Power System Dynamics, Control and Monitoring
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Lecture - 38
Automatic generation control conventional scenario (Contd.)

Ok. So, so all these things we have derived right. Whatever has been given here, whatever has been given here, so all these things here derivation were not given. So, I thought I should derive it, only thing is that it is on the your writing actually that your that my your this page is little bit thicker, but I hope you understood, you can easily do it of your own right.

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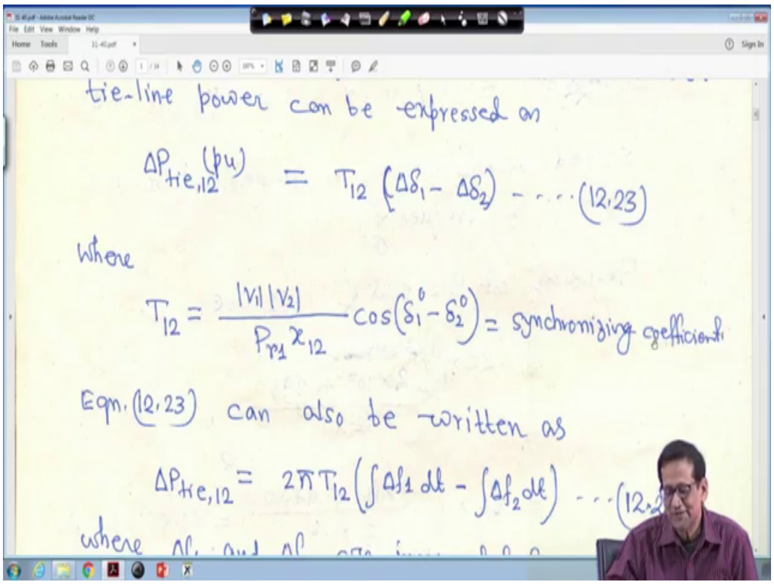

So, this is I told you synchronous synchronizing coefficient.

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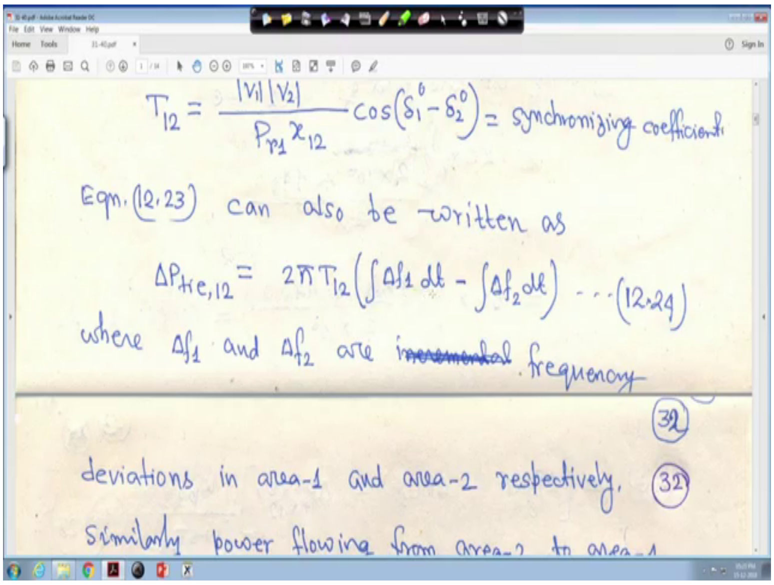

And therefore, delta p tie you want to also we derive 2 pi T 12 of this one so right.

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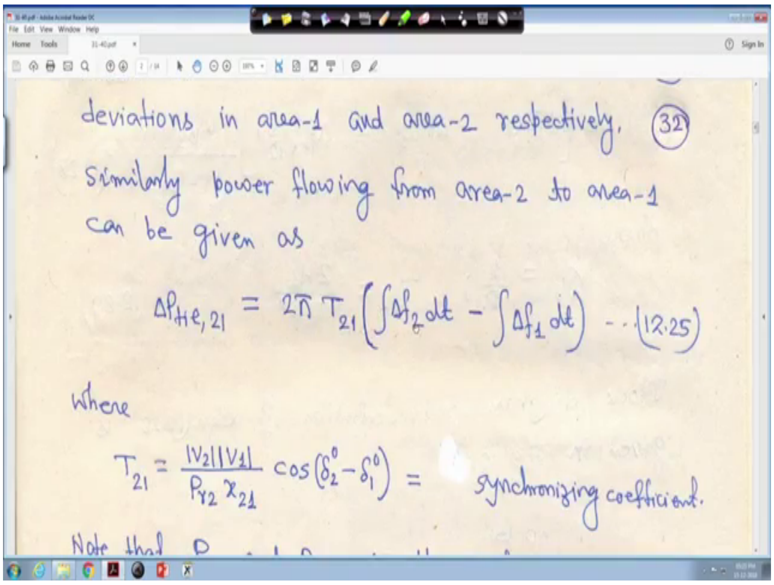

And similarly delta p tie 21.

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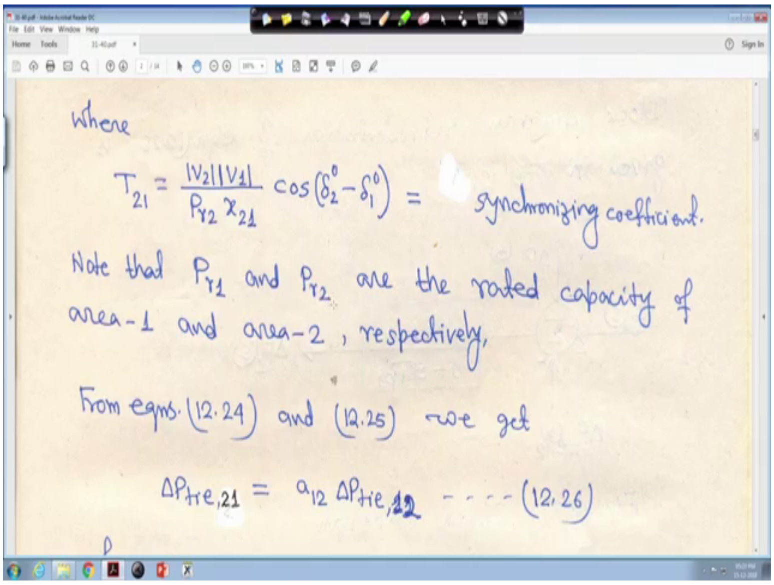

And finally, your T 21 also we have derived when we have given that right. Now, P r1 and P r2 I told you the area capacity ratio.

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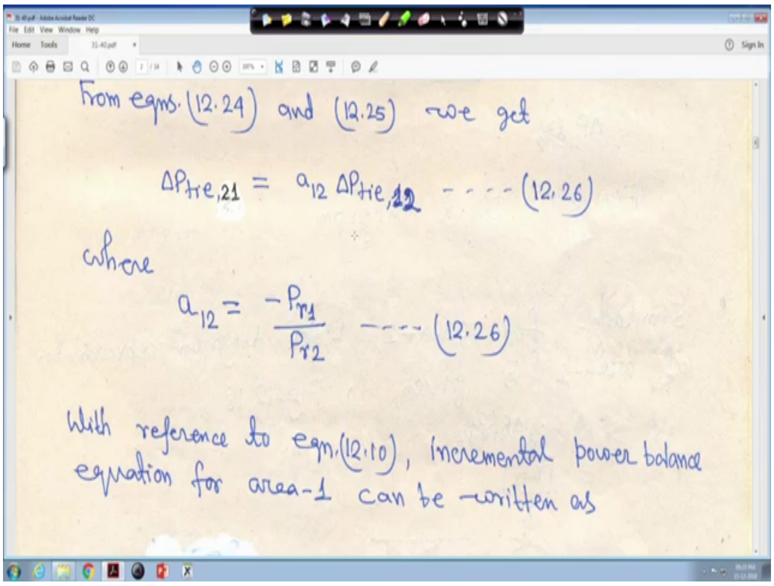

And the division also delta p tie 2 and I told you is equal to a 12 delta p tie 12, this already we saw. And a 12 equal area capacity ratio that is minus P r 1 upon P r 2, we take the minus sign. Otherwise, if you take only a 12 is equal to P r P r1 upon P r 2, then this will be a minus sign that is all nothing else right.

