Power System Dynamics, Control and Monitoring
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Lecture - 47
AGC in deregulated system (Contd.)

In the previous lecture that we started we will study that 4 different case studies right. So, first one is that in the previous lecture we might have discussed for 2 minutes only right. So, about this first case study that first thing is that unit 2 and unit 4 right; unit 2 and unit 4 are under load following contract only right.

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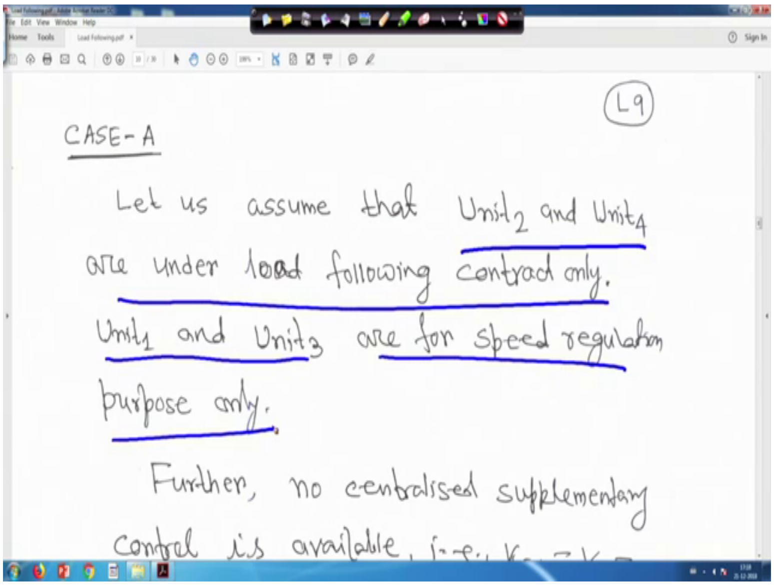

So, they are they will not be part of AGC that generation will actually chase the contacted demand right. And unit 1 and unit 3 are speed regulation purpose only ; that means, that there will be no supplementary controller that is K i 1 and K i 2 will be 0 and it will be only speed regulation purpose that is your delta f by r feedback that is coming know for the governor.

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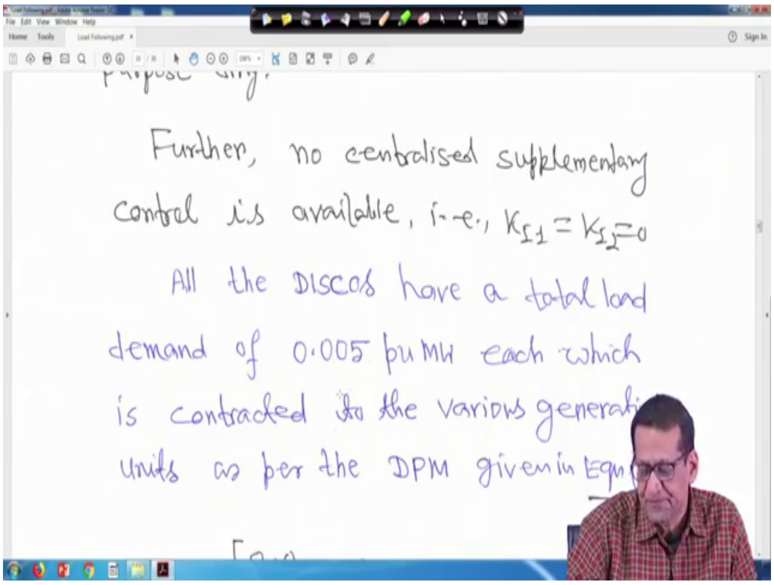

So, further no centralised supplementary control is available that is K i 1 K i 2 is 0; so, that is I told you that K i 1 K i 2 is 0. Now all the Distribution Companies in short we call DISCOs have a total load demand of 0.005 per unit megawatt. Here we have taken very small load disturbance 0.005 I mean load demand because we have considered the generation rate constant of 10 percent per minute for the thermal unit right.

Actually generation rate constant actually detorious is the dynamic responses. So, if we take because if you take instead of 0.005 if you take 0.001 or something, the settling time also will increase right a lot of oscillations will be there. So, even with 0.005 per unit megawatt right for your what you call total that all the load demanded by DISCOs that is DISCO 1, DISCO 2, DISCO 3 and DISCO 4 right. So, is contracted to the various generating unit as per the DPM.

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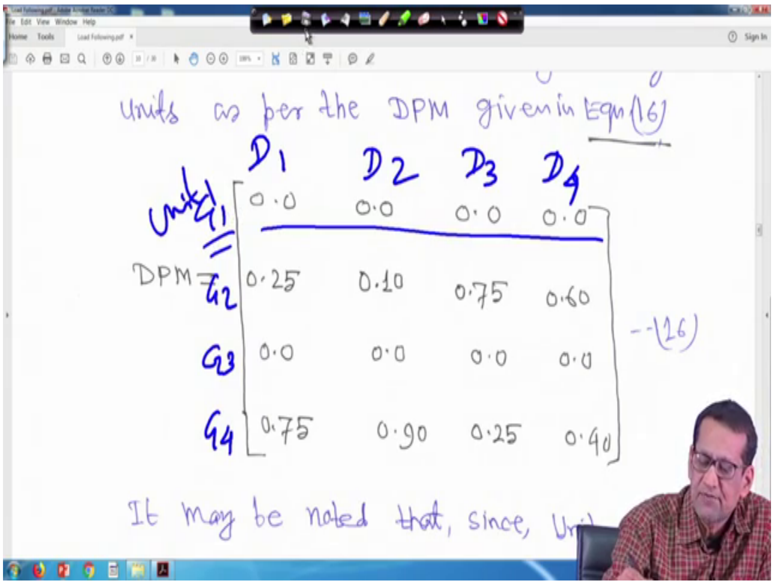

So, these distribution this DISCO participation matrix is considered like this. So, ~~[we/you]~~ you know that I making in short distribution company means this is D 1 this is D 2 this is D 3 and this is D 4 generation company means G 1 instead of ~~geneos~~ GENSCOS G 2, G 3 and this is G 4 right. So, unit that is your unit 1 in area one it is not taking part in load following that is why this all these elements actually it is your what you call that G 1 is not generating unit 1 is not that is your in this case GENCO know it is unit 1 ~~let me let me~~ let me just delete this one.

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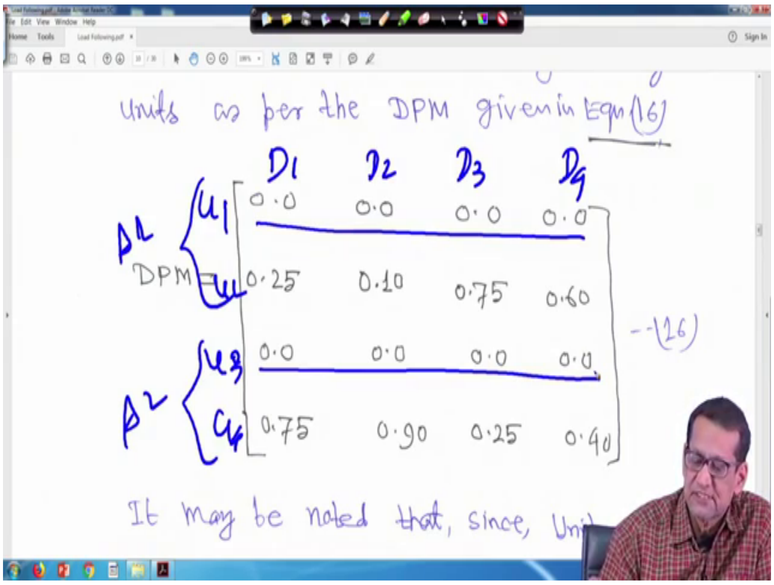

This is D 1 this is D 2 this is D 3 actually this is load following it is unit 1 unit ~~one~~ 1 unit 2 unit 3 unit 4 right. So, this is in area 1; so A 1 and these two units are in area 2. So, in area 1 that generating unit 1 right it is not taking part in load following right. So, in the that is why this all these element that is cpf 1 1, cpf 1 2, cp~~-~~f 1 3 and cpf 1 4 are 0. Similarly that unit 3 in area 2 also not taking part in load following right~~.~~ ~~So~~so, that is why cpf 3 1, cpf 3 2, cpf 3 4 and 3 3 and cpf 3 4 these all these things are 0 right.

