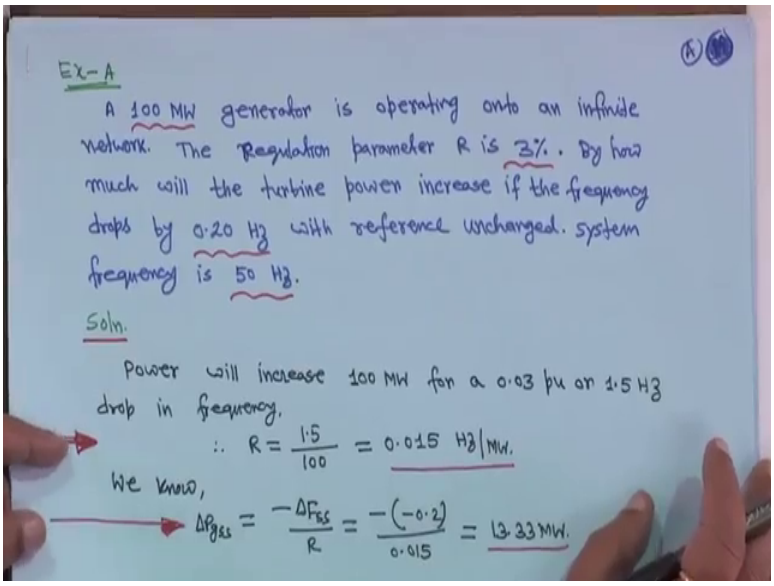
Power System Engineering
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 57
Automatic generation control

So, so far we have seen that two area interconnected power system.

(Refer Slide Time: 00:21)



Now we will see few more example this examples are quite easy one it because we are not carrying out any simulation or anything. So, this time made it example A B C D like this. So, after that I will tell you something more. So, a 100 megawatt generator is operating onto an infinite network right.

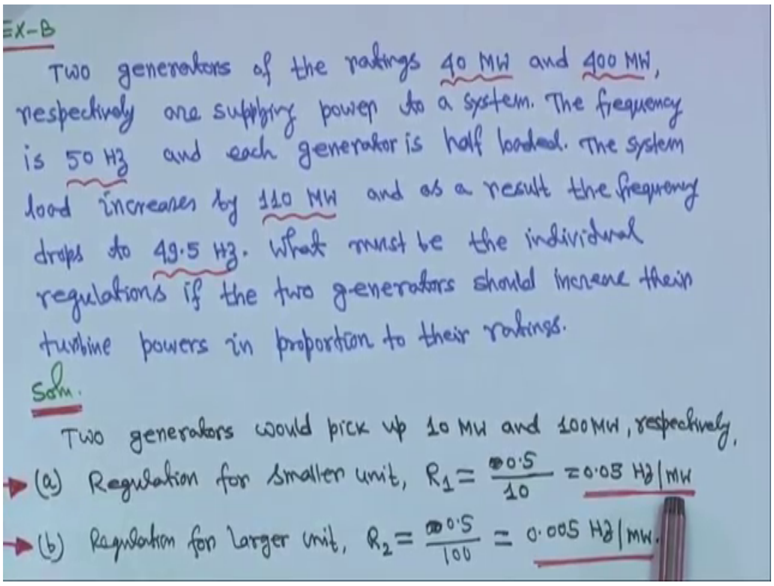
So, the regulation parameter R is 30 percent by how much will the turbine power increase if the frequency drops to 0.20 hertz with reference that your what you call with reference unchanged right. So, system frequency is here 50 hertz now it is actually 3 percent that regulation parameter is 3 percent right that is R is 3 percent mean that power will increase 100 megawatt for a 0.03 per unit or 1 point hertz drop in frequency.

Because is a 50 hertz right. So, 3 percents of 50 hertz means 1.5 hertz right. So, as it is understand level the 3 percent of 50 hertz is 1.5. So, R will be 1.5 upon 100; so, 0.015 hertz per megawatt not per unit megawatt because it is 100 megawatt right it is hertz per we are we are not concentric on your converting any (Refer Time: 01:45) in per unit it is hertz per megawatt.

Now, it is given that frequency drop 0.20 hertz this is delta F is equal to minus 0.20 we know this formula delta PgSS is equal to minus delta F steady state by R is equal to minus of this drop is actually which is actually it is drop not increase that it should be minus 0.2 right that is why this is minus of minus 0.2 and R you have got 0.015 right. Therefore, it is 13.33 megawatt right. So, this is what you call this is the answer 13.33 megawatt.

So, this example I will is not a your difficult one simple one only little bit understanding is required now look at this example

(Refer Slide Time: 02:31)



It is also small example, but. So, many things are written it is example B it is example B right two generators of the ratings 40 megawatt and 400 megawatt; that means, rating of 1 is 10 times more than the other one 40 megawatt and 400 megawatt respectively are supplying power to a system the frequency is 50 hertz that is operating frequency or nominal frequency of the system is 50 hertz.

