Power System Dynamics, Control and Monitoring
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Lecture – 36
Automatic generation control conventional scenario (Contd.)

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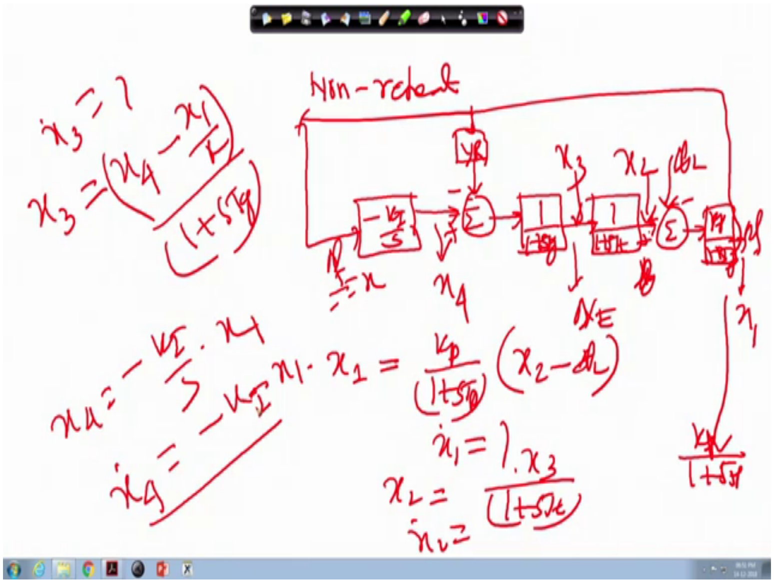

So, we are we are back again. So, actually I did not make notes for this just see how this. First you write down all the state variable equation right. So, first if you write this is plus sign right this is plus sign, so say x 1 is equal to your k p upon 1 plus S T p right in bracket, this is x 2 minus delta P L right. So, from here you find out equation of x 1 dot right, so you please write down here difficult to accommodate all these thing. So, please write down what is x 1 that cross multiply and simplify, it is now already we have seen that.

Similarly for x 2, similarly for x 2, I am making it here x 2 is equal to x 3 divided by 1 plus S T, from here you find out x 2 dot right. And similarly for x 3 x 3 I am writing here right, so x 3 will be is equal to your, this is x 1 it coming here, and this is x 4, and this is actually plus right.

So, x 3 is equal to x 4, because this one we have taken as a state variable. So, it is x 3 is equal to x 4 minus your x 1 by R right divided by 1 plus S T g cross multiply, and find out your what is x 3 dot is equal to here also what is x 2 that is equal to right.

So, this why you have to take similarly for x 4 is equal to it is minus K I upon S, and this is delta f means it is x 1, so into x 1 right. So, if you cross multiply x 4 dot will be minus K I into x 1 right. So, x 1 dot, x 2 dot, x 3 dot, x 4 dot if you take, you just your then what will be your order of a matrix, it will be 4 into 4. So, you can write x dot is equal to a x plus b u plus gamma p, so x that means, you are a matrix is a function of K I right, and other parameters are known to you accept K I, and you have to find out K I using degree of stability.

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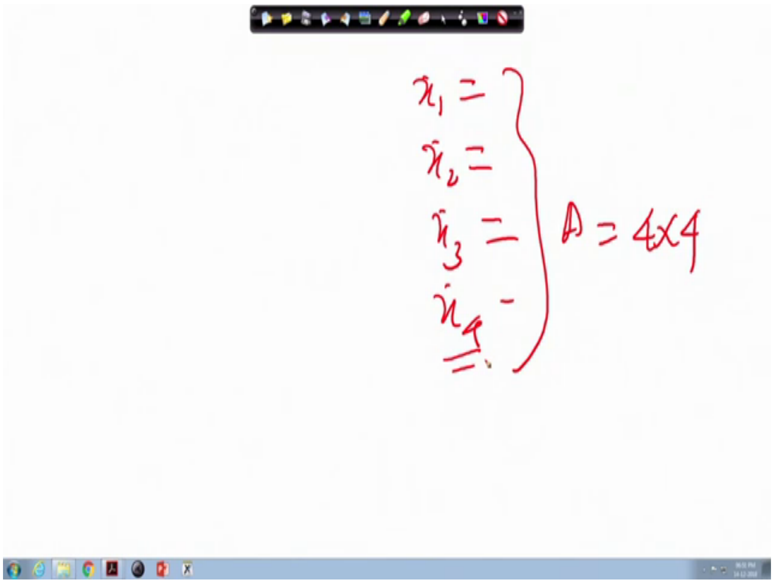

So, I suggest so I am I am now cleaning this one. So, I will suggest that you will write x 1 dot is equal to equation x 2 dot x 3 dot and x 4 dot, so you are A matrix will be 4 into 4. Here our interest is only A matrix, because A matrix is function of K I right. So, because we have taken that control variable U as a state variable that is your x 4 right, so that means, A matrix is a function of K I. So, it is a 4 into 4 matrix.

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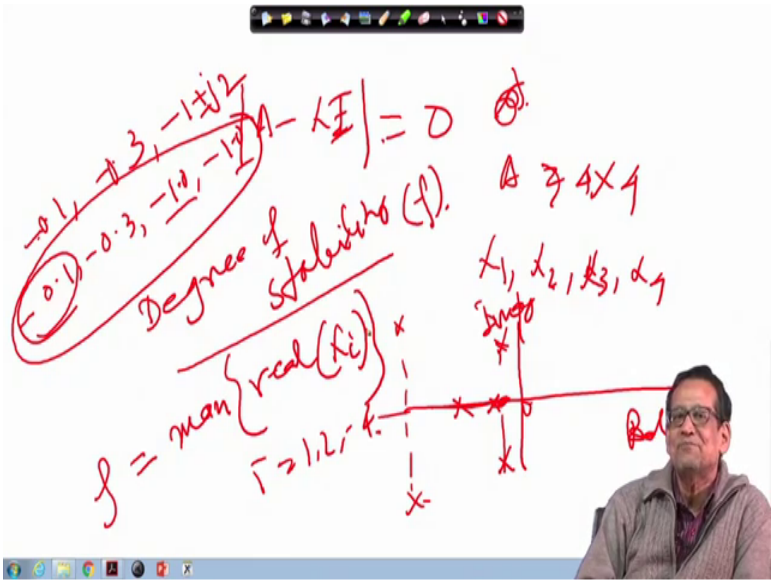

Now, what you will do for degree of stability that you find out the eigenvalues of the A matrix right, you will lambda I A determinant of A minus lambda equal to 0, you find out the your eigenvalues right. Generally, that lambda is like this, but these are become may have it right.

