Power System Engineering
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 59
Automatic generation control (Contd.) and Unit Commitment

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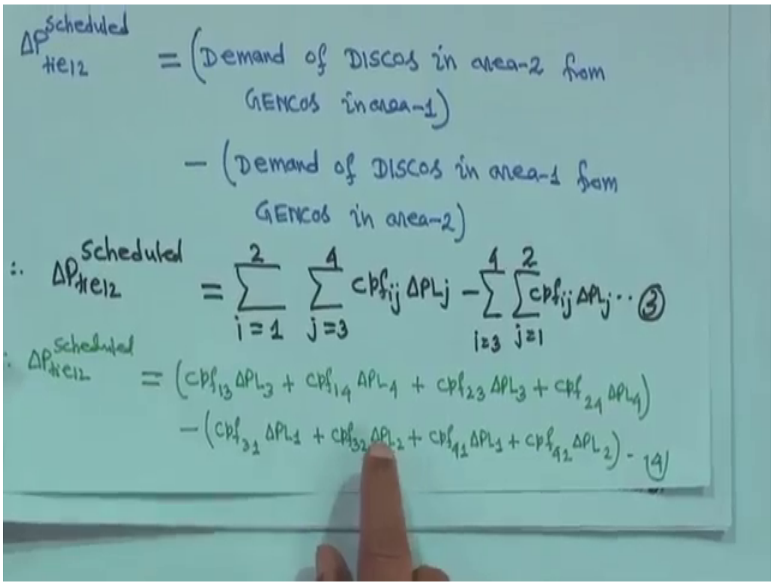

So, little bit we have seen that restructure you know power system particularly in for the load frequency control right. So, we have seen that this is that your schedule power flow that how the actually for 2 area system and in both of the areas there are 2 GENCOs and 2 DISCOs right and this is expression.

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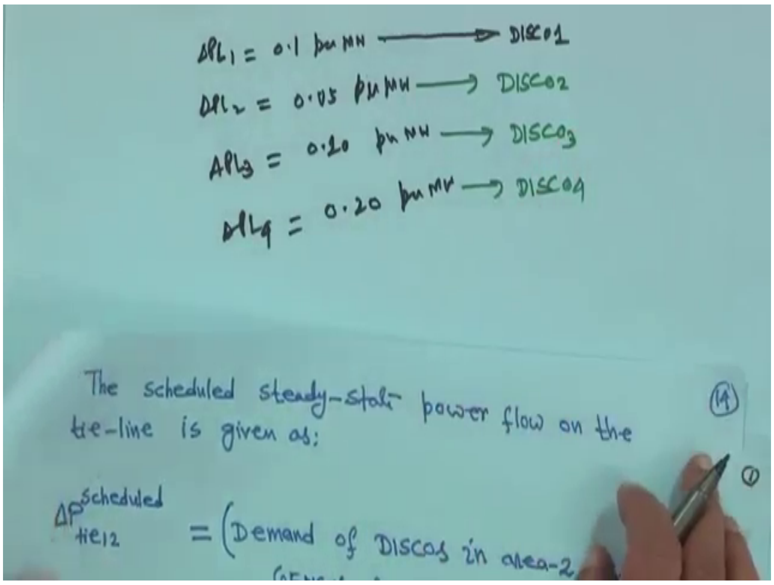

For example, for example suppose if we have suppose, if we have say delta PL 1 say is equal to 0.1 per unit megawatt, this is say per unit megawatt delta PL 2 is equal to say 0.05 per unit megawatt right delta PL 3 is equal to again say 0.10 per unit megawatt and delta PL 4 say 0.20 per unit megawatt; that means, this demand this delta PL 1 actually this is the total power demand that demand that that needs for the DISCO 1.

So, this is actually for distribution company 1 which is short we call DISCO 1 right. Similarly for the, this is the total power demand required by DISCO 2. So, this is actually for DISCO 2 similarly this is for distribution company 3 in short we call DISCO 3 and this is another distribution company we call DISCO 4 right.

So, this is the power demand that by the DISCOs right. Now, you have this matrix Cpf elements Cpf 1 3 Cpf 1 4 Cpf I mean how much contract is there, this DISCOs with the GENCO s right for example.

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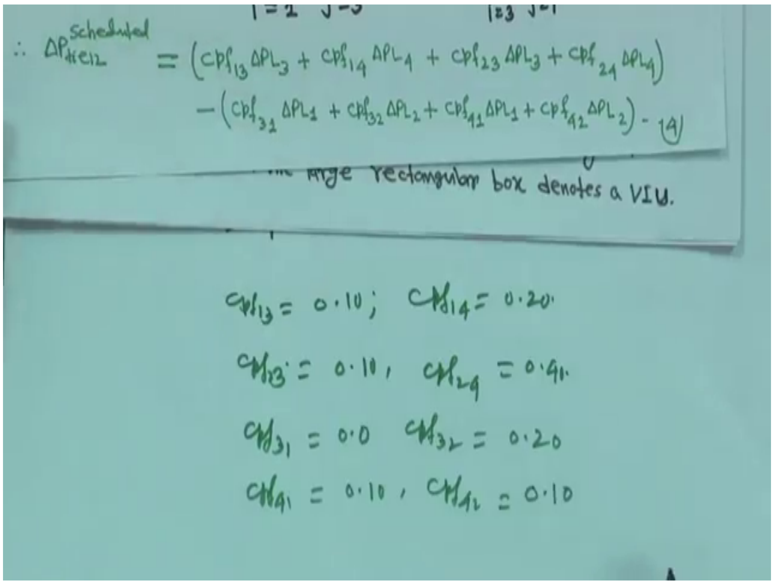