And each generator is half loaded; that means, 50 percent of that is loaded half loaded the system load increases by 110 megawatt. So, all of a sudden system load increase to 110 megawatt and as a result the frequency drops to 49.5 hertz that mean; if we actually frequency are your 50 hertz. Now operating frequency is 49.5 hertz; that means, delta F actually that drop actually minus 0.5 hertz right. What must be the individual regulation if the two generators should increase their turbine power in proportion to their rating right. So, whatever; that means, you have to find out R 1 and R 2 load two generators would pick up 10 megawatt and 100 megawatt respectively.

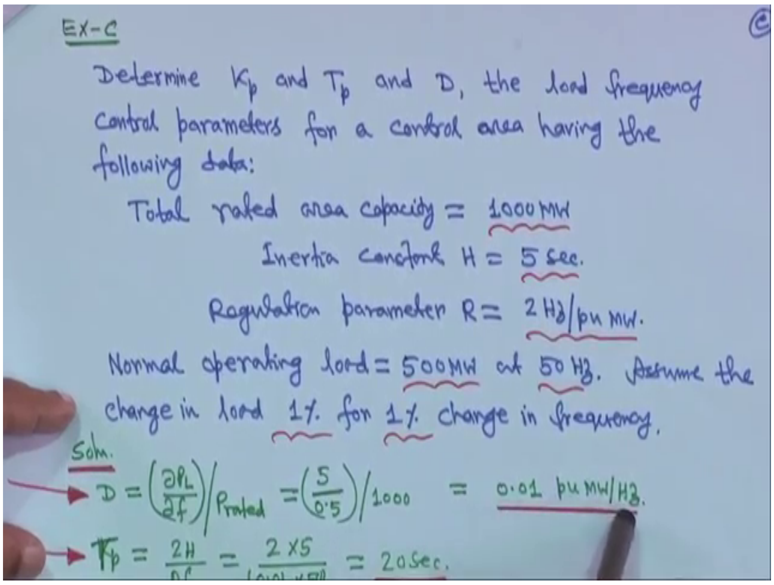
Because look one rating this rating is 10 times more right 10 times more and load increases 110 megawatt. So, if one the smallest one if and it was till mentioned that 50 percent loaded; that means, these generate 20 megawatt these generate two 100 megawatt is generating; that means, it can further generation power. So, here it is 110 megawatt; that means, 10 megawatt by smallest generator and 100 megawatt by the larger generator in proportion to the rating; that means, 10 times more because this rating is 10 times more.

So, here also this 110 megawatt can be divided that 10 megawatt will be picked up by this generator and another 100 megawatt will be picked up by this generator the total is one 110 times more has been proportion to the rating right. Therefore two generators would pick up 10 megawatt and 100 megawatt respectively; that means, smaller one will take 10 and larger one 110 times more here also it is 10 times more just in proportion to the rating. So, number a regulation for the smaller unit R 1 will be 0.5 upon 10 because that frequency drop actually 0.5 hertz it is 50 hertz 49.5 hertz.

So, 50 minus 49.5; so, 0.5 hertz right therefore, R 1 will be 0.5 by 10. So, 0.05 hertz per megawatt; so, simple thing similarly regulation for the larger unit R 2 will be frequency drop will remain same that is 0.5 hertz, but it picked up 100 megawatt. So, it will be 0.5 by 100 right. So, that will be actually 0.005 hertz per megawatt. So, problem is very big, but solution is just in two line.

So, you have to understand that how things are happening. So, R 1; it is case 0.05 hertz per megawatt and this is R 2 is equal to 0.005 hertz per megawatt no question of per unit here megawatt it is just megawatt right; so, this is that problem 2.

(Refer Slide Time: 05:45)



Now another one is; this is say this is your example C this is example c the third example you have to determine the determine K p and T p like there is K p we have told the power system gain sometimes we call and T p the power system time constant and D; that means, sometimes we call that your what you call that is del del P L or del P L upon del f right.

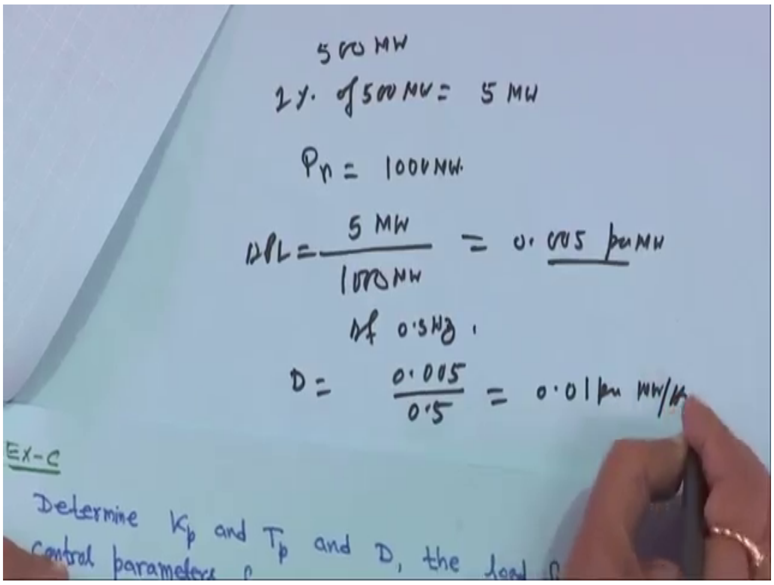
So, the load frequency control parameter for a control area having the following data you have to determine K p, T p and D and these are the parameter given. The total rated area capacity is given 1000 megawatt right, inertia constant H is given 5 second; regulation parameter R is given 2 hertz per unit megawatt here it is given hertz per unit megawatt. Normal operating load is 500 megawatt at 50 hertz. Assume the change in load 1 percent for 1 percent change in frequency right this is the problem you have to obtain K p T p and D.

