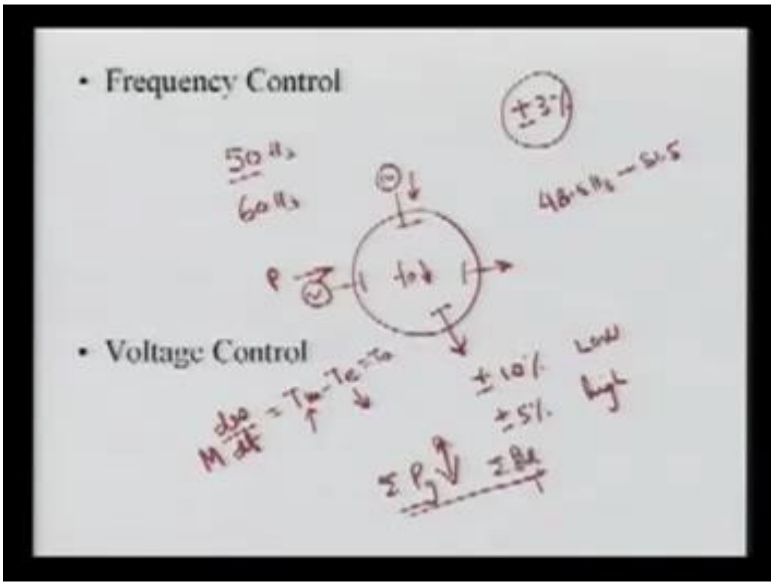
Power System Operations and Control

Prof. Dr. S.N. Singh
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Module - 3
Frequency and Voltage Control
Lecture – 1

Welcome to module number 3 that is a frequency and voltage control. And today just I will be discussing the basic introductory part of the frequency and voltage controls. This is the first lecture in which I will discuss first the frequency control and then some salient points about the voltage control. To see this frequency control although in the power system there are so many things are controllable, we can control. But in majority that is normally we control the voltage and frequency by controlling other of the generators load and other devices in the system. Frequency is very important and vital along with the voltage as we know for the efficient and secure operation of power system. We should have certain objective and those objective are that, we should maintain the reliability of the system we should have a security of the system. Our system must be stable and we must operate the power system in the most economical way along with that we must provide the power to the customers with the better quality of the supply. In terms of quality, normally we relate… earlier we were talking about the frequency and the voltage that we should have the frequency limit that is here.

(Refer Slide Time: 01:37)



There is a plus minus 3 percent that we can vary the frequency. However the voltage control we can even the go for plus minus 10 percent of the nominal or rated value. This 10 percent basically for the low voltage side low voltage. However, it is the requirement for the various op operating operators or devices in power system that we should very closely operate that the voltage should not exceed than plus minus 5 percent here for high voltage system. Now, in the frequency as you know the frequency is a global phenomena means the frequency throughout the system is the same. Means if you are measuring frequency at one end of the system and you are measuring the same time another of the sys another end of the system the frequency will be the same.

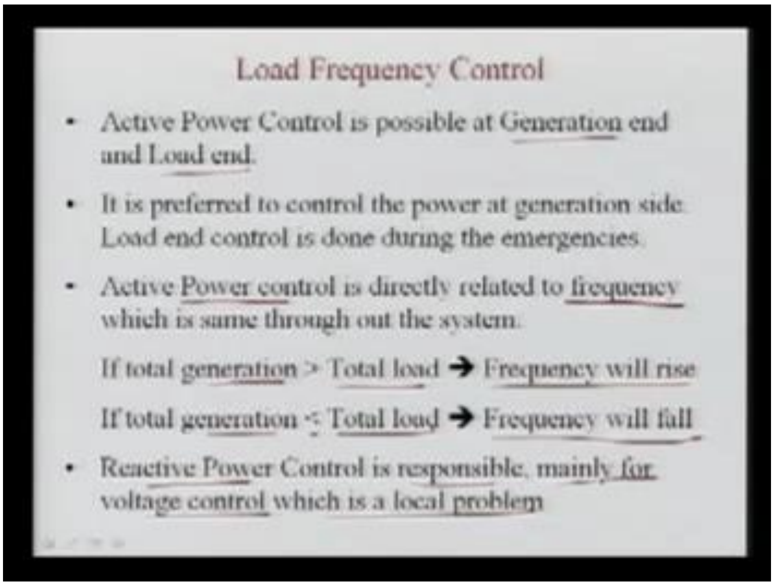
However, the voltage is the local phenomena and the voltage at one point here it will keep on changing means if you are a one point it will be different another point it can be also different. So, the voltage is the local control local phenomena and the frequency is the global phenomena. Now, the question here why we want the? So, rigid about that plus minus 3 percent what is harm to operate beyond this limit or we can go for any 10 or 20 percent to the application of the frequency control. You can see the several devices several elements operators they are operating on the very control frequency range. For example, you can see the electric clocks they are basically measuring the frequency of the ac supply and based on that it is shed. So, if the frequency of the supply is changing the clock which will be giving the timing that will be also change. Nowadays the modern control operators or you can say operators or you can say consumers utensils appliances they are also very much affected by the control. And they are using this sinusoidal frequency and that frequency is used to control these devices. So, if you are changing this even though there are so many computerized control machines C and C machines are there they also work on the system supply frequency.

So, if the supply frequency changes then whole control process will be changed. So, in the modern age we must operate our system very closely to its rated value. Again the frequency we know in all over the world we are having 2 type of frequencies to level of you can say one is your 50 hertz and another is your 60 hertz, 60 hertz basically it is used in the USA and Canada area. However, the 50 hertz is used in Europe, Asia and the most other countries.

So, we have to this nominal frequency just we are talking here plus minus 3 percent it is in our case in Indian case it is a just we can means we should operate our frequency range it 48.5 hertz to here 51.5 hertz. But normally the frequency sometimes when they go below that and that is not good for the system operation.

Now, if you are again if frequency is less no doubt apart from that is requirement for the electric clocks for the control units along with other requirements. If you are still operating below that then it may create the system stress and that may again give your poor reliability of the system and also your system may not be stable and it is very worse of collapse. So, always our intention is to operate in this plus minus 3 percent. This frequency kind we control by 2 way here you can see this active power control is possible at the generation and the load level.

(Refer Slide Time: 05:21)



This frequency basically it is a directly here is related to the frequency and that is a throughout the system. So, to control the frequency we must control the real power or active power. And the active power in whole system only we have the 2 sort of controls means we are injecting the power through alternators and we are consuming power through the loads. So, we can have the complete power system here let us suppose your system is there here we are having various generators. So, these generators are inj injecting the power that is the real power we are talking and here the various customers are there they are taking the load.