Suppose for this example suppose if my Cpf 1 3 is equal to some arbitrary value I am putting right say 1 0, then Cpf 1 4 say it is 0.20 right, then Cpf 2 3 is equal to I mean this 1 this 1 Cpf 2 3 is equal to say 0.10 again and Cpf 2 4 right is equal to you say 0.40 right.

Similarly, Cpf 3 1 say Cpf 3 1 say it is equal to 0 right say Cpf 3 2 is equal to say 0.20, then Cpf 4 1 right Cpf 4 1 is equal to say 0.10 and Cpf 4 2 is equal to say 0.10. If it is so, if it is so if suppose then what will be my scheduled tie power flow right so that means, if you go back to this your this DISCO participation matrix this is your DISCO participation matrix right.

This is your DISCO participation matrix and what we have taken there, that in this matrix if we put like this, if I rewrite this matrix like this right just hold on I will make it every such that everything should be clear to you, right this DISCO participation matrix wherever only these elements I will write because other thing I will not write only these elements I will write.

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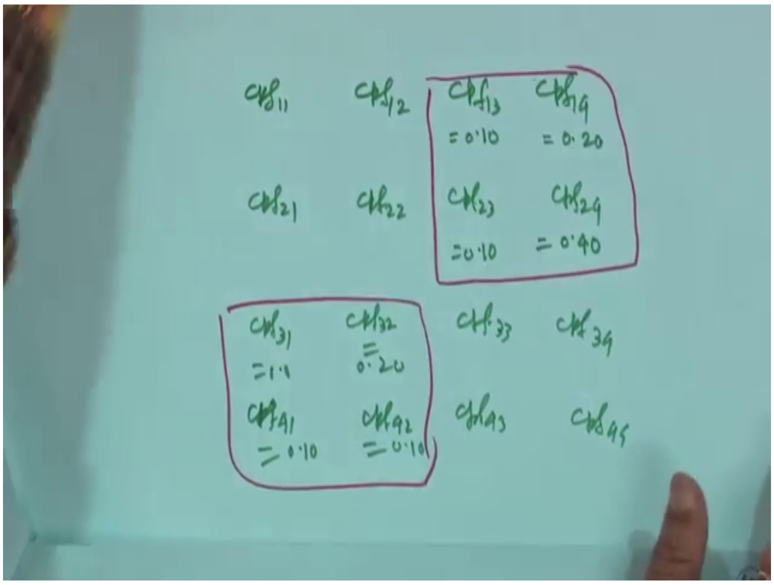

So, in that case what will happen that your first thing is that this the way we have written that your Cpf 1 1, Cpf 1 2, Cpf 1 3, and Cpf 1 4 right, then this Cpf value that Cpf here if you look Cpf 1 1, 1 2, 1 3, 1 4 nowhere right nowhere it is coming Cpf 1 4 is coming Cpf 1 3, 1 4 is coming. So, Cpf 1 3, 1 4 is coming so, Cpf 1 3 here say it is 0.10 and Cpf 1 4 it is 0.20.

Next you come to Cpf 2 1, Cpf 2 1 right first let me right down, then Cpf 2 2, then Cpf 2 3, then Cpf 2 4. So, if you come to that that Cpf 2 4 is 0.40. So, this is actually Cpf 2 0.40 right, then if you see here Cpf 2 3 is there Cpf 2 3 is your point your what you call 1 0 so, this is actually 0.10 right. Similarly if you come to that Cpf 3 1 right Cpf 3 1 is given 0.0 suppose Cpf 3 1 is 0 point, then Cpf 3 2 then it is coming Cpf 3 2 we have taken Cpf 3 2 is 0.20.

So, this is your 0.20 then Cpf 3 3 and then Cpf 3 4 right. So, no question of Cpf 3 3 or Cpf 3 4 that means, next is Cpf 4 1 Cpf Cpf 4 1 is equal to we have taken 0.10. So, this is 0.10, then Cpf 4 2 we have taken 0.10 0.10 then Cpf 4 3 and Cpf 4 4 right that means, when they are your what you call tie power schedule equation you will find in the direction of 1 2 only this portion is coming and here only this portions are coming, this is related to the DISCOs power demand your.

If any element is there mean DISCO is demanding power right from the your what you call from the GENCOs of it is own area so; that means, they will never come into the tie line power equation right, but this one will come this diagonal 1 that; that means, here 1 3, 1 4, 2 3, 2 4 and here 3 1, 3 2, 4 1, 4 2 these 1 will come in that your what you call in the schedule tie line power flow equation right.

So that means, and my our this thing is delta PL 1 is 0.10 this we have taken this data, we have taken when we will read this know this video please note down on the note book, because here then you need not go back to the your what you call next your flied, or this you can do yourself. when you see this you please note down this data right.

