Power System Dynamics, Control and Monitoring
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Lecture – 35
Automatic generation control conventional scenario (Contd.)

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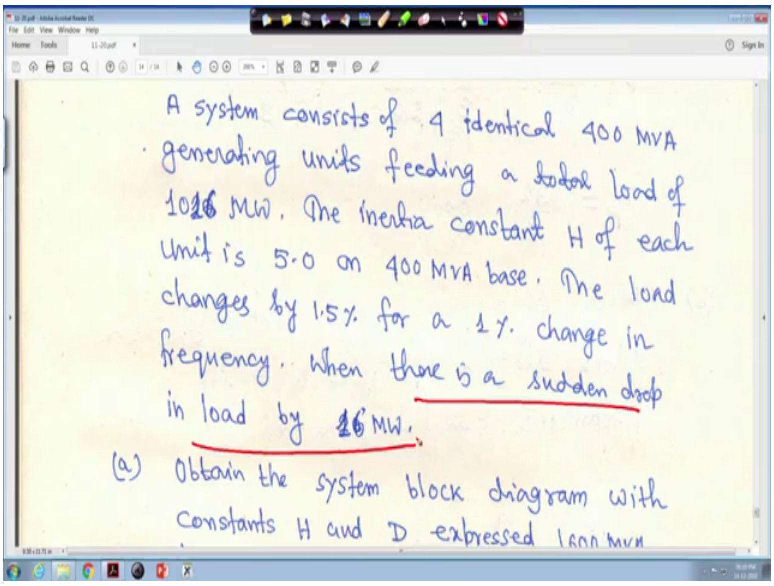

Ok. So, this problem we have seen in the, you know previous lecture that there is a sudden drop in load by 16 megawatt. So, already we have solved this problem. But, load drop means that you are what you happen the speed will increase that is frequency will increase right. So, I will go to the your what you call that next page. So, this already we have solved.

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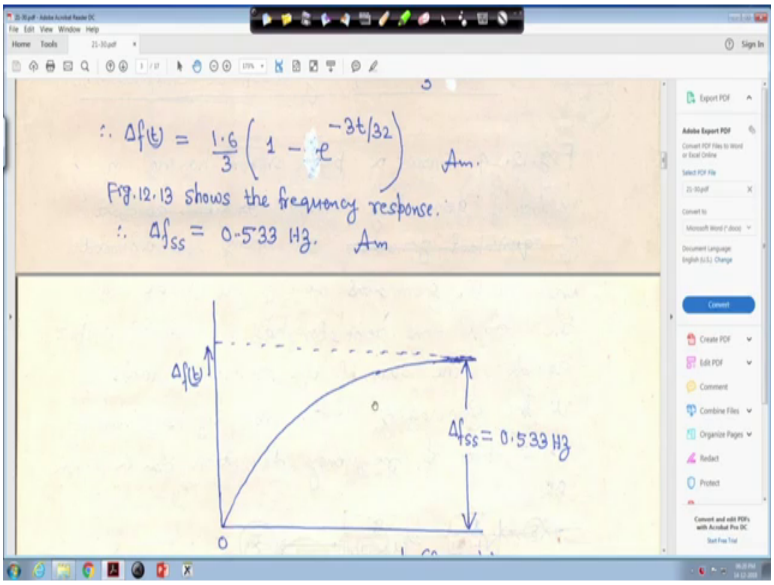

So, this from this you have seen that your what you call that steady state I mean its plot after solving this, when you have plotted for delta f t that is steady state error that is the frequency deviation that is showing steady state error is positive, because load has your what to call decreased. If load increase, then the delta f ss will become negative right.

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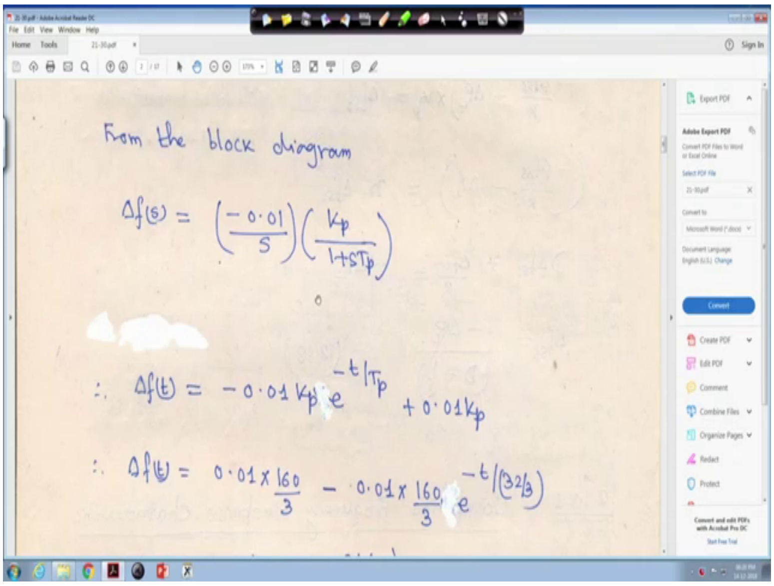

And this is your this is your dynamic response. And another thing is from this from here also directly, we will get the your what you call the steady state values from this way you are what you call this from this equation delta f s is equal to this much right.

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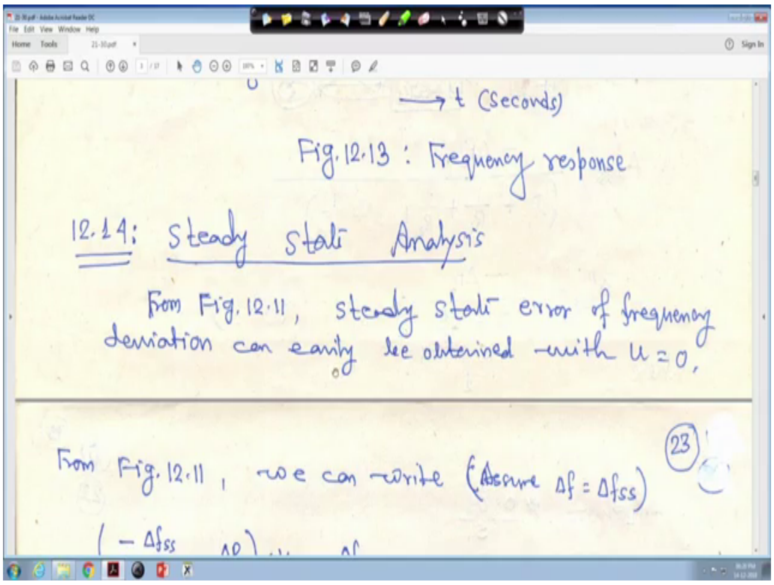

So, next one next is your steady state analysis. So, from to your figure-11, steady state error of frequency deviation can easily be obtained with u is equal to 0 right.

