Power System Dynamics Control And Monitoring
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Lecture – 20
Power System stability (Contd.)

We are back again from the same page right. So now next, we will discuss that you are what you call that damping one right.

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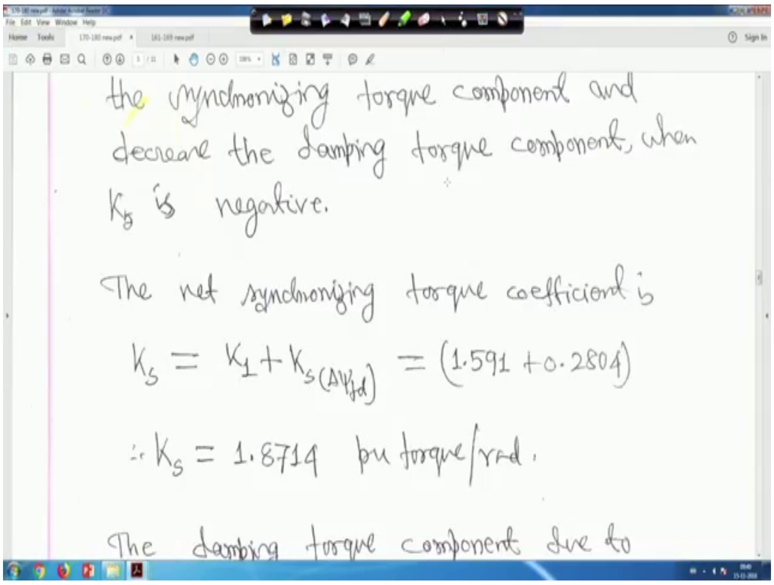

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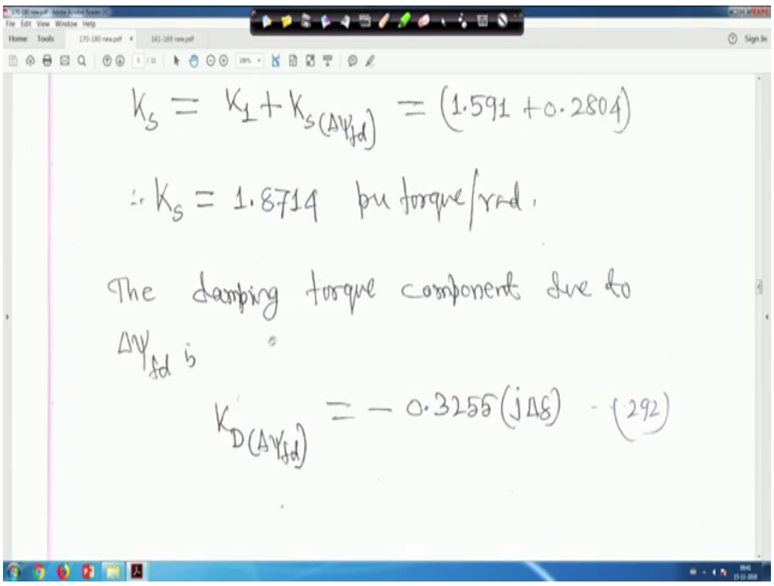

So now, damping torque component due to delta psi fd we call KD delta psi fd is minus 0.3255 j delta delta; that means this term, the second term it is j delta delta, look here only understanding is required nothing else only.

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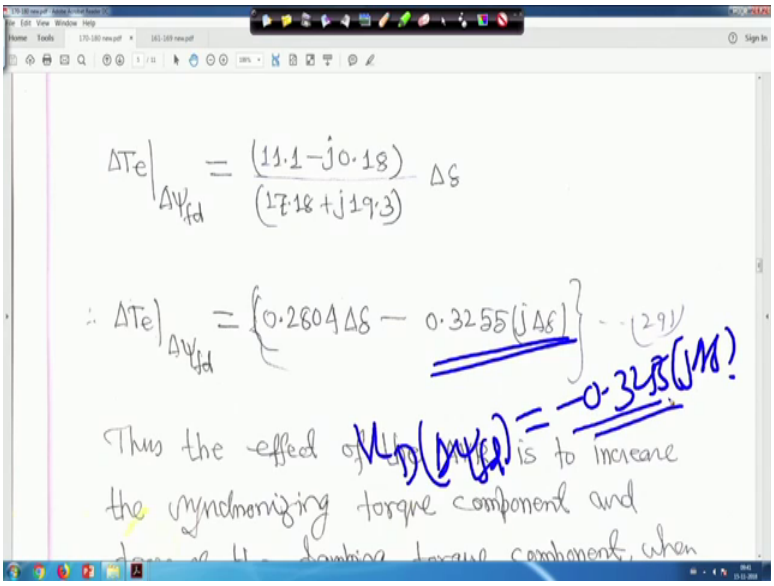

So, this term if we make KD due to delta psi fd, this is the meaning is equal to minus 0.3255 j delta delta right.

So, this is negative actually this is negative right. So, that is what we are writing here, what we are writing here that KD delta psi fd is equal to minus 0.3255 j delta delta this is equation 292. If you look throughout this just if you see this dynamics and control that equation we have come up to 292. So now, I will find such a long number of equations, but just to maintain the continuity and for easy understanding. So, easily you can refer to which equations are see if I break all these thing then things will become complicated and this equation comes 292.

So, when I teach here in the class I mean for our own student right. So, at that time actually when I make this 292 or 300 equation. So they feel that if this continuity is maintained and nothing actually is wrong everything is fine, because I had to collects all this information from various places right. So, that is why this continuity has been maintained otherwise in a particular topic you will not see that so many equations that to connect it to equations; further it will increase right.

So, it is made it has been made such that continuity will not be lost and all the equations are messed and immediately will go back and you can verify right. So next, we will come to the meaning of this one, that it is actually 90 degree out of phase because j delta delta right. So, if you look into this that go back to that if you go back to that block diagram, that figure thirty or a previous figure does not matter that delta now you will know why it is called in phase.

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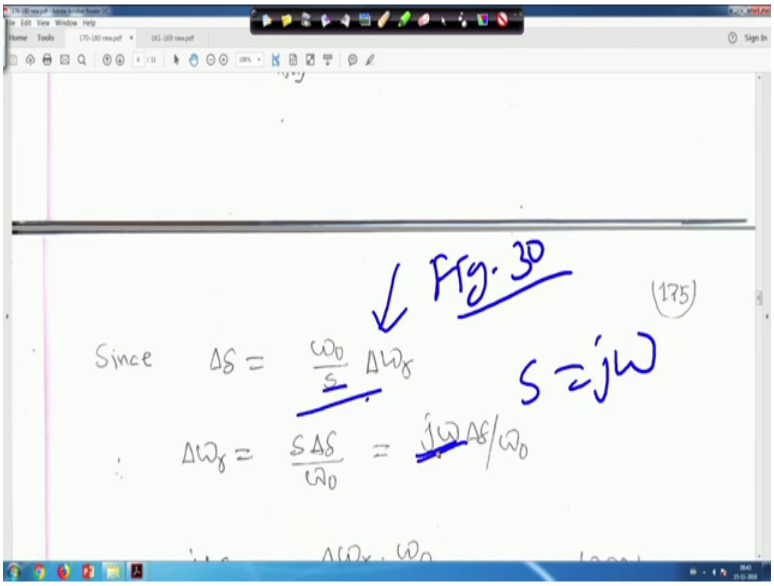

Now, if you look into this delta delta is equal to omega 0 S omega 0 by S into delta omega r we go to figure 30 and just see this you go to figure 30, and just see this right.

Now, we can write delta omega r is equal to s delta delta by omega 0 right and S is equal to j omega where you are substituting in that S is equal to J omega. Here you are substituting if you put S is equal to J omega then how it looks like delta omega will be j omega delta delta upon omega 0, right.