Then what will happen that your what you call this calculation that then what is the value of this tie line power flow. So, in that case this equation that that delta P tie your what you call this equation, this one also when you will study this please note it down such that need not look into this again and again you can do yourself therefore, my delta PL 3 we have taken 0.1 right. So, Cpf 1 3, 0.10 right therefore, Cpf 1 3 delta PL 3.

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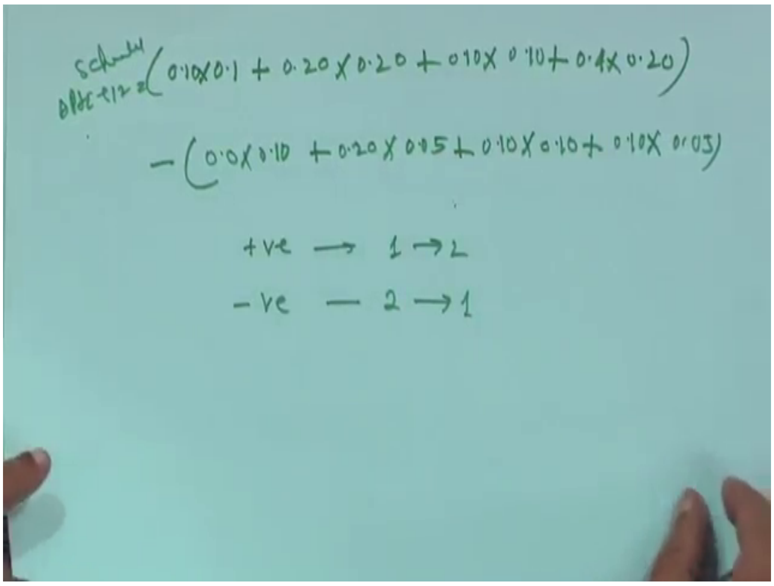

So, first term is Cpf 1 3 delta PL 3 Cpf 1 3 actually 0.10 into delta PL 3, we have taken 0.1 we have taken 0.1 so, into 0.1 plus your Cpf 1 4 delta PL 4 Cpf 1 4 we have taken 0.2 it is Cpf 1 4 into 0.2 into delta PL 4 that means, your 0.2 into 0.2 right, then plus then Cpf 2 3, Cpf 2 3 we have your taken 0.10 so it is 0.10 and then your delta PL 3 delta PL 3 is 0.10 right.

Then your CPf 2 4, Cpf 2 4 we have taken 0.4 this is 0.4 into PL 4 PL 4 we have taken 0.20 right. So, in this case just hold on this is your PL 3 PL 4 and this is this one right, then minus this is this one right minus your Cpf 3 1, Cpf 3 1 we have taken 0, it is 0.0 into delta PL 1 right.

So, PL we have taken 0.10 everything is here everything everything is given here everything is given here right from there only I am writing, then plus your Cpf 3 2, Cpf 3 2 we have taken 0.2. So, it is 0.20 into your delta PL 2 delta PL 2 is 0.05 so it is 0.05 right, then plus your Cpf 4 1 Cpf 4 1 we have taken 0.1 0.10 into delta PL 1 delta PL 1 we have taken 0.10 so 0.10 plus Cpf 4 2 we have taken again 0.1 Cpf 4 2 into your delta PL 2 delta PL 2 is 0.05 right that is actually delta P tie 1 2 is equal to this is schedule power.

Whatever will come plus minus does not matter I am to save sometime I am not computing this 1 here, I did not do any calculation before coming here right. So, whatever it comes if it if it is positive value means, if positive value if positive value of delta P tie 1 2 schedule this means that power actually flowing from 1 to 2 and if it is negative, then power actually flowing from 2 to 1 that is the thing that is the that is the that is the schedule power, I mean whatever they have contacted according to that that this power will flow to the tie line right, that is 2 area interconnected by your 3 phase transmission line, we call tie line right and whatever it will come that is your schedule power flow.

So, this is the way that we can calculate. Another thing is another thing is that what will be the I mean at the steady state what will be the power generated by your generation companies GENCO 1, GENCO 2, GENCO 3, GENCO 4 right for example, so this is I am not computing for you here just you can do it whatever it is right.

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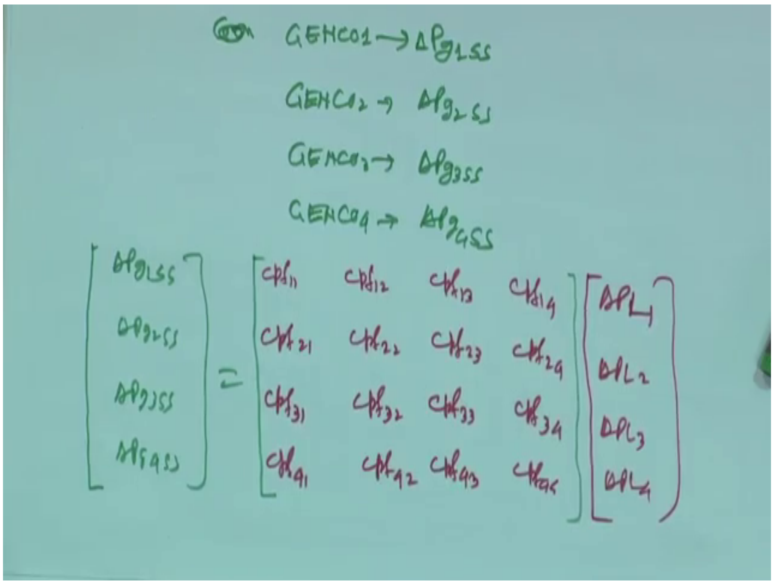

