Power System Engineering
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Lecture - 50
Load frequency control (Contd.)

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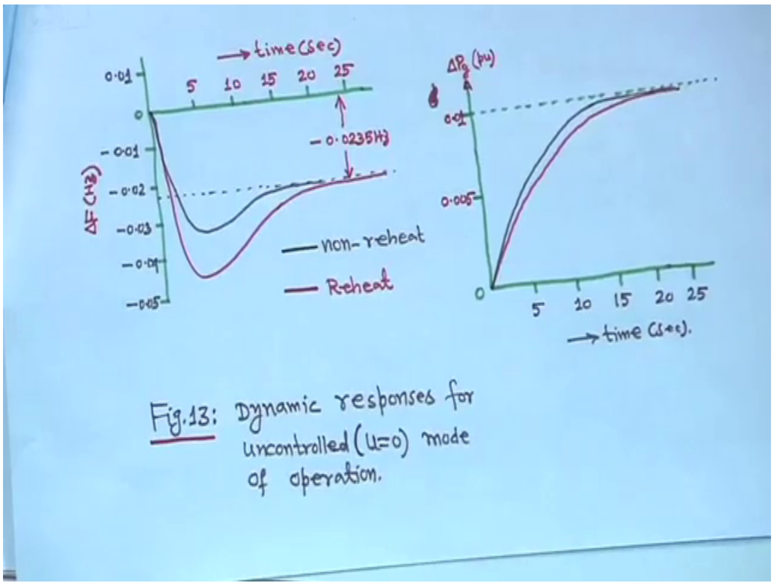

So, come to this diagram again; so, this is actually the steady state error minus 0.0235 hertz right. Say if you do the simulation it will be coming like this is for non reheat turbine.

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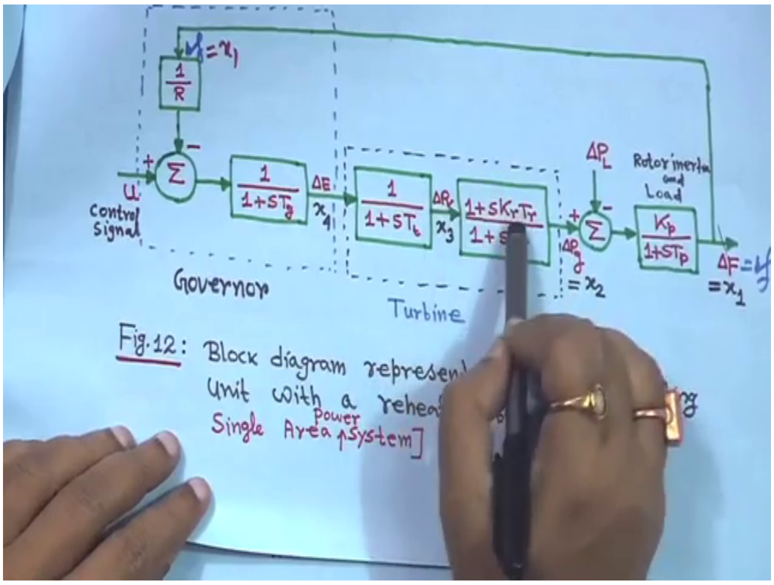

Non reheat turbine I told you that in the case of non reheat turbine right then your then this your what to call from this block diagram right, you drop this term only one time constant will be there. You would drop this term just hold on just hold on right term for non reheat turbine this term should be dropped I mean this term should be not in that case K r is equal to 1.

So, it will be it this; that means, this term will not exist. So, only this term will exist in that case it will be your what to call state there A matrix will be 3 into 3 this term should not be there. So, directly you join it this term should not be there for non reheat that I will that we have told you also earlier for non reheat turbine. So, in that case the responses are like this for reheat type that peak frequency deviation will be slightly higher right compared to your non reheat type.

But steady state error will remain same right because r and K p values are same for both the cases it will remain generation for your reheat type will take little bit little bit more time to settle it is uncontrolled mode. So, cannot be exactly 0.01 I told you it will be point your what you call a little bit less 0.0019 less right.

So, that is why your this is and it will take slightly more time because you have reheat time constant; 10 second is there little bit slower. So, dynamic performance slightly slow slower than the your non reheat type well black one is the non reheat type, but ultimately it will not exactly 0.01 through MATLAB simu link also you can check that it is not point 0.01 slightly less whatever you have solved.

So, this is uncontrolled mode dynamic responses for uncontrolled mode u is equal to 0 that is uncontrolled mode of upper. This is time this side is time this is time right and this is your side is frequency hertz and this is generator power in per unit megawatt right. So, that is your some ideas about the dynamic performances; I am not asking you to write code or anything just for general thing for this course no question of writing code right for your own interest you can verify in MATLAB.

Because I strongly believe that everyone knows MATLAB sim MATLAB simu link thing nowadays right. Code also code also very easily can be written for such kind of system, but that is beyond the scope and one can verify the result using writing code and MATLAB simulink you will find all the results are identical right.