So, A minus lambda I equal to 0 determinant and find out eigenvalue. So, there are four eigenvalue, because you are A matrix is your 4 into 4, so 4 eigenvalues. It maybe eigenvalues maybe four are real or maybe complex conjugate pairs or two real, one complex conjugate pairs it may be like this, so that is not the case you will get four eigenvalues right. So, lambda 1, lambda 2, lambda 3, lambda 4, if it is complex conjugate also it does not matter, but four eigenvalues.

After that the concept is the degree of stability right. So, you know this eigenvalues right you know that you see that this is my real part, and this is my imaginary part right. So, if you if your system is stable if system is stable, all the eigenvalues will lie on the laptop of the explain right that means, they are real part is say negative.

So, if suppose for example just for the sake of your clarification, suppose we have one complex conjugate pair eigenvalue, so it will be located here it will be located here say other two are real. For example so one is located here, another maybe located here right or maybe somewhere or maybe or maybe you are other another if also may be complex conjugate right, it does not matter pair it does not matter.

Our objectively for degree of stability that is we defined as a rho right fast what you do that rho should be that eigenvalues, which will be very close to the origin this is origin is most sensitive for your instability right. Because, if it moves to the right about the explain, then you are what to call system will become unstable.

So, eigenvalues which is very close to the origin that is our to your what to call interest, because that eigenvalue is more sensitive the stable operation of the system. Other again I will away from that that is our not consideration. So, our consideration is which is very close to the origin right that means we have to see the real part that, because even its complex conjugate also. Suppose if it is complex conjugate also, so I have to see the real part right. So, our objective is the push this one to that away from the origin.

Therefore, we can define rho is equal to right rho is equal to we have to find out your this thing makes of that is maximum of that real part of lambda i right, for i is equal to 1, 2, see here 4 right that means, we will take the real part of the lambda i, then will take that you are max value, because all eigenvalues are negative.

Suppose, one eigenvalue is minus 0.1, another is minus 0.3 right say 0.1, then minus 0.3, another is another is say minus 1 plus minus your j 2 right, there is something like this. So, out of if you take the real part of all these four eigenvalues, so it is minus 0.1, then minus 0.3, then minus 1.0, then minus 1.0, because complex conjugate pair. So, minus 1 minus out of this all these 4, it is all minus.

So, maximum you have to take so this is the maximum right that is why you right rho is equal to maximum of real of the lambda i right, so that means we will take the max of real lambda i, because it is your what to call that that it is eigenvalues, which is very close to the your what to call at the origin. And the, our objective will be push that eigenvalue to away from the origin such that system will become stable.

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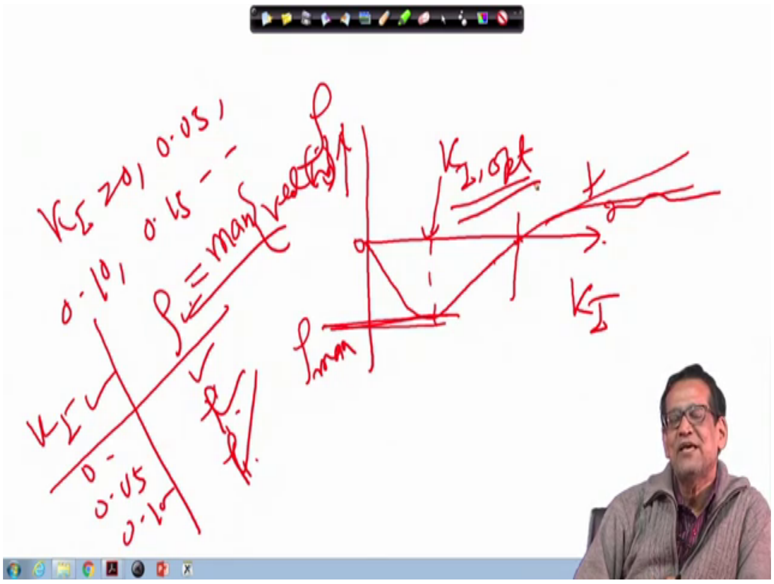

So, in that case what we will do that in that case you plot what you will do? Suppose, this is this is my K I values, because a is a 4 into 4 matrix. And this is my rho that is degree of stability right, so and this is origin. So, in this case what you do, you start from K I is equal to 0. Then next value of K I is equal to 0.5 say, 0.10, then 0.15 like this. In a step up 0.5, you change the value of K I.

And every time you find out the eigenvalues using say mat lab you put it in the mat lab every time you put it in a loop, and find out the eigenvalues of a matrix that K I is equal to 0, K I is equal to 0.5, and every time you find out what is the value of rho that means this will be your K I, and this will be your rho. And rho will be I told you, it will be real of it is a sorry maximum of that real part of lambda I right this is rho. So, this is K I, this is rho.

So, 0 find out rho, then 0.05 then find out rho, 0.10 find out rho right. So, all these value find out for the rho, this is K I, this is rho, after that you plot it. So, if you take care as soon as will plot it, what will happen? You will see you will observe that graph will be something like this, it will come. And finally, it will go to like this right, then I mean it will go like this.

So, in that case what will happen that this value this is the maximum value of the rho this is your rho max that is this is the maximum that means, this is the maximum that you can push that eigenvalues, which was very close to the origin away much away from that, you cannot after that even if K I is increase, it is actually decreasing, it is actually decreasing.

So, this value we call K I optimum value, and this is that this is your what to call most critical value of K I beyond that it will become unstable, because eigenvalue will move to the write about the explain right. So, this rho verses K I plot from that you will get your optimum value of K I. But, this is this is not like that that it will give you the best response right. But, it is one way to your find out the optimum value of K I, they your this thing you are what to call using degree of stability.

Similarly, if we use proportional controller or your PID controller, they are also you can easily find out that your what to call that your this thing that K I K p K I proportional gain, derivative gain, integral gain. But, your what to call you have to kind three together, you cannot do it first you optimize K I fix the value of K I, then try to find out the K d right, then you try to find out the K p, this way you have to try. But, if we put PID controller also this way, only thing is that that if you put P I your PID controller only modification, you have to make for your x 4 dot equation.