And then that unit 2; that is unit 2 this one right that is your unit 2 taking part in load following and unit 4 in area 2 also taking part in load following and this is there cpf values, but all the time this column summation it should be always your 1 right.

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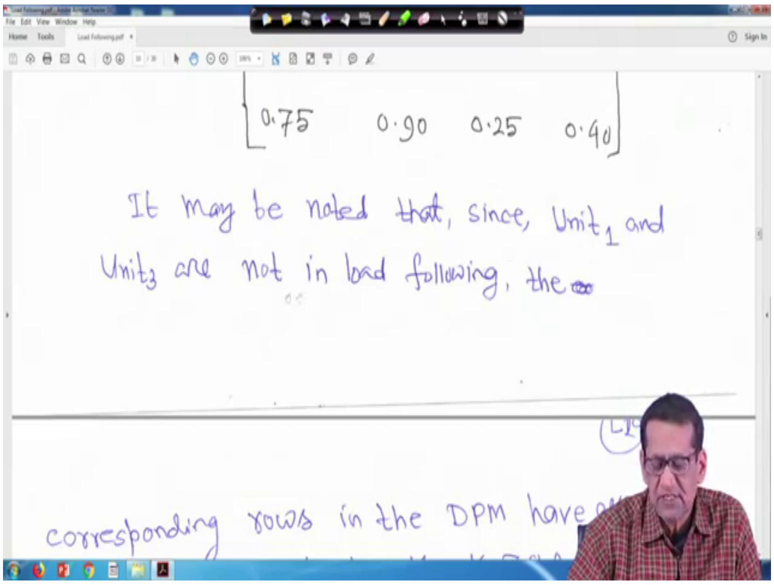

That I explain why it is; so this is equation 16-; so, this is that DPM has been considered for this case right. It may be noted that since unit 1 and unit 3 are not in load following.

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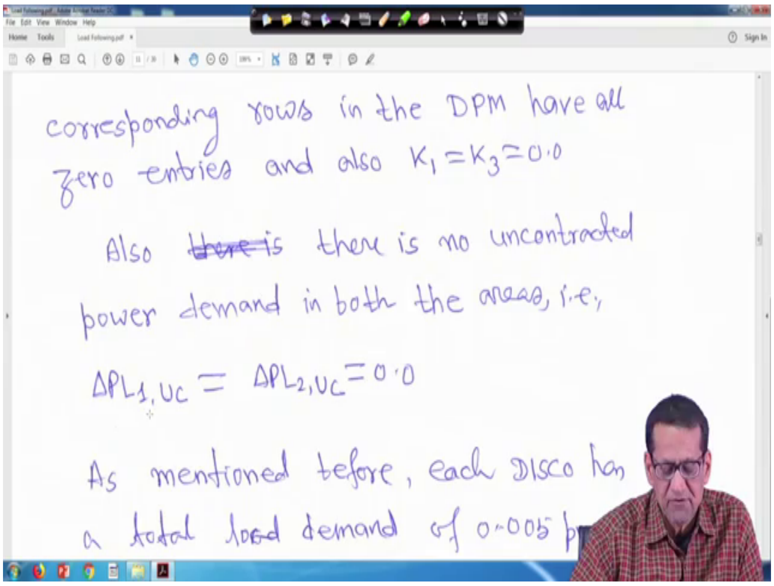

The corresponding rows in the DPM have all zeros entries and also K 1 K 3 is 0 because it is not taking part in load following and that load following controller gain for unit 1 was K 1 and for unit 3 was K 3 that was shown in the block diagram.

So, K 1 is equal to K 3 is equal to 0 right. Also you are assuming that there is no uncontracted power demand in the both the both the areas; so no uncontracted power demand. So, that is delta P L 1 U C that is uncontracted the abbreviation delta P L 2 U C is equal to 0 right.

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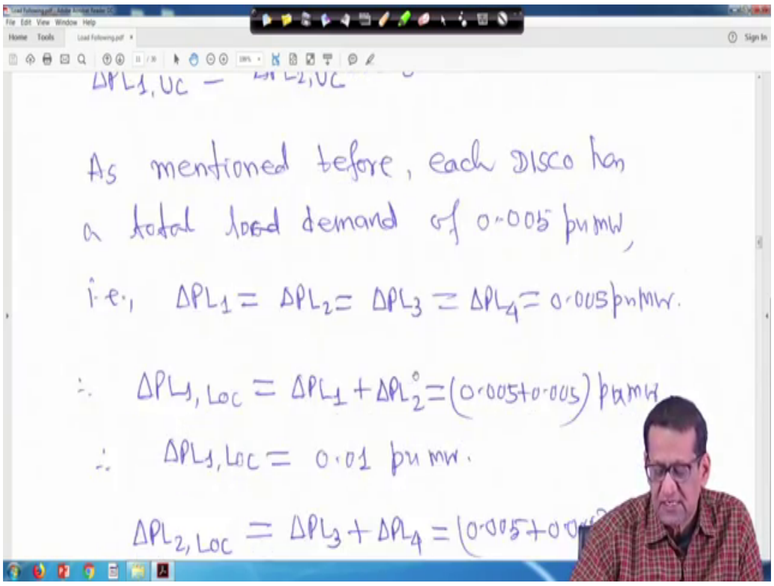

As mentioned before that each DISCO has a total load demand of 0.005 per unit megawatt-; that is delta P L 1 is equal to delta P L 2 is equal to delta P L 3 is equal to delta P L 4 is equal to 0.005 per unit megawatt right and delta P L 1 local same as before that is delta P L 1 plus delta P L 2; so, 0.005 plus 0.005 per unit megawatt that is actually 0.01 per unit megawatt that is delta P L 1 local.

