Power System Dynamics, Control and Monitoring
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Lecture - 42
AGC in deregulated system (Contd.)

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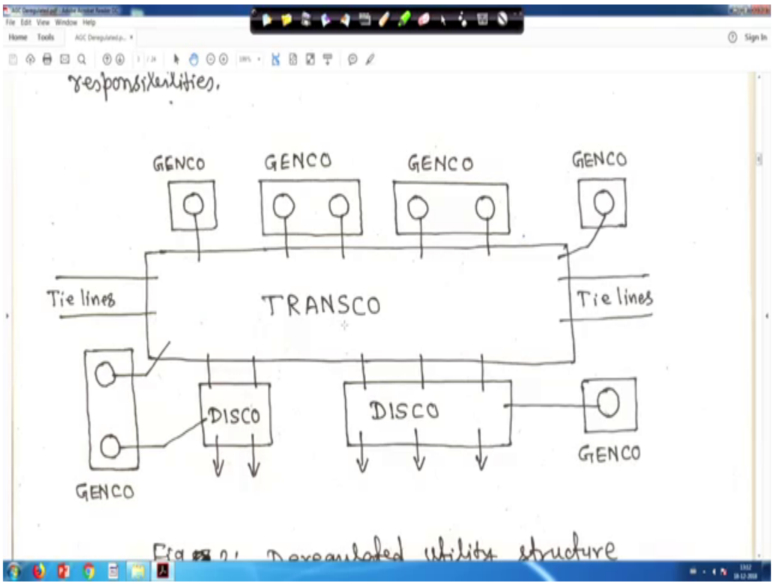

Ok. So, we are back again right. So, now if we look into if you look now that you are what you call that your deregulated environment, then each a entity this is a generation company, it has one generator, say it has two generator it has two generators, and this is all independent by power producer also. There is they will call it as GENCO, and this is also we call GENCO, and this two this transmission company we call TRANSCO, and distribution company we call DISCO right.

So, now we have earlier it was together. Now, it is a three different entity; generation, transmission, and distribution right. So, this is the concept for deregulated theme; so, that is deregulated utility structure. So, it is separated that was vertically integrated utility, now it is separated right.

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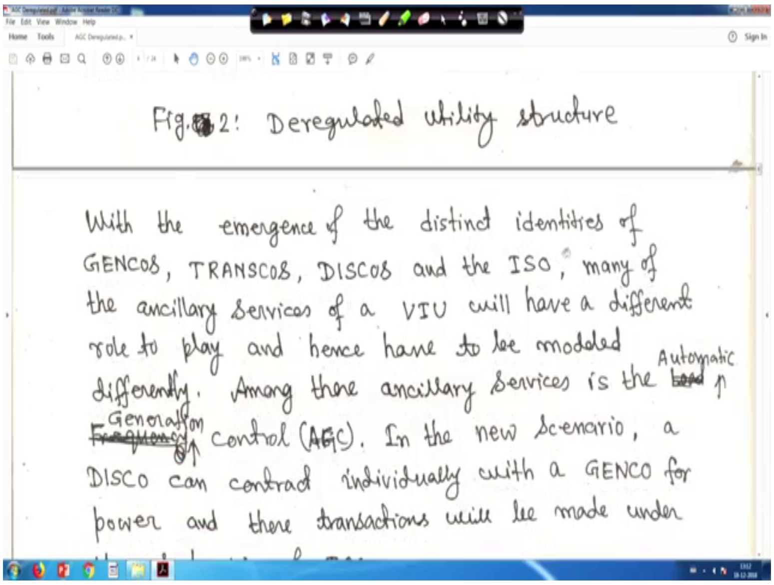

Now, with the emergence of the distinct identities of GENCOs, TRANSCOs, DISCOs, and ISO means Independent System or Independence System Operators right. So, in there you have to therein this ISO that many of the ancillary services of vertical integrated utility, we will have a dependent role to play. And hence have to be modeled differently right. So, not only AGC, there may be other ancillary services right. So, among those; among these ancillary services is the automatic generation control. So, in the new scenario, a DISCO can contact individual individual with a GENCO for power and their transaction will be made under the supervision of ISO right.

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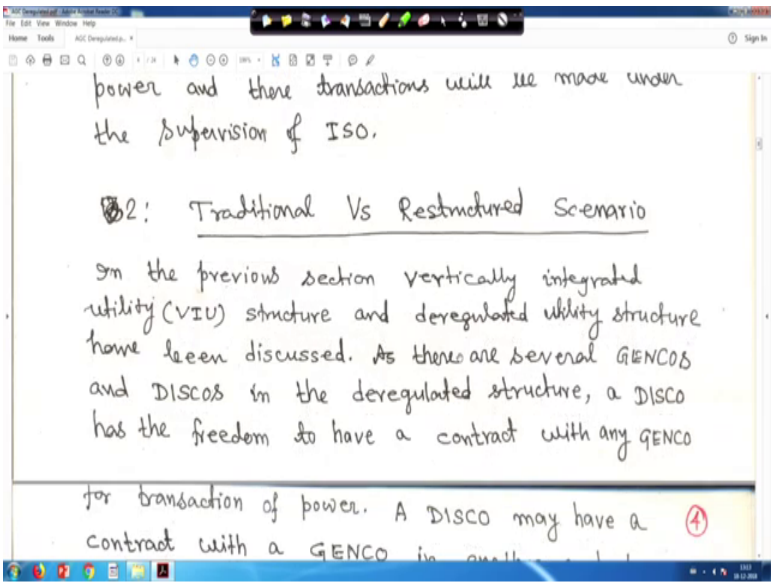

Now, traditional versus your restructured scenario. So, in the previous section, we have seen the vertically integrated utility structure. And deregulated utility structure have been discussed right. And there are several GENCOs and DISCOs in the deregulated structure, so a DISCO has the freedom to have a contact with any GENCO right for transaction of power.

