Power System Operations and Control
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Module-3
Frequency and Voltage Control
Lecture - 3

Welcome to lecture number 3 of module 3 which is frequency and voltage control. And in lecture number 1 and lecture 2 I explained the modeling of governor turbine and the generators. Now, we left one component that is very important and that is the modeling of load which we have we know this load in the power system can change with the frequency.

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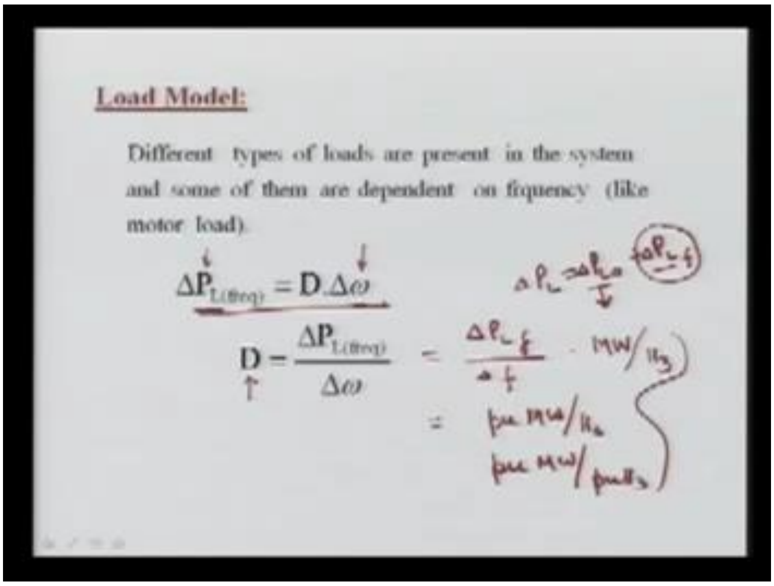

Change means we are having the loads which are dependent on the frequency and example is your motor loads. So, mostly loads that is seventy to eighty percent load is basically are the motor load and it is only you can say induction motor load. So, the different type of loads are present in the power system some of them are dependent on frequency like motor loads. So, whenever the system frequency changes the load which is that is a taken by the machine or motor it is also changing. So, we can define a term D that is a damping constant D here and that relates that your change in the load that is a frequency component only load and that is changed in the omega or you can say frequency. So, here this term D is defined as change in load that is your frequency dependent load means we can have the load total that I can say this P L will be your P L that is independent of frequency and another one is your P L that is the dependent on frequency. So, whenever you are going to change the load there will be change in the frequency and dependent non-dependent frequency loads and the frequency dependent loads.

So, here this is you can say independent on frequency this load and this load is dependent on the frequency. So, here we are talking that this will be changed if the system frequency will change. So, we can define here the term D that relates your change in the load that is a frequency dependent component with the change in frequency. Here we can also write if you are writing in the per unit means we can write here this P L that is a frequency component divided by change in the frequency. The unit of D here that we can take it is nothing but, your megawatt that is a power divided by your frequency that is Hertz. Again if you are writing in the per unit then we can write here the unit again or you can say per unit megawatt divided by Hertz or I can write the per unit mega watt over per unit Hertz. So, these 3 units are very widely used for that relating D always here we are assuming that D is constant. Because we have a linear relation bet relationship between the change in the frequency dependent load with the change in the frequency. So, this is a linear relation and we have assume and with assumptions we can again model the loads.

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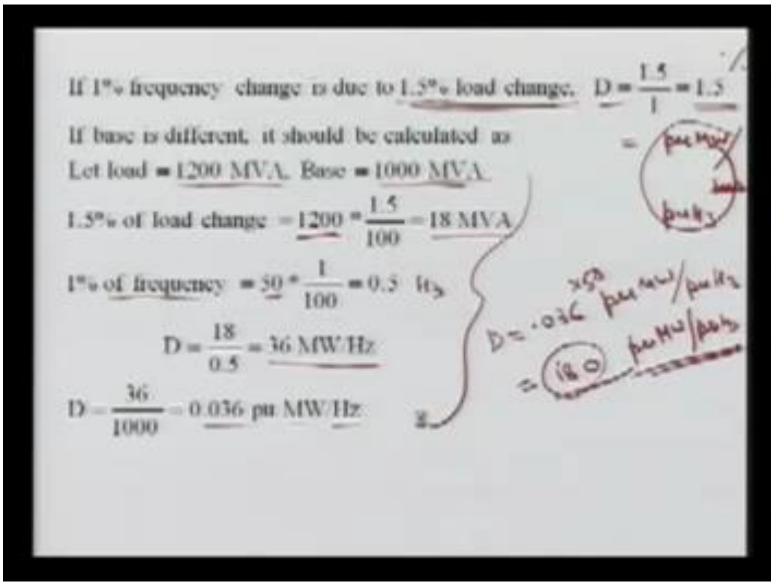

So, here you will see that how it is related that if 1 person change in frequency due to the 1.5 percent change in load. Now, we are talking in terms of percentage. So, the D will be 1.5 that is load the percentage change in the load divided by percentage change in frequency and the D is 1.5. Now, the question what is 1.5? 1.5, here it is in per unit means here the percentage we have talking means it is your per unit mega watt over per unit Hertz. So, for given these power and the frequency that is a nominal frequency or rated frequency we can calculate the value of D in actual quantity that is your mega watt per Hertz here it is not clear. So, here basically it is your per unit Hertz just we are talking. Now, if the base is different it should be calculated let us suppose your load here is 1200 MVA, but, your base may be something different that is Hu 1000 MVA. So, base can be any value.

So, here this per unit as you know the actual value is divided by base value then we get the per unit quantity. So, we can either directly calculate these value here by simply multiplying the in actual quantity or we can calculate the actual change that is 1 percent load change. It means 1 percent load change is nothing but, your load value that is here 1.5 percent load change is equal to 1200. That is load here multiplied by 1.5 divided by 100 that is a percentage we are talking. So, we are just changing a team MVA load or say the power factor is normally unity then it is a 18 mega watt. Now, 1 percent frequency change means your frequency is 50 hertz. So, 1 percent means 1 upon hundred. So, we are just getting this 1 percent change means this must hertz and if you are dividing here 18 upon 5.5 we are getting 36 mega watt per hertz with power factor as unity here the power factor we have taken unity.

Now, if you want to convert in the your per unit quantity that is here you are going to calculate here per unit what you have to do you have to divide by base. So, here we have divided by base that is a base power is this much and then we can get 0.036 per unit mega watt per hertz. Again if you want to get in the per unit again that is hertz value as well then here your D will be your 0.36 per unit mega watt. Now, it is per hertz I want to write here in the per unit here and for that we have to now multiplied by 50 if your operating frequency is 50. So, this value will be your, you will multiplying here. So, you are going to get this 0 here 36 15 18 and it is 1.8 here that is coming. So, here whatever we are getting that is showing that D here the percentage change here in this load with the percentage change here. So, that we can calculate the per unit quantity very clearly and this value is now it is not you can say this is not 1.5 it is 1.8 is a different value.

