Power System Dynamics, Control and Monitoring
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Lecture - 45
AGC in deregulated system (Contd.)

So in the previous lecture we finished it here that case 2 right those data everything I have given.

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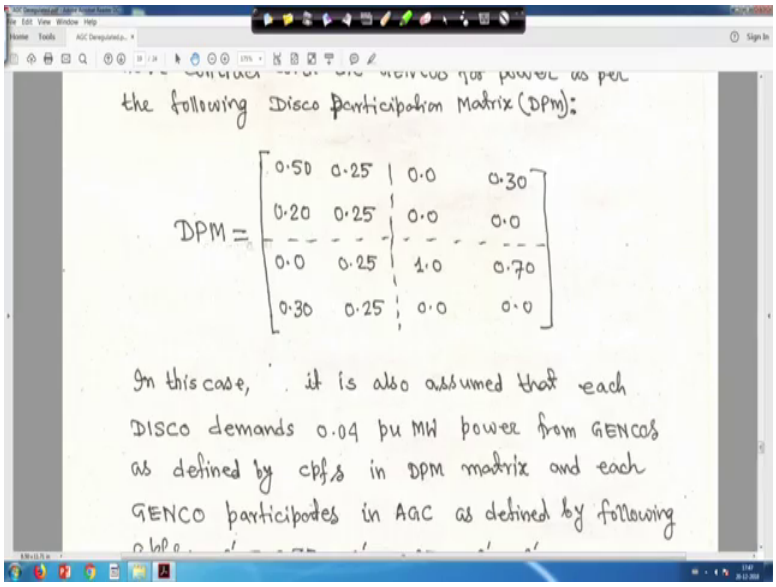

This is the Disco Participation Matrix DPM and based on that.

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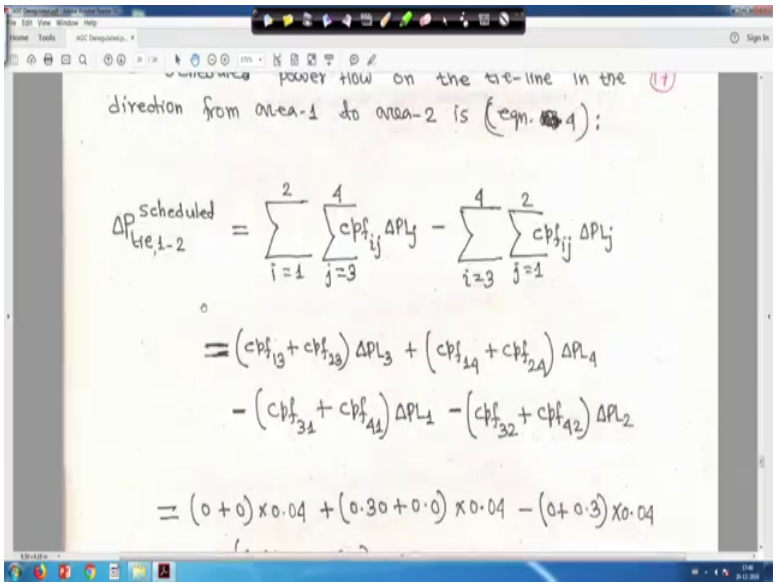

That your scheduled type power flow was calculated and it was minus 0.02 per unit megawatt.

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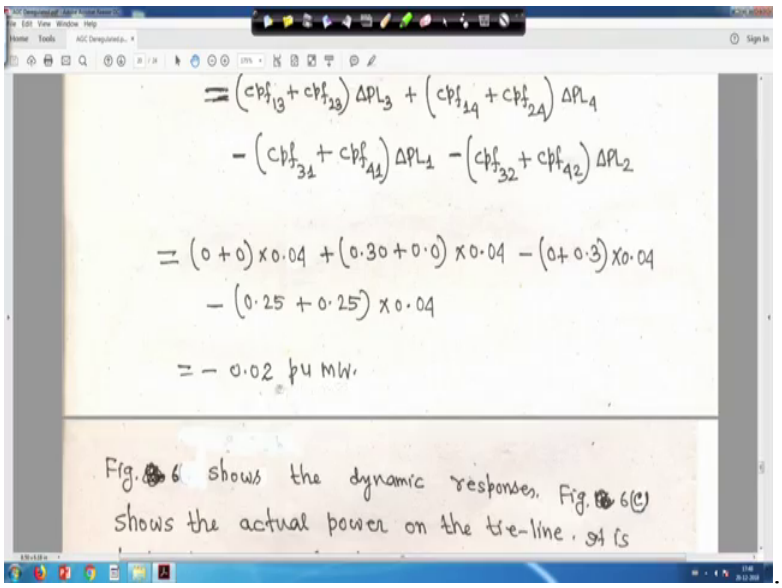

So, actual also will be minus 0.02 per unit megawatt at the steady state right. Now figure 6 was the dynamic responses. So, figures I will come later right I will come to that, but as given by equation 8.

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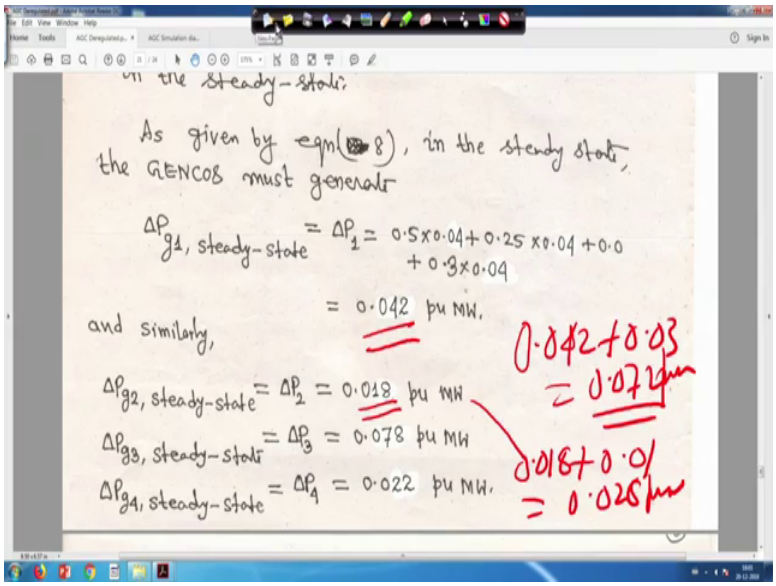

You can contact that steady state your power generated by each gencos, that is delta Pg 1 steady state is nothing, but delta P 1. So, you can easily calculate c pf 1 1 into delta P L 1 plus cpf 1 2 into delta PL 2 plus cpf 1 3 into delta PL 3. So, cpf 1 3 was 0 here right. So, cpf 1 3 was 0 and cpf 1 4 into delta PL 4, but pl delta PL 1 delta PL 2 delta PL 3 and delta PL 4 all are same 0.04 04 04. So, delta Pg 1 steady state will be 0.04 to per unit mega watt mega right.