So, this is the generation bus this is your load bus similarly, we may have other generators they all are injecting power into the system and the customers here they are taking power from the system. So, these 2 sub categories means generation and the loads they are responsible for the system frequency. So, if you want to change the frequency we have to change here the real power output of the alternators or real power consumption of your loads. So, that is why here I have mention this active power now active power we can control that is a possible only at the generation and at the load levels. So, it is preferred to control the power at the generation side load and control is done during the emergency.

Suppose your system frequency here if here the system frequency which was operating that f naught that is a nominal or rated or it is a 50 hertz in our case. So, if this frequency you can say this frequency falls means if this frequency decreases the options are with us that we have to increase the power the fall in the frequency directly shows that the we have the ((refer time; 07:18)) a power in the system. Means your supply as well as the load is not balanced means you are having limited generation and you are consuming more.

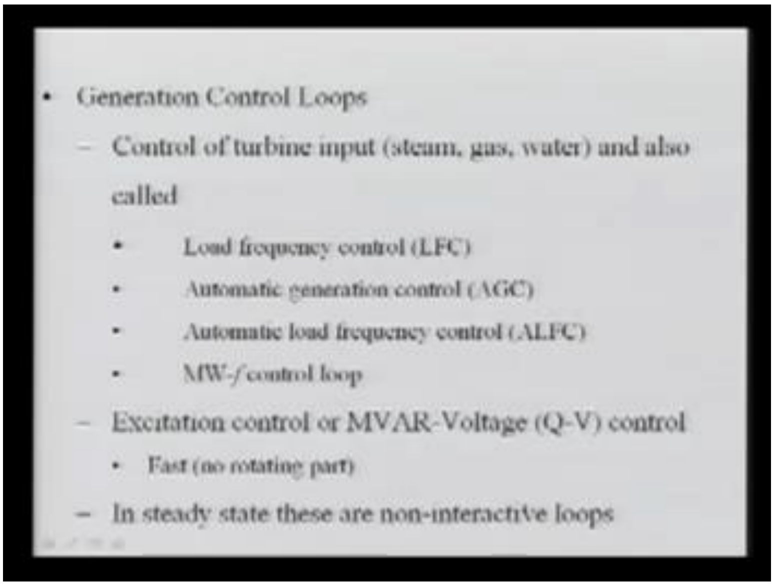
So, that is why your frequency is falling why it is. So, you can understand again with this that if your generation total generation I am talking generation of all the generating stations if we are adding together that is greater than your total demand or load. Then your frequency will rise and if your total generation is less than your total demand or load frequency will fall. Now, why it is so, in the previous module I discussed about the string equation. And you know it here that I can write the here this angular momentum here I can write the omega upon dt that is a rate change of angular frequency here I can go for here tm minus Te.

So, this is your power which is we are injecting that is a input here this is a electrical power it is output. So, what will happen if this is in balance if there is a acceleration or this is also called the Ta accelerating torque or isolating power if you are you can convert the unit per unit both are same. So, if this is positive then your speed will rise and if this is negative then this is speed will fall. So, in other words what is happening if your power generation here the total power generation that is a summation if it is more than your P demand total demand? What happens we have the surplus power and using the energy conservation theorem that energy cannot go anywhere? So, that energy is stored in rotating mask in the system.

And the rotating mask is you know rotating mass energy is nothing but it is a kinetic energy and that kinetic energy is increasing means we are increasing the speed of the system. So, if this is more than your demand then the frequency of the system will rise and reverse is also true that if your this P generation is less than here than your demand then what happens you are trying more power than your input.

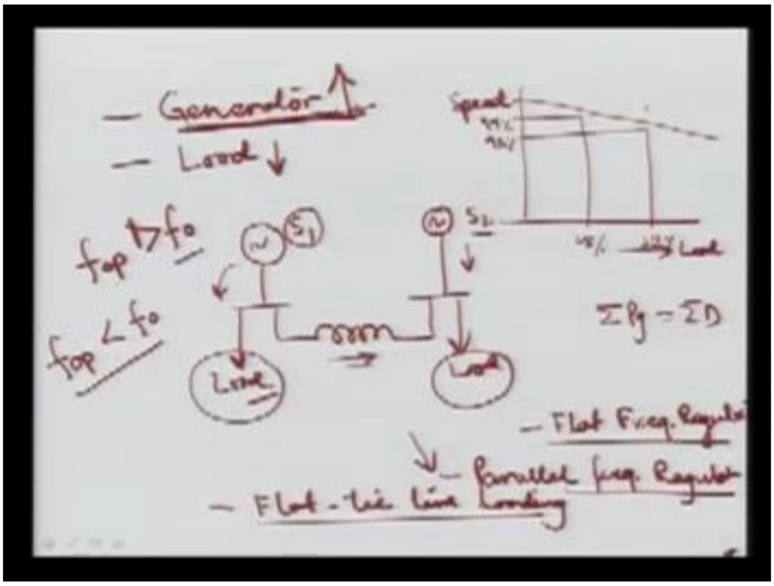
So, you have the energy ((refer time; 09:32)). So, what happens that more demand less generation means that demand which is required here more access is made from the kinetic energy stored in the system. And therefore, the frequency of the system will fall, because the kinetic energy is reducing means is the reduction in the speed and then therefore, is a frequency. So, this is true that here if the total generation is more than total load or demand load here is basically anything, but the demand frequency will rise. If your total generation is less than your demand then frequency will fall. So, the real power which is main source to control the frequency of the system. However, this reactive power means we have the 2 powers in the system that is a real as well as the reactive or alternator or a generator can generate real as well as the reactive powers. And load can consume real and reactive powers again. So, reactive power control is responsible mainly for the voltage control which is a local problem. So, this is your load frequency control.

(Refer Slide Time: 10:40)



Now, how we can control the loads? Again to understand the load frequency control if you can see a system the generators if they are connected into the complete system. So, to understand here our generator can be connected with the rest of the systems where the several generators are operating. So, it is called the interconnected systems where the various generators are operating in the parallel. There is also possibility the single generator is feeding through the isolated load and it is can normally called the generator which is operating in the isolated mode. So, the frequency variation if it is in isolated mode its not of the great concern, because if it is delivering the power, but if it is connected with the rest of the system where the various generators are there and they are operating in the parallel various generators. So, the frequency is very much regulated to understand here let us suppose here the characteristic normally all the generators are equipped with the speed governing system.