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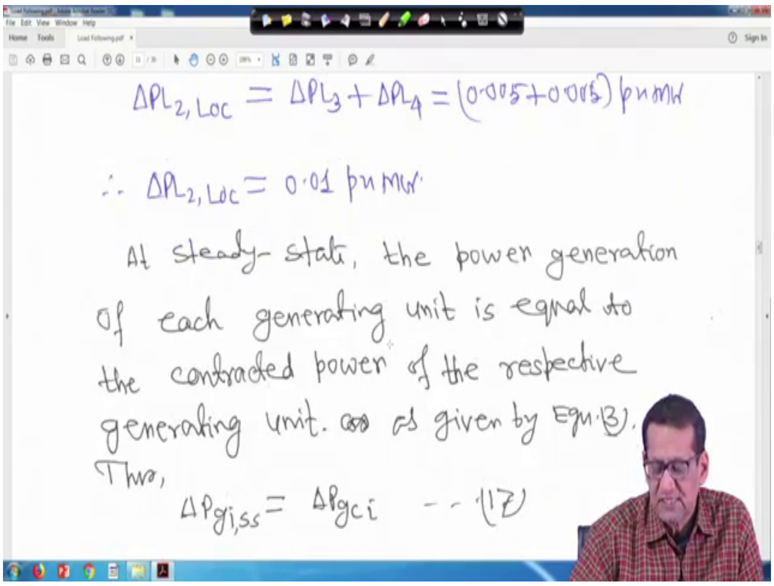

Similarly this load disturbance we have taken this DISCOs have same you can take different also you will get the desired result. So, delta P L 2 local is equal to delta P L 3 plus delta P L 4. So, this is 0.005 plus 0.005 per unit megawatt that is delta P L 2 local will be 0.01 per unit megawatt right.

Now, at steady state the power generation of each generating unit is equal to the contracted power of the respective generating unit as given by equation 3; that we have seen before right. So, thus delta P g i s s will be that steady state generating power will generated power by unit I will be delta P g c i, that contracted power that is your or contact power of GENCO as unit i right.

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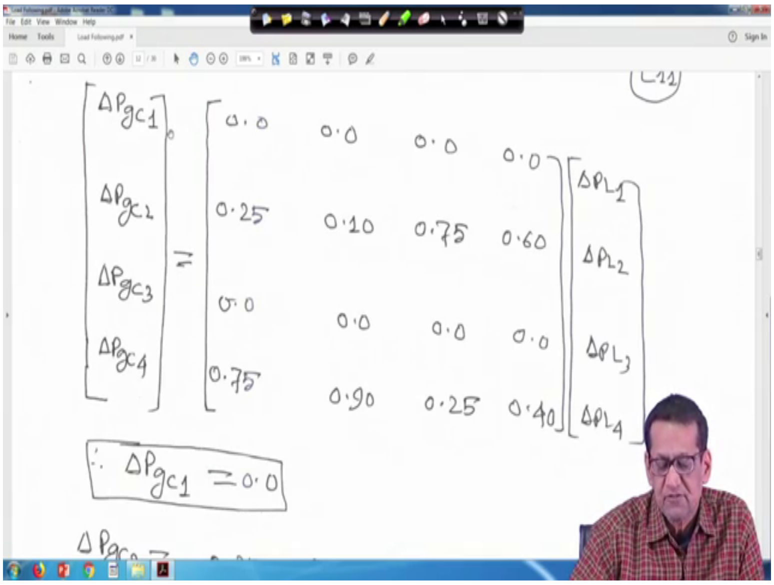

So, this way we can make it delta P g c 1, delta P g c 2, delta P g c 3, delta P g c 4 is equal to this DPM that is into delta P L 1, delta P L 2, delta P L 3, delta P L 4 right. So, if you calculate all ; so delta P g c 1 will be ze[ro]- P g c 1 will be 0 delta P g c 3 will be 0.

So, delta P g c 2 and delta P g c P g c 4 these two are contracted demand.

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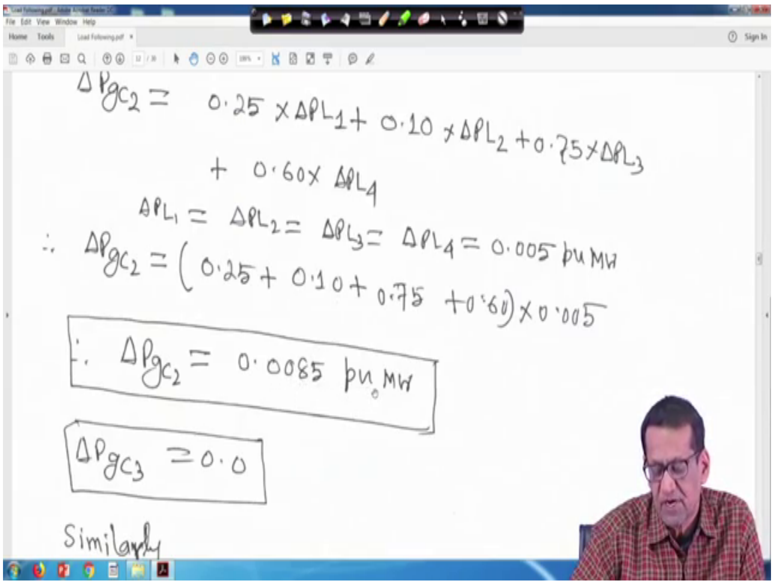

So, delta P g c 2 just you just you multiply this one with this delta P L 1 delta P L 2; P L 3 and P l delta P L 4. So, you will get delta P g c 2 will become actually 0.0085 per unit megawatt right and delta P g 1 and P g c 3 is 0.

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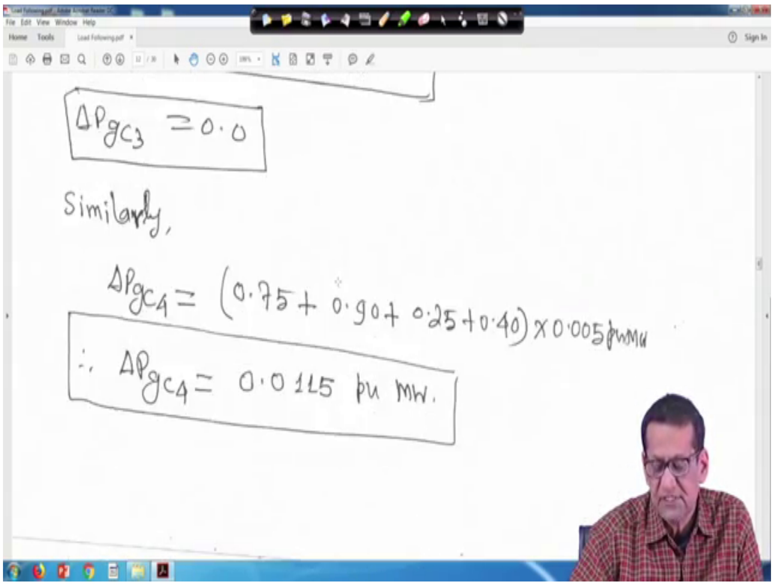

Similarly, delta P g c 4 you calculate you will get 0.0115 per unit megawatt right. So, this is actually your what you call that is steady state that is contracted power demand and your at steady state that your this is delta P g c 2 that is that DISCOs have all the DISCOs that total contracted power demand that has to be generated by this unit 2.

So, that is actually this is this is actually is equal to that delta P g steady state it because generation will follow the load. So, at steady state these value will come similarly for unit 4 at steady state these value must reach right.

