Power System Dynamics, Control and Monitoring
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Lecture - 39
Automatic generation control conventional scenario (Contd.)

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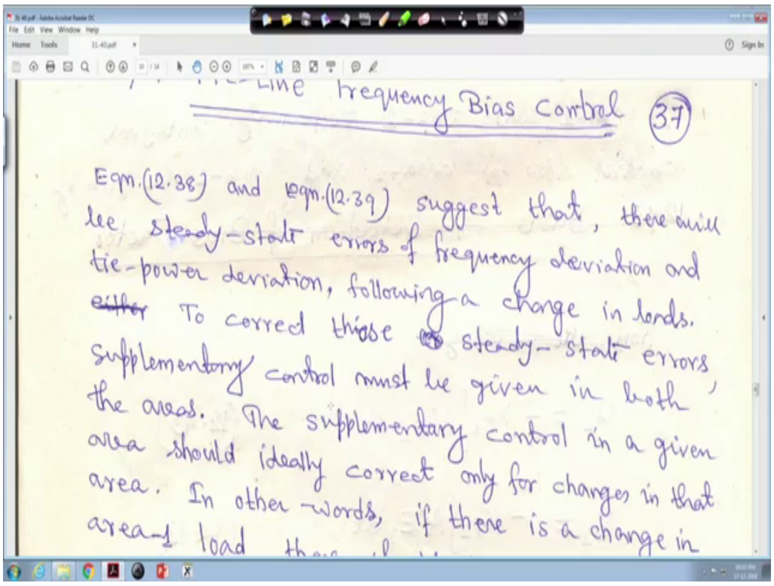

So in the previous lecture, we have just started with tie-line frequency bias control. So, here also starting from that same point that equation-38 and 39 is suggest that, there will be steady-state error of frequency deviation and tie-power deviation following a change in load that is load disturbance right either increase or decrease in load and that is equation 38 and 39 the steady-state values of both frequency and tie-power deviations are given right.

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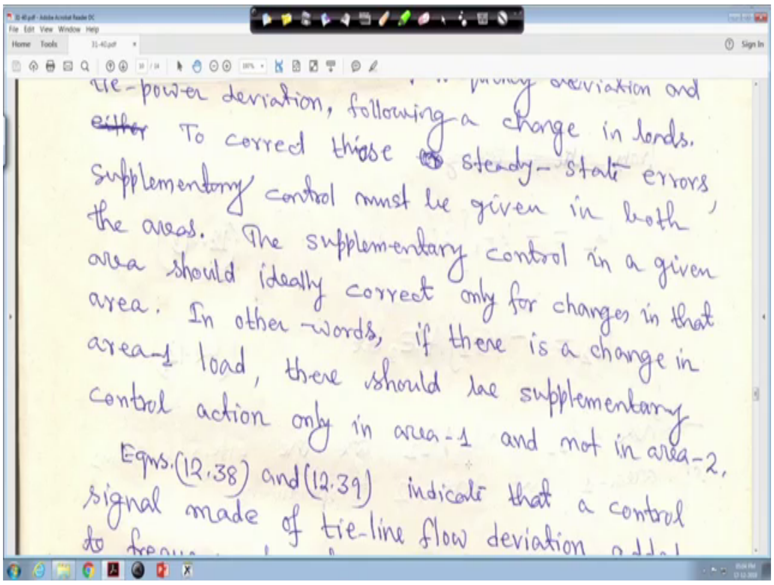

So, to correct those steady-state errors, supplementary control must be given in both the areas. I mean our objective is to bring this steady state error to zero for which we need that supplementary control action right. So, the supplementary control in a given area should ideally correct only for changes in that area right. 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.

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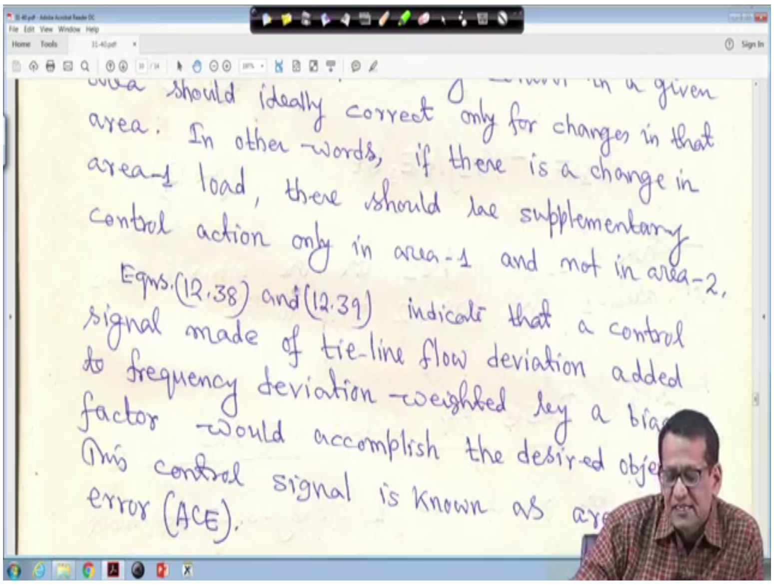

So, that equation-38 and 39, equation-38 for your frequency steady state error and this is for tie-power deviation steady state error indicate that a control signal made of tie-line flow deviation added to frequency deviation weighted by bias factor would accomplish the desired objectives. This control signal actually is known as area control error.

So, suppose you have a two area system that is we have seen, suppose if suppose a load disturbance has happened in area-1, then area-1 supplementary controller it should respond right and it should accommodates load changes. And area-2 supplementary; area-2 supplementary control should not respond to this, but it during your dynamic your transient period that it will act, but at the steady-state that if any load changes occur in area-1, that area-1 generation must accommodate that right. And there should not be steady-state, there should not be any power with generated by the generators of area-2 that means, a steady-state generation of area-2 will be 0, because there is no list load disturbance in area-2 right.

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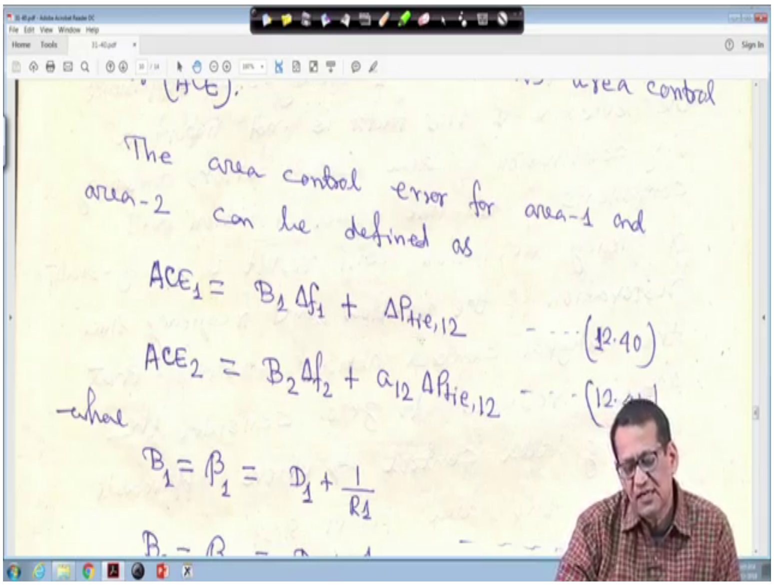

So, the area control error for area-1 and area-2 can be defined as generally ACE 1 that is Area Controller Error of area-1 is B 1 delta f 1 plus delta P tie 12 this is equation-40. And ACE 2 is equal to B 2 delta f 2 plus a 12 delta P tie 12 is equation 41.

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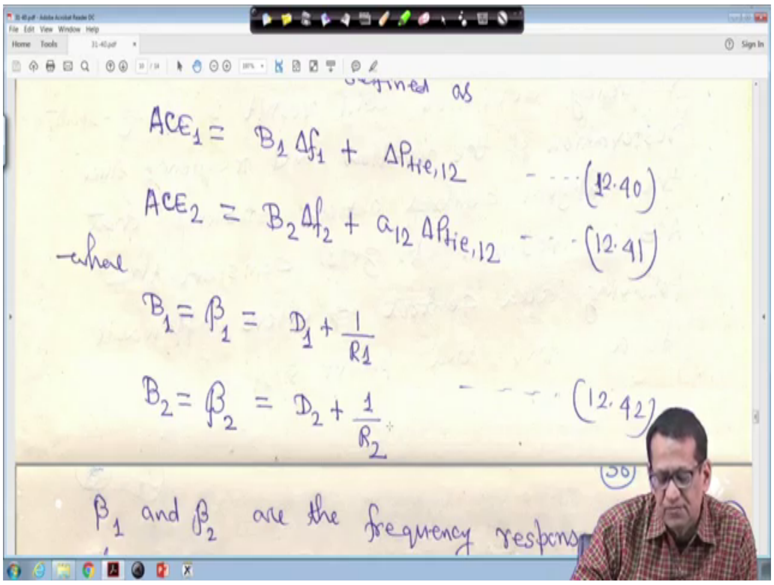

Now, we define say B 1 is equal to beta 1 is equal to D 1 plus 1 upon R 1 and B 2 is equal to beta 2 is equal to D 2 plus 1 upon R 2.

