Power System Dynamics, Control and Monitoring
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Lecture – 43
AGC in deregulated system (Contd.)

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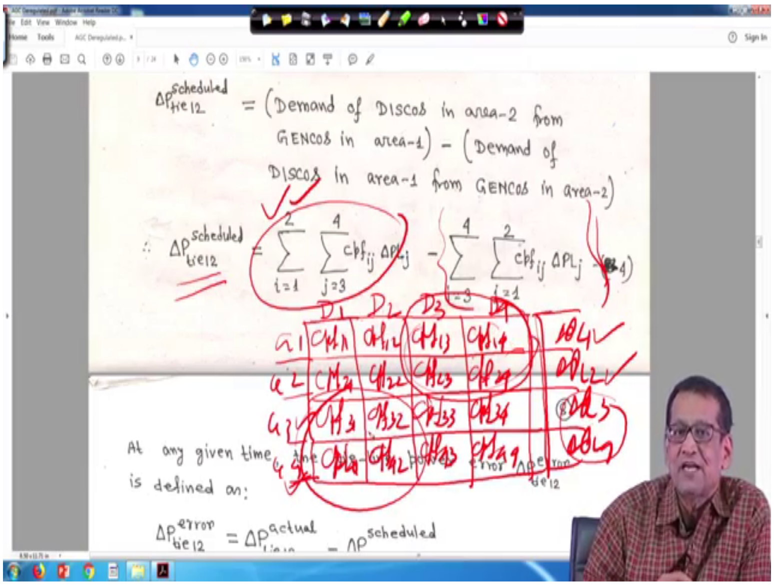

Ok, we are back again. So, in the previous lectures, we have seen that delta P tie 12 that scheduled type power flow that is sigma i is equal to 1 to 2, j is equal to 3 to 4 cpf cpf ij into delta P L j right, and this is minus i is equal to 3 to 4, and sigma again j is equal to 1 to 2 cpf ij delta P L j. So, this one we have actually discussed, and told you how to do this.

So, basically, basically what happened that suppose you have a you have your that cpf matrix right, cpf matrix. So, say I am just two DISCOS and two GENCOS are there in each area, so this way I am making it right. So, there will be 14 into 14, 16 element. So, DISCO means say this is DISCO 1, I make D 1 in short, say D 2 DISCO 2, DISCO 3, and DISCO 4, four distribution companies. And this is your GENCO 1, and this is your GENCO 2, this is your GENCO 3, and this is your GENCO 4 right.

So, here you have this participation a contract participation factor, this is cpf 11, then cpf 12, then cpf 13, then cpf 14 right. Then cpf 21, cpf 22, then cpf 23, then cpf 24 right. Then cpf 31, then cpf 32, then cpf 33, then cpf 34 right. Then this one is cpf over write even it, does not matter cpf 41, then cpf 42, then cpf 43, then cpf 44 right. So, if you look into this equation, then first thing is that you have a a distribution company is 1 and 2 are in area-1, and G 1, G 2 GENCOs are in area-1. And distribution companies D 3 and D 4 are in area-2, and power is being drawn from 1 to 2 by this distribution companies.

So, D 3 that it has and you are what you call, and this side that four distribution companies power demand is this is if this will be very easy to understand, I mean easy way to understand delta P L 2, delta P L 3, and delta P L 4 right. So, distribution companies you are in area-2 that is D 3 that is DISCO 3 has contract with generating unit in area 1 that is cpf 13 multiplied by your delta P L 3.

So, the first term will come cpf delta 1 your 13 delta P L 3. Similarly, cpf 14 with j your that distribution company in area-2 that is distribution company 4 DISCO 4 has contract with your generating company in area-1 that is G 1 that is cpf 14 delta P L 4; so cpf 13 delta P L 3 plus cpf 14 delta P L 4. Similarly, distribution companies in area-2 that is D 3 that is DISCO 3 has contract with GENCO 2 in area-1 that is why second term will come cpf 23 delta P L 3 plus your distribution companies area-2 that DISCO 4 has contract with G 2 that is your cpf 24 into delta P L 4, so this term is coming because of this block because of this block right.

Similarly, and the distribution companies in area-1 right, it is drawing power if it has a contract that is in area 2 that is GENCO 3 and GENCO 4. So, this is distribution companies D 1, if you look into that that it has a suppose it has a contract with cp 31. So, look into that when i is equal to 3 cp 31, then delta P L 3 right. Then cp then distribution companies 2 also have some contract with a generating companies is 3 in area 2, so that it is cp 32 you are sorry cp 31 into delta P L 1, then cp 32 into delta P L 2 right. So, this term is these two are attached with this one.

Similarly, if you take the distribution companies 1 and 2 has contract, whatever they have with your as your GENCO 3 and GENCO 4 right, then this part will come, so because of that you are what you call that which power will what power will flow through the tie-line, only this block is necessary and this not.

And these are the this block and this block basically that distribution companies are contract with their own generating companies that means the same area right, so that is why first you consider this part right, whatever it is this part minus that this part right and just you block it. So, this part whatever it comes cpf 13 into delta P L l3 plus cpf 14 delta 1 delta P L 4. Then cpf 23 delta P L 3 plus cpf 24 delta P L 4, this is that is this is this term minus here you take cpf 31 delta P L 1 plus cpf 32 delta P L 2, I mean everything you put in bracket right plus cpf your 41 delta P L 1 plus cpf 42 delta P L 2 minus inside that all this plus plus plus right.