Now, first you have to find out the D; D is equal to del P L upon del f divided by the rated capacity then D will be in per unit right. So, del P L is just look that your what you call it is del P L upon del f for what you are writing that total area rated capacity 1000 megawatt and your change in load is 1 percent for 1 percent change in frequency. So, 1 that total load is 1000 megawatt right total load is 1000 megawatt and 1 percent for 1 and your normal operating load is your this capacity and operating load is 500 megawatt right.

Therefore, 1 percent of 500 actually 5 megawatt; so delta P L actually 5 megawatt understandable not writing understandable because here load is 500 megawatt and your what you call change in 1 percent load 1 percent means it is 5 megawatt. So, delta P L is 5 megawatt right and your 1 percent change in frequency is 50 hertz. So, 1 percent will be 0.5 hertz. So, that is why this is 5 megawatt change in load divided by 0.5 hertz and divided by whole thing by your 1000 right.

So; that means, 0.01 per unit megawatt per hertz.

(Refer Slide Time: 08:00)

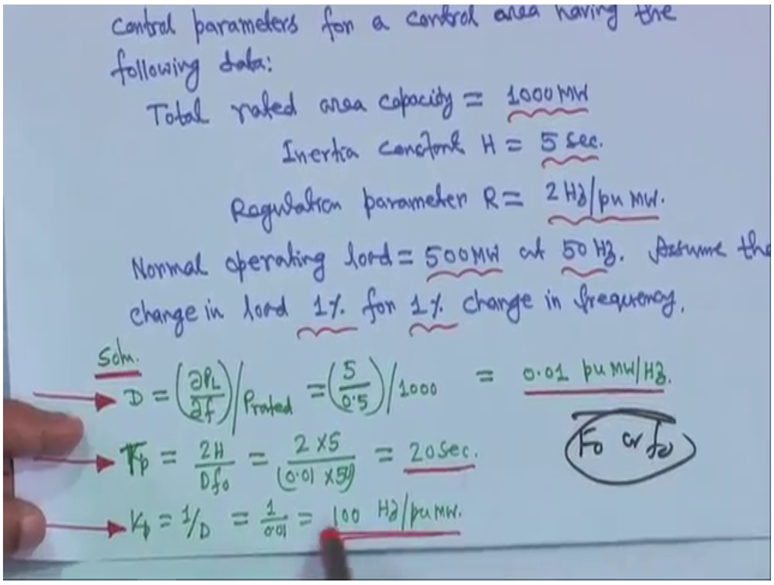


Actually if you have any I mean any confusion that operating load actually it was 5 megawatt right. So, 1 percent of these 1 percent of 500 megawatt is equal to 5 megawatt. So, your rated capacity this rated capacity is 1000 megawatt; that means, rated capacity is a P r is equal to 1000 megawatt right.

Therefore this 5 megawatt and if you convert it to the per unit by 1000 megawatt. So, that will actually become 005 we will call per unit megawatt right. So, that is why we have divided by 1000 and change in frequency actually your what you call that your 0.5 hertz. So, change in frequency is 0.5 hertz.

Therefore your D will be 0.005 this is actually your delta P L in per unit and this is actually your delta f. So, delta P L upon delta f right this will become 0.01 right per unit megawatt per hertz.

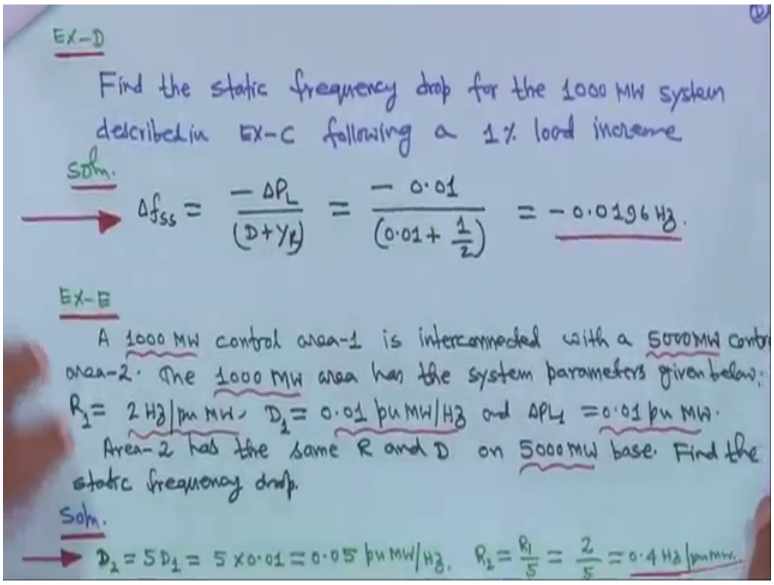
(Refer Slide Time: 09:13)



So, that is what you have got that D is equal to 0.01 per unit megawatt per hertz right. And we know T p is equal to 2 H upon D into f 0; f 0 is a nominal I told you that capital F 0 or small f 0 they are same right sometimes most of the cases capital F 0, but does not matter.