So, this value is giving in your percentage change that is the D relates. So, normally D we have to very careful about the unit cl. You can say this which I was telling is not correct now this is your correct here it is a per unit mega watt pa per unit here hertz. So, this is the actual unit of the D. So, whenever just you have given 1 percentage change of frequency due to this percentage then you have to go for the actual calculation then you can divide by the base quantities and then you can calculate here. The load and this is both are changing if both are same then directly it will be 1.5 without any problem. So, this in which is saying, because here this 1 percent load change just we are taking this is we are taking this 1 and we are assuming base that is a base case, but, here that is a different. So, load and base are different then you have to go for calculation in this way and then you can get the D. Why I am talking this, because later on we will see that is the D component calculation and also we will see the M component cap calculation that will be clear to you later on.

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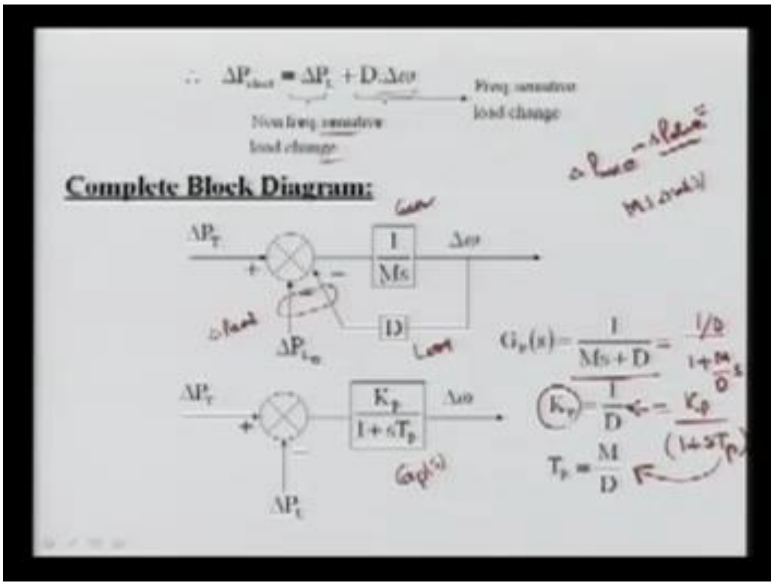

Now, here we can see just in our previous modeling of the generator just I wrote here that is I can write here this P mechanical that is change in P mech here minus change in P elect that was nothing but, your change in here this I was defining here your ms that is I wrote that that was the differentiation here. Now, we can this electrical component can be change into 2 components. Now, one is your related with this non frequency sensitive load and another is frequency dependent load that is a D into change in omega or change in your frequency that is a frequency sensitive load change. So, here this was your now I can include that this complete model of generator plus load. So, what we can do this P electrical was change here this PT is your turbine power at T mechanical which I was mentioning. Now, this P L here the term which is now is a constant that is a independent of frequency minus again another term that is here adding with the frequency means here minus you can say.

So, this and this now it is a total this is your change in P electrical and that is multiplied by 1 upon ms we are getting omega here. So, you can say here it was giving you a omega S if remember. So, this is your generator model this is your load model and now we can combine this with you are the remaining modeling that is a governor turbine and then we will see that what loop we are getting. Now, again we can simplify this loop because we have 1 close loop here. So, that can be simplified here is nothing but, we can get this GP here this is nothing but, GP we call GP means that is a transfer function of the power system generator; power system means that include your generator as well as the power system. So, it is called Gp; GP here we can simplify then we will get 1 over ms plus D you can see here directly it is going to be added and then here we are getting this GP there. Now, since all the transfer functions we define in terms of gain and time constant. So, we should also here define gain and time constant.

So, what we can do here we can write this 1 over we can divide by D. So, we are getting 1 plus here M over D into S. And here we are getting D means was just we are dividing D in numerator and as well the denominator together we are getting this. So, we can write here it is nothing but, your Kp over 1 plus ST and here this Tp is the time constant of the power system. So, what we are getting this Kp which is we are getting that is nothing but, it is your this value and your Tp is your M upon D. So, this is time constant of the power system and this is the gain of the power system 1 thing also we should very much careful. Because the M here sometimes your H is given because we can formulate here we have formulated the power system in the D that is no problem. Because it is a frequency dependent we are using directly frequency and here M we are using the angular momentum. Now, we can also use another constant that is inertia constant.

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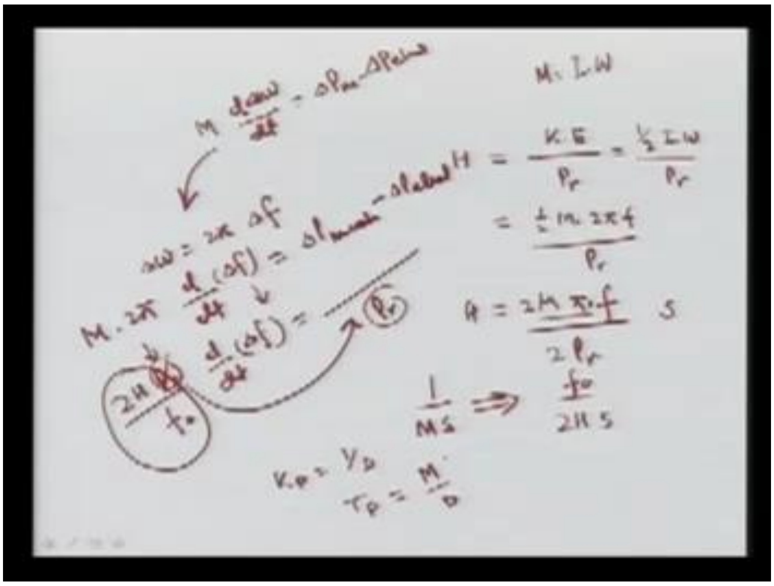

And let us see how it is related means you know that here this M we can write D omega change in omega over dt here I can write this P mechanical minus P electrical are these are the changes I can write. So, what we can do this which we are writing here again we are writing this M omega. Now, this H term that is called again this inertia constant S H constant and the unity second it is defined as the KE stored in the machine divided by the rating of machine I can say this Pr the rating of machine. So, the KE is nothing but, I can say it is half I into omega that is the speed divided by Pr and we know that M is nothing but, I into omega. So, I can write here 1 over 2 here M into omega and omega I can write 2 pi f. So, I can write 2 pi f here divided by Pr means finally, I am getting this 2 is cancelled. So, it is M into pi into f here divided by Pr from here again what we can do this omega can be replaced with the frequency omega is the rotational speed radiant per second I want to represent in the Hertz.