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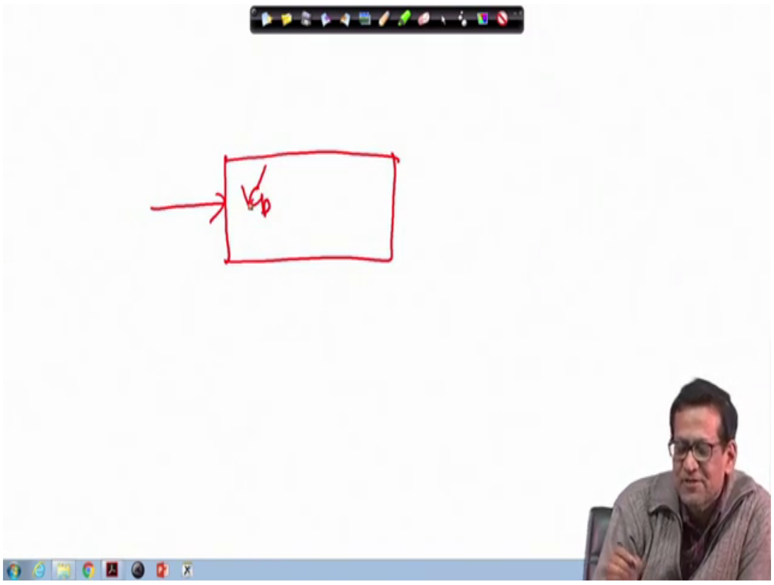

For example, for example suppose, this is my controller right. And this is my PID controller right. Say proportional gain is say K p dash, because power system gain you have taken K p say it is K p dash rather I can put it like this.

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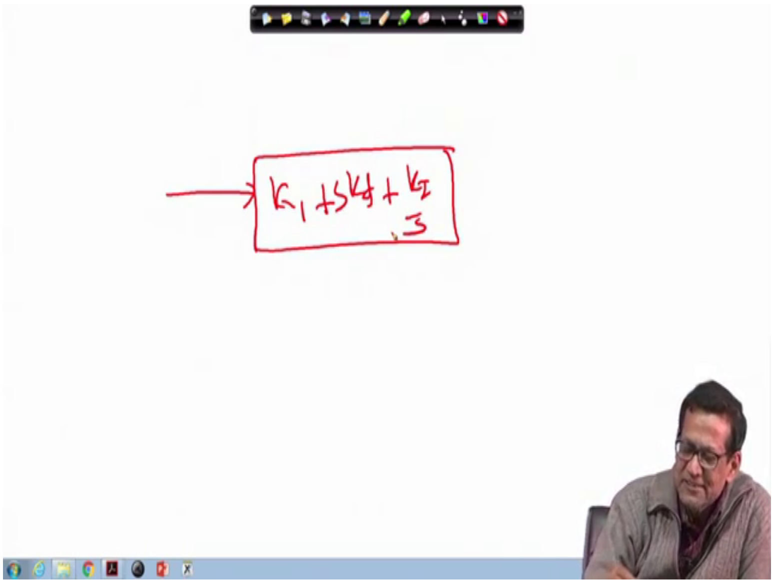

Say this is this is my PID controller. Say I can take this is k 1, right and then say this is my S k d that your differentiator that is your differential part and this is my K I upon S right take.

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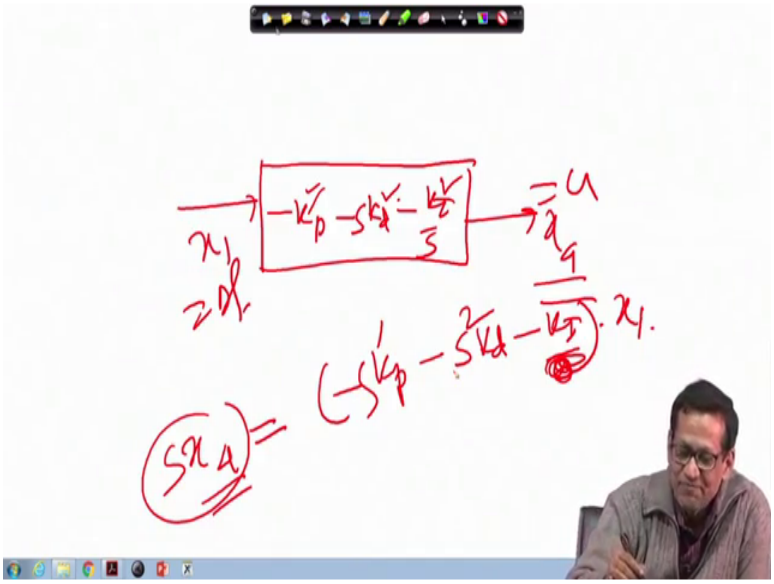

One thing is there that if you can take your, this you take minus k 1 just hold on just hold on I change the sign right, and I will ask give you this question. Suppose, this is minus K 1 minus your K d S K d and minus your K I upon S, and this is your x 4 that is nothing but your u that control variable.

And this is input the frequency is equal to delta f right. So, it is K p dash, you take because your proper power system gain has been taken as your K p right. So, it is minus S k d, so I will put a question. If when you take minus, minus, minus, we will take K I generally K I K d and you have depends of course on the system for this system K I, K d or K p you have to take positive.

But, if you take plus K p dash plus S K d plus K I, then you have to take K I negative, so we have to see that. By chance if you see that eigenvalues are your what to call system going to write about this plane, when be careful about the sign, and this is a question to you that why it happens right. If you put minus K I upon S, then K I is positive. So, why it happens, this is a question to you technical question to you right.

So, and these this is export, if you take like this there and this is x 1, then what will happen that x 4 will be is equal to just I am showing that how we write down the equation, this is K p dash, and this is your minus S K d, and this is your minus K I upon S into your x 1, this is x 4.

Now, both side you multiply your, what you call your x 4 is equal to x 1, x this one right. So, what you can do is that both side if you this thing if you try to find out that you are S K d, then K I upon S. So, how to how to actually your evaluate this one. So, in that case process will be little bit complicated, if you consider all these three suppose. If you take that you are x 4 dot, so you have to multiply both side by S right.

So, in that case this will be also S, this will be S square that mean double derivative, and this will be your this S should not be there, because it is multiplication. So, in that case it will become minus S a K p dash x 1 dot, and it will be minus K d into x 1 double dot because of S square. So, you have to find out x 1 dot is known to you, then you have to take another derivative and you have to mathematically you have to manipulate everything, and then you have to find out right. So, the procedure in that case little bit your complicated. But, it is possible to make, it because this is x 4 is x 4 dot, but only thing is that so many elements will come right.