So, operating frequency f 0 is 50 hertz this is 50 hertz therefore, T p is equal to 2 H upon D f 0. So, H is given 5 second; so, 2 into H D we have computed 0.01. So, D into your nominal frequency is 50. So, T p actually 20 second right this is the power system time constant sorry and K p is equal to you know 1 upon D. So, 1 upon 0.01; so, it will be 100 hertz per unit megawatt because reciprocal of this. So, dimension will be reversed right; so, it is your 100 hertz per unit megawatt that is your K p right. So, these problems are very simple you can easily do it.

(Refer Slide Time: 10:15)



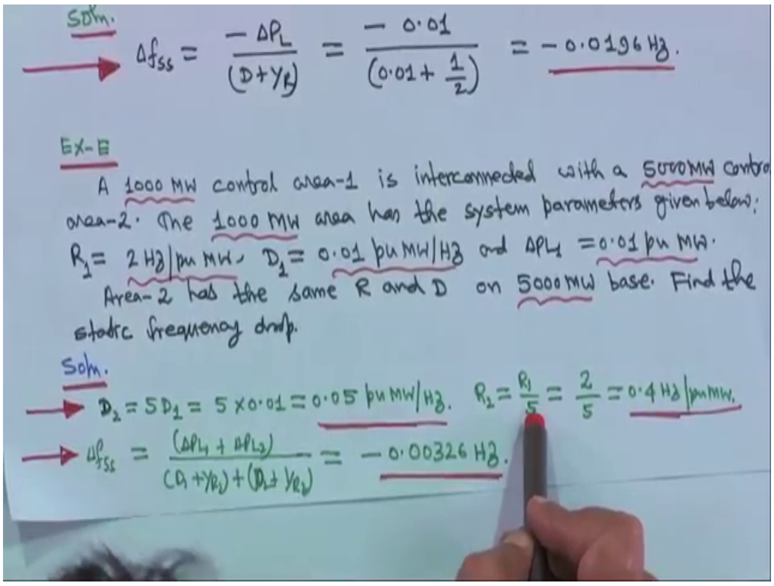
Now, another one is this is example D the fourth example right; this is example D find the static frequency drop for the 1000 megawatt system this your described in example in C; I mean same data whatever is here example data same has been taken right following a 1 percent your load increase. So, we know steady state error delta F SS is equal to minus delta P L upon D plus 1 upon R right.

So, it is it is given that delta P L that is 1 percent change in load means 1 percent means 0.01; so delta P L actually your 0.01. So, minus 0.01 a D is we have computed 0.01 and it is 1 upon R right R is equal to what you call 2. So, in this case your R is equal to given 2 hertz per unit megawatt this R is taken from this previous example data. So, R is given here 2. So that means this minus 0.01 upon 0.01 plus half because 1 upon R R is 2. So, that is minus 0.0196 hertz this is the answer this is example D a small example right such that you will have no confusion when we will go through this recorded lecture throughout right.

Now, example E this is last fifth example right some more I will show you a 1000 megawatt control area 1 is interconnected with a 5000 control area two; that means, area 1 P r 1 rated capacity is 1000 megawatt and area 2 P r 2 rated capacity is 5000 megawatt right. The 1000 megawatt area; that means, area 1 right has the system parameters given below that 1000 megawatt parameters are given below R 1 is given 2 hertz per unit megawatt then D 1 is given 0.01 per unit megawatt per hertz right and delta P L 1 is given 0.01 per unit megawatt this is a step load disturbance.

Now, area 2 has the same R and D on 5000 megawatt base. So, area 2 actually has same R and D value on 5000 megawatt base find the static your frequency drop then what is the frequency drop?

(Refer Slide Time: 12:39)



Now, as it is 5000 megawatt base look; so, find the static frequency drop and whatever it was given that was a say 1000 megawatt base and area 2 is 5000. So, D 2 should be is equal to 5 into D 1 just a straightforward you take. So, it is 5 because it is your 5 times more actually right.

So, 5 into D 1 is 0.01; so, 0.05 unit megawatt per hertz right and R 2 will be just R 1 by 5 because here it is area 1; 1000 megawatt area 2; 5000 megawatt and you have to area 2 has the same R and D are 5000 megawatt base. So, R 2 actually be R 1 by half right. So, if you if you look at that your what you call the example C data R is equal to right R is equal to that is your it is data 2 hertz per unit megawatt.