So, what I can write here? I can write this change in omega here I can write the twice pi change in frequency. So, this equation we can write here that is your M into twice pi D over dt change in your f here again your change in P mechanical power minus change in P electrical. So, now here you can see we are having M pi here we are having M pi H is also appearing. So, what I can write this I can replace it and finally, I can write in terms of h. So, sometimes H is give sometimes M is given. So, you must be very careful and also our output here just we are trying to write in terms of frequency because we will see your regulation are it was giving your frequency component. So, what we can do here this M pi can be replaced here means I can multiplied by 2 here I can multiply by 2 here. And this is here I can write here now twice H this Pr divided by your f and f is your that is a base frequency. And now I can write your D upon dt change in frequency and here the change in the power.

So, what we are getting this is your base power. So, if you are dividing this here that is replaced that is going here that is a Pr what is happening here the power now we are getting the per unit. So, this twice H upon f I can replace here M and then we can solve it. So, what is happening the M which we are getting this 1 over ms that is we were getting now that will be replaced by 1 over twice Hs here f naught. And the output here that is we are multiplying by per unit always we must be remember here this is the diving the per unit. So, the power which is coming the mechanical minus electrical it is in per unit. So, this H will coming here H the unit here is second. To see it let us see 1 example and then it will be more clear and you can also see what will be this Kp is every time it is 1 over d; however, your Tp it is nothing but, as I said it is your M upon D. So, we can replace this M with this value and then we can solve the Tp to see this let us see 1 example here.

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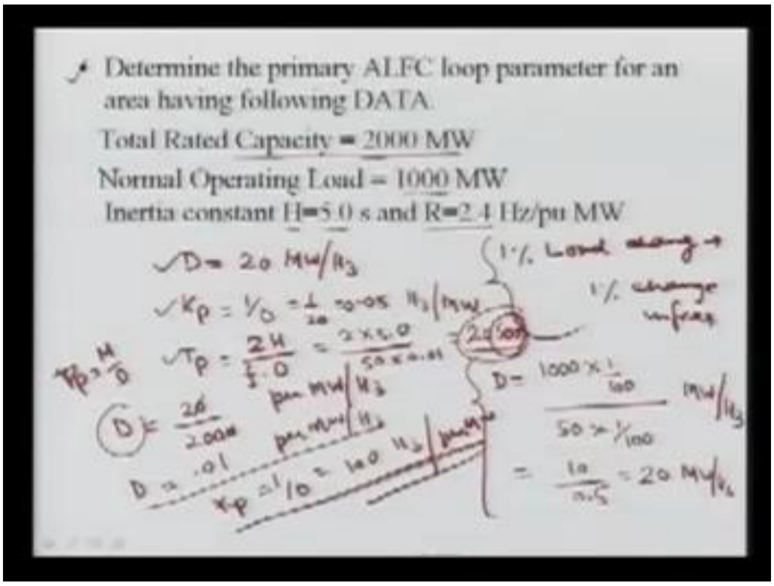

Here example is that is a we have to solve the determine the primary ALFC that is automatic load frequency control loop parameter for an area having fall in data means the total rated capacity is 2000 mega watt normal operating load is your 1000 mega watt.

Inertia constant H is given here that is a 0.5 second and your R that is a regulation it is given 2.4 hertz per mega watt per unit megawatt. Now, we have to determine here the parameter that is we have to calculate it is nothing but, we have to calculate this your I want to calculate here the value D that is we have to calculate the D. We have to calculate your Kp and we have to calculate the Tp now for the T D that is a coefficient which relates your change in load with a change in frequency here. Let us take that this a linear means if there is 1 percent increase means here if load we have given this for 1 percent load increase that is load change the frequency is also change. The frequency changes 1 percent change in frequency change in frequency. So, the D can be calculated with this relation it is given let us that 1 percent change in load will cause 1 percent change in the frequency.

So, this is assume to be a linear and then we have to write this for this what we have to write it is said the 1 percent change in the load. So, load is your here 1 thousand. So, D can be defined as that is here 1000 of 1 percent that is 1 over here 100 means this is your mega watt divided by there is a 1 percent change in the frequency. One percent change in frequency means your system frequency is 50 and that is 1 percent means here your 100 and this value is coming out to be your megawatt per Hertz. The unit here is very very careful always we must be careful about the per unit megawatts or here the per unit hertz etcetera. So, here the unit, because we are getting here megawatt 1 percent of this operating and here then this value will be here 10 divided by here now 0.5 and now we are getting here 20 means 20 megawatt per hertz. Now, we have calculated D means we have model the power system load which is a frequency dependent. And it is having if it is said that it is independent of frequency then the D here what will be the D there will be no change and this value will not appear at all. So, when the frequency changes any value there is no load change. So, this D will be 0. Now, D will be your 20 I can say megawatt per hertz. Now, we have to calculate the Kp and Kp as I defined Kp is 1 over D means here it is 1 over 20 means finally, we are getting it S 0.05 here that is your hertz per megawatt.

So, this is your hertz per megawatt will be your Kp. Now, we want to calculate this suppose we want to calculate in terms of per unit megawatt as I said normally if it is H is given. Then the value which we are calculating here that is coming this P mechanical minus this T electrical that was coming here it was in per unit megawatt. So, we can convert this 1 in the per unit megawatt then this D will be changed and here what I can do? Let us see this D will be now we have to divide here the base, base normally is the rated capacity of the system normally it is a higher value. So, rated capacity is 2000. So, what we can get here that 20 divided by 2000 now we are getting per unit megawatt divided by hertz or we are getting this here it is cancelled we are getting 0.01 per unit megawatt per hertz. So, this is your D now Kp in per unit will be the reverse of this 1 over D and this value will be nothing but, your 100 now hertz per per unit megawatt. So, this will be your Kp and here you can say the Kp just we got 100 hertz per megawatt power means there is a 1 per unit megawatt change there will be 100 hertz change in the frequency that D just says it.

Now, we want to calculate the Tp ad this Tp is nothing but, as I said this Tp is we can define here twice twice H divided by here your f and that is your D here it in per unit that is here per unit per hertz. So, what will happen here if we will putting that is 2 multiplied by 5, 5 second it is given here divided by your 50 hertz and your D is nothing but, 0.01 and then we have to calculate the time constant. If you are calculating the time constant how much we are getting you can see it is 10 here 10 and here we are getting 20 second. So, the Tp is 20 second and normally the power system time constant is very large compare to the time constant of governor as well as the turbine. So, this is a 20 second here we are getting and now we have determine the all the parameter if your values are given in the mega M value. Then you can directly use that is your Tp is nothing but, your M upon D and you can calculate and again unit must be here second. So, we can calculate accordingly and Kp unit now will be this much. Now, come to the another point that we combine completely means the transfer function of governor turbine as well as your power system and load.