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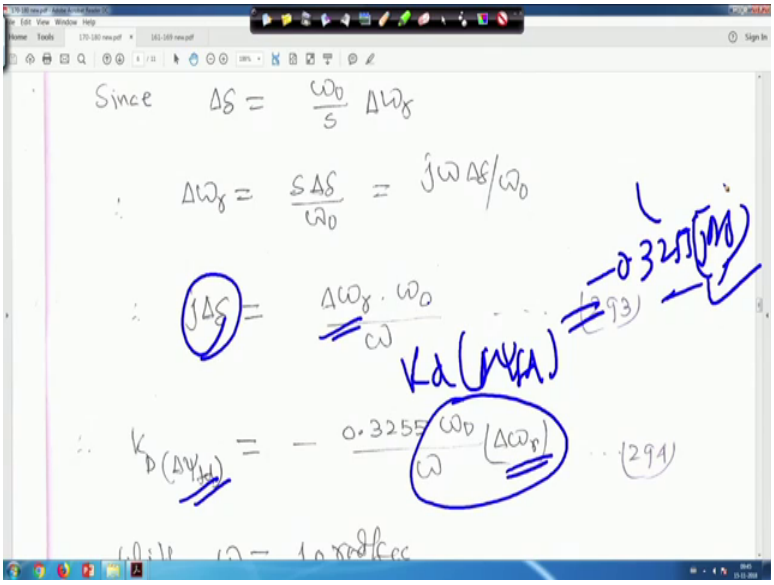

So, that means, j delta delta that means, just hold on; that means j delta delta right this j delta delta is nothing but is function of delta omega r and d by omega 0 upon omega right. So, your what you call that your; that means KD delta psi fd actually it is equal to minus 0.3255 then actually KD just we have seen delta psi fd im over writing is equal to your we got minus 0.3255 j delta delta right.

Now, if you replace j delta delta by j delta delta by this term delta omega r omega 0 upon omega then this is replaced by j delta delta omega 0 upon omega into delta omega r. At that time you can see it is function of delta omega r right that is why we call it is in phase with delta omega right and if you put in terms of j delta delta like this one j delta delta like this one right at that time we call 90 degree out of phase right. This is the your what you call the meaning, if you do so, it is actually coming like this omega 0 upon omega because j delta delta has been replaced by omega 0 upon omega into delta omega r, this is equation 294.

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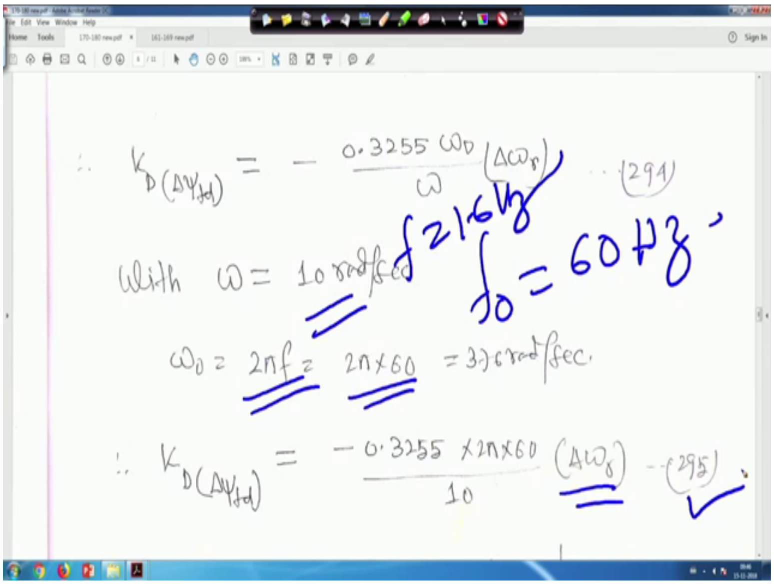

Now, when omega is equal to 10 radian per second, we have taken earlier also that is 1.6 hertz frequency is 1.6 hertz then you put omega is equal to 10 radian per second right.

Then and this omega 0 we have taken a 60 hertz system. So, omega 0 it is actually we say 2 pi into 60, because we have taken that nominal frequency f 0 is equal to 60 hertz and total frequency oscillation we have taken omega is equal to 10 radian per second; that means, approximately it is 1.6 hertz right. So, if in that case, KD delta psi fd will be minus 0.3255 into 2 pi into 60 upon 10 delta omega r. This is equation 295.

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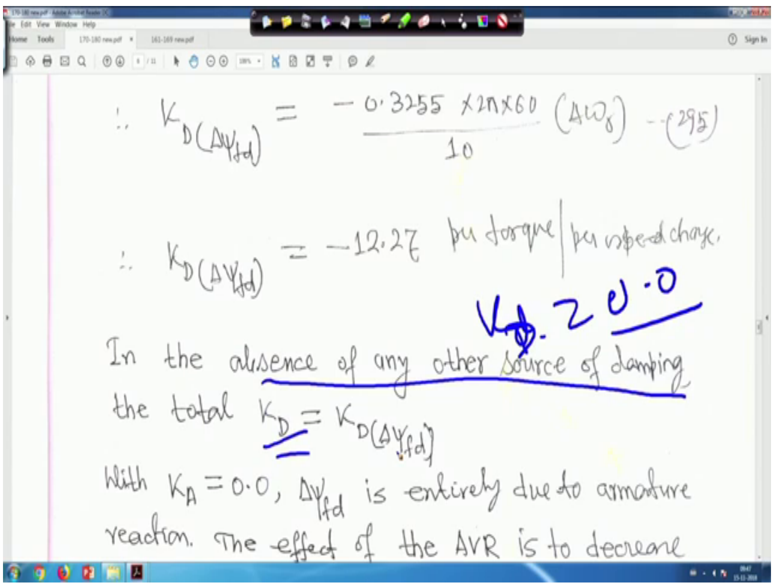

So, if you simplify it is become KD delta psi fd is equal to minus 12.27 per unit torque divided by per unit speed change right. So, in the absence of any other source of damping the total KD will be KD delta psi fd because just let me go up that if data is available or no here it is next page your what previous page that we have considered that KD is equal to 0 for this analysis right.

That is why your just hold on let me go back here, so in this case what happened that for our analysis that in the absence of any other source of damping, because for this thing we have taken now initial data KD is equal to 0.0 did not consider any damping rather capital D, KD is equal to 0 point 0 you have not considered any damping thing.

So, in that is why in the absence of any other source of damping, the total KD will be KD a due to delta psi fd right. Now let us make some analysis.

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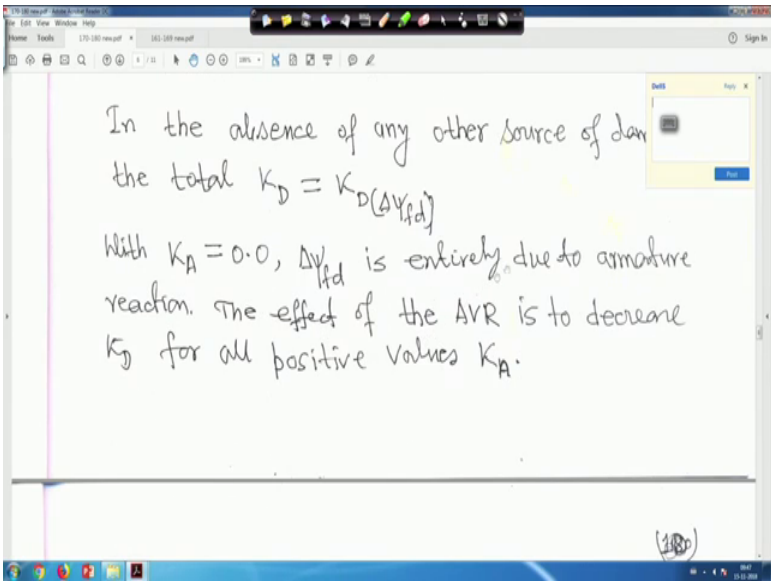

Now, when KA is equal to 0 delta psi fd is entirely due to armature reaction this you have seen earlier. The effect of the AVR is to decrease KD for all positive values of KA right. So, any positive value of KA is that it decrease actually KD, the damping coefficient.

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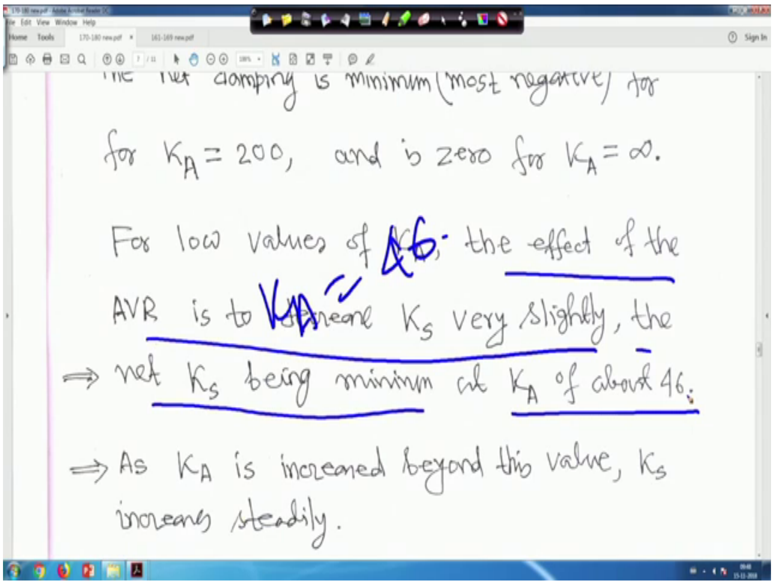

So, that net damping is minimum most negative for KA is equal to say the damping is the net damping is minimum that is most negative for KA is equal to 200 and is 0 for KA is equal to infinity right So, this one you please do it as an exercise take KA take KA tends to infinity right.

