Power System Dynamics, Control and Monitoring
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 32
Transient stability, Automatic generation control conventional scenario

We are back again.

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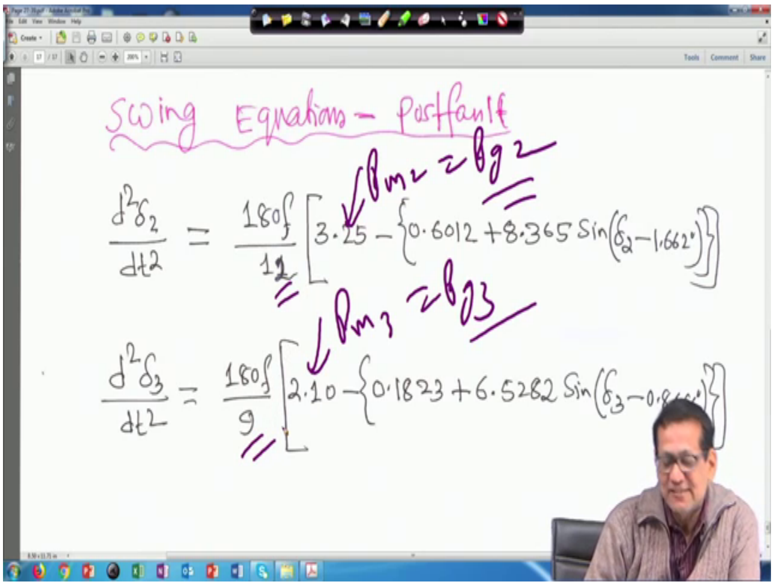

So, for this one that swing equation during for same thing will write only thing is that this is your P m 2 it is nothing but your P g 2 right and this is your P m 3, it is nothing but your P g 3; this data were given earlier right. So, and when you make this one and this is your h 1 and h 2, sorry h 2 and h 3 that is that is inertia constant now for after that you are this is swing equation, post fault condition.

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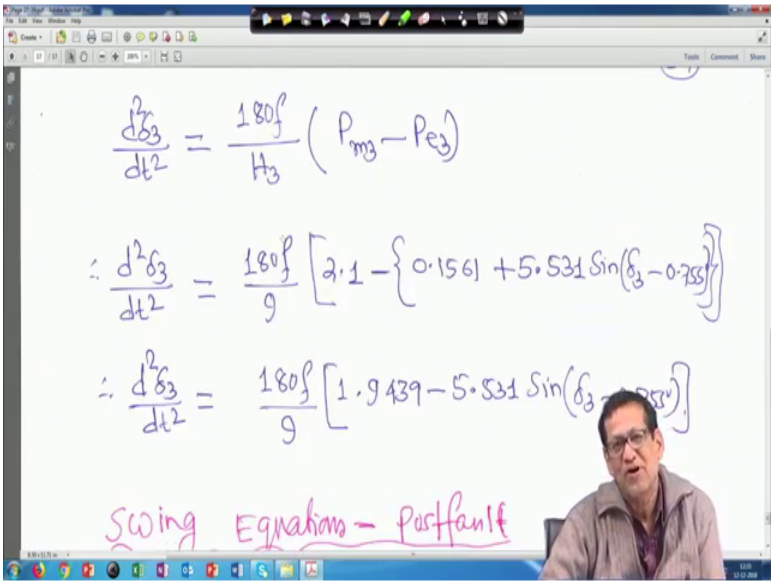

So, during fault also we have got, we have got this swing equation. So, during fault we have got this swing equation. So, you have to see that fault clearing time. So, how long this fault is persisting right. And when fault is cleared, then automatically it will move to this equation.

So, code and other things not be not cannot be done in this course because it will be it will be then something different. So, only I have to look into that you are from the point of view of classroom exercise, but this example I took just that you know such that that call you are what you call that all ideas our ideas will be clear right, only up to this. So, with that transient stability chapter will be closed.

But I suggest that before moving to the next chapter, I suggest that whatever has been given just a you pick up any book any book that multi machine system and transient stability you can get any book and just have a few small problem 3 bus, 4 bus problem and try to derive those swing equations and how these how these things are all these things are coming right. With this, we will close the transient stability chapter and now we will move to your automatic generation control or load frequency control right.

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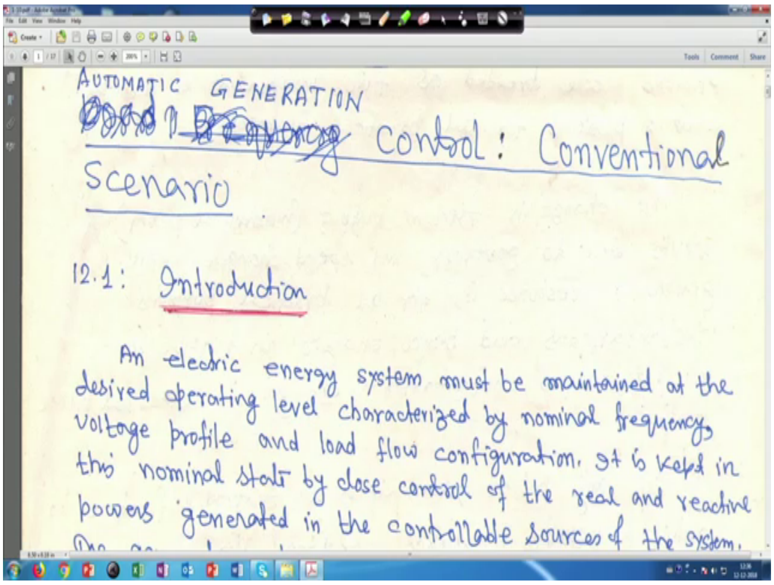

So, next is your automatic generation control. So, we have actually just before going to all these that whenever we are studying, it is automatic generation control in deregulated environment. So, at the time, you are what you call that we have to fast our start with your conventional scenarios. So, whatever a little bit here we will see it is your what to call right up and everything.

So, first we will go to that conventional AGC because up from there, we will move to your deregulated environment to different version we will see regarding your this AGC in your restructured or deregulated environment. Only will our we restrict analysis to the steady state part only, simulation part cannot be done in this video course. It is not possible actually, but I will show you some simulations and generally that we sometimes we call it at automatic generation control and sometimes we call it as load frequency control.

So, basically when we call automatic generation control that basically I mean in my words, it will be load frequency control plus economic load dispatch together will be automatic generation control, right but, when economic load dispatch will not be done here. So, we will consider that automatic generation control and load frequency control both are same, right. And in that, that means, we will term this as automatic generation control right and because in power system actually continuously that loads are changing right, I mean continuously loads are changing because see many loads are getting switched on or switched off continuously and that is why a continuous disturbance will be there right.