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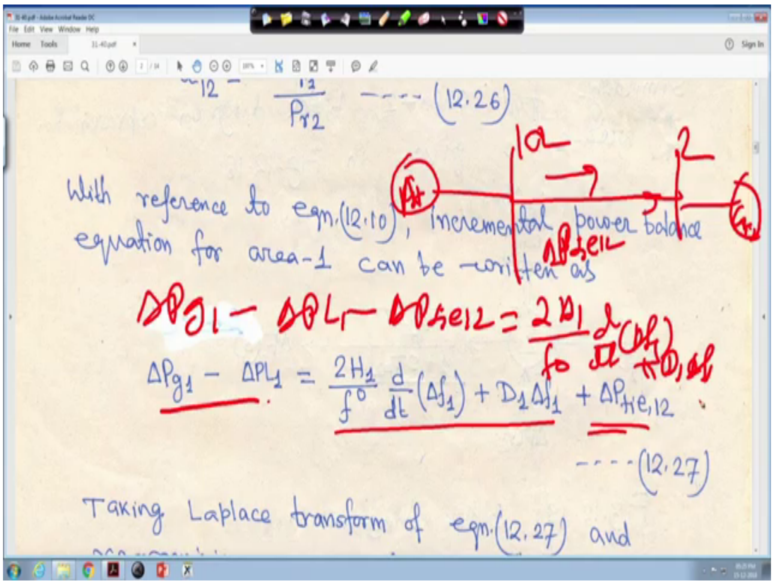

So, with reference to equation 10, now if you look into this earlier also we have seen for isolated system, just hold on for isolated system, for isolated system, what we have seen that your it was only delta P g minus delta PL1 is equal to only these much, because this was not there for isolated system, because there was no tie branch right there was no tie branch. Now, that your what you call you have the tie branch.

So, for example, this is your generator, this is your generator right. And this is your tie line that is 1 2, this is 1, and this is another this is generator 1, generator 2 or area another area 1, and area 2 right, and this is 2. And power is flowing here that is your what you call that your P tie 12 right delta P tie 12 suppose change right, and some load is also there.

So, generation has to match the load, and this tie line power. So, in general equation should be that area one say delta P g1 minus delta P L1 minus delta P tie 12 is equal to 2 H 1 f 0, then d d t of delta f 1 plus D 1 delta f 1 right. So, because generation has to match this your what you call that load plus whatever going to the load, and what was power flowing from 1 to 2 right.

So, in that case and loss is neglected, because the resistance is not considered. So, same equation that means, delta P g minus delta P L 1 is equality, this is already you have seen that because of that transient imbalance right plus this minus delta p tie 12 brought to the right hand side that is all right.

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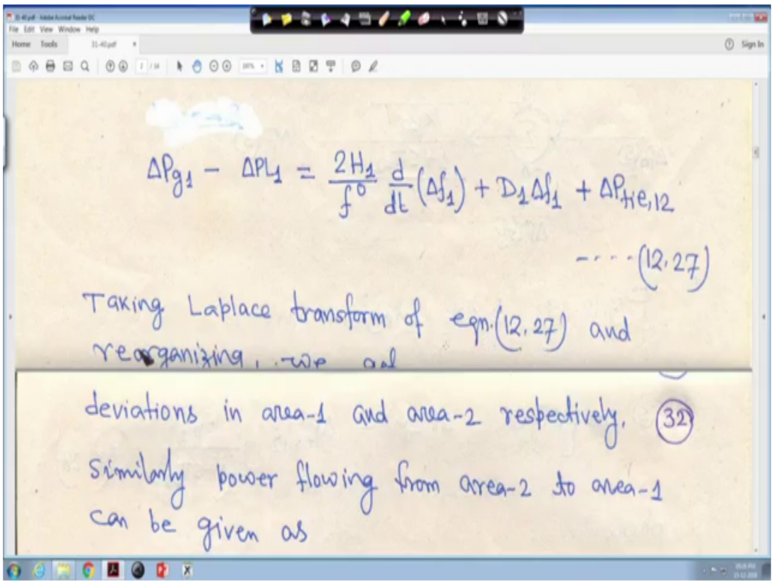

Now, with this if you take the Laplace transform and simplify right, so you can write your what you call this is one equation. Now, Laplace transform equation-27. So, we know that delta P tie 12, and delta P tie 21 both are known right. So, and this is just one thing this page that page 32 actually repeated once right, this is 32, and this is also 32 right. So, this page again do not read this page you skip right, because already we have discussed this page you just skip this page-32, because twice it has been scanned twice right. So, this one you skip, and then will go to the page-33.

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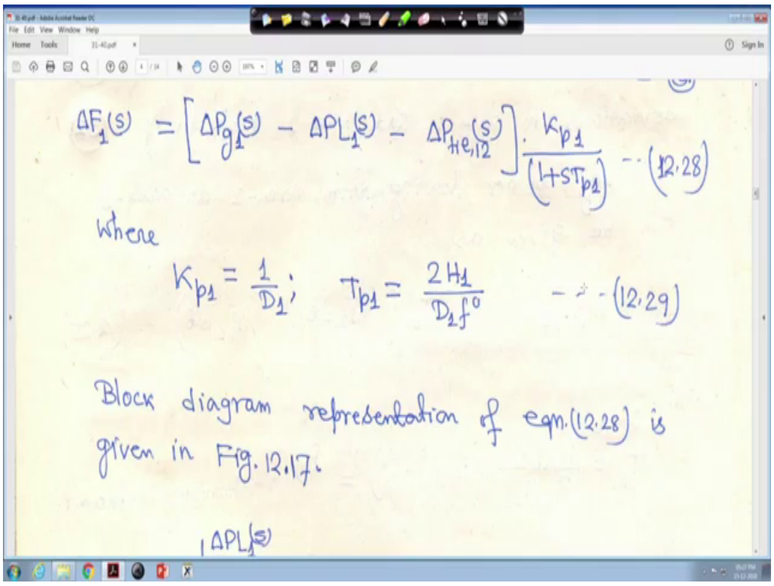

So, now if you take the Laplace transform of that, so delta F 1 s will be delta P g1 s again and again I will not put s, because it is understandable minus delta P L 1 s minus delta P tie 12 s into K p 1 upon 1 plus S T 1. The way we the way we simply it for isolated system here also you do that right. Whereas for area one K p 1 will be 1 upon D 1, and T p 1 will be 2 H 1 upon D 1 f 0 right. So, this is equation 28, and this is equation 29.

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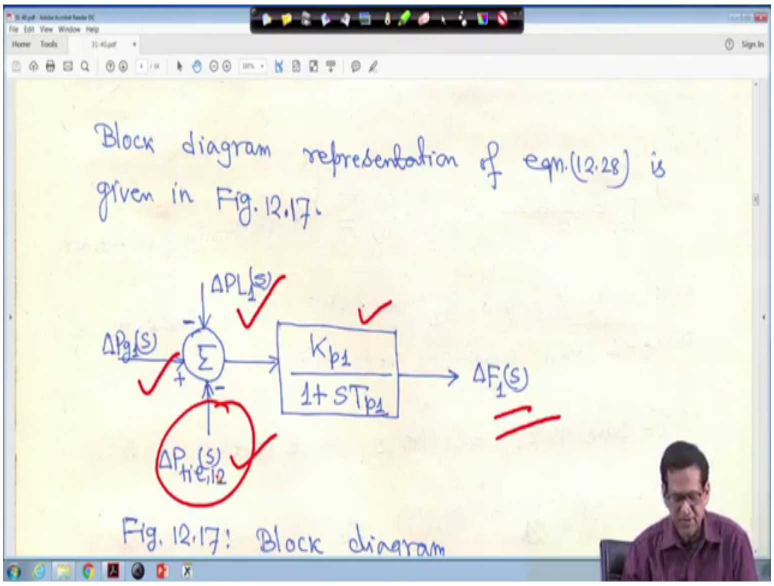

So, block diagram representation of equation 28, then equation you are what you call 28 this can be given as so it was actually it was delta F 1 s is equal to delta P g1 s minus delta P tie 12 s minus delta P L1 s into K p 1 upon 1 plus S T p1. So, this is delta P g1 s, this is delta P L this is a plus sign minus and this is your delta P tie 1 to s into this into K p 1 upon 1 plus ST p1 is equal to delta F 1 s. So, this is the block diagram to representation. So, for isolated system this was not there, but now it is interconnected to another area, so that is why this tie power flow also you have to we have to account it right we have to put it.