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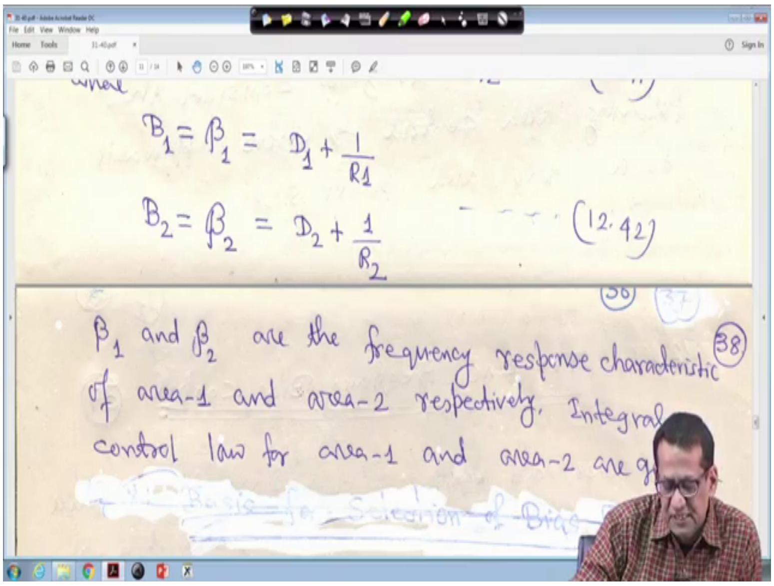

So, beta 1 and beta 2 basically are the frequency response characteristic of area-1, area-2 respectively. In general, we call this is area frequency response characteristic.

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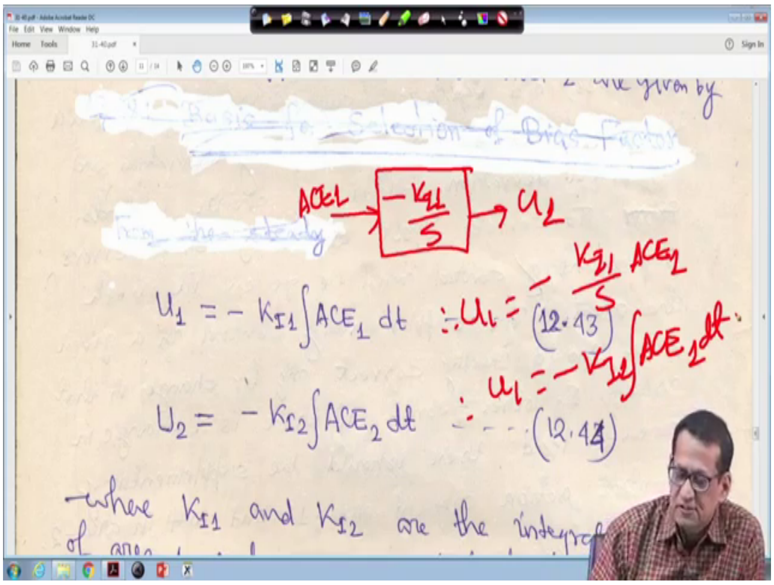

So, integral control law both for area-1 and area-2 are given by that U 1 will be minus K I 1 integral of ACE 1 d t. And U 2 will be minus your K I 2 ACE 1, ACE 2 d t right. So, it is actually later will see that you have your this is your input say for area-1 ACE-1 right. And this is your that integral gain K I 1 upon S and this is my u 1 right.

Therefore, u 1 is equal to minus K I 1 upon S ACE 1 right that means, its integration actually u 1 will be minus K I 1 integral of ACE 1 d t right, so that is why this u 1 is written as minus K I 1 integral of ACE 1 d t, this equation-43 for area-1. And u 2 is equal to minus K I 2 integral of ACE 2 d t this is equation-44.

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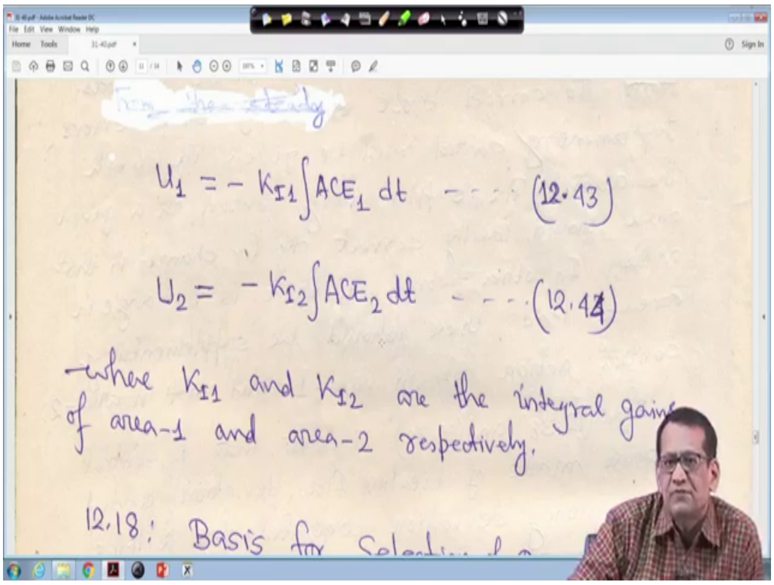

Where, K I 1 and K I 2 are the integral gain settings for area-1 and 2 respectively right. So, this gains K I integral gains actually need to be optimized at the of course for the class room purpose, we cannot optimize to simulation, but I will tell you how to optimize such things right.

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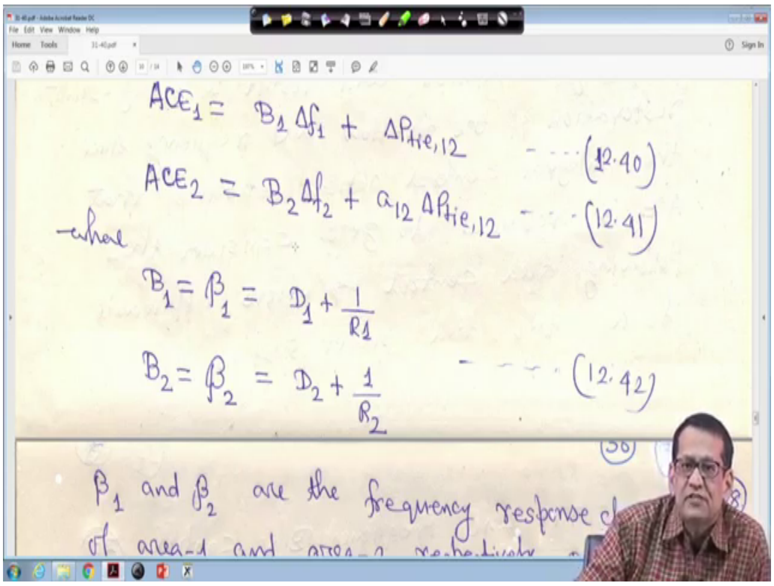

Now, next is basis for selection of bias factor right that means, this B 1 and B 2 selection for this one right bias factor B 1 and B 2 that is called frequency bias right.

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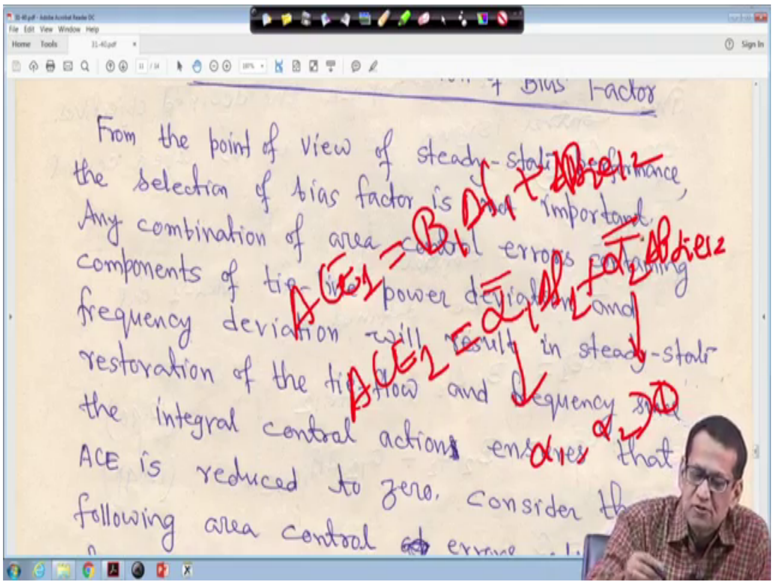

So, for the from the point of view of steady-state performance, the selection of bias factor is not important right. Any combination of area control errors containing components of tie-line power and deviation and frequency deviation result in steady-state restoration of the tie-flow and frequency. Since, the integral control actions ensures that ACE is reduced to 0 that means, you take I mean for example, suppose here I overwriting it, I hope it will be readable to you.

