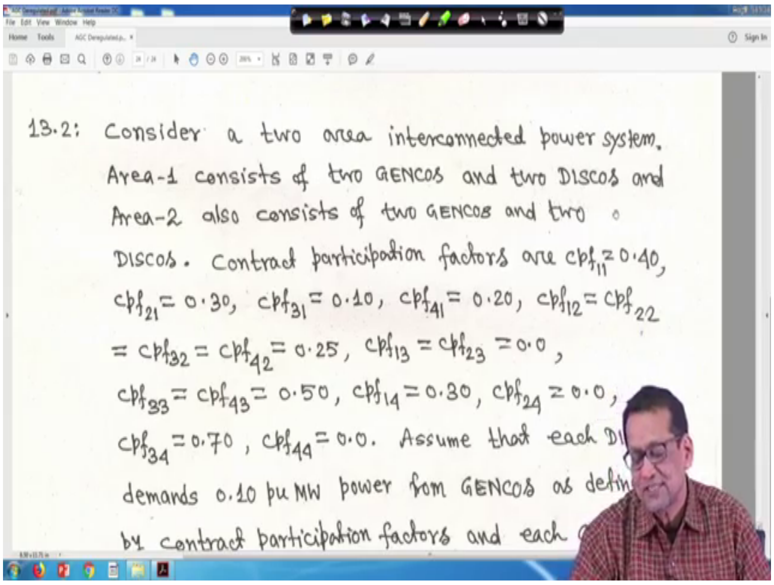
Power System Dynamics, Control and Monitoring
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 49
AGC in deregulated system, Reactive power and voltage control

So, load following we have seen it. So, previously in that your, we saw couple of problems, but not solved but one of them I will solve it.

(Refer Slide Time: 00:29)

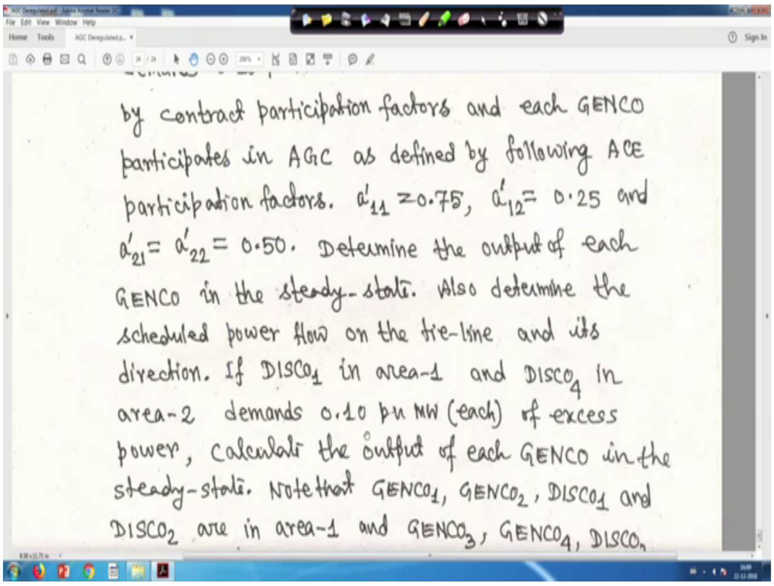


So, this is actually that in your deregulated environment that problem also I told you earlier to solve, but I will solve it for you now before maybe after this one more and after that we will go for another topic. So, consider a two area interconnected power system. Area 1 consists of two GENCOS and two DISCOS that is two generation companies and two distribution companies and area 2 also consists of two GENCOS and two DISCOS, right.

Contract participation factor are cpf 11 is equal to 0.4, cpf 21 is equal to 0.3 cpf 31 is equal to 0.0, cpf 41 is 0.20 cpf 12 is equal to cpf 22 is equal to cpf 32 is equal to cpf 42 is equal to 0.25. All are same. Cpf 13 is equal to cpf 23 is equal to 0.0 cpf 33 is equal to cpf 43 is equal to 0.50 and cpf 14 is equal to 0.30, cpf 24 is 0 cpf 34 is 0.70 and cpf 44 is equal to 0. Assume that each disco demands 0.10 per unit megawatt power from GENCOS and defined by contract participation factors.

And each GENCO participates in AGC as defined by following ACE participation factor that fact that ace participation factors are given as a dash 11 is equal to 0.75 a dash 12 is equal to 0.25 and a dash 21 is equal to a dash 22 is equal to 0.5, right. So, determine the output of each GENCO in the steady state also determine the schedule power flow on the tie line and its direction.