So, another thing is that your GENCO 1 suppose GENCO I am making in capital letter GENCO 1 generation company 1. Suppose is steady state suppose it is generating power that delta Pg Pg 1 ss right, or I can put delta Pg 1 ss does not matter say GENCO 2 say as steady state it is making delta Pg 2 steady state right.

Similarly, GENCO 3 it is producing delta Pg 3 ss right and GENCO 4 right, it is your delta Pg 4 steady state right, then how what will be the equation, then suppose this side you will make delta Pg 1 steady state, delta Pg 2 steady state, delta Pg 3 steady state and delta Pg 4 steady state right is equal to that your all the that DPM will come that DISCO participation matrix so, Cpf will come.

So, in that case you write here this matrix Cpf 1 1, Cpf 1 2, Cpf 1 3, and Cpf 1 4 right, then Cpf 2 1, Cpf 2 2, Cpf 2 3 and Cpf 2 4 right, then Cpf 3 1, then Cpf 3 2, then Cpf 3 3, then Cpf 3 4, then Cpf 4 1, then Cpf 4 2, then Cpf 4 3, then Cpf 4 4, then what will come here it will be delta PL 1, delta PL 2 very easy it is delta PL 3 and delta PL 4 right; that means, suppose this delta PL 1 actually the that power demand of distribution company 1.

It has contact with your GENCO 1, then GENCO 2, then GENCO 3 and GENCO 4 right. If you look into this if you I mean this contact has delta PL 1 GENCO this delta this GENCO 1 it has contact with GENCO 1 is this much right, if you look into the DISCO sorry DISCO 1 such contact with the GENCO 1, then DISCO 2 right it has contact also with your this GENCO 1 that is Cpf 1 2, then distribution company 3 it has some contact with this 1 will that is Cpf 1 3 and distribution company 4 it has contact with this 1 that means, If you multiply this one, it will be your what you call this will be power generated by this thing.

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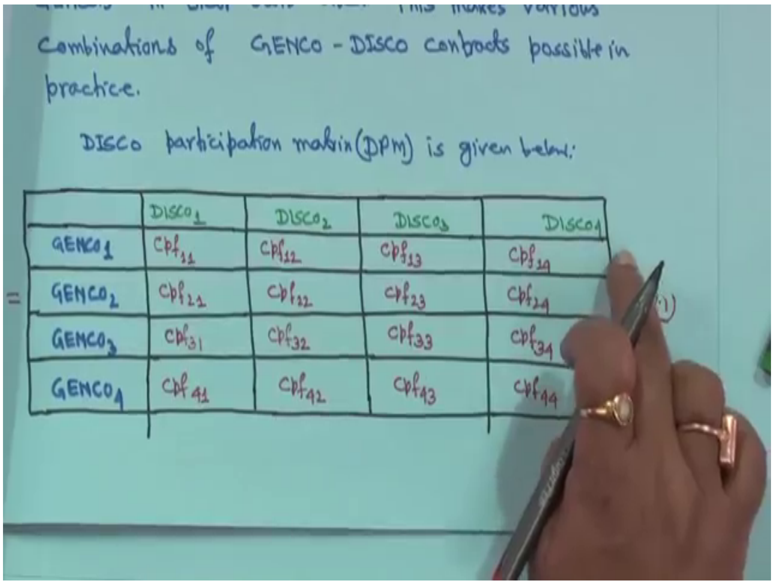

That is this is GENCO 1, GENCO 2 like this and this side, if you make delta PL 1, delta PL 2, delta PL 3, delta PL 4. Therefore, this that whatever DISCO 1 has the contact is Cpf 1 with GENCO 1, DISCO 2 is Cpf 2 delta 2 GENCO 1 see this DISCO 3, Cpf 1 3 this much of fraction with GENCO 1 and DISCO 4 Cpf 1 4 basically if it is demand is delta PL 1, then GENCO 1 has to supply that delta PL 1 into Cpf 1 DISCO 2 has contact with your what you call delta PL 2.

So, and it has contact with GENCO 1. So, Cpf 1 2 into delta PL 2, then plus DISCO 3 also has contact with GENCO 1 and fraction is Cpf 1 3 it demand is your delta PL 3, it will be delta PL 3 and DISCO 4 suppose is demand is total delta PL 4, but fraction is contact with GENCO 1 it will be Cpf 1 4 into delta 4 delta PL 4 rather right that is why this delta; that means, total power generated by GENCOs at the steady state it will be Cpf 1 one delta PL 1 plus Cpf 1 2 delta PL 2 plus Cpf 1 3 delta PL 3 plus Cpf 1 4 delta PL 4 right this way that means, delta PL 1 suppose this matrix is known to you this delta PL 1, delta PL 2, delta PL 3, delta PL 4 is also known to you.