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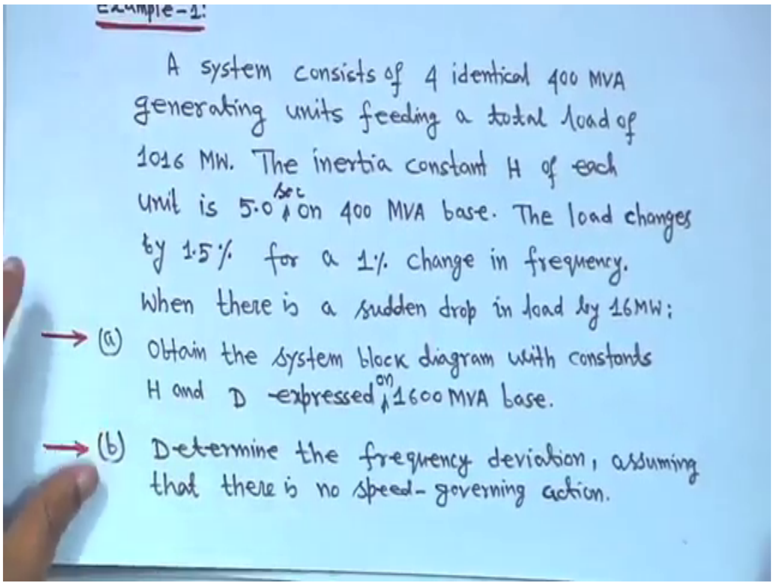

So, next we take say one small example right just you have to try to understand that this example. So, a system consists of 4 identical 400 MVA generating units right feeding a total load of 1016 megawatt; 1016 megawatt right. The inertia constant H of each unit is 5 second 5.0 second and your this total load is this 1000 megawatt; this is 400 MVA 4 identical generator and your inertia constant is 5 second on 400 MVA base for each unit. The load changes by 1.5 percent for a 1 percent change in frequency when there is a sudden drop in load by 16 megawatt.

So, initially a total load of 1016 megawatt, but there is sudden drop of 16 megawatt then what you have to do is you have to obtain the system block diagram with constant H and D expressed on 1600 MVA base right; you have to obtain the system block data with constant H and D. Second thing is determine the frequency deviation assuming that there is no speed governing system. If there is no speed governing system means that delta P g is equal to 0 you have to take; this should be in your mind that whenever they say no speed governing action means delta P g will be 0.

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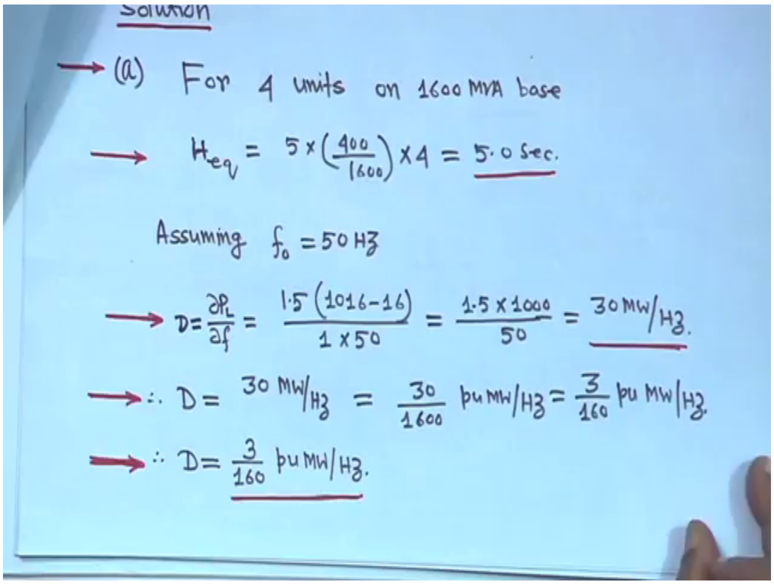

So, if you if you look at this now solution that how will make it; so, for 4 units on 1600 MVA base H equivalent actually will become 5 into 5 is the inertia constant H; it is given this H is given here 5 second; 5 into there are 4 units for identical 400 MVA units. So, 4 in 400 into 4 and on 1600 MVA base right; so, what we are doing is that we are typed because it is asked that you find out on 1600 MVA base. So, divided by the base MVA 1600; so that is actually H equal H equal becoming actually 5 second. So, same as whatever it is the equivalent one is 5.

Now, your frequency is not mentioned right then you ask say in this case we have ask you f 0 equal to 50 hertz. So, now if f 0 is equal to 50 hertz D is equal to delta P L upon delta F. Now it is given that it is 1.5 that load changes by 1.5 percent for a 1 percent change in frequency.

So, now there and what you call there is a sudden drop in load by 16 megawatt. 16 megawatt means initially it was 1016 now it is 16 megawatt. So, load is now 1016 minus 16; so, it is 1000 megawatt that is why and it is 1.5 percent the load changes 1.5 percent; that means, it will be 1.5 into 1016 minus your 16 divided by 1 percent change in frequencies 1 into 50. Percent will be cancelled; if you put if you put it is 1 1 percent here if 1.5 percent here even 1 percent of that percent means 1 upon 100 here also 1 upon 100 here also 1 upon 100 100 will be cancel will be canceled actually.

So, that is how you directly we are writing at 1.5 into 1016 minus 16 upon 1 into 50. So, if you simplify this and multiply all these things they write it is coming actually 30 megawatt for hertz it is in real unit because this 30 megawatt and this is hertz. Now D is equal to then your 30 megawatts for hertz and base is mention here 1600 MVA; this is the base; that means, this numerator is 30 megawatt you have to make it in per unit megawatt.