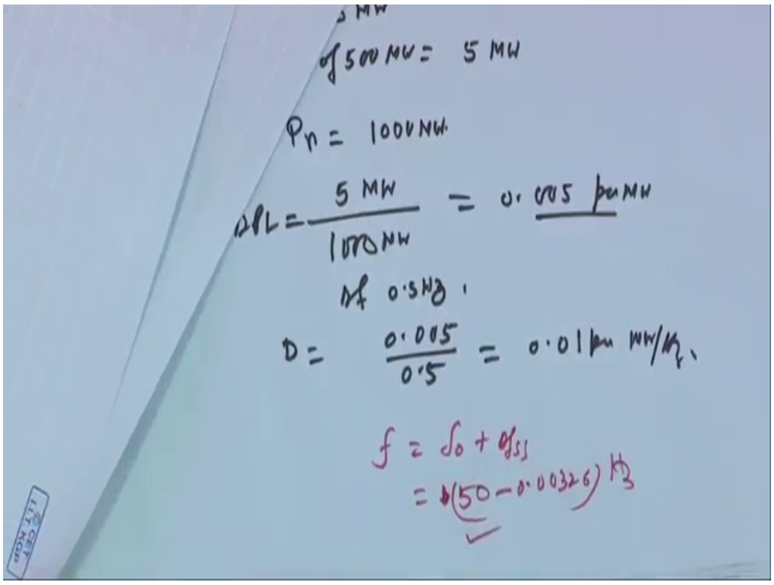
So, it is hertz per megawatt right if you if you do not convert it to that then it will be hertz per megawatt; otherwise hertz per unit megawatt and it is 5 times more and this base that is why R 2 is divided by 5 5 times more than multiply look at the dimension and then you do it. So, R 1 is 2 hertz whatever is taken right and whatever is given here 2 hertz per unit megawatt.

So, 2 by 5; so, it is 0.4 hertz per unit megawatt right and we know the steady state your what you call frequency this thing delta f SS we know delta P L 1 actually minus your what you call your a 1 2 delta P L 2 divided by D 1 plus 1 upon R 1 plus D 2 plus 1 upon R 2.

Anyway delta P L 2 is 0 right whatever it is and delta P L 1 value you put and D 1, D 2, R 1, R 2 everything is known right. And disturbance is only in area 1 that is your 0.01 per unit megawatt only in area 1 delta P L 2 is 0 if we take a 1 2 is equal to minus 1 it will become plus previously all this thing derived; you will get minus 0.00326 hertz this is the steady state yours error in the frequency.

So, whenever you say the static frequency drop means this is the steady state this thing right; that means, your if it is a 50 hertz system if it is a 50 hertz system then system frequency will be f 0 plus delta f SS.

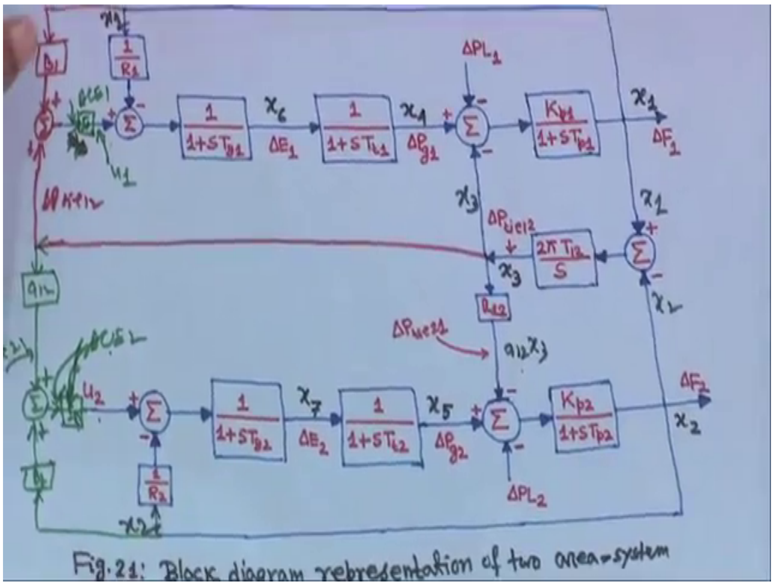
(Refer Slide Time: 15:00)



That means, it will be it will be 50 minus your 0.00326 hertz whatever it comes that will be the system operating frequency right and this is your what you call that steady state error of the frequency.

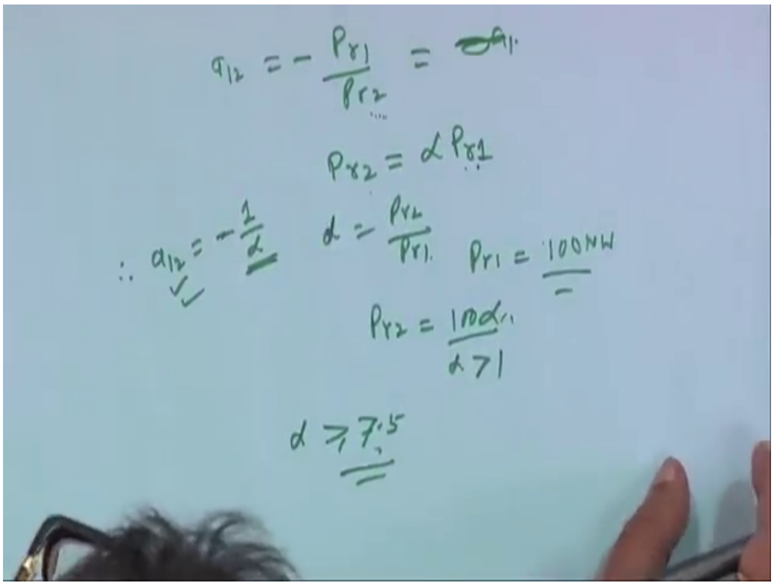
Now, if this 4 5 the example small one you should go through very carefully right. So, once this is done then what you can do is now look at this.