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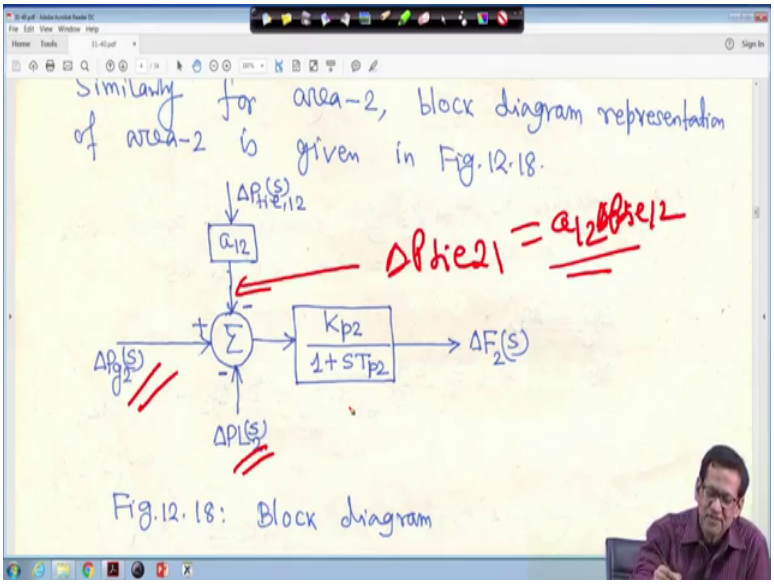

So, similarly for area-2 similarly for area-2 you can make it, this is delta P g2, this is delta minus delta P L2 s, and this is actually your delta P tie 21 right that is actually nothing but a 12 delta P tie 12 that is we have put s because of to take putting in problem Laplace operator right, but this is actually delta P tie 1 is equal to a 12 into delta P tie 12 s that is why it is written a 12 this one right into K p 2 upon 1 plus S T p 2. So, this is that block diagram representation of the here what you call of the power system side.

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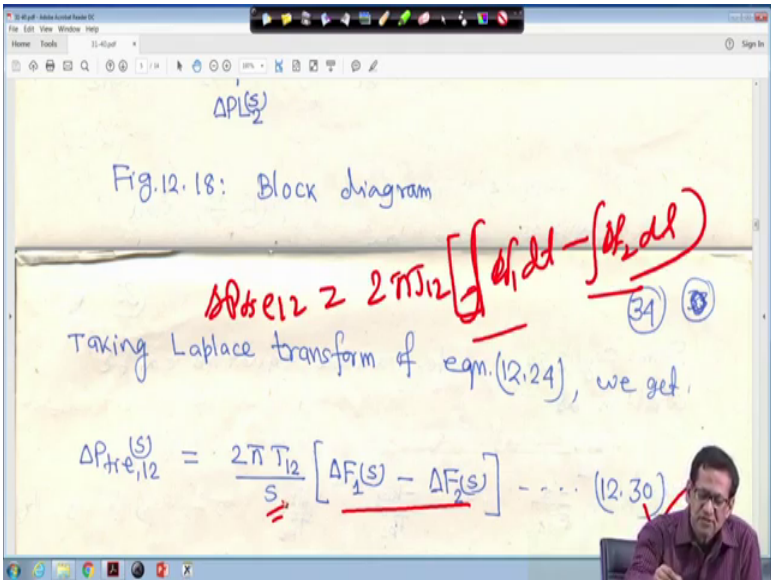

Now, if it is so, then if you make the complete block diagram for two areas system, where other point is that tie power. So, we know that your we know that your delta P tie 12 that we have seen is equal to 2 pie T 12, then integral of integral of del f 1 d t minus integral of del f 2 d t right.

So, if you take the Laplace transform both side, so because of integration this thing, so it will be 1 upon s, so 2 pie 2 12 upon s into delta F 1 s minus delta F 2 s, so this is equation 30. So, tie line power flow small factor machine tie line power model that also your what you call can be obtained using Laplace transform right.

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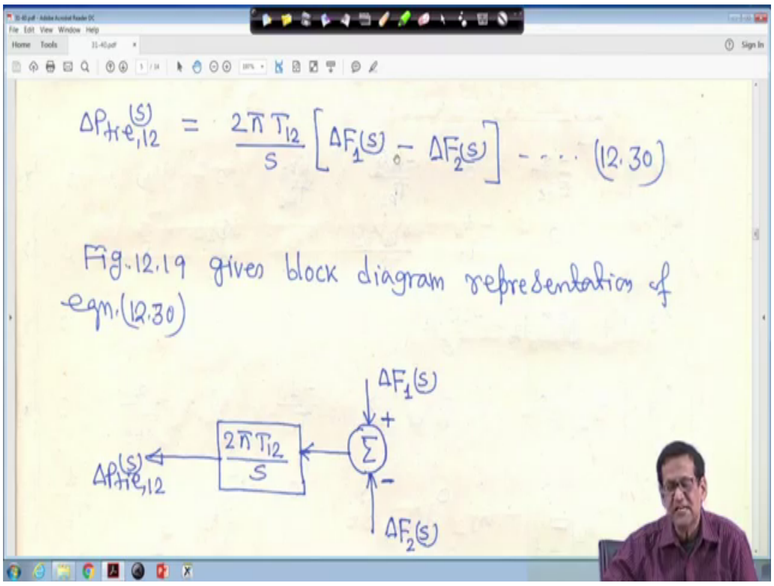

So, therefore this is your this is your from the for this equation 30, this is the block diagram that delta P tie 12 s is equal to 2 pi T 12 upon s into delta F 1 s minus delta F 2 s, I mean this equation 30 right. Therefore, the total complete block diagram of two area system it is like this let me let me just reduce it is this thing just hold on.

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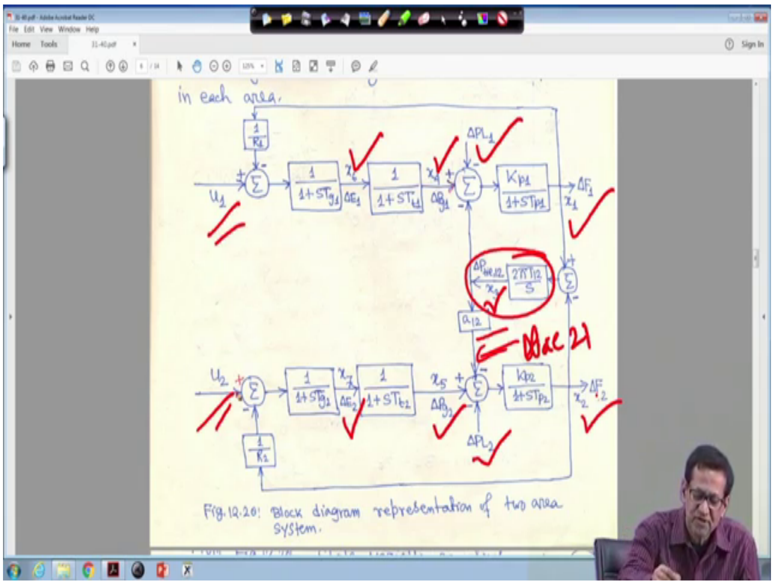

So, this is actually your what you call that block diagram for two area interconnected power system right. So, in this case if you look there are seven state variables, this is say x 1 that is delta F 1, x 2 I have marked delta F 2, and this is X 3 that is your delta P tie 12 right. And this is x 4 is delta P g1, x 5 is delta P g2, x 6 is delta E 1, x 7 is delta E 2 right. And this is your u 1 and u 2, this is coming from supplementary controller that will be seen later.

And this side minus 1 upon delta F 1, and this side minus 1 upon R 2 delta F 2, and this is the load disturbance delta P L1 all part by part we have seen, now we have combined together right. And this is delta P L 2, and this is that your a 1 2 that is this is actually delta P tie 21 right. And this is that this portion is the your what you call tie line modeling right. So, and this is that two area system, but without and u 1, u 2 is coming from some later will see right. So, this is two area your what you call block diagram model right, and you have seven state variables.