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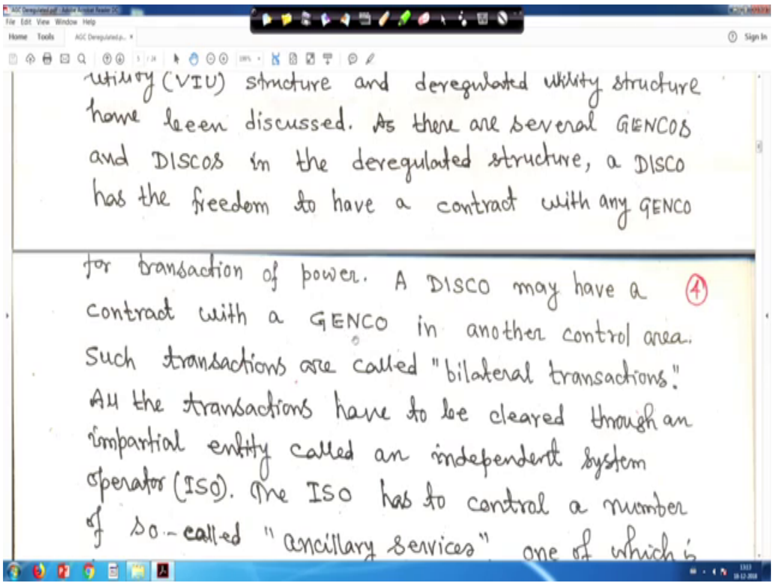

So, a DISCO may have a contact with a GENCO in another control area that I told you. Suppose, there are two areas, a and b. In the area a some distribution companies are there, generation companies also there. In the area b also some is also distribution company and generation companies are there, they are connected by tie lines right. So, if power is cheaper, then this cause every right to buy power not from its own area, but from other areas too, because if we finds the power energy purchase is cheaper right. So, such transactions are called bilateral transactions right.

All the transactions have to be cleared through an impartial entity called independent system operator right. So, I told you that independent system operator, it is a separate entity, separate office. All GENCOs, all biding will take place there only right. The ISO has to control a number of so called ancillary services one of which is AGC right.

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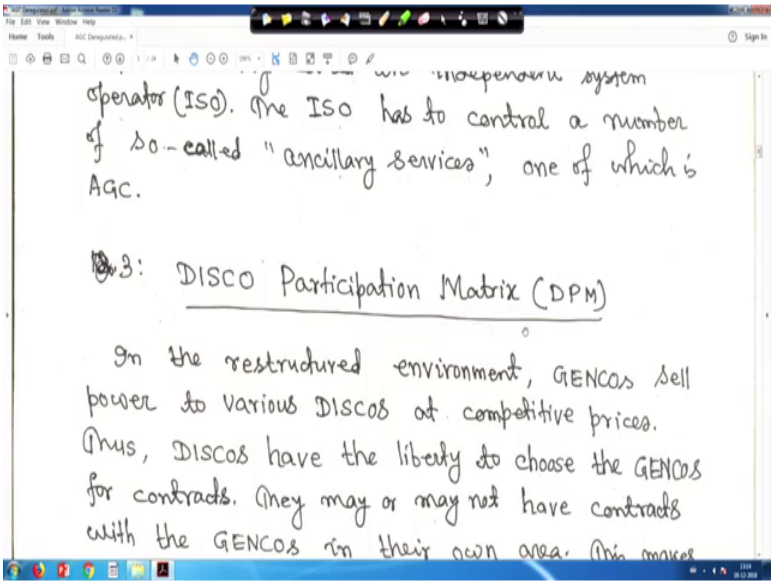

So, to realize this in mathematically to realize this, so what we will see that DISCO we call a term, the DISCO participation matrix in short we call DPM right. So, in the restructured the DPM little bit we have to understand. Just see how it is it is very simple that in the restructured environment, GENCOs sell power to various DISCOs right at competitive prices.

Thus, DISCOs have the liberty to choose the GENCOs right for contracts. They may or may not have contracts with the GENCOs in their own area. This makes various combination of [gesco/GENCO] GENCO-DISCO contract possibly you are possible in practice right.

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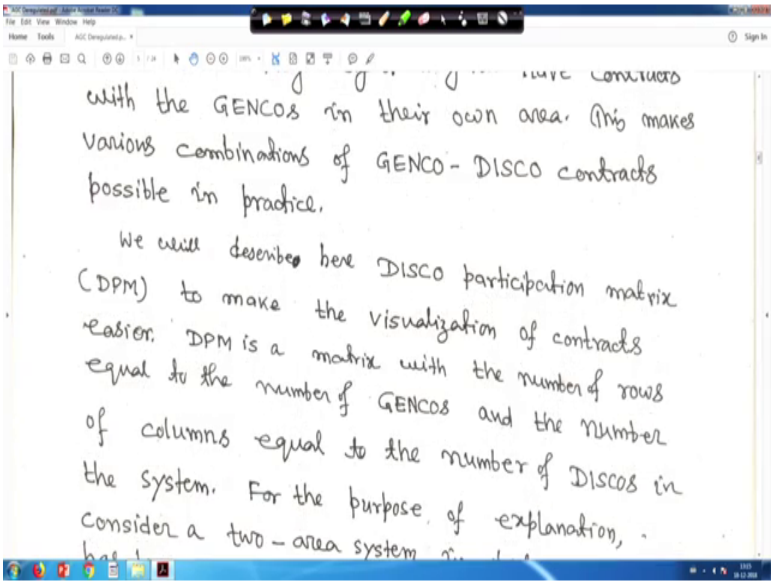

So, we will describe the DISCO participation matrix that is DPM right to make the visualization of contacts easier. Actually, DPM is a matrix with the number of rows equal to the number of GENCOs and the number of columns equal to the number of DISCOs in the system. For the purpose of explanation, just consider a two-area system in which each area has two GENCOs and two DISCOs right.

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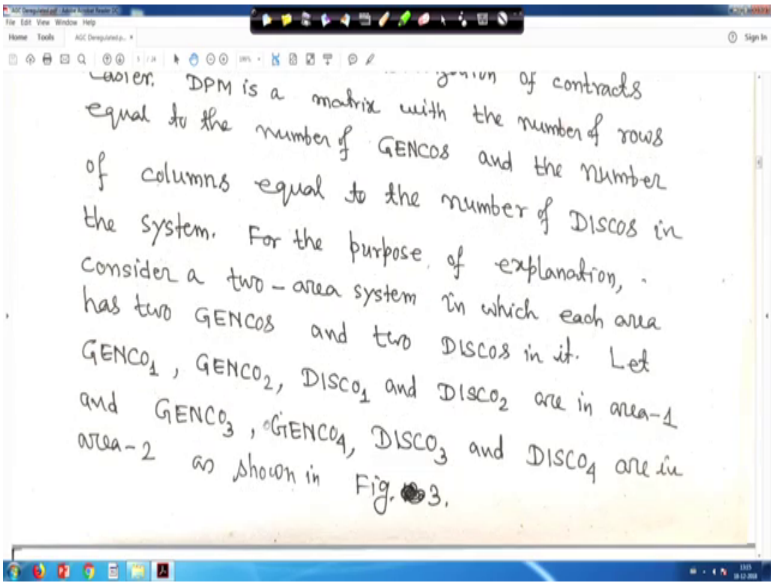

Let GENCO 1, GENCO 2, DISCO 1, DISCO 2 are in area-1. And GENCO 3, GENCO 4, DISCO 3, DISCO 4 are in area-2 as shown in figure-3.