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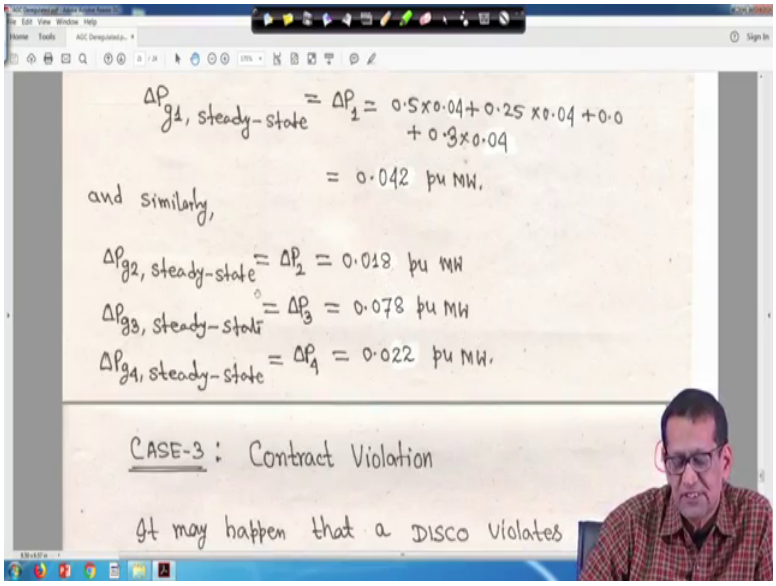

Now, similarly pg 2 pg 2 steady state is equal to delta P 2 and now you know everything delta P 2 is equal to cp f 2 1 delta PL 1 plus c pf you are 2 to delta P l 2 plus cpf 2 3 plus delta PL 3 plus cpf 2 4 delta PL 4. If you compute it will become 0.018 per unit megawatt. Similarly for delta Pg 3 steady state if you do it similar way it will be 0.078 per unit megawatt similarly delta Pg for steady state will be 0.022 per unit megawatt right now this is steady state. But when will see that your simulate your responses right.

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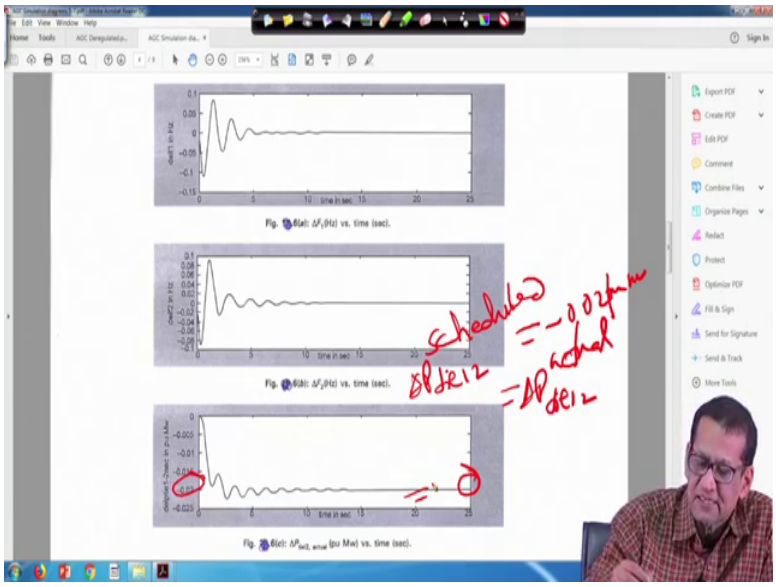

So, this is a figure 5 and but this is your now for the case 2 it is figure 6. So, frequency deviation a steady state it is going to 0 in area 1 similarly in area 2 also it is going to 0 right and delta P or P type actual when it is actually showing minus 0.02 look, that is delta P tie 1 2 that your schedule value we computed that is delta P tie 1 2 that schedule value was minus 0.02 per unit megawatt.

And here you are getting minus 0.2 per unit megawatt right and basically and that is your nothing, but that actual right this 1 actually delta P tie 1 2 actual because and the steady state where delta P tie 1 2 error will be 0. So, delta P tie 1 2 actual will be delta P tie 1 2 single power that is actually minus 0.02. So, just to give you a feeling of the dynamic simulation. So, this is the result right. So, similarly when you if you go to the generation right. So, this is delta P tie 1 2 error; delta P tie 1 2 error at steady state will be 0 because this is 0 0 line so, it is actually 0 right.

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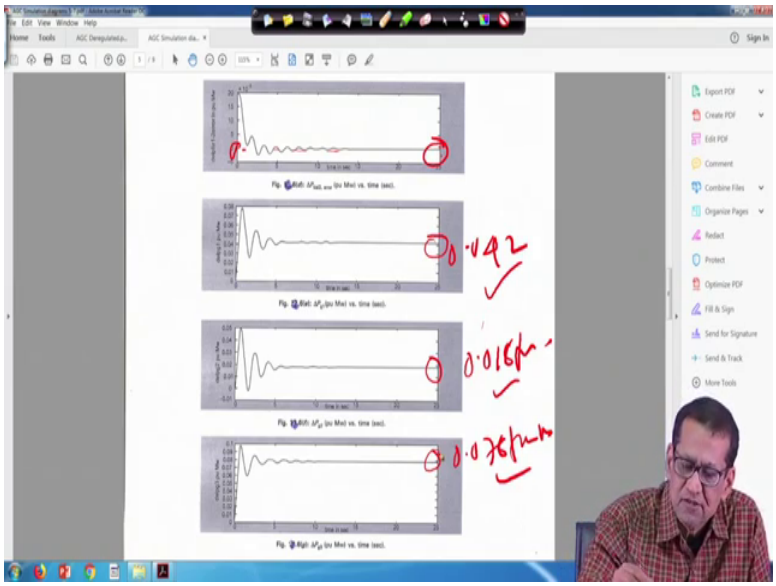

Now delta P g1 the generation if you see delta P g 1 per unit megawatt it is 0.042 at steady state. So, it is coming right. Similarly delta Pg 2 per unit megawatt it is 0 because if this is 0.042 per unit megawatt right similarly delta Pg 2 it is 0.018 per unit megawatt right and similarly delta Pg 3 as steady state your 0.078 per unit megawatt.

So, next I will come to your delta Pg 4 next page. So, all the things are matching at the steady state. During your transient imbalance or during transient some oscillations will be there finally, it will come to your steady state values right. So, and delta Pg 4 right and this is my delta Pg 4.