So, divide this one by 1600; so, it will be 30 by 1600 per unit megawatt per hertz that is your 3 by 160 per unit megawatt per hertz. So, D is equal to 3 by 160 per unit megawatt per hertz; I hope you have understood these because it is a real unit this is actually megawatt this is actually megawatt, but base is 1600.

So, we are dividing it by 1600; that means, this megawatt will be converted to power unit megawatt. So, this is the value d is equal to 3 upon 160 per unit megawatt per hertz, but frequency anyway you are not changing to it is per unit value frequencies its original value original unit that is hertz right.

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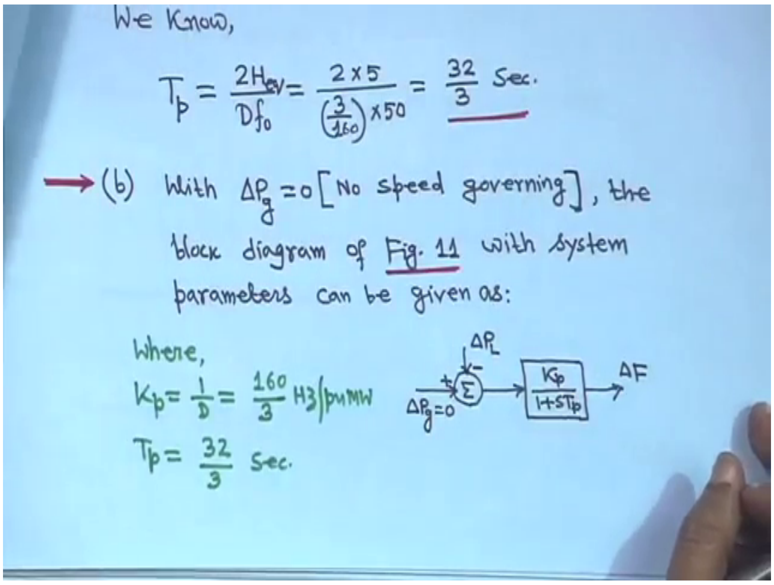

Therefore we know this we know that T p actually we know to H upon d f 0 we do, but in this case we found actually H e q is equal to 5 second that is why instead of H; we are writing T p is equal to 2 H e q upon d into f 0. So, two H q we got 5 second right H e q is 5 second, but we know T p is equal to 2 H upon f D 0, but instead of H we put H e q same thing same thing right; you put 5 H is equal to 5 here and divided by D; D we just got 3 by 160 and f 0 is equal to 50 hertz.

So, that is becoming 32 by 3 second right. So, this is your time constant T p and it is ask then the problem it is ask that what to call your obtain the system block diagram with constant H and D system block diagram is a no speed governing system actually block diagram I am made it here right that will made it here.

So, it is no speed governing system; so, that is why delta P g is equal to 0, this is delta P L; the load disturbance this is minus this is plus, but it is 0. No speed governing action means that it is 0 right delta P g is 0 and this part you know K p upon 1 plus S T p this is delta F; only this part it is asked not as a whole all because the speed governing is not there. So, no need to draw this side block diagram you have to understood this only this much only this one.

So, K p is equal to 1 upon D; so, D is equal to whatever we have got right. So, it is 3 by 160; so, it is 160 by 3 hertz per megawatt right. And T p is equal to 30 your what you call 2 by 3 seconds and this is your this is your D. So, D is equal to 1 upon K p? K p will be what? 160 upon three so that is your 160 upon 3 hertz per unit megawatt because unit also will be change and T p is equal to 30 by 3 second right.

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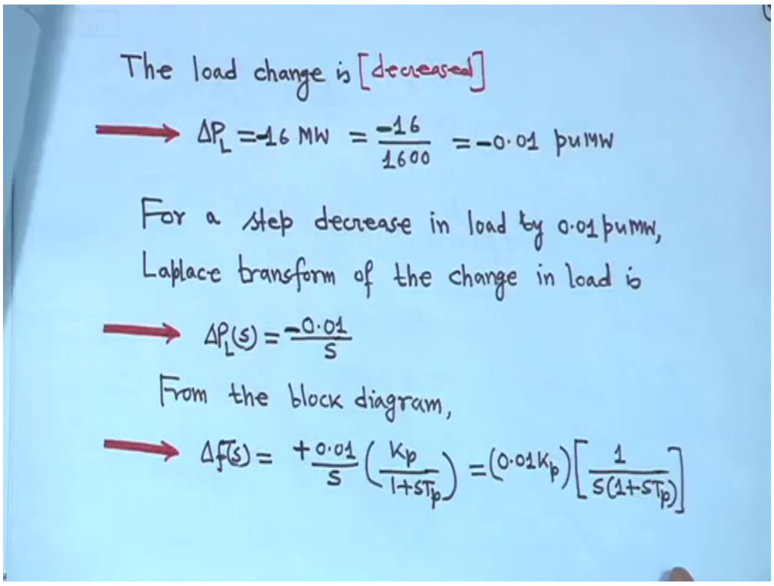

Now, the load change is decreased that is load change is negative because it was in the problem it was 1016 megawatt now it has decreased to 16 megawatt. So, it load change is negative; that means, delta P L is minus 16 megawatt divided by the 1600 MVA base. So, that is minus 0.01 per unit megawatt; so, load has decreased and there is a step change in a load. So, for a step decrease in load per unit 0.01 per unit megawatt and it is a step function.