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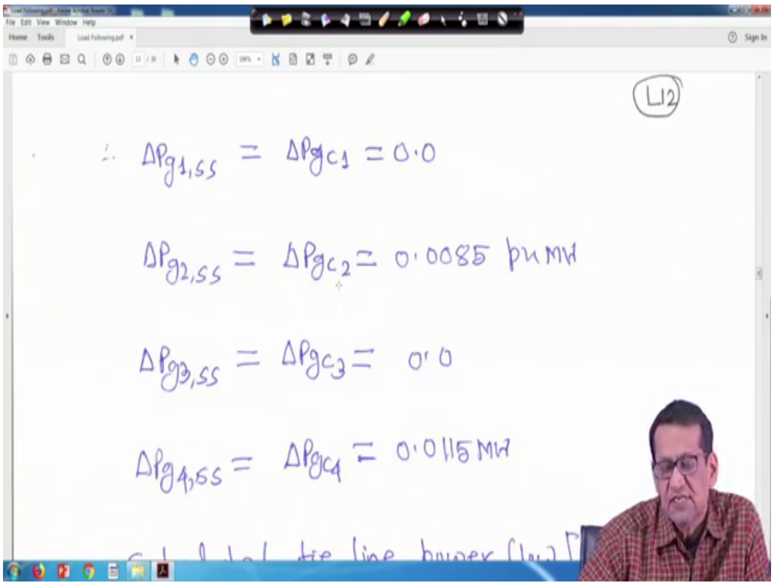

So, therefore, delta P g o[ne]- P g c 1 were 0. So, at steady state delta P g 1 s s will be 0 and delta P g 2 s s is 0.0085 megawatt because that is equal to delta P g c 2. So, delta P g 3 steady state is equal to delta P g c 3 is equal to 0 and delta P g 4 s s is equal to delta P g c 4 is equal to 0 0.0115 megawatt right.

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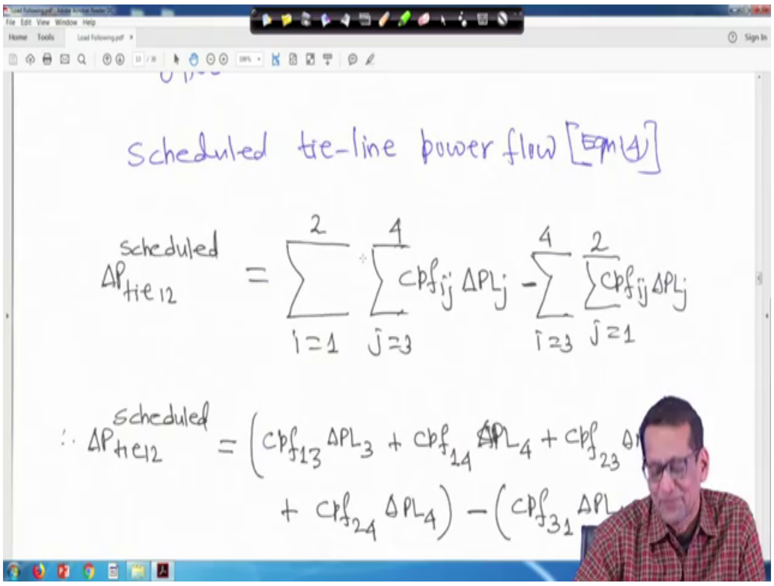

So, this is contracted one or tie line power; now schedule tie scheduled tie line power flow that is equation 4 that we know this. So, at delta P tie 1 2 scheduled this formula we know that i is equal to 1 to 2, j is equal to 3 to 4 cpf i j delta P L j this is valid for only that our system minus I general one I did not make it right, but your just for two or three areas your there is no need actually right. And i is equal to 3 to 4 and sigma and j is equal to 1 to 2; cpf i j delta P L j, but I request you that when you will go through this write down in terms of GENCO and DISCO.

Usually you will easily can write it right.

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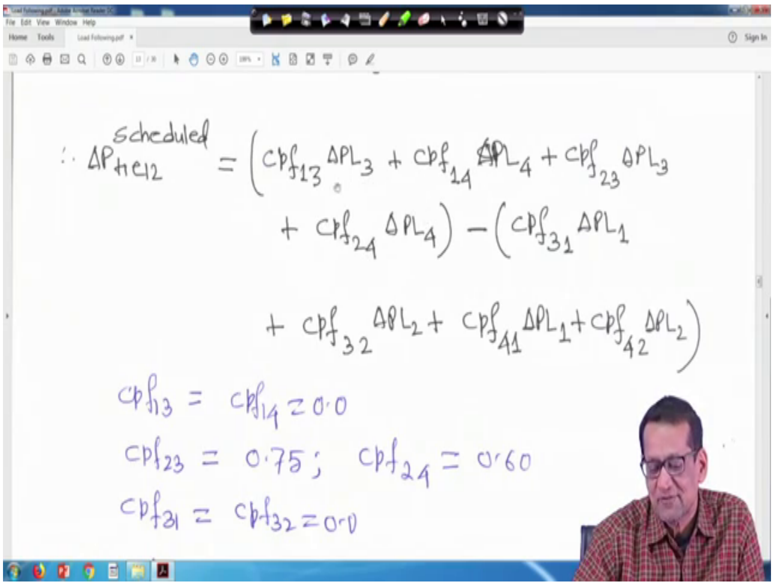

So, now, delta P tie 1 2 scheduled right; yeah that is equal to this much that all these term cpf 1 3 delta P L 3 plus cpf 1 4 delta P L 4 plus cpf 2 3 delta P L 3 plus cpf 2 4 delta P L 4 minus cpf 3 1 delta P L 1 all in bracket minus in bracket cpf 3 1 delta P L 1 plus cpf 3 2 delta P L 2 plus cpf 4 1 delta P L 1 plus cpf 4 2 delta P L 2; so, bracket close.

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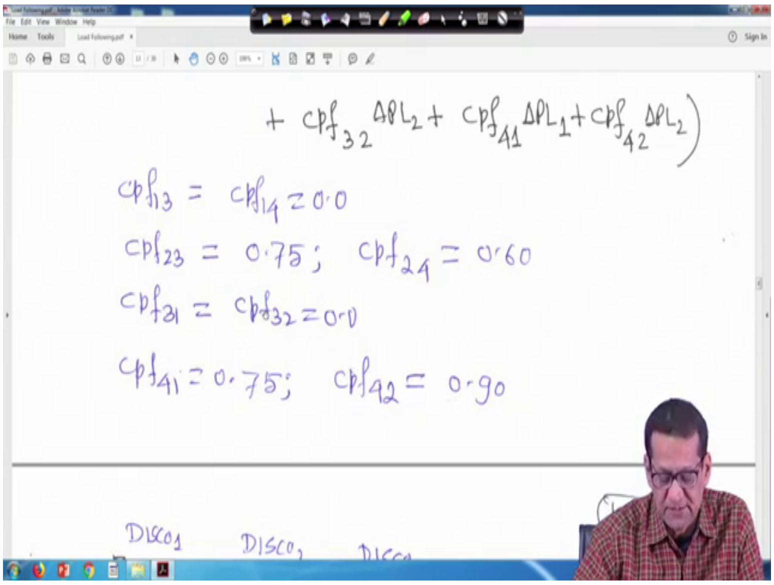

So, cpf 1 3 is equal to cpf 1 4 is equal to 0 cpf 2 3 is equal to 0.75 and cpf 2 4; 0.6 right cpf 3 1 and cpf 3 2 both are 0s.

That is from the DPM whatever DPM we have taken from that only and cpf 4 1 is 0.75 and cpf 4 2 is 0.9.