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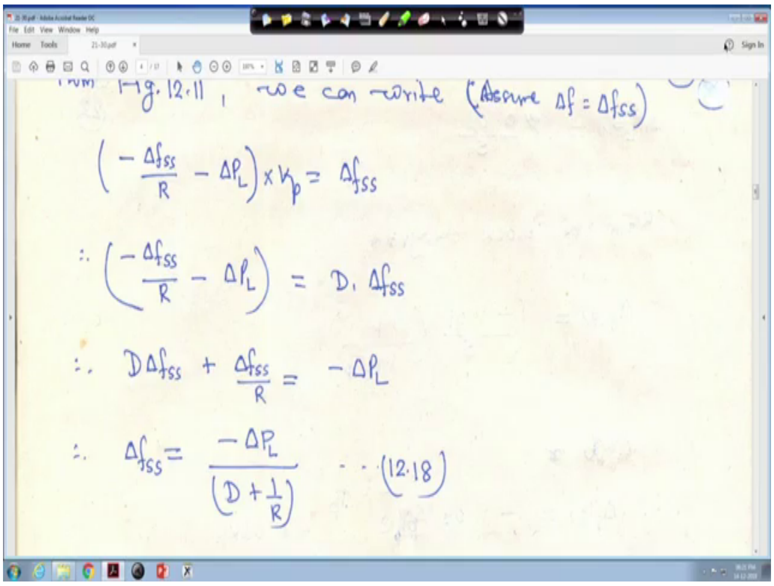

So, this is done here, but I will go back to this figure-11 right.

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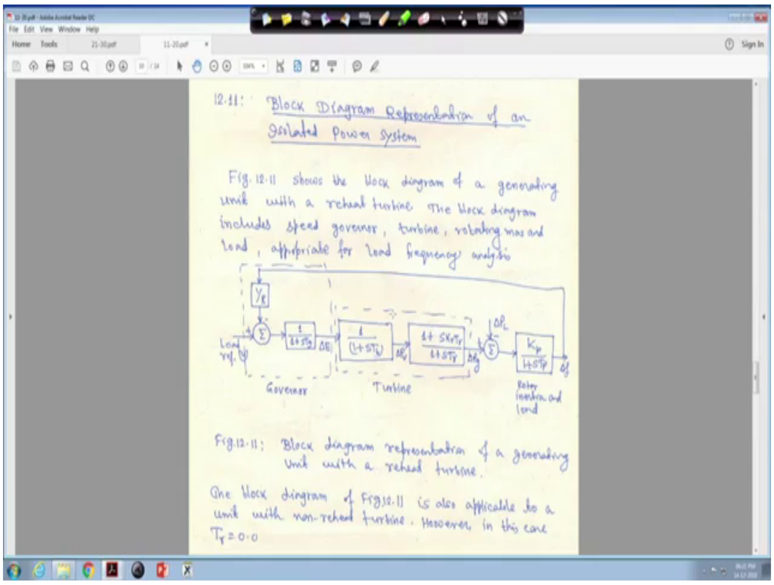

So, just hold on, I will go back to figure-11, this figure so this is our figure-11.

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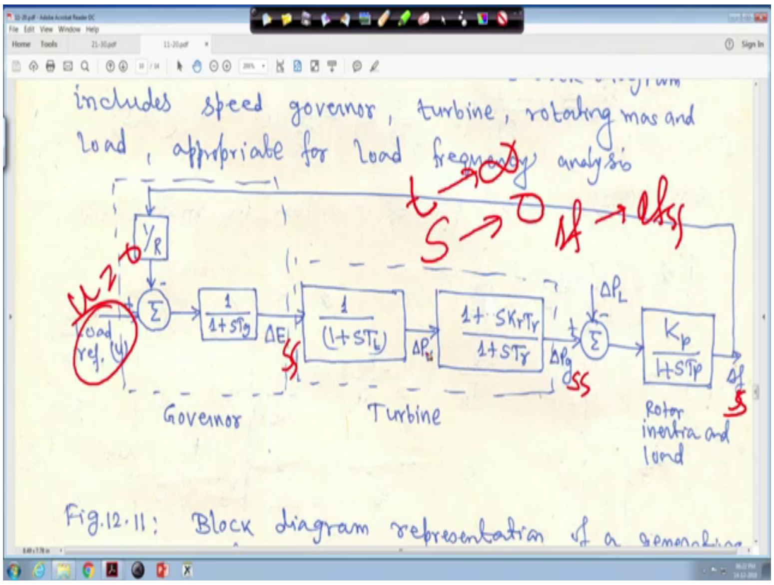

So, from this block diagram that I will go back to that you are from this block diagram, we will go for you are what to call the steady state error. Now, say that u is equal to 0 that is your it is u is equal to 0 means that is your uncontrol mode right u is equal to 0.

Now, we will try to find something like your steady state block diagram, when it is of course if that integrator term is associated with there like K like K upon S, then forever this technically not possible, but in this case it is possible. So, and you know that t tends to infinity right that means, S tends to 0 right.

So, in this block diagram you put S is equal to 0, and for this case your delta f will be your delta f steady state. Similarly, for other values this is delta P g ss as this is delta E ss, and this is your delta f ss steady state values right. So, if we draw the steady state block diagram right, so how it will look like that means, every block put S is equal to 0.