So, this way you will easily get that what is the scheduled tie line power part, this is a simple to I told you number of distribution companies and your what you call generating companies, it may be different. So, it not necessarily mean that equal number of GENCOs and DISCOs will be there in each area, but this is the way. This is actually tie line power, I mean this block actually it is from 1 to 2, and minus because direction is your what 1 to 2 minus it is 2 to 1 right. So, this way you can easily make it; so I am clearing this one right.

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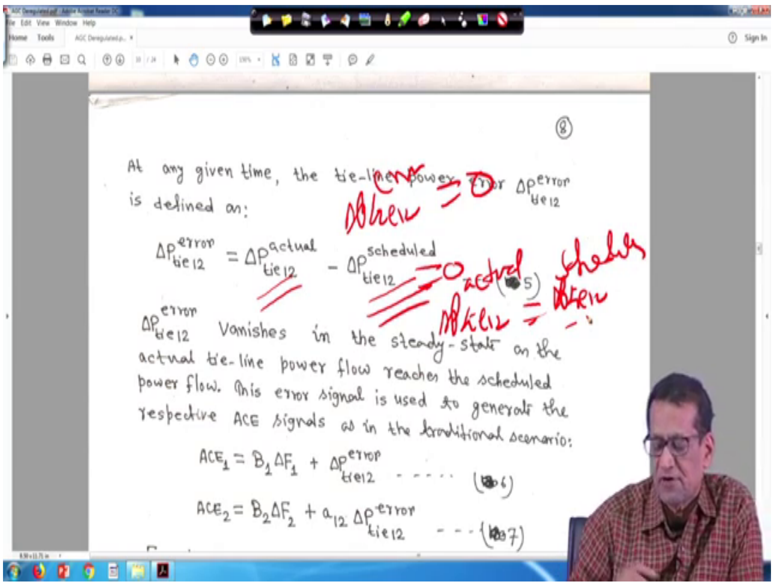

And say and then your just hold on, then that that tie-line power that error the delta P tie error, it can be defined as delta P of P y delta P tie 1 2 actual right minus delta P tie 1 2 scheduled right. So, this power is known this power is known, because we know how much power will flow, and this power actually actual one will come through your simulation. So, at steady-state at steady-state that delta P tie 12 right error has to be 0. So, if it is 0, then a steady-state that delta P tie 12 that actual right, because this is equal to 0, because error is 0 will be is equal to delta P tie 12 that your scheduled power, this has to happen.

And next one is that delta P tie error vanishes your that your delta P tie 1 vanishes right in the steady-state. So, I told you it will be 0, and actual tie-line power flow reaches the schedule power flow, this error signal is used to generate the respective ACE signal as in the traditional scenario. So, there we are also taking that ACE 1 is equal to b B 1 delta F 1 right plus delta P tie 1 2, but here it is deregulated deregulated environment that error is nothing but the actual minus scheduled, because you have the contract, so that is why the scheduled power flow will come. And ACE 2 will be B 2 delta F 2 plus as usual a 12 delta P tie 12 error. So, this is equation 6, this is equation 7, this is that your area control error right.

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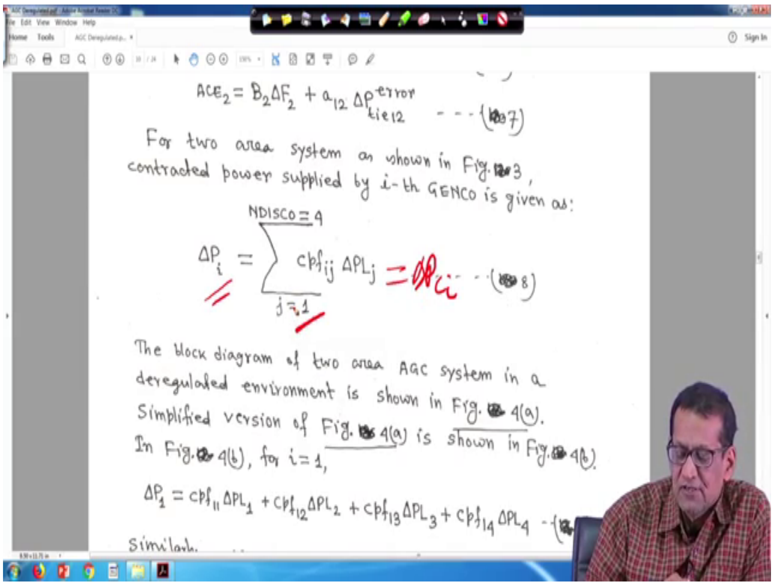

So, now for two area system as shown in the figure-3 right, contracted power supplied by ith GENCO is given as that is your j is equal to your j is equal to 1 to number of distribution companies are 4, because in area-1 two distribution companies, area-2 two distribution companies. So, NDISCO is equal to 4, so contracted power will be actually sometimes we define that this one is equal to delta P ci, but here I have written delta P i it is ok.