(Refer Slide Time: 11:35)



So, here if this axis is your laod, where if you are changing the load what will be your here speed and speed is directly related with the frequency of the system. So, here this characteristic normally here it is a just falling characteristic that if your load is here let us suppose here the 25 percent here it is a 50 percent. Now, if here is a hundred percent at this point it is let us suppose ninety nine percent of this speed here it is ninety eight percent. So, if your load is increased from the no load to the load the frequency of this here the system will fall the frequency of your generator will fall. So, you can see by increasing here the 25 percent or 50 percent frequency is going down then what happens the governor will try to lift to increase the speed by increasing the prime over input and finally, will settle to this frequency.

So, there is a some control and normally it is a closed loop control I will discuss about the detail about the control close loop controls there various levels of controls are there. And it will try to raise the frequency and try to maintain at its rated value that is a nominal value or you can say the 50 hertz in our case. Now, the load frequency problem again let us see what would the various type of frequency control that we can categorize. Let us suppose we have 2 generators here and these generators are connected with the tie line here and they are having the loads and feeding to the, its own here. Let us say this is your S 1 this is your S 2 generator and these are the loads here you can say load here it is also load.

Now, if there is a any change in the loads either at the service station S 1 or S 2 if only one generator let just say the S 1 is responsible to control to meet that demand means here if load is increased the system frequency will fall. Then if this S 1 will try to increase its generation as I said we had to meet the demand means always your total generation here will be equal to your total load or demand. So, if the load here at the generating station one here is 2 or 1 if it is increasing and only one generator is responsible for maintaining or to taking care of that load increase then it is called nothing, but it is your flat frequency regulation. So, it is called flat frequency regulation the main advantage of this this this key that here whatever the load is changing we are operating now S 2 let us suppose S 1 is taking care of the load change.

So, S 2 is operating at the base operating there is a possibility if this S 2 is very very cheap then it should keep on operating its maximum value. And those are the expensive generator for example, if S 1 then it should change its output to meet its demand. So, then we can have the economical operation in this S. But the problem here that is only all the load here that is the changing it is a met by S 1 and there is a huge excretion and huge loading that is coming on S 1. So, both advantage and disadvantage of this schemes are there. Now, other possibility is that that if the load is changing anywhere and both generator let us suppose the load at here it is changing. So, both generators are taking care of that increase and this type of operation is called the parallel frequency regulation. So, this is called parallel frequency regulation. The third type of possibility is that how we can control that if load change is occurring here then only S 1 is responsible means the load change in any particular area is met by the generator in that area itself means if load change here then S 1 is responsible. If load change here in the area 2 then S 2 is responsible then it is called another type of frequency and this is called flat tie line loading.

What does it mean? It means that here the tie line power is maintain fixed it is not changing; however, in the you can say flat frequency regulation if load here is changing and S 1 is changing then the tie line power is also changing. So, is a tie line power is not flat it is keep on changing no doubt if the load is increasing here and this generator is changing then there is no change. But since this generator is taking care of the load change in the both area both the generator. So, it is a flat frequency here in the flat tie line we are maintaining the tie line power flow here constant. And this load change in particular generation area is maintained are taken care by that particular generator itself and here if changing in S 2 zone then S 2 is taking care.

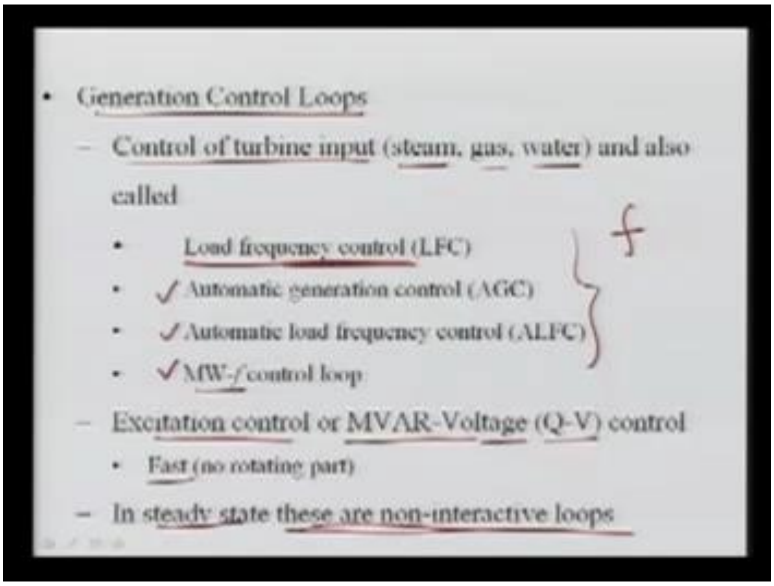
So, in normal way if you are the 2 big areas are connected by tie lines normally we try to maintain the tie line power to its schedule value unless until there is a some disturbance in any particular area if any one of area is in emergency state. So, then he can request and we can feed more power and then we can stabilize both of the systems. But in the normal practice what happens it is not only 1 generator most of the generators they are taking care. And now parallel frequency regulation is very very prominent means all the generators are changing their outputs to control the demand of the system and try to maintain the frequency. So, this is called your parallel frequency regulation.

Now, here it is clear that to control the frequency we must utilize the control aspect of the alternators or governors as I said in the beginning that we have the 2 possibility to control frequency one is your generator output and second one is your load aspect. Means if your frequency is high means let us suppose your frequency operating frequency here it is more I can say more than your nominal frequency f naught. Then you have to what is that mean that the operating frequency is higher means your load is less and your generation is high. So, the possibility that you can reduce this generator outputs and then you can match the demand. And you can reduce the frequency another option that you can increase the load and then again you can meet the balance between the generation and load.

Now, the load increase it is not in your hand it is very very difficult to increase the load unless until you are saying to somebody can you increase can you take more load. But normally it is not in the practice load increase is not possible. So, what we do? We try to ask the generators to reduce the output to maintain the frequency to its rated value. Similarly, if your frequency of operation is less than your nominal frequency, that is f naught or rated frequency, that is the operating frequency of the system which is 50 hertz in our case. This shows that your generation here means your generation is less than your demand. So, what we can do now here instead of going for the reduction in generation we can here increase the generation or we can go for reduction in the load.