So, Laplace transform of the change in load delta P L S and here I am putting S right just for your understanding will be minus 0.01 upon S because for a step input; you know if the load disturbance say delta P d and if it is a step input then it will be delta P d upon S and load decrease; so, minus sign. So, minus delta P g here delta P d is equal to your delta P L is equal to minus 0.01 upon S.

So, from the block diagram I mean from this block diagram from this block diagram right. So, delta F is equal to minus delta P L K p into 1 upon S plus T p right.

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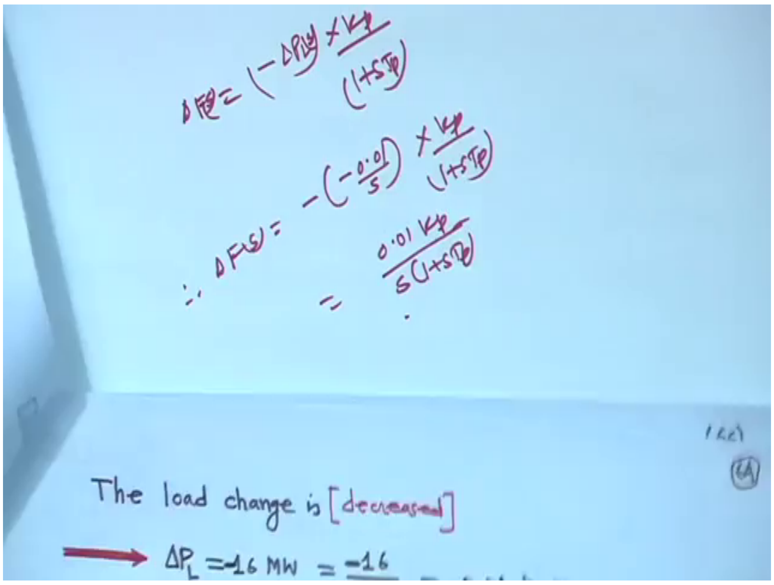

So; that means, I am I am I am making it one this thing for you that delta F delta F from this diagram is equal to minus delta P L because delta P g is 0. So, it is minus delta P L into K p upon 1 plus S T p right and; that means, you know in bracket if you want you can put S right Laplace transform, you can put what is; here also I have made it is right.

Because here in the problem itself here also I have made it is just for the purpose of your if your understanding this one is S. So, this one if you put it here then delta F S is equal to minus of minus 0.01 upon S into your K p upon 1 plus S T p right; then to K p T p value one can two. So, it will be 0.01 then K p upon S 1 plus S T p right.

So, this is the thing; that means, this is also same thing I have write in delta F S is equal to the c plus 0.01upon is to K p upon 1 plus S T p. So, it is 0.01 K p upon 1 by 1 plus 1 upon 1 S into 1 plus S T p right. Now this one you make it in that your this one you make it in that you are what you call in two terms right.

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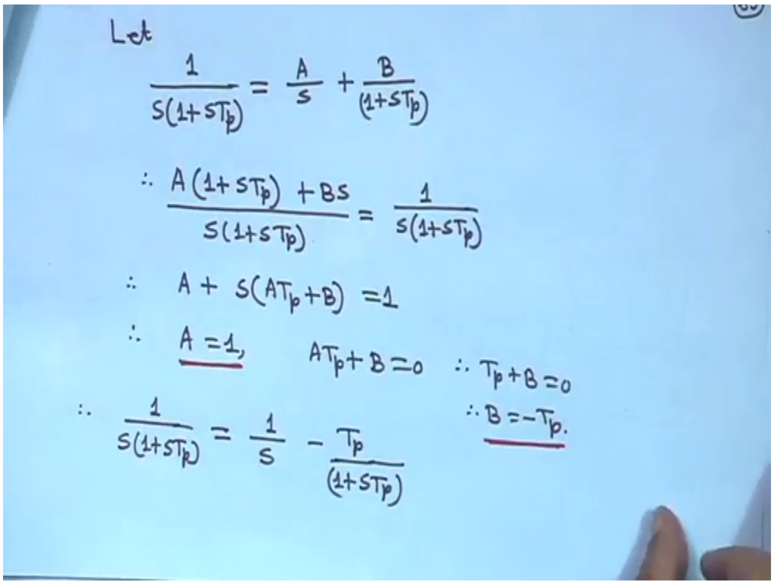

That means you know all these things this thing you always know from your calculus and other thing that let 1 upon S into 1 plus S T p is equal to A upon S plus B upon 1 plus S T p.

So, you have to obtain A and B this is an identity this is an identity therefore, we can write. So, we can write that this side this side I am writing left hand side fast that A into 1 plus S T p plus B into S upon S into 1 plus S T p is equal to this term right hand side; 1 upon S S into 1 plus S T p; that means, A plus S into A T p plus B is equal to 1. This an identity; so, we will compare the coefficient.