So, for low values of KA; the effect of the AVR is to decrease K s very slightly let me move up little bit. So, the effect of your AVR is to decrease K s very slightly right the net K s being minimum at KA is about 46; this is an exercise for you right. If KA this you find out KA is equal to 46, if it is then K s being minimum at KA up about 46 because the function is given in terms of KA you please find out this is an exercise for you. So, as KA is increased beyond this value K s increases steadily right or graphically also you can plot and you can see this math lab you can easily plot right.

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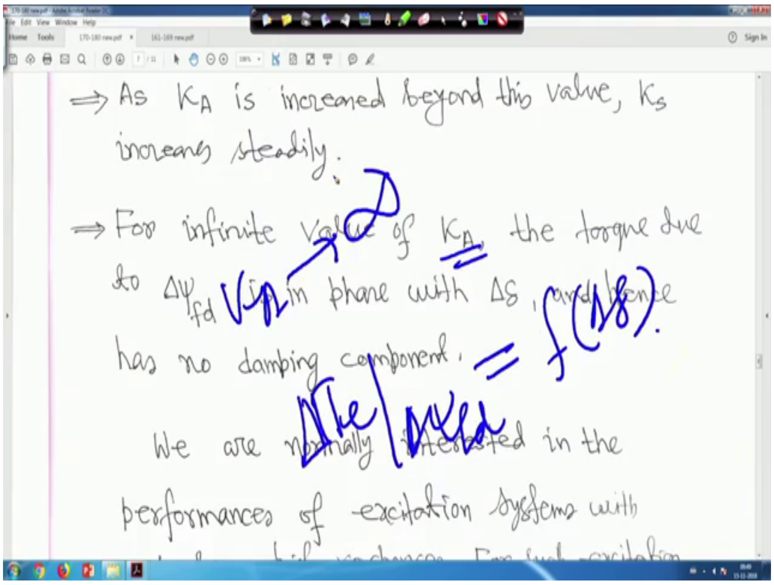

For infinite value of KA the torque due to delta psi fd is in phase with delta delta and hence has no damping component right. So, for infinite value of KA means when KA tends to infinity you will find torque due to your delta psi fd is in phase with delta delta and hence has no damping curve. That means, that delta te component due to delta psi fd. That means, delta just hold on that means, delta te due to delta psi fd will be function of only delta delta.

So, I can put it, it is function of delta delta, but no j delta delta term will come right due to your what to call for infinite value of ka; that means, when KA tends to infinity right this is a small exercise for you please try this one right this is small exercise for you. So, if I try to make everything then it will take more time.

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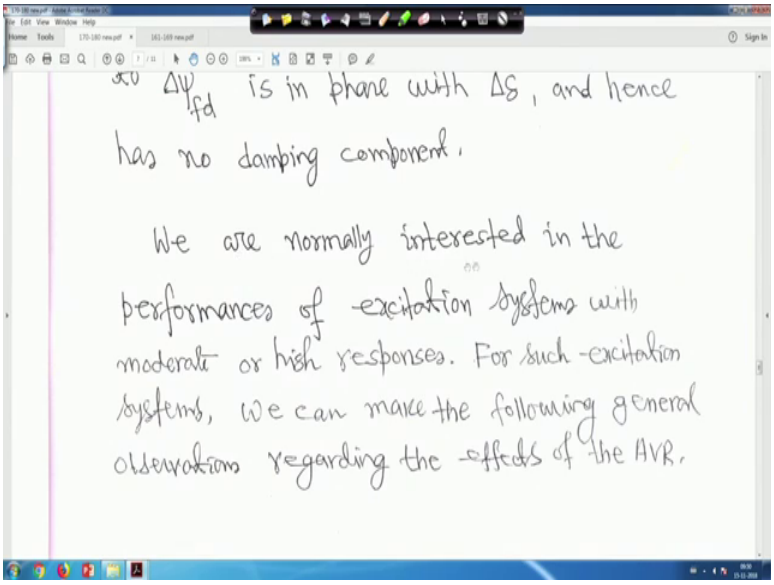

So, now we are normally interested in the performance of the performances of excitation system with moderate or high responses right. For such excitation system we can make the following general observations regarding the effect of the AVR right.

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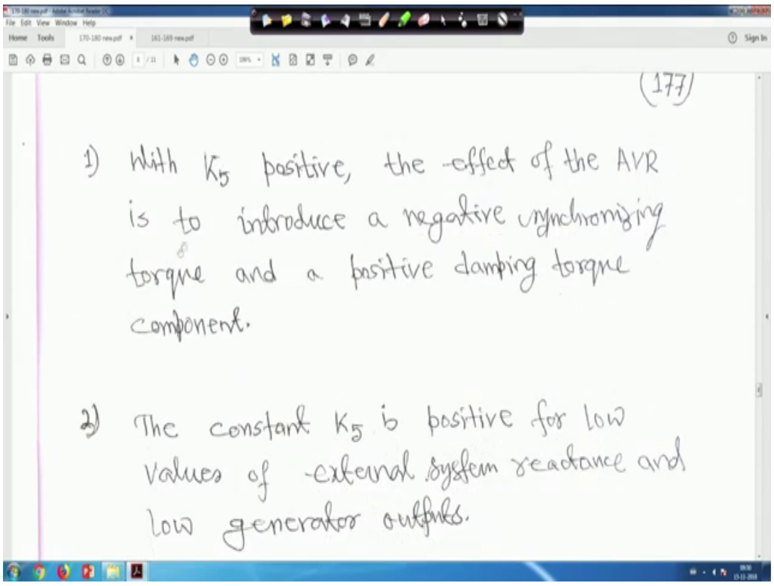

So, now number 1, this you will keep it in your mind with K 5 positive the effect of the AVR is to introduce a negative synchronizing torque and a positive damping torque component right when K5 is positive. So, what we have done is we have taken negative value minus 0.12, you try with plus 0.12 and see this, whatever has been mention here whether it is matching or not.

So, if K 5 positive the effect of AVR is to introduce a negative synchronizing torque just opposite it will happen and a positive damping torque component just opposite we saw that your some constant into delta delta minus some constant j delta delta, but if you take positive value it will be is minus into minus some coefficient your constant delta delta plus your some positive your some constant your j delta delta. Just this you do it for K 5 is equal to plus 0.2 0.2. Now number 2, the constant K 5 is positive for low values of your external system reactance and low generator outputs right.

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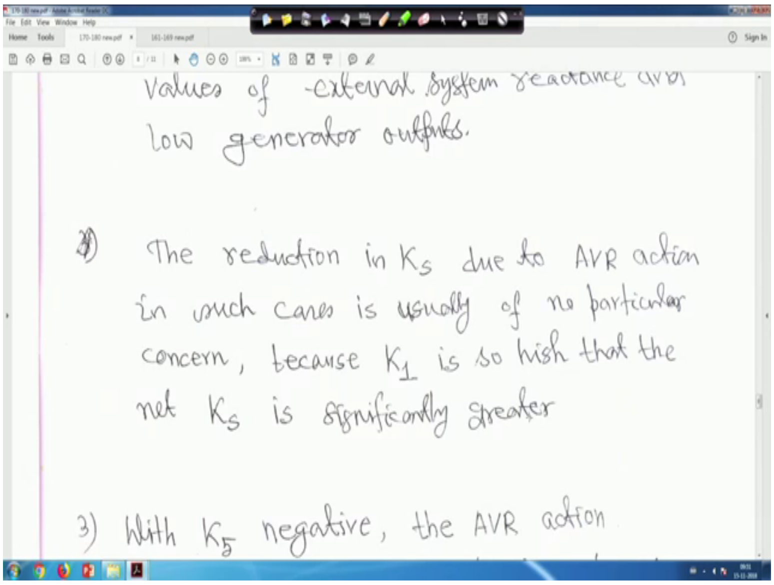

Then now, the reduction your the reduction in case due to AVR action in such cases usually of no particular concern, because K 1 is so high that the net case is significantly greater. Actually delta te is equal to your K 2 delta psi fd plus your K 1 delta delta.