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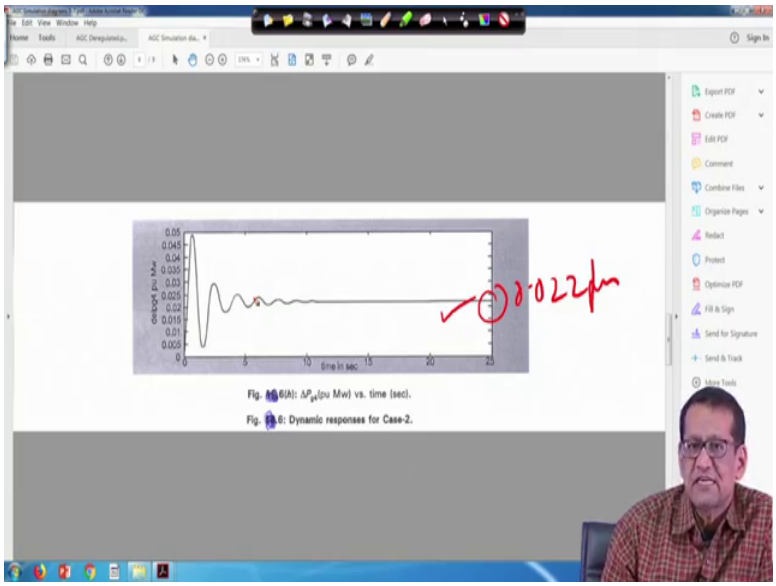

So, this is also your this one also at steady state, it is 0 point I think 0 2 2 per unit megawatt right. So, this is also matching in steady state. So, and then some transient when transient will disappear finally, this is to a steady state, but for the simulation for this thing no GRC was considered right that will see later, but no GRC was considered.

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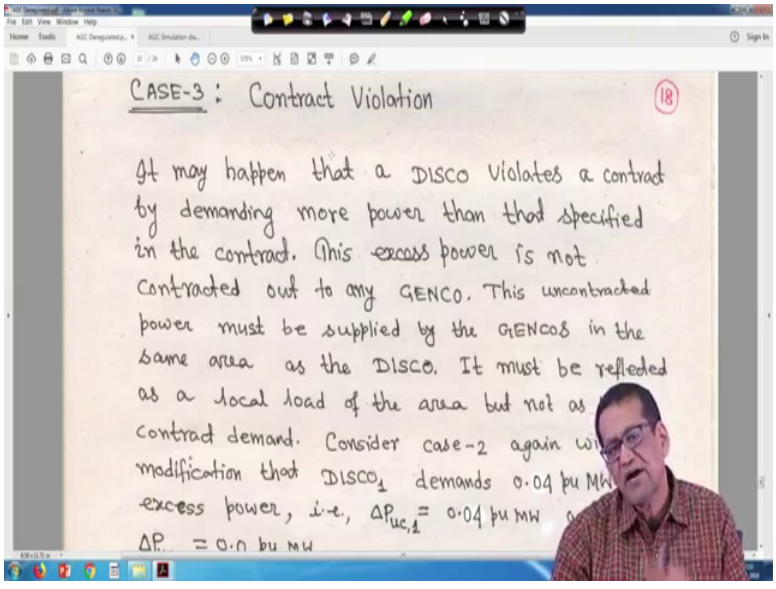

So, next is case 3 is actually we call is a contract violation right. Contract violation means suppose distribution companies they have some contract with different generation companies, but and based on that the contract participation fact contract participation fact

the DPM was formed. But when contract violation means suppose a distribution company is total contract power contracted power demanding you say 0.05 unit per megawatt, but all of a sudden it needs extra 0.02 per unit megawatt; so, which was not in contract. So, how to incorporate that uncontracted power demand in the model and simulation that we will see here.

So, it may happen that it may happen that DISCO violates the contract by demanding more power than that specified in the contract right. This excess power is not contracted out of any GENCO right. This uncontracted power must be supplied by the GENCOs in the same area as the discos right; that means, suppose in area 1 you have 2 distribution companies say DISCO 1 and DISCO 2 and 2 generation companies GENCO 1 and GENCO 2.

Suppose all of a sudden DISCO 1 demands some additional power which was not in contract. And it is expected that that power that power demand of the DISCO will be made by your GENCO in area 1 right; so, that was the idea.

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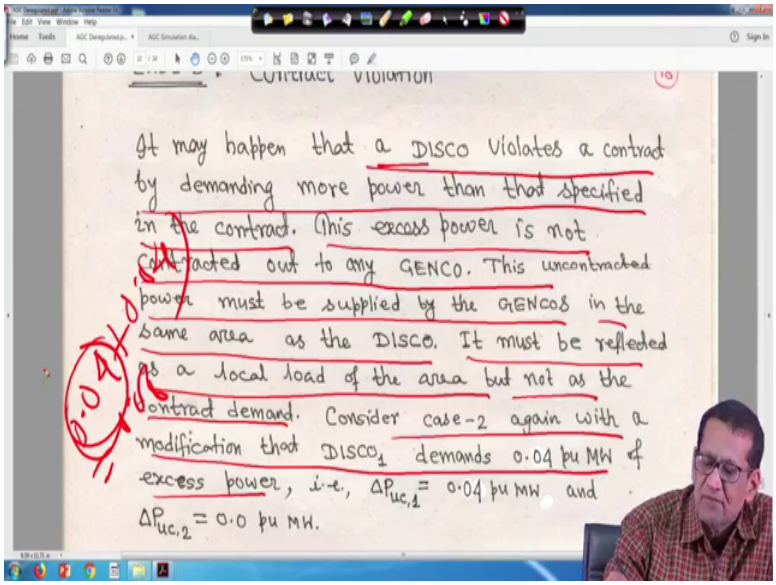

So, it must be reflected as the local load of the area, but not as the contract demand that is why in that block diagram in area 1 and area 2 it was shown delta P L 1 u c that is delta P L 1 uncontracted demand and in area 2 also delta PL 2 u c that delta P L 2 uncontracted demand.

Now, consider case 2 again with a modification that DISCO 1 demands 0.04 per unit megawatt of excess power. I mean it has a it has a contract power of 0.04 per unit megawatt, it has already 0.04 per unit megawatt in addition to that it also wants 0.04; that means, total now 0.08, but this 0.04 was contracted power, but other 0.04 that it has your that what you call that in area 1, 2 generation companies are there GENCO 1 and GENCO 2 and accordingly that this power will be supplied by that same GENCOs in the area 1.