But when these disturbance is very small, I mean in terms of say small compared to a large load if there is there is a small change in load, then basically what happens that small change in real power basically it is affect the your system frequency but leaves the bus voltage magnitude almost unaffected.

Similarly, if there is a small change in reactive power then, it affects the bus voltage magnitude, but leaves the system frequency unaffected hence that your voltage angles right almost unaffected. So, that is why, that your real power frequency control and reactive power voltage control these treated are these two things are treated your separately that is they are decoupled right. So, in this case you are what you call, first is introduction part right.

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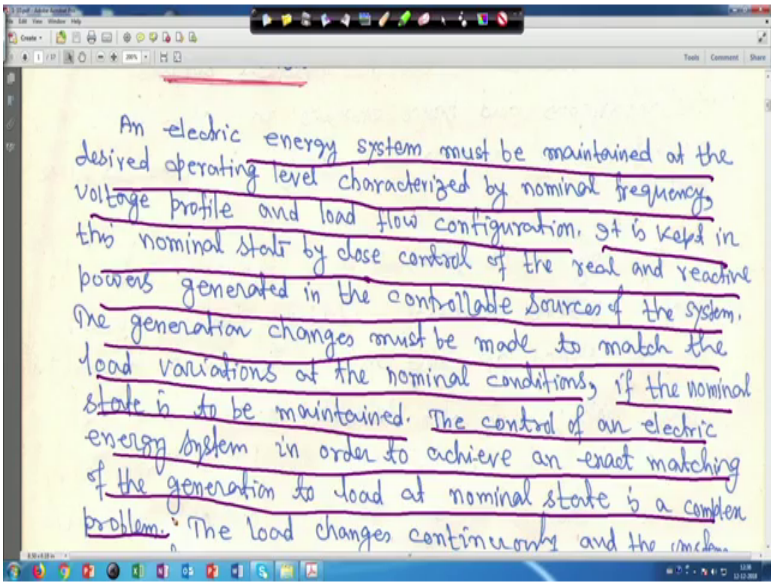

So, an electric and electric energy system, just I have underlining few thing. So, an electric energy system must be maintained at desired operating level characterized by nominal frequency, voltage profile and load flow configuration right. It is kept in this nominal state by close control of the real and reactive power generated in the controllable sources of the system, right. The generation changes must be made to match the load variation at the nominal condition right. So, if the nominal state is to be maintained that you see there is a suppose if there is a increase in the load right, so that means, immediately that there will be transient imbalance between generation and load because load will be more generation will be less, right.

So, transient imbalance will be there. So, therefore, generation will change the load. Sometimes, we call this is load following when generator is following the load. So, deregulated environment we will also see the load following right. The control of an electric energy system in order to achieve an exact matching of the generation to load at nominal state is a very complex problem, right. So, just hold on will move it up, right.

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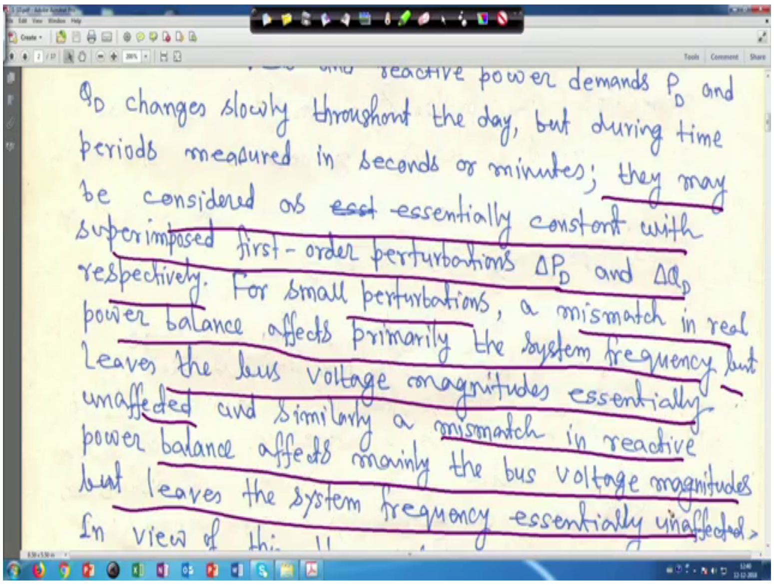

So,, so the generation, what happen that your. So, the load changes actually will go to this the load changes actually I told you that continuously, right.

So, if you and they may be considered as essentially constant with superimpose first order perturbation delta P D and delta Q D respectively, right. So, for a small mismatch your small perturbation a mismatch, in real power balance affects primarily the system frequency I told you, but leaves the bus voltage magnitude essentially unaffected. And similarly, a mismatch in reactive power balance affects mainly the bus voltage magnitude but leaves the system frequency essentially unaffected right.

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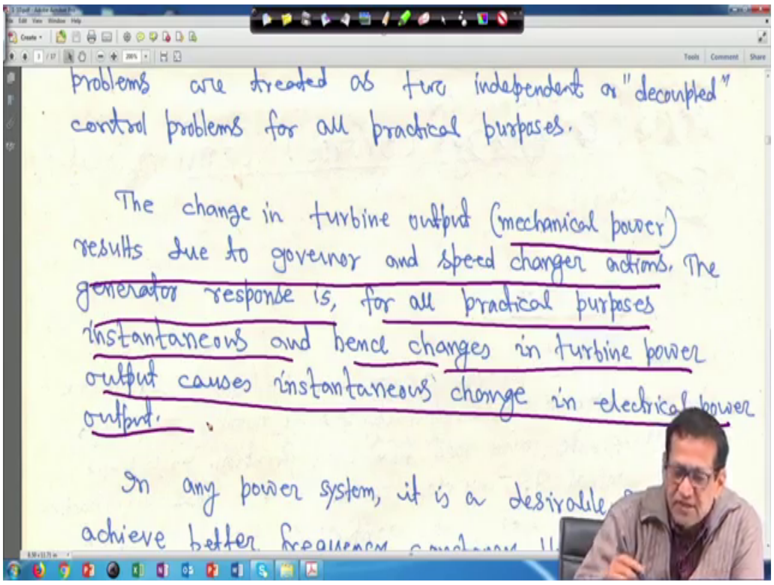

So, in that case, so in, so in view of this the real power frequency control and reactive power voltage control right, problems are treated as two independent as decoupled control problems for all practical purposes.