Suppose, ACE 1 for area-1 suppose we are writing B 1 delta f 1 plus delta P tie 12 right, so this area controller. I can take any but I can take any combination such that a steady-state integral controller is there. A steady-state you will find delta f 1 will become 0, and delta P tie 12 will become 0, hence ACE 1 also will become 0.

So, that means in general even if you take this combinations ACE 1, I am just putting in my way ACE 1 say alpha; alpha 1 into say delta f 1 I put plus alpha 2 into delta P tie 12 I put. Say alpha 1 and alpha 2, alpha 1 and alpha 2 both has to be your greater than your 0 right.

And so in that case what will happen any combination you take that ACE will become 0 at steady-state, because you have integral controller right. But, there must be but question is that once there choice will put some problem particularly during the transient behavior right, so that is why we have to abstract a your what you call some kind of philosophy for proper choice of B 1 particularly the frequency bias setting that B in general right.

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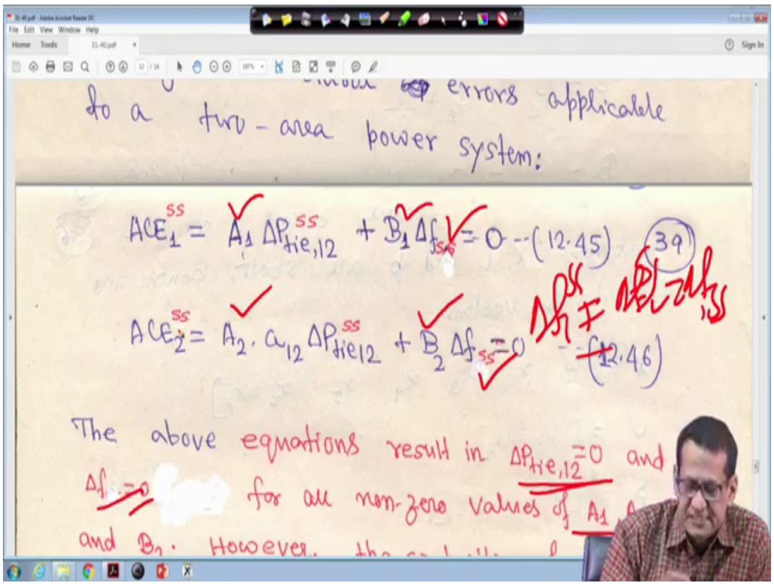

So, this therefore the ACE is actually consider the following area control error applicable for a two-area power. Systems, suppose we have taken just now I told say ACE 1 has steady state is equal to some constant A 1 into delta P tie 12 steady-state plus B 1 delta f ss steady-state is equal to 0 at steady state this is equation 45.

And ACE 2 steady-state a 2 into a 12 delta P tie 12 ss plus B 2 delta f ss is equal to 0 right. So, in that case what will happen at steady-state your steady state actually your delta f 1 is equal to delta f 2 is equal to delta f steady state. This is our steady-state all steady-state right so, delta f ss delta f ss.

So, as steady state actually delta P tie 12 will become 0. And similarly, delta f will become 0 for all non-zero values of A 1, A 2, B 1 and B 2 right, because you have the integral control action. Therefore, ACE 1 and ACE 2 their values will be 0 at steady-state right.

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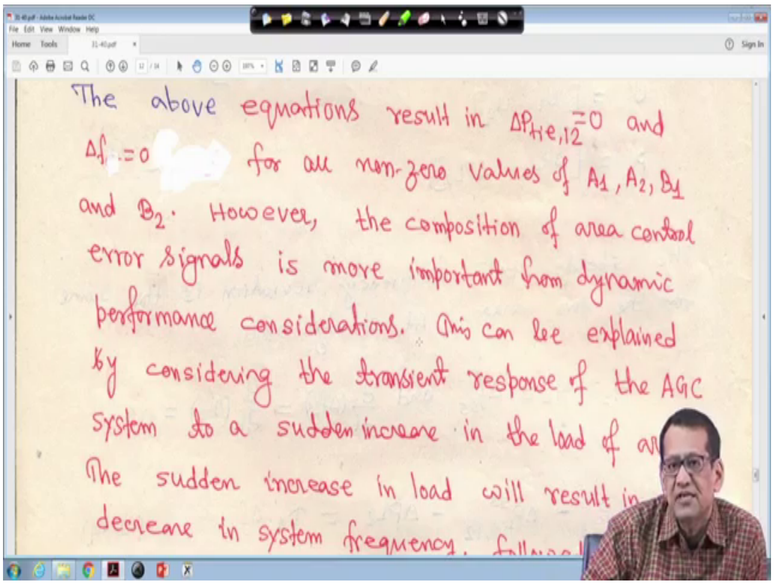

So, however the composition of area control error signal is more important from dynamic performance consideration right, because we have to see that transient behavior that is the dynamic performance. This can be explained by considering the transient response of the AGC system to a sudden increase in the load of area-1. So, sudden increase in load will result in decrease in system frequency, because we know that if real power load increases, the frequency falls right. And if load decreases, then frequency raises right.

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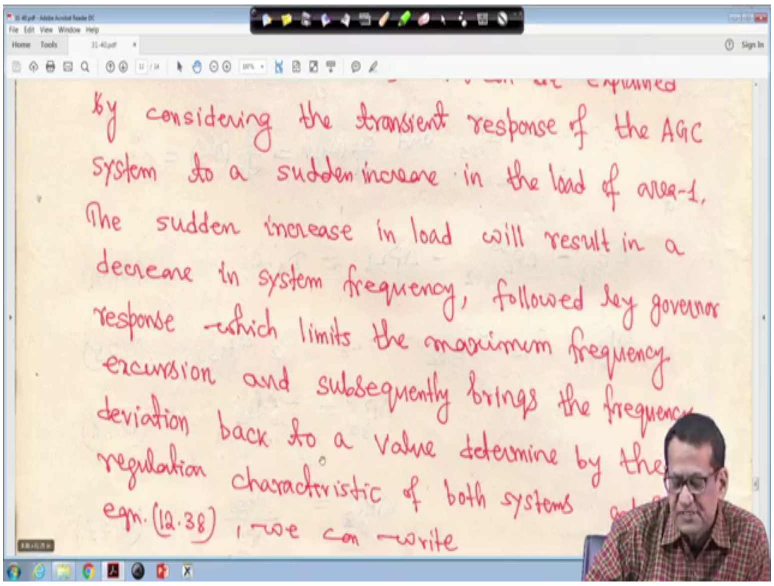

So, followed by governor response, which limits the maximum frequency excursion and subsequently brings the frequency deviation back to a value determine by the regulation characteristic of both system and from equation-38, we can write.

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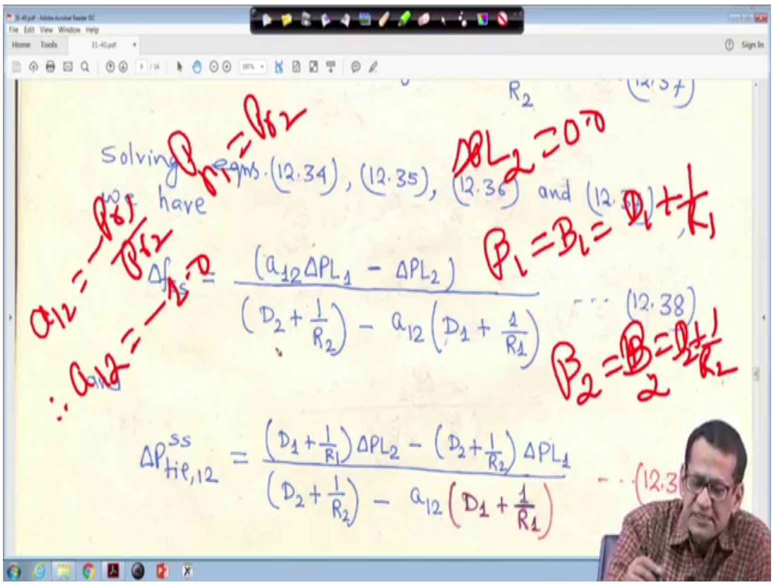

For example, we will go back to equation 38 right here, we will go back to equation 38 and 39 here. Suppose, load disturbance has happened in area-1 and there is no load disturbance in area-2 that means, delta PL 2 is equal to say 0 right, because there is no load disturbance in area-2. And another thing that frequency response characteristic let us define that beta 1 is equal to your B 1 is equal to D 1 plus 1 upon R 1 right.