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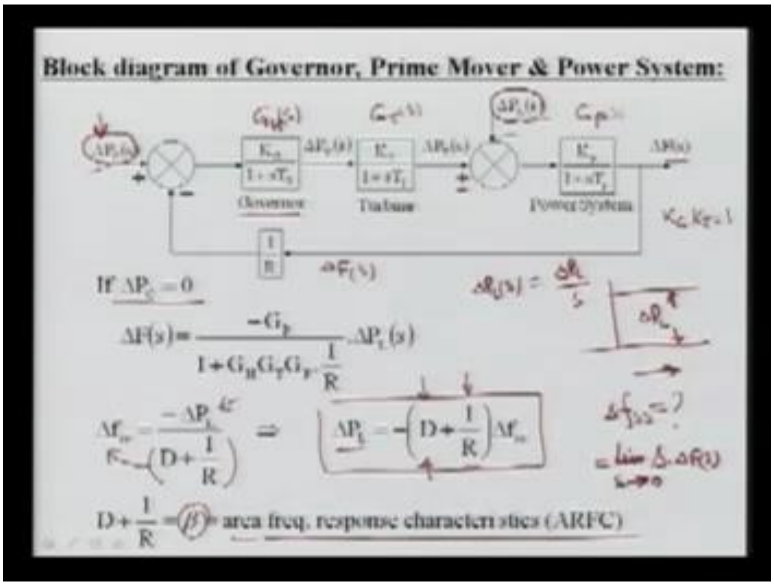

Then we can have this loop and you can see here what we model this governor if you remember we got the transfer function here. I can say it is nothing but, here I can represent this GH transfer function that is S normally represent, but, for here we are assuming since we are talking about the Laplace domain. So, S can be removed and we can simply write is the GH. Now, and you know already I said this is change in pc is the change in differentiating here we are getting from the frequency that change in frequency is coming here and we already model this governor. Now, turbine it is called your GT the transfer function here is T and I can write it S. So, the governor is changing your valve power and this power valve power is coming to turbine and this is giving your mechanical power after turbine power. And this is now related with the P L and the previous model I am using here for the power system and it is called your GP as I said in the previous case.

So, we have the 3 transfer functions and now here it is a change in the frequency we are writing. So, here we are writing change in frequency greater than omega, because this component was using change in frequency. So, we have changed and the factor that is 2 pi is included here instead of m so, here everything now in a frequency term. Now, to see this, what we can do? We can go for means for analysis that we can use this transfer function we can obtain what will be the steady state values when there will be some input change. And that input change may be that is I can talk input change may be your this or now input change is your P L means only the 2 inputs are there in the power system means if we want to change the output of generators you have to give raise or lower command or your load is changed means if you are putting more load or reducing the load then that is input and the frequency is accordingly shed.

So, the frequency is your output and that is your the disturbance or you can say change or inputs here that is your change in load or change in generation output. So, will see the response by changing your reference setting or by change in the load we can see how much they are going to be change and what will be the change in the frequency. In normal case what we are assuming that the change in the reference setting is 0 means there is no raise or lower command and the load is suddenly changed. Means we are not intensely changing we are just that is shed at that value means there is no change here in the raise and lower. And then load here the change in the electrical power is changed then what will be the change in the frequency during the steady state. If there is a sudden change if you are going for the step change here in your this is your time here it is change in the P L magnitude let us suppose. So, the transfer function of this change in P L in Laplace domain it is nothing but, change in its magnitude divided by S.

So, with this step change in the load I want to change I want to see what will be the frequency change and in steady state I can say what will be the frequency change during the steady state we want to determine. So, this is called the static performance static response and to see the dynamic response will see will use the transfer functions. And the time domain simulation at Ta time domain analysis and we will see how it is going to settle to it is a final value. We know it to obtain this it is nothing but, here as I said just we have to put use the limiting value theorem that is the final value theorem S tends to 0. Here we have to multiply S into change in fs then it will be giving your change in steady state frequency and this will see here. So, now for this if this is 0 now our transfer function here you can see this is your input this is your output. And now you can say this is your g and the remaining component here is I can say H means here what I want to tell that we can easily simplify this and to see this let us see here how we can get it. So, here already just we saw in the previous lectures that the multiplication of KG and KT is kept here unity KT is set to 1. So, we have only the gain KP here we can see. So, what I am going to do? I am going to derive and to see the, what will be the steady state performance of this loop.

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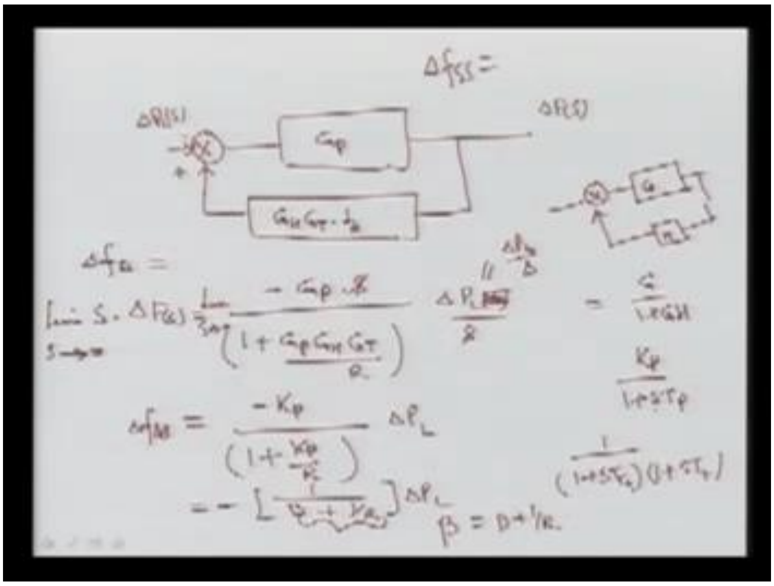

To see this here now what we are getting now I can just change the structure means the change in the structure means just I have a retain in the different form here. Now, I am writing this PLS just we got here now you can see here that is I am taking here PLS that is with the negative sign and. So, here it is your negative. Now, here it is your power system that is we are getting the Kp or you can say it is better I can write first GP then it will be better. So, I can write here GP and here we are getting change in the frequency S and now here it is your plus and we are getting several components. Now, you can see what are the components the components are your this component this component and this component is coming this the multiplication and this these are in series here.