So, this side if you compare that constant coefficient; so, A is equal to 1 right and there is no S coefficient here; that means, it is 0 so; that means, it is your A T p plus B is equal to 0; that means, A T p; A T p plus b is equal to 0 that with A T p plus B is equal to 0 right because just we are comparing that this is an identity.

So, T p plus B your what you call is equal to your 0 because a is equal to 1 you put A is equal to 1 here. So, T p plus B is equal to minus T p; that means, this expression that is 1 upon S into 1 plus S T p is equal to A is 1; 1 upon S and B is equal to minus T p. So, minus T p upon 1 plus S T p; so, this way has to make this you know this you know from your what you call that a second order system right in control system this you are very much aware of it.

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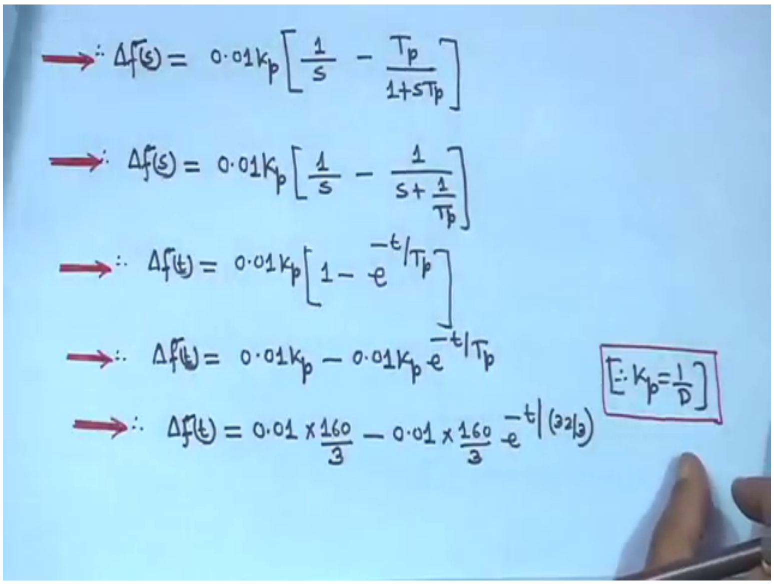

So, this is like this; that means, my delta F S will become 0.01 K p into this thing 1 upon S minus T p upon 1 plus S T p whatever you have got it here right. So, delta F S will be 0.01 K p 1 minus S divided T p this for numerator and because you have to take the inverse Laplace transform.

So, minus 1 upon 1 upon S plus 1 upon T p divided this one numerator and denominator by T p right. Then you take the inverse Laplace transform; if you take you know inverse Laplace transform delta F t is equal to 0.01 K p then 1 minus e to the power minus t upon T p capital T p right. Therefore, delta F t is equal to multiply this one 0.01 K p minus 0.01 K p e to the power minus t upon T p right, but K p is equal to 1 upon D; we know this value we know this value that is 160 by 3.

So, delta F t is equal to 0.01; 160 upon 3 minus 0.01 160 upon 3 to the power minus t upon T p is equal to 32 by 3; that we have already calculated. T p is equal to 32 by 3 right; that means, from this equation what you can guess? From this equation you guess that for the steady state values; steady state value K p is responsible K p and in this case those speed governing mechanism. So, r was not coming because delta p was 0, but K p was there, but for transient when transient response is taken T p has this effect, but a steady state T p has no effect right, but only a steady state, K p has it effects right, but as transient your what you call that when t tends to infinity means this term will vanish actually it will become 0 right.

So, in that case only K p has it effects on that steady state value, but all time constant they do not have any effect on the steady state only during transient this has the effect right. Therefore, this is we are substituting K p 160 by 3 and your T p 32 by 3; that means, delta F t is equal to 1.6 upon 3 after simplification 1 minus e to the power minus 3 t upon 32 actually.

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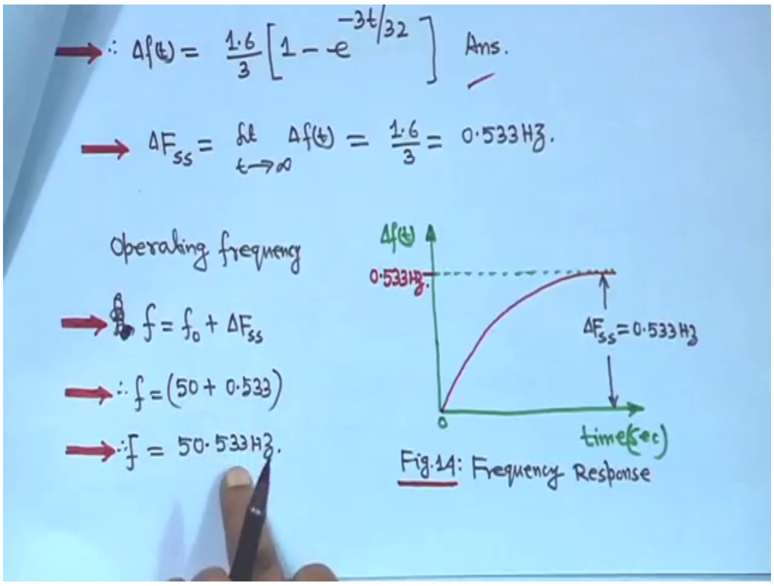

This is your response of the frequency like this. Now, at steady state your what you call t tends to infinity right from this time response. So, t tends to infinity means this term is 0 because it is your minus 3 t upon 3; 32; so, this term is vanish. So, delta F S equal to actually 1.6 upon 3 that is 0.533 hertz right. So, this is that because it is positive because the load has decreased 16 megawatt decrease because of load decrease the frequency deviation will be a steady state error will be positive.