Similarly, you define beta 2 is equal to your B 2 is equal to D 2 plus 1 upon R 2 right this you define. And assume that load disturbance has happened in area-1, but there is no load disturbance in area-2 right. Therefore, you put here delta PL 2 and another thing, we assume that area capacity ratio right a 12 define by minus sign P one P r 1 upon P r 2, you assume they are same that means, we assume P r 1 is equal to P r 2 right.

In that case your a 12 will be is equal to minus 1.0 right. So, all these things you put in this equation, you put a 12 is equal to minus 1 delta P L 2 is equal to 0. This one you make it beta 1 and this was you make it beta 2 for both the equations. If we do so, now I am cleaning this one, I hope you have understood I am cleaning this one.

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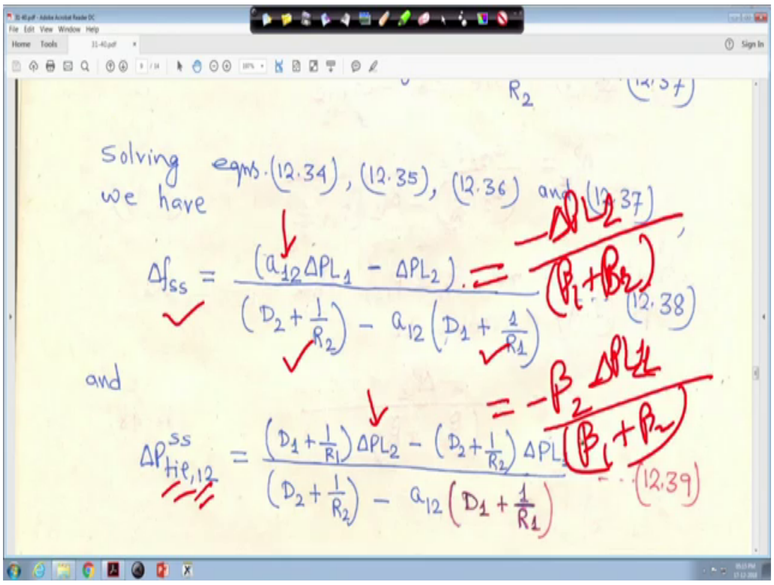

So, if you make it, then this equation actually this equation then it will become that your minus delta P L 1 become a 12 is equal to minus 1, this is 0. And here a 12 minus 1 means, this will be plus and this is beta 1, this is beta 2, so basically it will be beta 1 plus your beta 2 right. This is your delta f steady-state is equal to minus delta f your P L 1 upon beta 1 plus beta 2 following a load disturbance.

Now, in this case in this case the delta P tie 12 ss, in this case also same thing put delta P L 20 and this is my beta 2 right. So, this can be written as minus beta 2 delta P L 1 right divided by again this a 12 minus 1, so it will be plus. So, it is actually beta 1 plus beta 2 right. So, this is minus delta P L 1 upon beta 1 plus beta 2 and this is minus beta 2 delta P L 1 upon beta 1 plus beta 2 right. So, this is your this expression for steady-state error expression for this one frequency and this is for the tie-power deviation right. So, now will go back to that equation right that is your ACE 1 is equal to B 1 this thing your B 1 delta your what you call, this is your delta f ss, similarly for delta P tie right.

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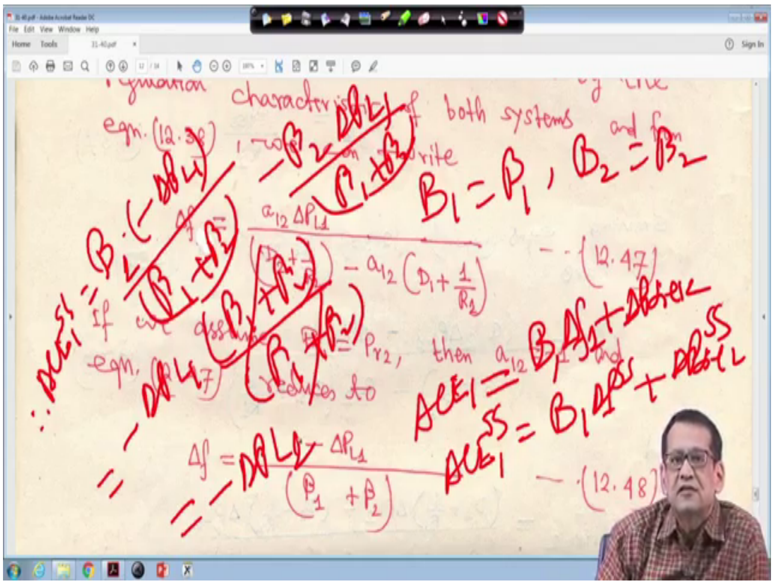

So, now will go back to this equation that your that your this thing just now I told you that if you put delta P L 2 0 put a 12 is equal to minus 1, it will be beta 1 plus beta 2. Now, ACE 1 is equal to say B 1 delta f 1 right delta f 1 plus your delta P tie 12 this is right. Now, as steady-state when you look into the steady state that means, ACE right 1 steady state is equal to B 1 delta f steady-state right plus delta P tie 12 steady-state.

Now, B 1 is equal to beta 1. This color is red, this is also becoming red, but it is much thick. So, I think it is readable for you right. So, in this case if we use beta B 1 is equal your what you call beta 1 and b 2 is equal to say beta 2 right. And steady-state we have seen the values, so B 1 is equal to beta one that means, here I am writing for you that means, ACE 1 steady state is equal to B 1 is equal to beta 1.

And delta f ss we have seen for a step load disturbance in area-1. Area-2 there is no disturbance, and area capacity ratio is same say 1 2 is equal to minus 1, because P r 1 upon P r 2 P r 1 is equal to P r 2. So, if we substitute here, it will be beta 1 right, then minus delta P L 1 divided by beta 1 plus beta 2, this is one equation.

Similarly, your delta P tie 12 SS I showed you before right that is equal to your minus beta 2 delta P L 1 upon beta 1 plus beta 2 right. So, if it is so, you take your what you call minus delta P L 1 common, if you take so it will be minus delta P L common, numerator will be beta 1 plus beta 2.

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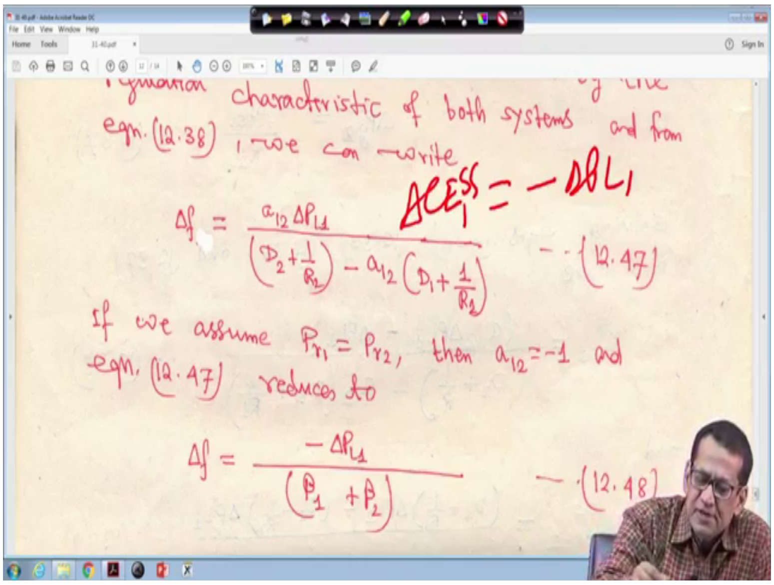

And here also beta 1 plus beta 2 right, so that is nothing but minus delta P L 1, because this one this one will be cancelled that means, at steady-state that means at steady-state that ACE 1 ss is nothing but it is coming minus delta P L 1 is meaning is that that if there is a your what you call there is sudden increase of load, so area-1 will accommodates in load changes that means that power will be generated from generators in area-1 right, and accordingly it will do this.