So, the change in turbine power output that is actually that is your mechanical power output right, results due to governor and speed changer actions. The generator responses for all practical purposes instantaneous and hence changes in turbine power output causes instantaneous change in electric electrical power output. We are actually considering it is a lossless turbine, right.

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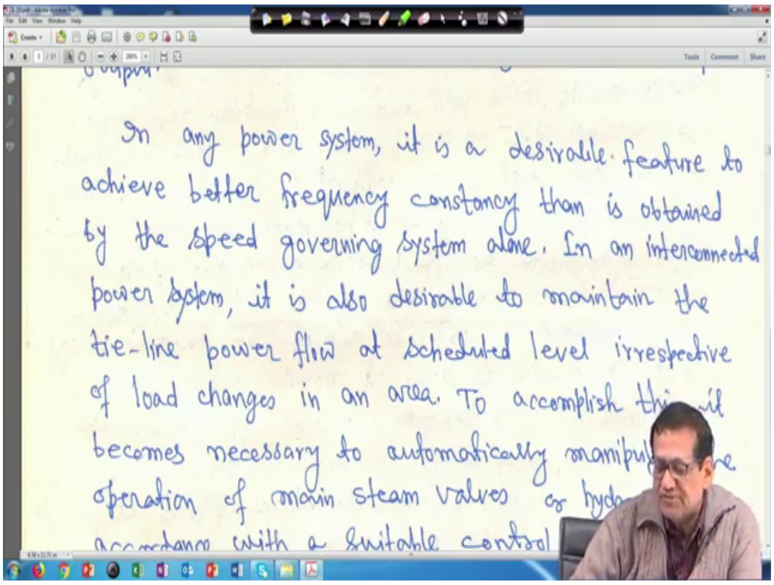

So, we will move next. In any power system is desirable feature actually to achieve greater frequency constant c, then is obtained by the speed governing system alone. So, in an interconnected power system, it is also desirable to maintain the tie line power flow at scheduled level irrespective of load changes in an area; that means, two power systems are there later we will see and they are interconnected by 3 phase line we call tie line right. So, I mean where I mean you have so many power systems are interconnected together and whenever to a particular power system we call an area right when it needs power from the other area or it buys power from the other power system right that has to be maintained, the scheduled power has to be maintained right.

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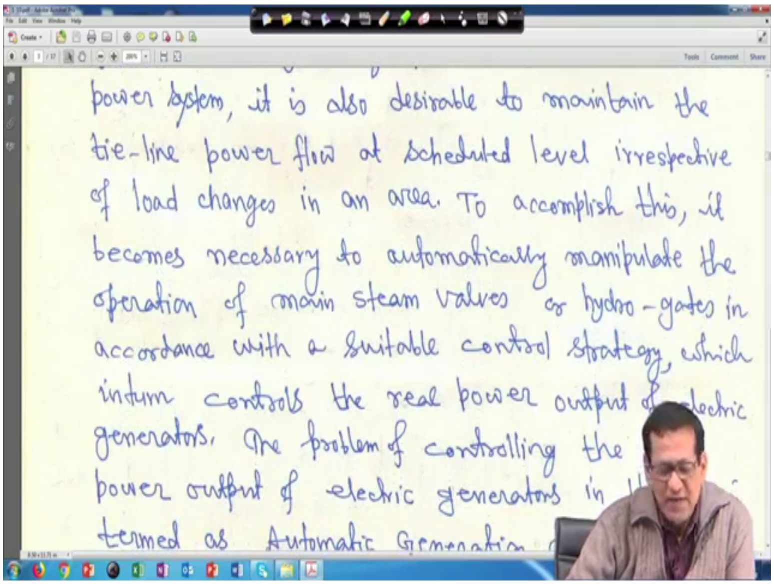

So, irrespective of load changes in an area, to accomplish this, it become necessary to automatically manipulate the operation of main steam valve in case of a steam power plant or hydro gates in case of it a hydro power plant in accordance with a suitable control strategy which in turns control the real power output of electric generators, right.

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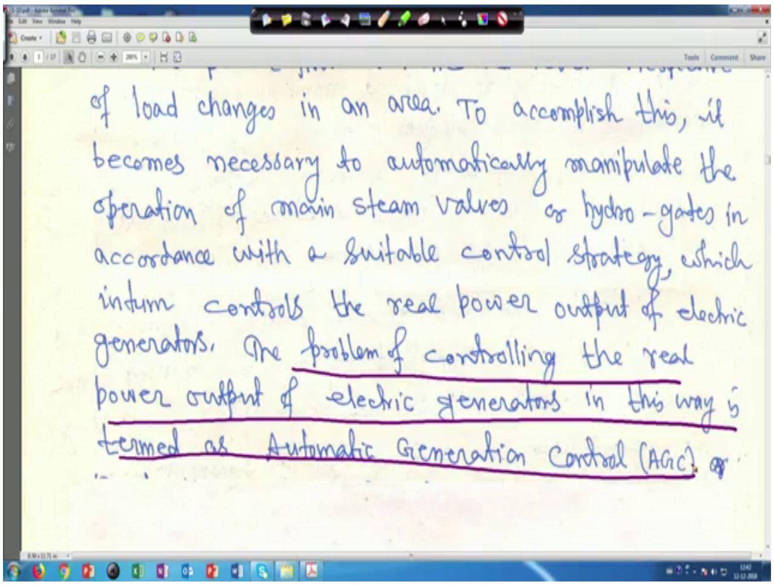

The problem of controlling the real power output of electric generators in this way is termed as automatic generation control right. So, in this case the problem of controlling the real power output of electric generators in this way is terms as your automatic generation control. This is I mean some kind of definition.

Now, whenever, whenever we will study this one that throughout I mean this deregulated environment that we will consider only your steam turbine right. If time permits then hydro turbine modeling at the end of this course I will do it for you and hydro turbine modeling, some special feature is there for hydro turbine modeling. So, as it is a your stability and this thing.

So, if time permits only at the end, I will see first after all this deregulated environment and. Although, also little bit half an hour also, I will see that a reactive power voltage control also. Little bit we will see and after that state estimation and after that if time permits excitation system and this hydro turbine modeling and AGC, how things are that will be at the end if time permits right.