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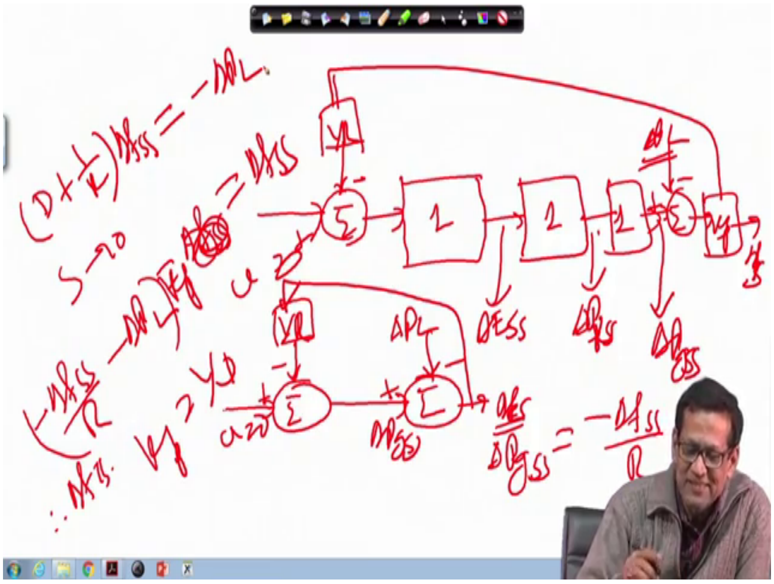

So, in that case what we will do right I am redrawing for you. Suppose, suppose this is your this is your 1 upon R right, and this then 1 upon 1 plus ST g is there. So, in that block you put 1, because S tends to 0 you put S is equal to 0 right. Then you are what you call next one is your 1 upon 1 plus ST t. So, there also you put S is equal to 0, it will be 1.

Next u 1 plus S K T r upon 1 plus S T r, put S is equal to 0. So, this also will become 1. Then this one your plus this is your minus this is delta P L right. And here you K p upon 1 plus S T p put S is equal to 0 from that figure-11, then it will be simply K p and output is delta f steady state, and it will be coming here.

And this is your u is equal to 0. And this is actually delta E ss. This is this is your whatever the block has been splitted, so delta P b ss. And this part is delta P g s s. And this is delta P L the load right, so that means in that block you put S is equal to 0.

So, this will be something like a steady state block diagram that means, feedback here is if you this all are 1 1 1 that means, equivalent I mean if I make it like this, so this is my plus this is u is equal to 0 right. And this is my minus and 1 upon R right. And all 1 1 1, so basically this is your delta P g ss, intermediate things we are not considering all 1 1 1.

And this is plus, this is minus, then delta P L, and this is delta f ss, and this feedback is there right that means, if you your delta P g ss steady state, actually it is equal to minus delta f ss upon r, because this delta f ss feedback is here is feedback is here right that means, that means this from here you can write.

So, delta P g ss means minus delta f ss upon R. So, we can write minus delta f ss upon r minus delta P L is equal to your delta f ss is equal to delta f ss right that means your delta f ss right and K p was there sorry well here K p was there.

So, it is actually your into k p into k p is equal to your delta f ss right. But, k p is equal to 1 upon D right K p is equal to your K p is equal to 1 upon D. So, substitute here k p is equal to 1 upon D and cross multiply, then it will become D plus 1 upon R, then delta f ss is equal to minus delta P L right. So, I am so this thing is clear. So, I am clearing this and writing the final expression of delta f ss.

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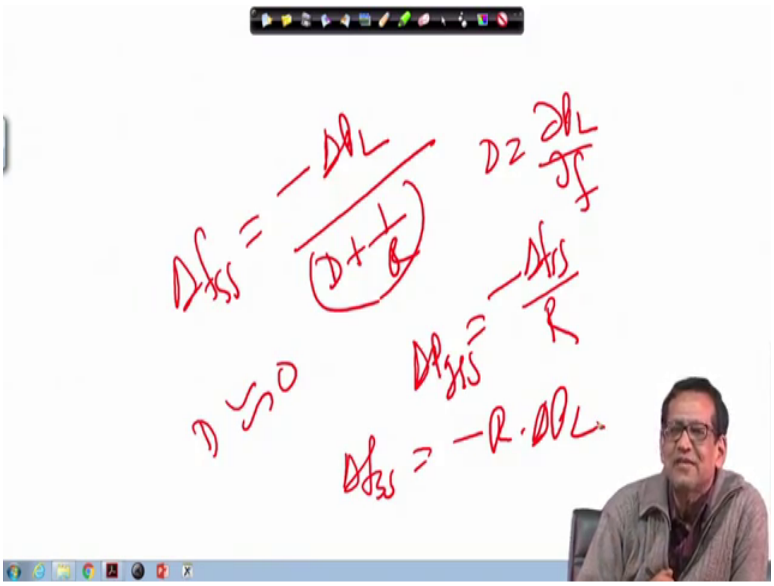

So, delta f ss, then is equal to minus delta P L divided by D plus 1 upon R, this is the steady state expression. I mean from the block diagram if 1 upon S is not there anywhere, because you cannot put S is equal to 0 there. You just put S is equal to 0, and it will be a steady state block diagram. And you take any other problem also; it will give you the result steady state values of all these things.

And delta P g ss also we have seen it is minus delta f ss upon R right. Therefore, if you look into this one, suppose they actually for realistic system that D actually we have seen that is delta P L upon delta f right.

Now, if D is neglected suppose D is actually very small compared to your 1 upon R right that means, your if D is neglected suppose D is approximately 0, then delta f the steady state value will be minus R into delta P L, this is the steady state error of the your what you call that the frequency deviation right. So, this is your what you call that is simply in one way to find out your steady state you are what to call steady state error by simply putting that another is that final value theorem right.

So, this is in so therefore in this diagram, we put simply S is equal to 0 right, and from that we got the your what to call it we got the steady state error. So, we will go back to this you know that that steady state that there next page right.

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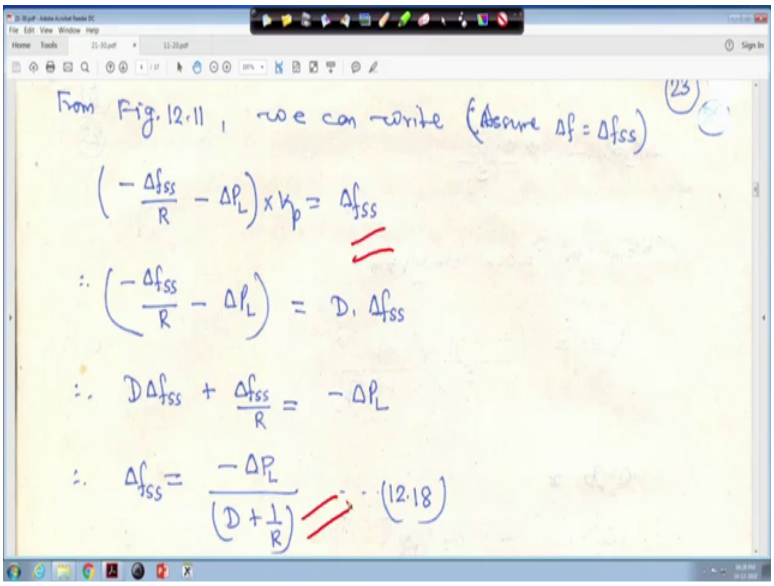

So, this is what I showed there that delta minus delta f ss R minus delta P L into K p is equal to this one. So, this is actually delta f steady state is equal to minus your delta P L upon D plus 1 upon R right. So, this is equation-18. So, this is the steady state error of the frequency.