(Refer Slide Time: 15:33)



What you call this diagram once again now suppose here only I a 1 2 going to the next page here.

(Refer Slide Time: 15:48)



Suppose a 1 2 is equal to you know that a 1 2 is equal to minus say P r 1 by P r 2 right that will define as your minus your what you call that area capacitor is P r 1 upon P r 2 right. Now if you if your P r 2 is suppose P r 1 is then P r 2 is increasing right; that means, this value will go down a 1 2 will go down right.

So, suppose something if you put that P r 2 is equal to say alpha P r 1 right. So, minus sign is coming because of the direction of the tie power flow right because. So, that is why whereas, we call it area suppose P r 2 is alpha P r 1. Then alpha will be actually what you call P r 2 by P r 1 right. So, if suppose for example, P r 1 area capacity say area capacity say P r 1 is equal to say for example, say 100 megawatt.

Now, then P r 2 will be then 100 into alpha now question is that if you go on increasing suppose area capacity suppose in higher your go on increasing then what will happen? This a 1 2 value will actually your decrease because alpha alpha make your alpha is greater than 1 right 1 2 3 4 so; that means, your a 1 2 it can be written as minus and P r 2 upon P r 1 is equal to alpha; that means, minus 1 upon alpha.

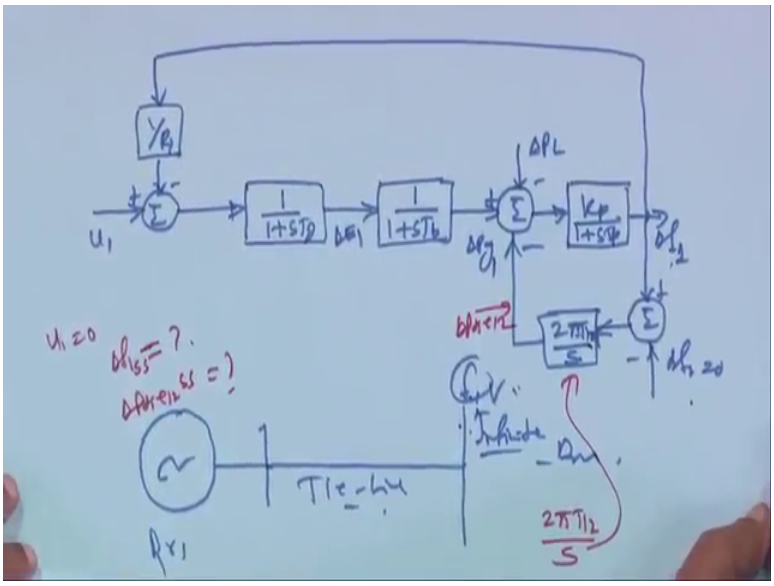
So, if alpha is greater than 1 go on increasing then a 1 2 value will decrease; that means, in this diagram when a 1 2 value is decreasing, I mean if you area capacity ratio of this area capacity of area 2 is increasing; that means, are we say 1 2 value is decreasing right.

So, if you go on increasing like this I mean if you see theoretically I will tell you then this whole system actually you will have no effect on this system right. Because this frequency deviation will be almost negligible right it is; that means, if it is much higher than this side will act like an infinite your system right infinite system. So; that means, that means if you with the area capacity ratio area capacity of area 2 is much higher than this one; then this whole system can be taken as the we have considered that single (Refer Time: 18:13) finite system.

So; that means,. So, not for this kind this system I have I for composite system and other thing I cannot tell directly, but I have some ideas that if your if your this what you call this alpha value; if alpha actually greater than equal to 7.5 say for this system; that means, if it is a 100 megawatt it is 7.5 times the 100 megawatt right at least greater than equal to then you will find this frequency deviation is almost negligible. That means, frequence operating frequency for this side compare to this one will remain constant; then whole this system that we consider as an single machine your what you call the way sorry system area 1 is connected we can infinite bar.

So, if you do so, if you do so, then it will be something like this just hold down I will show you. So, it will be something like this that this is your this is your system.

(Refer Slide Time: 19:15)



Right this is your system this is u 1 area 2 nothing will be there this is your 1 upon R 1 right or 1 upon R same thing this is your 1 plus STG right. And this one your 1 upon 1 plus STb and this is your delta Pg, this is plus, this is minus delta, P L this is your K p upon 1 plus STp, this is your delta f and it is coming from here it is coming from here and next this is delta f 1.

So, for example, I can put there delta Pg 1 say this is delta e 1 right and this side is a tie tie line will be there this is plus and this side is your delta f 2 is equal to 0 minus I told you that because area capacity is, but tie power will be there this will be there tie line is there. So, it is 2 pi p 1 2 upon S and here it will be there here it will be there this side it will not be there it is something like you have studied know single machine infinite bar.