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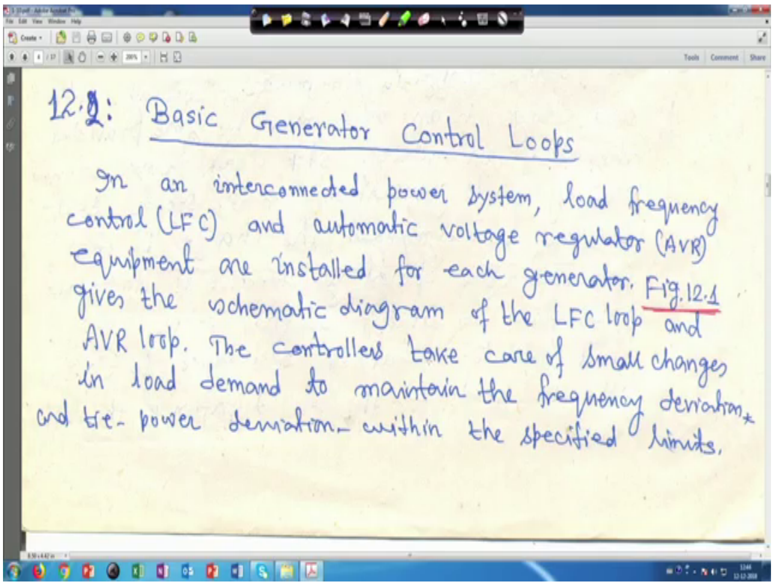

So, now basically your what you call next a basic generator control loops, right. So, interconnected power system, load frequency control and automatic voltage regulator equipment and install for each generator. This [FL] we have seen AVR another thing for that initials, initial lectures right first 14 lectures, more than 14 lectures right, all AVR other things we have seen right and install for each generator. That figure 1, I will come to that gives the schematic diagram of the LFC loop and AVR loop, the controllers take care of small changes in load demand to maintain the frequency deviation and type our deviation in the within the specified limits, right.

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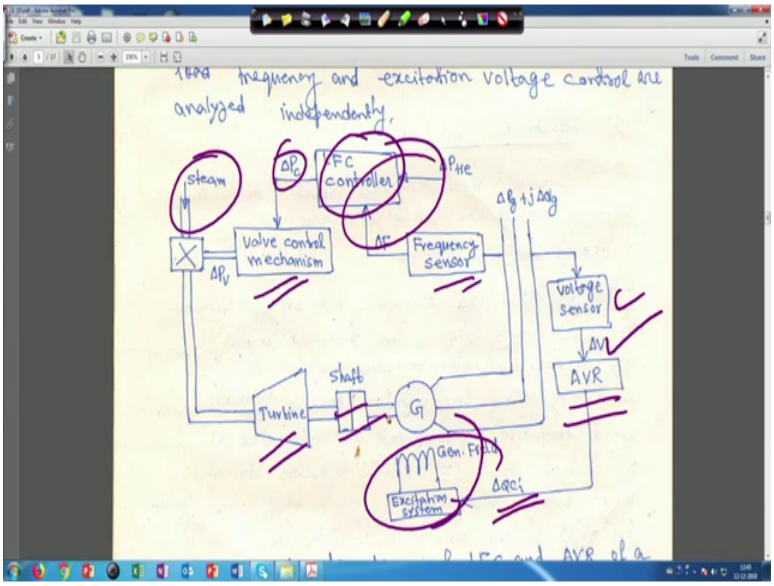

So, before going to that, this is the your what you call the schematic diagram, right. So, just just let me reduce it is size right. So, if you look at this schematic diagram, will come to that write off later; if you look at this schematic diagram, this is actually just showing first steam power for steam right and one LFC controller is here load frequency controller is there. And this is actually what happened? That it is sensing the frequency from here frequency sensor is there and delta F and delta P tie this combination is taken.

How it is taken? We will see at the end and output is actually delta PC, this is actually whatever signal is getting this is valve control mechanism right. And this is steam is according according to this signals that opening or closing back it will dictate the opening or closing of the steam valve right, then it is coming to the turbine, then shaft is there, then the turbine and generator coupled together right. And in power plant, there is no gear mechanism for this right.

So, the turbine and generator and then that three phase terminals are there. So, this is delta PG plus j delta QG right and from here that voltage sensor is there that this is delta B, then automatic voltage regulator is there and then delta QCI, this is excitation system for the generating system as generator. So, this is basically generator field, this is a schematic diagram right and we will not consider that this part, will not consider that this part right because we will T, T as separate thing. Actually, actually why we decouple it that particularly the excitation side, the time constant of all these things are very small right. So, whenever AGC action start before that the dynamics will be over, the turns in part will be over. So, almost they have no effect on AGC and so, it is basically decoupled right.

So, this is the schematic diagram, but they, but here that your here that for small changes in real power whatever I said, the small changes in real power are mainly dependent on changes in rotor angle delta hence the frequency right. The reactive power is mainly dependent on the voltage magnitude that is on the generator excitation. The excitation system time constant is much smaller than the prime over time constant and it is transient decay much faster and does not affect the LFC dynamics right that is I told you. So, thus the coupling between the LFC loop and the ABL loop is negligible and the load frequency and excitation voltage control are analyzed independently, right.

So, when I was very young at the time, I developed this model that you are what you call considering that reactive power demand the coupling thing and I simulated it, I found that your due to real power changes the voltage deviation is very negligible. Similarly, for small reactive power change, the deviation in frequency is almost negligible right. So, that is why these two are treated as decoupled. I mean several years back when I have very young at that time; I tried to develop this right. So, this is that I explained this one, right.

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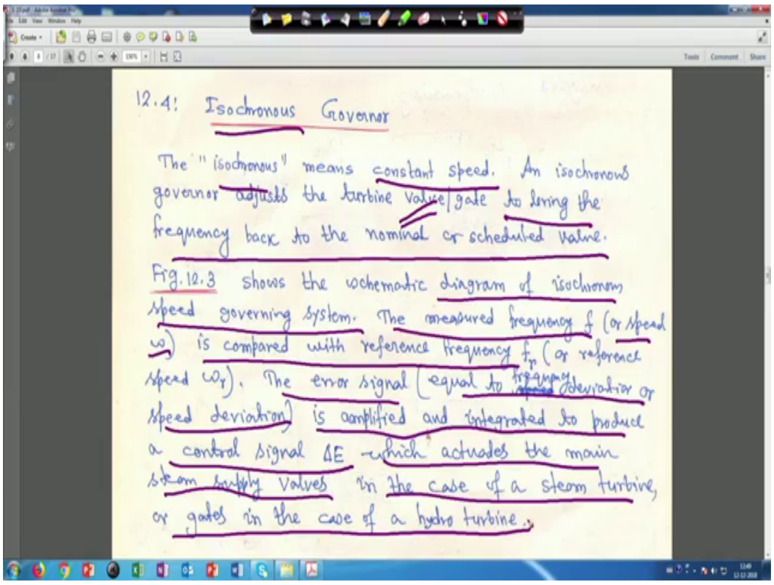

So, next is your what you call after this, we will come to another term called Isochronous Governor. Isochronous mean the constant speed right. So, meaning of this isochronous means that is constant speed right. So, an isochronous governor adjusts the turbine valve. If it is a steam turbine or gate means if it is a hydro turbine hydro gate, that is why valve means when it is when I right valve means it is steam valve, when I write gate means, the hydro gate for hydro turbine right.