So, this is multiplied by this this is 0. So, this is multiplied by this; this is multiplied and finally, it is plus sign we are getting. So, what I can do here? Here I can say it is your multiplication of this is your g GH GT and here 1 over R and that is coming here. So, now here from this as you know if you are having at like this here g and this is a closed loop system here it is your H is there. Then we can simply write it is the close loop transfer function will be nothing but, your g over 1 plus GH. Similarly, using this concept we can simply write here it will be your change in the frequency S domain will be nothing but, your minus GP over 1 plus here because minus is coming here the minus GH will be minus minus here. So, this is the plus this is the minus just we have taken. So, we can write here GP GH GT and it is divided by your R here we are getting and this is your change in pls.

Now, with this we want to get the final value that is here change in the frequency during the steady state means we have to go for multiplication of into S here. And then we have to put limit S tends to 0 this will give your steady state value means this will give your change in the frequency during the steady state condition by putting here the P L just we are going for the step response. So, this value will be replaced by your change in P L magnitude divided by your S. So, what we are going to do if we are multiplying here then you have multiplied by S this S will be coming here and now this will be replaced and we are going to get this S. So, this S will be cancelled and we have to put here limit S tends to 0 now you can see you have to put the actual value what you are going to get.

So, here I can say change in steady state frequency will be here you can go for first this one. So, here you can say what you are getting the GP GP is nothing but, Kp 1 plus stp. So, if you are putting this 0 you are getting here it is your Kp. So, we are getting here Kp with the negative sign divided by 1 of course,, it will be there now here what will are getting GH and GT just we are getting. You can remember here is 1 plus STG and here 1 plus ST TT we are getting this 1 and if you are putting S tends to 0 for this. So, this will be 0 this will be 0 means we are getting unity. Now, again the Kp term is there Kp this is 0 unity here. So, Kp so, we are getting here Kp divided by R and this value is multiplied by your change in P L magnitude.

So, here that change in the frequency again we can simplify this, what I am going to do? I am going to divide the Kp from both side. So, I can take minus sign outside. So, what we are getting this 1 over here 1 upon Kp is nothing but, it is your D and here it is 1 over R and then we are getting change in the load. The component which is we are getting here it is called b and will see this b is nothing but, your D plus 1 over R. Now, here just we can see here we are getting this value as I said. So, the change in the P L will be again this will be multiplied this will be multiplied with the change in the steady state frequency and we can get this ref reference. So, whenever there is a change in the loading here there will be change in the frequency and the negative sign shows that when the load is increased the frequency will fall when is load is reduced frequency will rise. So, negative will terms this one.

Now, we are having if you are suppose changing 1 megawatt will see 1 example. If you are changing 1 megawatt here then you can see this 1 megawatt change is will get the change in the steady state frequency, but, that a steady state change frequency will be multiplied by D and 1 over R means we are that load is met by 2 components. You can see this reg R is the governor characteristic and the D here is your load characteristic. So, whenever this there is a change suppose your load is increased if your load is increased the frequency will fall this will be cancelled out. So, that load increase will be met by your frequency dependent com component let us say the D that is load and this is a generator component. This D component is called basically the net load release means when frequency falls the loading on the system will be reduced.

So, when the frequency falls load will be less when frequency raise load will increase. So, this D relates the change in the frequency with the change in loading. So, some loading is released when the frequency falls and that is very very good to maintain the frequency. Suppose your megawatt loading is 10 megawatt and there is some drop in the frequency of 49 means 1 1 Hertz. Then there will be some release of energy means now load will be reduced that is and again the remaining that will be changed by the generator. So, this D 1 D plus 1 by R is equal to beta and this is called the area frequency response characteristic this is called your ARFC and this beta is very very useful and will see later.

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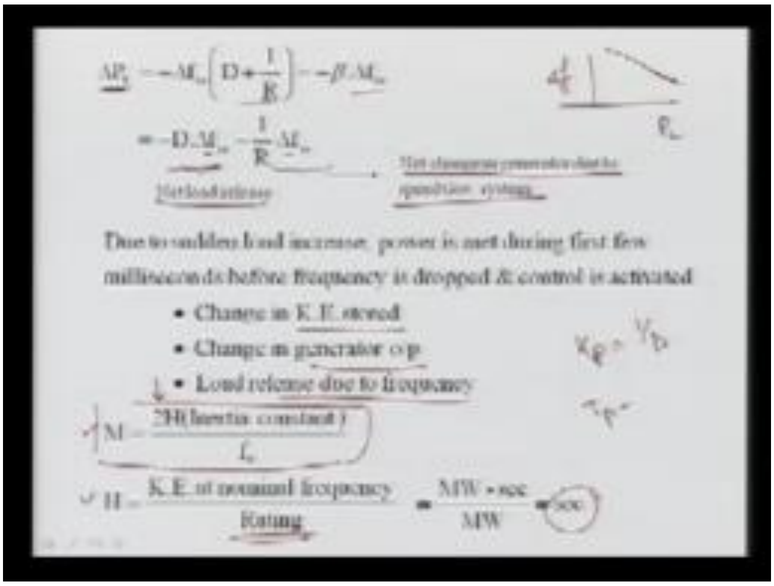

So, now here again we model this steady state. So, I can say the change in here the loading of the system will be equal to your change in the frequency with the minus here that component beta and we can write in this term. So, again I want to explain here now this change in loading is with the 2 component that is a D plus change in the steady state change in the frequency. And another component here 1 over R multiplied by change in the frequency this component is called your net load release and this component is called net change in the generation due to the speed governing system. Means when frequency falls in the characteristic of the speed governing system we saw the when frequency falls the governing system will try to increase the input. So, that frequency can be increased and that can be maintained. So, this is the due to the governor characteristic and the R is the characteristic that we have explained here this is your loading and this is your change in the frequency.

So, the characteristic here the drooping characteristic so, due to sudden load increase power is met during first few milli second before the frequency is dropped and the control is activated. So, the control activated here the change in kinetic energy stored the change in the generation output and the load release due to the frequency component. Because whenever there is a sudden load increase the power is MT during the few cycles before the frequency is draft means it will try to meet. And these are the things also I have related this M and H already I have explained this H is related that is inertia constant here this KE at the nominal frequency means kinetic energy upon the rating of the machine and here is a unit is your second. And then we can also relate here then we have used either you are using H to H upon f or you are using M you have to calculate your Kp and the Tp accordingly. Your Kp is independent of this M always you must remember.