Although there are although due to this that your that that your delta te component due to your delta psi fd will be very less actually compared to your K 1 value. So, it has not that significant, because ultimately it will be K 1 plus your K s delta psi fd into delta delta right, but K s delta psi fd if it is reduced does not matter because K 1 is quite high for a for your what you call given operating condition right.

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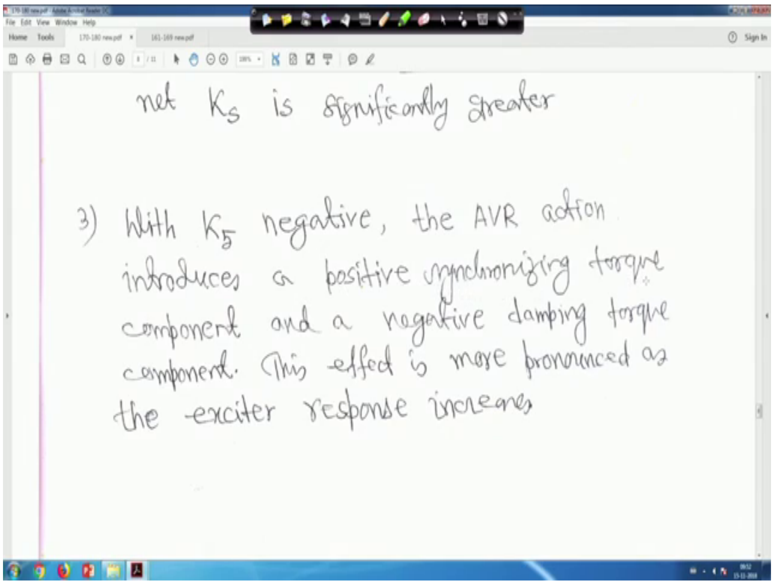

Now when we K 5 negative right the AVR action introduced a positive synchronizing torque that we have seen for K 5 is equal to minus 0.12 and a negative damping torque component that also we have seen just now right. And this effect is more pronounced as the exciter response increases, but details cannot be done in this video course or even in the regular classroom course, because it involves a actually huge computation and it takes time right. So, this is one next we will have to call, next we will consider that power system stabilizer.

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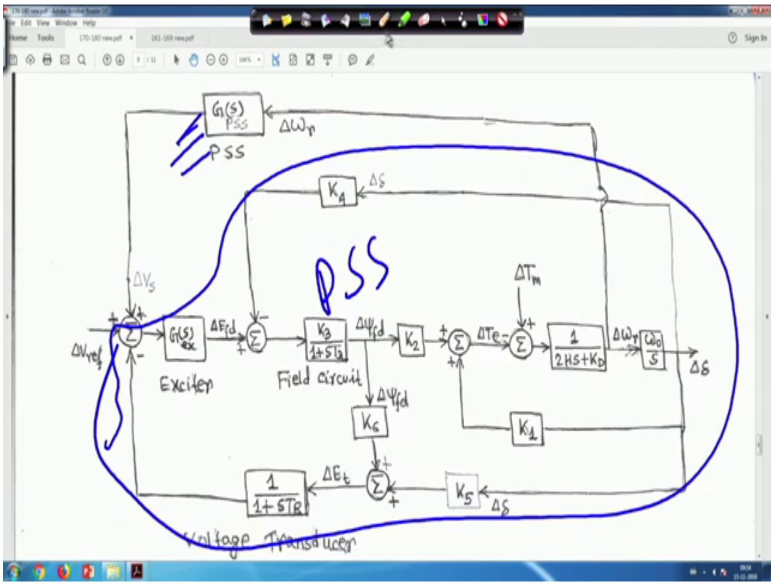

So, method this simplification other thing will come later. So, whatever block diagram we have seen, look whatever block diagram we have seen all these things are all these things are ok, we have already derived this all this time right. In addition to that we are adding one power system stabilizer. Basically it is a lead lag stabilizer from an input to this stabilizer is delta omega that the speed deviation of course, different versions of stabilizers are input signal to the stabilizer is available, but our interest is only for the classroom purpose. So, this is actually power system stabilizer function.

Basically it actually what we want actually it is acts what you call that, we want to damp out the rotor frequency oscillation. For this an additional signal is taken and that way we use that your power system stabilizer. Basically, lead lag stabilizer detail analysis for lead lag stabilizer for this course in the class, it is really difficult. But when we somebody does simulation or some your research work or thesis work at that time one can consider this for the simulation purpose right, but this is actually GS PSS means that is your power system stabilizer.

So, now if we put power system stabilizer thing then what will happen that if you look into that, that this signal is coming here this signal is coming here.

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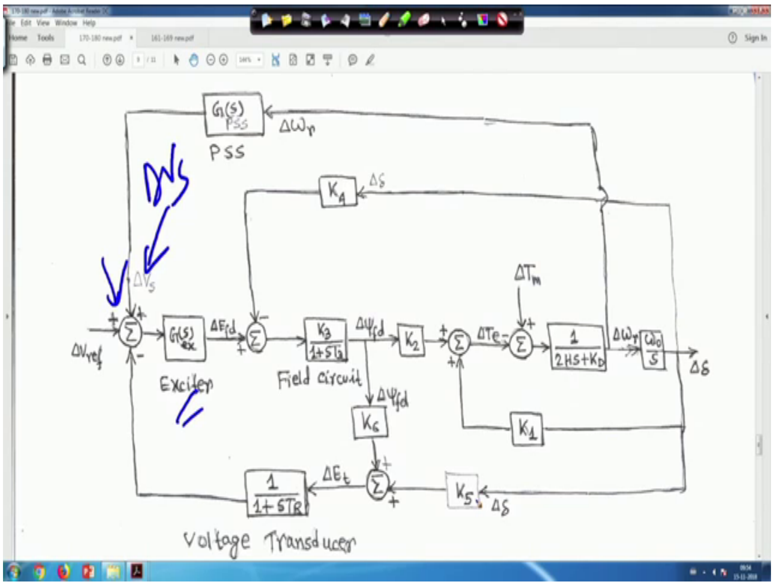

This output of the stabilizer signal is delta V S, which is here right and this is delta V reference, this is Y exciter and rest of the block diagram remains same right, rest of the block diagram will remain same. So, in this case block diagram will be coming back to that, but only thing is that this delta V S thing whatever you see here these are additional signal is coming here, additional signal is coming here right, this rest of the things are ok. Therefore, what will be our your observation or what will be our studies we see this due to this power system stabilizer what is its effect, so under damping right rotor frequency of oscillation right.

So, that is why this diagram I have made it before after that you are what you call, after that all these what you call; all this analysis regarding stabilizer, whenever needed we will come back to this figure. This is actually figure 31.

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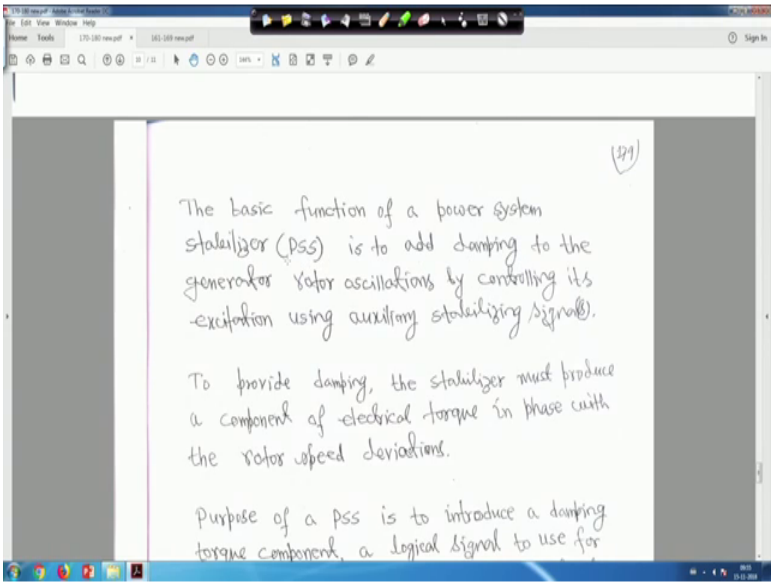

So, now the basic function of power system stabilizer is to add damping to the generator rotor oscillation right. By controlling its excitation using auxiliary stabilizing signal right. So, that is why feedback is given here feedback is given here right. So, excitation using auxiliary stabilizing signals, whether it is delta V S. Now to provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed deviation, this we have to see it right.