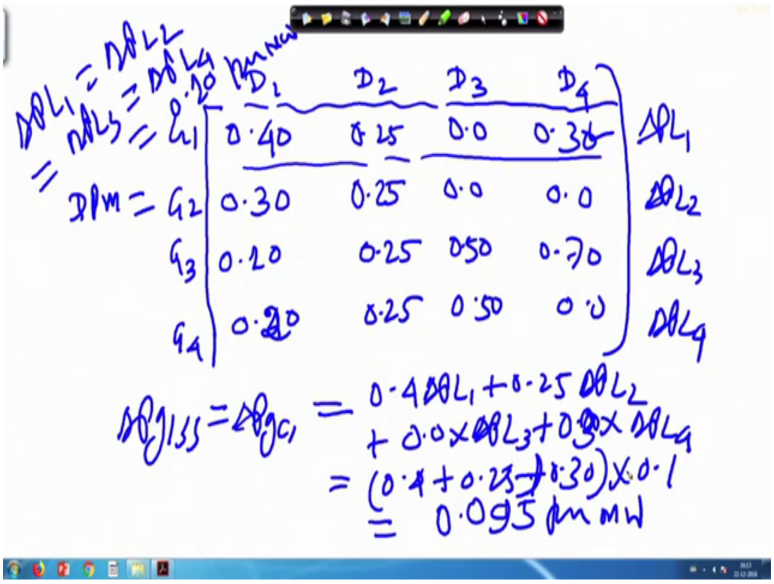
(Refer Slide Time: 02:21)



If DISCO 1 in area and DISCO 4 in area two demands 0.10 per unit megawatt each of excess power, calculate the output of each GENCO in the steady state. Note that GENCO 1 GENCO 2 DISCO 1 DISCO 2 are in area 1 and GENCO 3 GENCO 4 DISCO 3 and DISCO 4 are in area 2.

Here some of scanning cut GENCO 3 GENCO 4 DISCO 3 and DISCO 4 are in this one. So, if you look into that, that means DISCO 1 in area 1 and DISCO 4 DISCO 4 in area 2 demands 0.10 per unit megawatt each of excess power we have to calculate this one, right. So, solution I have to write it here. So, in this case your sorry just hold on, right.

(Refer Slide Time: 03:21)



So, whatever distribution participation matrix is given, so we can write here the DPM whatever is given look no notes are here. So, when you will listen to this, you please note down all these things right. Just one minute.

So, first I have to make it that there are 4 distribution companies to accommodate the space instead of your DISCO 1 DISCO 2 DISCO 3 and DISCO 4. I will write D1 D2 D3 D4; similarly GENCO 1 GENCO 2 GENCO 3 and GENCO 4 in short I will write G1 G2 G3 G4. So, in that way in that way my DPM is equal to say this is I will write D1 D2 D3 D4 that is DISCO 1 DISCO 2 DISCO 3 and DISCO 4 and this is my GENCO 1 G1 G2 G3 and G4, right. So, next I will put those whatever your contract participation factors are given. So, I will write here it was 0.40, right.

Then 0.25, then it was 0.0 and it was 0.30, right. Similarly this one cpf 21 10.30 0.25, then it was 0.0 and 0.0. Similarly for GENCO cpf 31 1 all were given I am just writing 0.10 0.25 0.50 and 0.70, right and 41 42 like this 0 point sorry 0.20 0.25, then 0.50 and 0.0. This is my DPM, this is this DISCO 1 DISCO 2. This way we write, right. If you add all this column, your you will find this all the solution of this is unity, right.

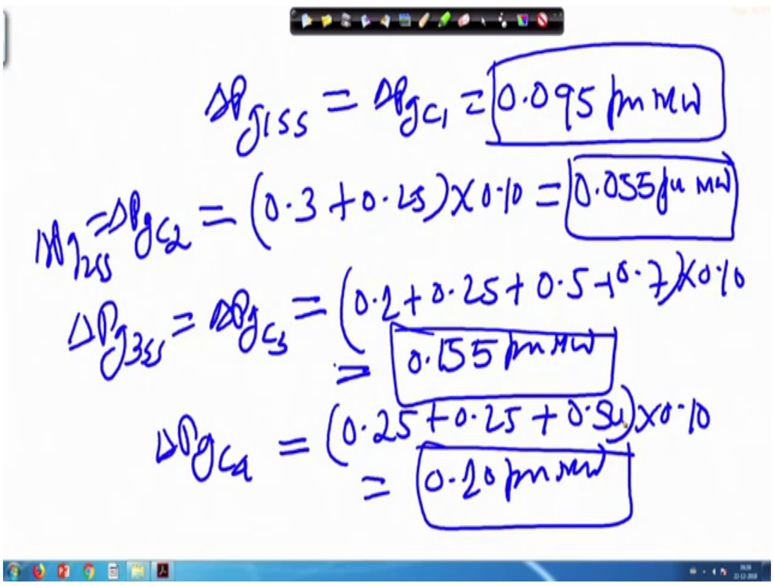
If you add this one, it is unity, this is unity, this is also unity, this is also unity, right and you have your what you call that you have that then 4 distribution companies. So, their power demand is delta PL delta PL2 delta PL3 call the steady state values or that power that has to be generated and delta PL4, right. Therefore, to find out the your what you by

GENCO 1 GENCO 2 GENCO 3 and GENCO 4 and steady state without considering the uncontracted power demand. So, delta Pgc 1 right that is nothing, but whatever will come that is contacted power demand that is nothing, but your delta Pg 1 steady state, right this much power will be generated.