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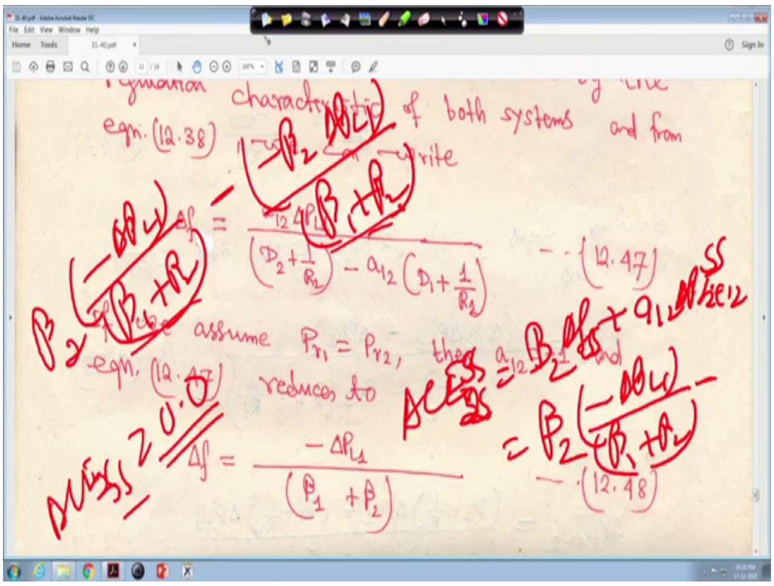

But, if you take now using the same philosophy, if you take ACE 2, so ACE 2 steady states directly I am writing ACE 2 steady state is equal to you know B 2, then delta f steady state right plus a 12 delta P tie 12 steady-state right. So, a 1 is minus 1, so this B 2 delta f ss delta f B 2 is equal to beta 2.

So, here you can make it this is my beta 2. And delta f ss is minus delta P L 1 divided by beta 1 plus beta 2 right. And delta P tie 12 delta P tie 12 ss also we have seen before right. So, a 12 is equal to minus 1, so I am making it here this one hold on I just hold on, I am writing here that it is beta 2, then minus delta P L 1 divided by beta 1 plus beta 2 right. And a 12 is minus 1 minus 1, so my dash. And delta P tie 12 ss we have seen before that minus beta 2 delta P L 1 divided by beta 1 plus beta 2 right.

So, in that case what is happening that this is your beta 2, this is also beta 2, this is minus and minus plus, so what will happen in the numerator will be 0 right, so that means, my ACE 2 ss will become 0 right, because this is mine beta 1, beta 2 denominator is common, and this is minus minus plus beta 2 P L 1, beta 2 P L 1 will be cancel. So, basically it will be 0 upon beta 1 plus beta 2.

Therefore, steady state error ACE 2 ss will be 0 that means, it suggests that that whenever there is there will be a load disturbance in your what you call in area-1, area-1 generation should accommodate this load right. And area-2 in the case of your area-2 this ACE 2 steady state is becoming 0 that idea is that the load disturbance happens in area-1 that disturbance which has happened in area-1, it will be completely unobservable by the area-2 this is the meaning of this one right, so that is why this is all these given, but I told you how to how we have got it right.

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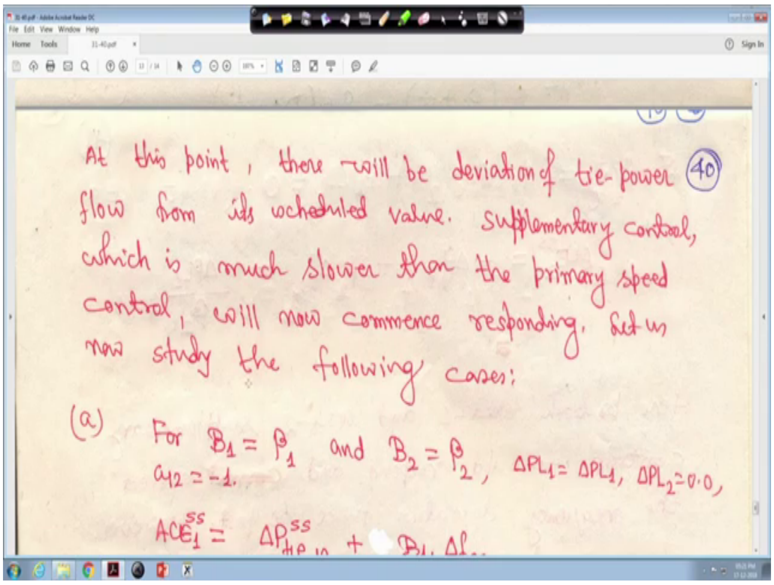

So, at this point just there will be deviation of tie-power flow from its scheduled value. Supplementary control, which is much slower than the primary speed control will now commence responding, let us now just study let us now study the following case.

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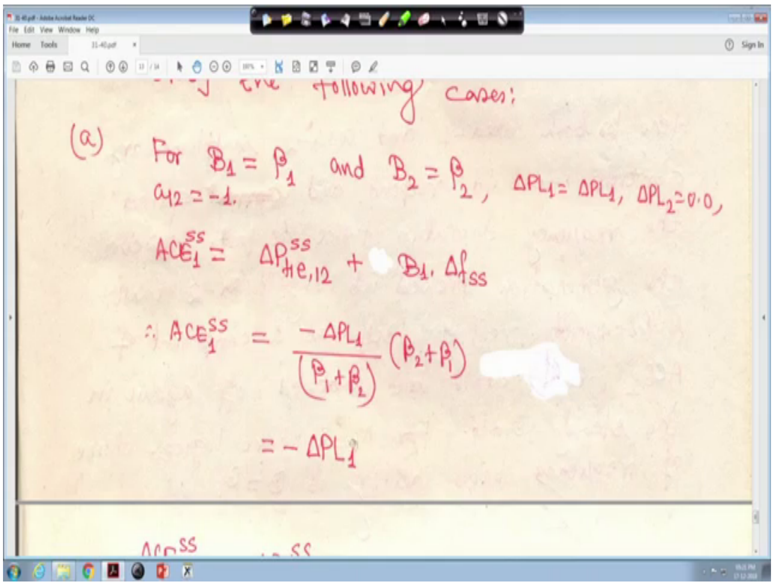

Now, second case this already I explained. This already I explained that ACE 1 will be steady-state will be minus delta P L 1, this already I told you.

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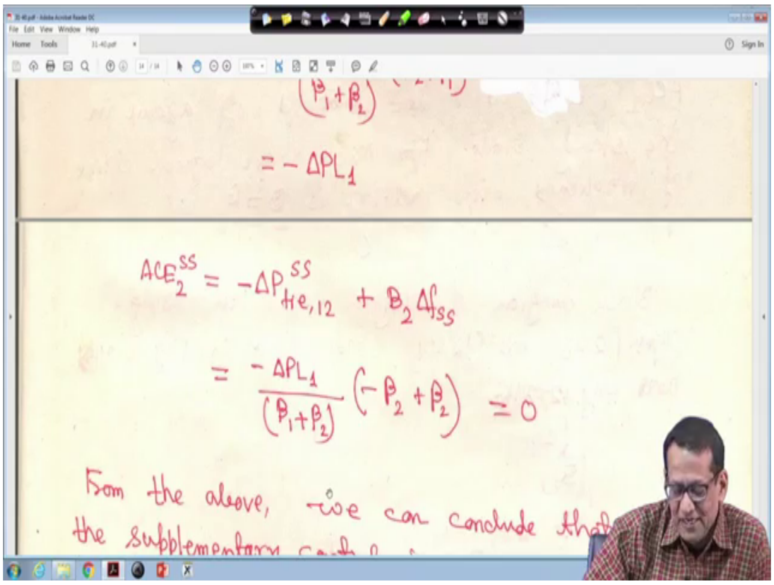

And ACE 2 ss will completely will become 0 right, this will become 0. This these two things already just I derived this right, so how the meaning is.

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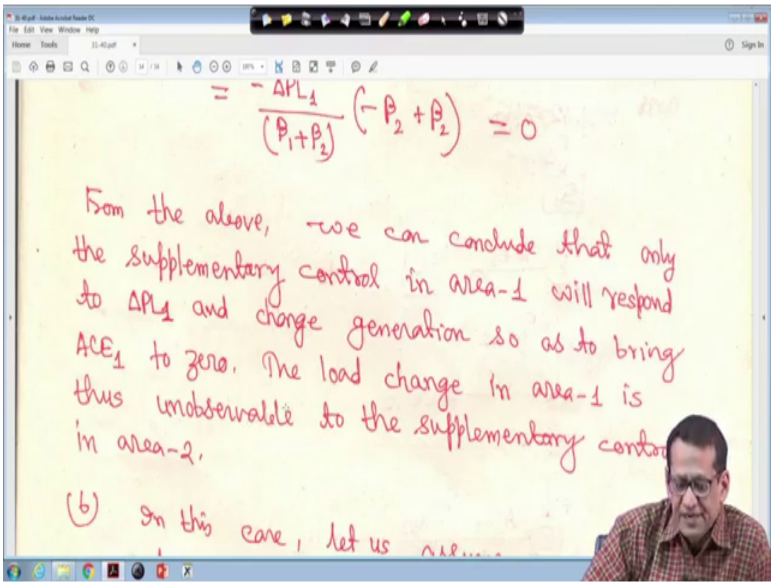

So, now from the above, we can conclude that only the supplementary control in area-1 will response to delta P L 1 and change generation change generation so as to bring ACE 1 to 0 that is area controller to 0. The load change in area-1 is thus unobservable to the supplementary control your in area-2 right, because ACE-2 at steady state becoming 0.