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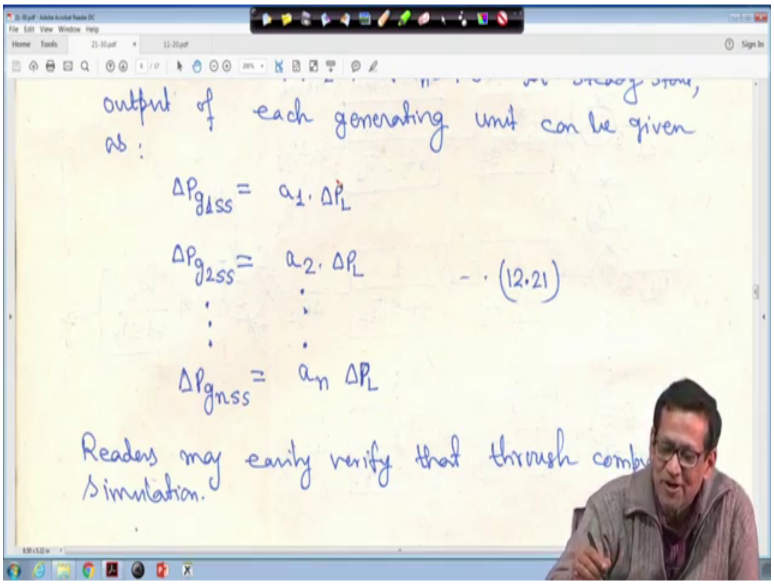

So, so that is that is your what you saw the degree of stability, and this is we have seen.

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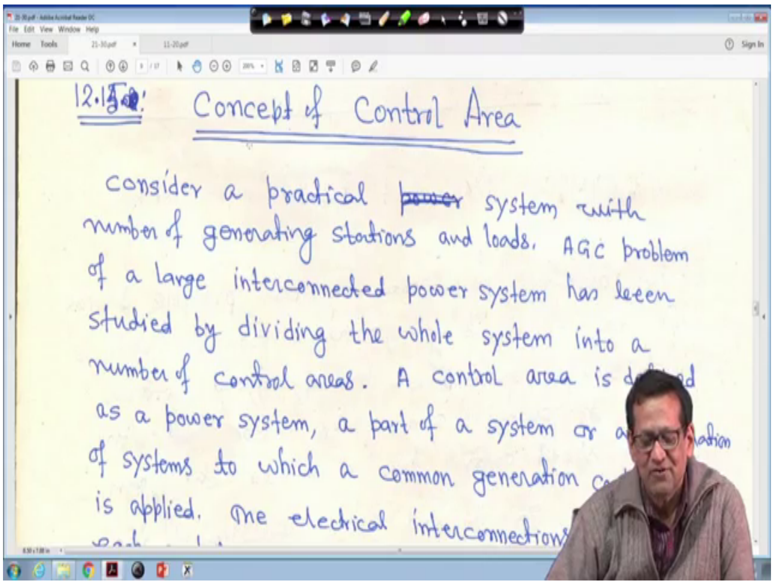

Now, next one is that concept of control area. Now, consider a practical system with number of generating station and load, suppose you have number of generating station and load. So, AGC problem of a large interconnected power system has been studied actually dividing the whole system into a number of control areas, we call it is a control areas right.

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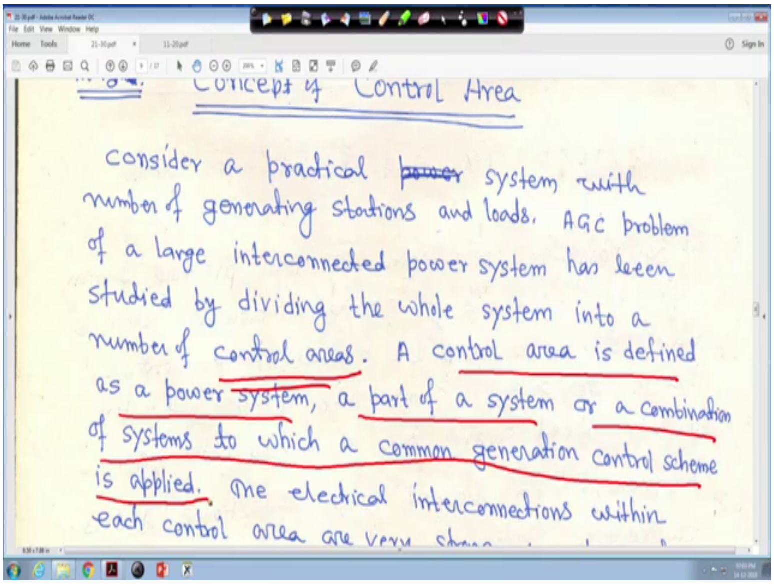

So, a control area is defined as a power system or a part of a system or a combination of system to which a common generation control scheme is applied. So, basically when you say that control area, actually it is a power system or a part of a system or a combination of system to which a common generation control scheme is applied. Suppose in a particular power plant, you have n number of generators.

So, all these generators actually in that we will assume there in coherent group that means a coherent means, that means they swing in unison that means, any load changes there it is increase or decrease of the speed will remain same right, so that is so in this case just hold on.

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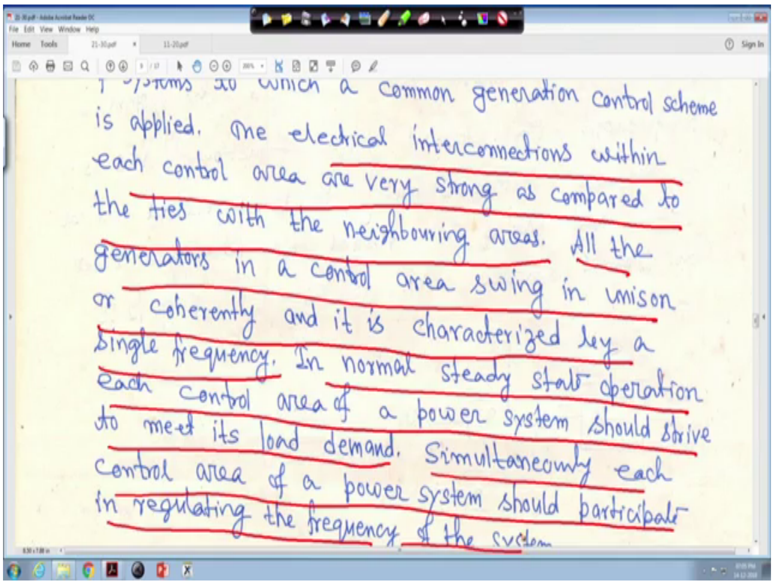

So, the electrical interconnection within each control area are very strong right so the electrical interconnection within each control area are very strong as compared to the ties with the neighboring areas that means, suppose you have a power system, where you have many generators many bus of stations right, so many lines are there.

And you have another power station power system suppose away suppose 400 kilometers away from that. They are also so many lines are there interconnected lines are there right. And these two power systems are interconnected by tie lines, we call it basically it is a three phase transmission line, whenever it is a because of the power exchange either from these control area to that that control area to this based on several criteria's right, so that is why compare to ties with the other neighboring area.