So, to bring the frequency back to the nominal or it is scheduled value that I write. The figure 3 will come later shows the schematic diagram isochronous speed governing system; I will come to that right. The measured frequency f or speed omega whichever you take either you take f or you take omega 2 pi f right is compared with reference frequency f that is a reference speed or omega r, refer or omega there is some reference p to with that it will be compared right.

The error signal whatever is come equal to frequency deviation or sometimes we call speed deviation. If it is a frequency deviation, suppose f is the frequency and f r is the reference frequency say f minus f r and if it is a speed you take, then omega minus omega r right is amplified and integrated to produce a control signal delta e right which actuates the main steam supply valve in the case of steam turbine or gates in the case of hydro turbine right.

So, we will go to that figure 3, right.

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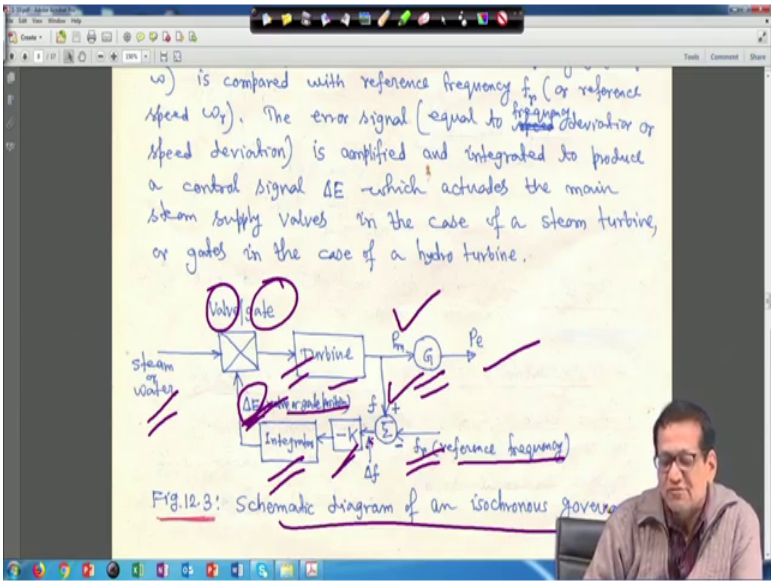

So, this is actually figure 3. So, this is your this is valve if it is a steam turbine and this is gate if it is a hydro turbine hydro gate. And hydro modeling a hydro turbine modeling is very interesting. It is called non minimum phase turbine model, what is the meaning of that those who are studying control system they will be knowing the meaning of non minimum phase and hydro turbine has a p or initially for any load disturbance has a different characteristic. If time permits, at the end I will do it for you right.

So, this is steam or water and this is your turbine right and it is P m that your power output and this is generator and this is P. We are not we are neglecting the any loss in the turbine right. So, P is equal to say P m and then this frequency sense because it is turbine generator is a rotating shaft right rotating shaft and your frequency is sense from that one. So, this is the frequencies measured say right.

And this is a reference frequency that is you are set that is your set point and you are comparing these two. So, f minus f r and e and your amplifiers gain is given suppose a minus K, gain is given and this out this output here is delta f and one integrator is there and output of this one is delta E the valve or gate position right and according to this signal this opening or closing valve for steam turbine or for hydro gate it will depend. And according to the signal, because of load increases real power load increases, the frequency falls. This is a question to you that if load increases, that frequency hence the speed actually decrease for the your alternator, but question is that it will never lose synchronism, but it will decrease I. And if load your decreases, then opposite happens right. So, frequency increases is the speed increases right. So, why it happens? So, that what is the philosophy behind that is the question to you right.

So, according to the whatever output signal it will get, according to the valve or gate opening and closing will be decided by this signal and then this is turbine and this is your what you call schematic diagram of an isochronous governor. So, in this case, for the case of isochronous governor, it is called constant plate governor.

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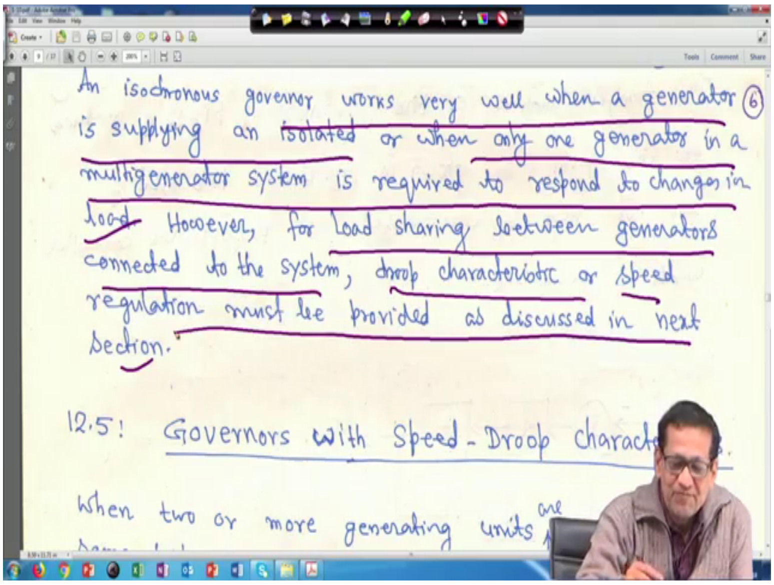

So, and I isochronous governor works very well with a generator is supplying an isolated load right or when only one generator in a multigenerator system is required to respond to changes in load right. I mean I you can use this one, but it is only supplying one load or in a your what you call in a group of generators right when required to I mean out of so many generators are there, but when only one generator in a multi generator system you required to respond to changes in the load. However, for load sharing between generators connected to the system right droop characteristic or speed regulation must be provided or discuss in that your next section, right.

So, a droop characteristic will be there otherwise what happen? There will be tug of war between the generator between that your what you call generator suppose load has increased. So, every generator has to share power among themselves right. So, and every every generator you are setting some reference set point right and that is manual you are doing it. And if manually when will set the reference set point, there is a possibility that all the generators it may not be exact right it may not be may not be exact one. So, there will be tug of war then. So, every generator will try to pull it to it is own side.