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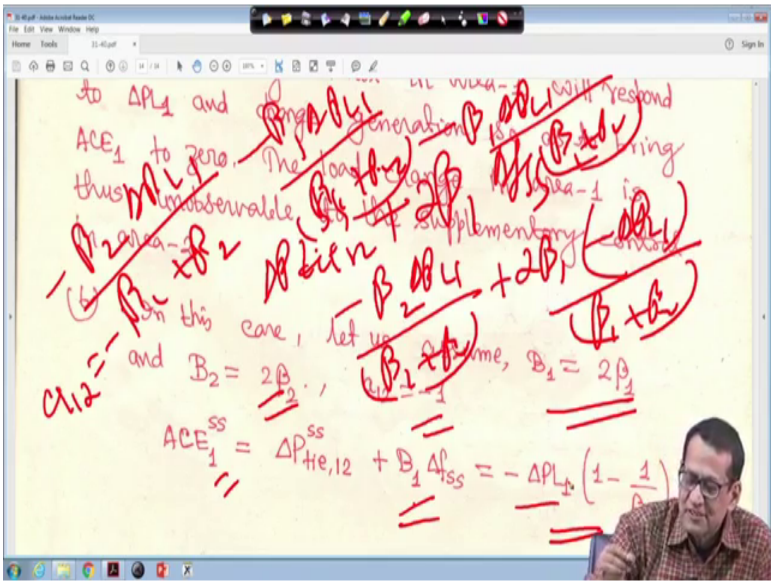

Now, another case just for the sake of this understanding, we let us assume another thing that your beta 2 is equal to B 2 is equal to 2 beta 2 a 12 is minus 1 and b 1 is equal to 2 beta 1 right. So, in that case what will happen that if you your what you call that use that same thing that suppose it is given that ACE 1 ss, you will get this one ACE 1 ss, so delta P tie 12 ss right plus this B 1 is actually 2 beta 1. So, it is 2 beta 1 delta f ss right.

So, we know delta P tie 12 ss, when a 12 area same thing a 12 is equal to minus 1 right. So, this term will be if I recall correctly it is minus beta 2 delta P L 1 divided by beta 1 plus beta 2 right. And this term plus it is 2 beta 1 and delta f ss already known that it is minus delta P L 1 divided by beta 1 plus beta 2 right.

So, in I mean this way your what you call sorry beta 1, beta 2, it will be actually your B 1 your what you call D D 1 plus 1 upon R 1 and D your what you call D 2 plus 1 upon R 2. So, if it comes like this, if it comes like this, so finally if you simplify this one, it will be minus delta P L 1, then 1 minus beta 1 minus 1 upon beta 2 right.

So, in that case what will happen just you simplify one term will come beta 1 plus beta 2 upon beta 1 plus beta 2, I mean break this thing, it is my it is minus beta 2 delta P L 1, and beta 1 plus beta 2 and it is plus it is minus plus minus 2 beta 1 delta P L 1 upon beta 1 plus beta 2 right, so that way you can actually what you just simply this, then you will get it will become one 1 minus 1 upon your what you call beta 2. Let me do it for you, let me do it for you.

So, this one actually it is minus beta 2 delta P L 1 divided by beta 1 plus beta 2 right. And this one also you can write separately minus beta one delta P L 1 by beta 1 plus beta 2 right. So, again another term you write minus your beta 1 overwriting will be able to understand B l this beta 1 plus beta 2 this way you write. So, in that case if you write and simplify right, then you will find that this one (Refer Time: 21:58) become minus delta P L 1 you take common beta 1 plus beta 2 here what you call that your what you call will be cancelled, so just let me make it here.

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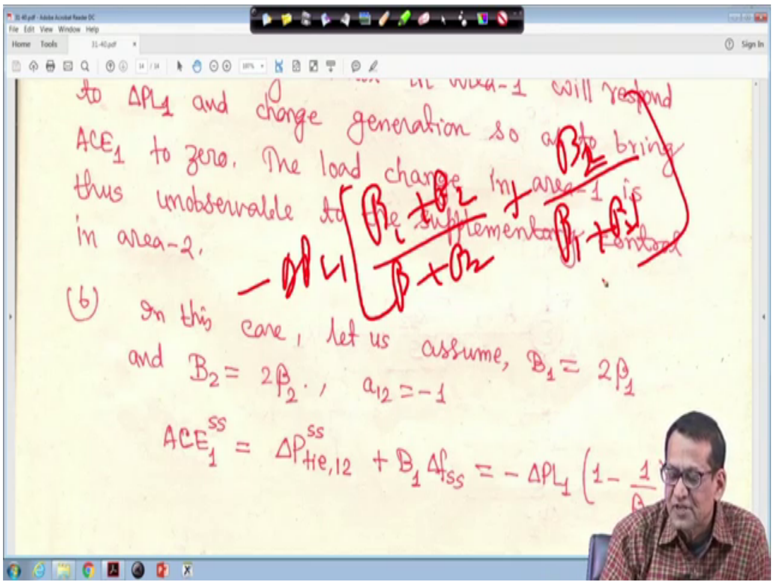

So, here what will happen that your minus delta P L 1, you take common. So, you will find beta 1 plus beta 2 upon beta 1 plus beta 2 right this is one term. Then another one you can write that plus beta 2 right divided by beta 1 plus beta 2 right, because your beta 1 is equal to your just hold on that B 1 is equal to 2 beta 1 right it is ok. So, it will be beta, it will be beta 1 upon beta 1 plus beta 2.

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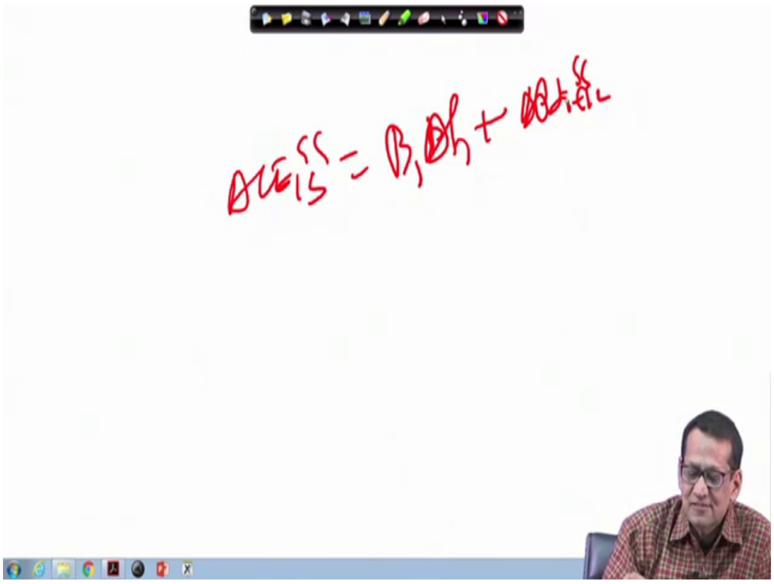

So, ACE 1 ss is equal to your B 1 delta f 1 plus delta P tie 12 right ss.

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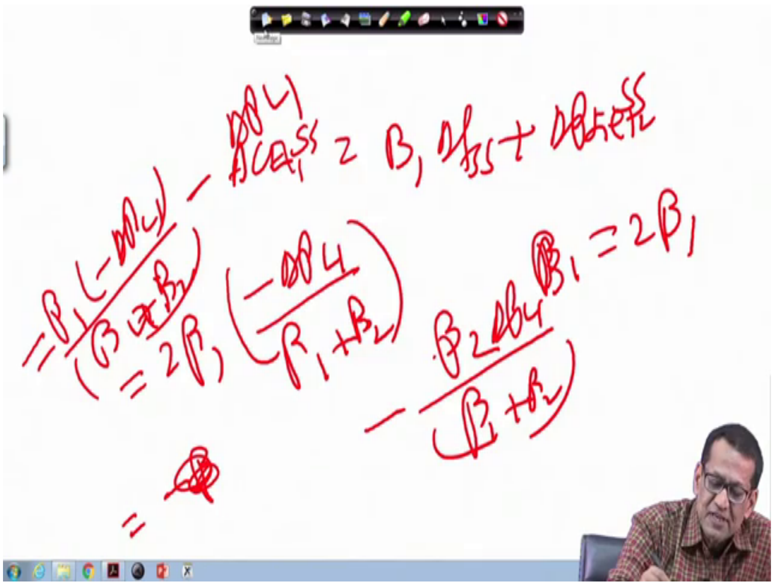

So, here I am writing again right. So, ACE 1 steady-state is equal to B 1 delta f ss plus delta P tie 12 steady-state right. So, we are taking say B B 1 is equal to 2 beta 1. So, if you put here 2 beta 1, so it will be actually 2 beta 1, and delta f ss we know that minus delta P L 1 divided by beta 1 plus beta 2. This is one term.