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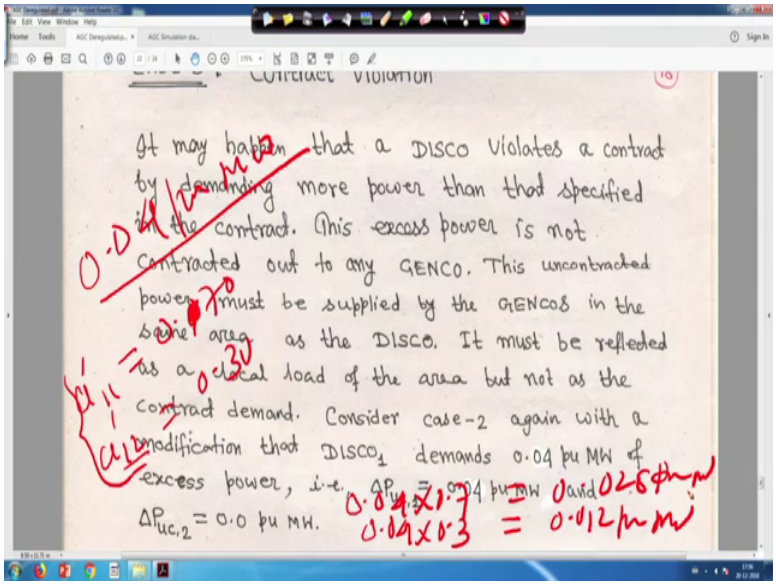

But how this my question is now that how this 0 point that additional 0.04 per unit megawatt power, how it will be decided by the your what to call by 2 GENCOs. It depends actually on the AC participation factor.

For example suppose if you choose in area 1 AC participation factor for GENCO 1, say it is 0.70 right and a dash 1 2 suppose it is 0.30 total has to be 1 so; that means, if you set these AC participation factor for example, then that GENCO 1 will generate 0.04 into sorry into your 0.70 right and this is 0.30. So, GENCO 1 will generate this one into 0.7. So, 0.028 per unit megawatt right similarly that GENCO 2 in area 1 because we have set the participation factor a dash 1 to 0.3. So, it will be 0.04 into 0.3 so, that is 0.012 per unit megawatt right, so, total is 0.04.

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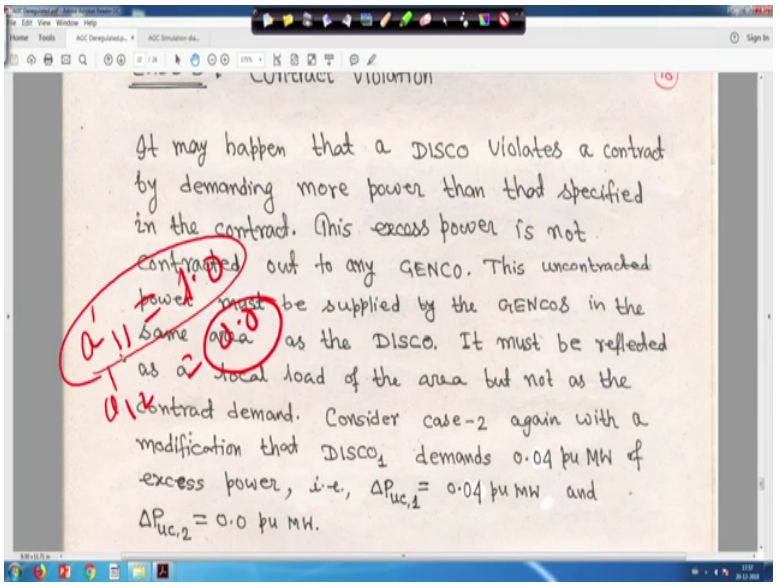

Now, suppose if I take a dash 11 is equal to 1.0 and a dash 1 2 is equal to 0.0. Then in that case the GENCO 2 will not generate not share any uncontracted power demand, but GENCO 1 as it is 1, so, it will be 1 into 0.04. So, GENCO 1 will generate that point 0.04 per unit megawatt power right. So, this is the idea that in that case suppose DISCO 1 demands 0.04 per unit megawatt power excess of power, that is delta Puc 1 that is in area 1 uncontracted power is 0.04 and delta Puc 2 is 0.0 per unit megawatt, because in area 2 no discos demand any excess power right.

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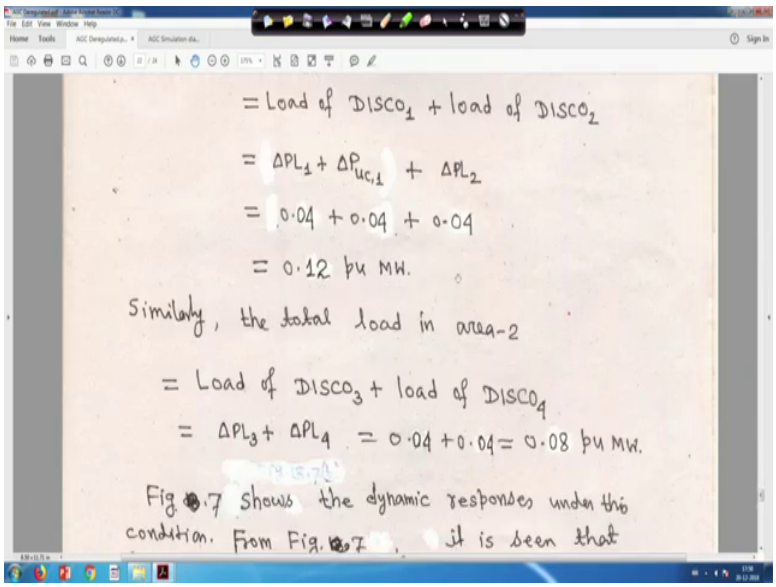

So, therefore, now total load in area 1 load of DISCO 1 plus load of DISCO 2; that means, that your total load will be that already delta PL 1 is the total load of the DISCO 1, then delta PL 2 is total load of DISCO 2 plus this additional your what you call delta P u c 1 coming which has been demanded by the DISCO 1 the distribution company 1. So, total will be 0.12 per unit megawatt that is the total disturbance in area in 1 right.

Similarly, in the similarly total load in area 2 will be 0.08 because that your here no DISCO your what you call has any excess power demand. So, delta PL 3 0.04, delta P l 4 0.04, so, total is 0.08 per unit megawatt right now simulation result I will come later that figure 7 it shows that dynamic responses under this condition right.

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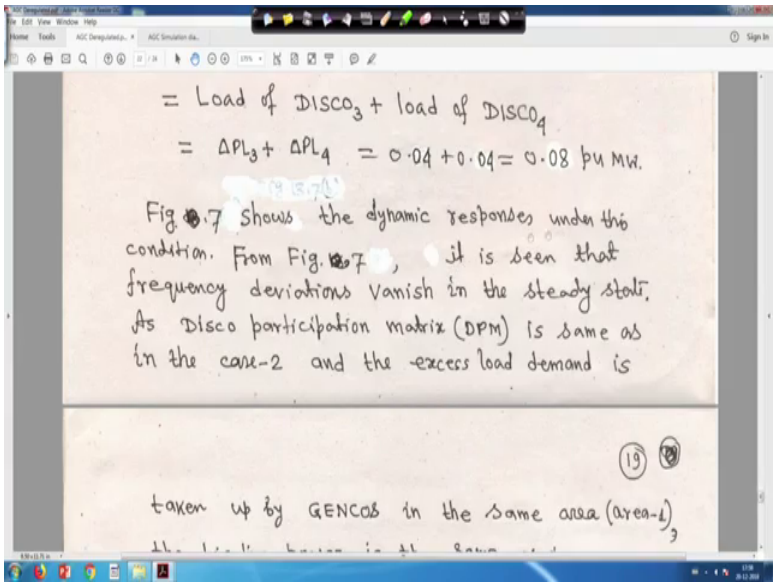

So, the question is that your what you call if you go back to your that AC participation factor, just let me recall how much we took we.