But, next when you will take the load following another version, if they are I have taken delta P ci, they are same. So, it is j is equal to 1 to your NDISCO 4 cpi cpf ij delta P L j.

In general in general for better understanding, just I am overwriting look at that say this is this is just hold on.

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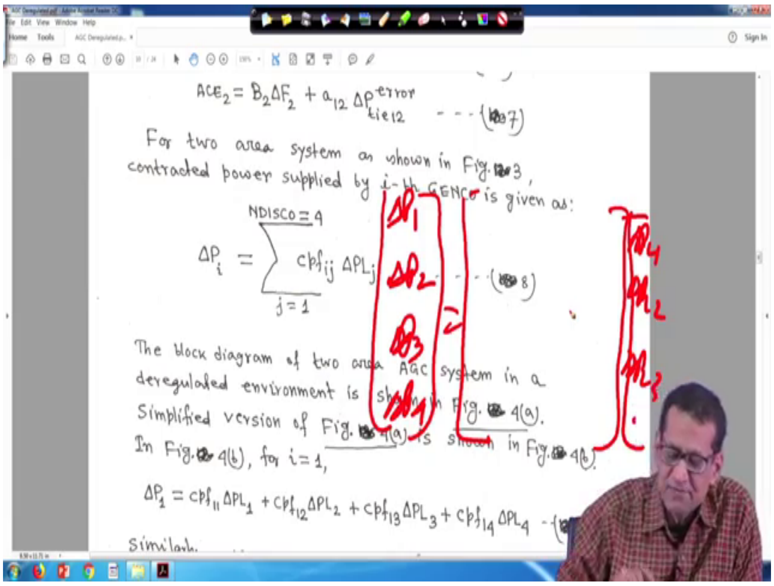

Suppose, this is delta P L 1 for your better understanding, say delta sorry delta P 1, delta P 2, delta P 3, delta P 4 right. So, this one where how what you will get that you make your cpf matrix that is your due to the space problem, I am just making it here. Say this is your delta P L 1, delta P L 2, delta P L 3 just hold on just hold on, let me enlarge this one just hold. So, suppose it is your that delta P i like this, so you can I am just overwriting see how is it, say this is my just hold on.

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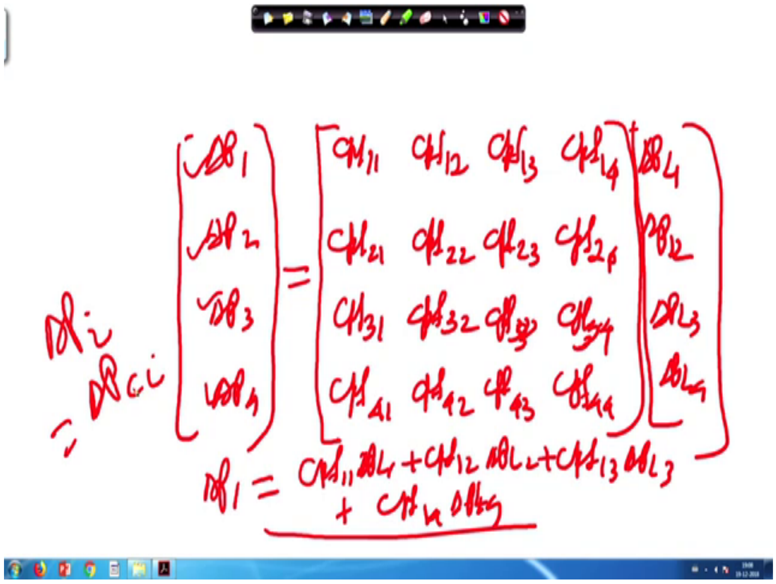

Say this is delta P 1, this is delta P 2, this is delta P 3, and this is delta P 4, there is a contracted power demand right, what will be that contracted power demand is equal to you can make it that yeah your this one that your cpf 11 cpf 12 cpf 13 and cpf 14 right, then cpf 21 cpf 22 then cpf 23 and cpf 24 right, then cpf 31 then cpf 32 then cpf 33 and then cpf 34 right, then cpf 41 then cpf 42 cpf 43 and cpf 44 this way you write in into this one delta P L 1, delta P L 2, delta P L 3, and delta P L 4 you write.

So, this way if you put this is a contracted power demand right that is what is your what you call by GENCO 1, GENCO 2, GENCO 3, and GENCO 4. So, in that case you can write that that means delta P 1, for example one I am writing delta P 1 is equal to cpf 1 1 delta P L 1 plus cpf 12 delta P L 2 plus cpf 13 delta P L 3 plus cpf 14 delta P L 4 right. So, this is a contracted power for your what you call for GENCO 1 I mean your, similarly delta P 2 also cpf 21 delta this way you can find out.

So, if you as delta P L P L 1, P L 2, P L 3, and P L 4, these are all the power demanded by that four different distribution companies in this case. And cpf is the contract participation factor, which will be specified. So, you will be knowing contracted power demand delta P 1, delta P 2, delta P 3 delta. So, generally we writing we write delta P i actually contracted power, sometimes we write delta P ci, c stands for contracted power same thing right. So, this is how this is how we can get it the directive or what you call that contracted power demand.