So, that is why, we need a droop characteristic for the governor.

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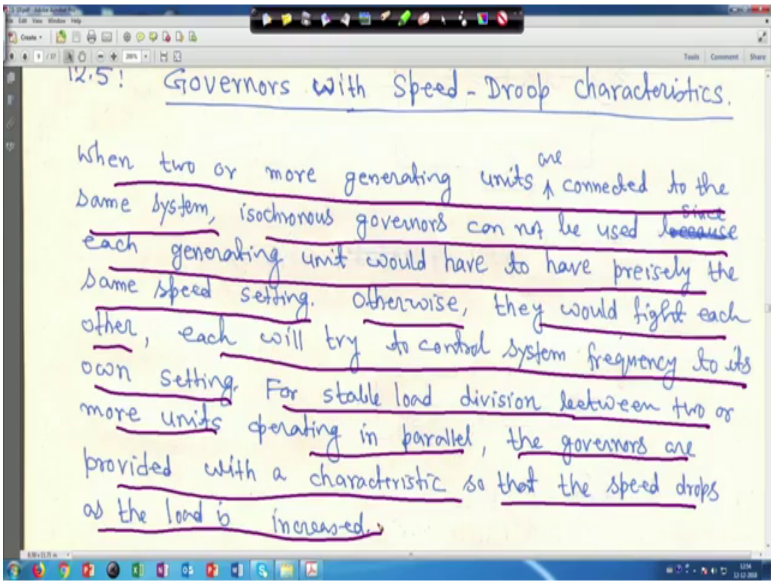

So, governor is speed we call speed do characteristic or sometimes we call speed regulation parameter or sometimes we call your what you call simply regulation parameter. So, when two or more generating units are connected, when two or more generating units are connected to the same system right isochronous governors cannot be used since each generating unit would have to have precisely the same speed setting right.

Otherwise, they would fight each other each will try to control system frequency to it is own setting for stable load division between two or more generating units operating in parallel the governors are provided with a characteristics. So, that speed drops as the load is increased, right.

So, some additional feedback is required right, then only things will be balanced.

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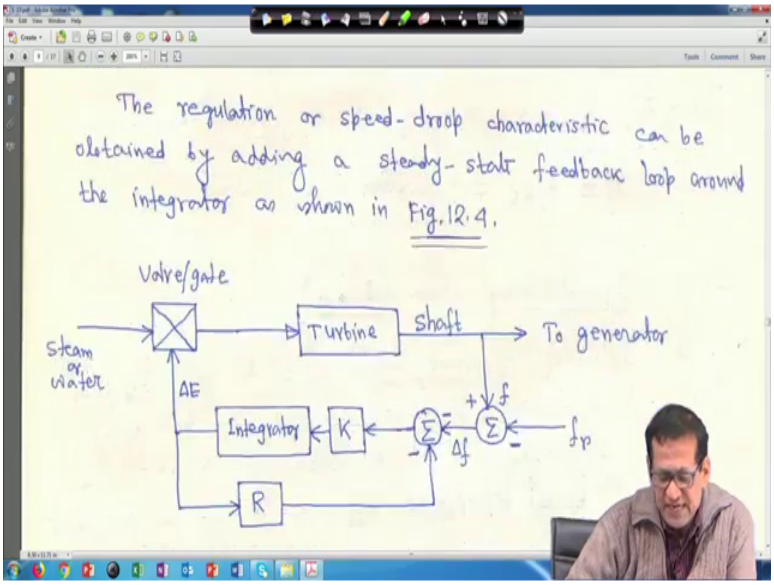

So, the regulation or speed droop characteristic can be obtained by adding a steady state feedback loop around the integrator as shown in figure 4. I mean here earlier for isochronous governor the everything was there, this part was there everything was there right, but to make this you are what to call, you have to add a steady state feedback loop around the integrator; that means, this your this feedback is taken and this R is called sometimes speed do parameter or regulation parameter right and this feedback is given here. So that means that whole governor portion actually is this much this much, right.

So, what will you do in the next diagram this portion we will bring it to the left hand side. I mean it will just make this just opposite way I mean 180 degree shift, right. So, this one this is your delta f, this is integrator gain right and this is minus and this is integrator. So, we will make just in this one we will bring to the left hand side and this one we will take to the right hand side in the next diagram.

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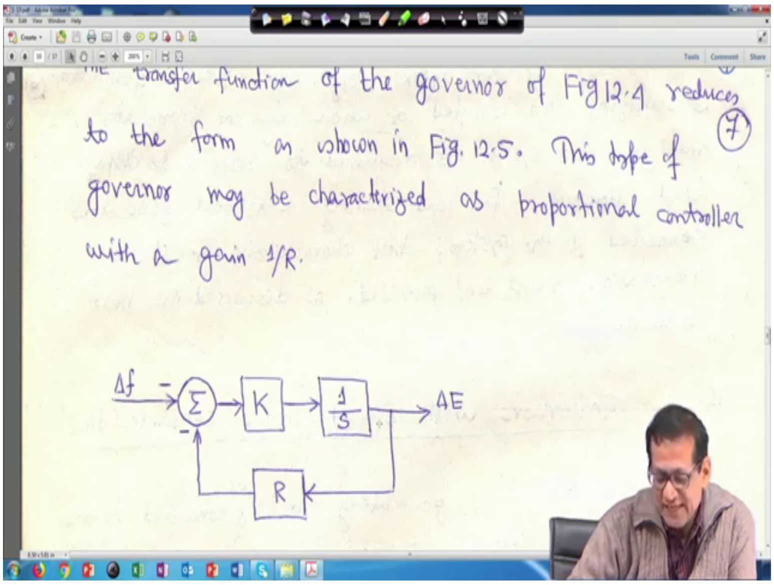

So, this is what I told you that this one, this one is delta f this is delta f right and your this is K integrator right that is 1 upon S. So, this is your delta f and if you look at the feedback delta f has a minus sign here and R is also minus sign here right and so, delta f both minus sign is here, then that gain right a an integrator 1 upon S, this is this is delta E, from here this our output R, this thing R a feedback is here right.