Then automatically you can calculate delta Pg 1 ss, delta Pg 2 ss, delta Pg 3 ss and delta. So, numerical I am not showing, but you can generate your thing, but only thing is that summation of all this column element should be 1 this should be 1.0 summation of all this column element summation should be 1 you have to careful when you take this right and, you can create your own matrix right and you take some delta PL 1, delta PL 2, delta PL 3, delta PL 4.

Then you will know how much this GENCO 1 will generate, GENCO 2 will generate, GENCO 3 will generate and GENCO 4 will generate right many other issues are there, but as it is a you know as it is a BTECH course 3rd year and 4th year and that is why simulation and other thing, regarding this thing I have skipped it is not required for you only this understanding will be more than enough right.

So, that is that is why this matrix is given and how thus and GENCO 1 generation actually this one, it is already given here. So, easily you can make it right, I will see that in the assignment or something this kind of problem can be given when that thing will come right. So, with this that load frequency control right we are concluding here and up then we will take that another topic that is your unit commitment.

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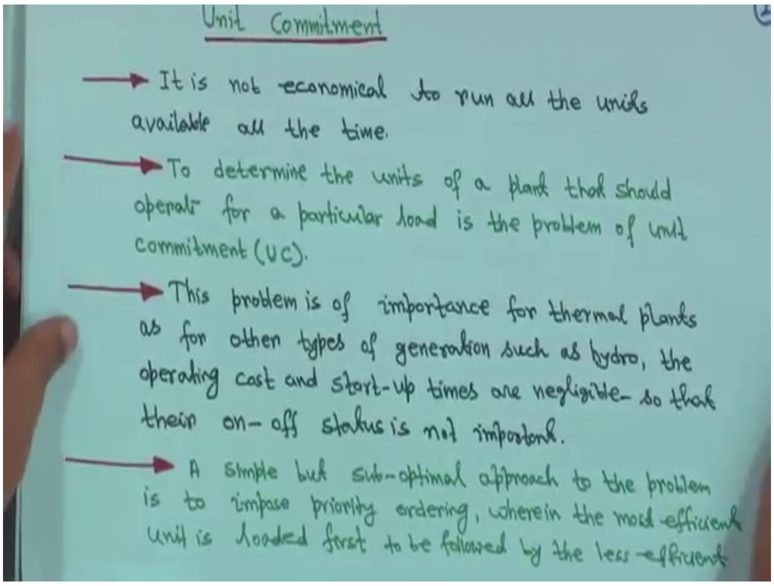

First thing let me tell you regarding unit commitment it is actually huge topic, but I thought at least you should know little bit little bit right, many issues are there and it is almost impossible to solve problems in the classroom right, but something will be give if something is given, then easily you can solve it, but if you try to find out that actually unit commitment in general means, that although several issues are there several constant are there right like your start up, shut down issues are there many other constants are involved in that unit commitment.

Suppose in a suppose every hour, that if you consider hourly load variation, then every hour you will find loads are changing right, every hour you will find that load demand is changing; that means, every hour you have to change the generation. Suppose in a power plant you may have 5, 6 or 7 generators say. So, you know that which generator is most economical of generating power because, generator that fuel cost characteristic are different.

Assuming that they are not identical so, in that case what will happen that suppose a suppose today at this moment, suppose that power demand is say 1000 megawatt right. So, I have I have the unit that which total install capacity say it may be 1500 or 1600 megawatt; that means, total generation capacity has we having more than your load demand right, the idea is that there is a possibility of routine outage, or force outage of the unity due to fault or something else right.

So, therefore, I have to pickup that which generator should involved to generate power and how much, such that your my operating cost will be minimum and, how many units will be committed for that right. And that is unit commitment suppose you are suppose to supply thousand megawatt, you need not run that your what you call all 5 units, you may you may have 2 suppose, if you have a large 2 3 or 4 units may be sufficient, if you have 6 or 7. And another thing is that that unit commitment issue actually it is coming for the your what you call for thermal power plant mainly.

Because hydro power hydro power case that hydro generation can pick up very quickly right and, it can meet the load very quickly, but in the case of thermal power plant it actually takes your what you call just to from the starting to your what you call generating power it may take 2 to 8 hours right.

This is one thing another thing for the shut down case also that thermal power plant just you cannot shut down immediately right, then this is a question to you that it is a very interesting question. Suppose a thermal unit is there and, it was running say it was just suppose it is rating is say for example, 250 megawatt for example, say a rated capacity.

And suppose you want to shut down it due to some reason right and question is that how many how many second minutes or hour it will take to complete the shut down right.

It is an interesting question I know some you have to you have to think and you have to answer this that suppose I want to bring that whole generated turbine generated system to a standstill right. So, how many hours it will take of course, not minute or second in any way it is hours. So, how many hours you are expecting to bring it to the 0 speed and what is the reason, why it will take long time and what is the reason right. So, this is a question to you.

And suppose you have before going to this mathematics is very less here, but understanding is more. Suppose in a suppose you have a 5 units which is suppose to supply power 1000 megawatt say at this moment and suppose my 3 units are operating and supplying power. So, in that case other 2 units say is your it was a standstill; that means, it is not under no load condition or not running. So, if sub shut down is there of the unit; So, in or sudden load increase also both can happen right.