So, 0.533 hertz; that means, operating system frequency will be f is equal to f 0 plus delta F S S. So, it will be 50.533 hertz right this is and if you plot this graph this is an exponential graph; if you plot this it will move like this from this one it will go to your what you call to a steady state values at 0.533 hertz right.

So, you will start from t is equal to 0 if you put t is equal to 0 that delta F at t is equal to 0 is 0. So, it is starting from here and exponentially increasing finally, reaching to a steady state and this is the steady state value that is there this much this is 0.533 hertz; this is the frequency response of this example.

So, I hope you have when we will go through this video I hope you will be understanding this right. So, things are simple.

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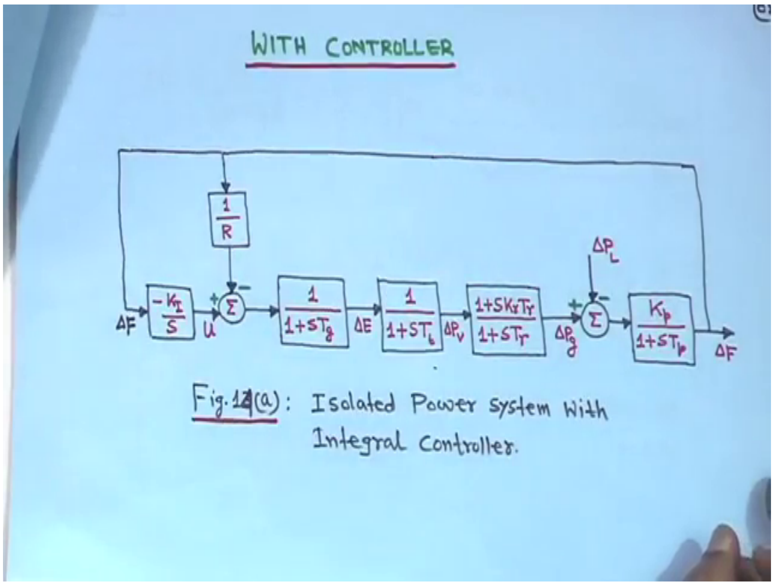

Now, with controller just a see with controller here if you controller that is there we cannot put at T tends to infinity or S is equal to we cannot do that. Here we have taken all the integral controller, a professional integral can be considered, then proportional integral derivative can be considered all set of controllers can be tried. But for the classroom exercise we have just taken that minus K I upon S K I is the integral gain setting and this we have taken right; so, only integral controller we have taken.

So, in this case what you call that if you take for this system; if you take for example, that is minus K I upon S we have taken that if K I is in this case K I will be positive; if you take minus K I upon S if you take only K I upon S then K I should be negative, but I have taken minus K I otherwise what will happen system will become unstable right. So, that so, minus K I upon S means K I you will take positive value.

Now, for this system it controller is there. So, we here we cannot get any steady state block diagram because of this is if we can put S is equal to 0, but here you cannot do that. So, we will go for final value theorem with controller right; so, it is isolated power system with integral controller. And this is your what you call will see the steady state value that when you put integral controller, you will find the steady state value delta F S

S will become 0. Our delta and with this controller at the time delta P g S; will be exactly delta P L it will because frequency at the time there is no frequency error delta F S is 0.

So that, will D into delta if a system was there, but in that case that the difference was coming because of the steady state error or in frequency, but in this case when delta F S S will become 0. So, d into whatever the delta F S S is 0; so, that term will not be there. And because of this controller action delta P g will become delta P L now look how to do it final value theorem.

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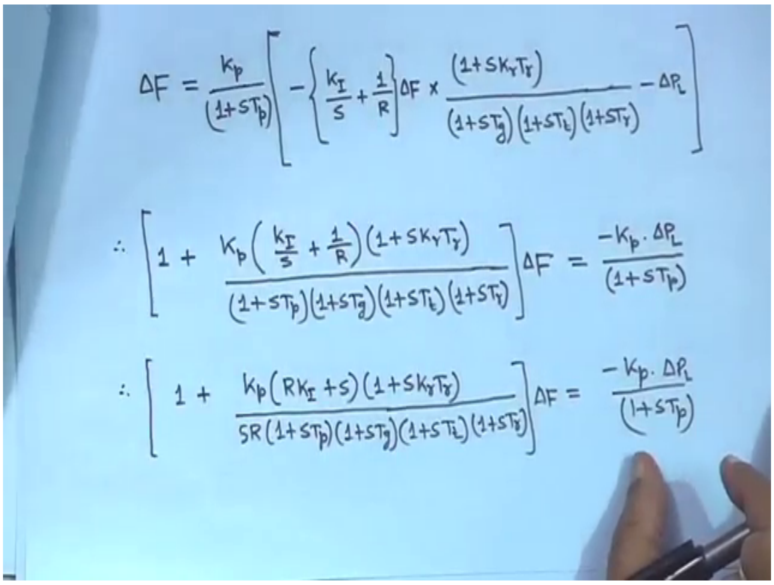

So, in this case in this case first you write down that equation delta F is equal to delta F is equal to K p upon 1 plus S T p right; this is known. Then this is actually this is known then what you will do that delta P g is equal to we I have written your fused one or two step ahead; but I am telling you how to make it right.