So, all the generators in a control area swing in unison or coherently and it is characterized by single frequency I told you right. So, in normal steady state operation each control area of a power system should strive to meet its load demand. Suppose, two power systems are interconnected, later we will see and suppose power system A is some are area, and power system B is 400 kilometers away from here.

Suppose, there is a load disturbance in power system a load increase say, so that generating units for that power system will accommodate that load. By chance if generation is not sufficient to accommodate that means, it has to borrower by power from the other interconnecting areas right. So, simultaneously that each control area of a power system should participate in every you are what to call in regulating the frequency of the system.

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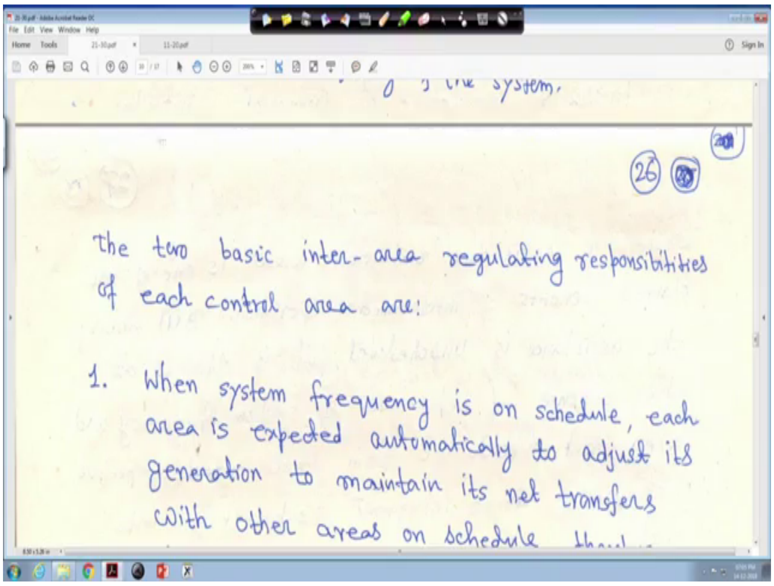

So, that two basic inter area regulating responsibilities of each control area are.

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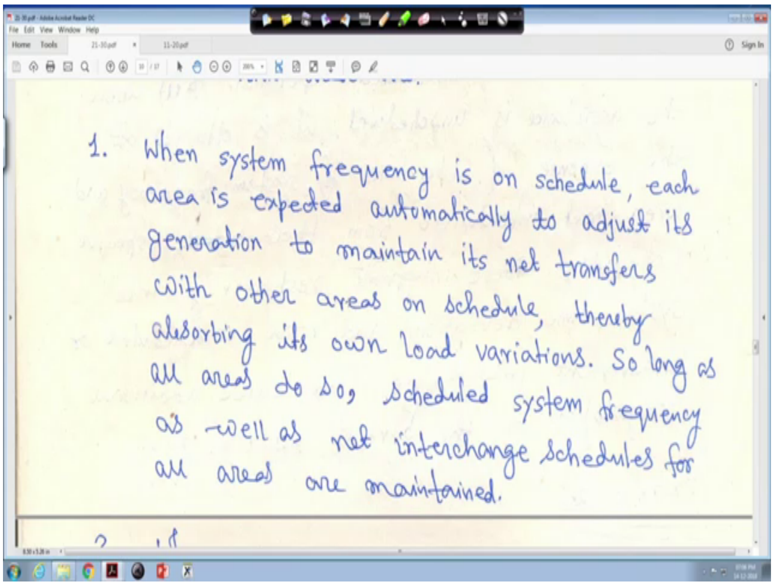

First one is that when system frequency is on schedule, each area is expected automatically to adjust its generation to maintain its net transfer with other areas on schedule there by observing its own load variations right. So, so long as all areas do so, schedule system frequency as well as net interchange schedules for all areas are maintained that means, that you have suppose you have two areas, it is interconnected by interconnected by tie lines.

Tie lines I told you it is transformation line. Suppose, when and when it is connected to two line tie line some schedule power will flow, because they have some you are what to call some agreement right. Suppose, at 10 o clock area A needs 100 megawatt power from area B that is your another power system. So, as long as it is same schedule right.

So, what will happen that whatever it is written here that when system frequency is on schedule, each area is expect automatically to adjust its generation to maintain its nets transfer with other areas on schedule, thereby observing its own load variation. Suppose, area A that load change, so it is expected that area A power system generating units will observing its own load variation such that frequency also will be maintain at a schedule value as well as that P interchange power also. But, of course, there will be little transient imbalanced, but ultimate thing ultimately it will achieve its objective.

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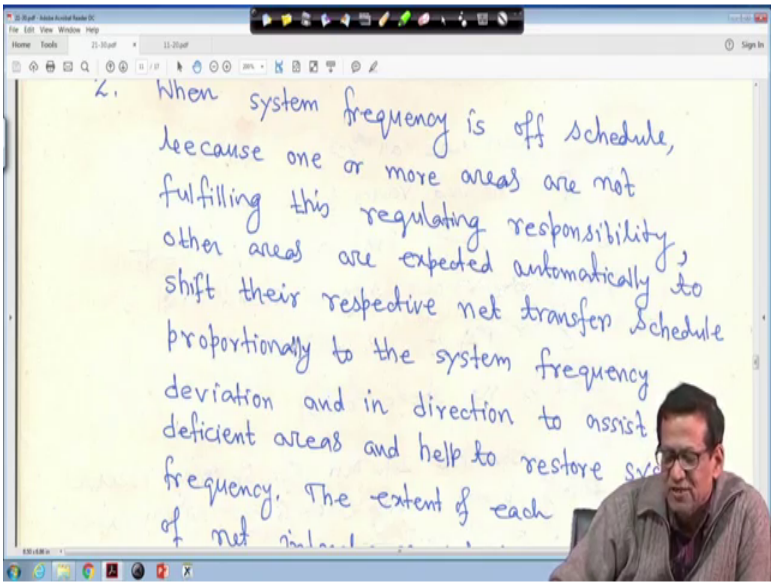

Now, second one is just when the system frequency is off schedule when it is not, because one or more areas are not fulfilling this regulating responsibility right. Other areas are expected automatically to shift their respective net transfer schedule proportionally to the system frequency deviation right and in direction to assist the deficient areas, and help to restore system frequency.

