Power System Dynamics, Control and Monitoring
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Lecture - 51
Reactive power and voltage control, State extimation in power system

So, we are we are back again.

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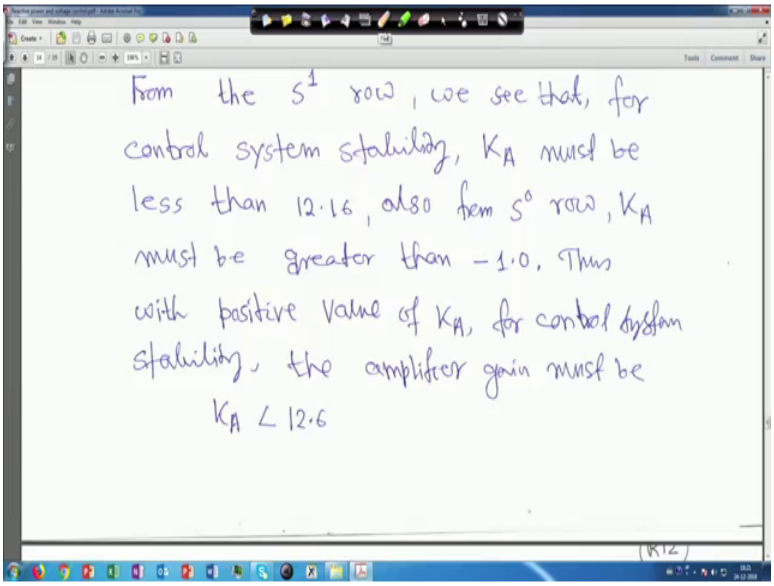

So, before moving to the next page that in the previous class I had no calculated actually this is correct 12 point, 12.16, it should be 12.16 not 0.6, right.

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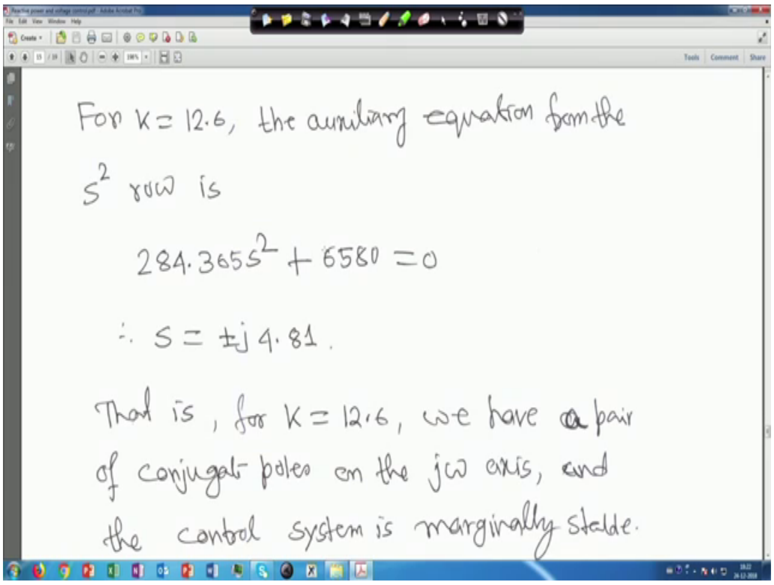

So, so this is all your this one 12.16, this is 12.16; so all corrected, right.

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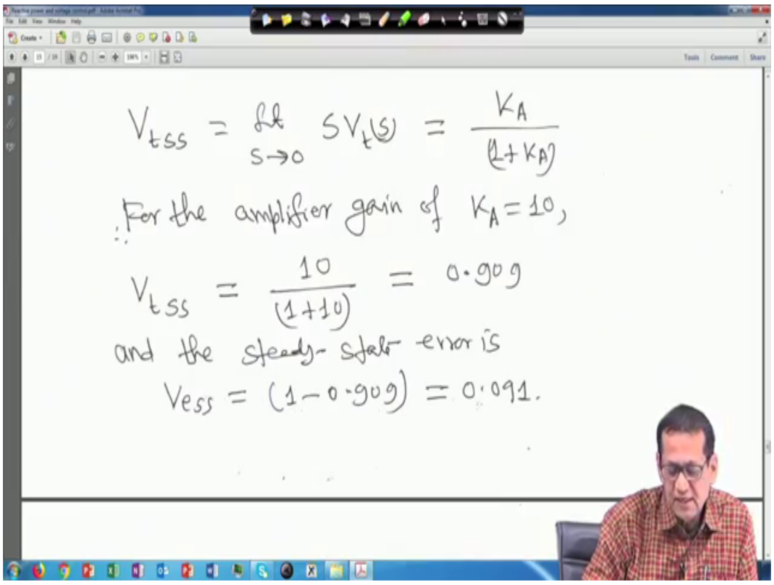

So, therefore the steady state error you have seen in the previous class lecture that it is V e ss is a steady state error it is 0.091, the error is quite high, right.

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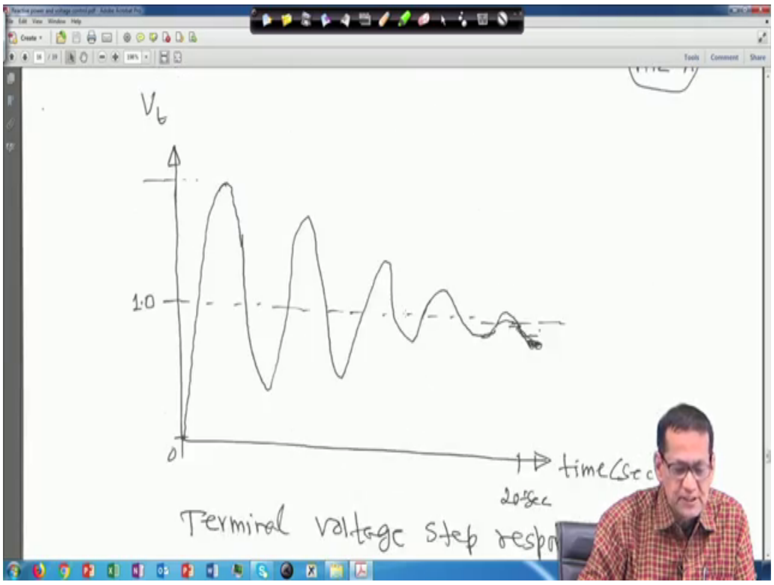

Now, if you if you plot the dynamic responses, right V t versus time it is 20 second time, although I have shown few oscillations, oscillations may be very you know let the oscillations may be more, right. It may be like this, it may be like this, may be like this, it may be like this, right. So, if you plot using your what you call that you are simulink or any other packages this is the time it is given up to 20 second and this is your while it is given step input that is 1 per unit voltage, 1 upon s.

So, ultimately settling to your it is going like this and settling to your 1.0, but peak deviation is quite high, right, whatever parameters we have taken. And your terminal voltage this is terminal voltage step response, right dereference is equal to we have taken 1 upon s, right.

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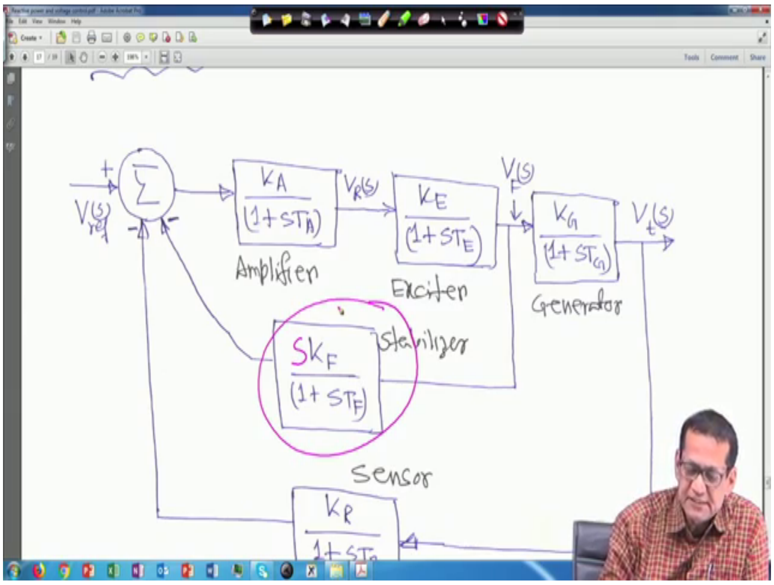

So, next is excitation system stabilizer rate feedback. Here one correction you have to make it that this is actually the; I just scroll down just hold on. So, this is actually your SK F, right. Just hold on. So, this is this is actually a SK F that derivative feedback. So, this is a my when I am making it was actually I miss the (Refer Time: 02:57); so it should be corrected.