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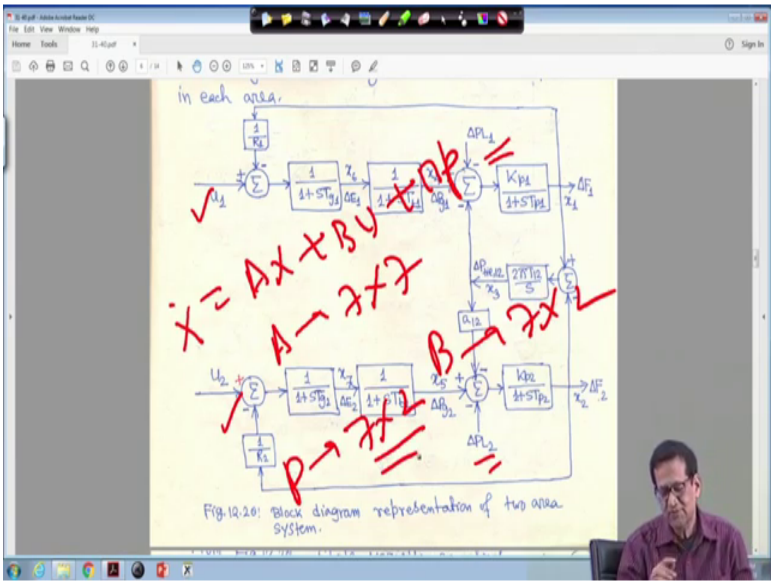

So, when you write the equation X dot is equal to A X plus B U plus gamma P right. So, you have seven state variable. So, A matrix will be 7 into 7 matrix right. And B will be there are B U, so two inputs are there for B. So, B will be your 7 into 2 right. So, and P is the disturbance matrix. So, this is P L 1 and this is P l 2, so two disturbance is there. So, P actually will be your 7 into 2 matrix right. So, this will be and you can easily write now all the state variable equation X 1 dot, X 2 dot all these things.

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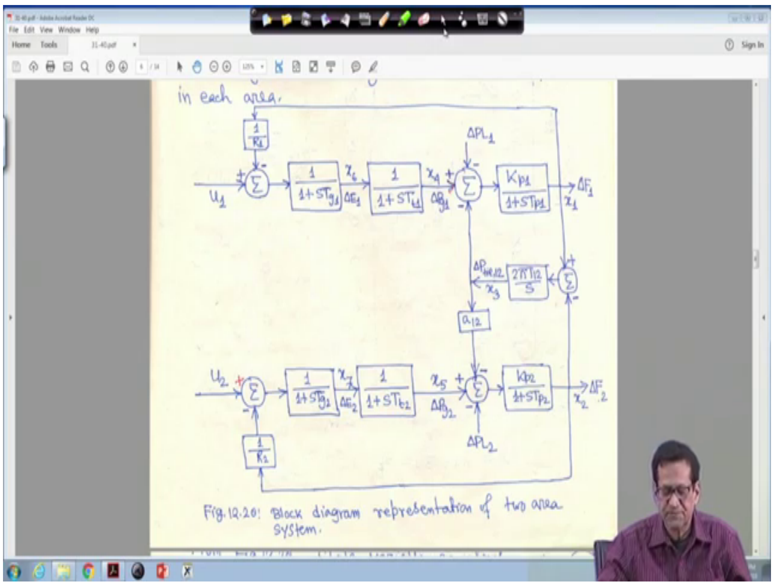

So, I am giving you in the complete matrix form, but you can easily write x 1 dot, x 2 dot, x 3 dot like this right.

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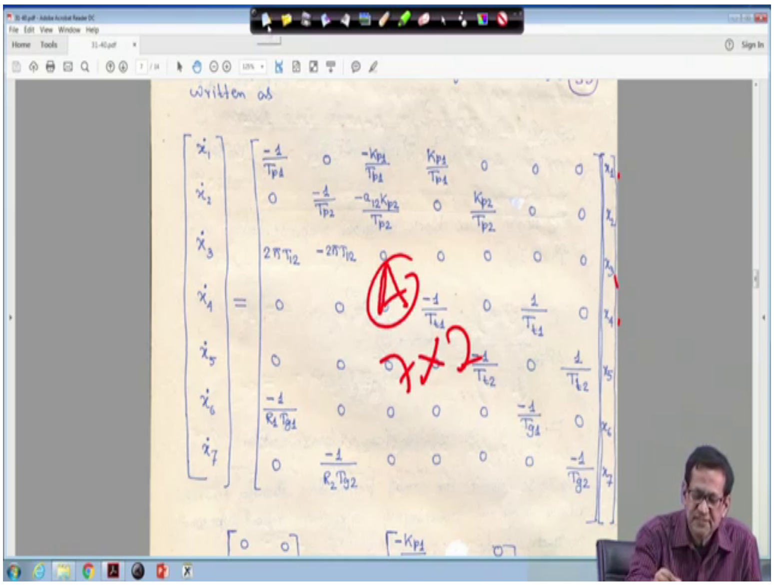

So, so if you write this, so this is actually your what you call that is your x 1 dot, x 2 dot, x 3 dot, x 4 dot, x 5 dot x dot x 6 dot, and x 7 dot right. And x dot is equal to A, this is your A matrix. This is 7 into 7, this is your A matrix it is 7 into 7, this is x 1, x 2, x 3, x 4, x 5, x 7.

So, this is A x x dot is equal to x, B U plus gamma P I will show you. So, when you write that this equation, you will find that for x 3 that diagonal element is 0, but all diagonal elements are negative right. And similarly, the sorry this you can easily make it of your own I am not making it here, the otherwise it will consume lot of time right.

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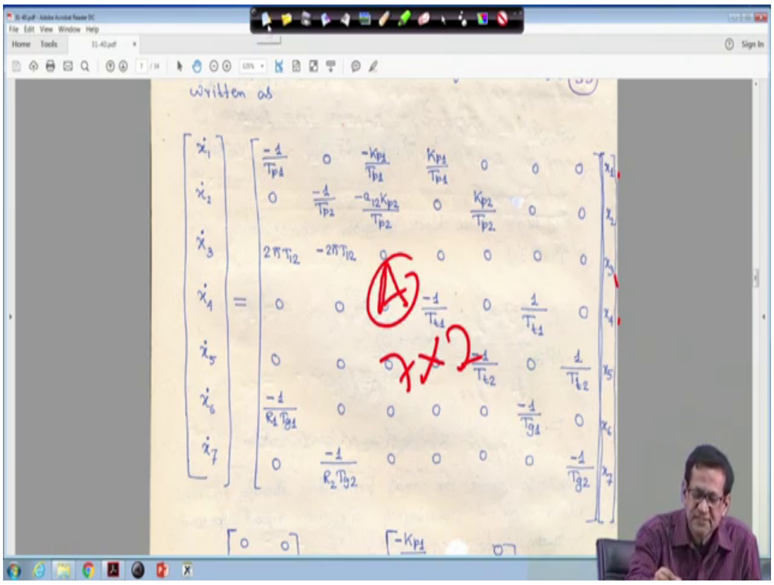

And next is your B U. So, this is my B matrix, this is our B matrix,this is your B matrix this is 7 into 2 right, and this is your gamma matrix right. So, gamma P, so this is gamma matrix right.

So, this is 7 into 2 not P previously continuously [Laughter] recording. So, I thought I made P 7 into 2; it is gamma matrix, because equation is X dot is equal to A X plus B U plus gamma P right. So, it is a gamma matrix. And p is at nothing but p L1, p L2 right. So, this is 7 into 2 so this is your equation right.

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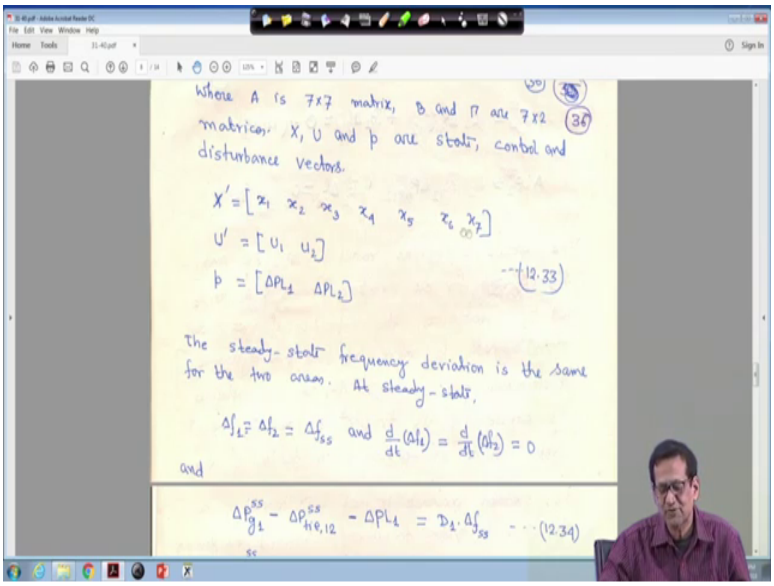

Now, where A is 7 into 7 matrix, B and gamma are 7 into 2 matrices X, U, p are state control and disturbance vectors. So, this is transpose X transpose is equal to x 1 to x 7 it is given. U transpose u 1, u 2 and p the disturbance vector that is delta P L 1 delta, P 2 right. Now, the steady state frequency deviation is the same for that two areas right, when it reaches to a steady state. So, as steady state delta f 1 is equal to delta f 2 is equal to delta f s s right. And d d t of delta f 1 is equal to d d t of delta f 2 right is equal to 0, because a steady state all the derivative will be 0 right.