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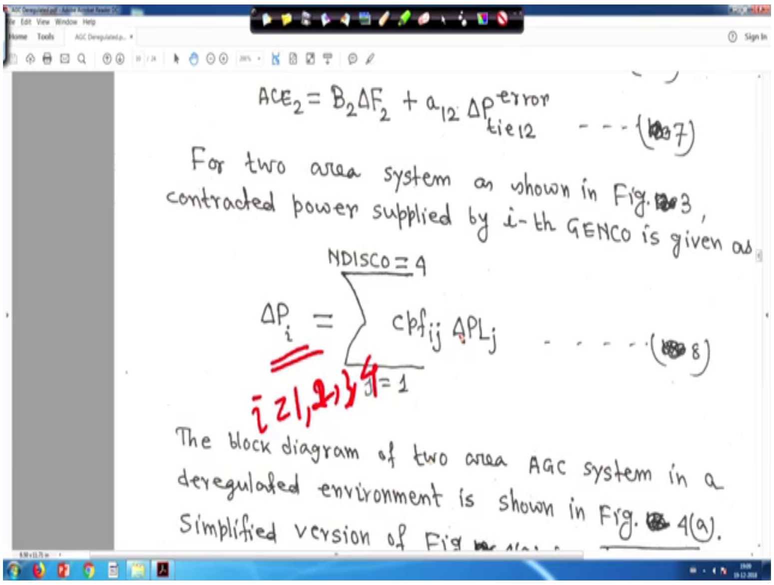

So, same thing actually same thing right whatever we have written here same thing here also in same thing here you have we have written here the j is equal to 1 to NDISCO. If you put i is equal to 1, then it will be cpf 11 delta P L 1 cpf 12 delta P L 2 cpf 13 delta P L 3 plus cpf 14 delta P L 4. If you put i is equal to 2, so you will get delta P 2, so it is j is equal to upper ith ith GENCO. And for this case i is equal to 1, 2, then 3, then 4 right. So, you will get delta P 1, delta P 2, delta P 3, and delta P 4.

But, that matrix form if you write, so no need to recall this one easily you can get it right. So, the block diagram of two area AGC system in a deregulated environment is shown in figure-4a, I am coming to that. So, simplified version of figure-4a is shown in figure-4b. For i is equal to 1, I showed you that delta P 1 is this one, this I showed you so in the matrix form, just now I showed you right.

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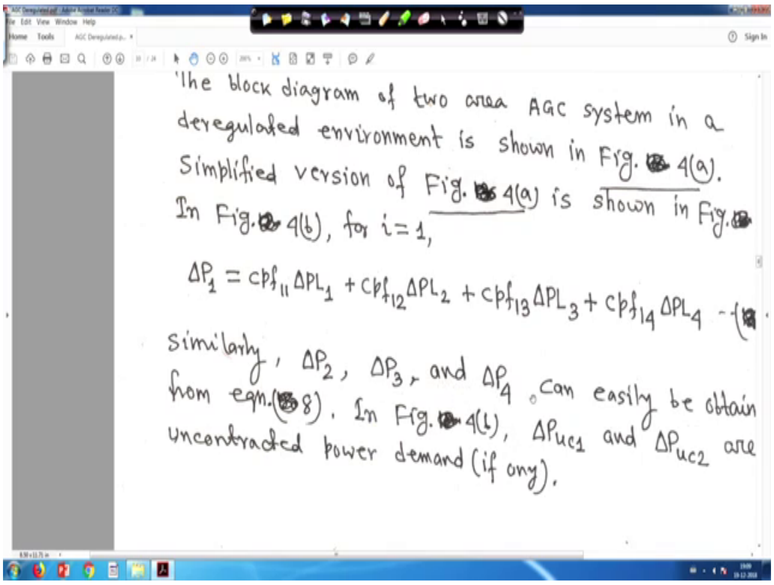

Similarly, you can get delta P 2, delta P 3, and delta P 4 right. And another thing is that in figure-4b, I am coming to that delta P uc1 and delta P uc2 are uncontracted power demand if any, it is what is uncontracted power demand, I will come later.

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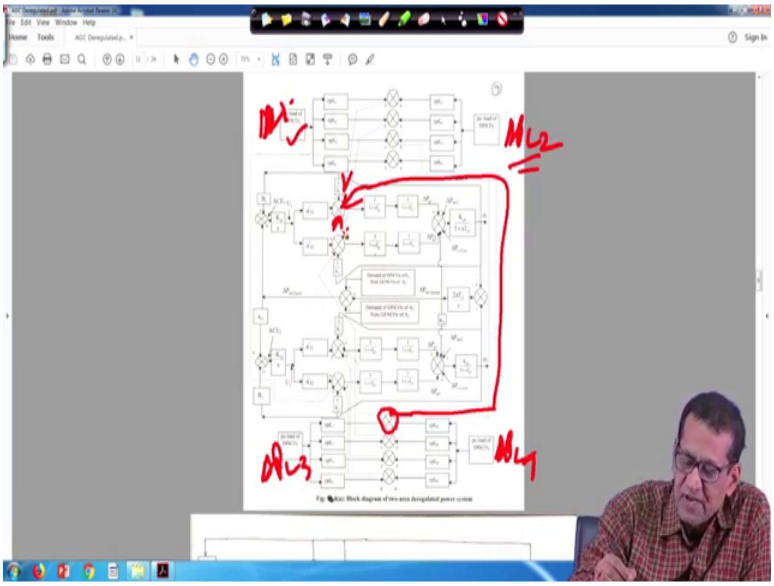

So, this is actually I have to reduce that size just hold on, it will be readable for you, when you will read it, but you will get the nodes right. Unless and until full block diagram, I cannot do this it is very bigger one. So, in this case you are in this case if you look into that that in area-1, two generation companies are there that is my this one, one is this 1 GENCO 1 and GENCO 2.