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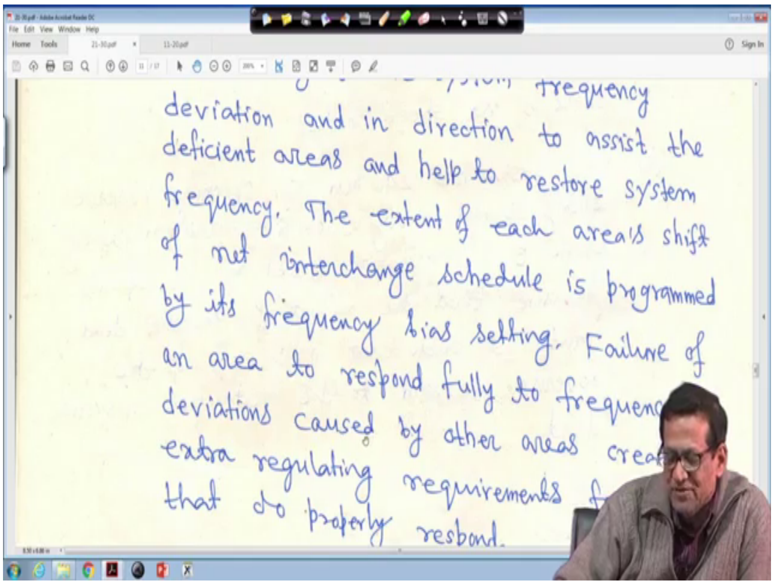

The extent of each areas shift of net interchange schedule is programmed by its frequency bias setting that will see later right. Failure of an area to respond fully to frequency deviation caused by other areas create extra regulating requirements for areas that do not properly respond.

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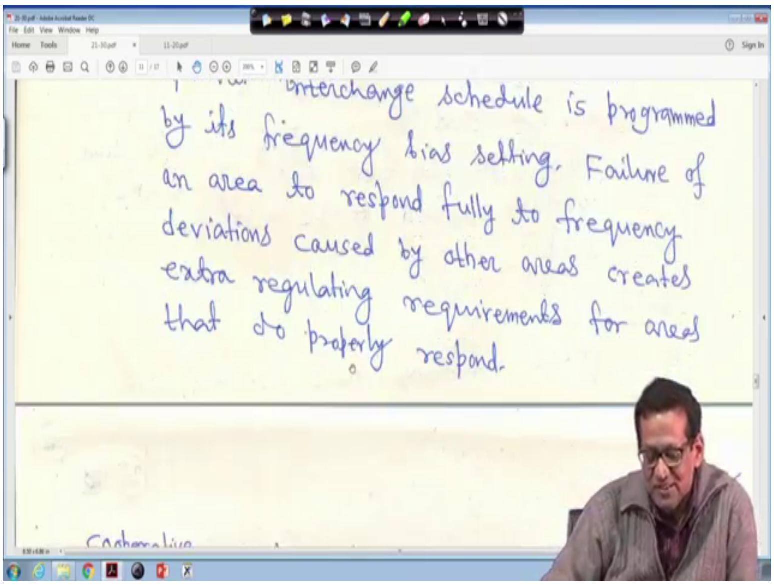

So, before going to actually deregulated system, all these things we have to study. Then we will find deregulated system, because simulation thing is not our purpose for this course, because we have to see from the point of view of the classroom exercise right.

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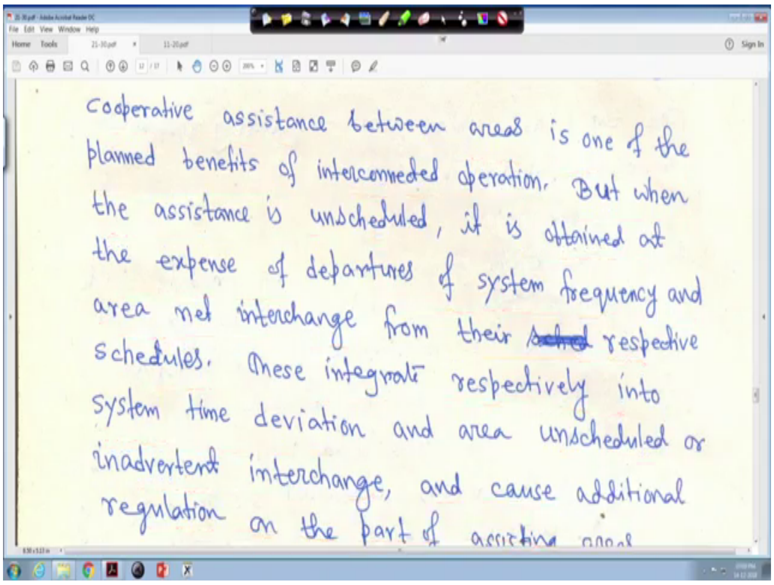

So, now if somebody ask you what is the advantage that is belong the your what to call interconnected operation, so this is that your maybe the answer. The cooperative assistance between areas is one of the planned benefits of interconnected operation right, but that means this is the thing the cooperative assistance between areas in one of the planned benefits of interconnected operation.

But, when you are the assistance is unscheduled, it is obtained at the expense of departure subsystem frequency, and area net interchange from their respective schedule right. Actually, these integrate respectively into system time deviation, this will is now study here right the time error, this will not study here.

And area unscheduled an inadvertent interchange that is your inadvertent interchange means; it is a energy right that will now study here thing the things will be much more you know that length of the lecture will increase right. So, will not do that right. And cause additional regulation on the part of your assisting areas right.

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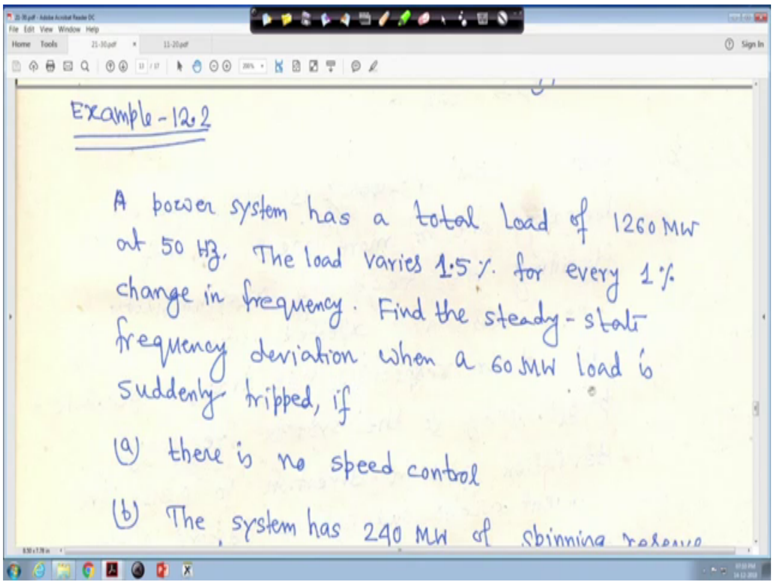

So, now with that that is the thing will come to that your area you are what to call to area, and other equations everything or derivation mathematical model, but before that we will see one or two to three, four examples right. So, first one is the second example-2, a power system has a total load of 1260 megawatt at 50 hertz. The load varies this we have seen also before that 1.5 percent for every 1 percent change in frequency we have seen that that how to find out that your R values.