So, this is actually stable one stabilizing transformer here there, right and it is excited by your x I this voltage V f, right excited voltage. And if you find out this transfer function it will be in this form SK F upon 1 plus ST F. I suggest you any book you will get this as what you call this transfer function of stabilizing transformer and I have been a clear given. So, it is actually it is SK F upon 1 plus is ST F.

So, previously this feedback was there, but one inner loop it is there and it going here. So, different it has some your what you call some other words and of representing this one, but I have taken this one. So, this is actually your what you call the block diagram of the compensator AVR system. This actually improves the dynamic performances because it is a great feedback. This a is actually a when I am cleaning it is a SK F upon 1 plus ST F.

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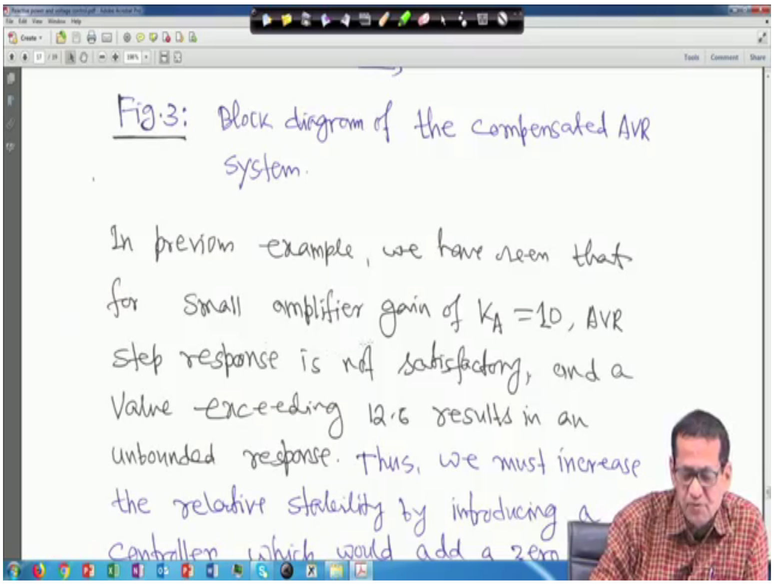

So, in the previous example we have seen that for small amplifier gain of K A is equal to 10, AVR step response is not satisfactory, and a value exceeding 12.16, it is 12.16, right result in an unbounded response; so that means unstable.

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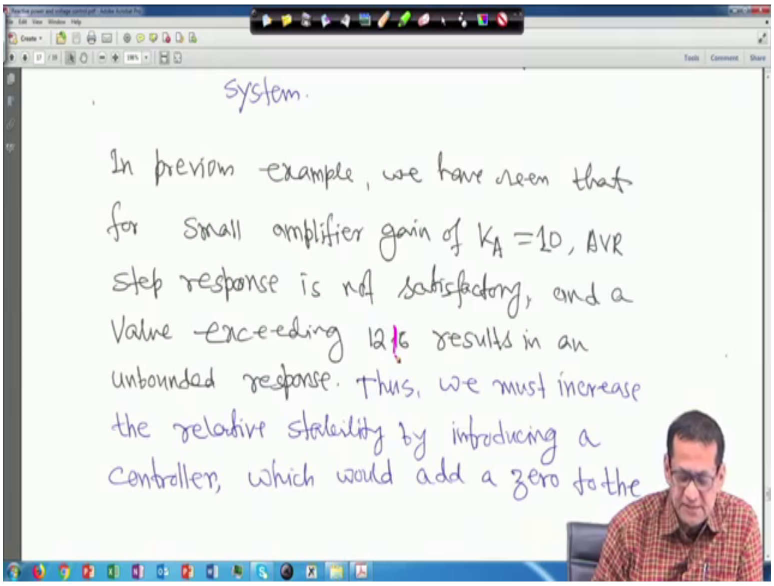

Thus, we must increase the relative stability by introducing a controller which would add a 0, right which is your; just hold on; so which would add a 0 to the AVR which would add a 0 to the AVR open loop transfer function.

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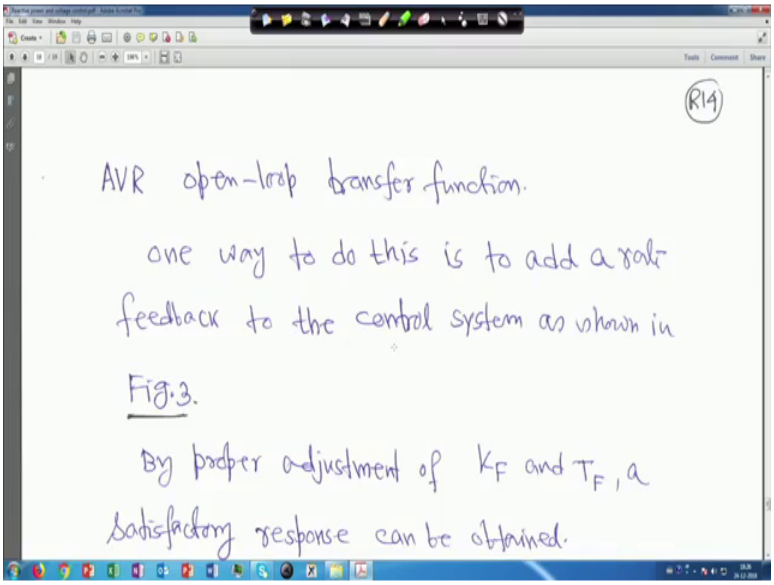

So, one way to do this is to add a rate feed back to the control system as shown in figure 3. So, this is actually your rate feedback. I told you there is a connection it should be SK F upon 1 plus ST F and this is a stabilizing transformer, we call it stabilizer, so it is transfer function it will be like this. Just I suggest that you see any book it is a small 4 5 lines derivation, but I am not putting it here, right. So, so we should add a 0 to the AVR.

One way, so figure by proper adjustment of K F and T F a satisfactory response can be obtained.

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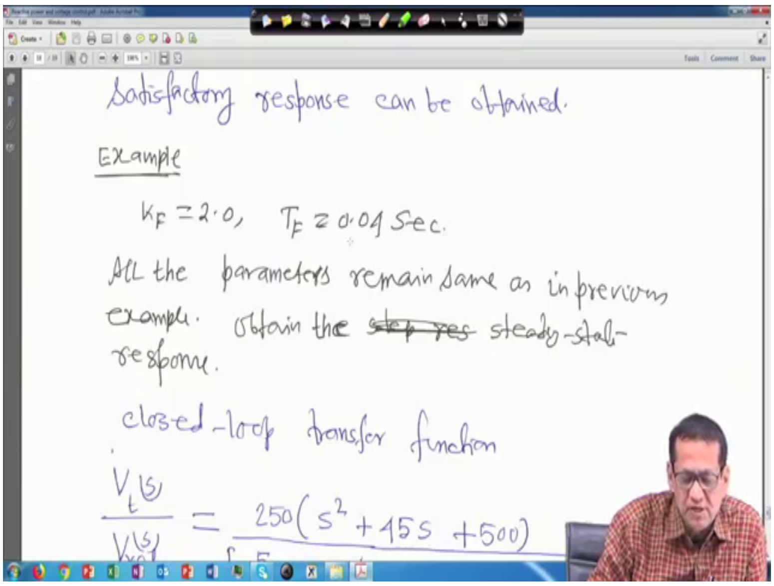

For example, suppose K F is equal to 2.0 and TF is equal to 0.04 second. All the parameters remain as in the previous example. So, whatever parameters we consider that your what you call same only K F is equal to 2 and TF is equal to 0.04 second (Refer Time: 05:39). So, obtain the steady state response, we have to obtain the steady state response. Steady state response means the steady state value say V t ss, right.