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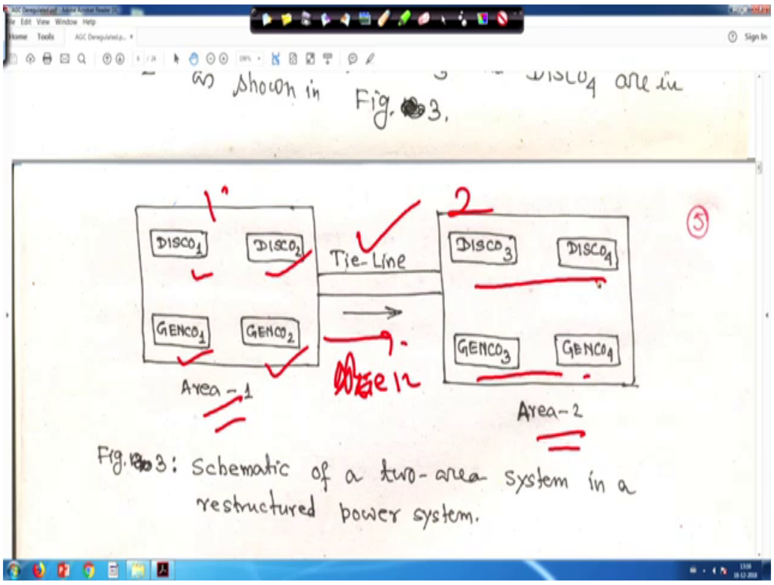

Now, let us see try to understand this. Although it looks like simple, but some understanding is required. Suppose, this is my area-1, and this is my area-2. So, in area-1 two GENCOs are there, two DISCOs are there. It does not mean anything, it maybe two GENCOs, four DISCOs or four GENCOs, two DISCOs, it is like that only right a just for the sake of explanation, we have taken like this.

And these two areas are interconnected by tie line. Say power is flowing from say this is my area-1, and this is area-2. So, power is flowing from 1 to 2. So, this power is delta p tie 1 2 right. And area-2, two GENCOs are there, GENCO 3 and GENCO 4. and two DISCOs are there, DISCO 3 and DISCO 4 and distribution company is 3, and distribution company four 4.

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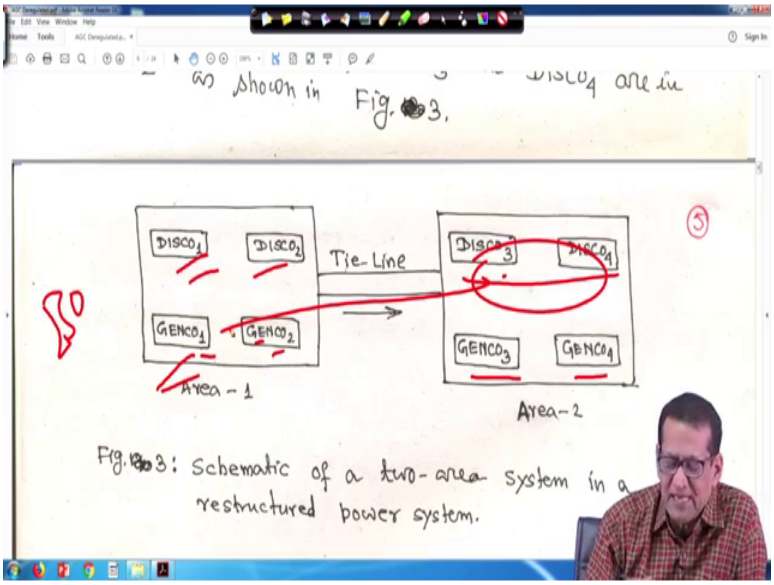

Now, I will and another independent is independent system operator is there right. So, (Refer Time: 05:31) we call ISO, so all beading will be done. Suppose, these distribution companies, they have a right if they find, the if I buy power from this area that is from GENCO 3 and GENCO 4, then my your what you call it will be cheaper, then it case it cannot buy power from GENCO 1 and GENCO 2.

Similarly, for DISCO 3 and DISCO 4, if it buys your power is this energy powers is a cheaper from GENCO 1 and GENCO 2, then these two also can buy power from GENCO 1 and GENCO 2. At the same time if they find that we, I can buy power we can buy power DISCO 1, DISCO 2, you can think that we can buy power from GENCO 1 partly GENCO 1 from GENCO 2 partly from GENCO 3 and GENCO that is also possible.

Similarly, for DISCO 3 and DISCO 4, they can also purchase power from GENCO 3 and GENCO 4 or from GENCO 1 and GENCO 2 right, and that power will be power willing will take place through the tie line. So, these are the certain things for this case, we are not considering any losses or anything right. Those are beyond the scope for this course right. This is a control type of thing, so that that is why, these two area system is taken. Now, question is that how to based on that how to form your what you call that your DPM that is DISCO participation matrix right.

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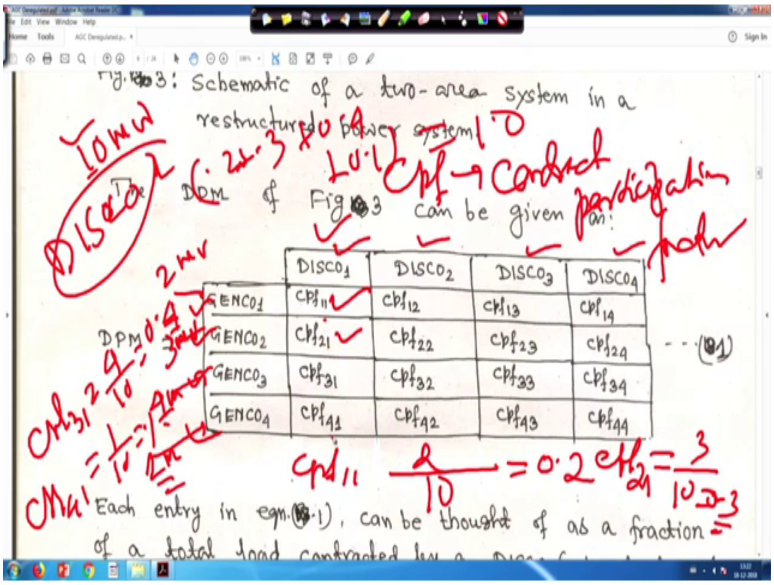

So, DISCO participation matrix is suppose I told you that this horizontal one the DISCO 1, DISCO 2, DISCO 3, DISCO 4, where the meaning is like this. And this is and this vertical one GENCO 1, GENCO 2, GENCO 3, GENCO 4. And accordingly, this matrix is not n into n matrix like this nothing like this, you have to see how many GENCOs and how many DISCOs are there. So, accordingly your matrix, this matrix order will be right.