So, that should be is equal to your if you just multiply this one 0.4, delta PL 1, then plus 0.25 delta PL 2 plus 0.0 into delta PL 3 plus 0.0 into delta PL 4 the first row, this first row and delta PL 1 delta PL 2 delta PL 3 delta PL 4. So, delta PL 1 all are given 0.1, delta PL 1 is equal to delta PL 2 is equal to delta PL 3 is equal to delta PL 4 is equal to 0.10 per unit megawatt. All are same right.

Therefore, this one will be actually 0.4 plus 0.25, right is your delta. One thing is that this is actually 0.30. So, this is 0.30, right plus 0.30 into 0.1. So, that is actually will come your 0.095 right, 0.095 per unit megawatt, right. Therefore, that contracted power this thing your what you call delta Pgc 1 is equal to delta Pg 1 steady state is 0.095. So, I am cleaning it right.

(Refer Slide Time: 07:51)

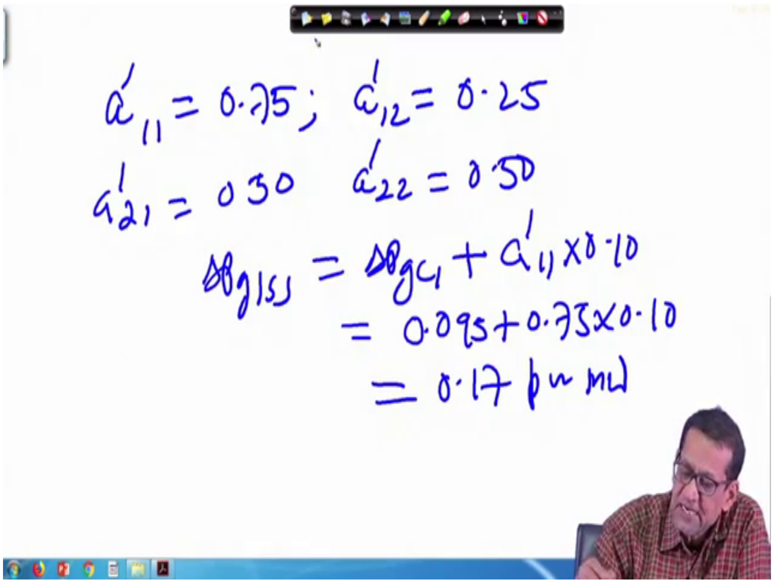


So, therefore delta Pg 1 steady state is equal to delta Pgc 1 is equal to 0.095 per unit megawatt, right. Similarly for delta Pgc 2 if you calculate delta Pgc 2 if you calculate I am writing for you it is 0.3 plus 0.25 into 0.10 that is actually is equal to 0.055 per unit megawatt that is equal to that is nothing, but delta Pg 2 steady state, right. Similarly delta Pg 3 steady state is equal to delta Pgc 3 is equal to if similar way you can calculate 0.1

plus 0.25 plus 0.5 plus 0.7 into 0.10 that actually comes out to be your 0.1 55 per unit megawatt, right.

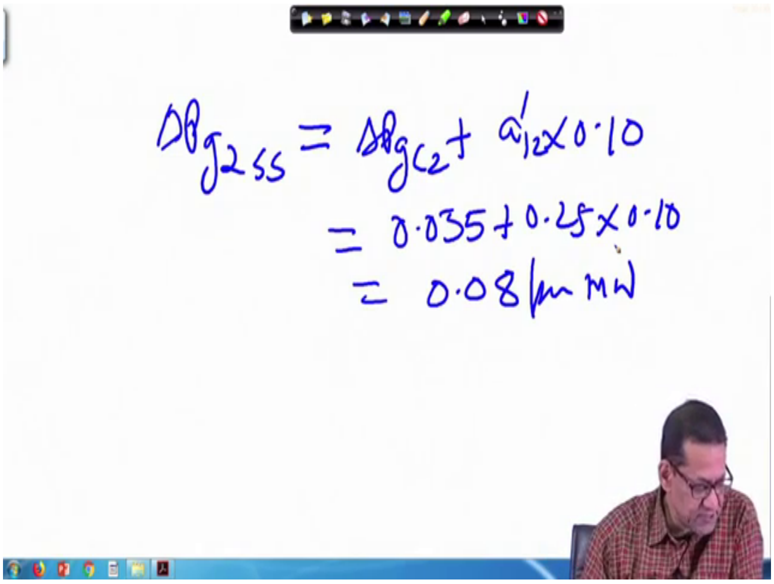
Similarly, delta Pgc 4 that should be is equal to you or whatever I have calculated 0.25 plus 0.25 plus 0.50 into 0.10, right that is equal to actually 0.10 per unit megawatt, right. So, this is actually your what to call that all these calculations I made for you this is actually for your steady state error that steady state error that whatever power will be generated by this is your GENCOs right at the steady state. So, this is one, this is one, then this is another one delta Pg 2 steady state, this is delta Pg 3 steady state and this is delta Pg 4 steady state, right.