So, power system analysis what is infinite bar everything detail has been explained. So, this is something like your infinite your system that is you call infinite bar right and here they; that means, here frequency is constant f is constant V is constant. So, frequency is constant mean delta F equal to 0 because this capacity is much higher in this one at least 7.5 or more this side if it is P r 1 and this side will be 7.5 times P r 1 or more then it can operate it can act like an infinite bar single machine infinite bar.

So, that frequency is constant, but this is tie line this is tie line tie line is there that is why this tie line modelling will be coming here right. So, and this is your what you call that delta f 1 delta f delta f 2 is not there, but this is your this is your what you call the tie line power flow; this is your tie line power flow and if you want area control error from this area it will come here right; I am not showing this.

So, what you will do this is an exercise for you and I will appreciate if you can when you go through this and if you can get the answer and let me know then I will I will I will know that you have really understood this right question is you take u 1 equal to 0 uncontrolled mode right.

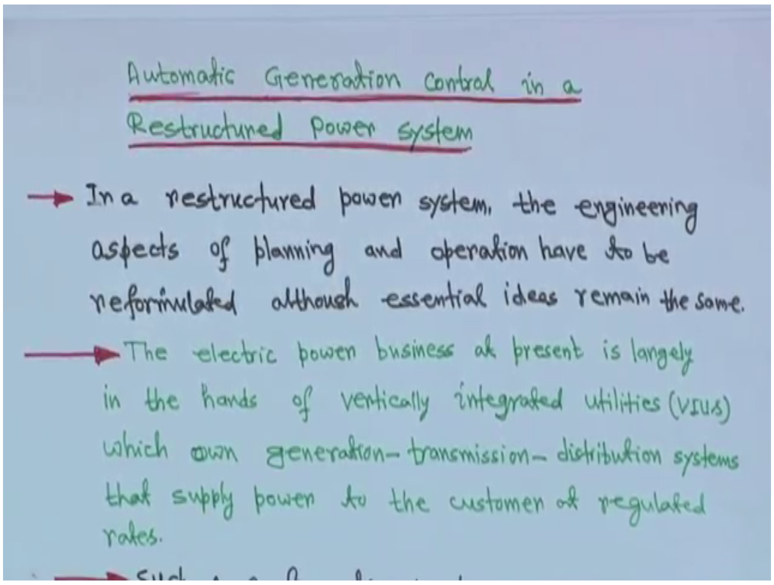
What you have to do is you have to find out steady state error of frequency and this tie power that you have to find out for uncontrolled mode delta f 1 steady what and delta P tie 1 2 steady state is what right these you have to find out in terms of R 1 and K p right and delta P L. Other things will vanish anyway I write this transient this 2 have no steady state and of course, in terms of 2 pi T 1 2 here two pi T 1 2 term is here also right here it is little bit clumsy here it is 2 pi T 1 2 divided by S this one this block right.

So, in terms of your whatever it come that in terms of 2 pi pi here T 1 2 is here K p K p is here and R 1 is here. So, and delta P L is there. So, they have to find out what is the delta f SS a steady state value of frequency in for such kind of system and what is delta p tie 1 2 SS for a state load (Refer Time: 23:10) state load for u 1e is equal to 0 this is an exercise for you right; you will do this once. Once all this things done; so, little bit your what you call that conventional your conventional EGC load frequency control (Refer Time: 23:31) right everything is explained.

So, and numerical; so, another thing are not very difficult one and putting in state (Refer Time: 23:39) analysis I hope everything I have I have told you. So, next is that that little bit will show you that what is automatic generation control in this structure power when deregulated market.

Here no block diagram I will show only some ideas will be given to you such that you know you will you will have some ideas what actually going on right. So, no block diagram representation, not much calculation just some concept and little bit of thinking that how you can go for deregulation for such kind of thing.

(Refer Slide Time: 24:15)



So, now that is actually or we call automatic generation control in a restructured power system restructure means in that deregulated market. So, before moving to that suppose earlier what happen actually all over the world that one utility use to own that 3 things that is generation, transmission and distribution. Suppose you have your own electricity company then you have your own generation transmission and distribution company right. And; that means, it is actually you yourself controlling everything that your generation, transmission and distribution.

Now, under the this structure system it is not like that in that case suppose you have suppose someone may have generation company. For example, suppose a suppose somebody called a he has his own generation company right and he is generating power, but he has to sell power and somebody has somebody has your say B call B he has say he or she has his just transmission company right and somebody called C he or she suppose has distribution company right.

So, ultimately power distribution company has to buy power from that generation company suppose several generation companies are there. And power willingly take place to the transmission network, but transmission company owned by B generation company own by A and distribution company own by C. So, completely 3 different entity right; so, in that case what will happen? That earlier if you have your own companies generation, transmission and distribution.

So, there is there is no change in infrastructure it will remain as it is right even your what you call that even if you break it generation transmission and distribution ultimately it is owned by you, but if somebody has that distribution part totally and he is responsible he or she is responsible for your what you call for selling power to the distribution side; then he has to buy power from the generation company through your through that transmission line, but transmission company is different right.