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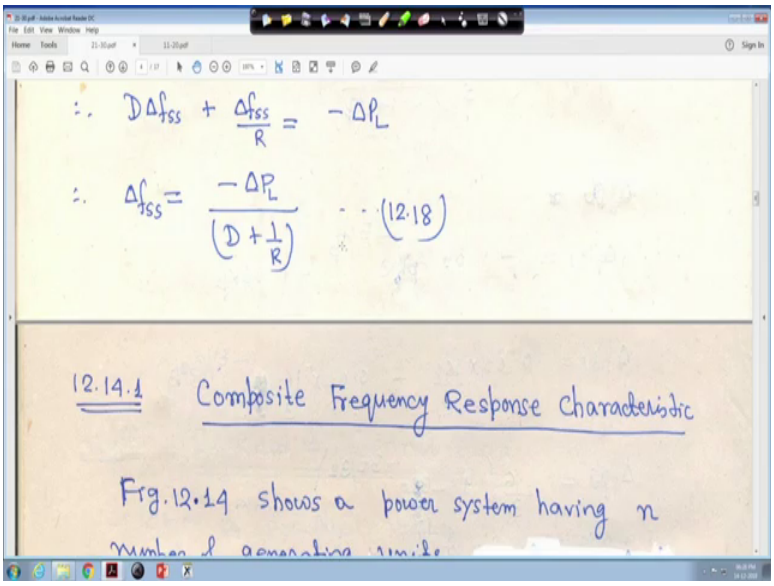

Next is that composite frequency response characteristic. So, now one thing one thing, we I would like to tell that when we write down the equation that delta P g minus delta P L is equal to 2 H upon your f 0 into d d t of delta f plus D p D u right. So, when you if you look into that equation, I will go back to that before moving to that right so just hold on I will go back to that right just hold on.

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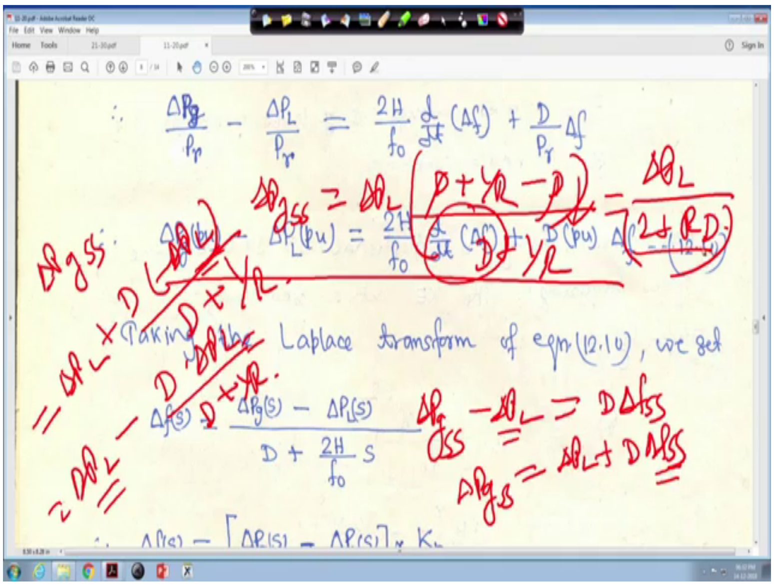

So, when we are going for your power balance equation this equation that this equation when you go right, this power balance equation when you go this one I mean simply if you go to this, then another point is that we assume that load is your what to call its a sensitive to that changes in frequency.

Now, at steady state this term will be this d 0 d d t upon delta P g will be 0 right and this is my delta P g u p per unit p u. So, understandable that it is per unit. So, I will write delta P g minus delta P L also per unit is equal to our steady state. So, I can write this steady state. And this is load delta P L right. And steady state this term is 0 mean this is 0 is equal to D into delta f ss right.

So, so this is your what you call delta P g ss my minus delta P L that means, my delta P g ss is equal to delta P L plus D into delta f ss right, this we know. They are there for two versions two versions are there one is delta f your what to call delta P g ss we know that delta P g ss is equal to minus delta f ss upon R right.

But, this delta f ss we know that here I am writing for you that delta p g ss steady state value is equal to delta P L is their and D plus D into delta f ss is equal to you have seen my now we are writing it divided by D plus your 1 upon R right this is your that means, that delta P L will be there minus your what to call D into delta P L divided by D plus 1 upon R.

So, in that case what is happening that if you if you look into this term, if you take your what you call delta P L and delta P L common, then here I am writing delta P g ss I am making it on it, but you do it on that notebook right. Delta P g ss will be is equal to take delta P L common, then it will be D plus 1 upon R this side minus D right divided by D plus 1 upon R, so D D will be canceled.

And finally, this one can be your what to call written as delta P L right your divided by your into your D your here it is 1 upon R. So, basically it can be written as 1 plus your what you call R D right, because it is 1 upon R multiplied, so it will be R D plus 1. So, delta P g ss will be delta P L upon 1 plus R D that means, this R D is greater than 0 that means, 1 plus R d is greater than 1, then in a steady state although generation should change the load.

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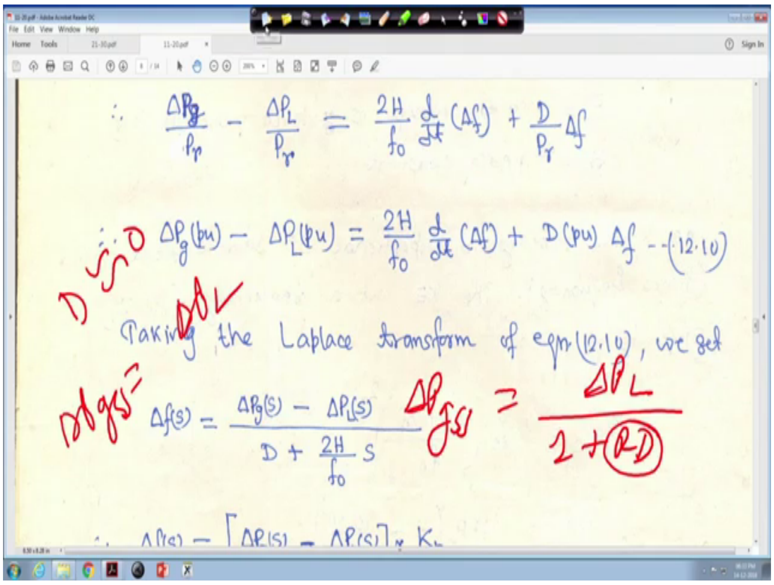

So, at steady state I am just I am just rewriting this, first let me clear it I am just rewriting that expression, so delta P g ss is equal to delta P L divided by 1 plus R D right. Although R D R into D actually for realistic parameter is quite small compared to one, but anyway it is greater than one that means, delta P g ss. If D if D is approximately 0, then at steady state delta P g ss will be is equal to delta P L right.