So, those generators cannot supply power suppose 2 unit shut down, then 1 generator cannot supply thousand megawatt, then in that case you do not have any spear unit also or speeding unit, such that you can connect it and supply the power; that means, easy solution is the load shedding, but suppose if, but if you have that hydro generation right hydro power generation then in that case hydro, you can bring it to the your what you call operation such that it connect it to supply the load, because hydro can pick up the generation very fast right and, I mean very quickly it can pick up the generation right.

So, in that case no problem, but assuming that hydro generation is not available. So, in that case you have to you know you have to see that you know this is a very and what you have to do is actually, this is basically it is a you know if you have look up table that in which hour which unit will operate, such that your what you call that operating cost will be minimum because whatever power you generate everything is ok.

But one thing is there as per as suppose if you have your own industry, you will also look into the profit nothing else right it is a business. So, in that case you have to see that economy that what will be how way how can I can minimise the cost of power generation, such that I can make more profit, or I in other way also I can your sell power at the cheaper rate right. So, unit commitment is a huge 1 there are several techniques are there to solve such problem, but it is a very time consuming process, but we will see the simple thing right we will see the simple thing such that you can have some ideas about the unit commitment right.

So, so it so first thing is that that unit commitment actually, it is not economical to run all the units right available all the time because, there is no need to run because, it may not be economical as I told you, second thing is to determine the units of a plant that should operate for a particular load is the problem of unit commitment that how many units you will be operating for supplying a certain load; that means, every hour there is a possibility that new unit some unit may be I mean what you call, may be connected to supply more load, or some unit may be you know it will be your what you call it will be running and suppose, but almost that no load right.

So, but it will be spinning because, if you shut down in unit for thermal unit it takes long times to start, I told you that at least 2 to 8 hours. It is because it is a it is a huge dynamics boiler is also involved and boiler dynamics is very slow 1 right boiler, economizer I mean those dynamics actually very slow dynamics it takes time and lot of non-linearities are involved also in that what you call AGCI did not tell those non-linearities only have mentioned right, I believe that for undergraduate level things are ok.

But many constants are there also right and security is another issue for unit commitment. So, this problem is of importance for thermal plant I told you right, as for other types of generation, I told you such as hydro the operating cost and start up times are negligible for hydro, as compared to the thermal power plant right.

So, that they are on off status is not important for therefore, for hydro generation that on off status actually is not that important, but thermal it is very much important a simple, but sub optimal approach to the problem is to impose priority ordering where in the most efficient unit is loaded first to be followed by the next efficient unit which is in order as load increases right.

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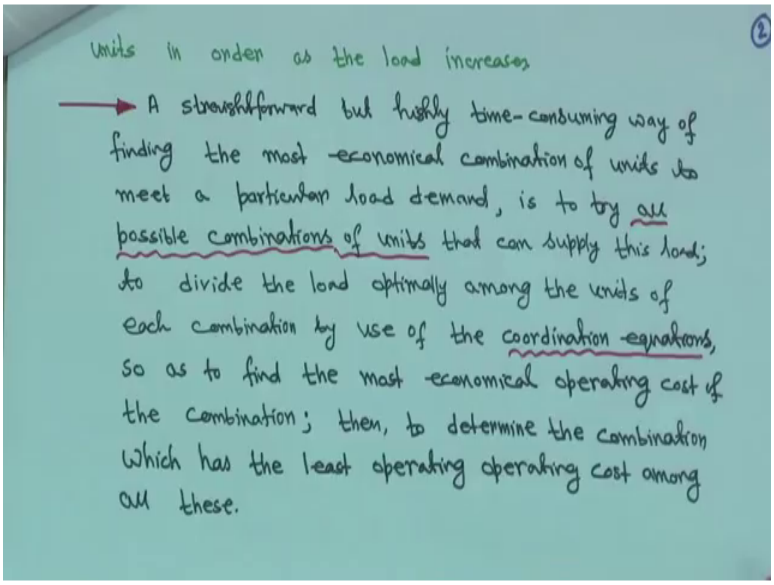

So, in that case what will happen suppose 1 1 1 very time consuming way, but suppose you have so, many units. Suppose 5 6 units are there suppose to supply particular load, if you go for all sort of combination it will be huge computation right so, but we have to avoid that and out of this huge computation you have to see which combination is giving you most economical operation. So, that is why a straight forward, but highly time consuming way of finding the most economical combination of units, to meet a particular load demand that is to try all possible combinations of units that can supply this load.

So, it is a very very time consuming process right, if you try for all possibilities to divide the load optimally among the units of each combination by use of the coordination equations. The coordination equation of little bit we have seen in the previous course power system analysis that optimal system operation right, we have seen and many good problems we have solved also that that you have also done right.

So, as to find the most economical operating cost of the combination right, then to determine the combination which has the least operating cost among all these right.