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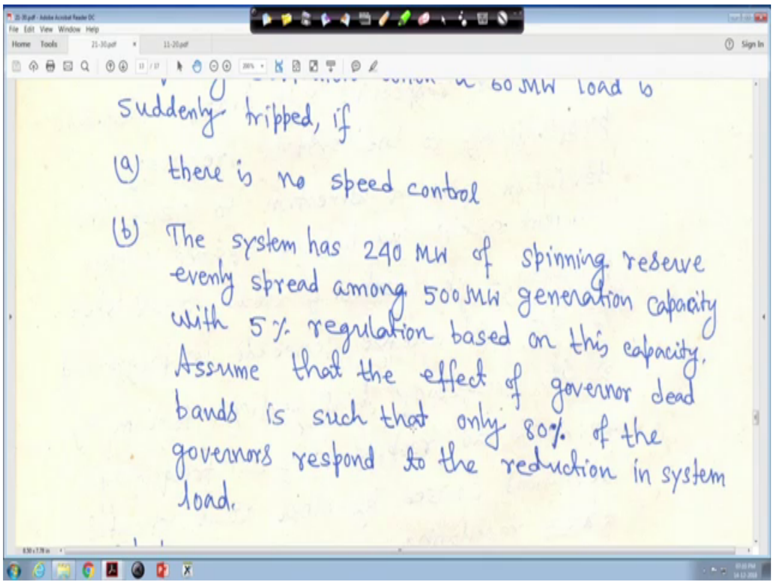

Find the steady-state frequency deviation when a 60 megawatt load is suddenly tipped right that means if there is no speed control that means, that speed control mechanism is not there. And b the system has 240 megawatt of spinning reserve right evenly spread among 500 megawatt generation capacity with 5 percent regulation based on this capacity right.

Assume that the effect of governor dead band is such that only 80 percent of the governor respond to the reduction in system load. Actually governor dead band will if time permits, I will tell you at the end if time permits that what is actually definition of every system, you can find dead band is there. So, definition of a dead band nothing will discuss here, but from the sake of this numerical will only study the study that one right.

So, so if time permits it actually dead band actually it makes continuous oscillation in the system frequency, and type our deviation right it is it sometimes it is called backlash. So, this can be studied every many mechanical system anything you will find that your dead band is there different type of dead bands are there right.

So, even in your cycle chain and this thing also you find the dead band is there for from here those things I should not explain that right. So, dead band will be your backlash will be there right. So, assume that the effect of governor dead band is such that only 80 percent of the governor responds to the reduction in system load. If time permits, half an hour I will explain governor dead band and mathematical formulation also, it will not take time if time permits right.

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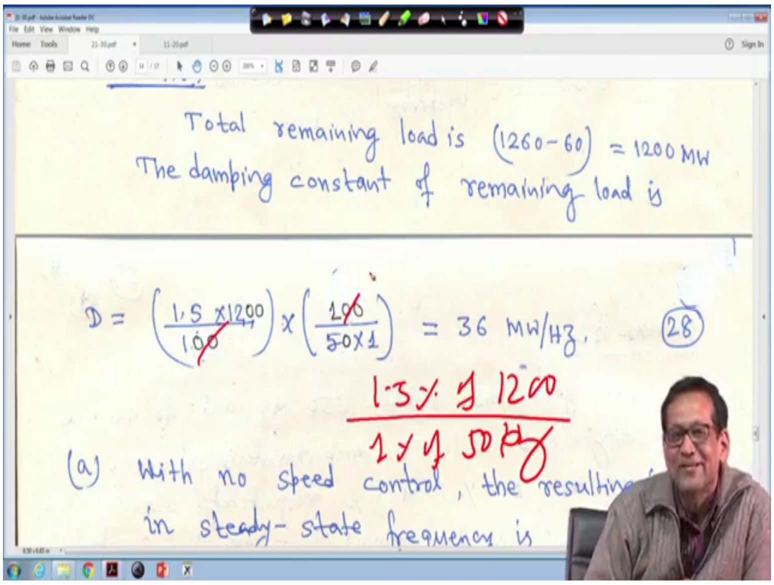

So, solution is total that is a it is given that that you are that when a 60 megawatt load is tripped that means, load actually is falling decrease that means, what in general the frequency will increase right. So, first thing is the total remaining load, now will be 1200 megawatt, because 60 megawatt load tripped right.

The damping constant of remaining load is it is given 1.5 percent of change of total load is equal to 1 percent change in frequency. So, I have just make a this one divided by this one that is why, it has actually if you write like this if you write like this also it is if I write like this that 1.5 percent of 1200 divided by that 1 percent of your 50 hertz right. So, this is 100 as taken like this right, so that so this is actually get it 36 megawatt per hertz right. So, so this is the value of the D.

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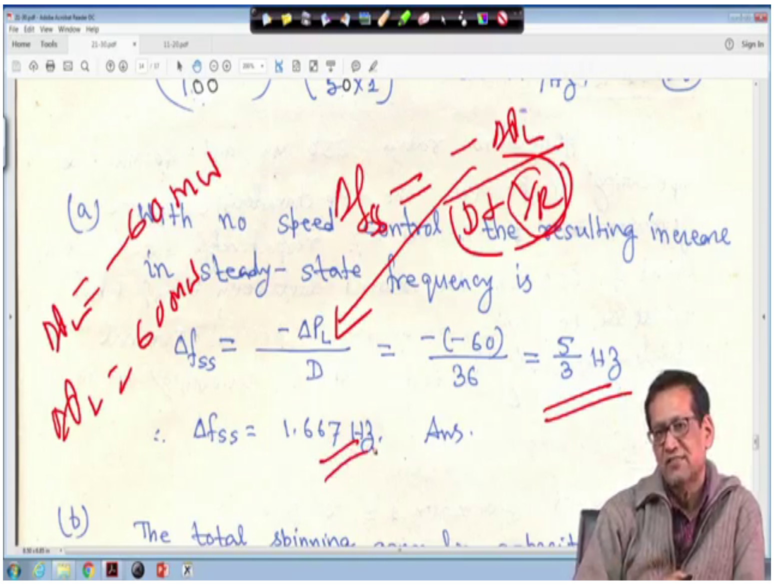

Now, part a given with no speed control resulting increase in steady state frequency is delta f ss minus delta P L upon D. Actually, we have seen the steady state value right delta f ss is equal to your minus delta P L divided by D plus 1 upon R right as no speed your what to call no speed governing system is there right, speed control nothing is there. So, this should not be there that is why, this equation only minus delta P L upon D right that means, and it is minus then load has tripped.