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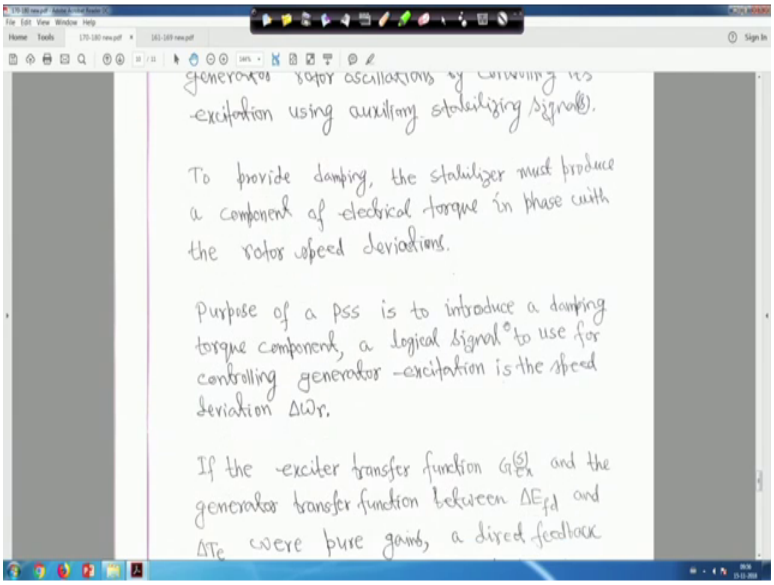

Purpose of a PSS is to introduce a damping torque component. A logical signal to use for controlling generated excitation is the speed deviation that is delta omega r. So, this input to this stabilizer this thing we have taken delta omega r right.

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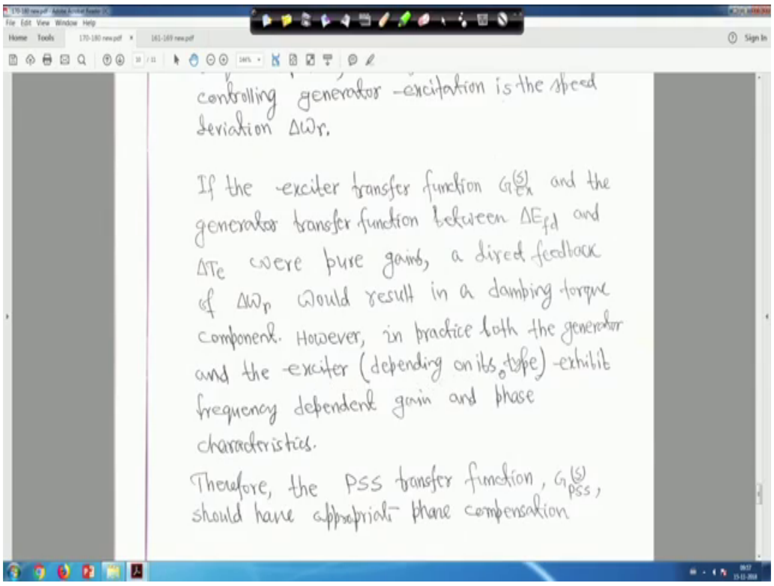

Now, if the exciter transfer function G X S and the generator transfer function between delta E f d and delta T e are pure gains; that means, in between this thing in between this thing and this thing, I mean in between this thing in between this thing right, if it is a just let me go back, if it is a pure gain right; that is your a direct feedback of delta omega would result in a damping torque component.

So, that we have to see how we can make this direct gain right. However, in practice both the generator and the exciter that is depending on its type, because different type of exciters are there right, exhibit frequency dependent gain and phase characteristics. Therefore, the PSS that is power system stabilizer transfer function that is we call G P S S function of phase should have appropriate phase compensation. That is why you called phase lead lag compensator reviews. Details we cannot analyze on this course, but I will explain those.

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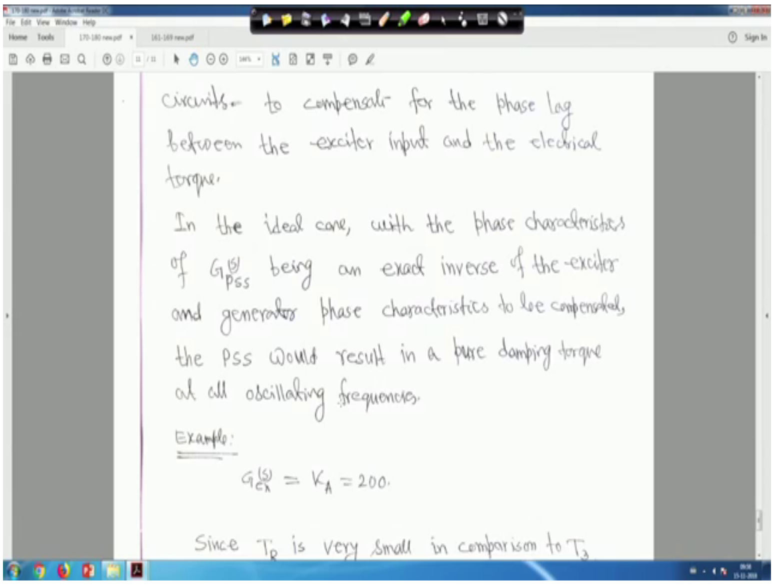

To compensate for the phase lag between the exciter input and the electrical torque right.

So, in the ideal case with the phase characteristics of G P S S; that is stabilizer transfer function, being an exact inverse of the exciter and generator phase characteristic to be compensated right. It will be a pure gain it has to be made it, the PSS would result in a pure damping torque at all oscillating frequency. That means, that lead lag network or lead lag compensator you have to design in such a fashion, such that is that lead compensator it will compensate the lag one.

We will take a small example and we will try to explain that one how things are right. For example, suppose this is just for the sake of understanding.

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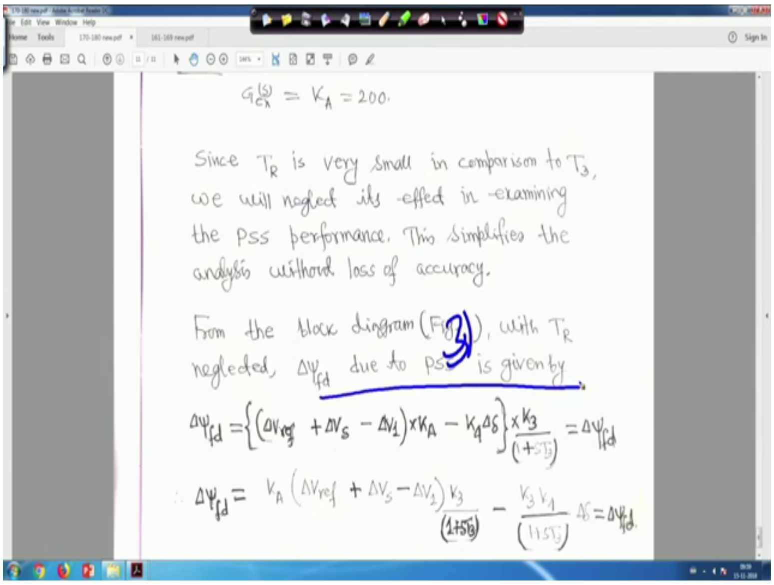

For example, suppose we have taken KA is equal to 200. Now, say it as I told you since T R is very very small in comparison to T 3, previously we have taken one example I told you at that time that T 3 is equal to what you call that 1.91 second conveiner T R is 0.02 seconds, so T R can be neglected.

So, previous example we have considered T R and you have analyzed I suggest that previous example you put T R is equal to 0 and repeat the same analysis for your K A S delta psi fd and KD delta psi fd also as an exercise.

So, your that the from the block diagram that is your this is from the block diagram whenever I am miss this one, this is actually figure 31 right with T R neglected that delta psi fd due to PSS is given by right. So, what you will do? You will go back to this figure, same as before same as before you find out that delta T e due to delta psi fd is equal to K 2 K 2 into delta psi fd right.