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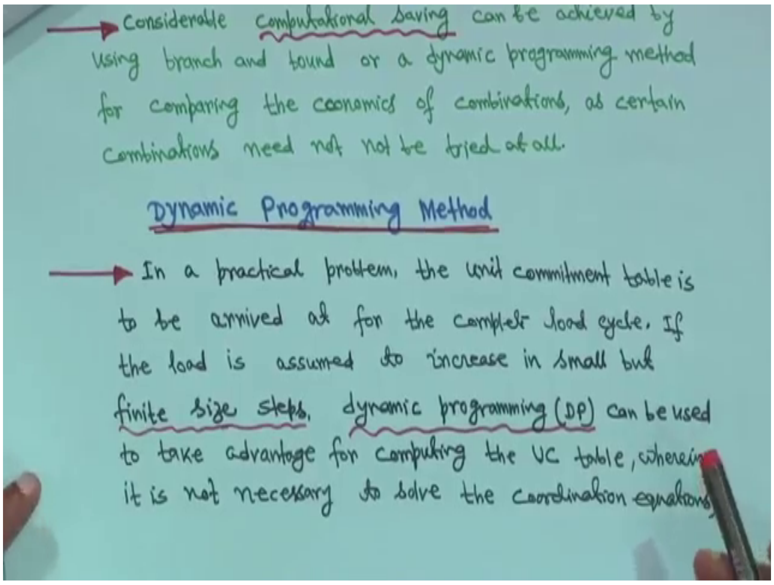

So, it is a very unit commitment actually the very very your what you call very time consuming process. So, considerable computational saving can be achieved either you can use branch and bound here we will not see, or a dynamic programming method we will see little bit on dynamic programming here, but all calculations cannot be done, right just I will show you that how can we do it some flavour will be given right.

So, for comparing the economics of combination as certain combination need not be tried at all because, there are certain combinations. So, here you will find that things are very complicated, I mean I mean not complicated that is your what you call that cost of operating cost is very high right, then dynamic programming method always it is also there are many other methods are there, but only dynamic programming I thought little bit I will tell you, soft computing techniques are available nowadays right and, it gives I mean very good results, but some soft computing also takes a lot of time, but it give the nearly global optimum result nearly global optimal, or best result right.

So, in a particular problem the unit commitment table is to be arrived at for the complete load cycle; load cycle means, suppose 24 hours load car you have. So, first hour second hour third hour like this right and, if the load is assumed to increase in small, but finite size step, I am we are taking the load is increasing discrete step a reality of course, it is not true, but we will have to you know we have to follow certain methodology right.

So, dynamic programming can be used to take advantage for computing unit commitment table and, where I am timing unit UC means unit commitment unit, commitment table means you have to make up a table first hour, how many units second hour how many units like this right, it is cannot be a online problem right it, if you have everything if you know the demand forecasting demand everything if you know.

So, you can know you can prepare this optimum unit commitment table, wherein it is not necessary to solve the coordination equation.

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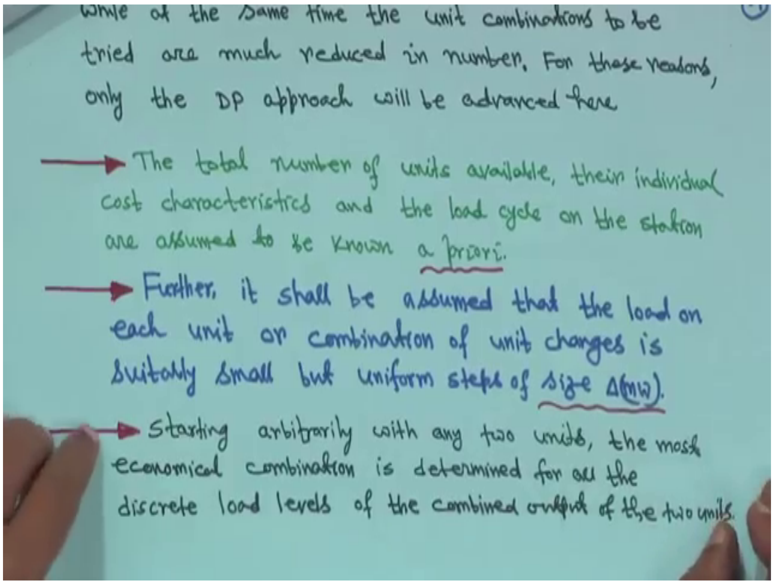

In this case coordination equation need not required, while at the same time the unit combination to be tried are much reduced in number for this reason only the dynamic programming approach will be advanced.

Here only little bit of dynamic programming thing we will see. The total number of units available their individual cost characteristic and the load cycle and the stationary assumed to be known a priori; that means, these fuel cost characteristic it is available from the manufacturer, it is available right.

And we are assuming that your load cycle; that means, load cycle and load curve is known to us right load curve is given that forecasted load what so, ever is given unless and until some unusual event happened right then loads will follow the same thing right.

So, further for example suppose if some final some important final match is going on may be football may be cricket what so, ever at that time we will find that all team is will be switched on. So, at that moment that hour right those hours that power demand will increase right. So, so many issues are there.

So, further it shall be assumed that the load on each unit, or combination of unit charges is your suitably small, but uniform step of size that delta megawatt; that means, we will see that that changes in a load it will delta megawatt, I mean very small size say it is step of 1 megawatt say that is why I have put delta in bracket I have made megawatt delta megawatt instead of delta Pg right.