But, in this case it will be less than delta P L, because it is greater than one. So, it will be less than actually for uncontrolled mode, so general there you are what to call generation, you will never match exactly to delta P L, it will be very less maybe 1 percent, 2 percent not more than (Refer Time: 14:04), because the load is sensitive to the frequency deviation that is why this term has come right. If you simulate it, you can easily verify this right. So, we will go back to your, what you call that to that is composite characteristic right. So, just hold on, so that means your, this is this I explained. So, also delta P g ss is explained.

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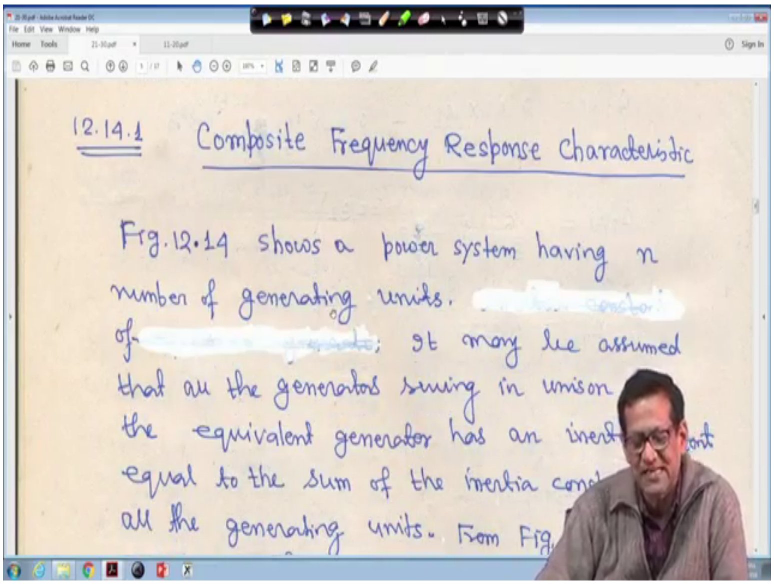

Now, composite frequency response characteristic for to figure.

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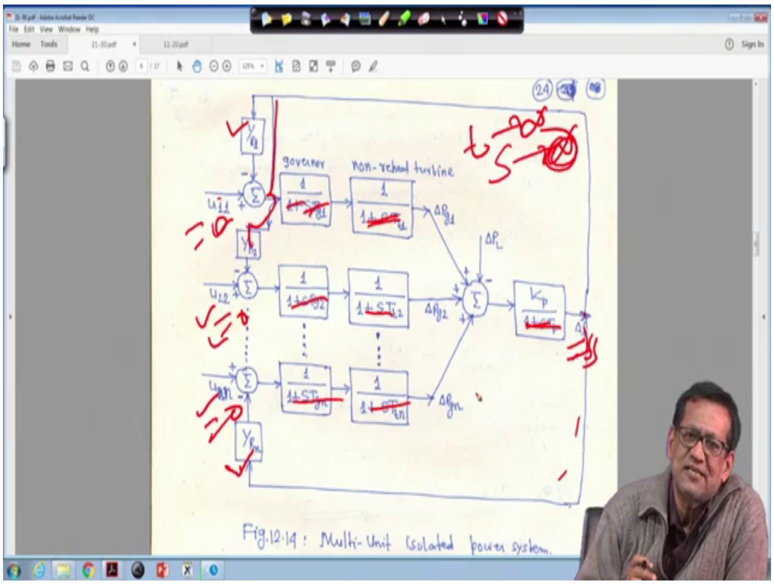

First let me go to the figure, then the composite frequency just hold on let me reduce this thing such that whole thing will come together, so just hold on. So, this figure that is suppose you have it is isolated system only; it is isolated system earlier suppose you have n number of generating units. And they are all I mean and all non-reheat turbine I have considered here you can consider it also no problem, but all are non-reheat type. So, and you have n number of units.

So, in that case what will happen that this is governor for unit 1 this is your governor for unit 1, a governor for unit 2, and this is say in general that n-th governor. This is the tie your what you call this is and this is the your turbine transfer function, because it is non-reheat types only one block 1 upon 1 plus S T that we have seen in the previous classes.

So, now for each generating unit generating power delta P g 1, delta P g 2 up to delta P g n right. And all these things can be represented by a single your power system your time k or a block diagram that is K p upon 1 plus S T p, because all these generating units they operate in parallel. Therefore, you can find out their equivalent inertia H, and from that you can represent is by a single block diagram.

So, no need to consider that separate block diagram for your separate unit, because we will assume all the units right they are in (Refer Time: 16:20) they swing in addition that means, their unit that their increase or decrease speed will remain same, so that is this part you can represented by a single transfer function right.

And if you look into that feedback that your feedback, then this is your delta f. So, it has gone to for unit-1 1 upon R 1 for n, it has come 1 upon R 2. Similarly, for n-th unit it is 1 upon R m right. And this side supplementary or your integral controller is there that we will see later if that is u 1 1 for unit-1, u 2 2 and u n n right.

So, in this case also if you want to find out the steady state values, then at steady state I told you when S tends to a sorry when t tends to infinity, S tends to 0. So, in this block you can put all S is equal to 0 that means, this term should not be there, it will be 1, it will be 1, it is 1, 1, 1, 1 and this will be only K p right.

So, after that it will be a simple steady state block diagram. Of course, u 1 is equal to u 1 1 0, u 2 2 0, and u n n 0 right. So, from that you can find out and this is delta f ss. Easily you can find out the steady state values. So, this is this is you are what you call in that composite your multi-unit isolated power system. So, so many units are there and this is isolated that means, not interconnected with any other your power system right. Now, we will go to your now we will go to your that that your derivation right.