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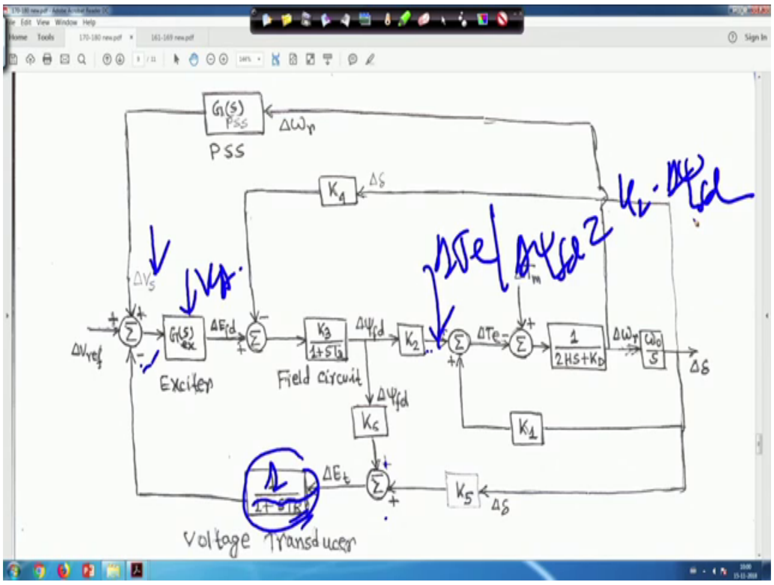

So, this only additional thing is delta V S term is coming with this thing and T R is neglected, this T R is neglected then this will be simply 1, this should not be there. So, in that case and this value is we have taken, this one is KA simple gain then, what will happen this delta V S will come plus delta V reference minus your from here it is coming minus K 5 delta delta. And here it is coming your what you call minus K your plus here it is minus, here it is plus it will be minus that is delta V reference plus delta V S then minus K 5 delta delta then minus K 6 delta psi fd into KA right.

Then bracket will be what you call, the bracket will be closed right. Then with that that minus K 4 delta delta will come right into K 3 upon 1 plus S T 3 and here another K 2 will be multiplied; that is your delta T e due to delta psi fd because, from your undergraduate your what we call that transfer function model, so this one will find out. So, again and again I am telling that delta T e has 2 component; one is K 1 delta delta, another one is another one is that is K 2 delta psi fd that is another component due to delta psi fd, but this K 2 we have to multiply right.

That means, when we write like this, that it will be delta psi fd; I told you delta V reference plus delta V S minus delta V 1, here I did not substitute that, I will substitute into KA minus K 4 delta delta again into K 3 upon 1 plus S T 3 right, is equal to delta psi fd right. So, delta psi fd is equal to there, little bit simplification if you make KA delta V reference plus delta V S minus delta V 1 into this term K 3 upon 1 plus S T 3 minus your K 3 K 4 upon 1 plus S T 3 delta delta is equal to delta psi fd right. So, just hold on.

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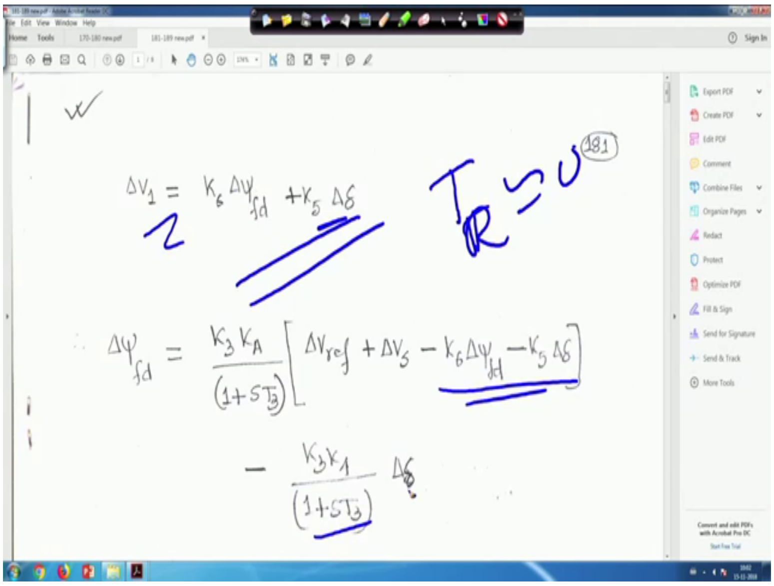

So, that way that delta V 1 is equal to K 6 delta psi fd plus K 5 delta delta, from that block diagram only. So, here you substitute, I mean from that block diagram, that is your figure the previous figure that delta V 1 is equal to this one and your T R is neglected, T R you have neglected right. So, directly you substitute, that your delta V 1 is equal to this one and then minus K 3 K 4 upon 1 plus S 3 delta delta right.

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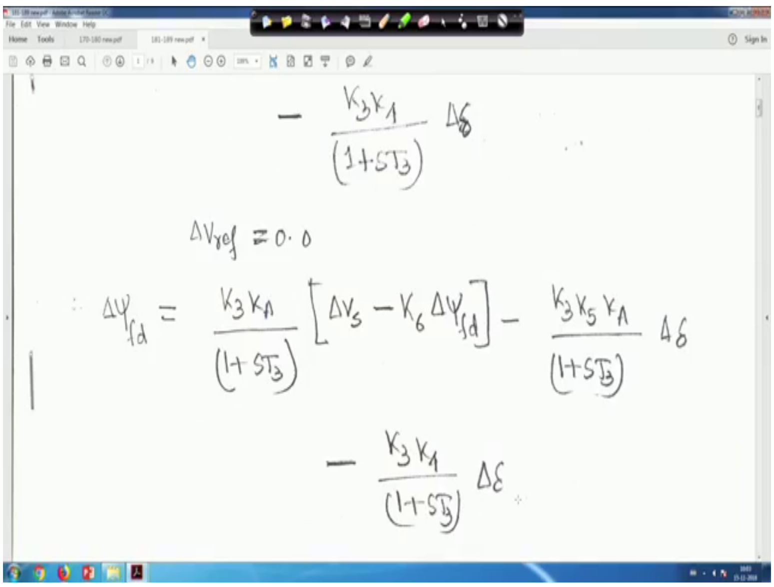

So, now let us assume delta V reference is equal to 0 right, you assume delta V reference is equal to 0. So, if delta V reference is equal to 0. Then this equation can be written as delta psi fd is equal to K 3 KA upon 1 plus S T 3 in bracket delta V S minus K 6 into delta psi fd minus K 3, K 5 K upon 1 plus S T 3 delta delta, Then minus K 3 K 4 upon 1 plus S T 3 delta delta.

Just one thing I would like to mention that so many terms and huge mathematics is involved by chance you hope everything is correct, I think everything is correct. But, if you see by chance any terms is missed or anything just please let me know then I can rectify this right, but I believe things are things are right.

So, this one, if you make delta V reference 0 and just simplify that this will be like this right.

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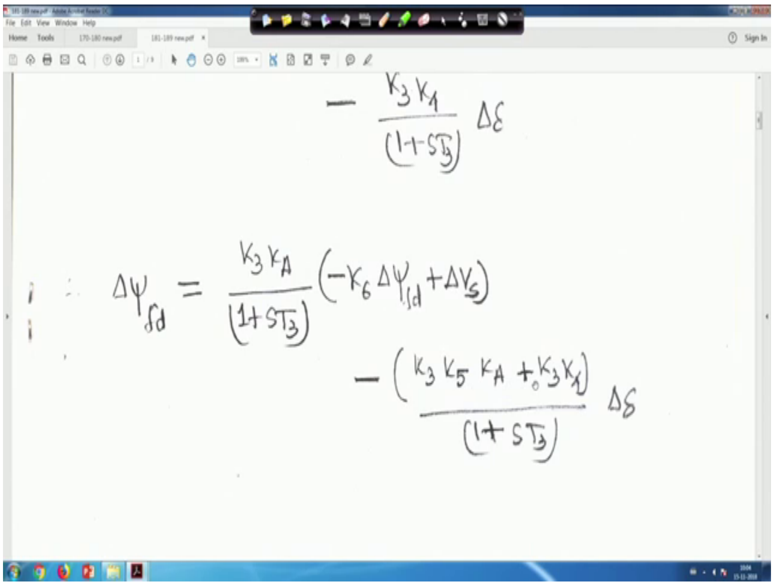

Now, therefore, delta psi fd we can rewrite this K 3 KA upon one plus S T 3 minus this term, this term we are rewriting minus K 6 delta psi fd plus delta V S, then these 2 term, these 2 term we are writing together. So, minus in bracket, K 3, K 5, KA plus K 3, K 4 upon one plus S T 3 delta delta right.