But, here two each, so that is why it is it is becoming 4 into 4, so but you have to order like this. Suppose, you have suppose in area-1, you have one more say, one more DISCOs, and DISCO 1, DISCO 2, DISCO 3 will come and DISCO 4, DISCO 5, DISCO 6 will come. For area-2 suppose if it is like this or if or DISCO 1, DISCO 2, DISCO 3 three distribution companies are there in area-1, so 3 will be there. And then DISCO 4, DISCO 5 will be there, so accordingly you have to take.

Now, suppose this is distribution company right. Now, suppose my for example, I have taken one example later. Suppose, DISCO 1 this cpf 1 and see this or this cpf, this matrix element in general cpf, this is called contract participation factor that is written there that is contract participation factor right, so contract participation factor.

So, in this case cpf, so this values are less than 1 right, this values are less than 1. Suppose, this DISCO 1 has some DISCO 1 say to it may total demand, may be say it take 10 mega watt. So, part of that it can borrow from GENCO 1, it can GENCO 1 DISCO from GENCO 2, GENCO 3 and GENCO 4.

Suppose, my DISCO 1 right DISCO 1 distribution company is one, its total power demand is 10 megawatt say 10 megawatt right. So, now it will it needs from GENCO 1 say GENCO 1, DISCO 1 it needs a 2 megawatt. So, a GENCO 2, it needs 3 megawatt right. So, here it needs 4 megawatt and for GENCO 4, it needs one mega watt right.

So, DISCO 1 needs 2 mega watt from your GENCO 1. DISCO 1 needs 3 megawatt from GENCO 2. DISCO 1 needs 4 mega watt from GENCO 3 and DISCO 1 needs 1 mega watt from GENCO 4 say right, total is 10; then what will be cpf 1 1 cpf 1 1 right, say total is 10 megawatt. So, denominator will be 10, and it needs 2 megawatt from GENCO 1. So, 2 by 10 that will be your 0.2 right.

Similarly, cpf 21, because DISCO 1 needs 3 megawatt from GENCO 2 right. So, it will be your cpf 21, it will be your 3 by 10 that is your 0.3 right. Similarly, your these 4 megawatt that DISCO 1 needs from GENCO 3 that means, my cpf your 3 1 cpf 3 1 is equal to 4 by 10 that is 0.4 right.

Similarly, cpf 41 because DISCO 1 needs 1 megawatt from your GENCO 4 so, cpf 41 is equal to 1 by 10 that is 0.1 that means, cpf 1 1 is 0.2 look, cpf 1 1 is 0.2, cpf 2 1, cpf 2 1 is 0.3, say plus 0.3 add all, and cpf 3.14 here plus you add 0.4 plus cpf 4 1 right your cpf 3 1 cpf 2 1 cpf 3 1 cpf 4 1 is 0.1. If you add all these, it is actually 1.0 right 1.0; that means, that means it is a fraction only that means, I have to put the fraction of that how much I need right. So, it is two megawatt means total is 10 out of this 2 is taking, so fraction will be that this matrix will be then, this column matrix will be then, it will be your 0.2, then your this one is taking 3, so 0.3, 0.4, and 0.1 right.

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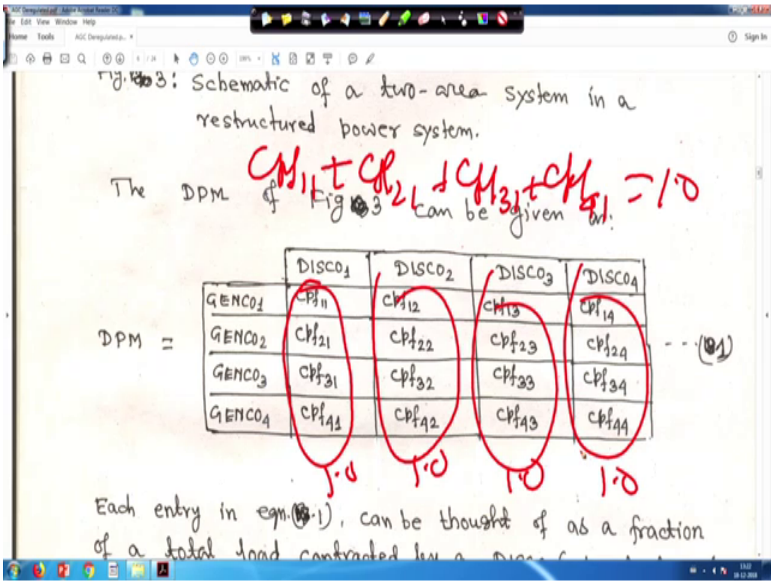

So, that is the meaning of your for DISCO 1 that means, this column you have elements if you add all, it will be 1 that means for that means, for all the cases for first column cpf 1 1 cpf 2 1 plus cpf 3 1 plus cpf 4 1 is equal to 1.0, column wise it should be 1.0. So, similarly if you add all, it has to be 1.0, column wise 1.0 right, so the that means, this is the idea this is the idea for your this DISCO participation matrix.

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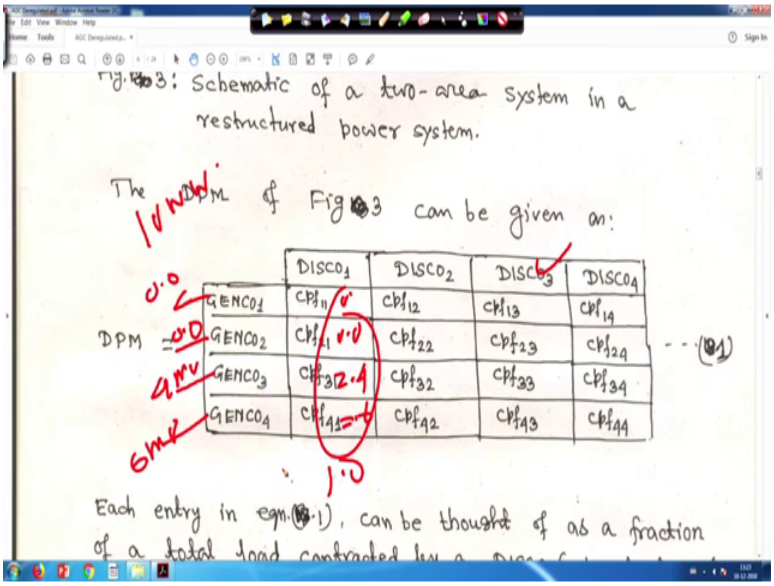

Similarly, say this is DISCO 3 right, this it is possible that it there is no there cannot be or what you call suppose DISCO 1 has 10 megawatt right DISCO, but it does not want anything from GENCO 1, so it will be 0.0. It does not want anything from GENCO 2, it will be 0.0.