(Refer Slide Time: 10:08)



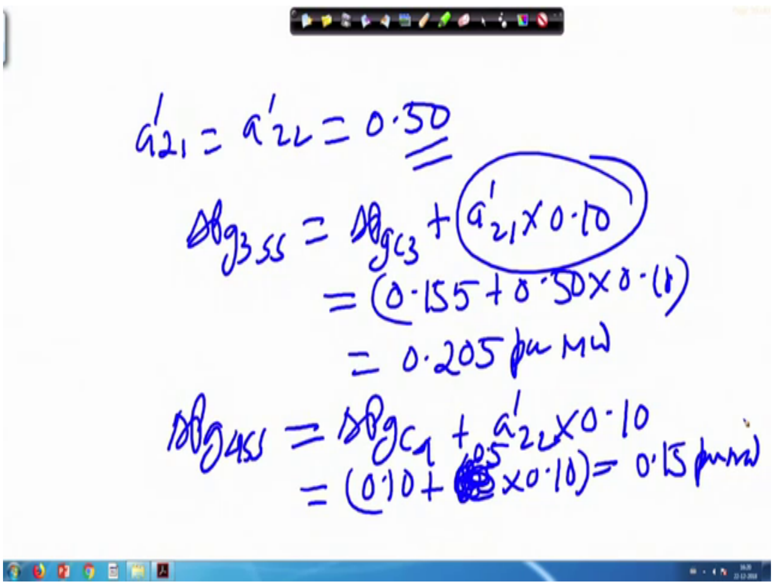
So, now I am cleaning this. So, now it is given ACE participation factor is given that a dash 11 is equal to 0.75, right then a dash 12 is given that is your then 0.25. Similarly a dash 21 it is 0.50 it is given and a dash 22 is equal to also 0.50. So, ACE participation factor is given right, therefore that that delta Pg 1 delta Pg 1 steady state right is equal to that contracted power demand delta Pgc 1 right plus your a dash 11 into that you are what you call the contractor, your that uncontracted power demand was point 1. So, that will be 0.10 because uncontracted power demand was 0.10, right in area 1. So, that is actually delta Pgc 1 c 1 was 0.095 that we have calculated into zero point plus 0.75 into 0.10. So, that actually comes out to be your if you add this thing, it will be 0.17 per unit megawatt, this is delta Pg 1 steady state, right. So, similarly your delta Pg 2 steady state so I am clearing this, right.

(Refer Slide Time: 11:38)



Similarly, delta Pg2 delta Pg2 steady state is equal to your delta Pgc 2 plus your a dash 12 into again that uncontracted power demand was 0.10. So, delta Pgc 2 it was actually 0.055 and this was 0.255 into 0.10. So, that is actually coming to be 0.08 per unit megawatt right.

(Refer Slide Time: 12:22)



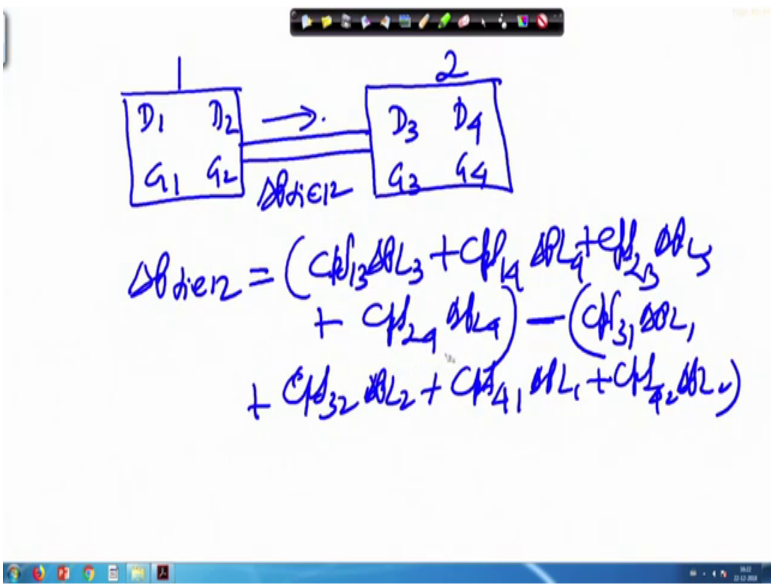
So, this is delta Pg2 similarly that your a dash 21 a dash 21 is equal to a dash 22 is equal to 0.50 right. Therefore, delta Pg 3 steady state that is your when uncontracted power demand was there when it was not there, then there is that is that we have done when uncontracted power demand was there in area 2 also. So, in that case your this one will be delta Pgc 3 plus a dash 21 into that 0.10 because right.

So, this delta p g c 3 we have calculated it was 0.155 plus 0.50 into 0.10, right. So, it comes around 0.205 per unit megawatt. This is when uncontracted power demand is there. That is why this term previous case also here case this term is coming. Similarly delta Pg 4 steady state when uncontracted power demand was there right is equal to delta Pgc 4 plus a dash 22 again uncontracted power demand was 0.10.