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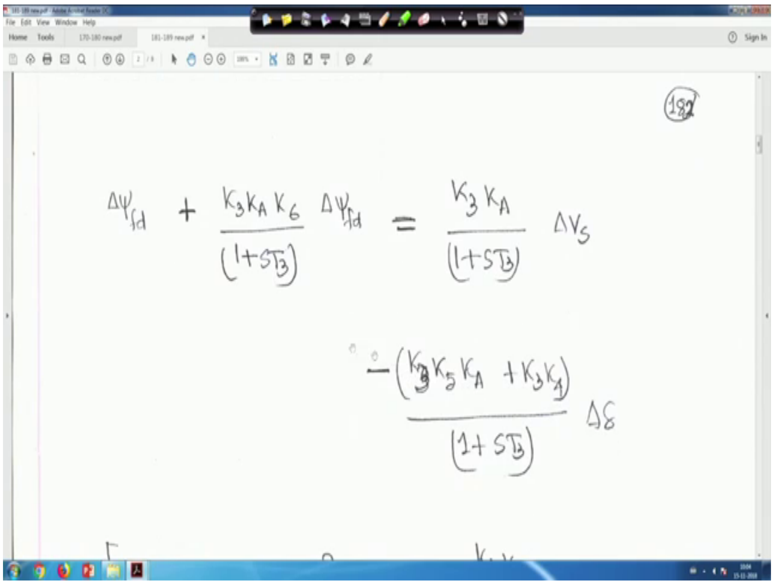

So, that means, upon simplification bring this thing to the left hand side. Bring this delta psi fd term to this left hand side. Then it is actually delta psi fd plus K 3, KA K 6 upon 1 plus S T 3 delta psi fd is equal to K 3 KA upon 1 plus S T 3 delta V S right minus K 3, K 5 K plus K 3 K 4 upon 1 plus S T 3 delta delta right. So, this side you simplify left hand side.

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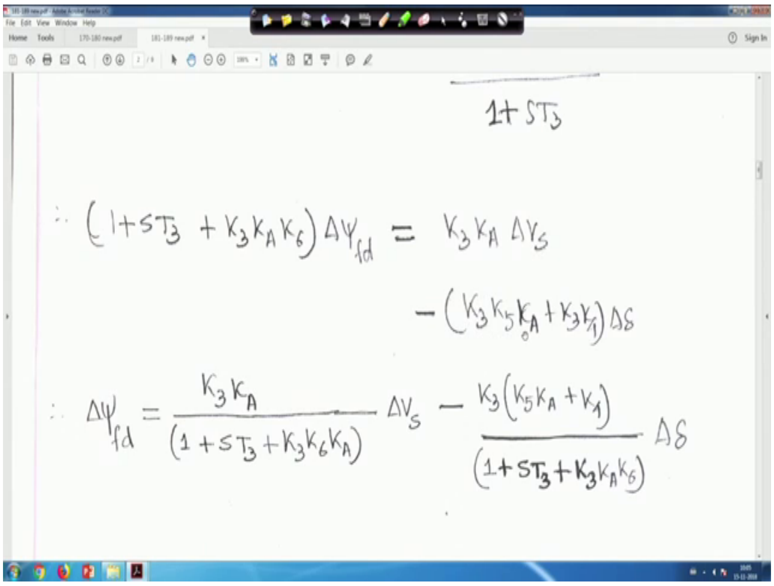

So, it is becoming actually, 1 plus S T 3 plus K 3, KA, K 6 upon 1 plus S T 3 delta psi fd is equal to K 3, KA upon 1 plus S T 3 delta V S minus K 3, K 5, KA plus K 3, K 4 upon

1 plus S T 3 delta delta right So, further simplification will give you that your 1 plus S T 3 plus K 3, KA K 6 delta psi fd is equal to K 3 KA V S minus K 3, K 5 KA plus K 3 K 4 delta delta or this term can be written as delta psi fd can be written as that your K 3 KA upon 1 plus S T 3 plus K 3 K 6 KA delta V S minus K 3 into K 5 K plus K 4 upon 1 plus S T 3 K 3 KA K 6 delta delta right.

So now, when that means, this term has come to this equation because of response system stabilizer delta V S right and earlier if it is not there previously this term was there, previously this term was there right, but in that case, your what you call, you have to neglect T R, you just neglect T R and do not consider delta V S, then you will see this term is there. But due to delta V S right, due to delta V S, this term had been introduced this term had been introduced right. So, that means, that means, we have to see that is providing actually damping.

So, that is why this term due to this is the output say output signal from the stabilizer is delta V S right. So that means, what we will do, just try to understand this right.

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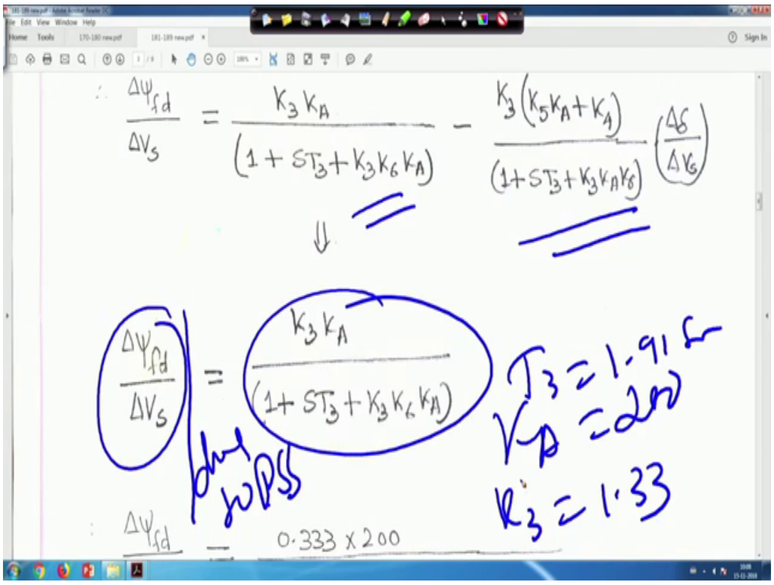

It is only understanding mathematics is you can easily make it right that means; whenever we are writing this, that delta psi fd upon delta V S. So if you write delta psi fd upon delta V S right, so this term will be there and this term is it delta delta upon delta (Refer Time: 26:27) both side you divide by delta V S.

So, delta fd upon delta of this term plus sorry minus this term into delta delta Y, your delta V S then; that means, due to stabilizer this term has been introduced right, this term this term has been introduced. That means, this term only this term we are writing this is delta psi fd you it due to your PSS, this much you write, this is I have not written here, because while I am teaching in the classroom, I am telling them that this is the thing, but your case delta fd delta this is due to PSS only this term we will consider now right. This term we will not consider, we will only consider due to delta PS, only this term first term will consider right.

So, we know that all the parameters initially given and KA is equal to 200 we have taken and T 3 also we have taken, I think 1.91 second right and K 3 also 1.333 and all other parameters previously you have taken some parameters, you substitute all these parameters right, you substitute all these parameters.

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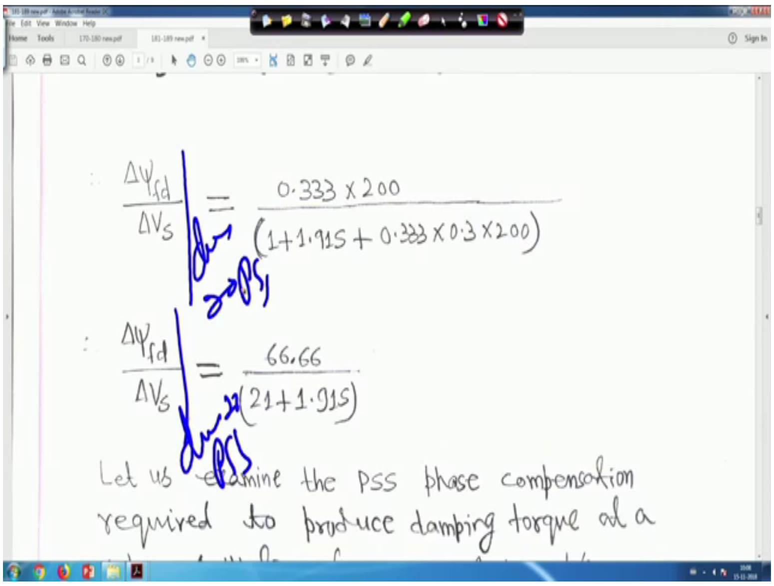

Then you will find that every time every time let me tell you, this is actually due to PSS right, this is actually due to PSS. So, there will be no confusion at all right.