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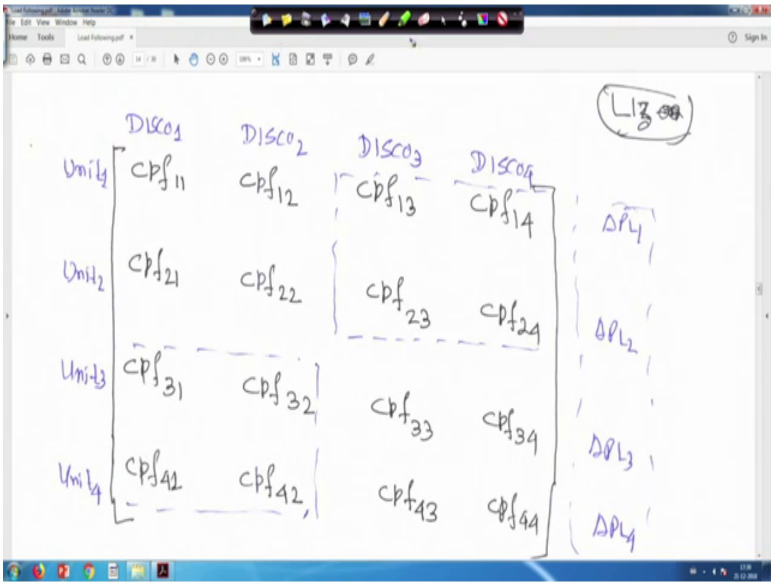

Now, that regarding this tie power actually that just I have made it that actually that you are for you can if it is for two area system that you have unit 1 unit 2 unit 3 unit 4 this is your unit 1 unit 2 unit 3 unit 4 right and this is my [disc/distribution] distribution company 1 2 3 and 4 right.

So, the tie line power flow equation actually if you look into that; this block this block actually DISCO 1 DISCO 2 only have contract with this units with this own area. So, this term will not have pair in the tie line power flow equation. Similarly if you look into that that DISCO 3 DISCO 4 it has at unit 3 unit 4 right this is unit 3 this is unit 4 this has only in that area 2 plus contract that DISCO 3 DISCO 4 in area 2 and it has con[tract]- it may have contract with only unit 3 and unit 4 its own area if any right.

So, so this kind of thing there will be no scheduled power flow for example, in the in that first case I mean previously we have taken 3 cases for that your what you call that for deregulated system at that time you took from; 0.5, 0.5, 0.5, 0.5. So, there was no scheduled power it was 0, but, but only thing is that when area 1 and area 2; we are taking the direction from 1 to 2. So, DISCO 3 and DISCO 4 are in area 2.

So, DISCO 3 and DISCO 4 actually has contact with GENCO 1 and GENCO 2 in area 1. So, in the direction of 1 to 2 that is why this term is written first minus that DISCO 1 and DISCO 2 actually it is trying to draw power from the GENCO 3 and GENCO unit 3 and unit 4 of area 2 that is why it is this one minus that one.

So, when you will when you will when you will make it right. So, if you make this if you isolate this all these DISCOs and unit 1 in that own area then only this matrix will be there and this matrix will be there. So, from that you can write as it is as it is in the direction that is from 1 to 2 right. So, that is why cpf 1 3 delta P L 3 plus cpf 1 4 delta P L 4 plus cpf 2 3 delta P L 4 plus cpf 2 4 cpf 2 3 delta P L 3 plus c f 2 4 delta P L 4 minus if you look into this that cpf your 3 1 delta P L 1 plus cpf 3 2 delta P L 2 plus cpf 4 1 your delta P L 1 plus cpf 4 2 delta P L 2.

So, this all these thing you add up multiplication this minus bracket all these things you add up and that is actually tie line power flow. So, in the direction of 1 to 2 though; earlier I have not told, but here whatever way I mean if you cannot recall those formulas, simply you construct and make it like this and easily you can get the power flow say either in the direction of 1 2 or in the direction of 2 1 if you want in the direction of 2 1; then this one should come first minus this one should come first right. So, this is that your what you call this is your I mean ideas.

So, basically when you take cpf 1 3 cpf 1 4 only two units are there right. So, in that case in that case you can I mean what we call you can easily make it right.

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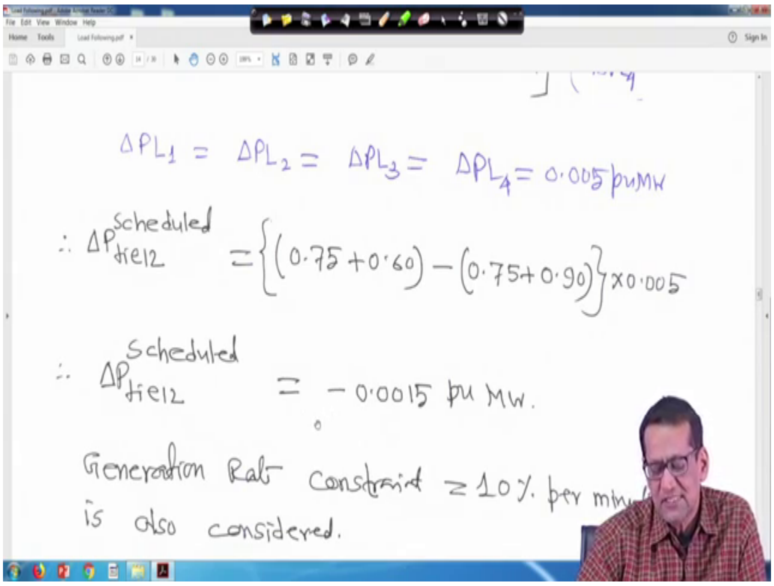

So, next is that delta P L 1 delta P L 2 all these things are given. So, you 0.005 per unit megawatt; so all these cpf values you substitute here you just put all the cpf value and delt[a]- all delta p ls are same you just put it then you will get that it is 0.75 plus 0.6 minus in bracket 0.75 plus 0.9 into 0.005.

So, it is come minus 0.0015 per unit megawatt. So, scheduled power flow it is showing minus ; that means, actual direction of the power actually from area 2 to area 1 because delta P L 2 is minus right. So, generator in this case the generation rate constant is taken as 10 percent per minute right.

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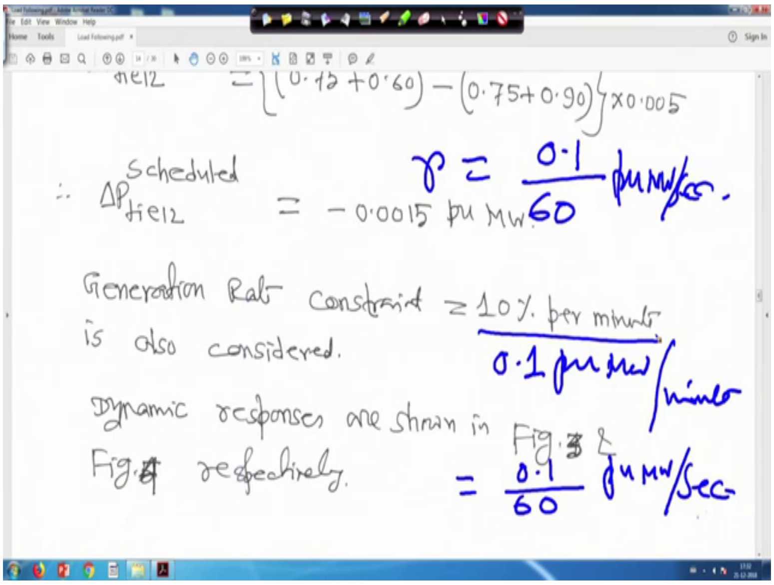

Actually 10 percent per minutes means it is your 0.1 right per unit megawatt right per minute right that is at 10 percent. So; that means, if you want to make it in second that is 0.1 divided by 60 per unit megawatt per second right.