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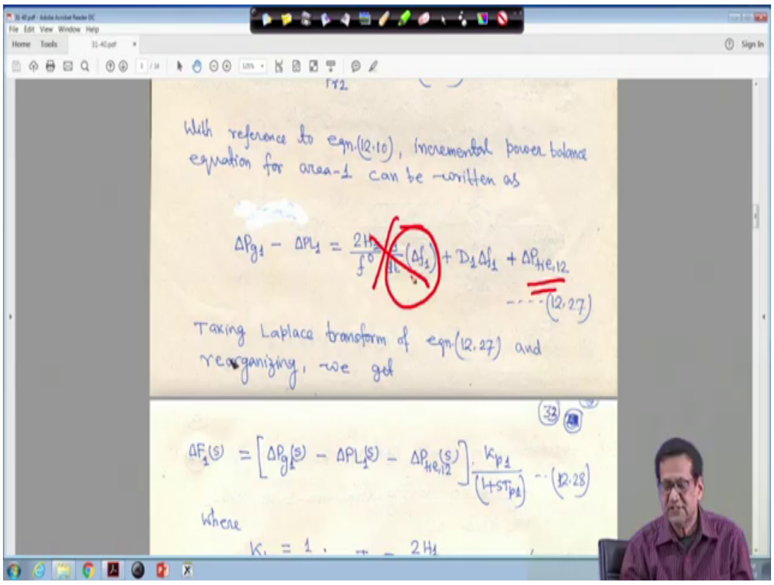

So, if we come back to this equation right If we come back to this equation this equation if you come back, then you will find that at steady state at this term will be 0 right. For area-1 this term will be 0, so delta P g1 minus delta P L1, 2 H 1 upon f 0 that means this term zero means, this term will not be there. But, other things will be there delta P g1 steady state minus delta P L1 is equal to D 1 delta f 1 steady state, and delta P tie 1 2, but this term will be 0. Similarly, for area-2 also d d t of delta f 2 is equal to 0.

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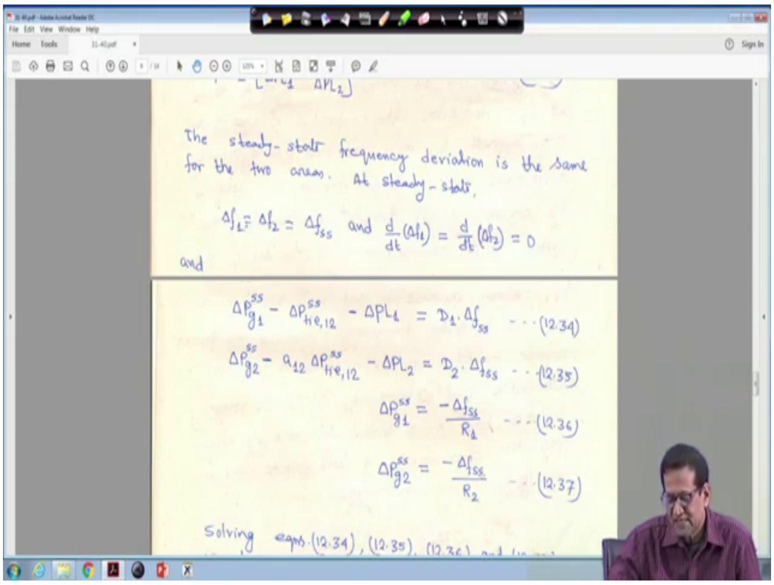

If it is so, then this equation we can write delta P g1 steady state minus delta P tie 12 steady state minus delta p L1 is equal to D 1 into delta f s s. If delta P tie 12 ss from right hand side, it has brought to the left hand side. So, this is equation- 34.

Similarly, for area-2 it will be delta P g2 ss minus a 12, because delta P tie 21 is equal to a 12 delta P tie 12. So, delta P g2 ss minus a 12 delta P tie 12 ss minus delta P L 2 is equal to D 2 into delta f ss right. And another thing is that has steady state delta P g1 s s will be minus delta f ss upon R 1.

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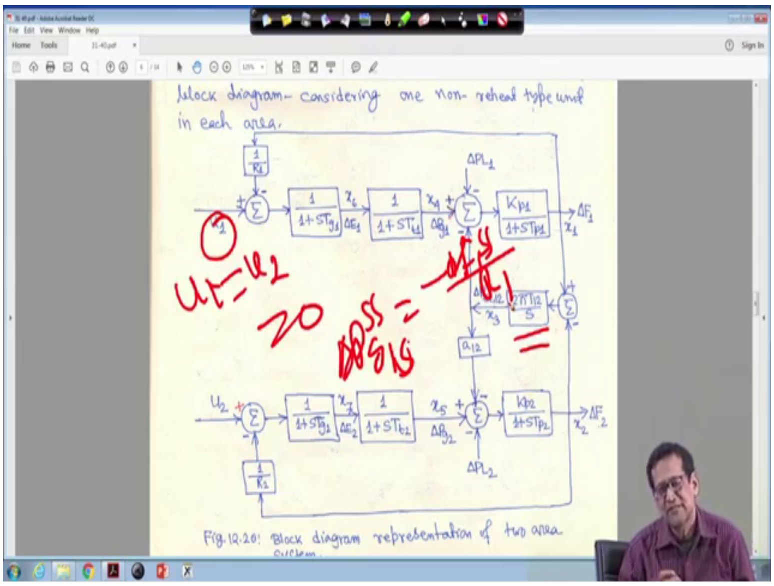

And delta P g2 ss is equal to minus delta fs f ss upon R 2 that means, this block diagram actually what we are doing is that we are first considering the system is on control that means, u 1 is equal to u 2 is equal to 0 right that thing first we have to see this right.

And second thing is I told you one technique that regarding you are putting your what you call that S T tends to infinity S tends to 0, but here you cannot make it right here you cannot make it. But, in general that your steady state that delta P g1 ss that is your delta P g1 steady state is equal to actually minus delta F1 steady state divided by R 1, this is this is known to us. Similarly, for delta P g2 ss right. So, if it so I mean if you draw your what you call draw the your steady state block diagram, then all these steady state value you have to make it right.

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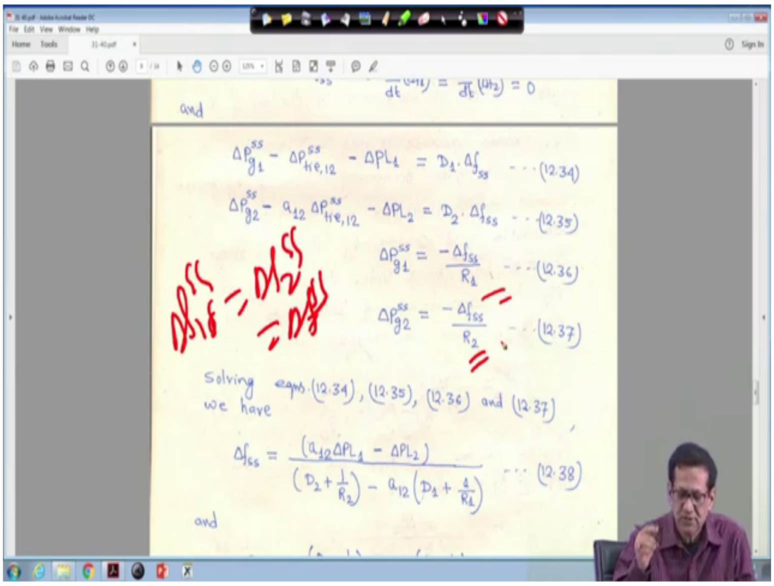

So, that is why in this case your that delta P g1 ss right is equal to minus delta f ss upon R 1, because a steady state that a steady state that your delta f 1 ss is equal to delta f2 ss is equal to delta fss right, so that is why you have written minus delta f ss upon R 1, and this is minus delta f ss upon R 2 right. So, now if you solve this equation for delta f ss, and your delta P tie 12 ss put this one this one you put it here. And this one you put it here, and you solve it and you solve it right.