Similarly, area-2 you have 2 generation companies that is this one, and this one, this that transfer function module is given right. And already we have seen for conventional two area interconnected system. In area-1, two distribution companies are there that is power unit load of DISCO 1, and power unit load of DISCO 2 that is in area-1. And area-2, you have another distribution companies power unit load of DISCO 3 and power unit load of DISCO 4 right.

Now, how will conceive this block diagram, because in deregulated system block diagram is as your certainly different. Now, we have seen just now we have seen that contracted power demand for this unit for this unit right, just you have seen that cpf 11 delta P L 1 plus cpf 12 delta P L 2 plus cpf 13 delta P L 3 plus cpf 14 delta P L 4 right. So, in this case for that that delta P L 1 is the power demanded by the distribution company 1 delta P L 1. Similarly, for this one, it is delta P L 2 right, similarly for this one it is delta P L 3, and this is your delta P L 4 that is the total power demanded by this distribution companies.

So, if you look into this just see that this is delta P L 1 multiply this 1, so cpf 11 delta P L 1, this is delta P L 1, because this distribution company 1. Then this is delta P L 2, so it is cpf 12 delta P L 2 right. So, all these things coming together look; so these two going to that this one, but two more terms will be there. Then what is there that cpf 13 delta P L 3 and cpf 1 4 delta P L 4, they are also coming if you look into this, they are also coming here right here also coming this one that means, and here also cpf 11 delta P L 1 cpf 11 delta, this is also coming here is the summing junction, so that is your delta P 1.

The contracted power demand that cpf 11 delta P L 1 plus cpf 12 delta P L 2 plus cpf 13 delta P L 3, here it is cpf 13 delta P L 3 plus cpf 14 delta. All are coming to this your what you call mathematically what the GENCO has the contract here; so all are coming together right. So, similarly so this one I am clearing, so similarly if you look into this that cpf 21 delta P L 1 plus cpf 22 delta P L 2, these two will be coming in will be coming here right for this one.

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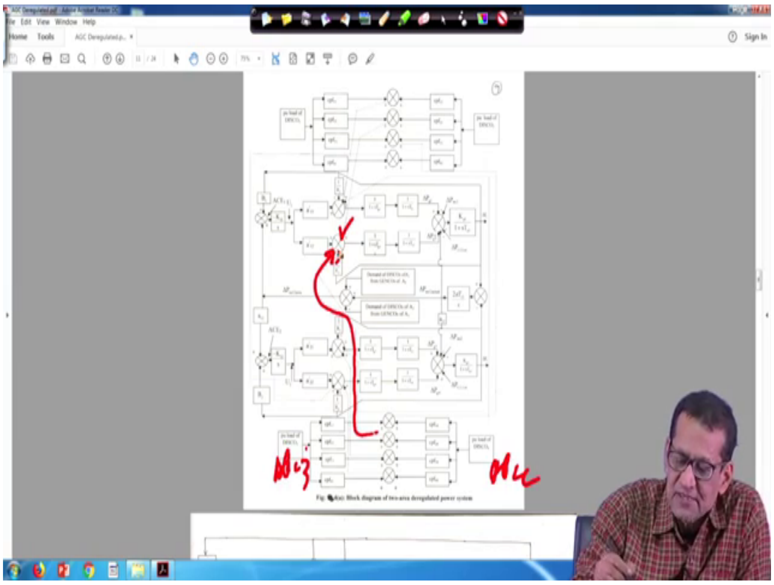

Then cpf 23 delta P L 3, this is your delta P L 3 for DISCO 3, this is delta P L 4, already I have told you understandable to right. And cpf 24 delta P L 4, if you look into that they are also coming to that GENCO 2, so that means that you have to give the feedback the total contracted power here. So, for example here total here the total contracted power feedback, I told you. If you sum it up, it will be delta p P 1. Similarly, here it will be delta P 2 right.

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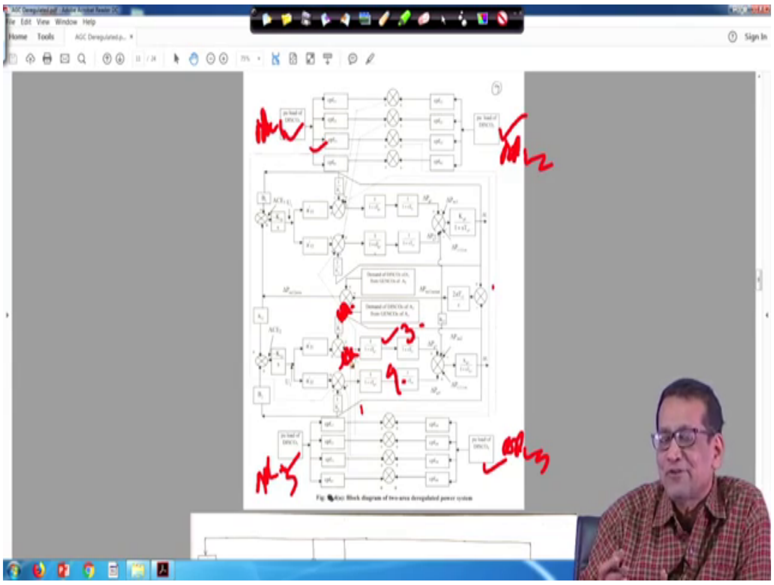