So; that means, generation rate constants values r actually we have taken 0.1 divided by 60 per unit megawatt per second right. So, that is why this generate [on] 10 percent per minute is considered; only thing I would like to tell you this all these things simulation thing result whatever I am saying for purpose of our understanding actually the code was written it was not directly not through the simulink; only code was written data were generated then it was plotted in the MATLAB environment right. So, now dynamic responses are shown in figure 3 and 4 respectively.

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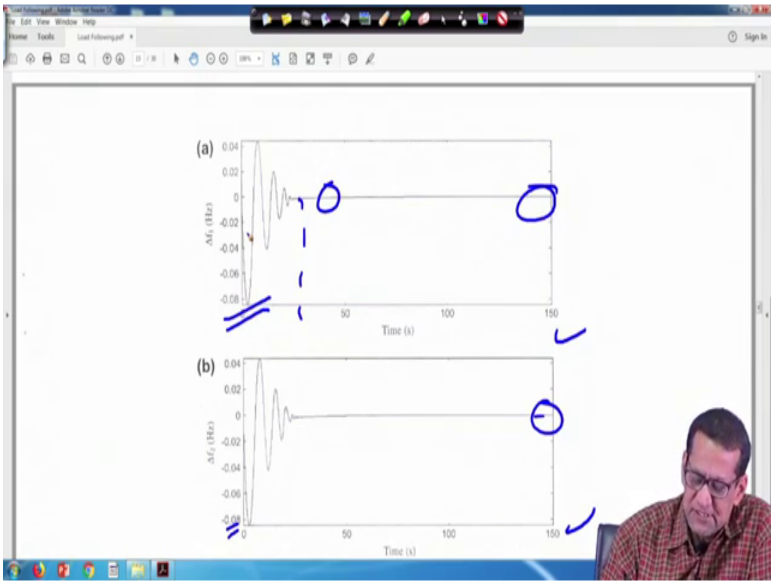

So, if you see the dynamic responses right we will go one by one. So, if you see that that frequency deviation actually it is steady state; it is 0 actually settling here only, but although 150 seconds plot was shown, but less than 50 second it will be somewhere around that. So, around 25, 26 again; it is a more or less settled right-; similarly for frequency area 2 this is also settling long we have given 150, 150, but not before that actually it is settling right aft[er]-, but only thing is that that if you do not consider GRC right. if If you do not consider GRC, then peak deviation also will be less here it is minus 0.08 Hertz approximately.

That frequency once similarly for area 2 also minus 0.08 Hertz the peak deviation, but if you do not consider GRC it will very less maybe minus 0.023 or 024 Hertz or even less right ; so, without GRC. So, frequency this is frequency deviation and steady state as decide that it is your what you call that deviation is 0.

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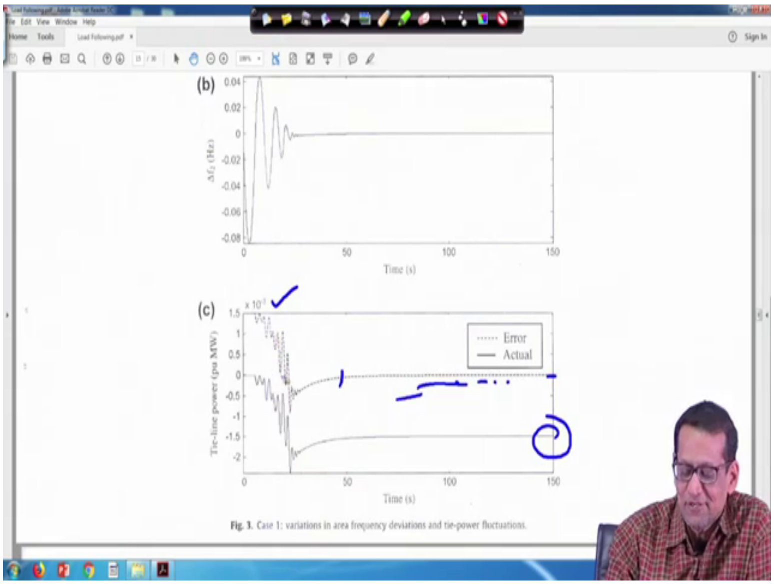

So, next is this is your let tie line ~~pow[er]-~~ power will actual an error right. So, actual will be that you are this is this was your what you call that your actual power that is your minus 0.0015 that is it is actually 10 to the power minus 3 right.

So whatever is given scale into 10 to the power minus 3 and it is coming minus 0.0015 per unit megawatt and a steady state that your delta P tie 1 2 error will be 0 because actual will match to the schedule value. So, that is why this dash line is error dash line is it your delta P tie 1 2 error right and that is actually a steady state; it is becoming 0.

But oscillations are there this is due to your what you call due to that your generation is constant. And if you look into this two curve actually it is both are what you call in the same shape only there scale have shifted because of this thing because it is delta P tie error is equal to actual minus schedule right.

So, just scale has shifted otherwise their nature is totally identical right. So, this is this is my your what you call that you are frequency type or next we will see the generation.

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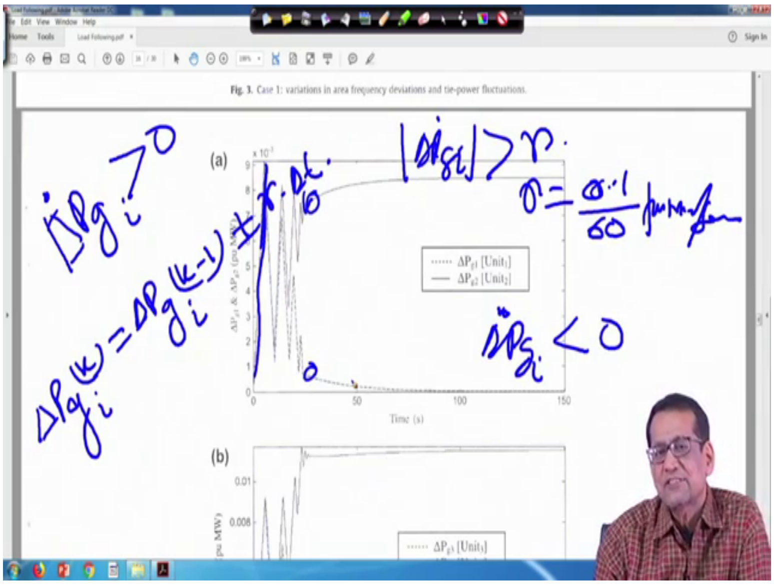

Now, if we come to the generation one interesting point is that that I will come to that first say see delta P g 1 steady state right. So, the dashed one delta P g 1 is your dashed one; so it has come to 0. Because, unit 1 was not in load following and also during put any load frequency controller and delta P g 2 right. So, it was in the load following and it is reaching to this value I mean steady state steady state value right.

I if I if I exact your values are there on top just let me see it right I cannot recall this things; I think it is 0.0085 right. Just let me see that your whatever that value this delta P g 2 have 0.0085 and delta P g for 0 0.0115. So, here it is actually going to the steady state right. So, a steady state this is actually going to that where your 0.0085 that is delta P g P g 2 because it was in the load following because contacted load demand was 0.0085.