So, because of this thing I think power system concept is becoming very very complicated, but competitive also; that means, suppose if suppose some 10 or twelve generation companies are there and it is a competitive market and you have a distribution company and you want to buy power from that generation companies. So, many suppose today when I am recording here that is now 2015 at this time suppose 5 generation companies are selling power to distribution companies right and distribution company will see from where I will get the cheapest power.

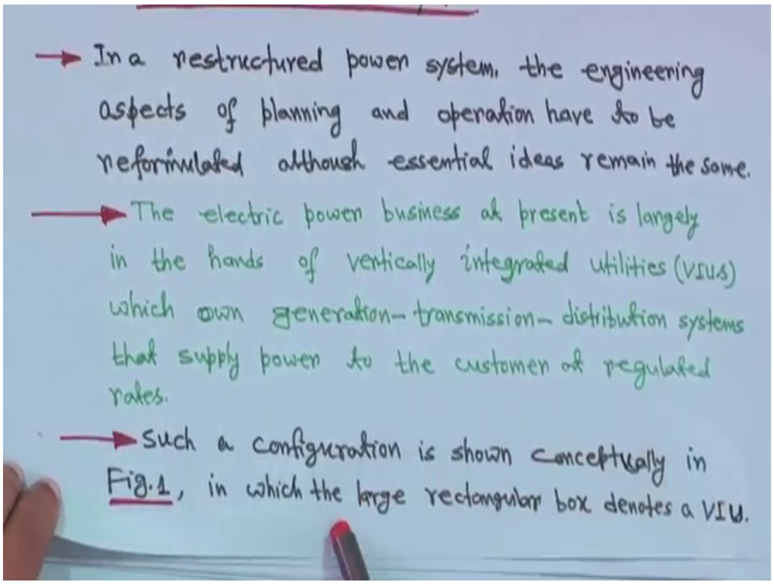
So, accordingly they can contact with the different generation companies. So, market is competitive and therefore, your what you call that expecting that because of this competition that your price of electricity may go down. Because competition has been your this concept has been introduced actually this restructuring of power system or this thing from where it has actually first generated; this concepts this concept I was listening on lecture from one professor from abroad.

So, he actually visited that country in South America. So, whatever I have learned from him I have I after reading he said this restructuring in power system actually concept came to that (Refer Time: 27:50) fast right actually they were thinking this kind of restructuring that was many years back that in his lecture I was listening to him when he was giving lecture in our department few years back. But today that that your what you call this concept of restructure has come to in effect.

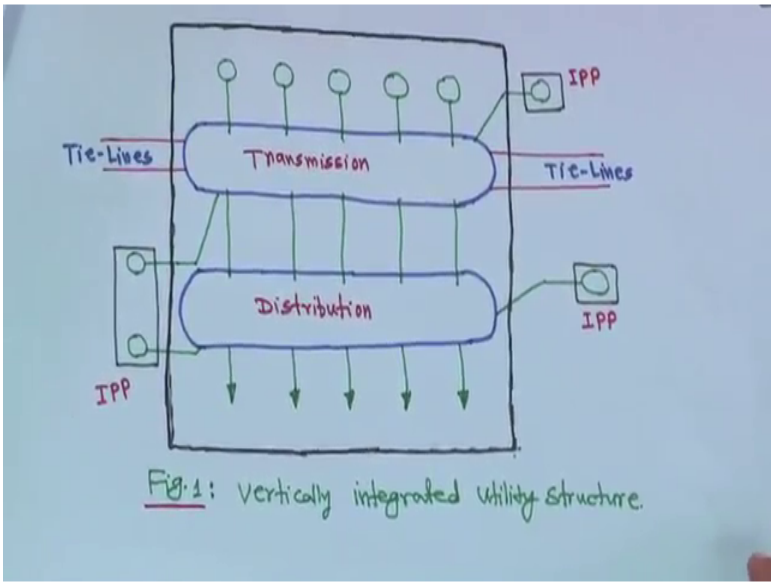
So, therefore, that restructure power system the engineering whatever I told you the engineering aspect of planning and operation have to be reformulated although essential ideas remain the same. Generation transmission distribution concept will remain same only competition has been introduced right. So, the electric power business at present is largely in the hands of vertically integrated utilities.

Vertically integrated utilities mean you have generation transmission distribution everything together you are the you are the owner of everything that is we call vertically integrated utilities which own generation, transmission and distribution that supply power to the customer at regulated rates right.

(Refer Slide Time: 28:54)



(Refer Slide Time: 29:00)



Now, such a configuration is shown conceptually in figure 1 I will show you in which the large rectangular box directly vertically integrated utility (Refer Time: 29:05) right that this is a big box I have given this is transmission side; these are all generation these are all generation right these are all generation.

And this is then this particular area it is I showed you that it is connected to some other areas tie line tie line these are tie line. And transmission power is coming directly to the distribution right and then power is being distributed and IPP is independent power producer; that means, private parties also some time it parties which are generating wire at high voltage level directly can be connected to the transmission system.

And some parties which are power generating power at low voltage level may be connected to that distribution side. These are IPP independent power producer here also IPP is there like generation compile is this IPP also generating power here right, here also here also. So, right this is actually vertical integrated utility structure everything is owned by you with that some private independent power producer some private parties are also connected with that.

Thank you very much we will be back.