And delta P tie 12 ss we know minus your beta 2 divide delta P L 1 divided by beta 1 plus beta 2 right. So, this is actually 2 beta 1. So, if you just what you call, now if you simplify this one, this is minus beta 2 delta P L 1, so this term, this term it can be written as minus I am making it here somewhere here, this term just you 2 beta one you make twice that is beta 1 into minus delta P L 1 upon beta 1 plus beta 2. Again you write minus beta 1 into delta P L 1 upon beta 1 plus beta 2 right. And then you take common and you simplify.

So, if you do so then this term will become this is your beta 1, then your minus delta P L 1 divided by beta 1 plus beta 2 right this term. Then again another term is there, so that will be your that will be your minus your beta 1 delta P L 1 upon beta 1 plus beta 2 and minus beta 2 delta P L 1 upon beta 1 plus beta 2.

So, if you take your minus common, then it will be beta 1 upon beta 1 plus beta 2 upon beta 1 plus beta 2, so basically it will become actually minus your delta P L 1 right. So, this way it will come. So, if you just take the take this things your what you call, the second term that you just take common minus delta P L 1, so it will become minus your beta 1 plus beta 2 upon beta 1 plus beta 2 and this is minus your delta beta 1 upon your what you call beta 1 plus beta 2 this one.

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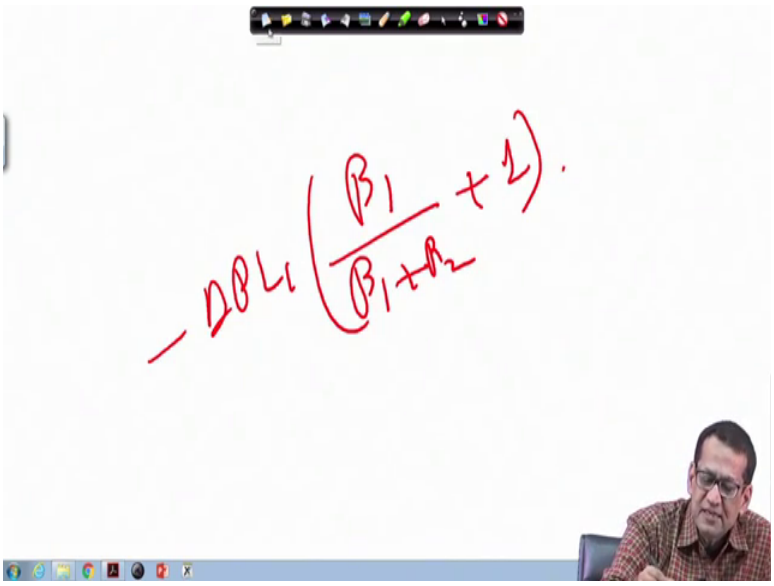

Now, further you can simplify this; you can simplify this, so I am just deleting this one that your then that means, if we take minus delta P L 1 common, then B 1 upon beta 1 plus beta 2 right. And then that term will be your what you call that term will be one right, if you take your this thing is common. So, after this if you just simplify right if you just simplify, then let me go back right let me go back.

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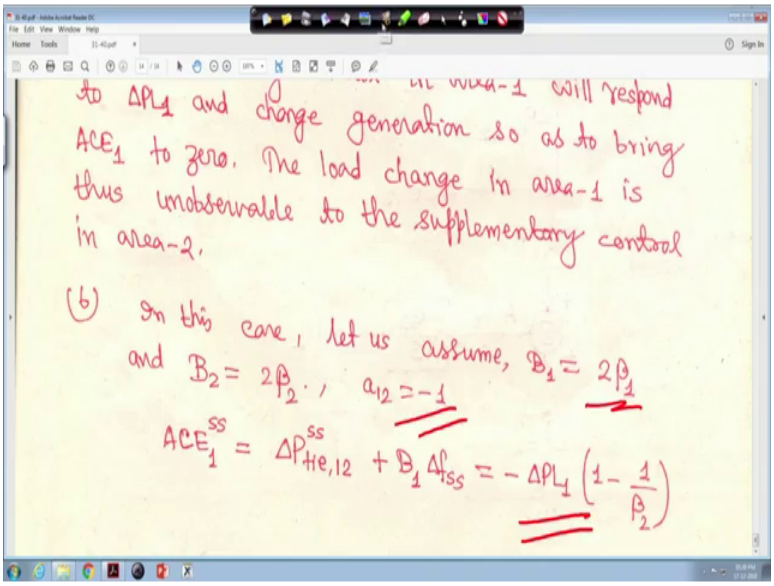

So, you will get this term actually your just hold on, this term that minus delta P L 1 1 minus 1 upon beta 2, just you simplify that one. Ultimately, you will get that this is minus delta P L 1 1 minus 1 upon beta 2. Just you put those thing that B 1 is equal to 2 beta 1 here. And just simplify and your a 12 is equal to minus 1. So, in that case what will happen if you put B 1 is equal to 2 beta 1, then we have to just hold on when B 1 is equal to 2 beta 1 here right here.

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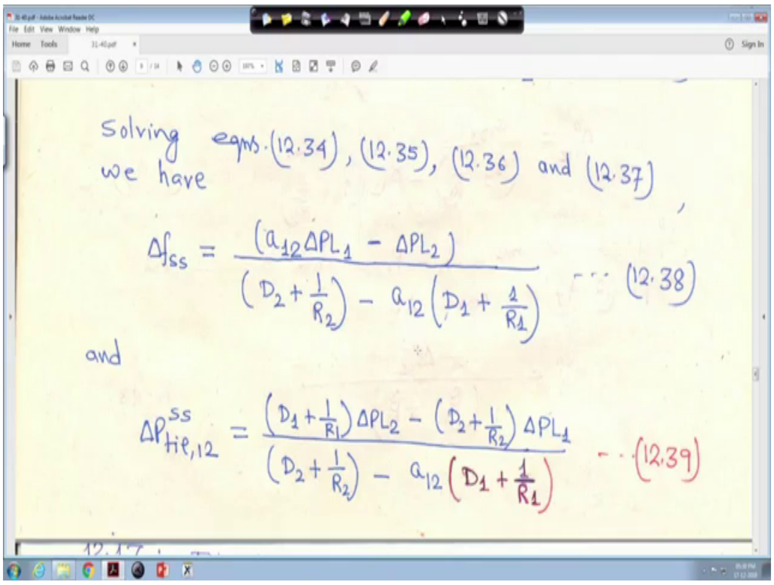

So, in this two equation I mean whatever we are made it from here that your B your in this expression just you make it that your B 1 is equal to beta 1 is equal to your B 1 and beta 2 is equal to B 2 right. So, whatever it is now we are changing it that we are making it to that your what you call that your B 1 is equal to 2 beta 1 and B 2 is equal to 2 beta 2.

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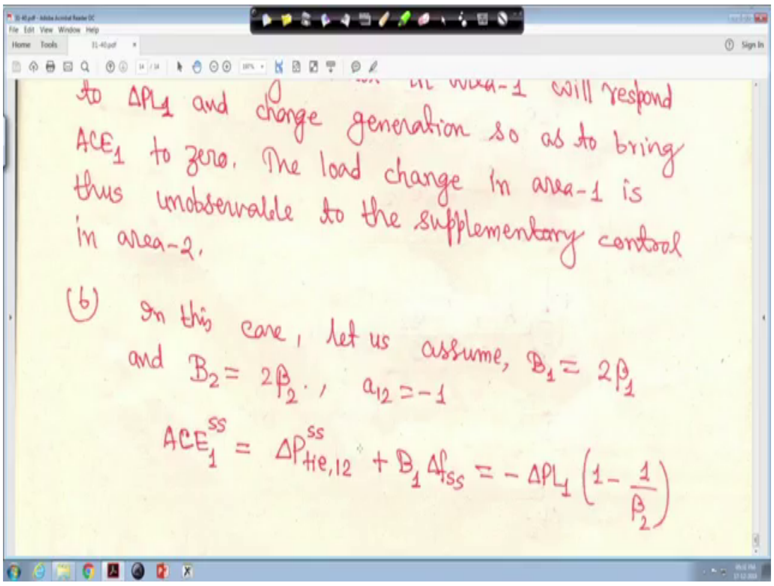

So, in that you just put it and simplify, then you will get this expression this what you call this expression this delta P tie 12 ss plus B 1 delta f ss will be minus delta P L 1, then

1 minus 1 upon beta 2. So, if you look into this, then you will see it is not simply minus delta P L 1 another term is getting added right.