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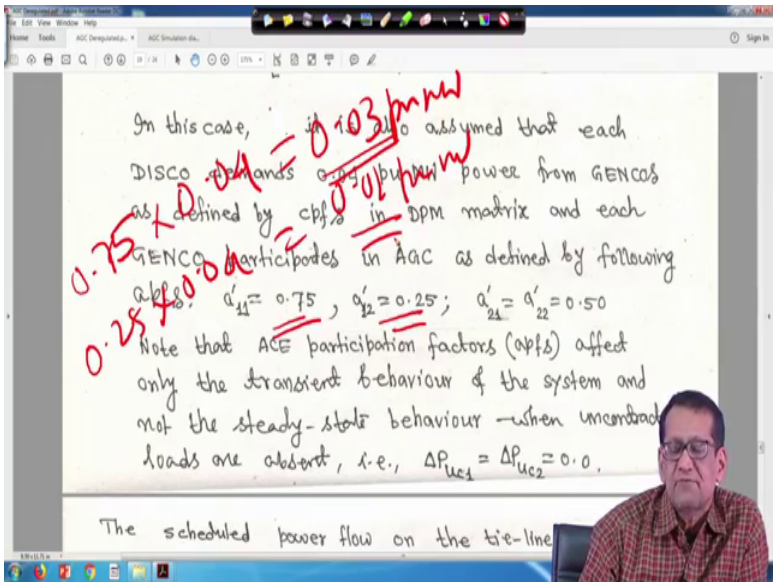

Here what we did that look we took AC participation factor for GENCO 1 0.75 and for GENCO 2 0.25 right area 2 there was no excess demand; that means, that GENCO 1 we will see here 0.75 right additional thing into your 0.04 right. So, that is nothing, but 0.03 per unit megawatt right.

Similarly, that you are GENCO 2 that is 0.25. So, it will be 0.25 into 0.04. So, that is 0.01 per unit megawatt. So, apart from generating you are contracted power that is in case 2 right. So, whatever delta P g 1 steady state was there according to apart from that, this 0.03 will be added to GENCO 1 power and 0.01 will be added to GENCO 1 power that will that they have to generate at the steady state. So, if you go back if you now move; if you now move to the problem. So, here that this is called contract violation right. So, if you look that all data remains as in case 2 right.

That means I am coming to the case 2. So, in for the case 3 that uncontracted power demand. So, delta P g 1 steady state in the case of uncontracted power demand, that GENCO is generating another additional 0.03 per unit megawatt; that means, has steady state will generate this 1 plus 0.03 because fef is given that AC participation factor that is a dash 1 1 is given 0.75; so, 0.75 into 0.04 that is the uncontracted power given.

So, basically it will become 0.072 per unit megawatt mega that is supposed to generate at steady state. Similarly delta Pg 2 it was 0.018, but in addition to that is AC participation

factor is 0.25, so, 0.25 into 0.04. So, 0.1 01 that I showed you so that means, this one will generate g at steady state plus 0.01, so, 0.028 per unit megawatt.

But delta P g 3 and P g 4 will remain same because there is no uncontracted power demand in area 2 right sorry by the discos in area 2 so; that means. So, figure shows the dynamic responses right. So, I will go to the dynamic responses. So, if I go back to your figure 7 right, so, this is figure 7 a. So, if you look into that that figures 7 the frequency deviation in area 1 a steady state it is 0 right.

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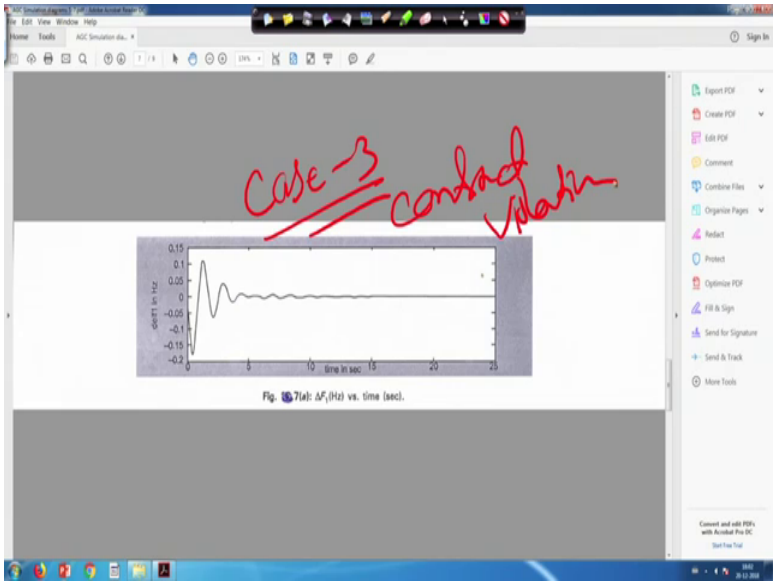

This is frequency deviation in area 1, this is for your this response is for your case 3 that is your contract violation below all the responses are contract violation right. So, this is your delta f 1. Now we will go to the next response that delta f 2 and others right. So, now, delta f 2 that the frequency deviation at steady state it is also and delta P tie you want to actual will remain as it is, that is a steady state 0.02.

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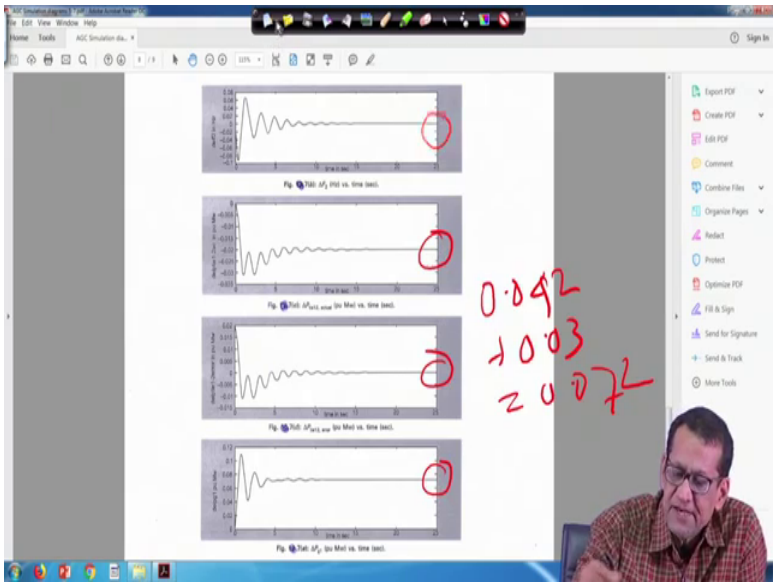

Because your only uncontracted demand is there and AGC that controllers are also there now delta P tie you want to error also will be a steady state it is 0 right. But as I told you that your it was for the case 2 it was 0.04 right plus AC participation factor for GENCO in area 1 was 0.75. So, plus 0.03 will be added because 0.04 into 0.75. So, total will be your 0 point 0 it was what you call, for 2 plus 03 so, 0.072 right. So, that means, if you look into this your dynamic responses that your gen you delta P g 1, it is actually your 0.072 right. So, similarly your for your delta Pg 2 it will be 0 point your what you call 028.