So, directly multiply so that delta Pgc 4 it was actually 0.10 plus 0.5 into 0.10. So, it comes out to be your this is actually 0.25 because 0.25, so sorry it was 0.5. Sorry 0.5 just making it 0.5 into this one. So, it is coming around 0 point your what you call 15 per unit megawatt, right. So, this is a steady state when uncontracted power demand is there because uncontracted power demand will be distributed as per the way you have defined the ace participation factor, right.

So, this is done. So, another thing is that your tie line that your tie line power flow right as two each at each areas there are two GENCOS and two DISCOS.

(Refer Slide Time: 14:41)

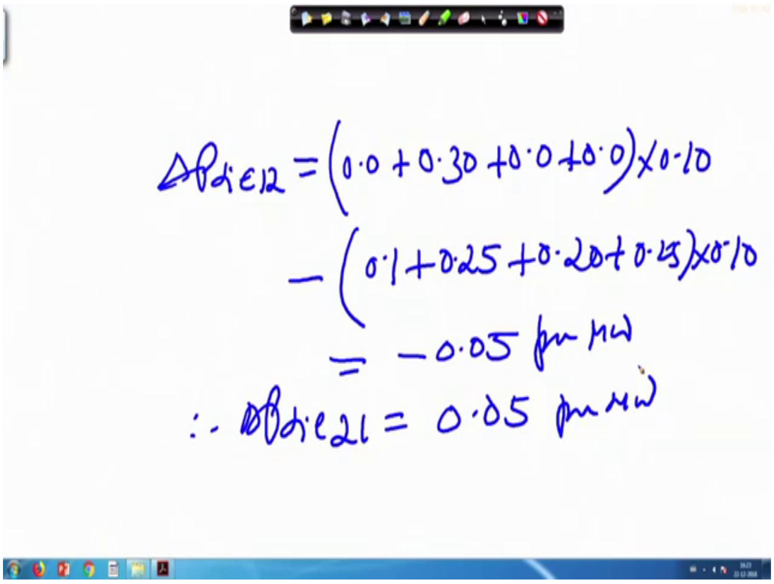


So, this is my area 1, this is my this is already we have done it, but this is say DISCO 1, this is DISCO 2, this is GENCO 1 GENCO 2 and that tie line, right and this is my DISCO 3 and DISCO 4 and this is GENCO 3 GENCO 4, right and direction is this way I think it has been asked find out the direction of the tie line power flow. So, this is area 1 and this is area 2 and therefore, the way we have taken the direction it is delta p tie 12.

So, from that if I recall correctly that equation delta p tie 12 I think equation I have forgotten the equation number perhaps it is equation 4 or 5, right. So, delta p tie 12. So, if you expand that equation delta p tie 12 is equal to I am writing here cpf 13 I told you how to make it right delta PL3 plus cpf 14 delta PL4, right plus cpf 23 delta PL 3 plus cpf 24 delta PL4, right. This one minus in bracket that cpf 31 delta PL1 plus your cpf 32 delta PL2 plus cpf 41 delta PL1 plus cpf 42 delta PL2 right.

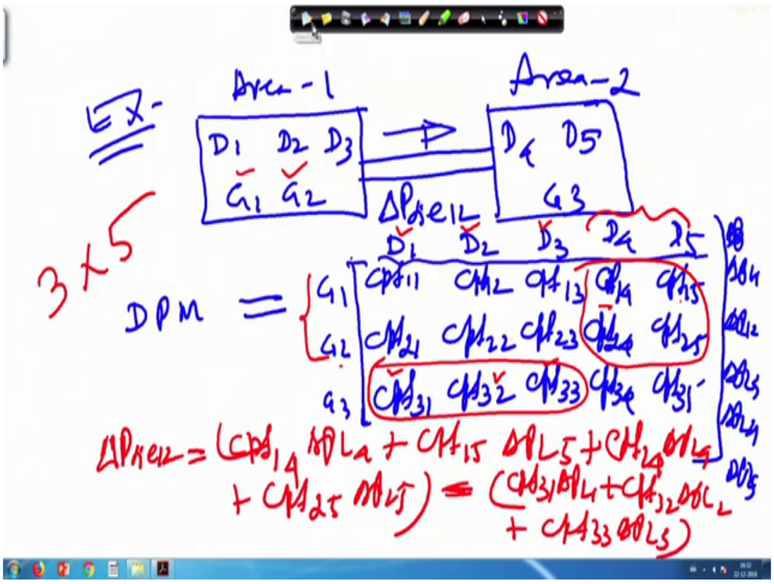
So, this thing we know this thing we know right now if you substitute all this value and try to calculate right, so I am just cleaning this one, clearing this one.