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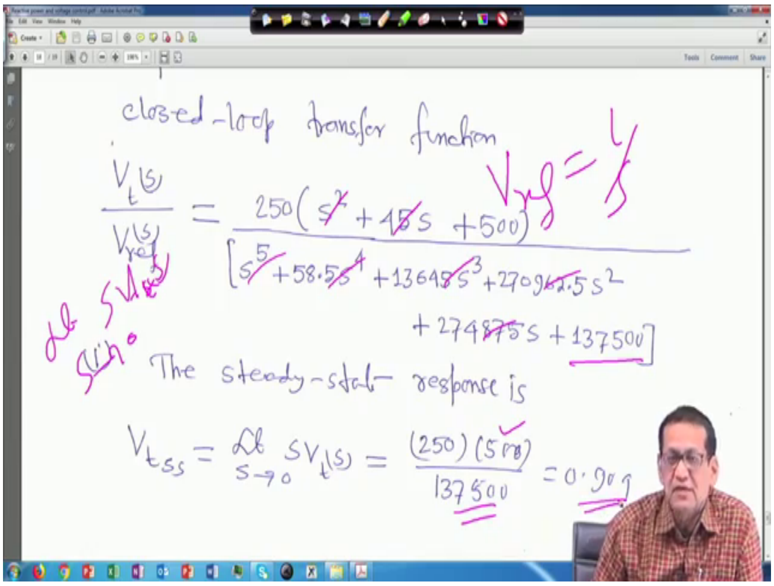

So, when you find out the closed loop transfer function of that system that is in figure 3, right you will find V t upon V reference is equal to 250 into a square plus 45 s plus 500 divided by s to the power 5 plus 58.5 s to the power 4 plus 13645 s cube plus 20 your what 270962.5 s square plus your 274875 s plus 137500. So, this will be your what to call the transfer function after substituting all the values, right.

Therefore, now, first only the steady state responses; if you put limit actually V reference actually V reference is equal to 1 upon s if you put V reference will be 1 upon s, so this side actually automatically will become S V t s, V t s and then you are taking limit s tends to 0. So, if you make s tends to 0, right then this one will be 0 this one will be 0. So, 250 into 500 at numerator and denominator will be all will be 0 these are all 0s. So, only 137500, 137500; so its value is coming 0.909, right. So, this is actually steady state value of V t s s.

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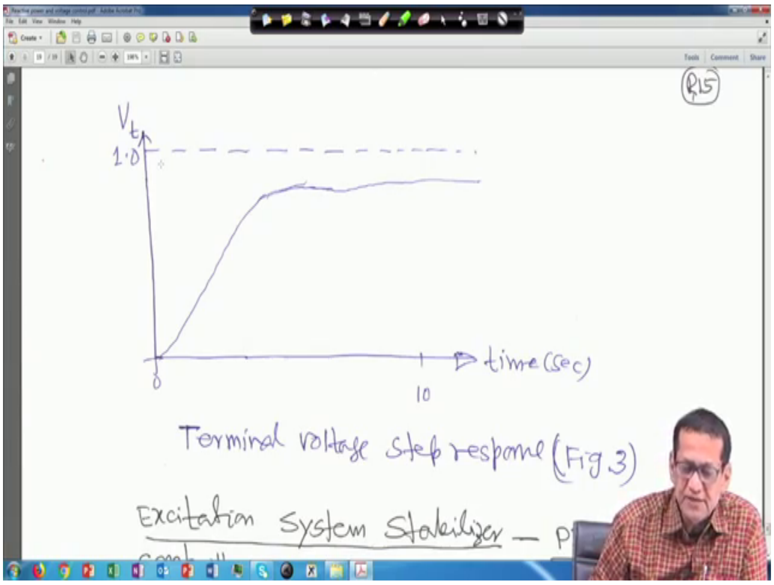

Now, if you plot that that terminal voltage V t, right. So, it is up to 10 second and this is V t is equal to 1.0, so you will find that there is no overshoot here, there is no overshoot here, but it is settling to some value say in early 0.9 we have saw you see I just you have seen that it is 0.909. So, it is 1.0, but still not still not achieving to 1.0, but it is showing 0.909. So, this is terminal voltage step response, right. So, this is actually I think it will be figure 4, not figure 3, previous one was figure 3, right.

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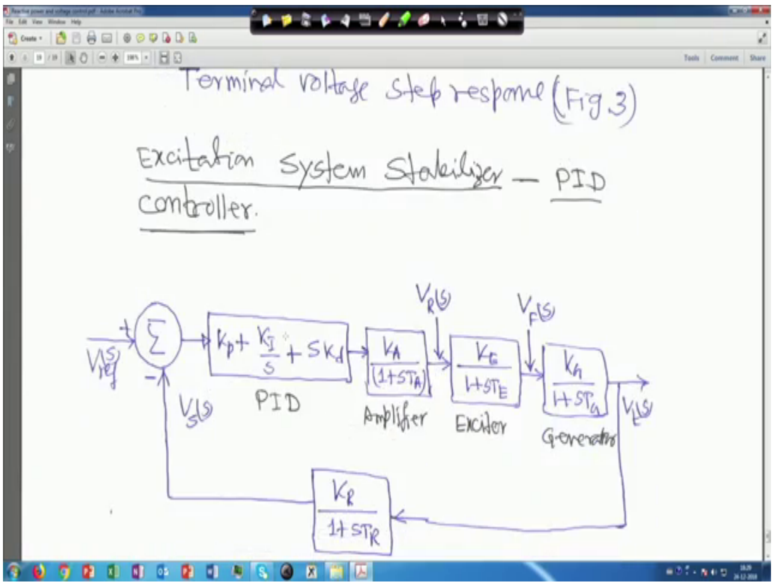

So, next is that your next is your excitation system stabilizer that is PID controller. Now, if you use that one PID controller K p plus K i upon s plus S K d and this is your as usual amplifier x tighter generator and this is V t s, no, no stabilizing or no stabilizer is here. That is no stabilizing transformer is connected here, right. And this is a PID controller. So, optimization nothing will be discussed here, just we will see how the response is for a particular value of K p, K i and K d, right.

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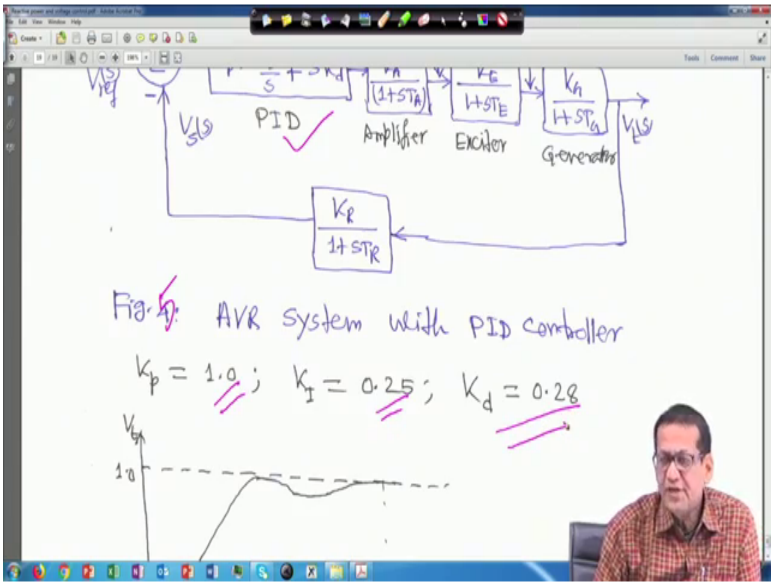

So, this will be then your figure this will be then your figure 5, they are not 4 just check it correct it. So, figure number is not a problem our thing is that look into that. So, suppose K p is equal to 1, proportional gain is 1 for that PID controller, K i is equal to 0.25 and K d is equal to 0.28 this is this you have taken we have taken. If you see this then you will find that your; just hold on.

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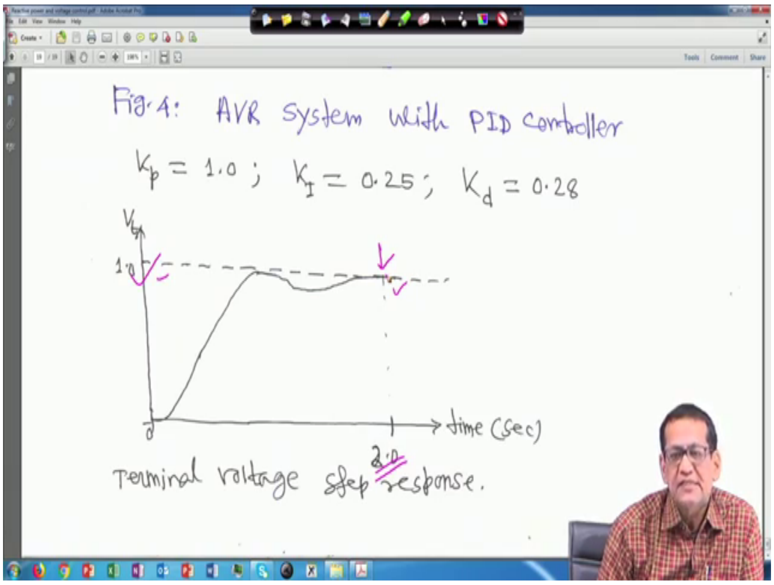

Then you will see that that V t that is that is your 1.0, so that with PID control and it is actually settling to 1.0. So, then it is actually at settling nearly 2.0 second, right and this is terminal voltage step responds. No figure number for this one, but it, but there is although there is no overshoot here, right. There because of derivative action oscillations have been wiped out and there is no your what you call that overshoot, you know overshoot and in set links here somewhere near nearly 2 seconds. So, when you are putting PID controller you can see that your settling time is very less, right.