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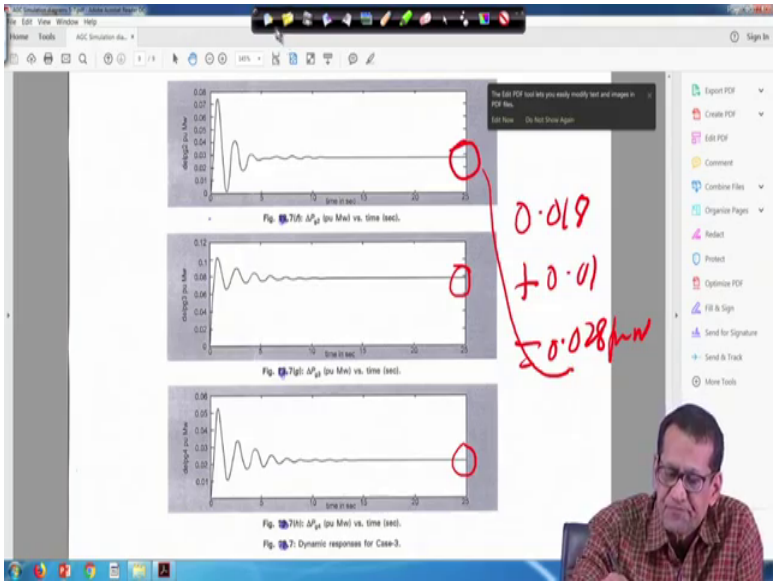

So, if you look into that this dynamic responses that this one for delta Pg 2. So, for the case 2 it was 0.018 plus that AC participation factor for area for GENCO 2 for GENCO 2.25. So, 0.04 excess demand into 0.25, that is 0.01 right that I told you that is actually 0.028 per unit megawatt. So, that is why it is 0.02 per unit megawatt, but delta Pg 3 and delta Pg 4 it will remain unchanged a steady state. So, this is 0.078 right and this is actually your 0.018, so, this is actually the responses right.

So, so; that means, this one is 0.02 8. So that means, your contract violation that your if it happens so, then it is expected that the generators of that company. So, you have that area will be able to give extra power to the discos in that same area right. So, just hold on right just hold on.

So, all these things if you look into this that I explained everything that therefore, this your it is seen that frequency deviation vanish in the steady state as DISCO participation matrix is same as in the case 2 right and the excess load demand is taken up by GENCOs in the same area, the tie line power is the same in case 2 in the steady state.

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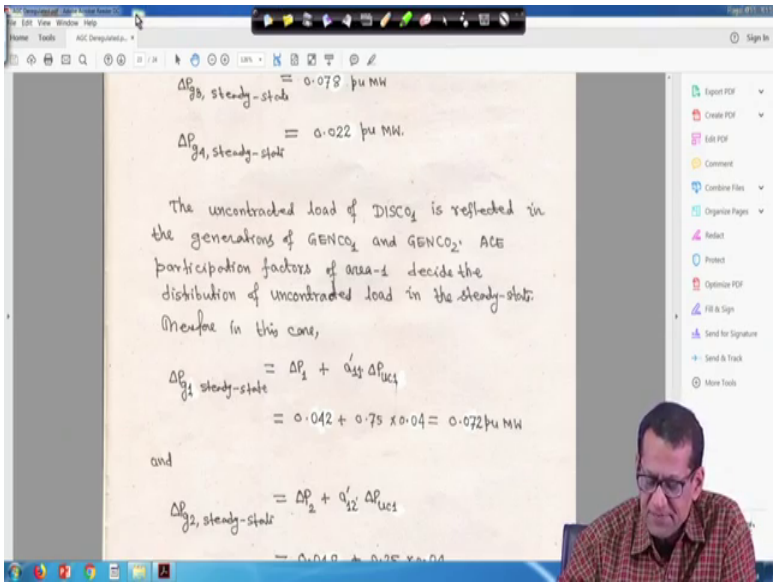

In the steady state the generation of GENCO 3 and GENCO 4 are not affected by the excess load of DISCO 1 I told you. I told you also that delta P g steady state will be 0.078right this thing and delta P g 4 steady state will be 0.022 same as before right, but delta Pg 1 I told you it will be 0.0 because it is whatever it was contracted demand was I told you already, that was the delta P 1 and see simulation also I showed you right.

Plus a dash 1 1into delta P uc 1, so, that is 0.072 per unit megawatt right similarly your delta Pg 2 steady state also it was 0.012 plus your that 0.25 that A C participation factor of area your. So, GENCO 2 in area 1 into that uncontracted power given. So, it is 0.02 8 per unit megawatt this is also shown in figure 7 right. So, I have showed you all this things right. So, this your one thing and this exercise 2 problems and there I before coming to exercise I will come to one problem.

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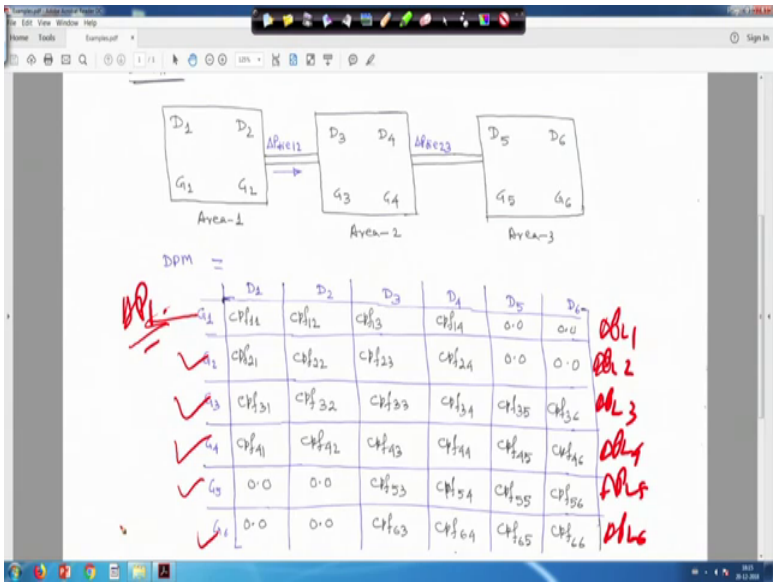

Now, suppose you have a; suppose you have 3 areas system, this is called longitudinal system; that means, no loop actually it this is area 1, this is area 2 and this is area 3. And just for the sake of our you know analysis we have taken just hold on; just hold on. So, we have just hold on. So, have taken your what you call that your 3 areas. So, area your area 1 you have 2 GENCOs and 2 DISCOs. So, in just into accommodate you know space. So, D 1 D 2 is actually DISCO 1 and DISCO 2.