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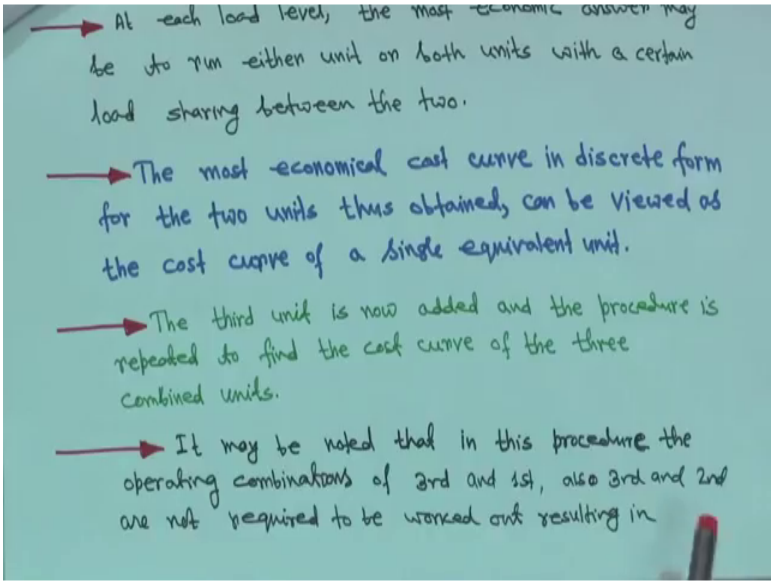

So, starting arbitrarily with any 2 units you start with any 2 units, the most economical combination is determined for all that discrete load level of the combined output of the 2 units right first we will take 2 units, then we will add another one, third one, fourth one like this and there is no question that is your the way we will unit number 1 2 3 4 it is arbitrary, it is not like that I will first most efficient, then second most efficient nothing like that just arbitrary right.

So, at each load level the most economic answer may be to run either unit or both unit with a certain load sharing between the 2 right, first we will start 2 units may be between the 2 units may be 1 units will be economical also right, it is not necessarily the 2 when it still run right for example, suppose load is 50 megawatt the 2 units, you are tried and you find 1 unit generating 50 megawatt is most economical that also possible if 2 units are so, possible say 1 unit may be generating thirty megawatt another may be twenty megawatt increase right that is also possible.

So, the most economical cost curve in discrete form for the 2 units thus obtained. Suppose that is that that data little bit I will show you that it will be available, can be viewed as the cost curve of a single equivalent unit that we will see. The third unit is now added and the procedure is repeated to find the cost curve of the 3 combined units actually. So, this dynamic programming yesterday 4 5 6 pages I think all calculations are made.

Then I found I will not show these calculations here, because it will be very hectic. So, I will show only 1 or 2 small thing how to make it right. So, it may be noted that in this procedure the operating combination of third and first also third and second also are not required to be worked out.

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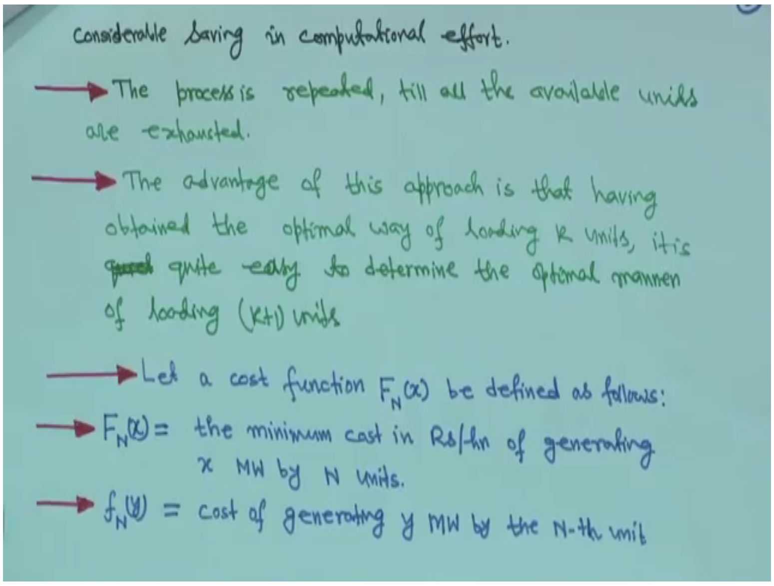

Your resulting in your what you call considerable saving in computational effort. Suppose 1 to unit suppose first 1 or 2 units are operating and you found that their combination optimal combination.

So, when third unit is added in dynamic programming you need not consider again, 1 and third and second and third no need actually there is no need right. So, this way computational some computational efficiency can be achieved; that means, effort of computation will be less. The process is repeated till all the available units are exhausted then you have to consider in this way all the all the units right.

The advantage of this approach is that having obtained the optimal way of loading k units this is k k units right, it is quite your what you call your easy to determine the optimal your what you call here actually optic optimal manner of loading k plus 1 units right. So, basically what happen that 1 after another suppose we have k number of units k number of units just you are considering first 1 and 2, then 3rd, then 4th like this way up to k-th number of units right. So, this way you can test and you can find out what will be the best combination.

Thank you.