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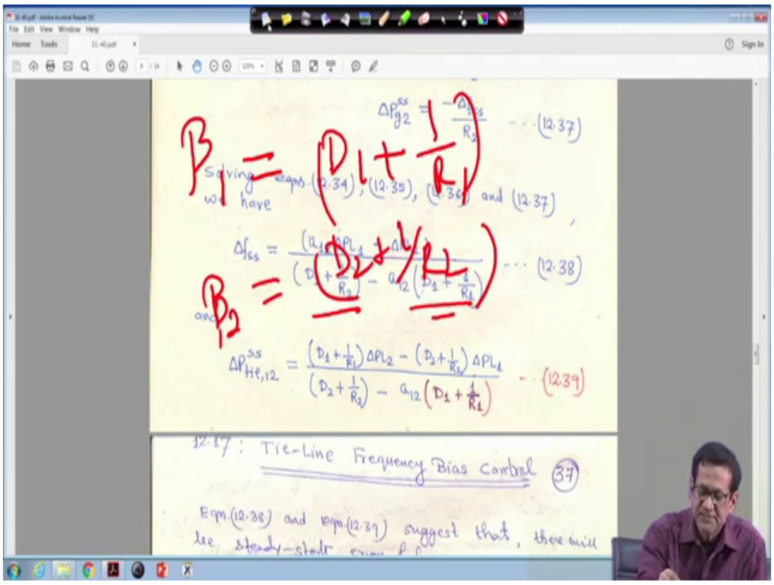

So, if you solve it, then you will get delta f steady state is equal to a 1 into delta P L 1 minus delta P L 2 divided by D 2 plus 1 upon R 2 minus a 12 into D 1 plus 1 upon R 1. Similarly, delta P tie 12 ss you will get D 1 plus 1 upon R 1, delta P L2 minus D2 plus 1 upon R 2. Delta P L1 divided by D 2 plus 1 upon R 2 minus A 1 2 D 1 plus 1 upon R 1 right.

So, sometimes what we do before moving further we define that area frequency respond characteristic right earlier we make beta is equal to D plus 1 upon R, this is called FRC. FRC area Frequency Response Characteristic right. Therefore, for area one this one your this one, and this one, we can write that beta 1 is equal to D 1 plus 1 upon R 1 right. Similarly, we can write beta 2 over writing on it beta 2 is equal to D 2 plus 1 upon R 2 right. So, this is beta 1 and this is beta 2.

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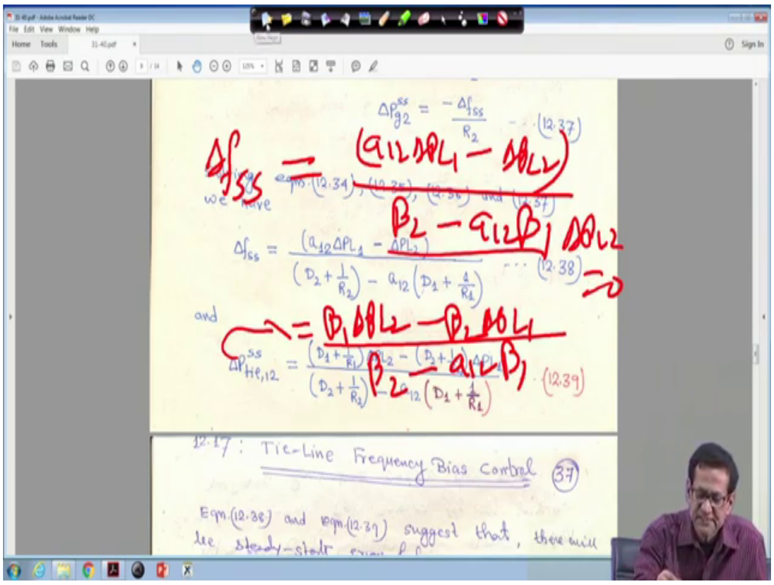

So, that means this delta f ss, I mean this equation delta f ss I am writing here, delta f ss, it can be written as your numerator a 12 delta P L1 minus delta P L2 divided by this is beta 2 minus a 1 2 beta 1 right.

And similarly, for tie power this one this one can be written as your beta 1, delta P L2 right minus beta 2 delta P L 1 right divided by your say divided by your beta 2 minus a 12 beta 1 same thing divided by your beta 2 minus a 12 beta 1 right. Now, if for example if a 12 suppose disturbance load disturbance had occurred only in area-1 right, and your what you call and delta P L 2 is equal to 0 say delta P L 2 is equal to 0.

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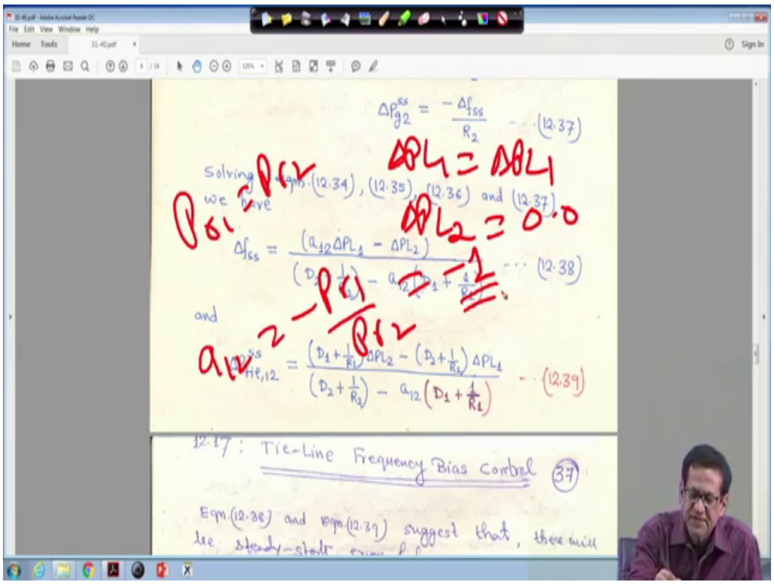

For example, for this thing suppose load disturbance has occurred only in area one. So, keep delta P L 1 is equal to delta P L 1, there is no load disturbance area-2. So, make it as a 0. And say that both the areas have equal your what you call at your equal your area capacity that means, a 1 2 is equal to minus P r1 upon minus P r2. And if P r1 is equal to P r2, then this will be actually minus one right. So, if it is so is for this condition for this condition if a 12 is minus 1, and delta P L1 is there, but delta P L 2 is 0, then right then you can little bit let me see right.

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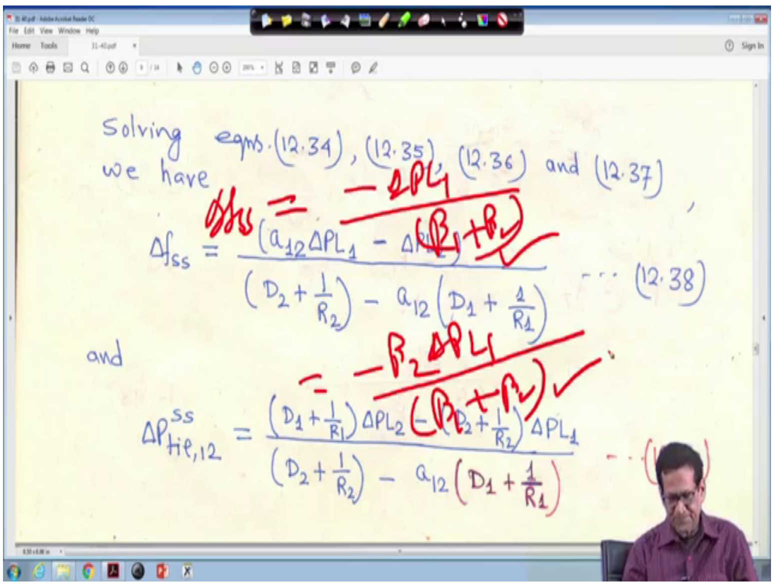

Therefore, this one you can I mean therefore, delta f ss will be then your delta just hold on delta f ss will be delta P L 2 is 0 and a 1 2 is minus 1. So, it will be delta P L 1 right divided by your this is D 2 and a 1 2 is my beta 2, and this is your a 1 2 is my minus 1. So, basically it will be B 1 plus beta 1 plus beta 2 minus delta P L 1 divided by beta 1 plus beta 2.

Similarly, for this one also if delta P L 2 is 0, then this one will be minus beta 2, then delta P L 1 divided by your here again beta 1 plus beta 2. So, both the cases denominator is same right when area capacity ratio, we are taking same right.