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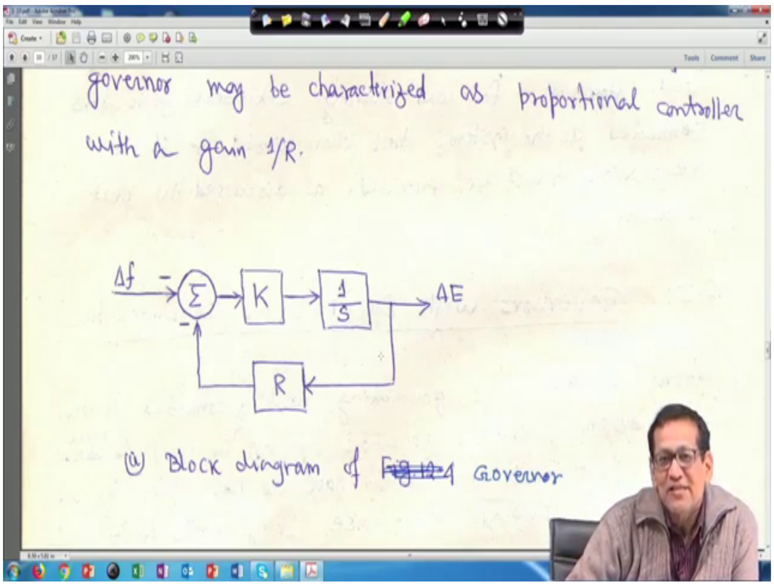

So, this is your simply there block diagram, block diagram of the governor right.

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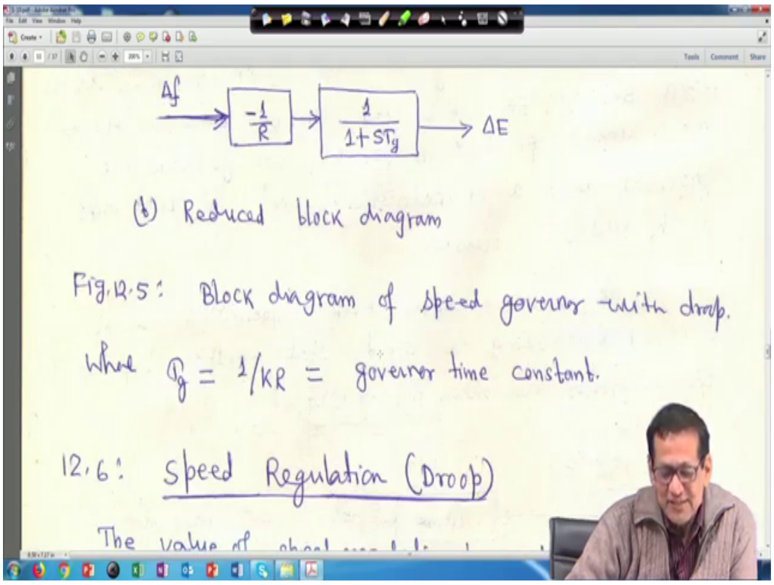

And your if you simplify this one if you simplify this block diagram, then what will happen that if you simplify this one, that your it will come like this delta f, then 1 upon 1 minus 1 upon r 1 upon 1 plus S T G, our delta E where your T G is equal to 1 upon K R governor time constant actually this one you simply this one you will simply yourself you can do it, right.

So, just to the way you have done that your control system that block diagram output by input, same way you can make this one also. I have not done it here, the small thing that is why we have not done it here. Simply, I have written that your delta f this will become actually minus delta F by R. So, delta F is the input. So, minus 1 upon R into 1 upon 1 plus S T G and T G is nothing but 1 upon k into R that is governor time constant right. So, and R is the speed regulation parameter.

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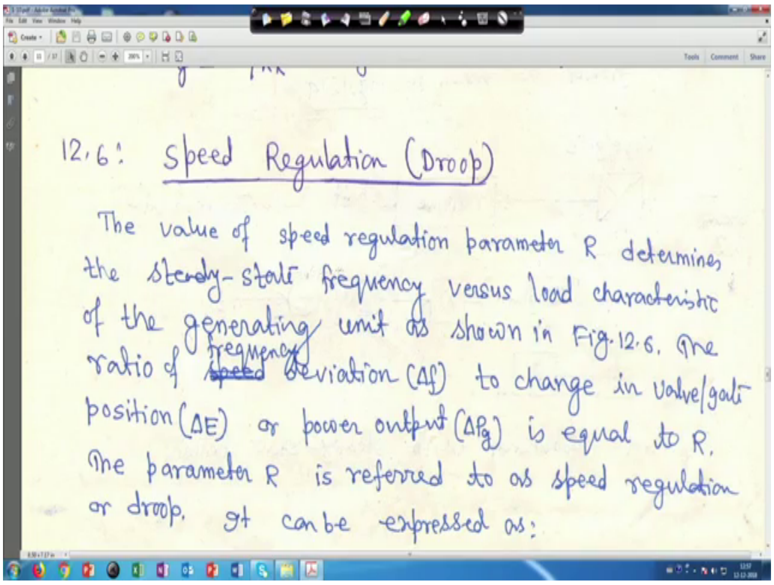

Now, is the speed regulation that is the droop, sometimes we call droop parameter right. So, the value and speed regulation parameter R actually it determines the steady state frequency versus load characteristic of the generating unit as shown in figure 6. I will come to that figure 6, right. The ratio of frequency variation deviation that is delta F to change in valve or gate position delta your position or power output delta P G is equal to R. The parameter R is referred to as a speed regulation or droop parameter or sometimes we call speed regulation parameter.

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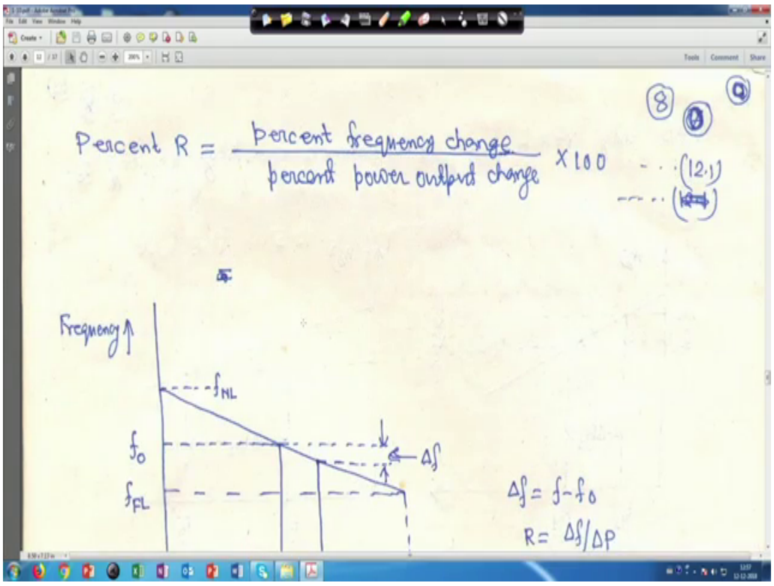

It can be expressed as the percent R this percent R right is equal to the percent frequency change by percent power output into 100 percentage, right. So, this is equation 1.