So, you put all these parameters and this delta fd delta V S it is actually due to power system stabilizer this term has been introduced right. So, because we have 2 component that we know K 2 delta psi fd that is one component due to that, but this term is coming, because of PSS right. So, if you put this one and simplify it will become 66.66 divided by 21 plus 1.91 S right.

So, this is coming actually. And if you try to simplify, you will feel some lagging angle will be coming right when you put S is equal to j omega.

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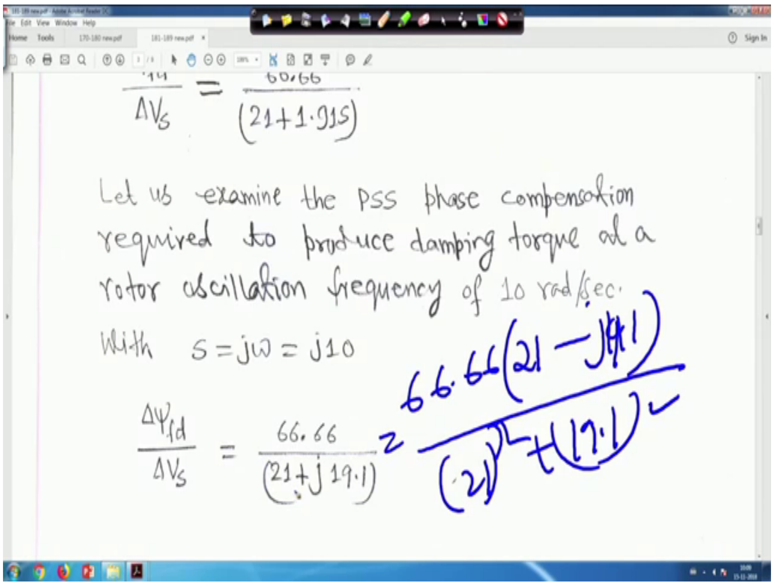

Now, will examine the PSS phase compensation required to produce damping torque at a rotor oscillation frequency, we have taken earlier 10 radian per second that is 1.6 hertz right.

So, if S is equal to j omega you put j omega your omega is equal to 10. Therefore, it will become delta fd upon delta V S will become actually 66.66 upon 21 plus j 19.1 right. Now numerator and denominator, now numeral this is equal to 66.66 numerator and denominator you multiply by j or 19 or 21 minus j 19.1 divided by if you multiply it is 21 square plus 19.1 square right. We will see is a complex operators are just multiply numerator and denominator by 21 minus j 19.1 and you simplify and you simplify right.

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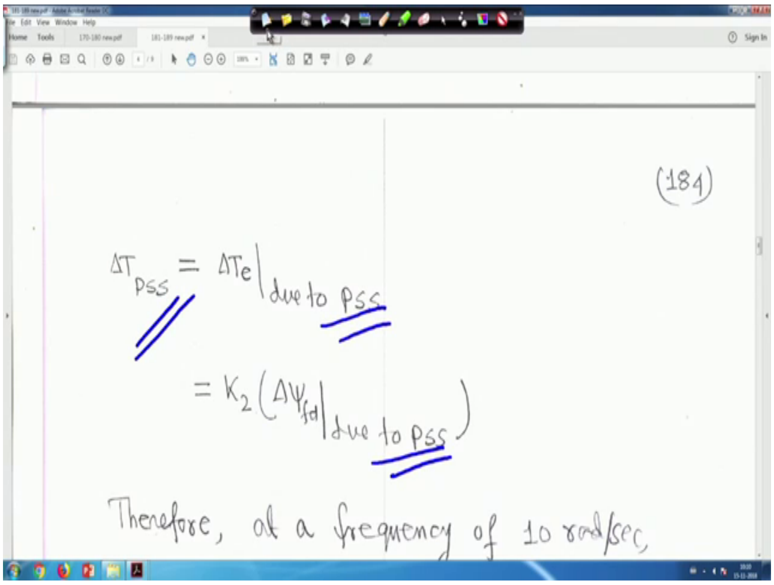

So, if you simplify that is delta T. Now we are changing the term delta T sorry delta T PSS right; that is delta T e due to PS PSS rather right will be K 2 into delta psi fd due to PS PSS, that I wrote earlier also that term right.

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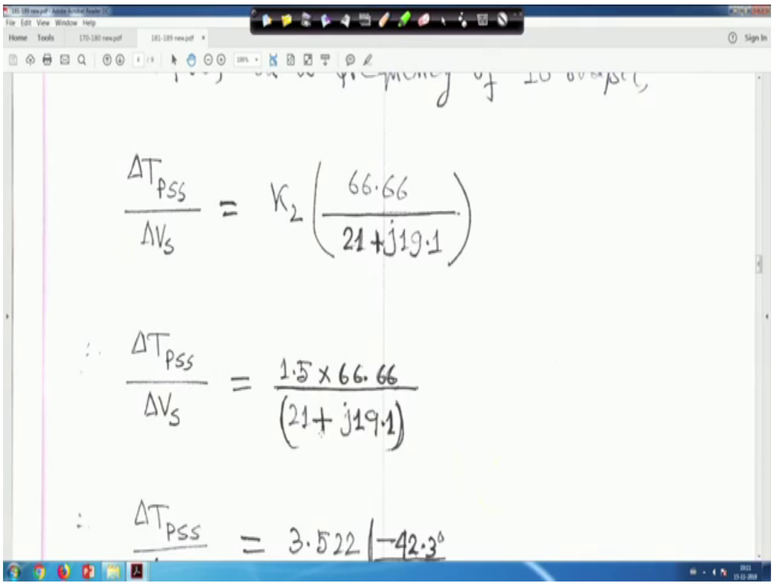

So therefore, at a frequency of 10 radian per second delta T PSS upon delta V S, now we can write like this right is equal to. Now meaning is clear to you, meaning is completely clear to you, it will be K 2 66.66 upon 21 plus j 19.1. Now if you simplify this right and multiply by this K2, so K 2 is 1.5, it will be 1.5 into 66.66 upon 21 plus J 19.1 and this one I told you, when you simplify multiply numerator and denominator by 21 minus j 19.1 that I have just told you right. If you do so, it will come 3.522 angle minus 42.3 degree.

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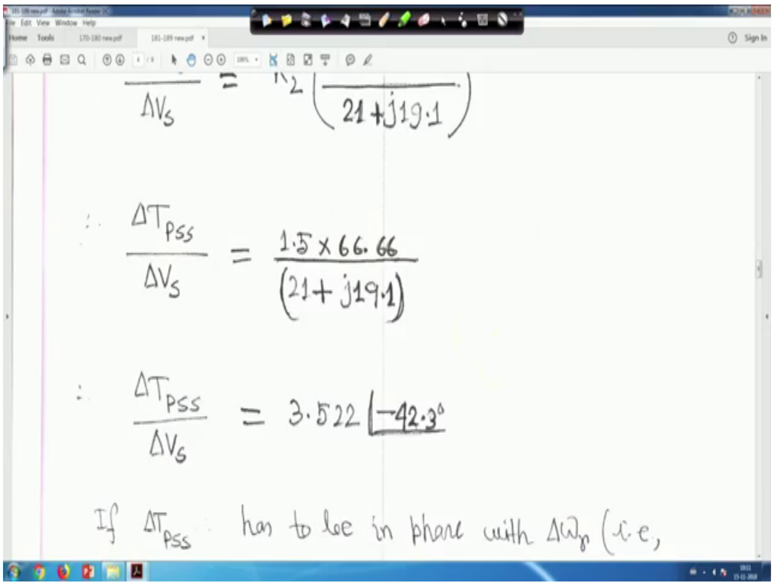

This lagging angle is coming right and we have to this said the your what to call is a gain is a pure gain. That means, you need a lead compensator, just to what you call just to nullify this gain there this angle minus 40 angle 42.3.

Thank you very much. We will be back again.