So, generation which was change the load change the load and this is also your more or less settling at this thing time right it is less than 100. So, actually all are supposed actually because of this plotting and that units right that is why perhaps it appears that here it has settle in a 27, 28 or 30 second frequency and tie power right, but still not exactly it is what you call that exactly 0 right. So, some difference is there that is why it is depending on the scale right. So, that is why it appears that it is still going, but their value is very negligible whatever scale you so 10 to the power minus 3 right. So, delta P g 1 unit 1 it is going to 0 and delta P g 2 it is going to this value right.

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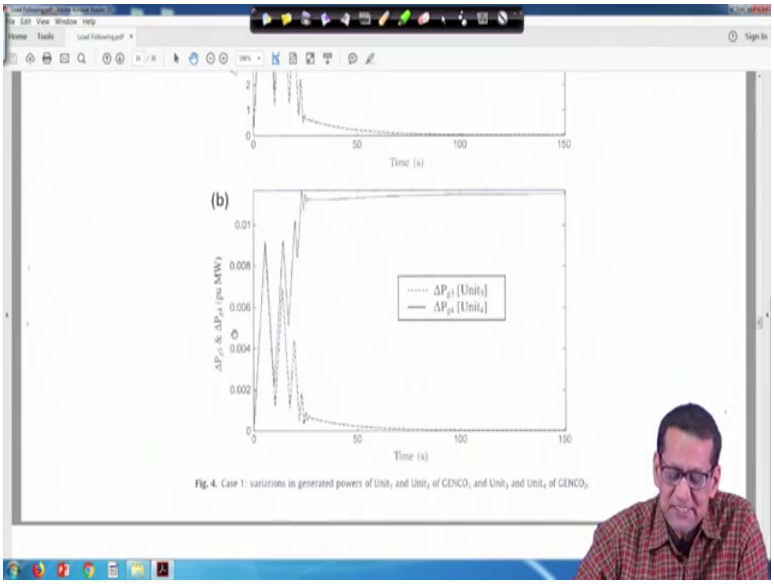

So, similarly for delta P g 3 and P g 4 plotted as a delta P g 3 here also it is going to 0.

Because steady state it was 0 and delta P g 4 it is going to steady state I think minus 0.0015; 0 1 5 right. So, that is actually go[oing] the generated by the unit 4 right; so steady state value it is matching. Now interesting point is that if you look into look into their responses look into the responses that generation responses initially right actually it is a ramp increase or ramp decrease right.

That I told that we have when we are discussing about generation rate constant that is your delta P g say for i'th unit a k is equal to delta P g for i'th unit k minus 1 that we have discuss plus minus r into delta t. So, in the simulation that r I told you that we have taken the 10 percent per minute; so, that is 0.1 divided by 60 per unit megawatt per second right.

So, every time that generation rate were checked right. So, and whenever you see the ramp type of responses right at that time you will find the generation your what you call limit was violated. So, when it is ramp increase means at that time it were at that time that your delta in general I am just putting delta P g for i'th unit that dot right at that time it was greater than 0. So, that is why the plus sign delta P g i k is equal to delta P g i k minus 1 plus r delta t right.

When delta P g i was your first thing is it was greater than 0 and second thing is that absolute before that absolute value of this one was greater than r right. So, when it first you have to check that it greater than r or not and then you have to check if greater than r; absolute greater than at first you check that delta P g i greater than 0 or not dot greater than 0 if it is. So, then it has to be constant by delta P g i k is equal to delta P g i k minus 1 plus r into delta t.

So, as long as this graph is going like this going like this right; so that means, it is ramp increase because generation rate is violated. Again for it is absolute first you are checking now again when it is your delta P g i dot right now you have to if it is first it is check violated or not.

If it is less than 0 delta P g i dot less than 0 that is negative, but ah, but it is then this delta P g i k will be delta P g i k minus 1 minus r into del[ta]- your delta t that is why it is a this ramp increase ramp decrease ramp as long as this constant will be violated. But when constant will not be violated say this region in this region or in this region; at that time within this band you will find that small oscillations are there.

Otherwise this generation responses whatever we will see like a straight line straight it is it will go up go down go because at constant it violated right those constant it violated generation rate is violated. That is why the because of generation rate violated that is why your response of frequency or tie power deviation all getting deteriorated including the generation responses.

So, that is the reason that you are that your GRC effect right. So, this is also that this increase or decrease just because at only one some oscillations is there at that point you will find GRC not violated right. So, this is actually your what you call that why it is look like ramp increase or ramp decrease of the generation. So, this is your for the case 1 now first case now case 2; actually now first one I have by this thing I have written case a make it case 1, so this is case 2.

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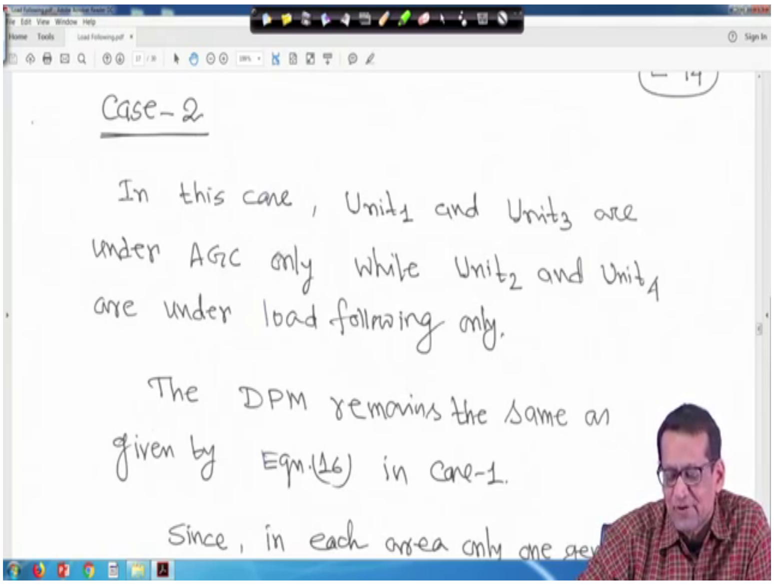

In this case what we are doing is that unit 1 and unit 2 are under AGC only while unit 2 and unit 4 are under load following only. So, unit 1 and unit 2 are under your you are under AGC. So, the DPM remaining the same as given by equation 16 case 1.

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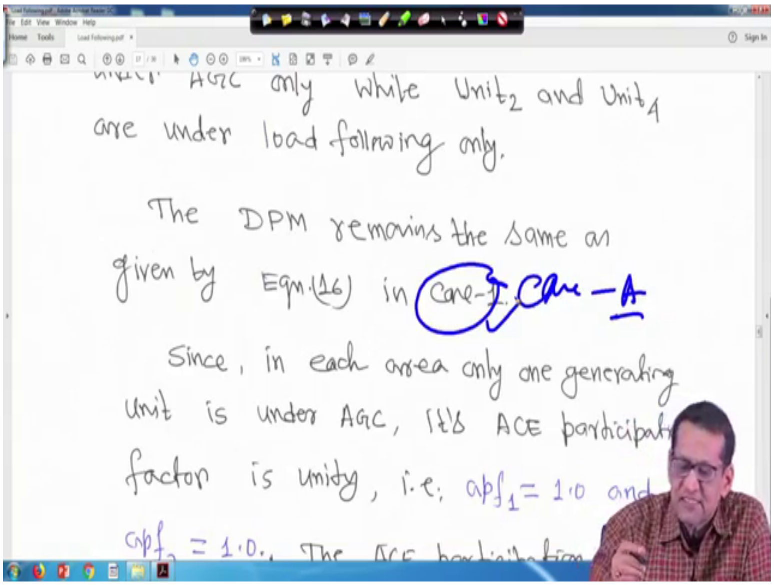

First one I have written actually it is case A right; so better you make it case 1 right. Since in each area onl[y]- in each area; that means, I will I will I will go to that your block diagram once again that your; in this case that your unit 1 and unit 3 are under AGC only while unit 2 and unit 4 are under load following only right.