(Refer Slide Time: 16:46)



So, if you calculate then delta p tie 12 should be is equal to your 0.0 plus 0.30 plus 0.0 plus 0.0 into 0.10 minus right 0.1 plus 0.25 plus 0.20 plus 0.25 into 0.10. Therefore, this actually comes out to be minus 0.05 per unit megawatt that is 1 to 2 it is minus. That means, power actually flowing in the direction of delta p tie 21 is equal to. Then 0.05 per unit megawatt. That means, power is flowing from 2 to area 2 to area 1, right. So, just when I am making all these small calculations and this, so I will request you that if you find any error in my calculation and other thing, you just either put the question in the forum, we will rectify that and or you can send you may and mail also, right. So, this is that problem I. Another is there that you will solve it, right.

(Refer Slide Time: 18:15)



So, after this another small thing we will take that suppose this is another example. This is another example right. Suppose you have 2 area only. Suppose you have 3 distribution companies area 1, D1 D2 D3, right and you have two generation companies G1 and G2 and this is your tie line, right and in area 2 this is your area 2 right. Here we have two distribution companies D4 D5 and only one generating company that GENCO 3, right. So, DISCO 1, DISCO 2, DISCO 3 in short we make D1 D2 D3 and this is area 1 and this is my area 2, right and say for example that power is flowing in this direction. So, this is delta p tie 12, right. So, we have to find out that delta p tie 12, right.

So, first we have to see that we have to see that DPM DISCO Participation Matrix. So, disc in this case, DISCO participation matrix we will write like this you have three generation companies. So, making it here right say this is you make G1 G2 and G3. This way we will make and then, you have 5 distribution companies. You write D1 D2 D3 D4 and D5. This way you write right then you make cpf 11, then cpf 12, then cpf 13, then cpf 14, then cpf 15, right then this one also you make cpf 21, cpf 22 cpf 23 cpf 24 and cpf 25, right and then last one cpf 31, so cpf 32 cpf 33, cpf 34 and then cpf 35 right and five DISCOs are there. So, each disco demanding delta PL1 delta PL2 delta PL3 delta

PL4 and delta 5 delta PL5 power demand side. So, this say I am writing delta your what you call this is I am writing say delta PL1 delta PL2 delta PL3 delta PL4 and delta PL5. Just right hand side I wrote delta PL1 delta PL2 delta PL3 delta PL4 delta PL5, right. Now, what will be the expression? Now I am just hold on. I will change the colour right.

So, now I want to find out what is my delta expression. For delta p tie 12 what is my delta p tie 12 right. So, look that distribution companies D4 and D5 right this D4 and D5 that it can have contract with G1 and G2 and that means if D4 D5 distribution companies here if it draws power from area 1 GENCOs in area 1, so power will flow from 1 to 2, right. So, that thing we take positive and another thing is that D1 D2 D3 has contract with G3. So, power basically this power there power from here it will flow to this. That is why we take this minus such the resultant one in the direction of 12.

So, that means if you look into this, that D4 and D5 D4 and D5 in area 2. So, this is my D4 and D5, right. So, this is in area 2 and it will draw power right from G1 and your what you call G2 right that is here these two GENCOs are in area 1, right. So, in that case what will happen that this one that D4 and D5 drawing power from G1and G2 and if you look into that that D4 has contract with G1 that is cpf14 and D5 has contract with G1 cpf 15. Similarly D4 has contract with G2 because these two are in area 1 that is cpf 24 and D5 also has contract with G2 say cpf 25.

That means this block first will considered right in the direction of 1 to 2. That means, that cpf 14 that delta p tie 12 will be cpf 14, then your delta PL4 plus cpf 15, then delta PL5, right. So, this one then your what you call that is 1415 now plus that cpf 24 delta PL4 plus cpf 25 delta PL5. This is the power that this D4 and D5 has contract with G1 and G2. So, it is moving this way, right. Now, minus that D1 D2 D3 has contract say with G3. So, power will be going to from this to that.