I write little bit slowly here right such that things will be this thing look at this diagram; look at this let this diagram right that this; that means, this is delta F this is delta F; that means, here also it is your delta F right here also have written delta F; that means, your delta P g is equal to delta P g is equal to your minus K I upon S into delta F minus 1 upon R into delta F.

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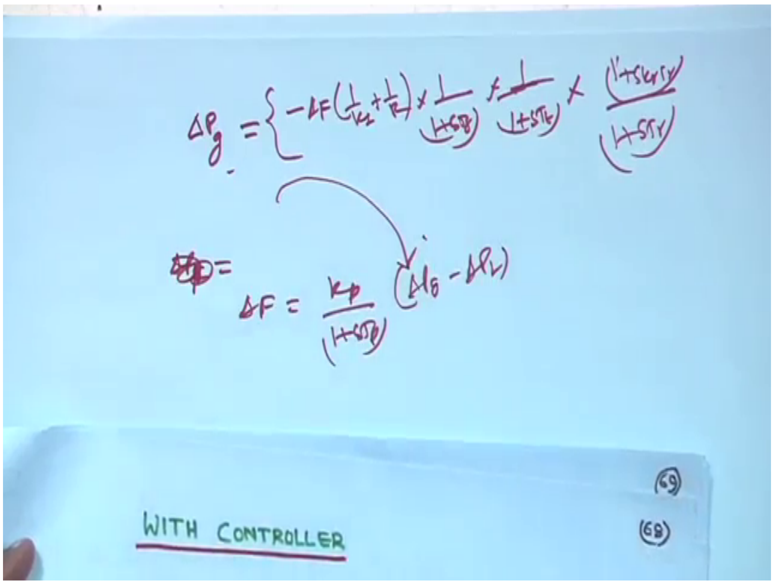

So, delta F delta P is common so; that means, delta P g right is equal to this delta P g multiplied by all these things will come right. So, it will be your minus delta A prime minus delta F; that means, your if you take minus delta F upon r minus K I upon S. So, delta F will be common and then you are in bracket it will be 1 upon K I plus your 1 upon R right; let me put it little bit this thing right minus 1 upon K I plus 1 upon r right into this all this term into all this term; that means, into 1 upon 1 plus S T g into 1 upon 1 plus S T t right into your 1 upon your 1 plus S K r t r right divided by 1 plus S T r.

So, all this term will be coming delta P g is equal to that is why whatever we are writing here. So, this delta actually delta P g minus delta P L into K p upon 1 plus S T p; so, delta P g write delta P g is equal to your sorry delta F is equal to your delta F is equal to your K p upon 1 plus S T p from this diagram; K p upon 1 plus S T p into delta P g minus delta P L. This delta P g whatever it is written here; this delta P g you substitute here, you substitute here right.

So, if you do; so, that is how you are writing that K p upon 1 plus S T p; this whole term this whole term actually this term which is delta P g. Just now just now we have written that this term is delta P g right this term is delta P g. So, all these terms are written here minus delta P L del this term is delta P g minus; it is delta P L right. If you simplify this; that means, this one if you want to write right I mean after simplification.

So, this is your delta F is equal to so, what you can what you can do is that this your this term all these things 1 plus K p into if you multiply. If you multiply this thing it will be K p into K I upon S plus 1 upon R; then this side it has come because when you multiply all this term this delta F term is there with this delta F term is there. So, this term multiplied this term into the or this thing will come to the left hand side right; then minus K p into delta P L 1 plus S t I mean if you make it like this that this is your delta F is equal to this one. And this term with this term from I mean from here to here with this term delta F is associated with that multiplied by your what you call K p upon 1 plus S T p.

So, you what you do you multiply this right; you multiply this then you bring this term to the your what you call to the left hand side just writing one or two lines for you such that because here it will consume some time for writing this one, but it is understandable look at this term this term.

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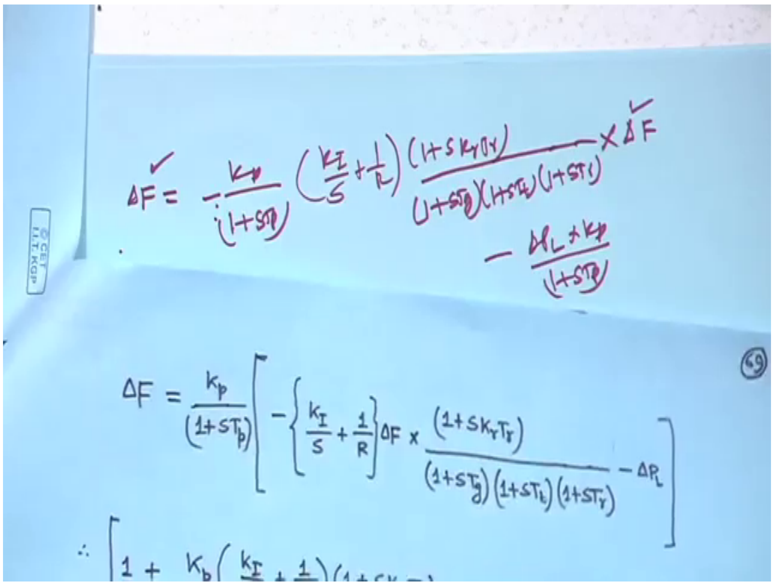