Suppose, it wants 4 mega watt from here, and 6 megawatt from here, so that mean this value will be 0.4, and this value will be 0.6, this is 0.0, this is 0.0, you add all it will be 1.0 right, so that is your what you call the concept of DISCO participation matrix right. So, I hope you have understood this part right, so that is after that everything whatever I have explain, that after that everything is written.

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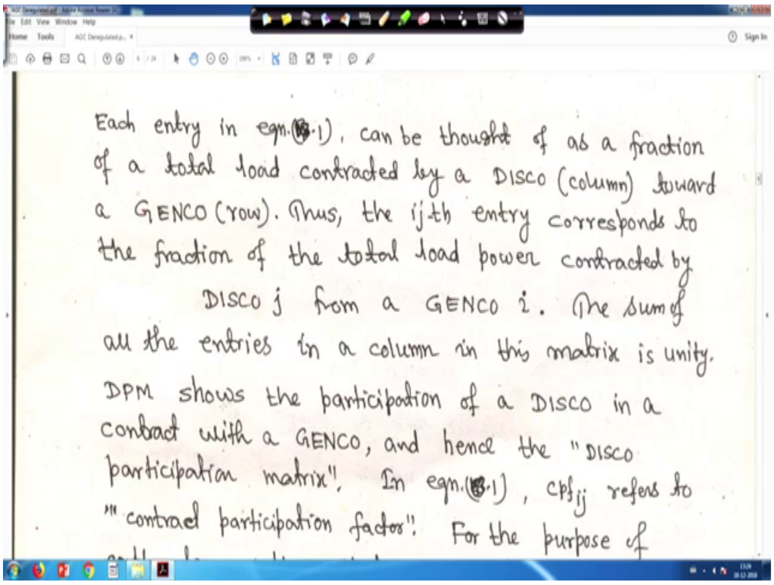

So, can be thought of as a fraction of total your load contacted by DISCO I told you toward the GENCOs right. So, thus that that is i jth entry correspond to the fraction of the total load power contacted by DISCO j from a GENCO i in general, but I told you what exactly it is right.

The sum of the entries in a column in this matrix is unity that also I told you. So, DPM shows that is DISCO Participation Matrix shows the participation of a DISCO in a contract with a GENCO, and hence that DISCO participation matrix that is why, its name is DISCO participation matrix right. So, the DISCO that is or the DPM shows the participation of DISCO in a contract with a GENCO, and hence this name is DISCO participation matrix right.

So, in equation-1 cp ij, that is your cpf ij Contracts Participation Factor cpf ij refers to contract participation factor right. So, again I have taken another whatever example I have given. For another example that for the purpose of explanation, suppose that DISCO 2 demands 0.1 per unit mega watt power right total is 0.1 per unit, out of which 0.02 per mega watt per unit megawatt is demanded from GENCO 1, 0.035 per unit mega demand mega watt demanded from GENCO 2, 0.025 per unit mega watt demanded from GENCO 3 and 0.02 per unit mega watt demanded from GENCO 4 right.

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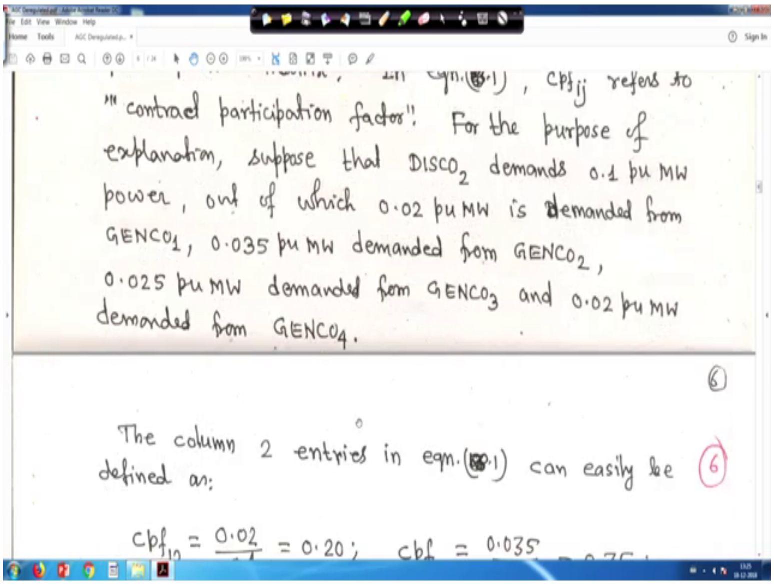

Therefore, the column 2 entries one column I showed you, this is another one that cpf 12 right will be your 0.02 upon 0.1, so 0.2. cpf 2 2 will be 0.035 upon 0.1, because 0.1 per unit megawatt is a total demand is equal to 0.35. cpf 32 is equal to 0.25 upon 0.1, so 0.25. And cpf 42 is equal to 0.02 upon 0.1, so 0.2.

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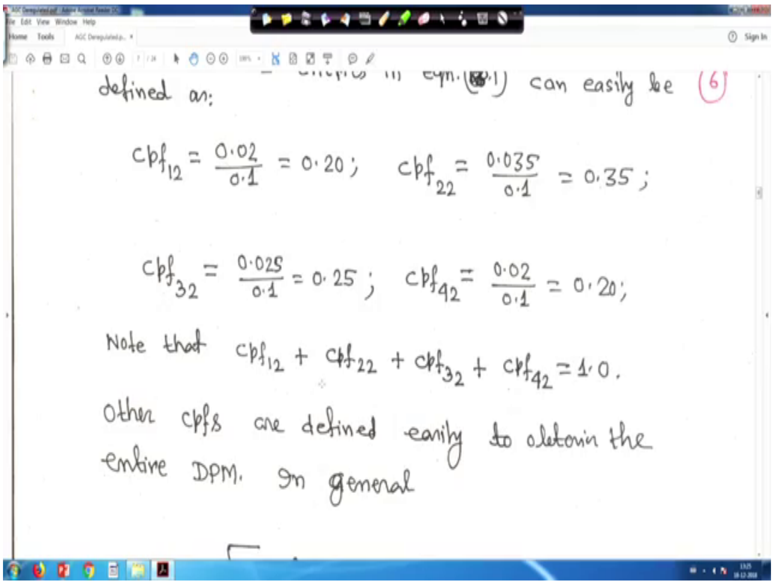

Now, if you add all the column wise, cpf 1 2 that is second column cpf 1 2 cpf 2 2 plus cpf 3 2 plus cpf 4 2. If you add all, it is 1.0 that means, this column this second column 1 2 cpf 1 2 plus cpf 2 2 plus cpf 3 2 plus cpf 4 2, if you add all that it has to be your one right. So, in general in general for all i, cpf ij will be 1.0 right, so column wise it will be 1.0 right.