So, similarly if you see here if you see in the area 2 right area-2, where you have if you look into that, then for your delta P 3. So, this is your unit 3 this is your unit 3 for area-2, and this is GENCO 3, and this is your GENCO 4. So, you when it is coming to your GENCO 3, then your delta P 3 will be cpf 31 right delta P L 1 plus cpf 32 delta P L 2.

So, if you look into this cpf 31 delta P L 1, and this is your cp this is actually DISCO 1 delta P L 1 demand, DISCO 2 delta P L 2 demand, DISCO 3 delta P L 3, and DISCO 4 delta P L 4, this way I have seen. I have already just mentioned right it. So, here it will be cpf 31, and this is your delta P L 1, and this is your data P L 2. So, cpf 31 delta P L 1 and cpf 32 delta P L 2 add it, and if you look into that right, it will be coming to this unit 3 right.

And similarly, your what you call similarly if you if you take now cpf 31 32, now cpf 33 and cpf 34, so this is see delta P L 3, and this is delta P L 4. So, cpf 33 delta P L 3 plus cpf 34 delta P L 4 if you come like this, you will see that your it is coming to this unit 3, just hold on this is your coming this is your coming to the unit 3 right.

And here also other one also coming to your unit 3 that is your cpf 31 delta P L 1 plus your cpf 32 delta P L 2 right, it at look into that it is coming coming coming, and it is your what you call it is coming like this, and you are basically it is getting added here right it is very bigger block diagram, so that is why a little bit your this thing little bit your the little not here it is here, so that is why little bit here complicated. When you will get this note, at that time you will enlarge it and just see this right.

Similarly, other one is delta P 4 same as this at cpf 41 delta P L 1 plus cpf 42 delta P L 2 plus cpf 43 delta P L 3 plus cpf 44 delta P L 4 right. So, all these thing 41 delta P L 1, and 42 delta P L 2, it is taken from here it is coming like this it is coming like this it has come here. And from here also 43 delta P L 3 and 44 delta P L 4, it has come here right. So, this is actually you are that whatever contracted power demand will come, so that mathematically you have to model. So, basically what happened, all feedback you have to give at this point right, so input to the governor turbine right.

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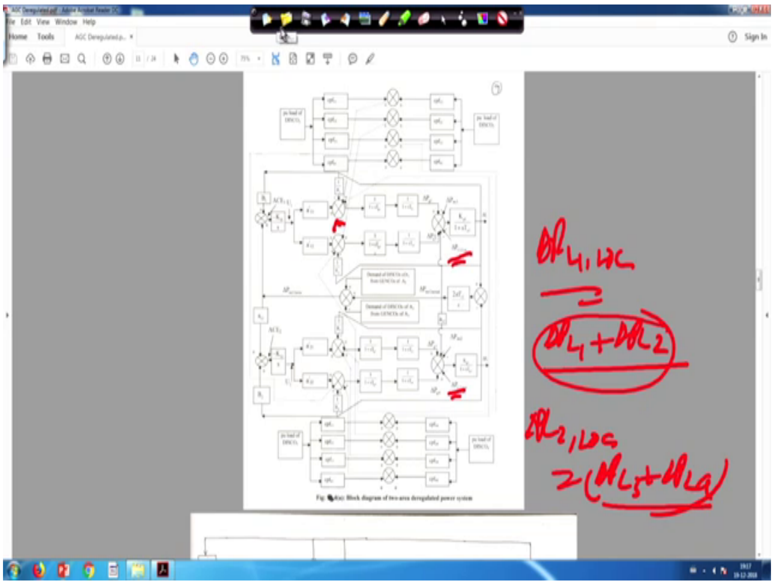

Now, next is your what you call that delta your P L local right, so what you have to see is that your delta P L local I am writing here that delta P L 1 local. Local means, that you are you have two distribution companies in area-1, their total power each distribution companies demanding powered delta P L 1 and delta P L 2 respectively. So, delta P L 1 local will be delta P L 1 plus delta P L 2 right, so that is why delta P L 1 local means, it is delta P L 1 plus delta P L 2 right.

So, similarly when you come to delta P 2 local, so area-2 you have that to your distribution companies, their power demand is delta P 3 and delta 4, because DISCO 3 and DISCO 4. Therefore, that delta P L 2 local is equal to delta P L 3 plus delta P L 4. So, this is actually delta P L 2 local, actually nothing but delta P L 3 plus delta P L 4 that is the meaning.