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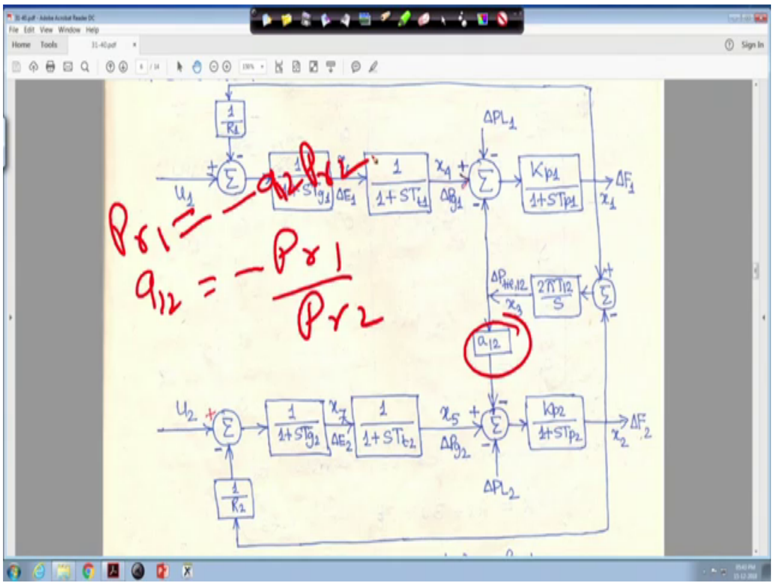

So, next will move to this thing. Now, another thing is that that before moving further, I will go to that block diagram right. So, this is actually again I have to reduce the your what you call that size right. So, so in this case what will happen that this a 1 2 area capacity ratio right. So, in that case is plays the significant role, what is this that we know that a 12 is equal to minus P r1 upon P r2 we right this we right that means that means P r1 P r1 is equal to your minus a 12 a 12 into P r2 right, this is the your this is the thing.

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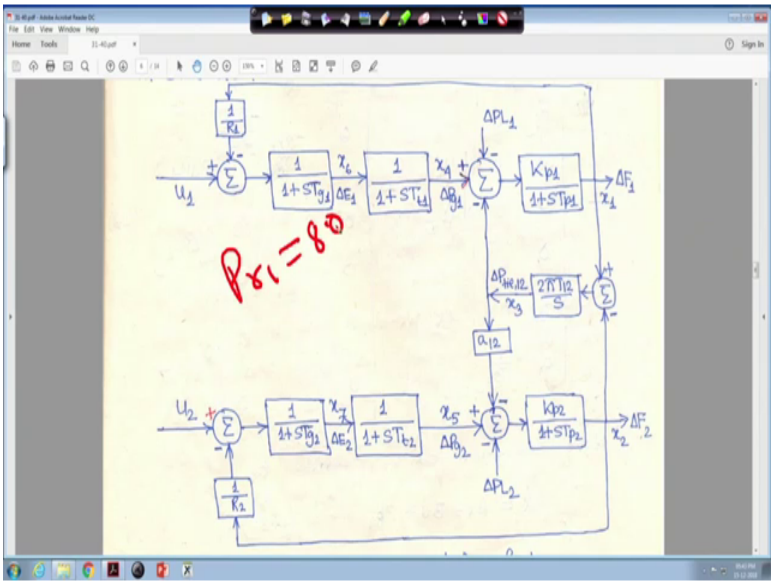

So, or suppose for example just for example, suppose my P r 1 is equal to say 8 point sorry.

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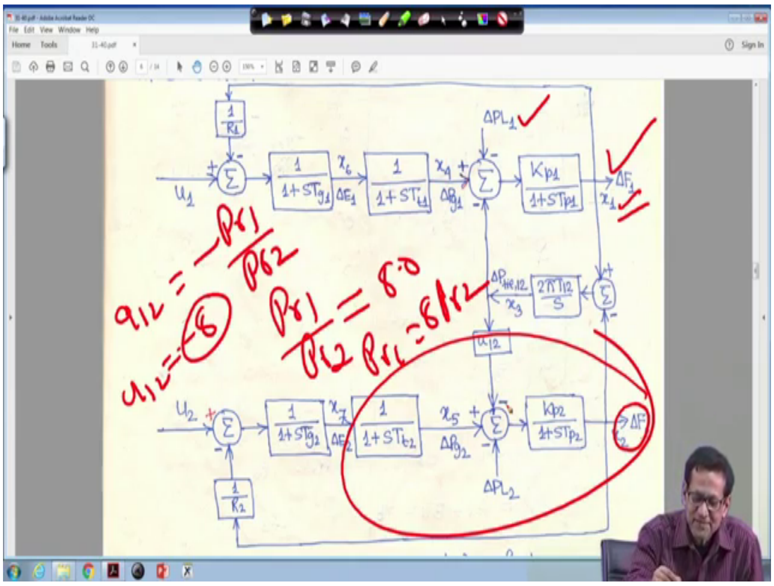

Just suppose a 12 is equal to minus P r 1 upon say P r 2 right. Now, suppose my P r1 upon P r2 is equal to say 8.0 right. This is the ratio this is the ratio that means, that means, my a 12 is equal to minus 8 that means P r 1 is equal to 8 times P r 2 that means, if P r 1 is 100 megawatt sorry P r 2 is 100 megawatt, then P r 1 will be your 800 megawatt.

So, if you go on increasing this ratio, suppose 1, 2 like this if you go on increasing, then what will observe as will go on increasing and for a and give a load disturbance here a step load disturbance here right. So, what you can observe it that through the simulation only, you will find there will be deviation and frequency area-1, but as this ratio will increase go on increasing, you will find that other area deviation is very small compared to the area-1 almost flat right almost flat that means, if delta f 2 I mean if you if area capacity ratio increases continuously that means, area capacity ratio increases means that for this case the way we have taken that your what you call that your P r 1 is higher than your what you call much higher than your P r 2.

Then in this case you will find for a load disturbance here, you will find that your this frequency deviation will be there in area-1. But, area-2 you will find it is almost flat I mean delta f 2 is almost I mean very negligible deviation. And go on increasing, it will happen that at that time what will happen the area-2 basically will act like your infinite bus right, because I mean it is because frequency deviation is constant frequency is constant right.

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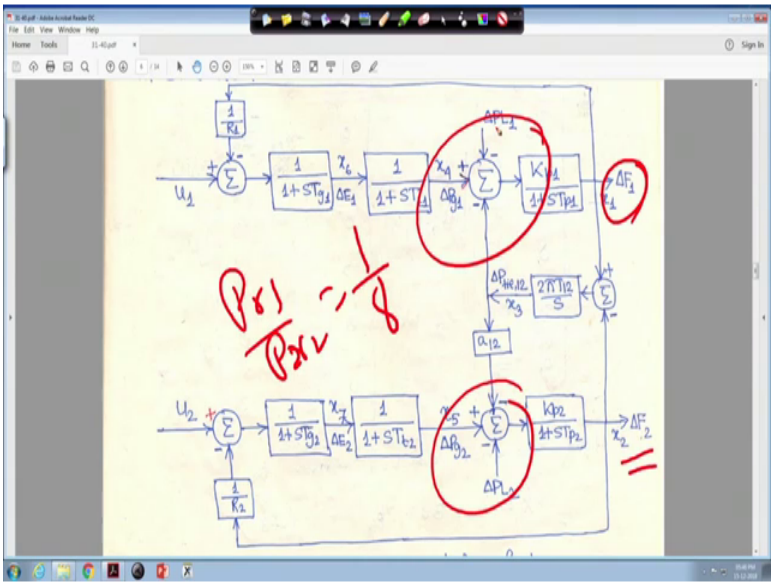

So, so in that case there will be that means, this two area system can be called as it is single area connect it to an infinite system, because capacity is your what you call capacity of this area is very high just reverse is also possible reverse is also possible. Suppose if you if you make P r 1 by P r 2 is equal to 1 upon 8.

In that case, what will happen that your area capacity of this area is very high? So, if disturbance occurs in this area, then you will find this side frequency deviation is negligible compared to this one. So, this side you will act as an infinite capacity right, you can verify it through the simulation, and this will happen right.