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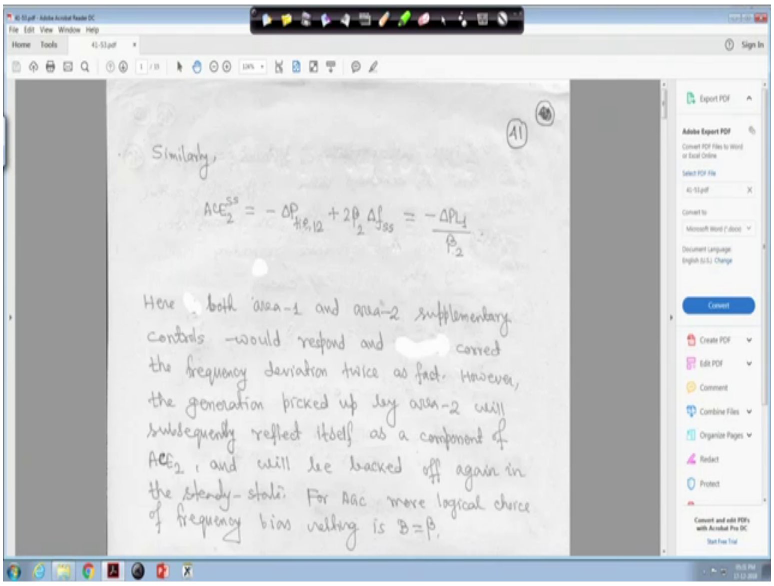

So, similarly for area-2 right similarly for area-2 if you look into that that ACE 2 ss will become if is minus because a 12 is minus 1 minus delta P tie 12 plus 2 beta 2 delta f ss right. So, in that case it will simply become that your what you call that your will become minus your delta just hold on minus delta P L 1 upon beta 2, this means this means what that a steady state ACE 1 also some showing some steady state error.

And in this case ACE 2 also showing some steady state error, it is not 0 it is minus delta P L 1 upon beta 2 right that means, if we say such kind of thing in that case B greater than beta that area-2 your what you call that your generator also has to respond to generate this amount of power at the steady state, so that is not desirable. So, best choice for AGC is b is equal to beta ok.

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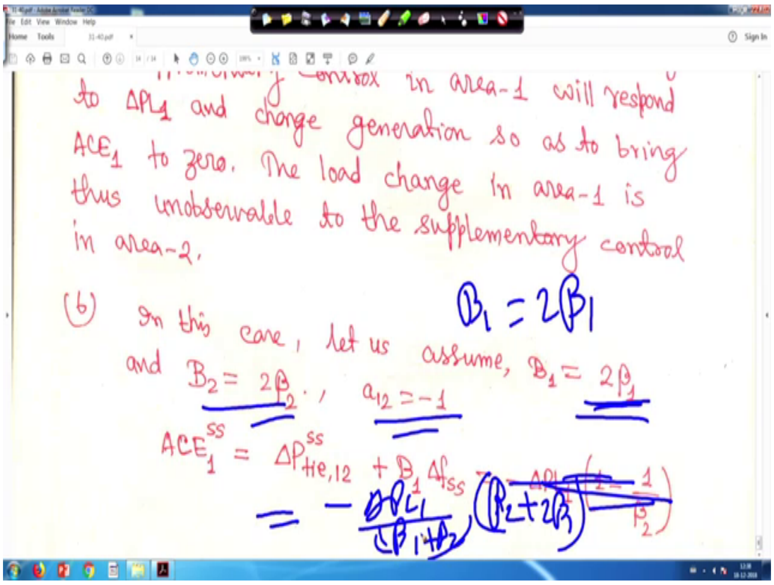

Next will see that when previous case, we saw that when B 1 is equal to B 2 is equal to your B 1 is equal to beta 1 and B 2 is equal to beta 2. But, in this case we will see that your B 1 is equal to 2 beta 1. And B 2 is equal to 2 beta 2 and A 12 is equal to minus 1. Then if you find out this one you forget about this thing, if you find out that ACE ss is equal to delta P tie 12 ss plus B 1 delta f ss, but B 1 is equal to 2 beta 1 here it is right.

So, if you substitute and if you do it like this, then this will actually become that minus delta P L 1 divided by B 1 plus beta 1 plus beta 2, then into beta 2 plus 2 beta 1 right. So, in this case it is not minus delta P L 1 into your beta 2 plus 2 beta 1 upon beta 1 plus beta 2 right. This is your ACE 1, so ACE 1 is not becoming actually minus delta P L 1 right.

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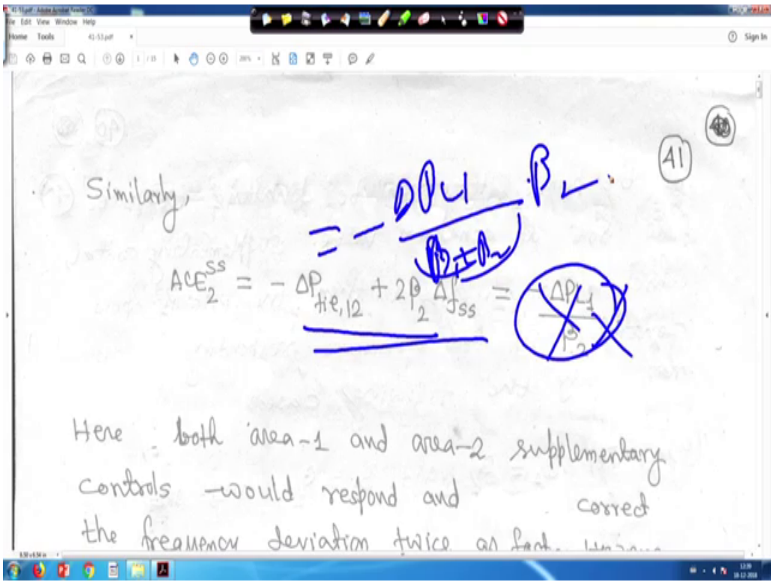

So, next will go to your next so similarly for the next one that your minus delta P tie I want forget about this one right. So, in this case your if you substitute all these things if you substitute all these things, it will actually become just check from yourself minus delta P L 1 divided by beta 1 plus beta 2 into your beta 2.

So, we can see that on the both the cases for a c in this case ACE 2 ACE 2 ss is not 0, as when B beta B 1 is equal to beta 1 and B 2 is equal to beta 2. At that time it was yes it was 0, but in this case it is not that means, what does it signify. Actually it signifies that if we not say that B is equal to beta, then your generators in area-1 will generate some power, similarly area-2 generator also they will also respond to this right. So, most therefore the most logical choice for B is equal to your what you call that B is equal to beta right.

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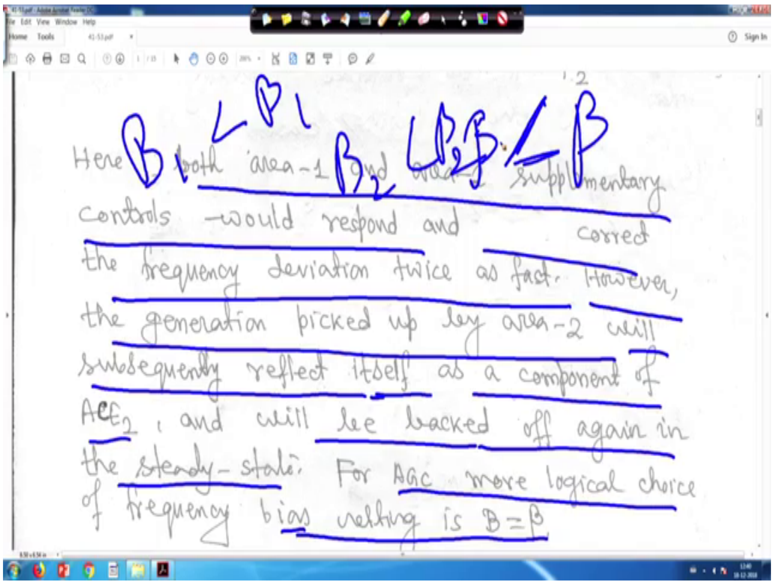

So, whatever right up is written here that your that in here both area-1 and area-2 supplementary controls would respond and correct the frequency deviation twice as fast. However, the generation picked up by area-2 will subsequently reflect itself as a component of ACE 2 and will be backed off again in the steady-state. For AGC more logical choice frequency bias setting will be B is equal to beta right.

And another thing is there that b also, it cannot be you it cannot be less than beta right, so that is not desirable the reason that your what you call there is a question to you that why B cannot be less than beta that means, B 1 it if you out B 1 less than beta 1 and B 2 less than beta 2 that is actually not the correct choice there is some reason. So, this is a question to you right. So, next will go to the regarding integral controller of your what you call to various system.

So, thank you very much, will be back soon.