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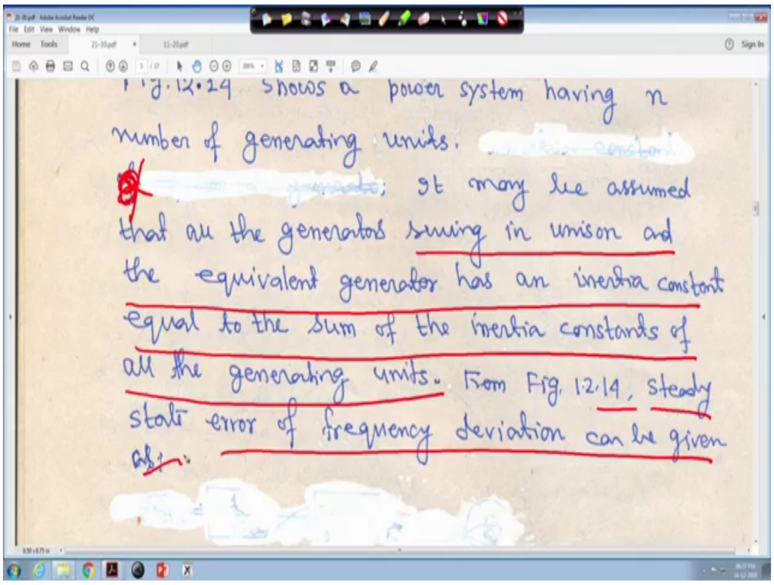

So, now if you go back to this, so I explained everything, it maybe one thing is there that your, what you call this is nothing this is nothing right. So, it may be assumed that all the generators that I told you swing in unison, and the equivalent generator has an inertia constant equal to the sum of the inertia constant of all the generating units I told you. So, from figure-14 that is the figure-14, I so explain steady state error of frequency deviation can be given as right. So, same way you can find it out.

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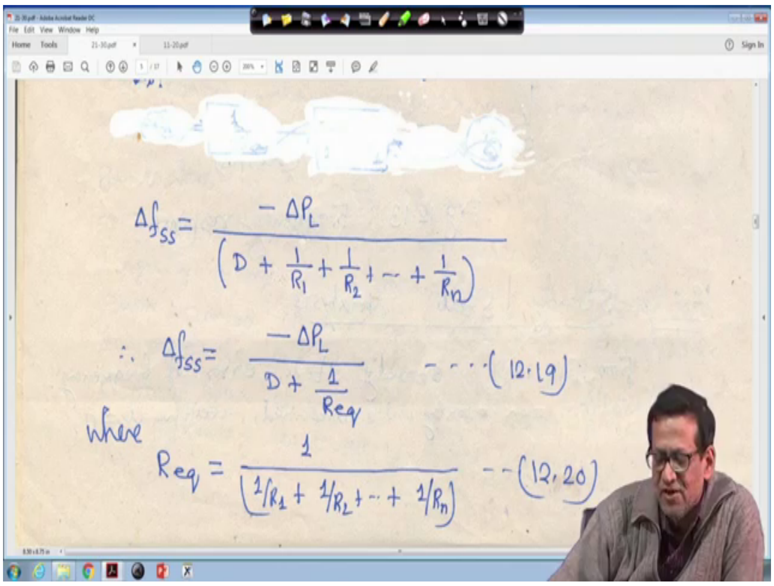

So, you can write delta f ss is equal to minus delta P L upon D plus 1 upon R 1 plus 1 upon R 2 up to 1 upon R n summation right or we can write delta f steady state is equal to minus delta P L divided by D plus 1 upon Req. Req is equal to 1 upon 1 upon R 1, plus 1 upon R 2 plus 1 upon R n.

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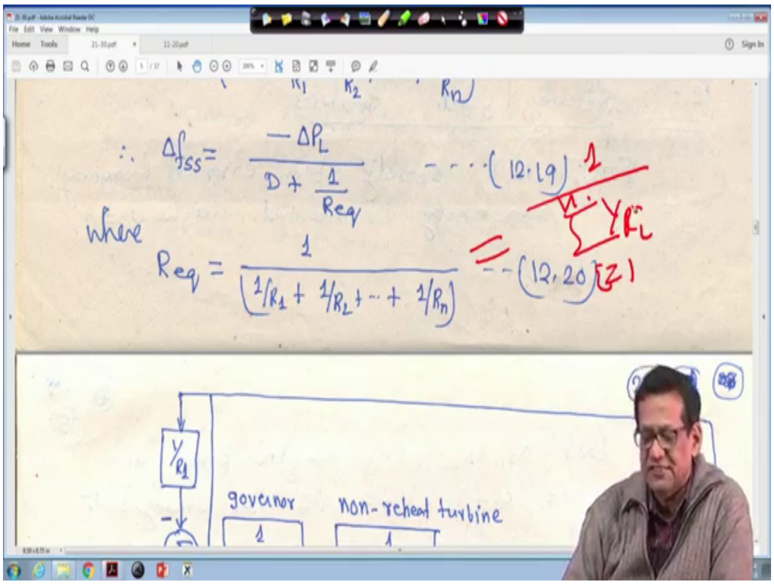

In general in general sometimes we write sometimes we write 1 upon write sigma I is equal to 1 to n 1 upon R i right sometimes we write this way. So, this is your what you call this is your that you are equivalent this thing, and this diagram already explained right.

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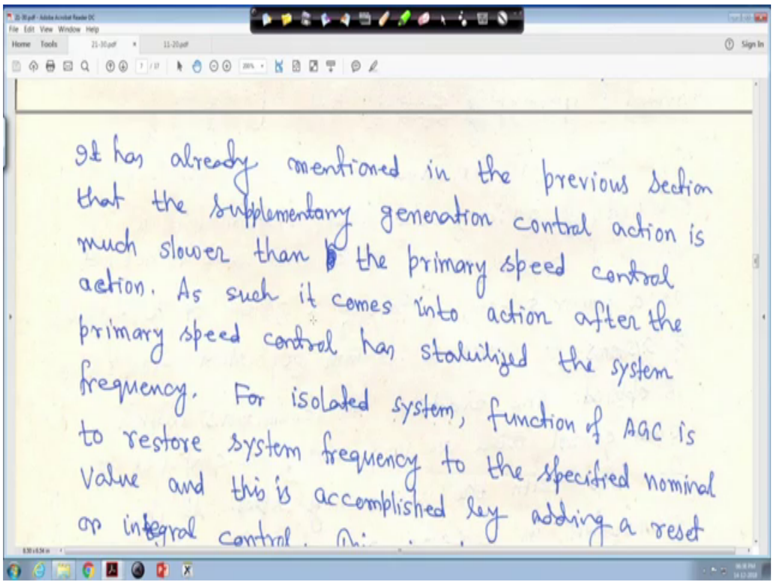

Now, I already we have discussed in the previous section that the supplementary generation control action right is much slower than the primary speed control action that we have discussed. As such it comes into action after the primary speed control has stabilized the system frequency right. When actually primary your control is quite fast acting right compared to that your slower supplementary control action right.