So, the reduction in load that can be done we can use the under frequency relays and then the frequency falls down to its set value it will try to set several loads it will try to set the feeders switch off the feeders. And the huge amount of load will be released and the system frequency will be restored, but this option is again very expensive normally it is not used. So, we try to increase the generation to take care of the frequency. So, normally we normally go for the generation control and the generators are equipped with the governors. So, we will see here how the governors are work.

(Refer Slide Time: 20:58)



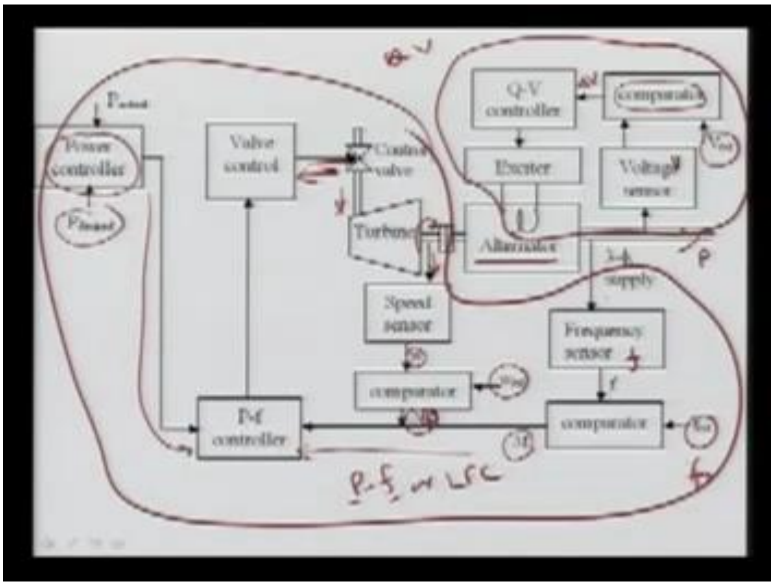
So, the generator control loops here in the generators normally we have the 2 loops again I will describe one is the control to the turbine input and the inputs are your steams gas or it is water. And here this load frequency or generation control loops are known as load frequency control. Basically in the literature you will find the different names are used and, but the purpose here is to control the frequency of the system.

So, it is also known as load frequency control normally it is called LFC problem or it can be called as automatic generation control. AGC is also very popular and sometimes people call it automatic load frequency control ALSC ALFC or here we can call it it is a megawatt frequency control loop, because we are changing the megawatt frequency is changing. So, we can say megawatt frequency loop. Another control loop in the generating stations which are equipped with that is called the excitation control and that excitation control is related with the control of the voltage of the power system.

So, the excitation control is also known as the MVAR because we are controlling the reactive power with the help of excitation and what we are achieving they are of voltage. So, it is called q we control this is very fast because there is no rotating part; however, the control here that is ALFC. Or you can say LFC or AJC that is a frequency control it is slow process, because we are having some we are the turbine inputs and turbine is a mechanical device. And then mechanical device is rotating it is coupled with the alternator and then your electrical power output which coming out.

So, the dynamics of a time constants after wind the steam pipes steam flowing as well as the alternator accounted for. So, this is a slow; however, this excitation control is very very fast, because only we are having the exciters and there may be static exciters and no rotating power. So, it is a very fast. So, in steady state these are basically non interactive loops means they are not interacting to each other both loops are separate, but during the transient or emergency conditions they also work together and voltage because voltage is also related with the power is not only with the Q. So, in that case here both loops are interactive, but in the normal steady state here both loops are non int interactive to see here now see the various control loops.

(Refer Slide Time: 23:38)



Now, what we have? This is your alternator this alternator basically is a coupled with the turbine again there will be the several stages of turbines. Depending upon the output rating of your alternator if you are using 5 hundred mega watt alternator then there are 3 turbines. One is called your high pressure intermediate pressure and the low pressure turbines. So, there are 3 stages of turbines. So, all these 3 stages here it is coupled and it is retained here in the turbine system. So, this turbine system is a mechanical rotating device the input to this is coming here your steam and since you can say there is a expansion of this thing. So, work done here by this turbine on the system the turbine will try to rotate and it will here try to rotate the system complete mask. And then alternator is now will be rotating with the help of turbine shaft and finally, it will be giving here the power output that is P.

So, what is happening now to change the speed we have to change the input flow here to the turbine and that input is a steam in the thermal power stations gas may be in the gas power station and the water in case of the hydro power station. So, to control this now we have to measure the speed of the system here we can measure the frequency of the system. Here we are measuring the speed with the sensor and this omega is coming this omega is basically compared with its reference setting speed. And if there is any change then we are getting a input signal that is change it omega it is not double basically it is omega that is a speed. And then a speed is basically coming here that is a power frequency controller and this power power frequency controller here is changing to the valve control unit. And this unit will try to change its input to this here turbine means ti will try to open and close depending upon the requirement.

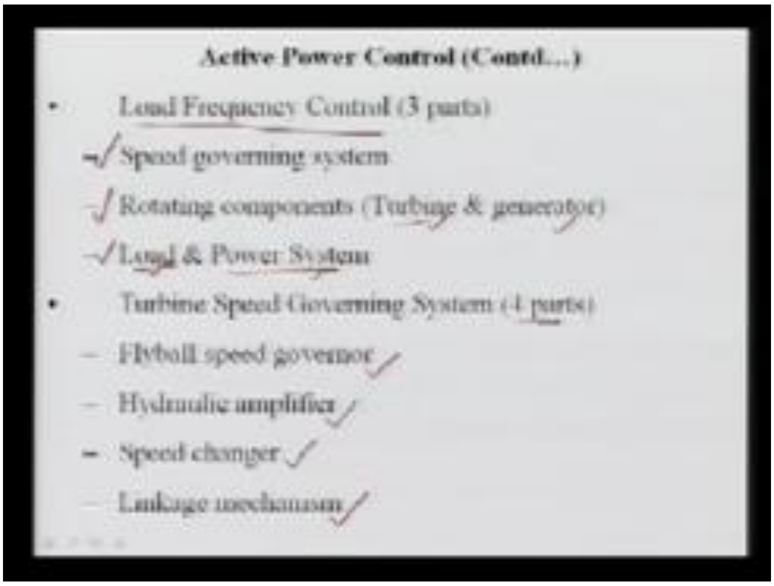
Means if your speed is high what it will do it will here this value will be positive. This controller will try to close the input to this turbine means will try to reduce the steam which is passing through the turbine. So, here mechanical power is reduced and the finally, the speed will be settled down to its rated value. In other words if frequency is less or speed is less then here this will try to open more and more steam will pass so that we can increase the mechanical input to this turbine. Another sense that we can go for here we can sense the frequency of the since system that is here we are sensing the frequency.