So, with this your reactive power voltage control this much, but if I do not I do not think time will permit. If permits I will see that that how AGC system and excitation system and p, f and q will look how to how to couple it, right. Although coupling effect is negligible, but how to couple it if time permits I will make it for you, right.

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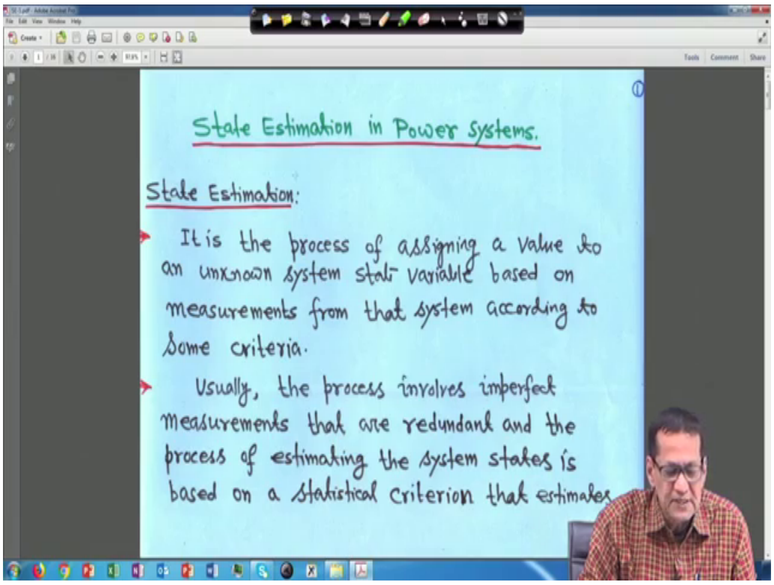

So, with this next one is that you are state estimation. Just hold on. Next one is that your state estimation. So, in this case, so what is state estimation and state estimation in power system. Actually, what happened just if we start with this that when you are suppose what you are doing in experiments in the laboratory you have so many meters like voltmeter, ammeter, Watt meters, and other types of meters. So, when you are taking the reading using all these instruments you will find that there must be some error because you cannot take the exactly the reading, right.

Suppose, when you are collecting or your trying to take readings of Watt meter, voltmeter, ammeter, you will find the pointer actually oscillating around some point that is the around the your what you call that your exact reading, but ultimately whatever reading you take this is a it is not a correct one because measurement error is there. This is one thing. And another thing is if you I am not sure that you are anything is written or not, and the your what you call instrument the accuracy sometimes it may be given the accuracy is the plus minus 3 percent or plus minus 1 percent, right. So, that is actually accuracy means it is a 3 sigma, that is if you have a normal distribution it is a 3 sigma and that is basically a standard deviation, right.

So, whenever you are measuring certain quantities that it has some error, right. It is not correct one, it is not the exact one, right. So, sometime measured value we will call it as a true value. And there are many state variables are there and you are taking measurements, right, but those measurements have error, right. So, we have to find out some methodology such that we can estimate those parameters it is as close as the true value (Refer Time: 12:34) correct value, right that is the idea. So, that means, a state estimation it is the process of assigning a value to an unknown system state variable, right based on measurements from that system according to some criteria, right. We will see what is that criteria.

So, that means, idea is that assigning a value to an unknown system state variable based on measurement from the system according to some criteria. That means, you are measuring the value, but those measured value have error, right it is not a correct one, but using those data that measure data we will try to estimate this value which will be as close as the correct value, right. So, this is the idea for state estimation. Actually, state estimation concepts first developed for aerospace engineering, right.

After that in at the end of your see 1960, right; so application came to the power system and after that people are found that this technique is very useful the state estimation concept is very useful, right. So, you may have suppose you may have assumed your what to call sometimes suppose you have none number of state variables are known to you, how many state variables you have to estimate, sometimes number of measurements are more the number of state variable, sometime number of measurement less than number of state variables and sometime number of measurement is equal to number of state variables. So, the because of this you have a different type of concept and different type different type of mathematical derivation, right.

So, usually the process involved imperfect measurement that are redundant and the process of estimating the system states is based on a statistical criterion, right. That actually estimate the true value of the state variables. True means in this case we will call it as a measured value, right to minimize or maximize the selected criteria, right.

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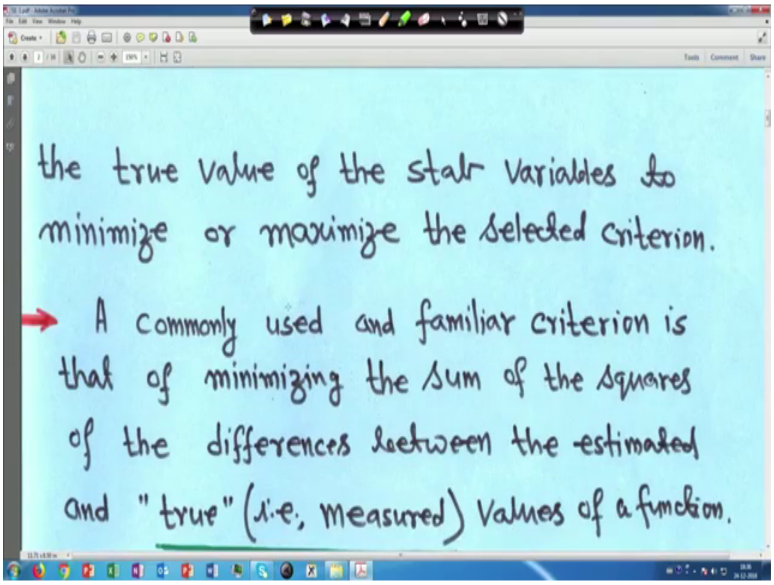

So, a commonly used and familiar criteria is that of minimizing the sum of the squares of the differences between the estimated and true that is measured values of a function, right; we will see that. So, this is actually your what you call that true value means will define it that is a measured value.

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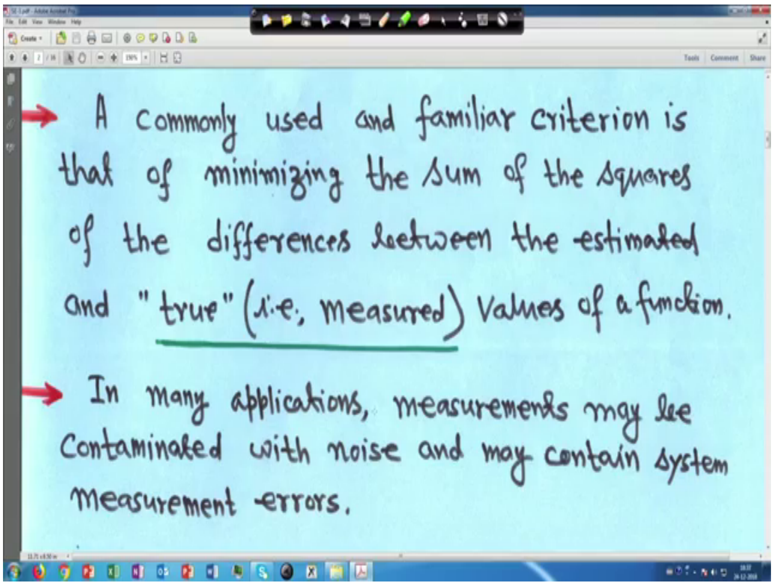

So, in many application measurements may be contaminated with noise and may contain system measurement errors because it may not be correct one, measured value may not be correct one it has some errors and if you have your; it is the last system. Suppose if you have last system say 100 plus problem and if you are measuring that all the buzz voltage magnitude, right even each buzz voltage magnitude some error will be there small error will be there, but if you see 100 buzzes are there then cross error will be high, right. But we have to estimate up using those measurement data we have to estimate those mass voltage which will be as close as the correct value, right that is the idea for state estimation.

