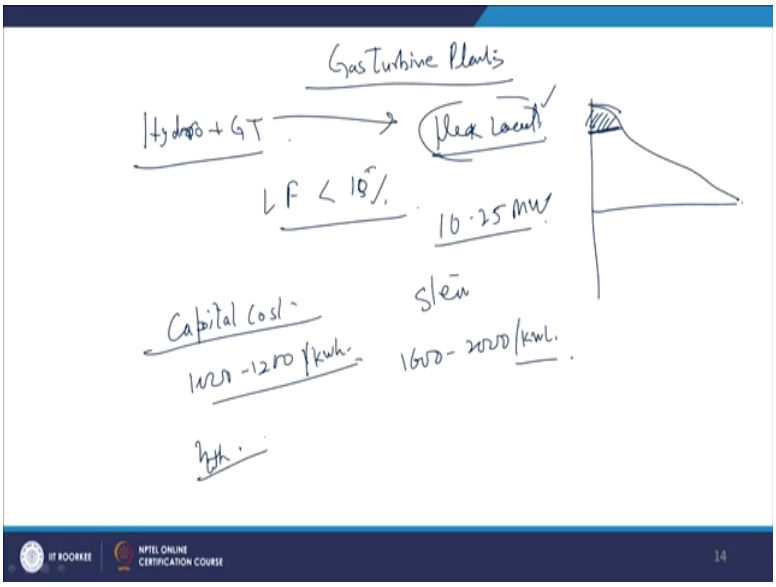


Now, gas turbine station gas turbine is also one of the thermal power plants gas turbines, so hydro plus GT hydro plus gas turbine plants. Now, the gas turbine plants is I mean there is easy, easy to fabricate they start quickly, and this gas turbine can be used with the peak load is less. This is small amount of energy suppose the power plant is the power the requirement goes like this for the year, in that case for this period we want some additional power. So, the current contribute in a substation manner.

So, when the peak load requirement is a small or is or not very significant in comparison to the base load, in that case gas turbine type of plant can be used where the load factor is less than 50 percent 15 percent. We have gas we can have gas turbine plants in the 10 to 25 megawatt capacity ok. Capital cost if you cost if you compare the capital cost, it is 1000 to 1200 per kilowatt hour for gas turbine power plant.

If you go for the steam, it is 1600 to 2000 per kilowatt hour. Thermal efficiency of gas turbine power plant is less as compared to the steam power plants, because we have gases being used as a working fluid. So, I mean the discharge of energy is quite high in case of gas turbine power plant.

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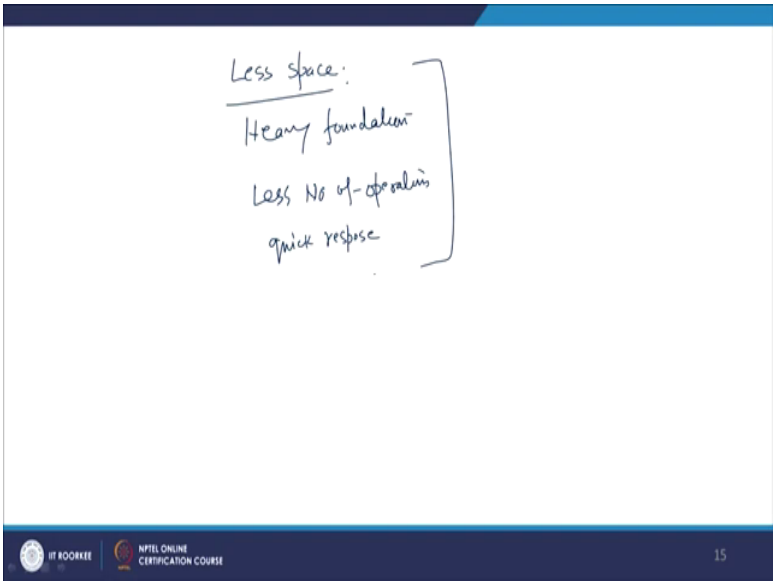


But they claim certain advantages also gas turbine power plant, less space they occupies less space, power density is high right, heavy foundation is not required right, short time construction, the restriction period is less, cooling water, less cooling water is required if you compared with the steam power plant the less cooling water is required in the gas turbine power plants, less number of operations, less number of operations, and quick response, these points they go in favor of gas turbine power plants.

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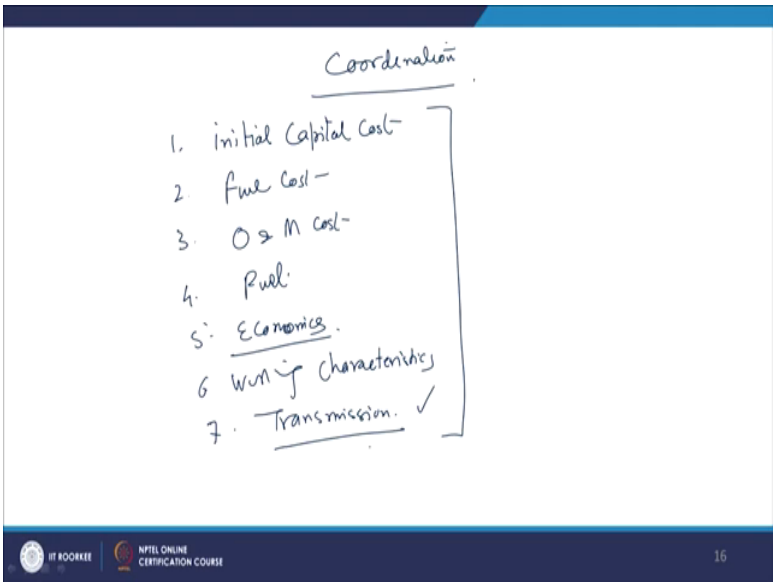


So, if we want to coordinate between a coordination if you want to look at the coordination between different plants, we doing different plants, first of all the points to be taken in the consideration are initial capital cost initial capital cost, second fuel cost, third is operation and maintenance cost, [FL] fuel availability. Suppose, you are going for nuclear power plant, then you have to ensure the availability of the fuel as well. Economics peak and based up thermal plant what should be the capacity of the peak load plant, what should be the capacity of the base load plant.

Working characteristics, and transmission, transmission of power is also important. Suppose you generated a power in the place we have load is far away. So, transmission of power is also important that transmission of power should take place in minimum of energy losses right. So,

this is how and these are the points which are to be considered while we develop coordination between different type of power plants, that is all for today.

Thank you very much.