So, we can measure the frequency of the system that is here it is generating 3 phase supply system. So, frequency is measured and this frequency is now compared with the differentiating that is a rated or you can say here f naught of the system supply. So, if there is any discrepancy mismatch in the measure frequency and the difference value. So, then we are getting another signal and that signal is also coming to the Pf controller. So, we have here this control is basically called your the real power frequency control loop. So, you can say this is a loop here this is a loop now another point here just normally it is equipped it is not only the with the relation to the frequency sometimes ((refer time; 27:20)) one to increase the power irrespective of the system frequency. Means they want to control that is called the manual control these are the basically automatic taking care.

So, if we want to change the output alternator manually then we can change here and that is called power controller. So, if we want to increase the power then here your desired here what is actually coming that we can measure here the power output that if you want to change your output level. And there is a some difference then it is also coming to this pf controller and then it will try to do this. So, here we have the automatic as well as the manual normally it is called the race command will again see an model the governing system. So, this is basically related with the governor valve control is nothing, but there some governor systems means we have to try to move this here it is movement of this system so, that the input to the turbine can be changed. So, this whole system here which I discuss in this boundary here it is your called the real power frequency control or it is called LFC control or LFC control or it is your acc and so on so forth.

Another control loop is that that we have here you can see we are sensing the voltage this supply voltage is sensed. So, we are measuring the voltage of the system and now we are using the comparator to compare its reference value. So, normally the terminal voltage of alternators are set into 3 specified value. It may be 1 per unit it may even sometimes it is more than 1 per unit. And if there is some here error signal is there means change in voltage is required then your cubic controller will act and it will try to change the excitation system and. So, that we can change the excitation of this alternator and that will try to change the terminal voltage as alternator. So, this loop here it is called your Qv loop are sometimes called this MVAR voltage control loop. So, now let us see the how we can achieve this active power control.

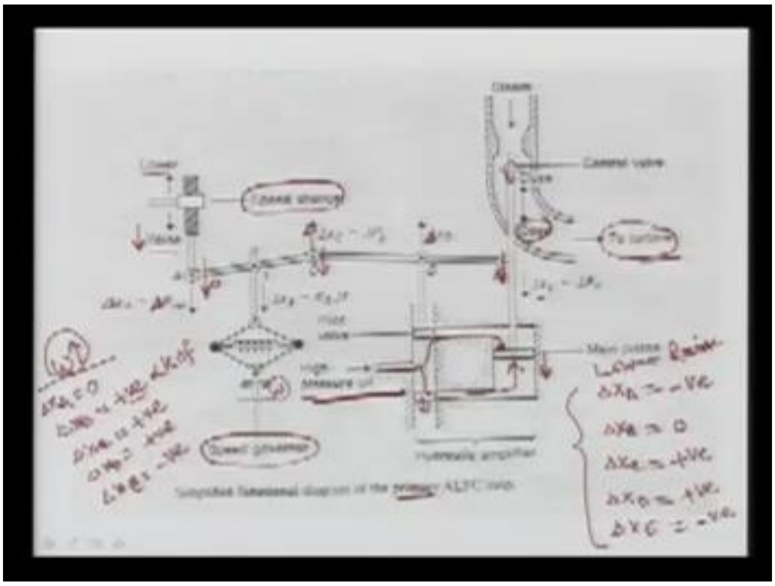
(Refer Slide Time: 29:42)



So, in this load frequency control loops we have 3 major parts. One is your speed governing system means speed governor normally it is called another is your rotating component. And that component basically consists of your turbine and the generators those are rotating, because it is related with the mechanical rotation and we have also the load and the power system. So, we have this 3 major components that we can classify here the load frequency control loop in the speed governing system rotating components that is your turbine and the generator. And we have the load and the power system that is a electrical part.

So, here this is a mechanical. So, we have to model the turbine and generator combine together that is a rotating component then we should have your speed governing mechanics and its characteristic, its modeling. And then will also model the load as well as the power system together and then we can analyze that control loops and will see the load frequency control loops how they are working. Now, in the speed governing system or you can say turbine speed governing system that is same it is consisting of 4 parts first one is the, your fly ball speed governor system. Hydraulic amplifier speed changers and various linkage arrangements are there to see it you can see this diagram.

(Refer Slide Time: 31:12)



This is basically the simplified functional diagram of primary LFC I will come to the later part why it is primary I will mention later on, because they have primary and secondary control loops and here it is called automatic load frequency control loop. To understand they are here as I said main purpose here to change the frequency that we have to change the mechanical input to the turbine. And that can be changed by here closing or opening of this var means if this is closed steam is passing less mechanical input is reduced and the frequency of the system will increase. So, here we have to only just input that is called to the turbine which is going we are changing this one that is a input to the turbine.

And for that we have the various mechanism one of that is called the speed governing mechanism here you can see and that is what we are doing we are measuring the speed and this ((refer time; 32:16)) is called your fly ball speed governor. What happens here if your speed is more here speed is going to be more what will happen? This value will change and finally, the movement of B will occur I will come to that whether this P will increased or reduced will see later. But if your speed here is changing from the base case the movement of this B will be changing depending among the more speed or less speed and then by this mechanism here this movement here will be changing. Another ((refer time; 32:54)) as I said that we have another that is a manual control means we can intensely increased or reduced the power output of alternators irrespective of the system frequency. And by that we can have here this lower and the raise commands means if you want to increase the power you have to for here raise. If this value is shifting down means your position of a is going down that is ((refer time; 33:21)) change in the P ref then power will be increasing.

How it will be? It is functional, to understand this let us that we are going to increase the here just we are giving the raise command means just we are trying to increase the output of this here turbine output means we are increasing the steam which is passing to the turbine. So, here and this mechanism is called your speed changer. So, if want to increase let us see that is I want to change the frequency I want to change the power increase means by the raise command. We are not concerning about the here change here what will happen the position of a will go down or we can say the change in XA position is that is a directly related with the change in the power reference that you are changing.

So, if this is going down this is if B is constant we are not changing this B, what will happen the position of the C will go up? If this will you can say this is a linkage mechanics if this a is coming down C will go up if this B is constant. So, what will happen if this will go up? Now you can see if this is going up your XD here will also go up if this XC will XD will go up here. We are just putting high pressure oil here you can say the high pressure oil is coming and this is going up then the direction of this oil will flow like this and it will try to flow here.