Because here I said this Kp is nothing but, it is 1 over the D that is coming to the power system that is a gain that is a load (). And your Tp no doubt that is dependent upon D as well as this inertia of the system and if you remember here I said it is M upon D or you can write in terms of H here I can write twice H upon f into D. So, these are the things that is we have to use and we have to solve the problem. Let us see that the previous example means this example I discuss to calculate your Dp Kp D and the Tp. And we obtain this D in the per unit here thus I got this value AD the Kp I got in the per unit this and the Tp. I calculated that 1 T second with this I want to calculate what will be the change in the steady state frequency? If there is a sudden change of let us suppose 20 percent of the load means that is a drop of the let us suppose the 20 percent here in this or we can go for the 20 megawatt load and we can calculate what will be the change in the frequency.

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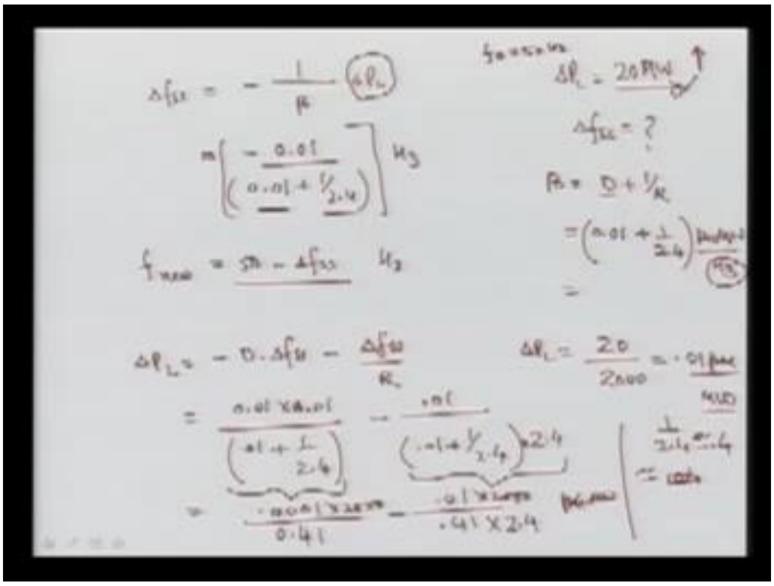

Now, here just I want to say that is here if you are change in the loading let us suppose this is the 20 megawatt means 20 megawatt is changed it can be also given let us suppose it is given the 10 percent is increased of the base loading. So, the loading was 1 thousand and accordingly you have to go for that. So, here we are considering if the 20 megawatt is changed what will be the steady state frequency just we have to calculate here there is fss and we want to calculate this value. To calculate this what as I define this here change in fs here it is nothing but, your minus 1 over your beta that is change in the P L you can see above this equation. Here what is this? This your, this value is divided by this and we can get this D plus 1 upon R is your beta and we can simply find this means your beta is nothing but, it is D plus 1 over R.

Now, this value beta here dv calculated D it is our in that case it was if you remember 0 1 that is your per this value was per unit megawatt per hertz. Now, 1 over R that is already given it is a 2.4 hertz per unit megawatt. So, it is 1 over 2.4. So, we are getting here this beta value is per unit megawatt per hertz. Now, you can calculate this value and you will find this is a some constant that is you are getting now. Here you can say this is the beta it is in per unit and this P L which is given to you it is in megawatt. So, you have to convert in per unit quantity. So, our this P L will be now this P L will be your 20 megawatt divided by the base quantity and this base was the rated capacity and it was your 20 2000 megawatt.

So, we are going to get here 0.01 per unit mega watt. So, we have to use in per unit megawatt always because here the value is same. So, that is here multi cancelled out. So, we can get actual value now we will get in the hertz. So, what we can do? We can now if this value is increased if this value is increased let us suppose that 20 mega watt is increased. So, I can say this is the positive value increase if it is decreased then it will be negative value. So, this is your positive. So, I can say minus point 0 1 this value minus it is coming here divided by this value and that value is your nothing but, I can say how much that is we are getting point 0 1 plus 1 over 2.4 and here this value we are going to get in Hertz.

So, this quantity is showing the negative means there is a fall from the 50 hertz. So, the system frequency change will be this much magnitude and your base value will be we calculated all things though rated was your 50 hertz cycle. So, your new frequency that f nu will be your 50 minus, this value that is your change in fs and then this will be your in Hertz. So, whenever you are increasing the load your system frequency will fall and we can calculate with this one. Now, I want to see that how much load in that this 20 megawatt load who is contributing how much means who is con means who is means what this who means this D this load component that in that load release. And another is due to the governor action and then who is going to make this how much quantity of the 20 megawatt?

So, what we can do? We can again get as I said this change in P L it is nothing but, your minus D into change in fss here minus that I can say change in fs divided by R. So, this steady state value here if we will put here we will get the change in the how much we are going to get. Now, we can put we can put this value here and we can calculate. So, this D and this is minus it will be plus. So, the D value I got point 0 1 multiplied by 0 point 0 1 here and this value we are getting point 0 1 plus 1 over 2.4 here and another value just we are going to put R now this R is going to be 2.4 just we had used. So, here it is your point 0 1 divided by point 0 1 one over 2.4 and into R is your nothing but, 2.4 here multiplied.

So, this value is given by your governing action this value is your net load release and now you can see this quantity is very very small why because if you are going to divide you can see here 1 upon 2.4 is approximately I can say 2 0.5 here. So, how much this value 4 means we are going to get 0.04 approximately this value. So, what is happening 0.5 sorry it is your value will be here approximately 0.4. So, if you are going to simplify let us take 0.4 means because this value or you can change the value R 2 0.5 it is very easily we can calculate. So, here thus we are going to get point 0 0 the four zeros 1 divided by here 0 0.41 and this value we are going to get here 0.01 here this value is 0.41 multiplied by 2.4.

Now, these quantities are in per unit. So, we have to multiplied by our base rating. So, what will happen? We can multiplied by here this it is your per unit megawatt. Now, we can multiply its rating that is 2000. So, if you are multiplying here the 2000 let us multiply 2000 here and 2000 here now what we will get? We will get the megawatt only and now you can see how much we are meeting. So, this value again I can now replace all these things here and we will get this value as here you can see this now this 30.