So, in this case what you can do is that delta F delta F; you multiply all these things, it will become your K p upon 1 plus S T p a minus sign because of this 1 into K I upon S plus 1 upon r right into your 1 plus S K r T r divided by right all the terms; 1 plus S T g 1 plus S T t 1 plus your what you call S T r right into this delta term is their into delta F right. Then minus your delta P L into K p divided by 1 plus S T p; this term you bring it to the left hand side this is delta F this is delta; bring it to the left hand side and take delta F common.

If you do so, and little bit you simplify if you do. So, you will get this 1 plus K p into all this term into delta F is equal to minus K p into delta P L upon 1 plus S T p that is whatever I have just written minus delta P L into K p upon 1 plus S T p right. So, if you bring to this side and then your after this little bit; you simplify it will be R K I plus S upon S R; so S R is here right and R K I plus S R is here and this is 1 plus into everything is there delta F is equal to minus K p into delta P L upon 1 plus S T p right.

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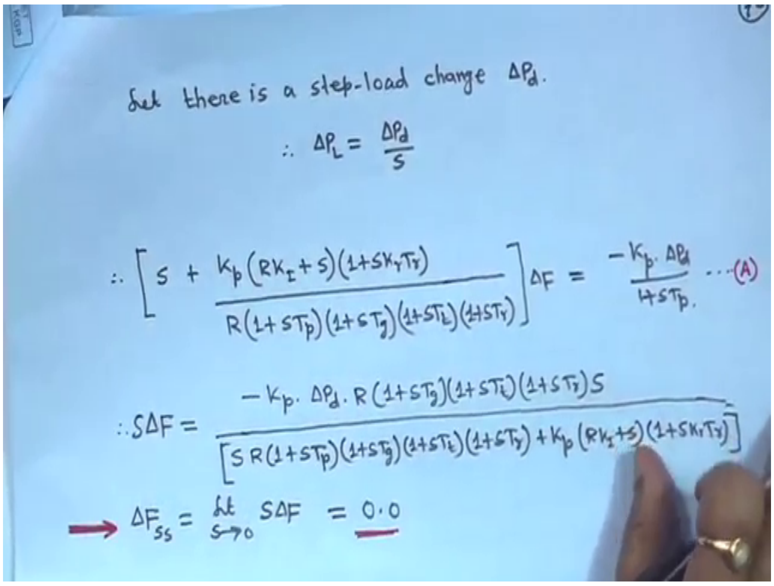

Next is so, next one is let there is a step load change in delta P dib there is a step load change is a final value theorem we want to apply. So, delta P L will be delta P d upon S; this delta step load change I have said no a question of increase or decrease; according to the increase it will plus according to decrease it will be minus. So, in general delta P L will be delta P d upon S for a step load disturbance right. That means, for a step load disturbance in this equation delta P L you put delta P d upon S here delta P d upon S if you do.

So, then it is becoming actually if you put delta P d upon S then delta P d upon S; you put it here and multiply both side by S right. So, first you put delta P d upon S in this equation, delta P L is equal to delta P d upon S you put it here. And both side you multiplied by S if you do so, that is why here it is 1, if you want both side multiplied by s. So, if it is delta P d upon S this S will be cancel it will be S plus S into something.

So, that is why your it will be S and this S if you multiply both side that S S will be canceled here; you multiply this is actually this term will be delta P d upon S. So, multiply both side by S; so, this new denominator S will be canceled, it will be minus K p into delta P d upon 1 plus S T p. And this side if you multiplied by S, it will be S plus this one S is here. So, S s will be canceled it will be K p into this thing R into all these things.

So, whatever you are doing is same thing we are getting. So, not writing here I think you can do it yourself; just a simple thing put delta P d upon S, then multiply both side by S. So, you will get this expression right; that means, that means your S into delta; if you simplify this one that S into delta F is equal to your whatever things coming right. So, is equal to minus K p then delta P d into r all these things I mean what will happen actually; if you make it like this it will be it, it will become is look at the new denominator. It will be S R, S R into all these things S R into all these thing plus this is a plus sign, there is a plus sign here plus K p into R K I plus S into this term right.

And then this one you are what we call minus K p into delta P d into R; 1 plus S T g, 1 plus S T t, 1 plus S T r into S; that means, both sides what we are doing is actually we are multiplying by S; both side we are multi here it is yes here also it is s. So, both side we are trying to multiply by S; so, that is why this side when you multiply that minus K p into delta P d is there, along with that this side will multiply at R into all these things; divided by this thing. Then both side you please multiplied by S right; that means, the S del F; so, delta F S is limit S tends to 0 S delta right and it has S tends to 0 means it is 0. So, steady state error of the frequency will be 0.

So, thank you very much I think you have understood this little way to do it and multiply both sides. So, it is S S by from control system you have studied all this so.

Thank you will be coming.