And generally state estimation have two types, static and dynamic. So, in our in this course we will study the static state estimation, but not much in detail, right. So, many things are there which cannot be solved in the class particularly for AC state estimation; it is impossible to solve in the class you need computer, but we have to see things that we can solve in the classroom, right.

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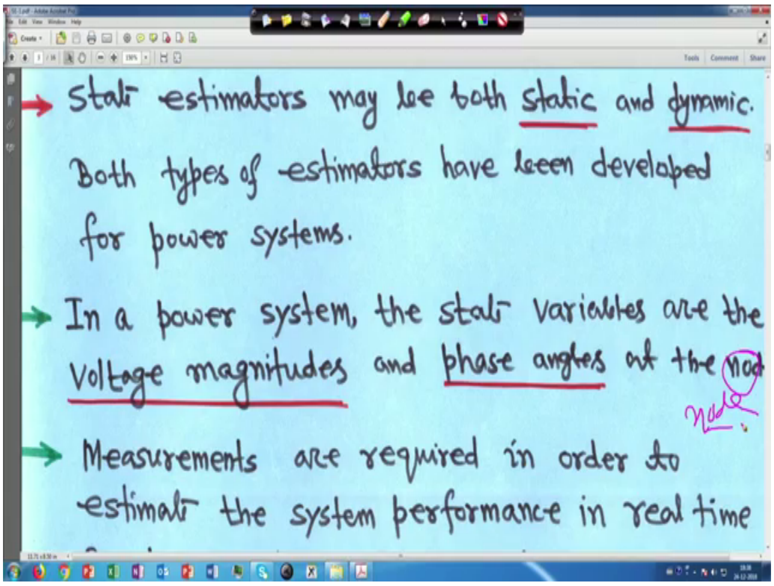

So state estimation maybe both static and dynamic, right; so, both type of estimators have been developed for power system. In a power system the state variables are the voltage magnitudes and phase angles, right. At the node actually here that e e at a during scanning that e has cut actually it is no, right or buzz. So, basically it is not only the voltage magnitude and phase angles, but also the power the megawatt real power the reactive power omega bar or that MVA that that is your mega volt ampere or that transformer tap changes setting, right. So, all these all these things are there, so, but here will you that we will see they are when we will consider the AC state estimation for AC network, right. So, voltage magnitude or phase angle at the node or buzzes, right.

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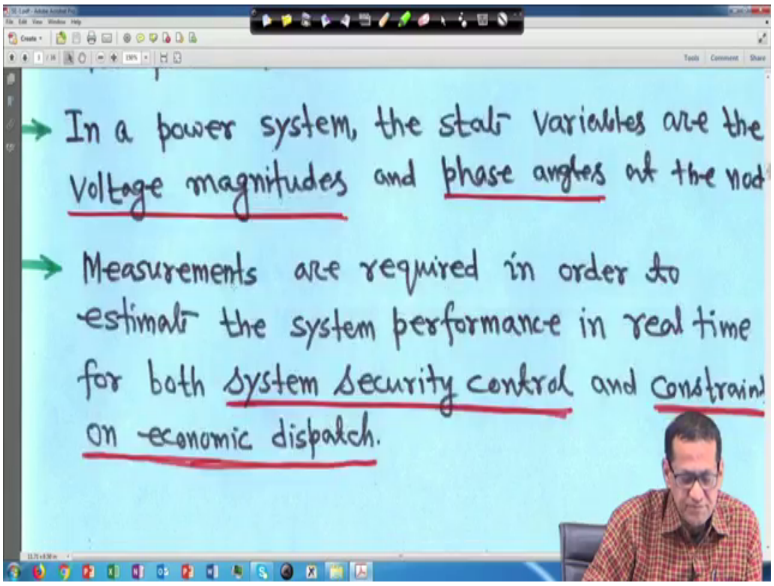

So, measurements are required, measurements are required in order to estimate the system performance in real time for both system security control and constant on economic load dispatch, right.

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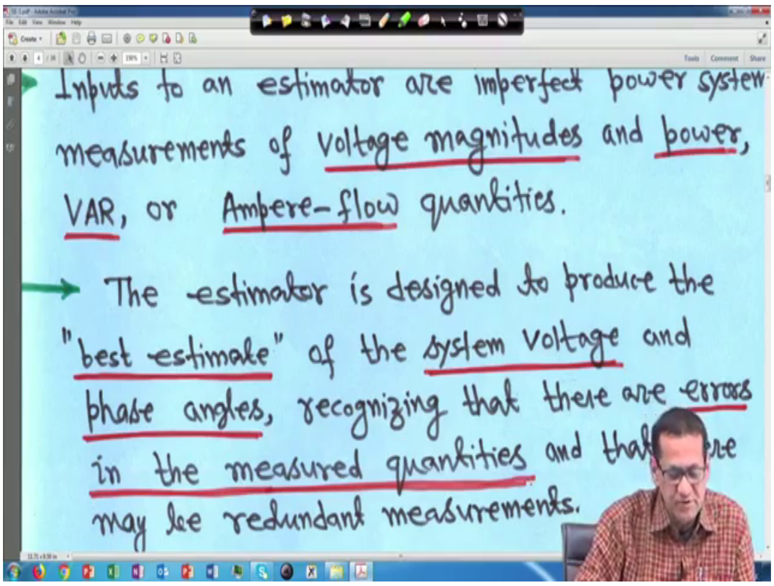

So, inputs to an estimator are imperfect power system measurement because when you are putting this where what you call input to the estimator. So, basically it is measurements are not correct, we are assuming that measurements are not correct and (Refer Time: 17:31), and voltage magnitude and power that is our volt ampere or ampere flow quantities, right.

So, the estimator is designed to produce the best estimate of the system voltage and phase angles say, right; so recognizing that there are errors in the measure quantities. So, you assuming that whatever, whatever you are measuring through the instrument it has the error, right and that there may be redundant measurements also. So, suppose you have for example, suppose you have 3 state variables, but your number of measurement data are more, but we have to see that how to utilize that one, that we will see.

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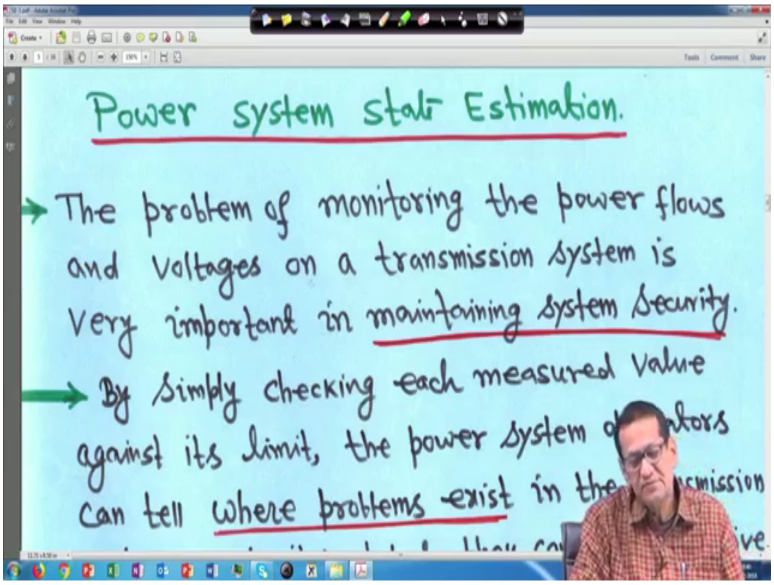

So, power system state estimation. So, the problem of monitoring the power flows and voltages on a transmission system is very important in maintaining system security, right. By simply checking is each measured value against its limit the power system operators can tell where problem exists, right in the transmission system and it is hoped that they can take corrective action to relieve overloaded lines are out of limit voltages, right.