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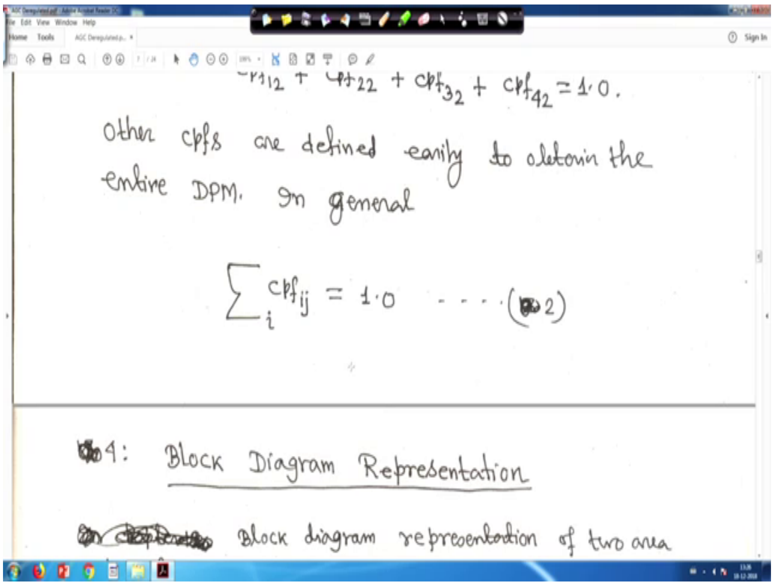

So, next is the block diagram representation of AGC in deregulated environment.

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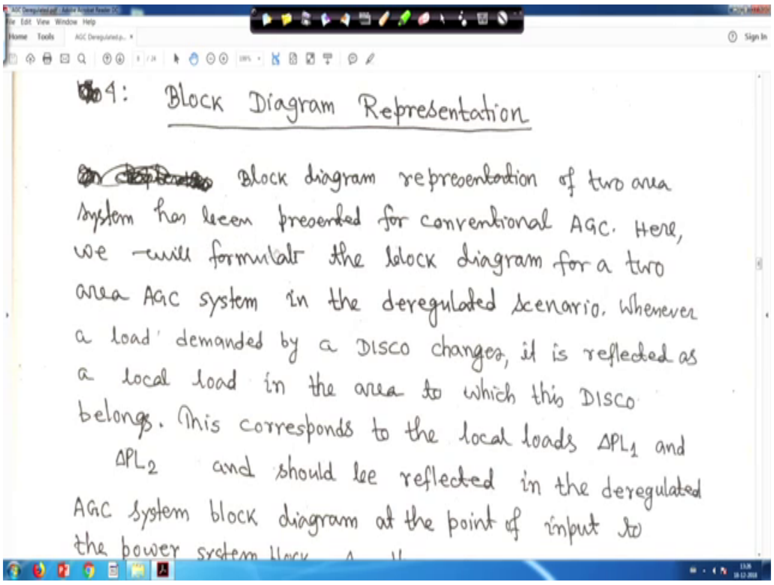

So, block diagram representation of a two area system has been presented we have seen for conventional AGC. Here we will formulate the block diagram for a two area AGC system in the deregulated scenario. Whenever, a low demanded by DISCO changes, it is reflected as a local load in the area to which this DISCO belongs right.

This correspond to the local load del P L 1 and delta P L 2, because that del P L 1 that is a total load demand demanded by DISCO 1, and delta P L 2 total load demanded by DISCO 2. So, this can be consider as local load, and it will be reflected in area 1. And should be reflected in the deregulated AGC by block diagram at the point of input to the power system block right. This we will see, as there are many GENCOs in each areas ACE signal has to be distributed among them in proportion to their participation AGC that also we will see. Little bit we have seen in conventional AGC that ACE participation factor. Coefficient that distribute ACE participation factor right.

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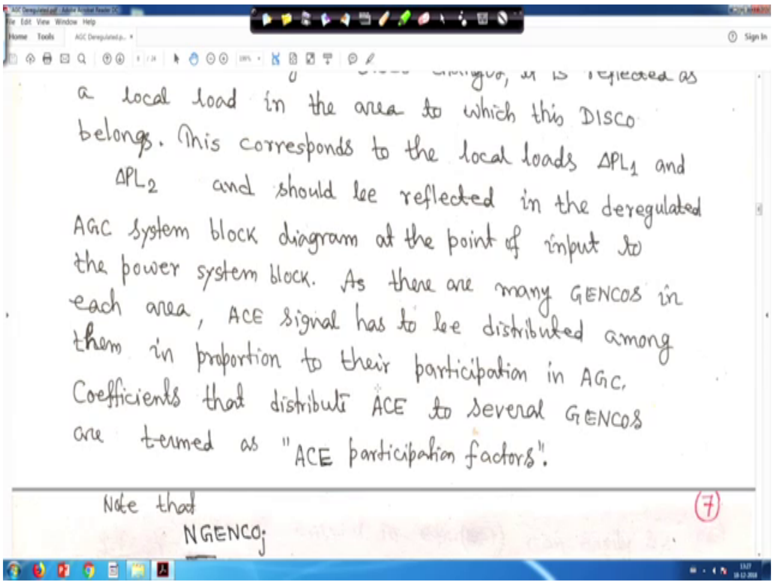

So, as long as long as in the system, there is no uncontracted power demand, we will come to that later. Suppose DISCO distribution companies have some contracted power with all the generation companies, apart from that if that distribution companies need some extra power, which was not in contract right that is called uncontracted power demand right. At that time ACE participation factor will plays significance role. Otherwise, if no uncontracted power demand is there, then they ACE participation factor a has its effects on transient, but not at the steady state that we will see right.

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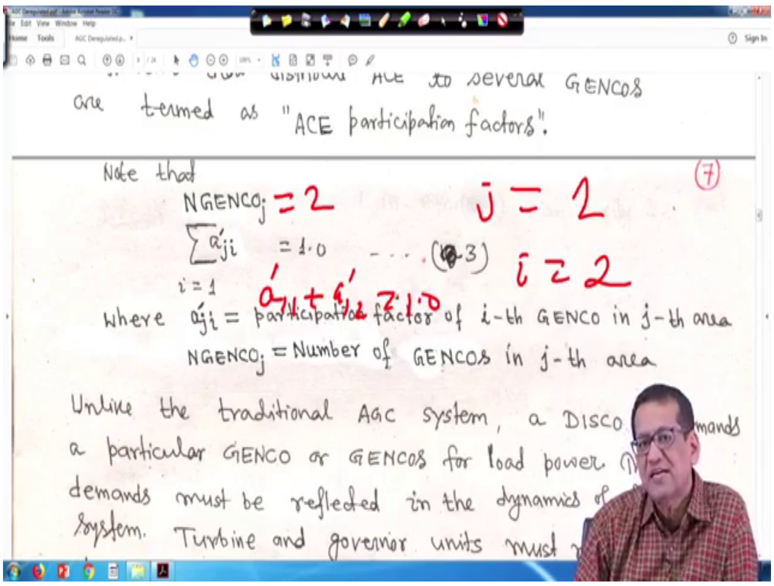

So, note that; that your this is a ij the a ji dash actually this is actually call that ACE participation factor that we will see later it is NGENCO j right. So, a ji dash is participation factor of i-th GENCO in j-th area and we have putting a ji dash. And NGENCO j is number of GENCOs in j-th area right. Suppose in area 1, suppose you have two GENCOs, so it will be i is equal to 1 to 2 right. And j is a i-th GENCO in the j-th area right.