So, if unit 2 and unit 1 are under AGC right; so I will go to that block diagram once again such that it will be easy for you to realise this. So, just hold on let me reduce the size right.

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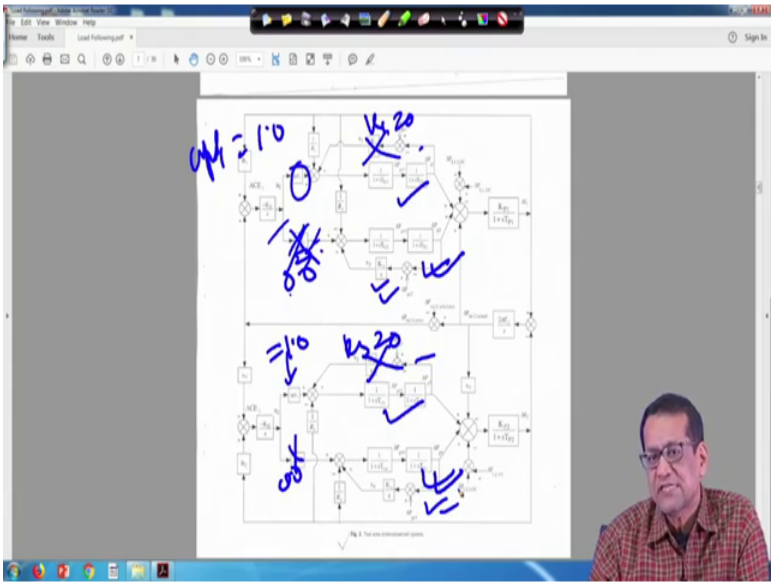

So, as unit 1 and unit 3 right it was now; now unit 1 if unit 1 and unit 3 if there in your what you call in AGC right. So, this is my unit 1 and this is my unit 3 right. So, if these two are in AGC and unit 2; this is unit 2 this is under load following this is under load following and unit 4 under load following. So, unit 1 unit 2 and AGC means that and this is only load following means that apf ——— 1 is 1 right apf 1 is equal to 1.0 and apf 2 actually it will be 0 point 0.0 right.

So; that means, that means this term this term should not be there. So, unit 1 only is under and here the; your K 1 has to 0 because unit 1 is not under load following. So, this thing also should not be there only simple unit right a simple the way we have done it before. And in the case of your unit 2 is under load following ; so K 2 will be there right, but apf 2 is 0; so this thing should not be there.

Similarly here also similarly here also that unit 3 is under AGC; that means, my apf apf this is apf 3 this value should be 1.0 and this should not be there this value should be 0 right and here it is K 3; as it is under AGC right, so K 3 should be 0; that means, this block should not be this load following controller should not be there, but and in this case it will be there it is under load following. So, that way that way your so many cases you can generate right.

Therefore, therefore, let me go to that go back to that case 2 this one. So, if; so in this case you will under AGC I told you and unit 2 unit 4 are under load following only. So, DPM the DISCO Participation Matrix; it remains same as my equation 16, so same DISCO DPM has been consider identical right.

So, in each area only one for generating unit is under AGC it's ACE participation factor is unity I told you apf 1 will be 1.0 and apf 3 will be 1.0, apf 2 will be 0 and apf 4 will be 0.

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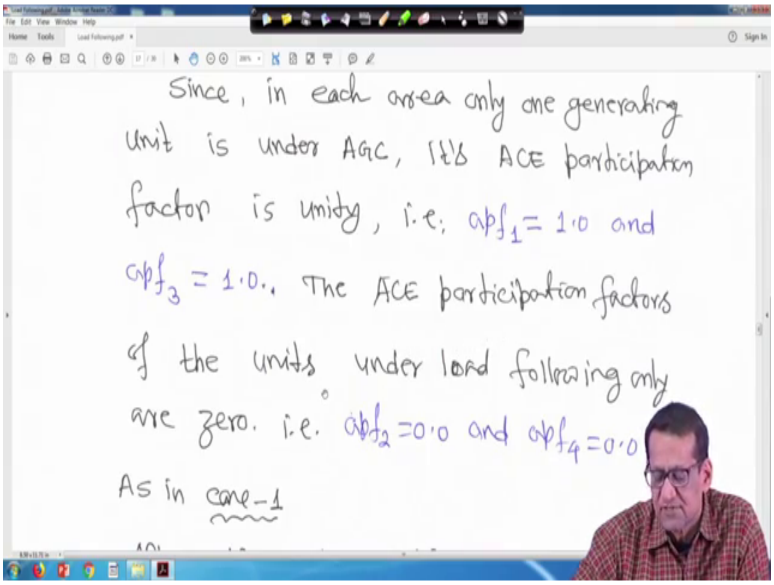

So, the ACE participation factors of the units and the load following only are 0; so apf 2 is 0 and apf 4 is equal to 0 right.

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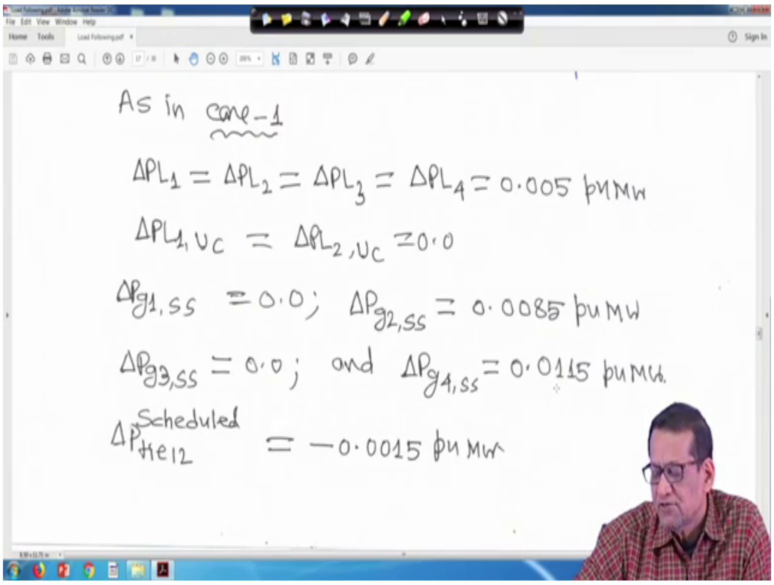

So, as in case 1, same data taken delta P L 1 is equal delta P L 2 is equal to delta P L 3 is equal is equal to delta P L 4 that is 0.005 per unit megawatt right. And no uncontracted demand was there; so delta P L 1 U C is equal to delta P L 2 U C is equal to 0.0.

Therefore as steady state we have seen earlier delta P g 1 s s same as we for; it will 0 point 0 delta P g 2 s s same as before 0 0.0085 per unit megawatt because DPM remains same. So, if this things will be same and uncontracted part demand is not there; that means, 0.Therefore, delta P g 3 s s will be 0 point 0 and delta P g 4 steady state will be 0 0.0115 per unit megawatt same as before. So, and delta P tie 1 2 schedule also is equal to minus 0.0015 per unit megawatt right so.

Thank you very much, we will back again.