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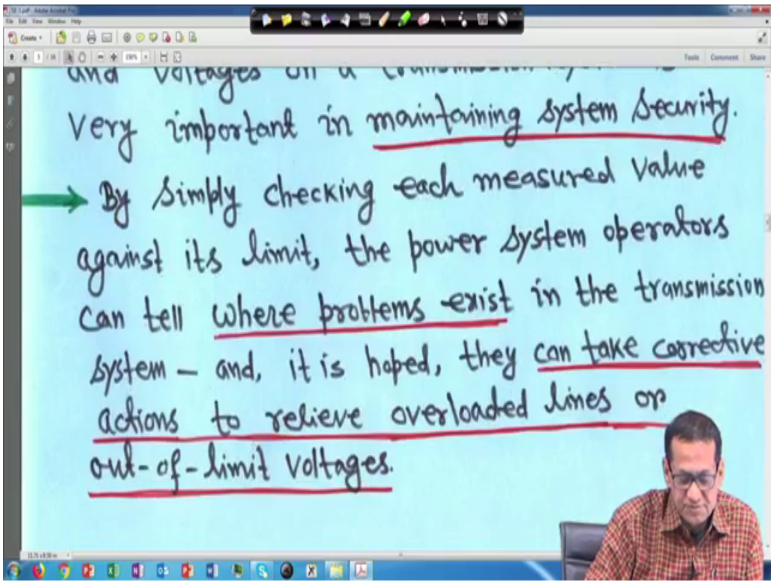

So, the here what you call the problem of monitoring the power here what you call power flows and voltages on a transmission system is very important in maintaining systems security. So, power system operators when they will see the overloaded, overloaded line or the or the buzz voltage are also crosses limit, so they can take the looking at that they can take that corrective action, right.

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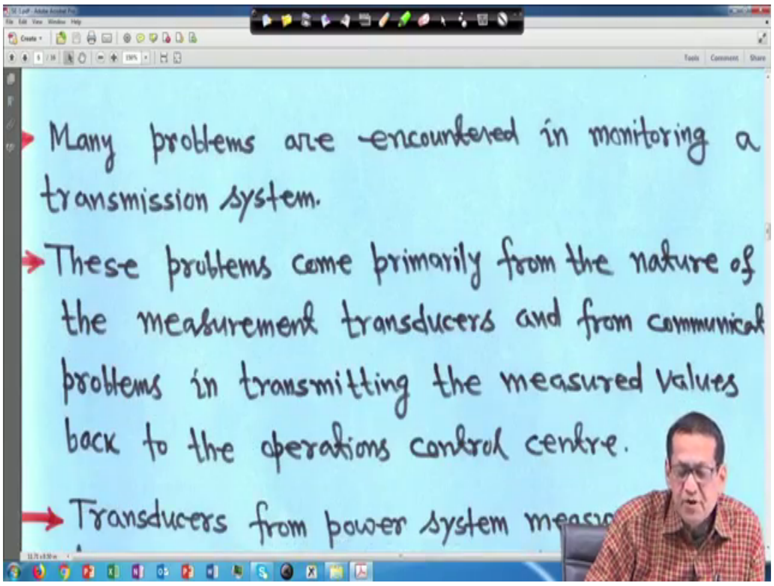

So, many problems are encountered in monitoring a transmission system. These problems came primarily from the nature of the measurement transducers and from communication problems, right, your in transmitting the measured values back to the operation control center.

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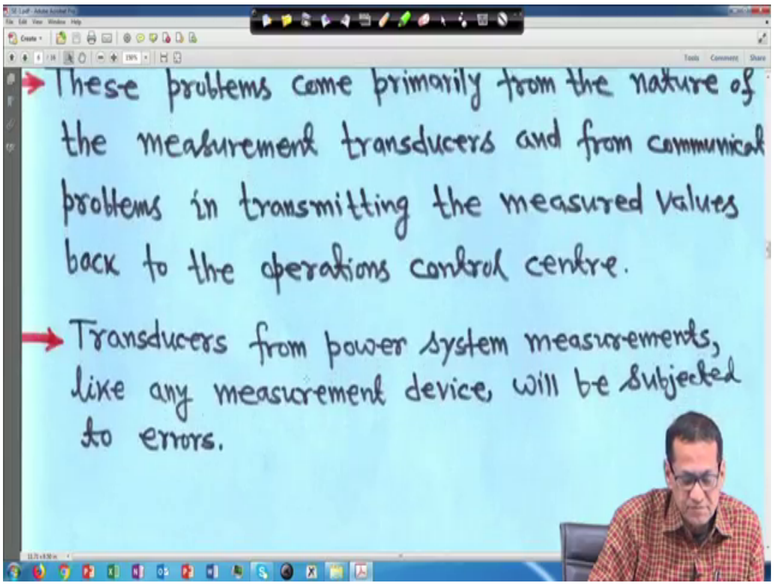

So, transducer from power system measurements like any measurement device will be subjected to errors. So, nothing is error free, you will have error, right.

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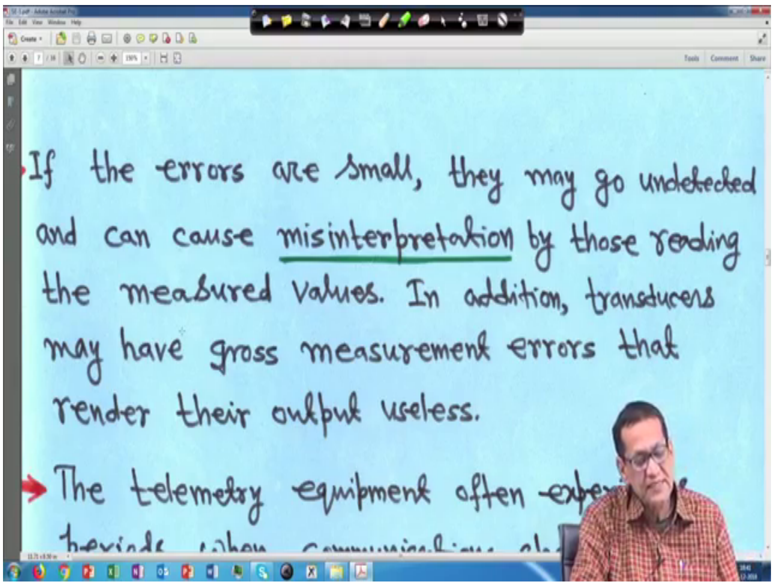

So, if the errors are small they may go undetected and can cause interpretation misinterpretation by those reading the measured values, right. So, even if the errors are small, they may go undetected and can cause misinterpreted interpretation by the reading of the measured values. So, in addition that transducers may have gross measurement errors that render their output useless, right.

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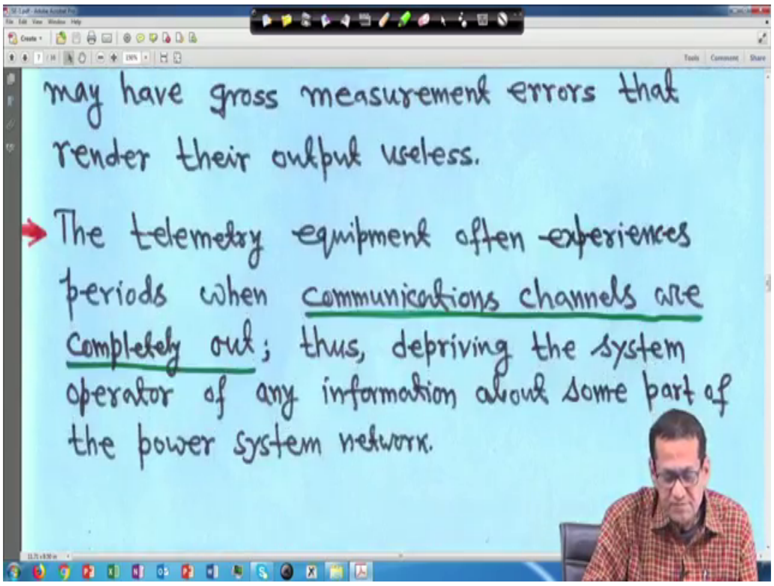

So, the telemetry equipment often experiences periods when communications channels are completely out this is another problem, right. Thus depriving the system operator of any information about some part of the power system networks; that means, that is actually, this call due to that communication channel failures, right. So, because data has to be transmitted to the control center; so it is for these reasons that power system state estimation techniques have been developed, right.