So, what will happen? It will try to insert a very high pressure on this main piston we have here the pilot valve system here that is a movement. So, here this will be going down means that is your change in XC position will come down. And finally, it is going down this position means it is opening and the more power or more steam is passing through the turbine. There by we are increasing the output of the turbine and finally, we are increasing the mechanical this electrical output of the turbine. So, this is one way that various linkages various positions are changing by change of even though one condition.

Similarly, we can also see the speed governing system approach. So, in this condition we saw that is if you are giving the raise command this only I talking that is we are increasing we want to increase the power output of the alternators and here if raise command is given means we are changing the position of A. Now, if we can assume that the change in position just I want to write this XA change in position B at the point XB that is I can say this XC here change in your XD and here change in XE. Means we have this 5 linkage mechanics. So, what is movement for which linkage that is can be related by plus and minus so that we can model later on we will see how it is usual.

Now, if I will take the downward movement as positive no problem you can take a negative. So, here it is better to understand that, because we are increasing the power. So, it is always better to take the downward movement as a positive. So, here what we are doing if you are giving the raise command. So, movement a is the downwards positive value. So, that the movement of that linkage will go down negative means it will go up. So here as I said a will go down now the B as I said it is not here speed governing system we are not taking in to consideration we are assuming this is the constant this link is this which is fixed

So, what is happening your change in position B is 0 means it is not moving at all now if it is a is coming down B C is going up means here C position that is changing upwards and that is it is against our convention. I said that if position movement is going down then it is positive if it is going up it is negative. So, your XC here will be negative now your XD is also going up that is your also negative; however, here the power your XD is coming down at due to this pressure it is your positive. Similarly, if we are giving the lower command means all here this I have retained for the raise command. So, if we want to similarly to understand that if we want to give lower command means you want to reduce the output.

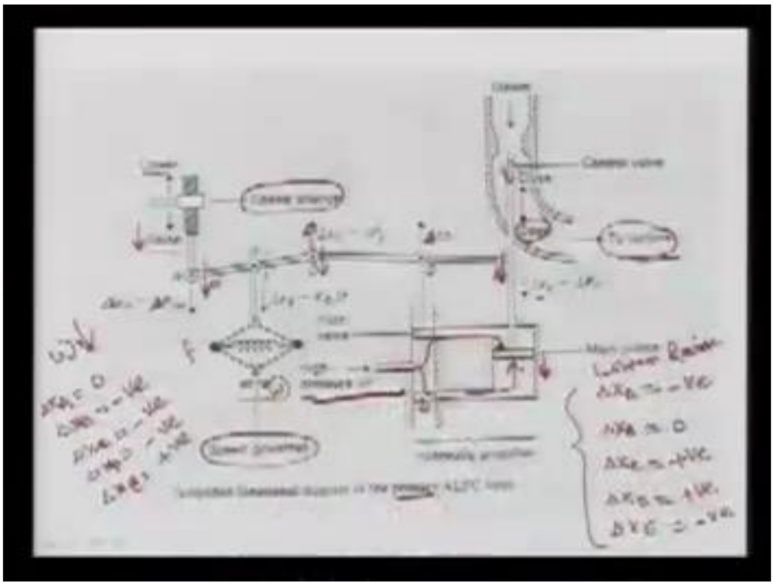
So, here what we can do here this, the sign of the various positions will be changed and finally, will see here the A will go up means it will move up. So, it will be negative B will be 0 there is a no change in the position. The position of C now it will be going up C will be coming the positive here your D will be also positive and your E will become negative and it will try to open. So, this is for your lower command. So, this is the change in the position again I am not writing how much magnitude it is going to it depends upon the several factors it will depends upon the length of the linkage it will depends upon that how much it is regulated. So, it will be decided later and the several constants are coming into the picture. So, this is basically which I explained for the, if you are giving raise or lower command to increase the output or to open this steam valve.

Now, let us see that is here the frequency of the system has gone out means here the frequency omega or you can say omega is directly related with that. So, if this has gone out then what will be the position of this various linkage again I will try to write here XA change in your XB position change in your XC position change in your XD position here D and here change in your XE position. Now, let us see here now we are starting from V. So, what is happening we are assuming that is here a is not changed, because we are not neither giving raise or lower command it is fixed to its rated value. So, there is a no change in position A so, it will be 0. Now, the B position here if it is a speed is increased what will happen? This will ((refer time; 40:22)) will try to extend and it will try to reduce your XV position and here it will be your positive. Means if your frequency is reduced then this ((refer time; 40:37)) will try to close here and here it will go up or going down here depending.

So, the change in XC position is directly proportional I can say it is some constant with the change in frequency. So, if frequency is more this is a positive if frequency here is a less. So, then it is a negative. Now, if this is here is kept 0 XB change in XB it is a positive it is going down then your C here if it is going down. This will also going down, because whole this linkage is taking a as a center if C is going B is going down C will be also going down. And then it will be I can say now the movement is in the positive direction that is a downwards. Now, if the C is also going down here now what will be the D D here will also be going down and then here it will be your positive. So, if the D is going down what does it mean? You can see if D is going down this is pilot valve will move down. And this high pressure oil will try to move here and it will try to insert a pressure on the main piston and this piston will try to lift the position of E upwards and try to close and then here it will be your negative.

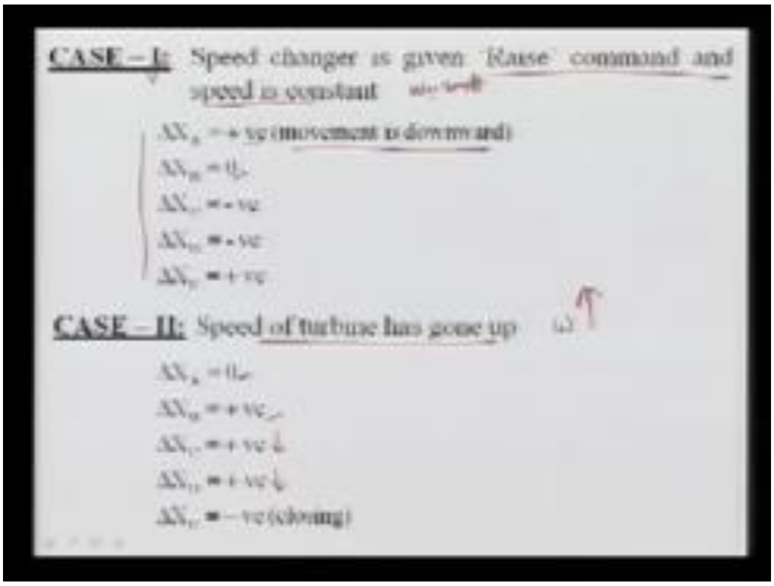
So, what is happening that is the position of E is going upwards means it is the closing of steam or input to the turbine. And we want that if here the frequency is more means the input to the turbine must be reduced and that we are achieving here. So, this is the linkage mechanic we can also write for the reverse case reverse case means if your frequency here is falling down. And then we can simply we can write what will be the position I will let you know.