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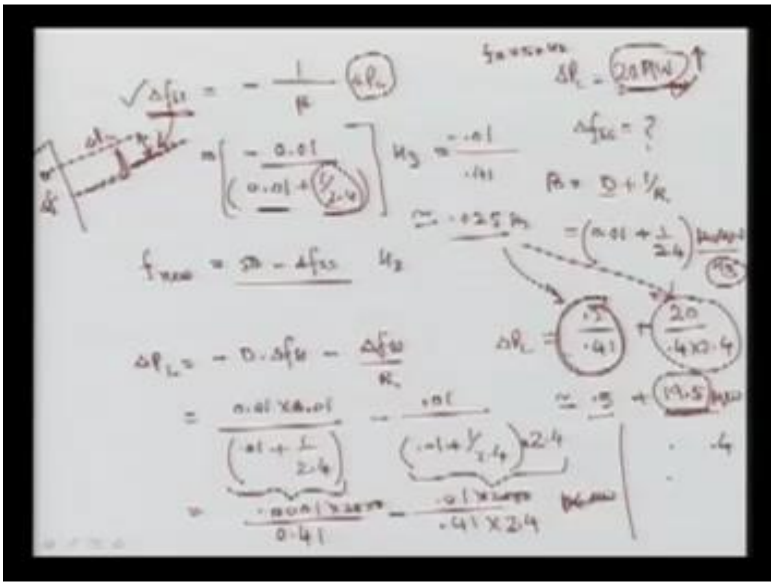

So, we are getting point 2 over 0.41 megawatt for 1 that is a P L for this case and here the remaining you can see here how much we are going to get it is your 20, 20 divided by 0.4 1 multiplied by 2.4. So, you can see this value here is very very less means this value is approximately here you can say this is approximately I can say it is nothing but, your 0.5 megawatt and remaining here this value this is positive plus here we can say nineteen 0.5 megawatt comes from here. So, now we can say the net load release is very very small this component this megawatt we are talking. So, the lines here is coming from the governor action. So, it is taking care of that 1 if your D is again this D is very very small means there is no change then only it is met by you're the governing action.

So, this is you can say now steady state frequency just we have calculated and now here we can see what will be the steady state frequency. By assuming this is a this component is 0.4 I can say here 0.01 with a negative sign minus 41. So, here approximately this again we can go for it is the value here that is 0.025 hertz that is we are going to change. So, frequency change is no doubt is very small, but, that is also we can say the load that is met by these 2 components. So, this is your steady state response and thus static response of this ALFC that is a area lo automatic load frequency control loop else the important information about the frequency accuracy means how much that is you are getting the steady state. How the dynamic response of the loop will inform about the tracking ability and the stability of the loop.

Here one thing we can also see when the load is changed governor is acting your net load release is there, but, is still what is happening you can see your frequency error is still persisting. Means governor is supplying no doubt the load is supplied by governor net load () and thus what about the 20 megawatt has increased. It has been supplied, but, the steady state frequency is still your dropped or reduced are a different value. So, for example, let us suppose if you are here what is happening your frequency is now your change in the frequency is 0. Your load is increased here your change in the loading what happens your frequency at the steady state?

It is going to be this value means there is some reduction in the change in frequency means fall. In other side if you are is a release then frequency will be going some steady value here. So, what is happening the dynamic nature in the during some time constant we are unable to see and by that we will see the dynamic performance or dynamic response, but, the steady state error here that is ex existing and here this one. So, it is not sufficient and then for that we need some controller that, because if the load is changed we must not only the supply this load, but, we must try to bring back se frequency to its normal value.

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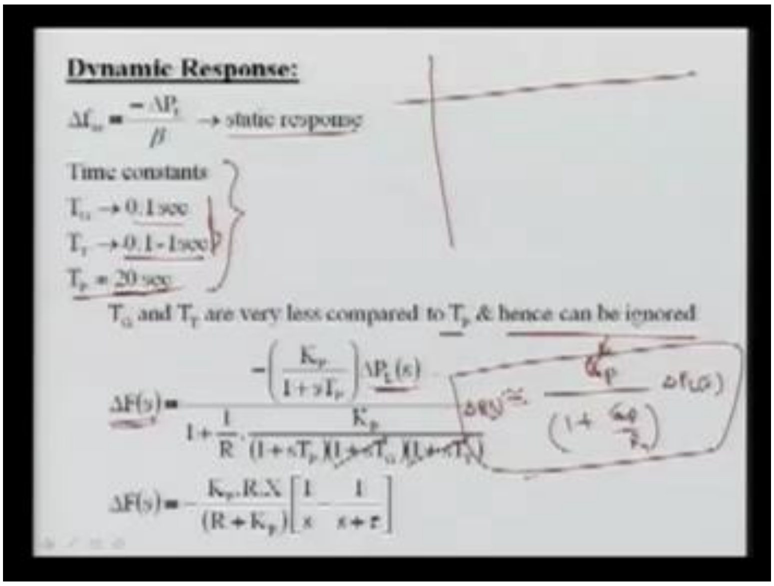

So, let us see first the dynamic response here the dynamic response already we calculated this value from the static response. The various time constant although here it is to explain here in this class it is not possible that we can go for the all this time domain analysis of this, because is a very complex system it is easy to understand by making some simplification some assumptions. You can say the TG that governing time constant as I said it is normally near about point 1 second your this turbine time constant from point 1 to 1 second, but, your, the Tp is almost near to the 20 seconds which is very high. So, what we have to do? This time constant are very small and suddenly there will be transient and they will be settled out means they will take action. But the Tp is 20 second. So, we can ignore here the transfer functions corresponding to those and only we can take this and then we can analyze that dynamic response of the system. So, the TG and TT are very less compare to Tp hence can be ignored. So, we can ignore the transfer functions here corresponding to this you can see here now I derive this 1 here it is your GP here your other things ad here change in this function we can write in this fashion.

So, we want to ignore due to this T TG and tt means here we can ignore this transfer function and this one. So, what we are getting? You can see here we can simply here we can write we are getting this minus you can say this is f divided WI we can divide it simply and then we can simplify here. And what we are getting that we can see that here we are getting this GP over 1 plus GP by R and then it is multiplied by your PL. So, we can simplify from here and we can get very easily the dynamic response of the system and this is your S here now I can say approximately this is change in your fs. So, now only we have to consider that time constant of GP means we have considered only the transfer function. Because here in this time domain if you are going to see we want to see the initially there will be effect of this and then time constant is as you know is very less. So, they will be settled out and finally, this will be taking care of the change then we can go for again we can just replace this values Kp Ad other things. Let us see how we are going to simplify that is a GP means this function we can simplify and let us see this phase.