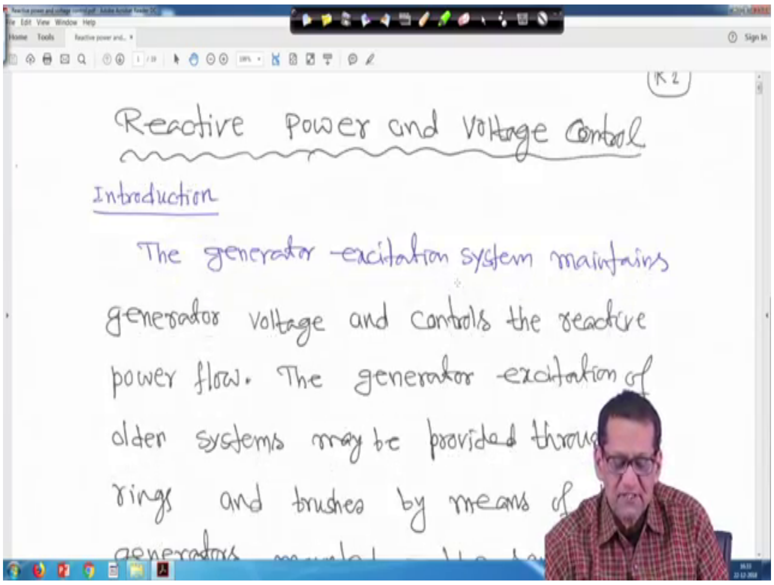
So, resultant will take that is why this is minus right, then if you look into that D4, your what you call D1 D2 D3 that means this one, this one and this one that is in area 1 has contract with G3 that is D1 has contract participation factor say cpf 31, this is D2 has contract cpf 32 and this one has contract cpf 33, right. So, if it is so, that means this block you considered only this part right therefore minus it will be cpf 31 delta PL1 plus cpf 32 delta PL2, right plus cpf 33 delta PL3. This will be the expression for tie line power flow hope. Handwriting is little bit this thing because it is a digital screen right digital frame, right. So, question is that now you understood that, that D4 D5 has contract with G1 G2 in the direction of 1 to 2 power will flow. That is why cpf 14 delta PL4 plus cpf 15 delta PL5, right. So, plus cpf 24 delta PL4 plus cpf 25 delta PL5 right minus this D1 D2 D3 has contract with G3. So, cpf 31 delta PL1 plus cpf 32 delta PL2 plus cpf 33 delta PL3.

So, this is the expression of tie line power flow. That means, it is not necessarily mean that how many DISCOs and how many GENCOs will be there in area. So, this matrix in this in this case this matrix actually that is Dpm actually 3 into 5 right. So, three rows five columns right. So, that your what you call that your that concept of DISCO participation matrix and find out what is delta p tie 12, right.

So, this way this way you can calculate that what will be that steady state contract participation, sorry that your contract power demand with each GENCOs right. So, generally it will be cpf 11 delta PL1 for GENCO 15 delta PL5, right. This way three GENCOs following load following we have and that the our AGC in the structured power system more or less many things are there on that, but I have to skip that considering that it is a video course and I have to see from the point of view of the class room exercise, right.

So, hope things are not at all difficult as far as exam purpose is concerned Wwe will only consider the steady state part right. But simulation result I showed you for the better understanding and what exactly is happening right and so, next we will move to just hold on. Next we will move to that your little bit on reactive power and voltage control, right.

(Refer Slide Time: 27:00)

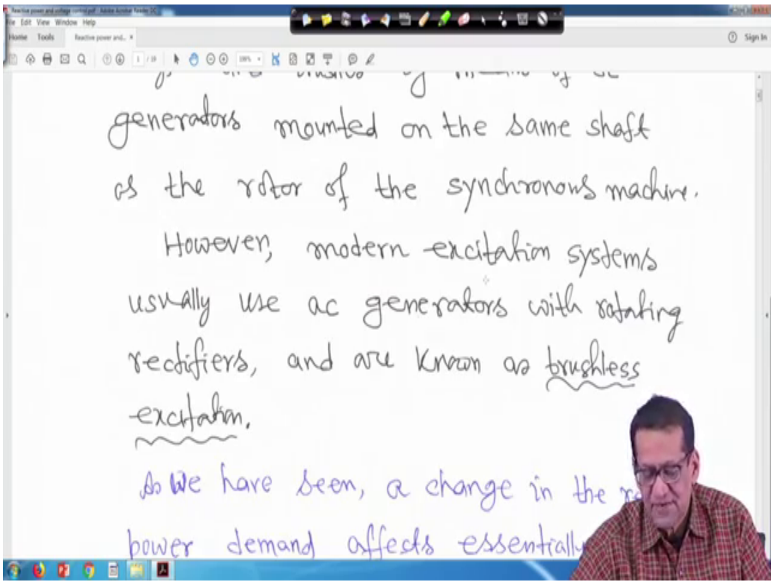


So, reactive power and voltage control, but we will not try to couple it, If time permits I will see right. So, reactive power and generally and the beginning of the that load frequency control or automatic generation control part I told you that for a small change in the real power load right that it does not, it affects actually the system frequency.

Hence the speed right of the speed of the synchronous generator, but it does not actually affect the bus voltage magnitude. Similarly a small change in reactive power actually is essential. It actually it does not affect the system frequency, but it affects the bus voltage magnitude just vice versa. That is why you call Pf that is real power frequency control or reactive power voltage control, right.

So, little bit we will see it here. Suppose the actually the generator excitation system maintains generator voltage and controls the reactive power flow, right, so the generator excitations of older systems may be provided through slip rings and brushes by means of dc generators mounted on the same shaft as the rotor of the synchronous machine.