(Refer Slide Time: 42:36)



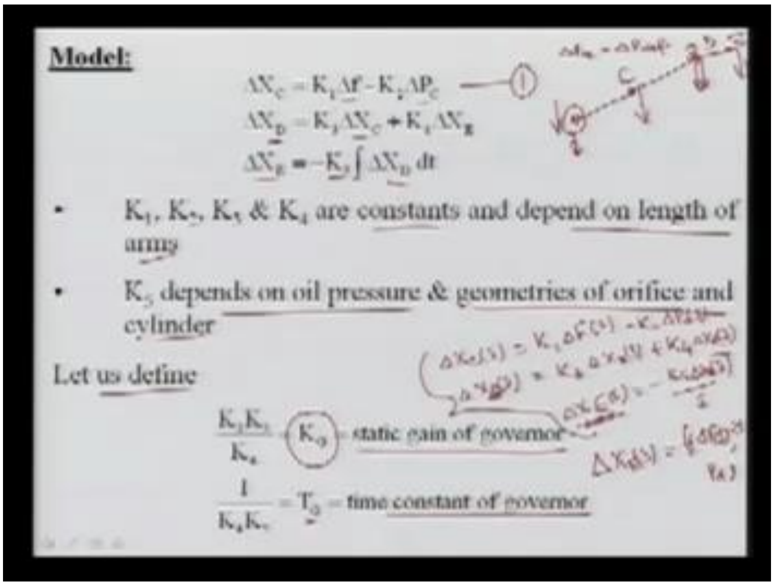
Let us suppose your frequency here is reduced. So, again your change in A is 0 we are not giving the raise or lower commands. So, the position of A is change in position of A is 0 and now here B will be going up that is it will be your negative. Once it is going up your C will be also going up that will be negative if this is going up your D will be also going up and that is your here negative. If this is going up what will happen here you can say now the oil pressure will come here and this will be position will be E will be going down. And it will try to open the inlet to the turbine and more steam or water or you can say input of the turbine will be increased. And then finally, then we will be more and then we can increase the frequency.

(Refer Slide Time: 43:27)



This can be here summarize again in this here the case one just I have considered 2 and based on these 2 cases I will just write the equations for this governing system. Already I explained the speed changer is given the raise command and the speed is constant that is here that is omega is constant. So, we can have these changes in the positions again here the positive movement is in the movement in the downwards I have taken as a positive. So, change in a if you are giving raise. So, it is positive no changes position in the B because the speed is constant C will go down up D will go up and E will be going in positive direction that is downwards. So, if speed of the turbine has gone up that is omega has increased and your this raise or lower command is fixed it is not given. So, the position of a will be 0. Now, the B will be frequency as gone this. So, B will be going down C will be going down and here D will be also going down, but this will be this will be going up and it will be trying to close the input and the frequency of the system will be restored.

(Refer Slide Time: 44:38)



Now, with these 2 cases what we are going to do? We are going to model these governing system means you can see your change in the position here that is change in position C is nothing but change of the 2 things. Means the position of C is controlled if we will see this figure here change of the position C is related with the change in here as well as change in B. So, the position a is changed by these command and that is nothing, but changing your power reference that is how much power just you want to change and another that is P reference card another is a system frequency. So, these 2 change position is directly related that is changing the position of C.

Now, you can see here and I can write this position of the C is the summation of or some constant again the change in the frequency with some constant K 1 this is giving the position of C minus K 2 change in position of the C that is the reference value. Why it is minus you can see that we have the 2 options that the change in position here simply you can see the linkage mechanics. So, this is your a this is your B this is your C. Now, if you are changing this means if it is moving in the positive direction this is fixed then this is moving in the negative direction that is opposite ward. So, that here if you are changing more power this term is negative; however, if your frequency here is your increase what happens this is going down here this is a constant this is also going down. So, here this is a positive. So, the position of C is directly related with the change in the system frequency; however, the position of here the C is here the reverse of this position of A.

So, we have retained that change in the position C is a function of the frequency and the change in the power that is a PC it is nothing but change in the PC is equal to your change in the P reference setting. So, we can write the change in the position C is a function algebraic equations in terms of K 1 and K 2 constant and these depends upon the length of arms means one is moving how far it is. So, it depends upon the movement. So, these are the constants and basically once it is decide that K 1 K 2 can be obtained

So, this is equation one another that is we have this position of XD, XD is also here its linked with the D that is the D position and we can see this XD position here if the C is going down D will be also going down.

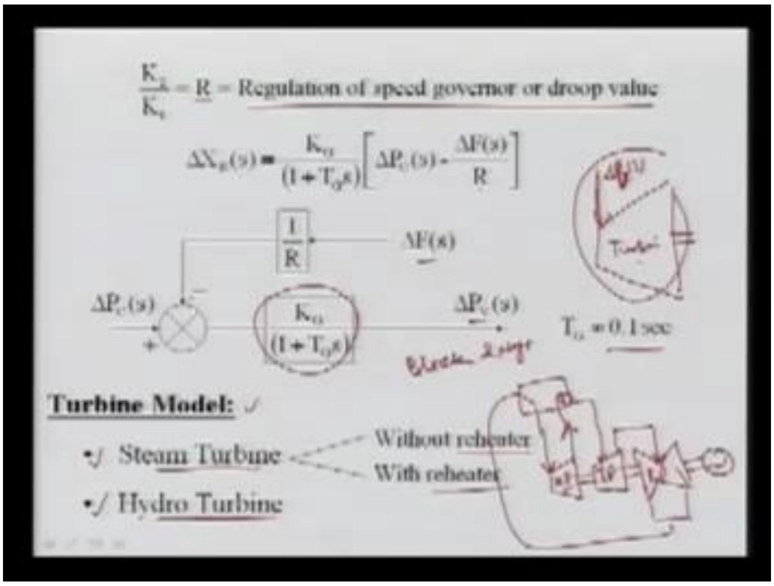
So, here the change of position XD is the related with the position of here is here C is D and here let us suppose here we have E. So, if D is here going down means here the both E is going down then it will go down and if here both are going up it will be going up. So, it is a combination of the change in the positions of C point and the E point at the same time. The change in the E position it is with the negative to the XD position and that is a integration here are the change in position. Why it is so, you can see again with this help of this diagram now what happens here earlier it was moving up. Now, what is happening if it is going up you can say now the oil pressure is coming here and it is going down. One way if this B is moving up E should move, but by moving this here the l I will prefer it is trying to reduce in the negative direction.