DISCO distribution comparison I have made it short. And GENCOs I have made it G 1 and g 2. So, DISCO means D GENCO means g right. So, and this is 1 2 3 and here also power flow is there say 2 to 3 right. So, in this case that you are delta P tie is 1 2 right and your this is delta P tie 2 3. So, first is how to form your DISCO participation matrix? First you look that it is a longitudinal system one is connected to 2 two is connected to three, but 1 is actually not connected to 3. That means, DICOs here in area 1 they cannot

have any contract with GENCOs in area 2 because there is no line in between that area 2 is coming right.

Similarly the discos in area 3 that is D 5 and D 6 right they cannot have any contact with GENCOs in area 1 that is G 1 and G 2 you know right, but discos in area 2 that is D 3 D 4 they are the they can contract with GENCOs in area 1 that is G 1 G 2 or GENCOs in area 3 that is G 5 G 6 because this side also its connected this side also is connected by the tie line right. Now if you try to find out the your context participation in general some of the elements C p 3 2 or C p 4 3 it may be 0 depends on the which discos have contract with which GENCOs.

But in general when we will make this your what you call that DPM DISCO Participation Matrix now consider D 1 right. So, D 1 this is D 1, so, distribution company 1, it may contract with GENCO 1. So, cpf 1 1 cpf 1 2 right. So, I cpf 11 right and DISCO this D 1 right also can have contract with your what to call that your GENCOs in the same area G 2. So, cpf 2 1 right similarly these this distribution company they have contract with GENCO 3 that is why cpf 3 1 is there, similarly this one will have contract with G 4 that is GENCO 4 that is why cpf 41.

But this distribution companies cannot have any contract with G 5 or G 6 right because there is no line, there is no line here, there is no line here right. So, it is blank not connected so; that means, your this part is 0, this part is 0 right. Now similarly if you take about D 2 similar way cpf 1 2, cpf 2 2 will be there because it has contract with G 1 G 2.

It can have contract with G 3 G 4. So, cpf 3 2 c because this is G 1 G 2 G 3 G 4 G 5 G 6 GENCOs right and these are all discos these are all discos right. And, but this distribution companies D 2 cannot have any contact with G 5 and G 6 that is why this is 0 this is 0 right. Similarly if you take distribution companies D 3 D 4 D 3 and D 4 first you take D 3. So, D 3 distribution companies can have contact with G 1 G 2 of area 1 or can have contact with G 5 or G 6 in area 3. Therefore, this matrix cpf 1 3, cpf 2 3, cpf 3 3, cpf 4 3, cpf 5 3 and cpf cpf 6 3 all are there.

Similarly, for D 4 also can I contract with I G 3 G 4 or G 1 G 2 or G 5 G 6 because all are very this side and this side interconnected by tie line right. So, that is why cpf 1 4, cpf 2 4, cpf 3 4, cpf 4 4, cpf 5 4 cpf 6 4. So, contract participation factor similarly if you

take D 5; D 5 cannot have contract with anyone G 1 or G 2 because it is not connected; it is not connected it is open right it is not connected therefore, that your cpf your 1 5 is 0 and cpf 2 5 is also 0.

But this distribution D 5 may have contract your contract to G 3, G 4 or and G 5 G 6 that is why cpf 3 5 cpf 4 5 cpf 5 5 and cpf 6 5. Similarly D 6 cannot have any contract to G 1 and G 2 that is why 0 0 rest is c p is cpf 3 6 cpf 4 6 cpf 5 6 and cpf sis 6 right. So, this is your how to form that your for longitudinal system that your what you call that your DISCO participation matrix, this is actually DPM; this is actually DPM right.

Now, so, similar way the delta P tie 1 2 that is your schedule tie line power flow you can easily; you can easily compute because here 2 2 2 all are there similarly delta P tie 2 3 also you can easily compute right the way I have told you same philosophy you can easily compute, your what you call delta P tie 1 2 schedule value and delta P tie 2 3 schedule value right.

Now, if it is connected suppose you 1 to 2 2 to 3 1 to 2 2 to 3 3 to 1. Now if it is connected if it is a loop system; now if it is a loop system now it is connected. So, 1 2; that means, every distribution companies in any area they have the access to contract power with all the GENCOs in other areas.

For example now the D 1 D 2 the DISCO 1 DISCO 2 now can contact also with GENCO 5 GENCO 6 right. So, apart from your GENCO 3 and GENCO 4 and apart G 1 G 2 already there those generators are there in their own area; that means, the at that time this matrix will not be it need not be 0 at that time it will be cpf matrix; cpf 5 1, cpf your 5 2, cpf 6 1, cp f 6 2 similarly here also it will be your cpf 1 5, cpf 1 6, cpf 2 5 and cpf 2 6 right.

But after that a distribution companies may not have contract with all the generation companies. So, some of the elements may become 0 right. And finally, anyway some of all the column element should be 1, here also all the column elements should be 1. So, all column elements if you add all column elements if you add all should be your unity right and your and another thing is that contracted power given. So, in this case what will happen that, contracted power demand for this one say delta P L 1 that will be this is your delta P L 1 that power demanded by distribution company 1, this is delta PL 2, this is delta PL 3, this is delta PL 4, this is delta PL 5 and this is delta PL 6 right therefore,

delta P 1 will be cpf 1 1 delta P l 1, cpf 1 2 delta P l 2 cpf 1 3 delta P l 3 plus cpf 1 4 delta P l 4 other 2 terms 0 0 so, it is 0 right.

So, similarly for G 2 delta P 2 you can calculate; similarly for G 3 you can calculate similarly for G 4 you can calculate the contracted of power given, similarly for G 5 and G 6 and all the in general all the contracted power demand is equal to that this one registered value; that means, whatever contracted power demand for each GENCOs that that is actually a steady state value that is a power generated by the GENCOs at steady state right. So, this is actually or what you call that this exist if it is a longitudinal thing right. So, little bit you will practice.