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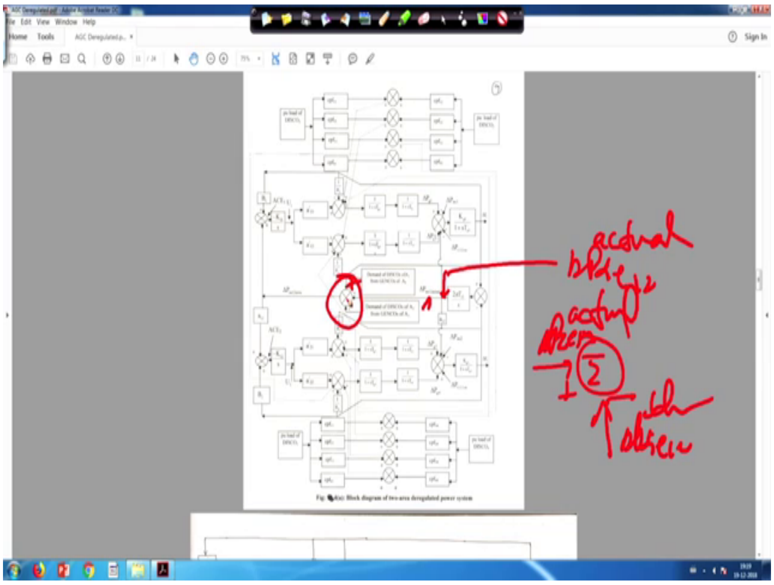

Next if you come here that this is actually this is delta this part that is a tie-power, this is actually delta P tie 12 actual. This is actually delta P tie 12 actual, so that is written here also. And this is actually delta P tie 12 scheduled, so actually what happen a look, the first term of that equation that whatever we have we wrote that equation that are the delta P tie 12 your scheduled value.

So, demand of DISCOs of area-1 A 1 means, area-1 from GENCOs of A 2 that is area-2, so that is why this plus sign is taken and minus demand of discos of A 2 from GENCOs of area-1, so that is your minus. So, this actually give delta P tie 12 scheduled power right. And this is actually and this is delta P tie 12 actually your what you call that your actual one; so these are compared here, these are compared here.

So, basically when it is compared means, this is your put sigma. So, if this is my delta P tie 12 actual right, and this is my say minus delta P tie 12 that is your scheduled power right, so that that is why it is it is made like this for just understanding. And then output of this one, it is nothing but delta P tie 12 error that error signal.

And then this error signal, and this is your frequency area-1 frequency is deviation is delta F 1, and area-2 frequency is delta F 2. So, this delta F 1 is coming here through B 1, so B 1 delta F 1 plus delta P tie 12 error. And this output is nothing but the area control error of your what you call area-1 right. Similarly, if you look into this that area control error a ACE 2 means, this is your del F 2. So, it is coming B 2 del F 2 here plus A 1 2 into delta P tie 1 2 error right, and here it is ACE 2 right.

Then now I am clear in it then this is integral control error in area-1, and this is integral control error in area-2, we have taken integral control only. But, if you want but you can you can you are what you call you can choose other types of controller. But, from practical point of view, generally that utilities were using this into a controller, generally they prefer that you are integral controller are proportional integral controller, but not derivative controller for thermal system right.

So, actually derivative controller for thermal system is not recommended right. So, the so and their and their gain of this, because every unit has your that your generation rate constant right, and this is a physical constant for the from the point of view of the thermal units, so that is why the gain generally will be very small right may be 0.1 or below that in reality when your considering the generation rate constant.

And in that case, what will otherwise what will happen that system will become unstable right very small integral gain, and proportional also may be very small, but integral gain is preferable. But, if you want to (Refer Time: 25:00) I told you for hydro system it is a derivative is ok, but for thermal system that derivative action is not recommended derivative type, you find out that why it is right.

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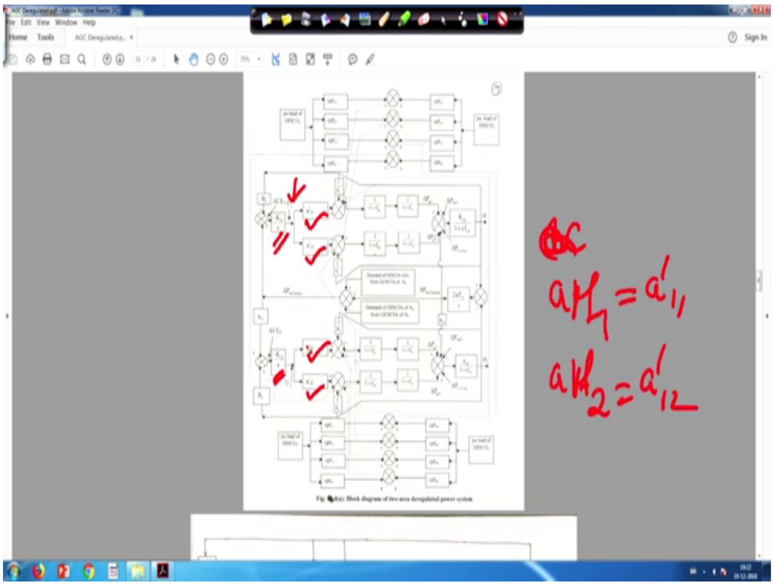

So, next is so after this the output is u 1 that is the controller it is u 1 is nothing but you are a minus K I 1 integral of ACE 1 dt. Similarly, u 2 is equal to nothing but you are minus K I 2 integral over what you call minus K I 2 that integral of ACE 2 dt right. And then this A 1 1 dash, and A 1 2 dash, and similarly A 2 1 dash and A 2 2 dash, we call this is ACE participation factor. Sometimes we use that ace a your what you call ace participation factor, sometimes we use that is apf right.