So, primary speed control has stabilized the system frequency, then supplementary control comes into action. For isolated system, the function of AGC only to restore the system frequency, because it is not interconnected with any power system, so that power flowing through that you are collected a collector line that is we call tie-line is not considering is not coming in this picture right, it is only isolated system to the specified nominal value. And this is accomplished by adding a reset or integral control, so this is actually integral control.

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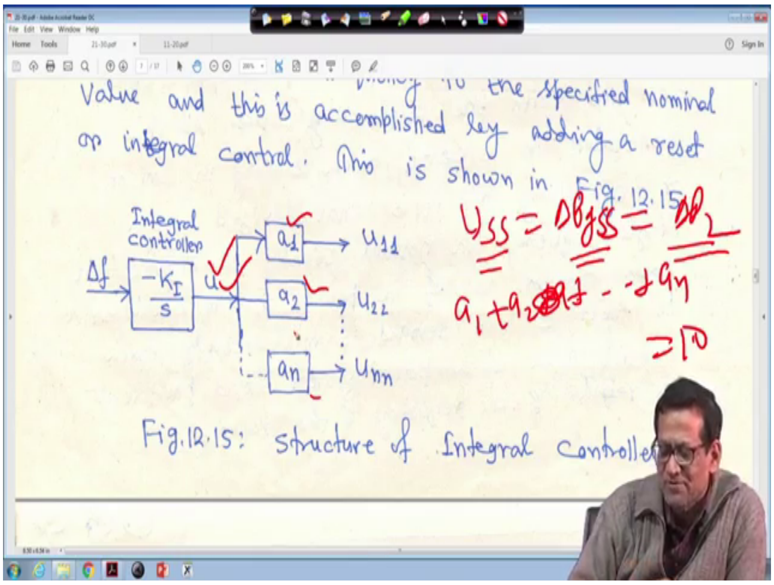

So, what happens this is a composite system delta f that is the integral controller minus K I upon S, then output is u this output is u right, and then this fraction of that one a 1, a 2, a n it had gone to this right. So, a 1 plus a 2 plus a 3 sorry plus up to a n, this is equal to 1.0 right.

Now, actually in steady state, this is delta f input is given to the controller, but at steady state you will see that u steady state actually is equal to delta P g steady state right. I mean it is something power increase your what you call power increase upon load demand has increased, so u as steady state and that is actually is equal to delta P L the total load right.

Because, when you consider steam hydro turbine or your steam turbine thermal power plant or hydro power plant for if load demand increases say, then you have to give more input to that you are what to call this your to the steam turbine right.

And for in the case of hydro turbine that hydro power plant that where you have to open the water gate right, so that equivalent whatever is come for steam or water that is nothing but equivalent to that I mean considering lossless that power generated. So, actually at steady state you will find U ss is equal to delta P g ss is equal to delta P L right. So that means you suppose you have n number of units, and you have to give this fraction that which generator will generate how much.

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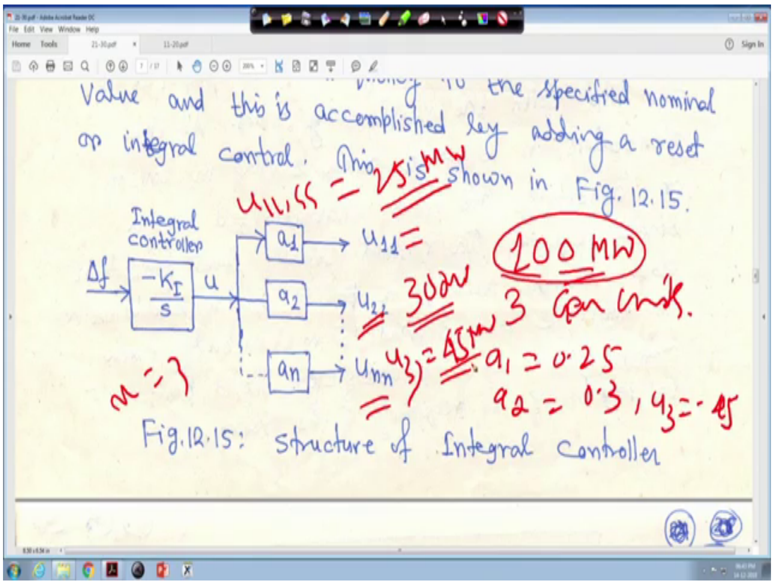

For example, suppose my load demand has increased to 100 megawatt right. Suppose, I have 3 generating units right I have 3 generating units. Now, that this will not consider in this course right, but here that economic load dispatch comes, because suppose this 100 megawatt you that you will you are what to call you distribute among these three generator such that your fuel cost will be minimum right.

For example, suppose if for this case if a 1 comes 0.25, say a 2 comes 0.3, then a 3 will be 0.45 right that means, you are what you call that that means at steady state that u 11 I mean that steady state all u 11 I can I can put it like this u 1 1 that steady state will be your a 1 into u right. And that is my hundred that I told you that u steady state will be delta P g ss will be is equal to P L is equal delta P L is equal to say 100 mega load.

Suppose I am considering, so small thing suppose I consider that 100 megawatt for your understanding. Then this u ss will be actually 25 megawatt right. Similarly, this steady state value of u 2 2 will be also will be 30 megawatt right. And this u 3 3 right u 3 3, because you have taken 3 units suppose n is equal to n is equal to 3, it will be your 45 megawatt right, so that means this at steady state that generating unit 1 will generate 25 megawatt.

The two will generate 30 megawatt, and the unit-3 will generate 40 megawatt, but that will not consider here right, so that means that a 1 plus a 2 up to summation of all a, this is called actually that participation factor right. So, so a 1 plus a 2 that is there is the meaning that is the meaning for this one right.