So, it will be I mean it is something like this for this same example, suppose that i-th GENCO in j-th area. Suppose, jth area means suppose area is equal to 1, j is equal to 1 right. And your what you call that number of GENCOs is j-th area, suppose that is i suppose i is equal to 2 GENCOs are there. For area 1, we have seen two GENCOs to DISCO, so basically it is this will be is equal to 2 right that mean this one actually will be your j is equal to 1, so it will be a dash 1 1 plus a dash 1 2 is equal to 1.0, this is the meaning right.

So, unlike the traditional AGC system, a distribution company that is the DISCO asks or demands a particular GENCO or GENCOs right for load power. These demands must be reflected in the demands of the your what you call, this must be reflected in the dynamics of the system right, because of the load demand that when you consider dynamics right that transient behaviour will change.

So, turbine and governor units must respond to this power demand right, because this signal will go to the set point of that. So, whatever power demand is coming that we will see this things right. And thus, as a particular set of GENCOs are suppose to follow the load demanded by a DISCO. When GENCO is following this load, what is demanded by DISCOs will other term, we can load following right.

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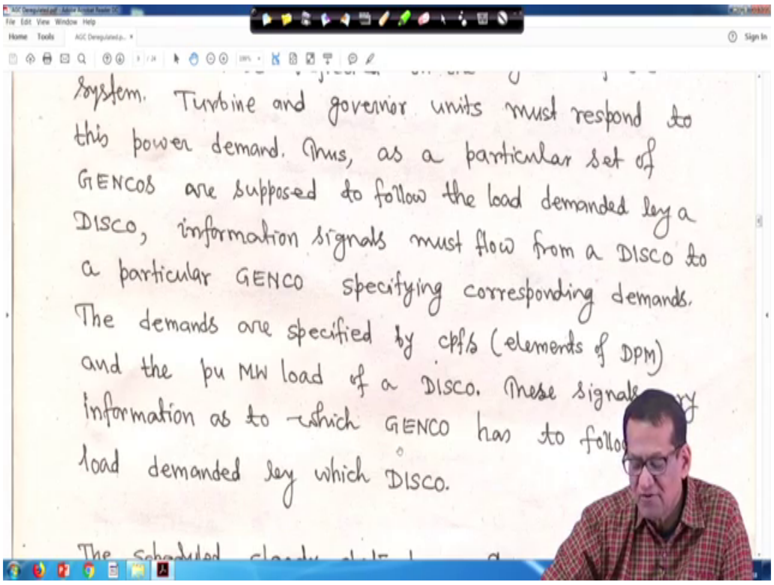

Information signals must flow from a DISCO to a particular GENCO that means, you have a better for deregulated system, you have a better communication channel right, so that mean this otherwise how this information will reach to that right must flow from a DISCO to a particular GENCO specifying corresponding demands right.

The demands and are specified by contacts participation factor that is your elements of DISCO participation matrix DPM and the per unit megawatt load of a DISCO. These signals carry information as to how which GENCO has to follow a load demand load demanded by which DISCO right. So, this signal will go accordingly generation generator that is GENCOs we generate the power that means, GENCOs will follow the load right of the demand of the DISCOs, you know other name is load following.

The steady states, now in this case, what will happen? The scheduled steady state power flow on the tie-line is given as. So, before going to that, we will go back to that diagram again right. So, in this case these two area, these thing right; so, in this case in this case that it is it is area 1 and it is area 2. So, in this power is flowing, so we have taken the direction say 1 to 2. If 1 2 delta P tie 1 2, become negative means, it is flowing from 2 to 1. So, it when is taking 1 to 2, so how we will do this? I mean how we will find out the delta P tie 1, 2 schedule power flow, when all the demanded load demanded by DISCOs are known..

Then what will happen that you have DISCO 3 and DISCO 4 in area 2 right. So, what we will do is, that first we will take that what is the power demand of DISCO 3 and DISCO 4 that whatever contract they have with this one and with this one right. I mean whatever they have, so that means DISCO 3 and DISCO 4, we will take power from GENCO 1 and GENCO 2, whatever contract cpf they have right, so that means this power if DISCO 3, DISCO 4 takes power from GENCO 1 and GENCO 2 so, this power will be flowing in this direction right.

And similarly, DISCO 1 and DISCO 2 whatever will they are, whatever they will take from GENCO 3 and GENCO 4, this their power will try to flow in this direction. So, ultimately resultant will be that this power whatever DISCO 3 and DISCO 4 is drawing minus your this power demanded by DISCO 1 and DISCO 2, which are now is that contract with GENCO 3 and GENCO 4; so, that means first you have to consider that whatever DISCO 3 and DISCO 3, your distribution company is 3 and 4.

Have contract with GENCO 1 and GENCO 2 that you take first, so that will be the first thing minus your whatever disc because this power is flowing, because this power is flowing in this direction right. But, our objective is in this reaction, but this power DISCO 1 and DISCO 2 power flowing in this direction, so this direction. So, resultant will be this power minus the power demanded this one right, so that is the idea that delta P tie 1 2.

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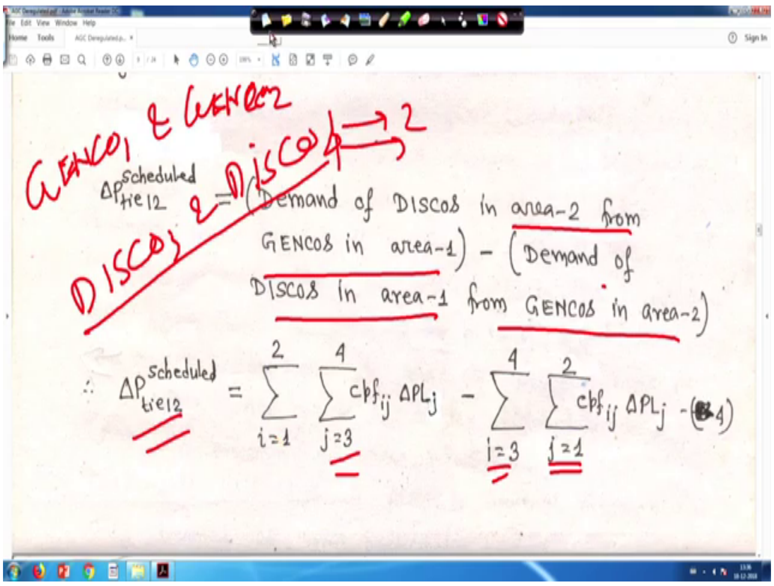

So, mathematically so mathematically we can represent like this. So, mathematically we can make it like this that delta P tie 1 2, this is a scheduled tie power flow right. So, demand of DISCOs in area-2 I told you from GENCOs in area-1 minus demand of DISCOs in area-1 from GENCOs in area-2, because we have taken direction 1 to 2 that is why demand of DISCOs in area-2 from your one.