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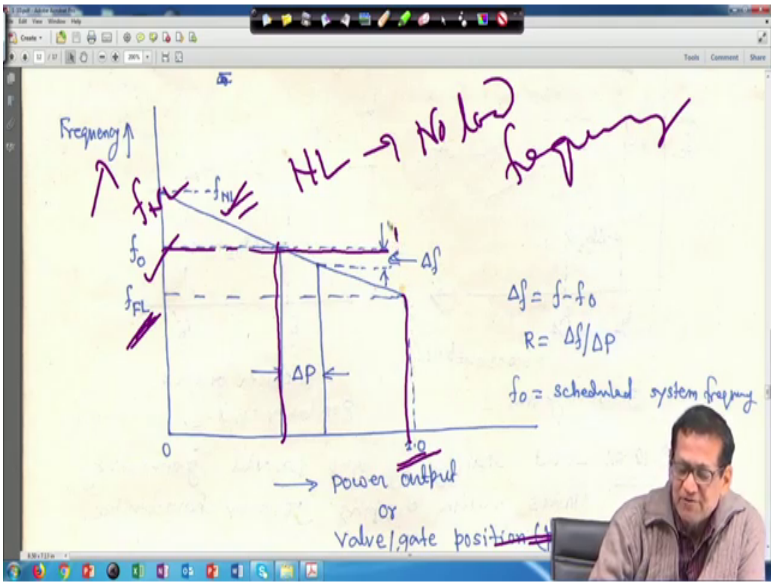

So, that means, your meaning of this one, I will come later. So, for example, if you go to this figure that this is actually, this is actually frequency this side is my frequency and this is my power output right power output or just hold on let me move it little bit up right. So, this is my frequency and this is my power output or valve or gate position power your P in per unit. You will find that your they will be same right. So, and this is F N L means N L means that is your no load frequency right and F L means the pull or frequency. So, you and the droop characteristic is almost this is your linear. So, and this is your maximum power output in power unit 1.0.

So, and this is my nominal frequency that is f 0 and this is this is your f N L, this is your f N L and this is a full load right. So, at no load means, so in power is 0, frequency is like this right and when you are when it is nominal operating at nominal frequency, this power is this much right and when it is full load. So, this much frequency drop from here to here right.

So, in this case delta f is equal to for some frequency f, it is f minus f 0 because f 0 is the nominal system frequency say if it is a 50 hertz, it will be 50 hertz. It is a 60 hertz system; it will be 60 hertz and then are the slow part will be delta f upon delta P. So, this difference is delta P. So, this is delta f right. So, basically this is also delta f. So, R is equal to delta f upon delta p, right. So, f 0 is equal to some time we call scheduled system frequency or nominal system frequency, right.

So,, so, this is actually figure 6, this is a steady state characteristic.

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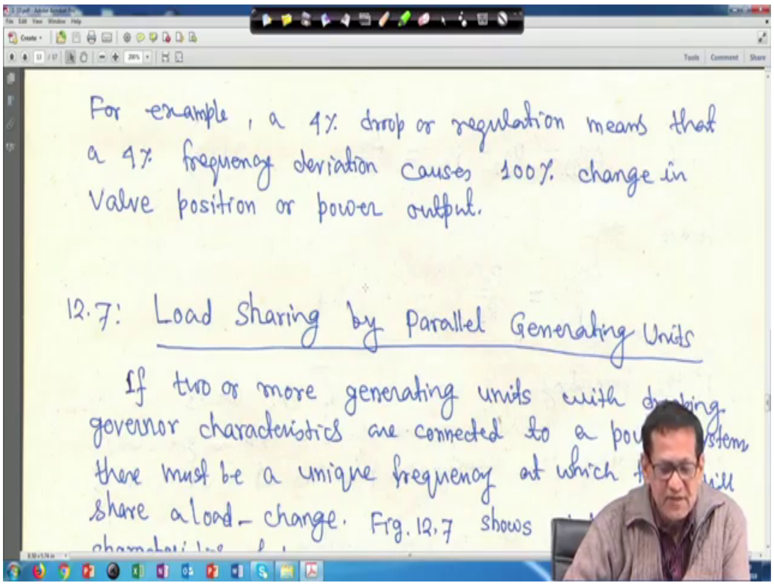

So, for example, that is the meaning of equation 1, that a 4 percent droop or regulation means that 4 percent frequency deviation actually causes 100 percent change in valve position or your power output.

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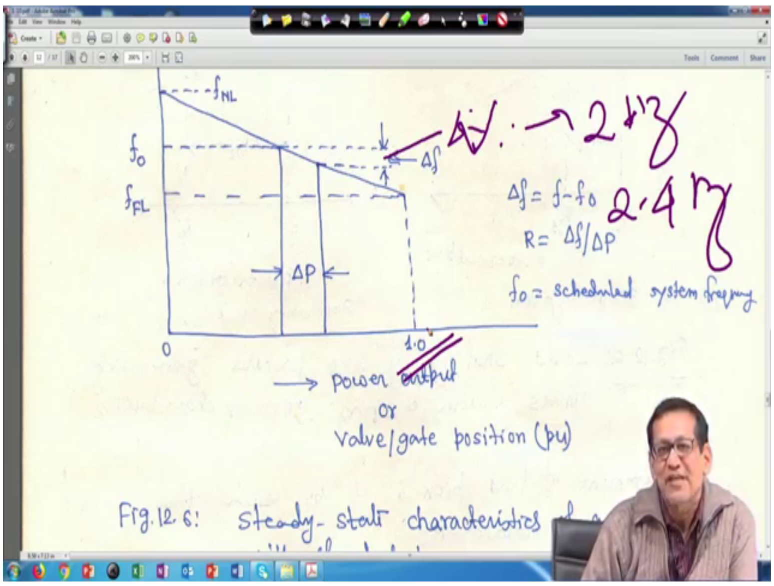

For example for example, suppose if this is your if this is your what to call that is your 4 percent change, this is your 4 percent change in frequency that is nothing but 2 hertz for your 50 hertz system. And if it is a 60 hertz system, then it will be 2.4 hertz right because 4 percent at 0.04 into 50. So, 2 hertz. For that, if it happens that there is a 100 percent change in power output, that is your 1 percent that is 1 per unit is given, then 100 percent right that is the meaning of that equation 1.

So, thank you very much we will be back.