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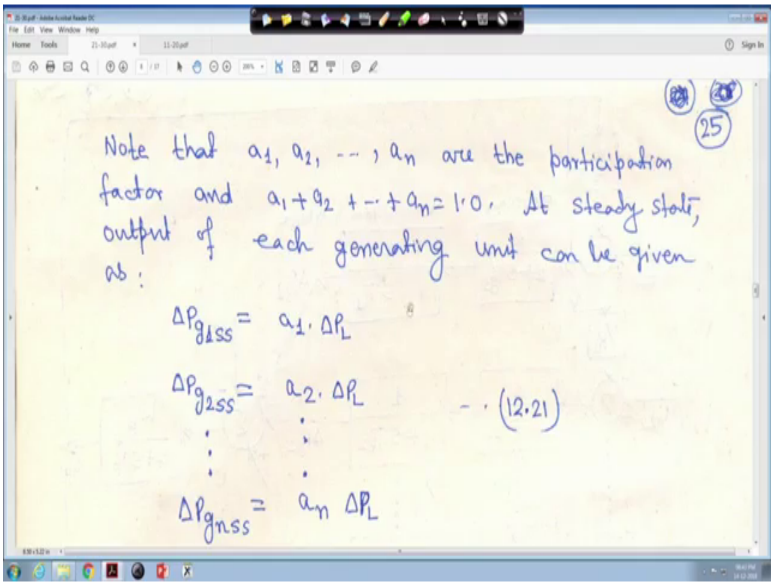

Now, another thing is so this is already given.

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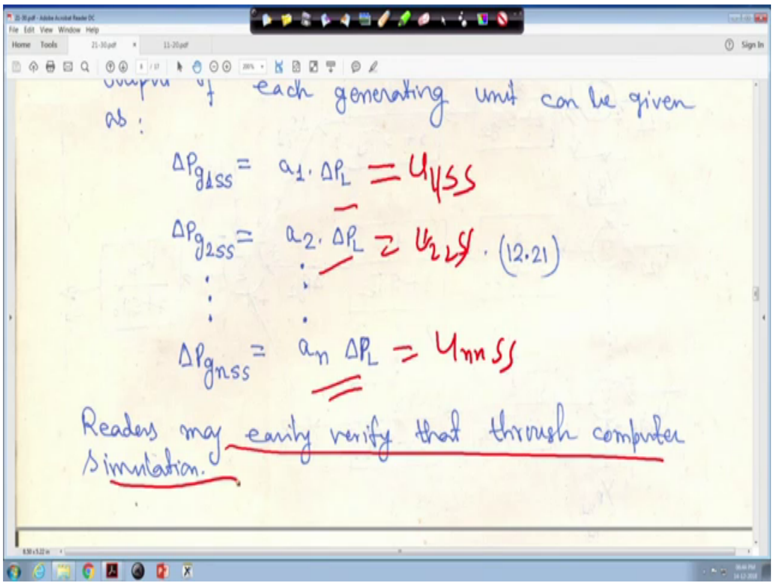

So, that is why delta P g whatever I said, because here delta P g 1 ss, actually it is nothing but u 1 ss same thing you will get. This will be also u 1 1 rather u 2 2 ss. And this will be actually u n n s s all steady state values, so that is why delta P g 1 steady state will be a 1 into delta P L, a 2 into delta P L for delta P g 2 s s. And similarly, for delta P g n s s, it will delta p g n s s, it will be a n into delta P g l right.

Actually, something is written the readers may easily verify to the computer simulation, you can check it in mat lab you can easily check it right. Data another thing I did not mention yet later, I will tell you right.

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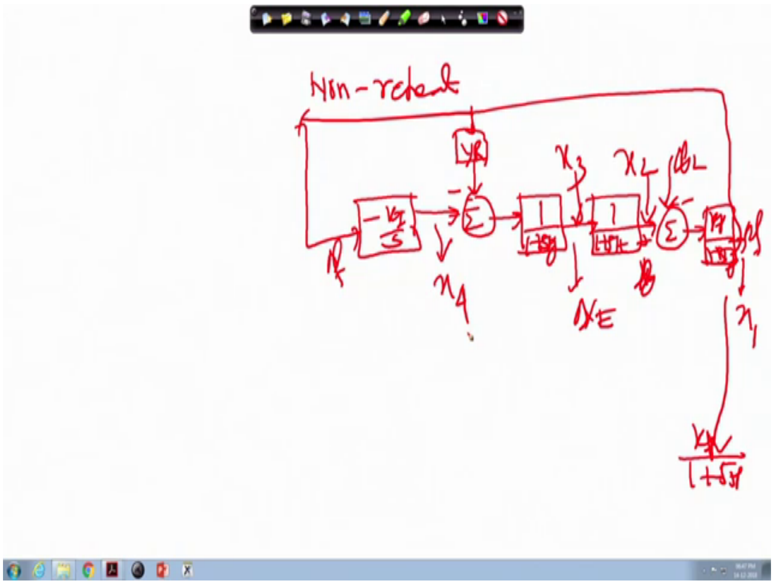

So, another point is that just hold on another point is that you are regarding that integral control action. First we will see isolated area, because in this note it is not there. So, I will write first I do, I will draw it here right. The block diagram only for non-reheat type non-reheat type turbine such that our analysis will be easier non-reheat type turbine. And this if you understand this, it can be it can be applicable to other system also.

So, if we draw the block diagram, I am making it somewhere here. If you draw the block diagram, this is minus 1 upon R right. And this is 1 upon 1 plus S T g, this is 1 upon 1 plus S T t, and this is your delta P g this part, this is minus delta P L.

And this is K p by 1 plus S T p just add, I hope it is understandable. It is 1 plus S T p numerator denominator, and numerator is K p. And this part is delta f right. And this block is completed right. So, and this is actually you have an integral controller that is your minus K I by S, and is feedback is that is your frequency, this is frequency so in input is the frequency right.

So, in this case what we have to do is that regarding optimization, we have not talked about. So, for isolated system, we will talked about something on optimization right. So, this is my delta P g, and this is your delta P b right, delta X E, this variable is actually delta X E, the non-reheat turbine. And this is output u right, but output you will consider now as a state variable, because our objective is to find out the optimal value of K I right, how will do it. There are many ways.

So, this [vari/variable] this state variable this one is x 1, this one is x 2 right, this one is x 3. And instead of u, because output of integral controller u, but we will treat this one as your x 4. So, four state variables are there right so four state variables are there. So, from that we will find out x 1 dot, x 3 dot, x 4 dot, x 3 dot and x 4 dot right, and how to optimize K I using that concept of degree of stability.

Thank you very much, we will be back again.