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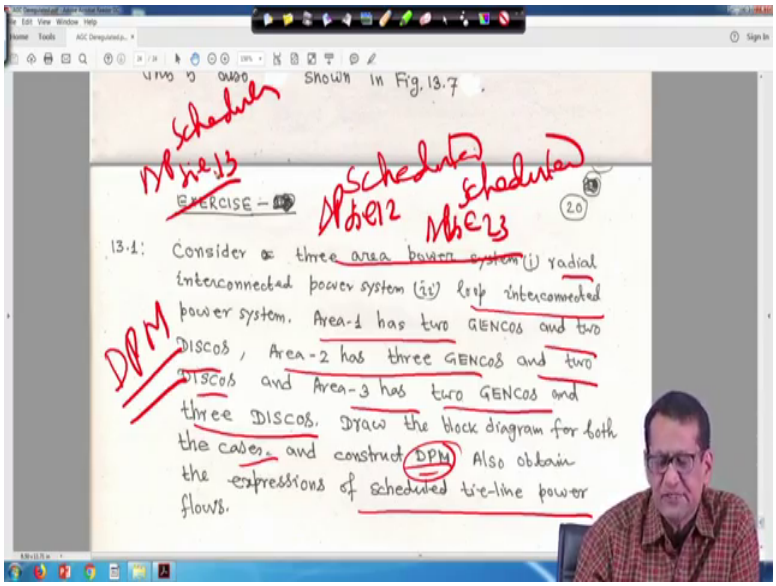

So, there is here I have given a problem. So, right; so, consider a 3 phase your 3 phase power system 1 is radial interconnected that is I told you the longitudinal; another is loop interconnected both I told you right area 1 has 2 GENCOs and 2 discos, area 2 has 3 GENCOs and 2 discos and area 3 has 2 then GENCOs and 3 discos right. So, you please a what you call in this case draw the block diagram for both the cases that is a bigger one, and construct DPM in this case you please you will construct the DISCO participation matrix right.

All the all the also obtain the expression of scheduled tie line power flows; that means, you will find out delta P tie 1 2 scheduled delta P tie 2 3 scheduled and 1 2 2 3 then delta P tie 1 3 scheduled when it is loop right; when it is radial delta P tie 1 2 and delta P tie 2

3 when it is a loop you find out also delta P tie 1 3 scheduled expression only the expression right.

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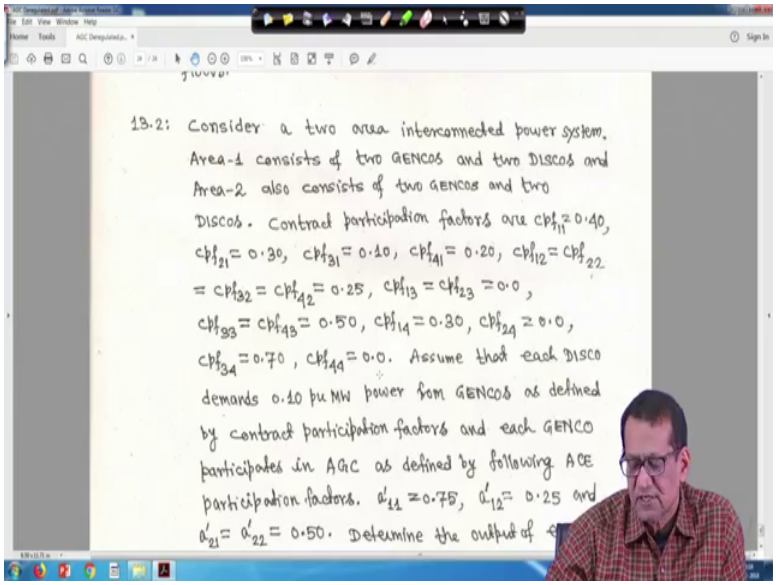

And another example this one if time permits I will solve you for just see that let me see that another thing is the load following after that this type of one problem I will solve you now consider a 2 area interconnected power system. Area 1 consists of 2 GENCOs and 2 discos, area 2 also consists of 2 GENCOs and 2 discos right distribution companies. Contract participation factor cpf 11 is given 0.4, cpf 2 1 0.3, cpf 3 1 0.1, cpf 41 0.2. And cpf 1 2 is equal to cpf 22 is equal to cpf 3 2 is equal to cpf 4 2 is equal to 0.25. Now cpf 1 3 is equal to cpf 2 3, 0.04 cpf 3 3 is equal to cpf 4 3 is 0.5 cp f 1 4 is equal to 0.3, cpf 2 4 0 point 0 and cpf 3 4 is equal to 0.7, cpf 4 4 is 0 right.

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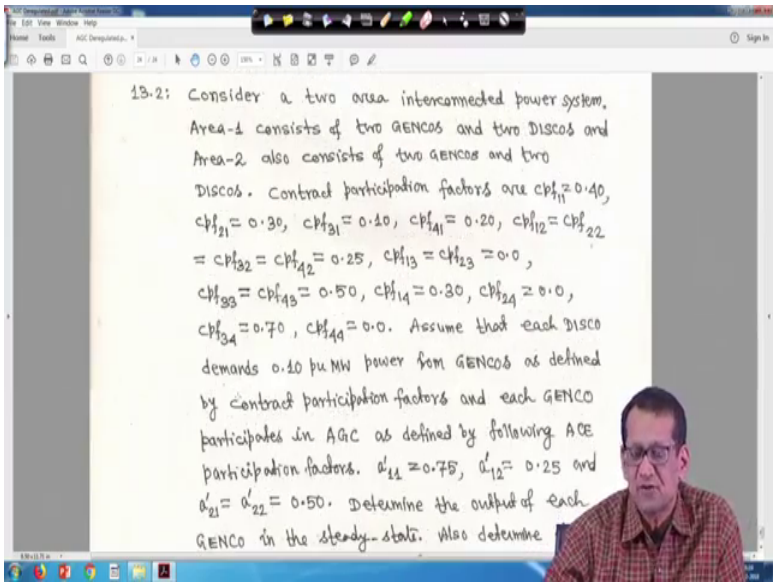

Assume that each DISCO demand 0.10 per unit megawatt power from GENCOs as defined by contract participation factor. And each GENCO participate in AGC as defined by the following ace participation factor that is a dash 11 is 0.75, a dash 1 2 0.25 and a dash 2 and is equal to a dash 22 is equal to 0.5 right.

Determine the output of each GENCO in the steady state, you only find out the steady state because classroom we cannot ask you simulation only study state right. Also did you determine the schedule power from the tie line and its direction I mean it is in the direction 1 2 or 2 1 right. If DISCO 1 in area 1 and DISCO for in area 2 demands 0.10 per unit megawatt each of excess power that is uncontracted power demand right that is your; that is your delta Puc 1 will be your 0.1 as well as delta Puc 4 will be 0.1 also right calculate the output of each GENCO in the steady state right.

So, note that what you call that GENCO 1, GENCO 2, DISCO 1 and DISCO 2 are in the area 1 and GENCO 3 GENCO 4 and DISCO 3 DISCO 4 are in area 2 right. So, this problem you will try to solve of your own.

Thank you very much we will be back again.