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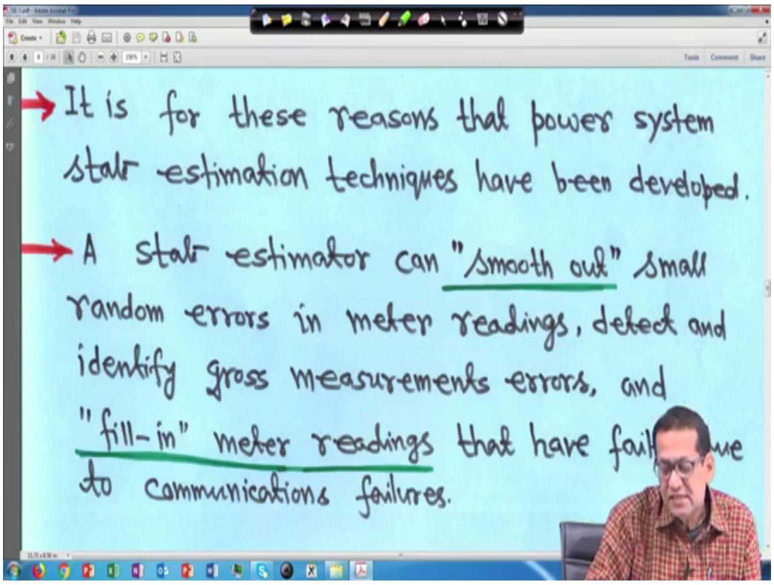

So, state estimator can smooth out small random errors in meter readings detect and identify gross measurement errors and fill-in meter readings that have failed due to communication failures. So, this is the important thing for your what you call state estimation in electrical engineering particularly in power system, right.

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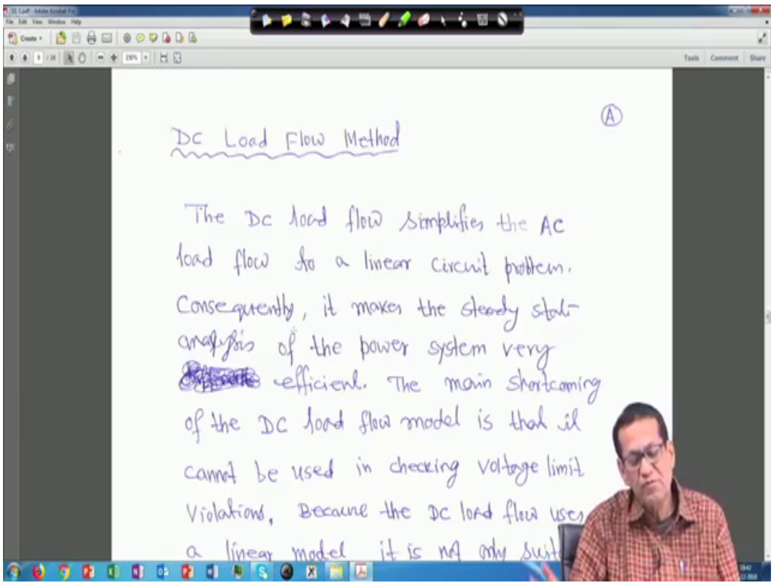

So, before that actually when we will go for state estimation mathematical thing that we will start with a DC load flow method, right DC load flow. That is why I thought before moving further little it has little bit discuss about that the; what is DC load flow, right.

So, the DC load flow simplifies the AC load flow to a linear circuit problem. Those who have gone through that you are a little bit on DC load flow they know it, but here I will make it in brief not in detail very simple thing.

Consequently, it makes the steady state analysis of the power system very efficient quickly you will get the result although results may not be exact, but it helps a lot, right. The main shortcoming of that DC load flow model is that it cannot be used in checking voltage limit violations, right. So, voltage limits violations you cannot check it because the DC load flow uses a linear model, it is not only suitable to efficiently treat the problem of your line outages, but is also suitable to form linear optimization problem. So, it is directly you will get the solution, right.

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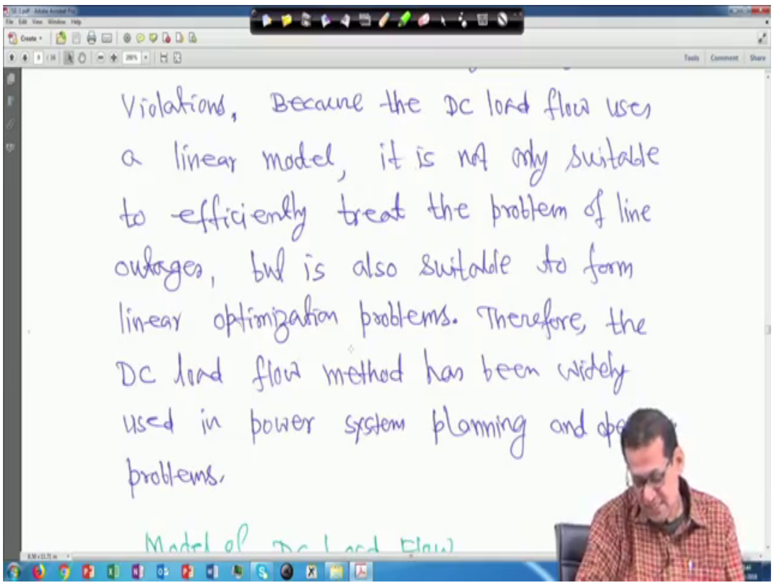

So, no cost no iterative method whatever little bit will study. Therefore, the DC load flow method has been widely used in power system planning and operating problems.

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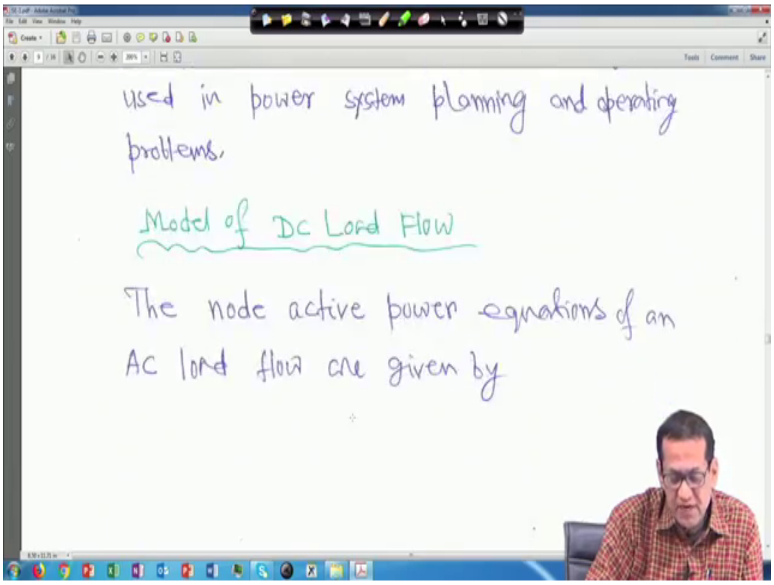

So, here also for state estimation we will see first DC load flow. Now, model of DC load flow the node active power equations of an AC load flow are given by, right.

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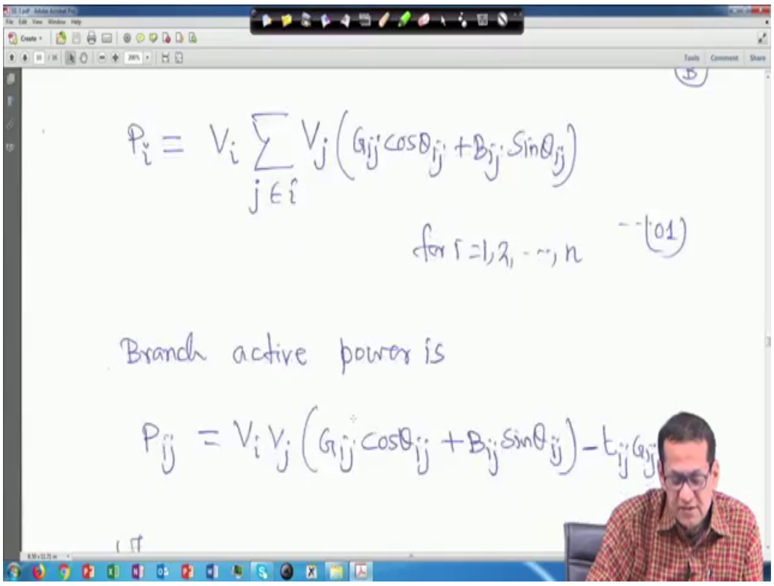

So, different book has different convention. So, here I have taken some convention actually whatever convention is there you can take it no problem, right. So, that power injection P i is equal to you know that V i then j belongs to I, so V j, G ij cos theta ij plus B ij sine theta ij. It depends this sign before V ij depends on V is negative and positive that is whatever way you studied does not matter, final result will remain same. For i is equal to 1 to n, this is equation I put 0 1, right.