So, power is flowing 1 to 2 minus demand, because minus taking, because it power is flowing from 2 to 1, because DISCOs area-1 demanding power from your GENCOs in area-2. So, we have only two DISCOs, and two GENCOs right. So, i is equal to 1 sigma, i is equal to 1 to 2. And j is equal to 3 to 4 cp i cpf ij delta P L j right minus your i is equal to 3 to 4, then j is equal to 1 to 2 that cpf ij delta P L j.

So, if you look into this right, so DISCO 3 and DISCO 4, this is demanding power from I mean in the area 2, you have DISCO 3 and DISCO 4 to distribution comparison. And an area this is your area-2; an area-1, you have GENCO 1 and GENCO 2 right; so that means, you have two your DISCO 3 and DISCO 4 is area your 2. So, sigma j is equal to 3 to 4 cpf ij delta P L j. And GENCOs there are two GENCOs, i is equal to 1 to 2 that is so we have taken.

Similarly, in that you are what you call that in area your what you call that your demand of DISCOs in area-1. In area-1, there are your two DISCOs right, so that is your j is equal to 1 to 2 right, so this is for DISCOs. And you have a and you have a two GENCOs that is in your area 2, so that is i is equal to 3 to 4. So, this is this way the mathematically this way you can write right. So, this is my your what you call schedule power total schedule power.

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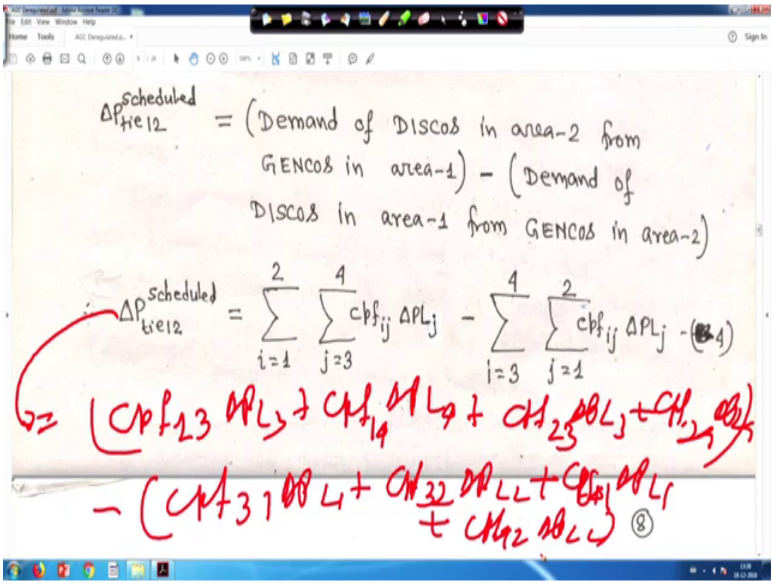
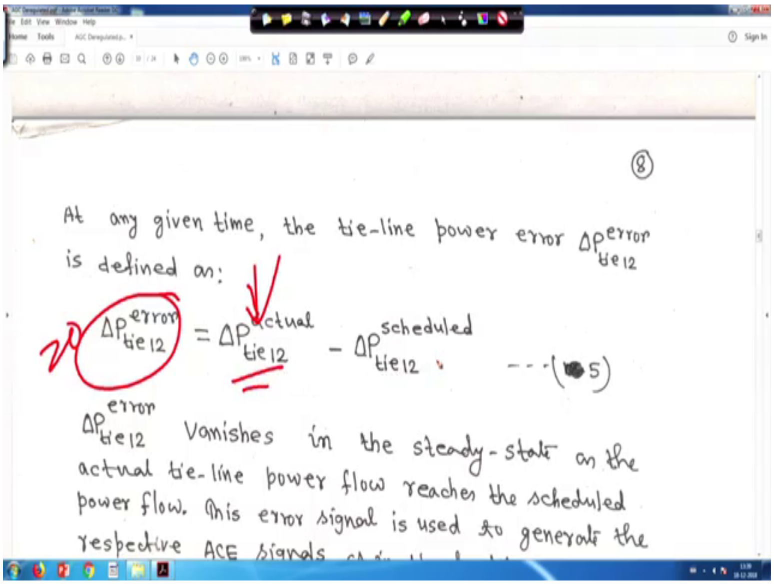


Now, if you so mathematically just hold on, so that means that means mathematically if you expand this one if you expand this one, so I am making it here that this is actually delta P tie 1 2 schedule right, is equal to that if you put when i is equal to 1, j is equal to 3 to 4 right.

When i is equal to 1 that means, cpf right i is equal to 1 that 1 3 delta P L 3 right plus cpf 1 4 right your j is equal to 4, then delta P L 4, this is for i is equal to 1. Then plus your when i is equal to 2 cpf 2 then 3, your delta P L 3 plus cpf 2 4 delta P L 4 right. Whenever I will writing all this, please check yourself right.

Hope I will not making any error or mistake, but from expansion and other thing be careful, because here video recording once it is missed, then it will remain as it is. So, you should correct it. By chance if you find any error or anything, please let me know. Then this is minus, so when i is equal to 3, j is equal to 1 to 3, so cpf right your what we call that i is equal to 3. So, cpf 31 your delta P L 1 right, then your plus your cpf 3 2 delta P L 2 plus then while i is equal to 4 cpf 4 1 delta P L 1 plus cpf 4 2 delta P L 2 right. So, if you expand this, it will be like this.

(Refer Slide Time: 27:29)



So that means, your that delta P tie error will be then that actual power flow minus delta P tie 12 scheduled power flow. This actual tie line power flow later, we will see right that it will come from the your mathematical model, what is the actual, what is the schedule. But, at steady state you want this one should be is equal to 0. If this one is equal to 0, then actual power flowing will be is equal to your schedule power flow at the steady state right. So, thank you very much, we will be coming more about this thing in the next video lecture.

Thank you.