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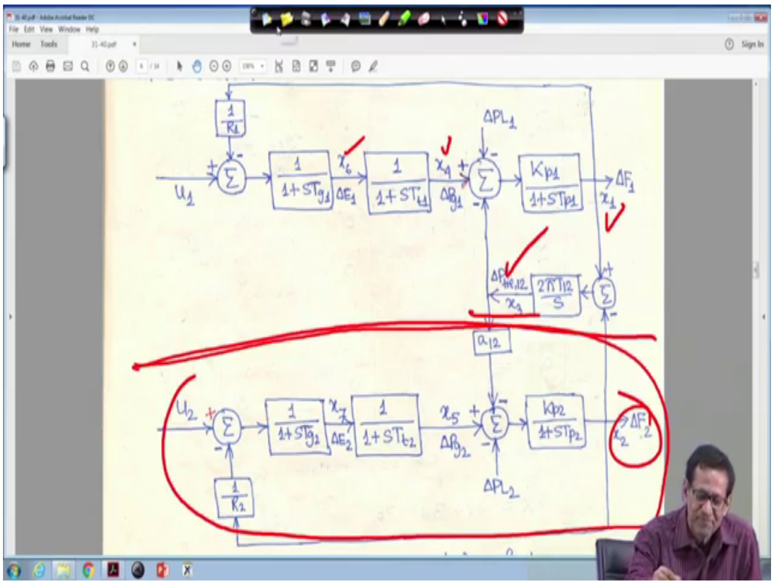

So, and you at that time system may be considered as that your what you call that your single area your connected to an infinite capacity system that means, in this case that means, in this case if it happens so for higher value of a 12 ratio, then this part need not be considered for the simulation, because this is actually your what you call there will be almost no deviation in system frequency.

In that case, this part should not be there this part should not be there that means, in that case 1, 2, 3, and 4, there will be four state variables right. So, this is something interesting. So, you can verify through simulation that this will happen right.

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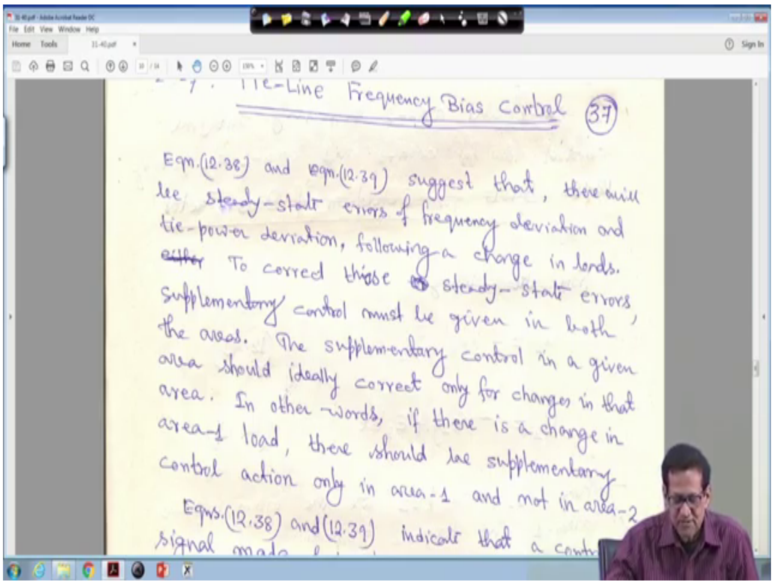

So, we will go to now that regarding that area control error right. So, tie line frequency bias control will call. So, equation 38 and 39, I mean these two equations steady state error of frequency and tie power frequency, and tie power deviations.

Suggest that there will be steady state error of frequency deviation, and tie power deviation right following a change in loads. To correct those steady- state errors, supplementary control must be given in both the areas right. The supplementary control in a given area should ideally correct only for changes in that area, I mean suppose integral control area is suppose you have integral controller in area-1 and area-2. If there is a load disturbance in area-1, then that controller in area-1 must correct that frequency deviation of its own area right.

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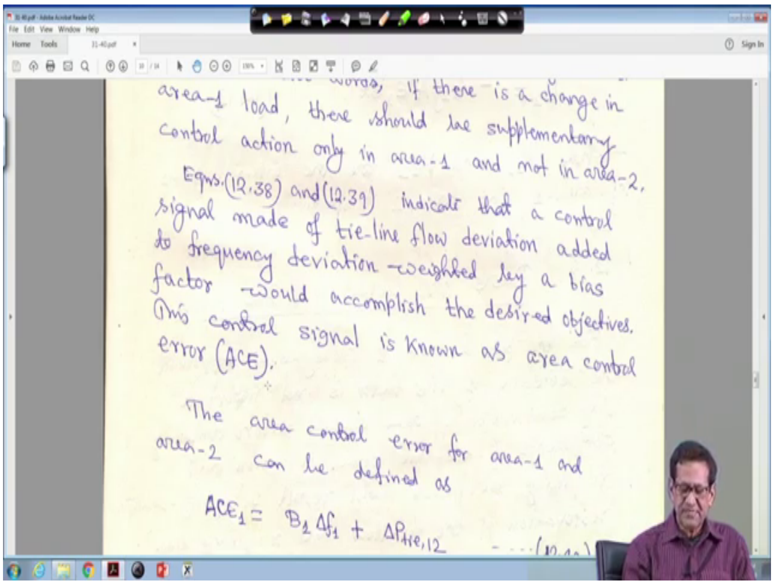

So, in other words if there is a change in area-1 load, there should be supplementary control action only in area-1 and not in area-2. Therefore, equation 38 and 39 indicate that a control signal made up tie line through deviation added to frequency deviation weighted by a bias factor that will see would accomplish that desired objective, this control signal in known as area control error. So, area control error basically it is a function of frequency deviation, and tie power deviation right.

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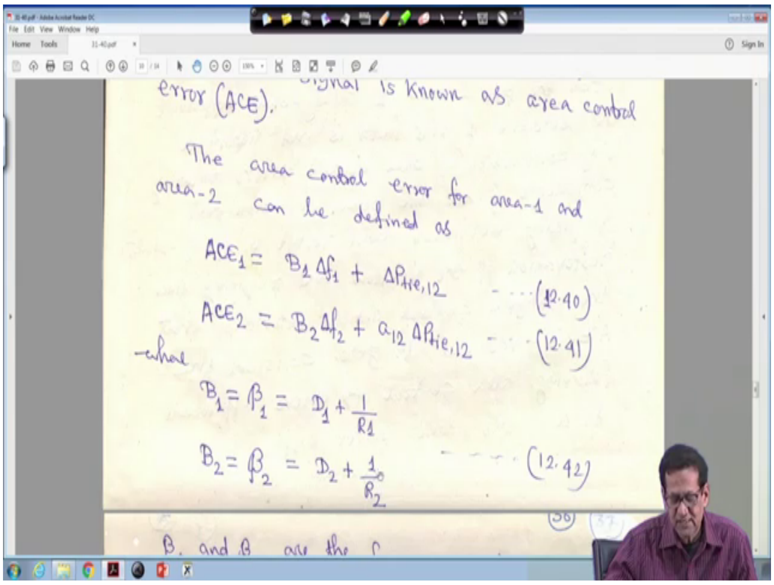

So, the area control error for area-1 and area-2 can be defined as ACE1 is equal to B 1 into delta f 1 plus delta P tie 12, this is equation-40. And ACE2 will be B 2 delta f 2 plus a 12 delta P tie 12 that is the equation-41. So, B 1 is equal to beta 1 is equal to D 1 plus 1 upon R 1, and B 2 is equal to beta 2 plus is equal to D 2 plus 1 upon R 2.

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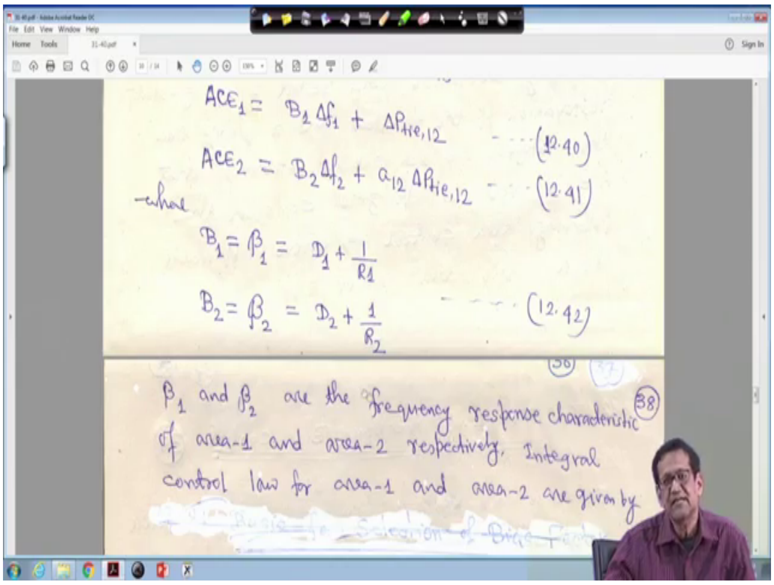

So, beta 1, beta 2 are the frequency response characteristic or area frequency response characteristic of area-1, and 2 respectively right.

So, thank you very much, we will be back again.