So, basically apf say one is equal to I can make it that a dash 1 1 that is area per ace ace participation factor. Similarly, for unit 2 ace participation factor a that is nothing but your a dash 12 right, so similarly here also. But, I have made it just to made the symmetry that a dash 1 1 a dash 1 2, then a dash 2 1, a these are actually ace participation factor.

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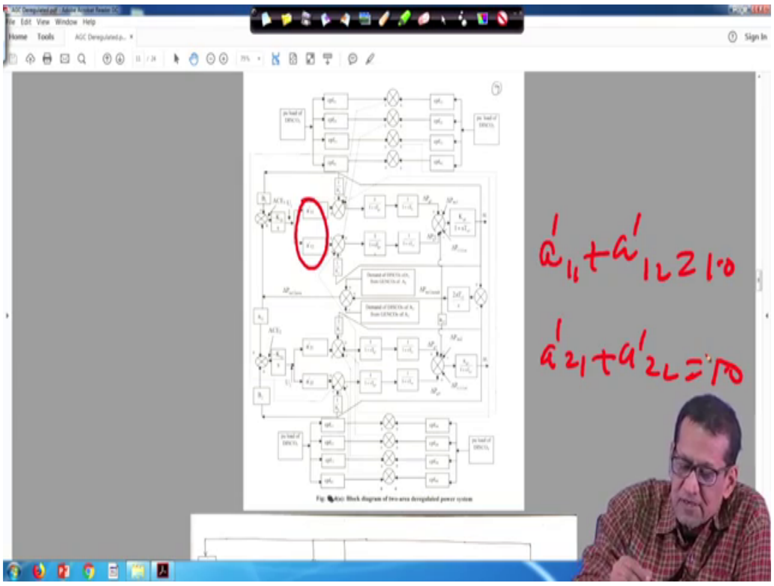

But, as long as long as your scheduled power everything is ok, then this whatever value you put right. And there mathematically a dash 11 plus a dash 12, it has to be is equal to 1 right. Similarly, in area 2 let a dash 21 plus a dash 22, it also has to be 1.0 right, so it has to be one.

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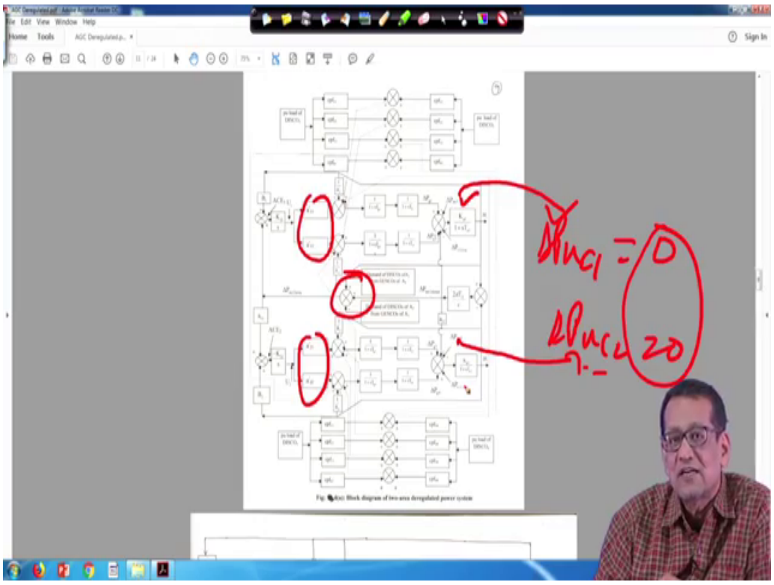

So, this actually this one, and these two term as long as it has effect on the your on the during transient behaviour right, but at steady state as long as you are un as long as they are effect may not be there, when that uncontracted power demand delta P u c 1 is equal to if it is delta P u c 1 0, and delta P u c 2 0, this is actually uncontracted power demand.

And this is also you are here also this is actually uncontracted power demand that means, that distribution companies, they have some contract power with the different generation companies, but all of a sudden. If anywhere any distribution company, they want extra power which was not in the contract that is also called uncontracted power demand right, and that is why this is reflected here delta P u c 1, and this is reflected at delta P u c 2.

If this is 0 if there is uncontracted power demand, then this participation that ace participation factor has no effect on the steady state right, only it has effect during transient condition. Otherwise, at steady-state, it has no effect right. So, the now what difference you saw from the conventional and this one that deregular system you have a contracted power demand right.

And accordingly, you have to what you call that you have to formulate, so basic philosophy remain same, only thing is that that your one that every GENCO you are input to the governed turbine, one additional signal has come. Apart from that here the tie-line power here equation here change right, this is second thing. And third thing is that this delta that uncontracted power demand, and of course that your local load right, it will be reflected as here right, similarly delta P L 2 local right.

Thank you very much, we will be back again.