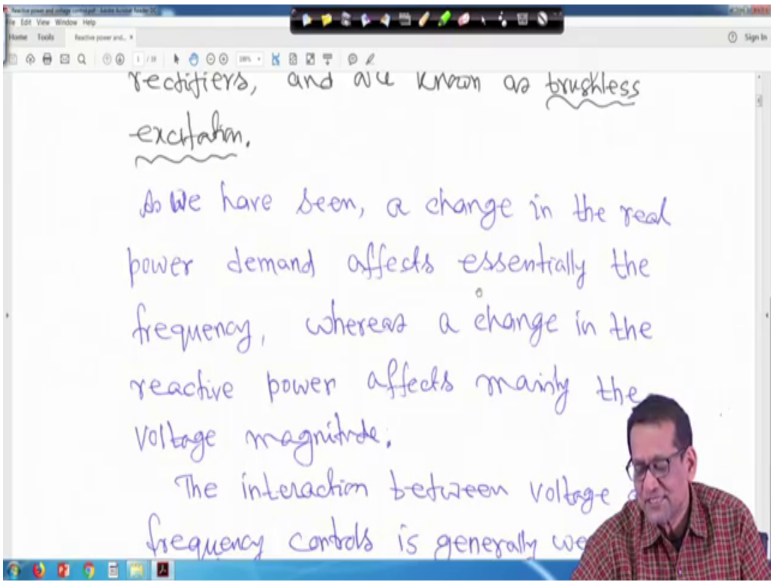
(Refer Slide Time: 28:22)



However, modern excitation systems usually use ac generators with rotating rectifiers and are known as brushless excitation. Several types of excitation systems are there.

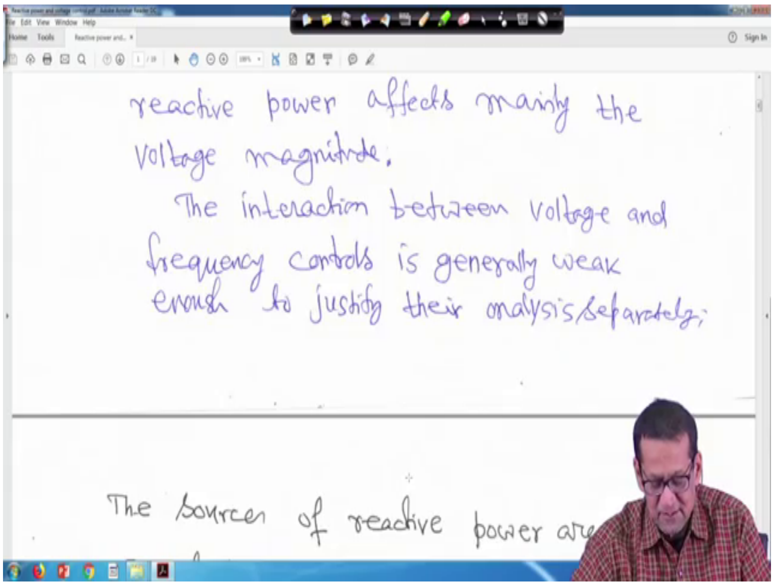
So, in this course perhaps I will not find time. If I find little bit because after finishing this we move to state estimation. If after state estimation if time permits, then I will derive that your block, I derive that your what you call that high rotor by modelling right that is for AGC suitable for AGC and after that I think we will not find time to excitation system because different type of excitation systems are there and it will take time to explain, right.

(Refer Slide Time: 29:06)



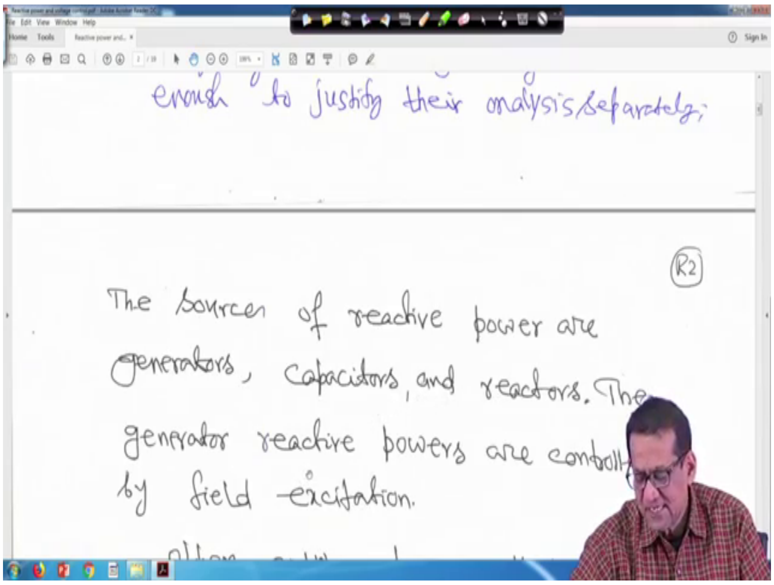
So, as we have seen a change in the real power demand affects essentially the frequency I told you whereas, a change in the reactive power affects mainly the bus voltage magnitude, right.

(Refer Slide Time: 29:15)



So, interaction between voltage and frequency controls is generally weak enough to justify their analysis separately, right.

(Refer Slide Time: 29:26)



So, the sources of reactive power are generators that is synchronous generators, capacitors and reactors, right. So, generator reactive powers are controlled by field excitation. So, thank you very much we will be back again.