So, actually if convention is if load has increase, if delta P L suppose had it been load as they you are what to call decrease. So, you have to take minus 60 megawatt right. And if load has increased, then you will take delta P L is equal to 60 megawatt right. So, for increase of the load, you will take delta P L value positive, and for decrease is load you will take negative. So, it is minus of minus your 60, so that is actually 5 by 3 that is 1.677 hertz, so simple thing.

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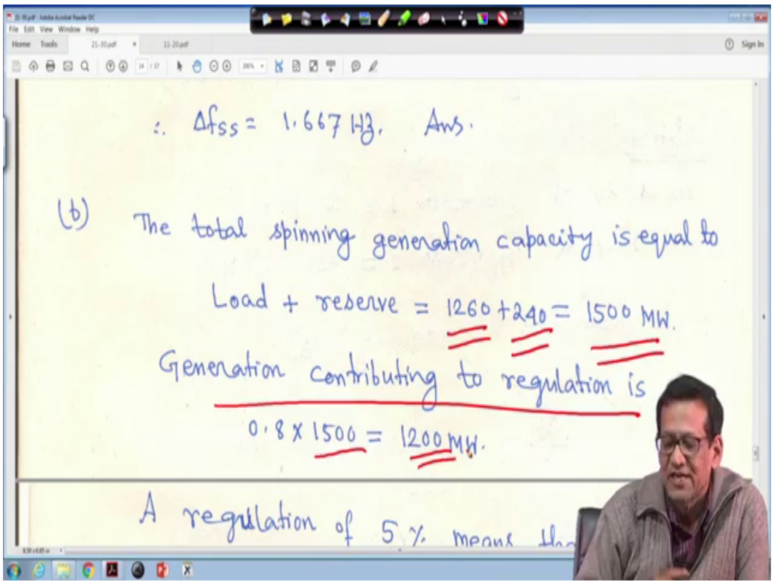

Now, now the total spinning generation capacity is equal to load plus reserve right. So, this is actually load 1260 was there, and spinning generation capacity is that is a spinning reserve that means, total is 1500 megawatt right. Therefore, generation contributing to regulation is it is 80 percent of that right so, 0.8 into 1500; so basically it is 1200 megawatt right.

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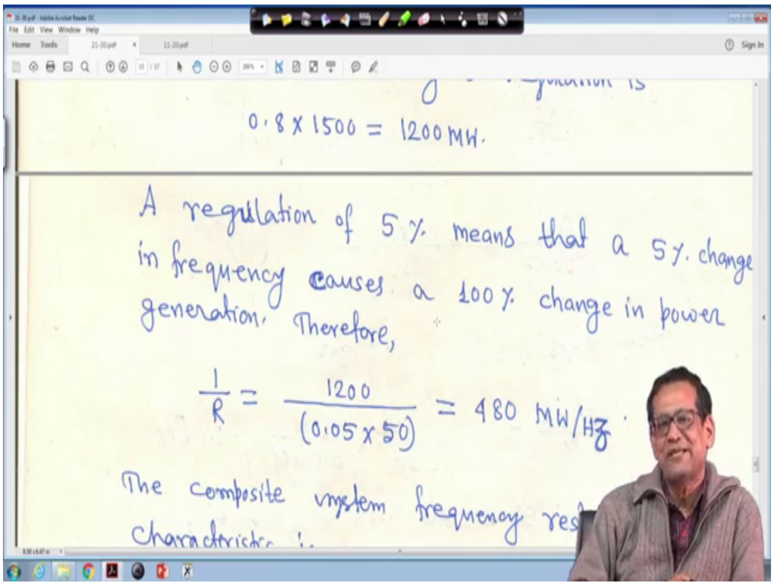

So, a regulation of 5 percent means that a 5 percent change in frequency causes 100 percent change in power generation right. Therefore, we can find out R, so 1 upon R I have written. So, it is 1200 divided by 5 percent change in frequency. So, it is megawatt and 5 percent change in frequency that 5 percent change in frequency causes 100 percent change in generation. So, total was 1200 right. So, 100 percent means 1200, so that is why you have written 1200 right. And 5 percent change in frequency right, so that is your 1200 by 0.05 into 50 you have it is a 50 hertz system. So, it will be for 480 megawatt per hertz right, so that is your 1 upon R.

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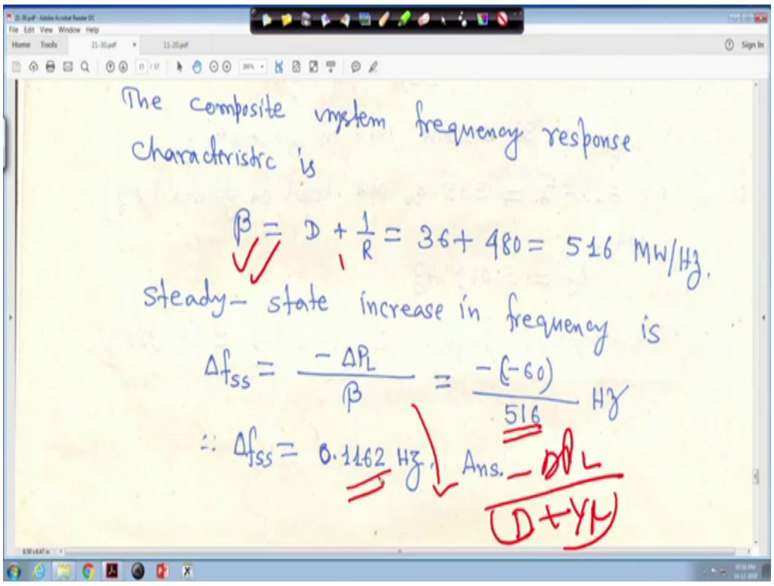

Therefore, the composites frequency response is sometimes with [de/defined] defined that is beta, we call it is frequency response characteristic or sometime right. So, beta is equal to D plus 1 upon R, so D we have already got your what you call 36, and this 1 upon R is 480 right. So, total is 516 megawatt per hertz right.

Therefore, the steady state frequency is so load is decreased right. So, basically it is your b delta f ss minus delta P L upon beta, beta basically it is your this term is actually minus delta P L divided by D plus 1 upon R that is our beta that is our beta right. So, it is load has tripped, so it is minus of minus 60, so 60 upon 516 hertz, so 0.1162 hertz. So, this is the, your answer right.

So, problem is very simple and your this is so far whatever you have studied, then isolated system and your little bit on degree of stability also I told, it can be applicable to any other control system also right. But, it is a video course, so all these things cannot be put it to be here right, I have to think from the point of view classroom exercise.

Thank you very much. We will be back again.