So, this movement of E here is directly related with the XD and with the negative direction means if it is going up it is moving down. But at the same time here this is oil pressure is there and it is a continuous movement it is taking time. Because here the some piston mechanism there how much time it will be traveling here to the saddle value means that pressure is equalize. This pressure and this pressure must be collapse. So, it will take time and that is why it is a integration time that is we have considered. And that here we can write that is a XE position is with the negative means opposite direction of XD with the integration and that is related with the time. So, the coefficients K 1, K 2, K 3 and K 4 are the constants, and depends upon the length of the arms. However, this K 5 depends on the oil pressure geometric of orifice and the cylinder of your piston valve as well as the orifice of your the main valve system.

So, how much pressure that is going to equalize? So, the K 5 depends upon that now if we can define the constant K 2 K 3 divided by 4 is kg and it is normally known as the static gain of governors. And similarly, one upon K 4 K 5, that is a TG that is called the time constant of governor. So, with these we can derive equation in this you can say Laplace form and here if you are taking the Laplace of these equations means I can write here the change in XCS taking Laplace. So, here it is nothing but your 1 in your frequency that is here now I can write the capital that is change minus your K 2 change in your PCS. Similarly, I can write here your change in XDS that will be equal to your K 3 change in your XCS plus your K 4 change in your XES. And your XES change again is equal to minus K 5 here change in XDS and here divided by S, because is a integration.

So, what we can do now here while simplifying these 3 equations we can have a relation between this XE, because XE is directly giving this input output how much it is a orifices open of the steam. So, we can simplify means we can put here XD XC here we can put here and then we can get a relation between XD and XE. From here XD we can put here in this equation will get this change, change in your XES that is a function of no doubt your change in fs and your change in PCS.

(Refer Slide Time: 51:41)



And that you can see we can get this expression here, here this K 2 upon 1 is normally known as R and that is nothing but it is your regulation of speed governor or droop value or droop is very very important this characteristic the 1 K 2 upon 1 that is R this is a basically related will see later how R is very very useful to control the frequency of the system. Because this is the characteristic of the governing system who is taking part and how much output is changed basically this R is the very valuable criteria. However, the TG the time constant putting all the constant and simplifying we can get the change in XCS in the Laplace domain that will be equal to your kg. That is a gain after governor over 1 plus the TG that is a time constant multiplied by the S. And here we are getting the change in PC minus change in the frequency Laplace divided by R that is a regulation of speed governors or the droop value. This equation can be represented into the block diagram and the block diagram you can see here this is your block diagram.

So, this block diagram basically you can see here. So, what we have done this change in the frequency divided by R this is 1 upon R that is coming here this PC is positive this is negative. And that is multiplied by this governor block diagram you can say transfer function is a very well that is a input output relation in the Laplace domain is your transfer function. And this is giving your change in position in E and this change in position is directly related that is nothing but change in the valve power means how much it is changing. So, it is a valve power is coming normally this TG is point one second here and the gain again depends upon different criteria and also depends upon K 2 upon K 1.

So, this is basically the model or you can say transfer function model of the governor system. So, this power that is a valve power means we are changing the input to the turbine. So, we have model this is your raise and lower command means how much difference you are changing. This is the frequency related component that is coming here and the governing here that is a opening or closing your valve and this is going to your turbine. So, the turbine you can see the turbine here that is we can model like this. So, this is the which is coming here it is nothing but change in terms of PCS. And then this turbine is giving some output and that output is going to in terms of rotation and then we will see here how it is related in this model of this turbine. So, this is basically turbine. So, this valve which is the not to it is V that is valve power that is coming here and it is going in this way. So, now we require to model this because before that we have already modeled we model complete the governing system.

Now, we have modeling the turbine system here and the turbine model again depends upon which type turbine we are going to use it may be your steam turbine and it may be your hydro turbine. For example the nuclear power stations they also use the steam as a energy transfer medium. So, the steam turbines are common again slightly deviation that which type of steam turbine we are using. So, the hydro turbines are very simple; however, this steam turbines may or may not have the re heating facility. So, we can have the re heating facility or we cannot have the re heating facility it depends. So, then we will have the different approach for the re heating means again what happens if the steam is coming here. For example, if you are having the different stages for let us see let us suppose this is your turbine this is your hp that is a high pressure turbine. And now it is connected with your IP that is intermediate pressure turbine that is your IP. And then you will have here your lp that is a low pressure turbine and finally, you have your alternator.

So, this is a diagram I can say this lp ip that is intermediate pressure. So, here a steam is coming a steam is expanded. So, what happens this steam which is coming from coming out from hp here basically this is your boiler let us suppose. So, here from boiler it is coming then this is again re heated means it is going back this is steam and then after that it is coming to IP and from I IP outlet it is coming to lp. And then finally, here it is collected and it is going again to the boiler. So, this is the steam diagram. So, what is happening here this HP the exhaust of that is a steam which is coming out of the SP. After doing the work the it has the very less temperature and the pressure and there is a chances that the blades of this turbines which are very very expensive will damage.

So, what we do? We send it back to re-heat. So, what happens? It will take some time means it will be going here and then it will be coming and then finally, it is going to HP again we will see in the modeling. So, what I can say in this module first lecture is devoted to the modeling of the speed governing system. We model thus in terms of Laplace transform to analyze the performance of the speed governing system or you can say load frequency control that is very very important. So, here I just represented the block diagram for the governing system now the next is you have the turbine model. And we will see for the turbine’s we can either we are having the steam turbine or hyhro turbine or sometimes for analysis purpose we go for the very simple model of the turbine and that is used.

So, this turbine model will be discussing in the next here with both reheating and the reheat with and without reheating facility I explained what is the reheating means coming the steam which is coming out from SP is re heated before passing to the intermediate pressure turbine. Then it is called reheating and due to this the trouble of steam is coming here. So, sometime delay is involved and will see the power output of these two how it is related.

Thank you.

.