So, later will make 1 2 3, but the separate node has been made, so it is 0 1. So, branch active power is that is a power flows from branch i to j it is V i, V j then in bracket G ij cosine theta ij plus B ij sine theta ij minus t ij G ij V i square, right where t ij the circuit transformer ratio per unit branch ij, right per unit of branch ij. So, this is that circuit transformer ratio sorry and theta ij the phase angle difference across branch ij, this is your theta ij.

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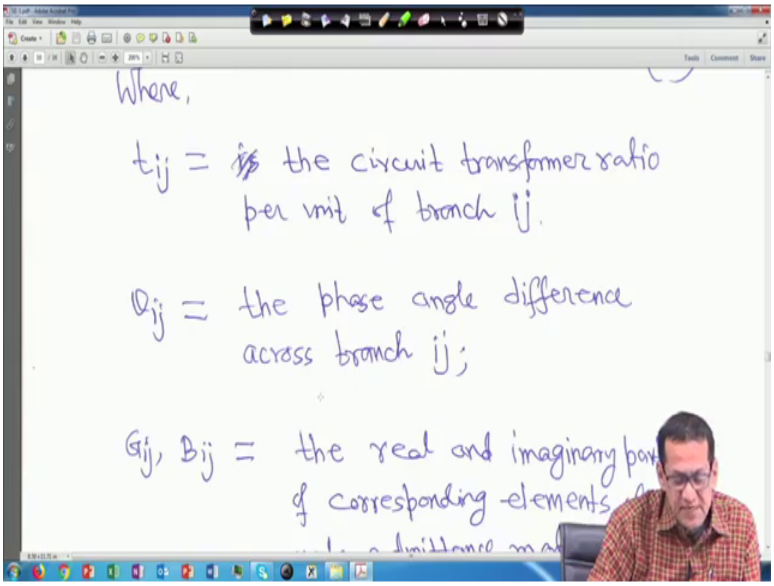

And G ij, B ij both the real and imaginary parts of corresponding elements of the node admittance matrix respectively this you know conductance and susceptance, right. So, and theta ij we know that theta i minus theta j this is equation 03, right.

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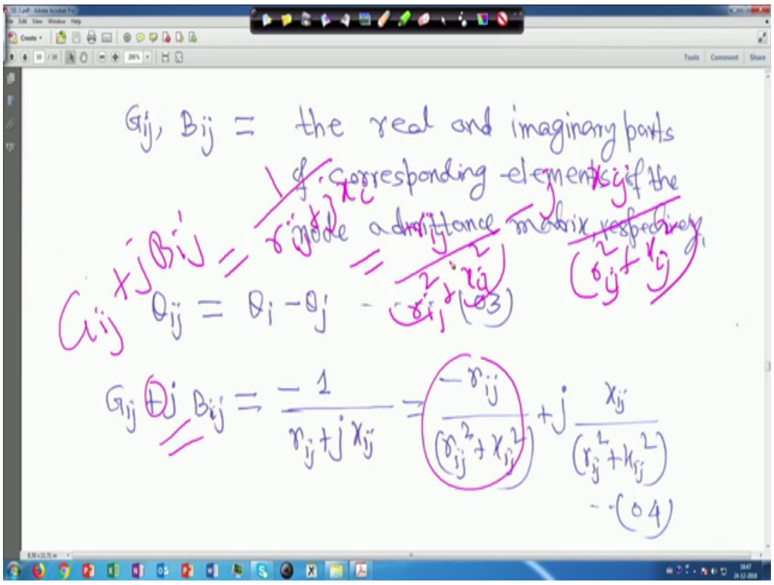

Now, we will define something that G ij plus j B ij is equal to minus of 1 upon r ij plus j x ij just we have defined, generally it is I told you this sign actually depends; however, you take. So, we are taking if you take minus then minus 1 upon r ij plus j x ij. So, this part will be minus r ij upon r ij square plus x ij square plus j x ij divided by r ij square plus x ij square.

This I have taken later we will see that we will simply take that your G ij plus j B ij, right is equal to actually it is 1 upon r ij plus j x ij that is nothing but your r ij divided by r ij square plus x ij square. Then minus j x ij divided by r ij square plus x ij square, right but here we have taken a minus from the convention the way I think different book might have taken different thing, right. So, does not matter later we will see that; we will use these convention only, right here what you call for your B ij.

So, in that case suppose for this case suppose if you just neglect r because for transfer (Refer Time: 25:36) just for the here what you call simplicity suppose if we neglect r because transmission line the r is very small compared to x. So, let us neglect r.

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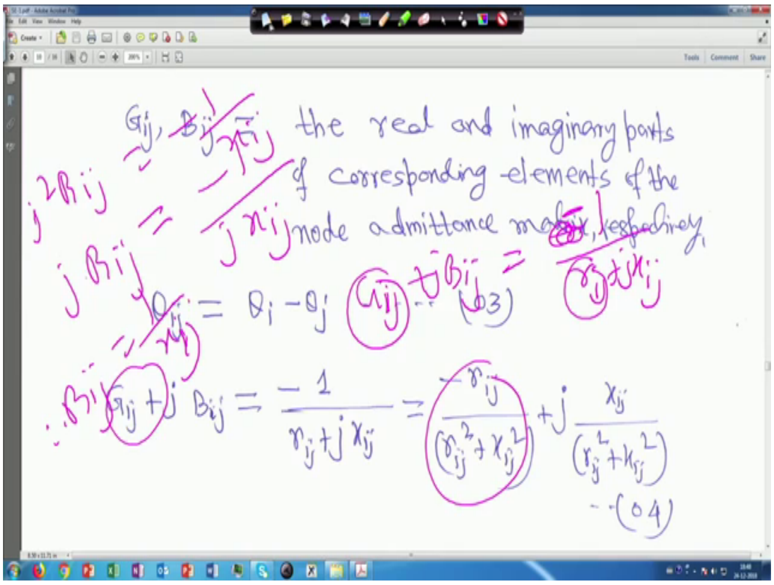

So, if you neglect r then the G should not be there if you neglect r, G should not be there, right. So, in that case your what you call we write like this that your G ij, right plus j B ij is equal to say if you write like this minus 1 upon forget about minus 1 upon r j plus j x ij, right. If you write like this and keep it minus it does not matter keep it 1 upon r ij plus j x ij.

Now, as r is neglected, so r should not be there here. So, G also should not be there, there because G is equal to this much and r is equal to 0 say this neglected. Therefore, what we will see that j B ij is equal to actually it will become 1 upon minus 1 upon j x ij, right. Now, if you cross multiply then I am over writing on it, right then it will be j square B ij, right is equal to minus 1 upon x ij, right.

That means, j square is minus, so minus minus will be cancel both side, therefore, your V ij is equal to 1 upon x ij, right. So, r, later we will see that for DC load node r will be neglected.

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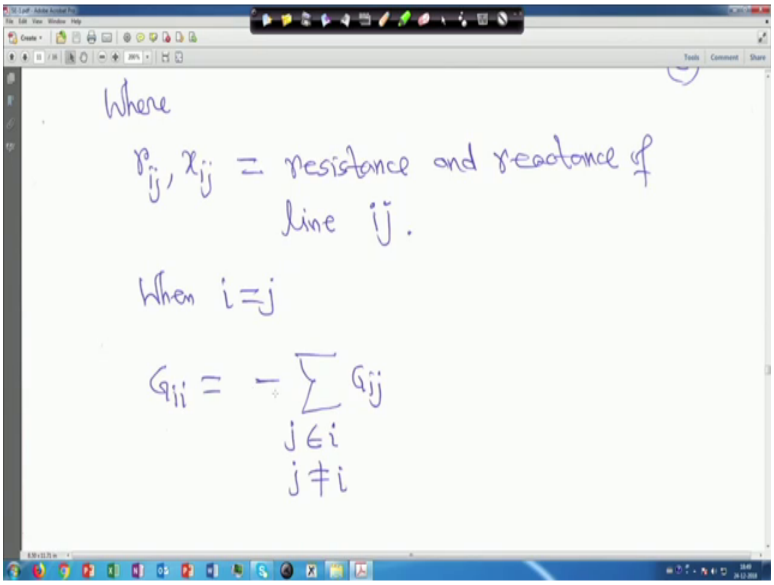

So, with this that you are, so where r ij, x ij resistance and reactance of the line ij or branch ij respectively, when i is equal to j G i will be is equal to sigma minus your sigma j belongs to i, but j not is equal to i that is G ij, right. So, minus sign will be there before that.

Thank you very much. We will be back again.