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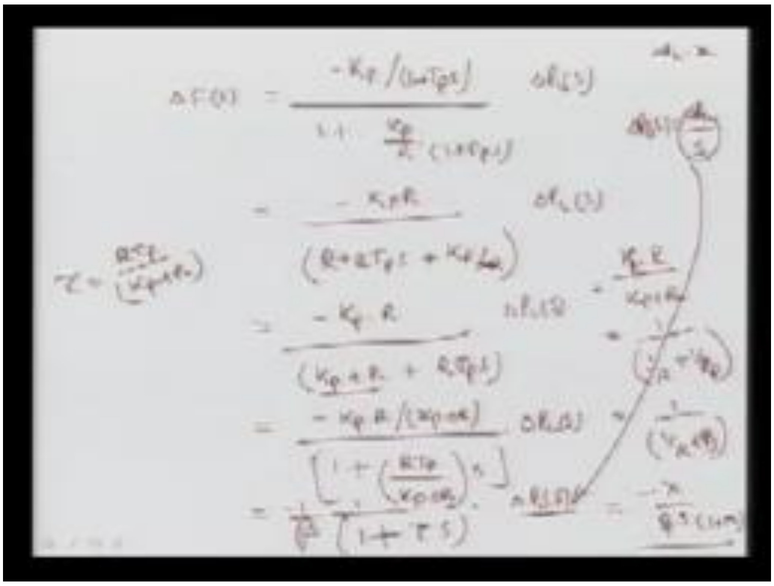

So, what we are getting? We are getting the change in your system frequency that is your now I have to write this Kp over 1 plus Tp s divided by 1 plus Kp into R and here into 1 plus Tp s. And we have this change in PLS we want to you can see here what I did I just I calculated minus time here and we are sorry here the minus was appearing. And then we can see we are just simplifying here and we have to get in this fashion. Let us see what we are going to get. So, now, what I am going to simplify this in the simplification now you can get the Tp here and then we can simplify like this. I can write this is your Kp now this Kp here I can write 1 plus Tp s plus your Kp over R this value and this will be cancelled out and then we are getting PLS. So, now here you can see what we are getting this can be again we just want to go for r. So, I can write here R here I can write your R and this R will be replaced and here we can get R.

So, we are getting minus Kp into R here Kp plus R plus your R Tp S into your change in PLS. So, this is your constant and then we want to simplify it means we want to simplify in other fashion. We want to go for here I can say minus Kp into R divided by Kp plus R here this term divided by 1 plus here I want to write R into Tp here Kp plus R and then I can say S and we are getting this term function. So, what here I can say this is another tau this is some constant you can say what is this value of this the value of Kp into R over Kp plus R. This is nothing but, you can divide this you are getting 1 over this Kp sorry if you are dividing. So, you are getting 1 over R here and here plus 1 over Kp this 1 over Kp is nothing but, I can say 1 over R plus D and this is nothing but, your beta. So, here we are getting the beta you can see in this previous equation here we are getting Kp upon R that is the beta and then we will see how much we are going to get. So, here this is your beta.

So, I can write here 1 over beta again minus and again I can say 1 over 1 plus this time constant. This time constant again we can simplify and we can say it is another constant. Let us suppose tau here S I am writing this is a time constant and this time constant I can say tau is equal to your R Tp over Kp plus R. So, and here into change in again I am missing this term every time this will be PLS. So, now if going to put we want to go for the step response. So, this value change in PLS can be replaced by change in P L that is magnitude or you can say x divided by S. This value let us suppose this P L is equal to some x value some constant value or P L. You can replace no problem this value if you are putting here and then you have to go for and you have to solve this. So, you are going to get here now I can simply say it is we are getting minus your x upon beta S here 1 plus tau S and then we have to solve this.

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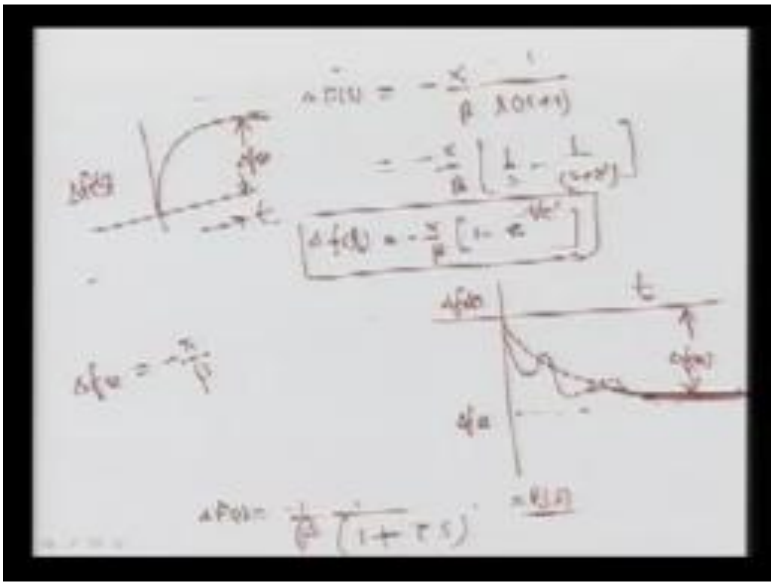

Here what I calculated means change in your frequency in the Laplace domain I can write minus x upon beta here and then it was your S s plus here tau S into 1 and it was your unity. So, we can write here the simply minus x upon beta I can write 1 over S minus 1 over your I can simply write S plus tau another tau prime here and then we can solve this. So, to go for this we can say this is your change in frequency in the time domain means we can take the Laplace inverse. Then we can get here minus x upon beta here I can say 1 minus e power minus here T tau prime that we can get the T upon tau prime here it will be coming. So, this is your first order equation and the time domain here because we had only 1 transfer function and that is a 1 order transfer function. So, this is your time domain response of your this loop. So, we can draw here the figure draw this time domain here let us suppose your time is there and your system frequency here that is a change in the frequency here steady state your time domain here.

So, what will happen if there is a some increase in the loading when you are going to increase what will happen? You are the frequency will fall. And the finally, here this will be going for this and this value is your nothing but, change in your fss that we calculated. And this value was nothing but, this value here is your nothing but, this change in the frequency that is change in f steady state it was minus your x upon beta. So, you can see here the frequency here is reduced and settled and saturated that is a steady state. If you are going to include as in the previous assumptions thus we made that TG and TT are very small. And we ignore if we are going to include and we are solving with the computers what will happen here we will find some transients here and then finally, it will be settled down.

So, few transients will be coming in the beginning and what finally, here we will get this say and that is here you can say decaying. So, always we are getting 1 steady state error and that steady state error here is that is fss which is not required hence we have to use another secondary controller. So, this loop is called your primary control loop where the steady state error exist. So, we have to design some controller and then that we will see in the next lecture and for that we have to see that error must be reduced our prime objective that is to go back to its normal frequency. So, in this lecture what now I can recap in this lecture? We just modeled this load model. Then we analyze the steady state response and the dynamic response for that primary automatic load frequency control

And we found that there are some error exist means error here is not only in the negative direction frequency fall, but, it is also in the positive frequency change means when the load is released. Then we will find the our change here will be slightly here like this and it is your change in the raise in the frequency when the load is reduced that is your time domain. Here your change in this ft and this magnitude will be your change in fss if load is reduced here load was increased that is x if is positive. Then we will get this otherwise will go in the different direction here the negative sign will become positive and then we will go here. So, in the next lecture, we will see how the secondary ALFC loop will be calculated.

Thank you.