Automatic Control
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Lecture – 03
Design Process

So, welcome to the lecture on automatic control system. In this lecture, we are going to discuss the design process for a control system. So, in the previous lecture we discussed that, there are certain design objectives for a control system like transient response steady state error and stability. So, we can deduce some process for design. Because design is a process for any system. And when it comes to a control system, we should have some process that must be followed.

So, a control system of course, it is a physical system, consisting a process or a plant. And some other elements, they they have certain functions. And there are each controller that has certain functions. So, it is a physical system that has been evolved from the design of a system. Now if we have an existing system existing physical system, how we should analyze, or if we have some idea of a physical system how we should start with to analyze this system and redesign this system.

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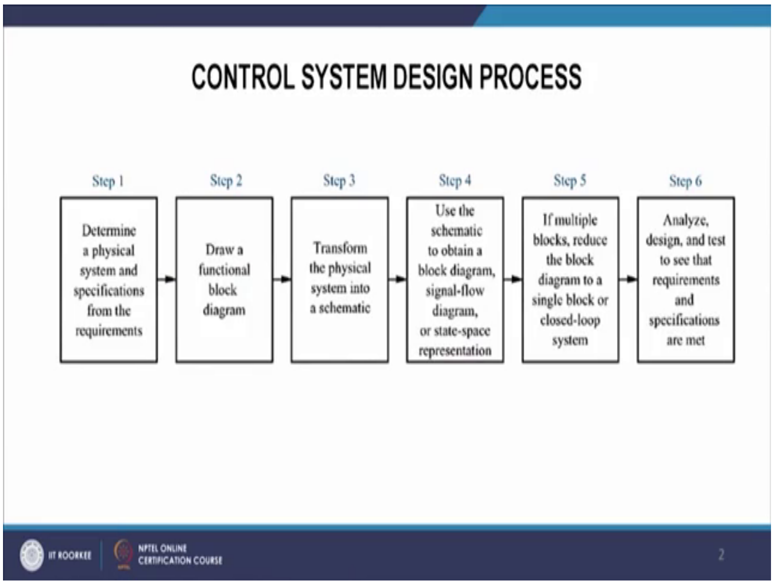

So, we can see here. So, control system design process it has certain steps. So, the first step, step one ; that is, physical system specifications as per the requirements..

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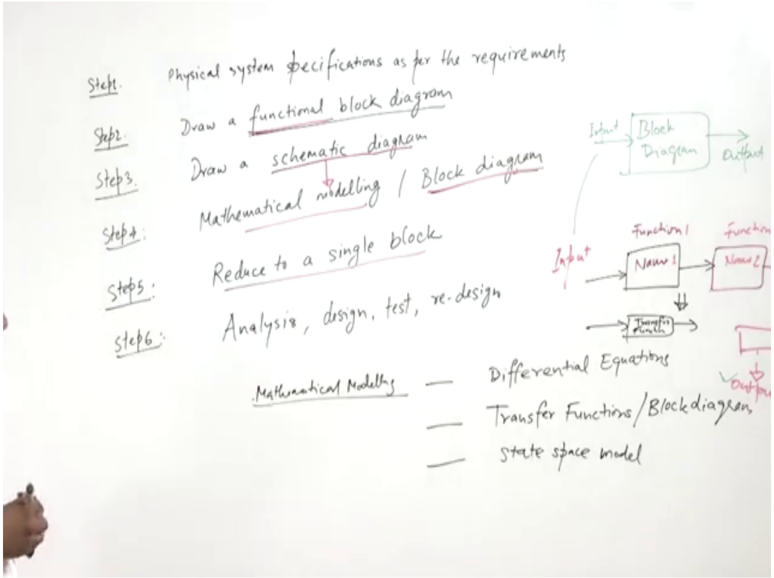

Step 2 is draw a functional block diagram. Step 3 is draw a schematic diagram. Step 4 is modeling. Let us say mathematical modeling, or oblique block diagram.

Step 5 is so, if there is multiple block we can reduce to a single block. Step 6 is analysis design and test, re design . So, these are the 6 steps to the as a design process for a control system. So, step one we have an existing physical system or existing system. And we have to upgrade, this system because this system is not going to meet the required output desired output or the specifications.

So, we have to upgrade this system. So, we have to redesign the control system. Or if it is a new system it is in form of idea, and we are going ahead with that idea. So, we get some initial rough idea of the system, some components and assemblies. So, we have some physical system. And we expect certain specifications regarding the performance, because we discussed that we have some basically 3 performance especially specifications. Like transient, response a steady state response or a steady state error and stability.

So, if we have a physical system, and we can set the specifications in the first step for the control system. And then step 2 we will draw a functional block diagram. So, functional block diagram, we know that this system will be made of several components. And each component we can represent as a block. So, we can represent as a block. So, this is a block. And a block has certain input and certain out output. Because we know that a control system is again the assemblies of certain components. That are assembled such a way that they will perform certain functions, desired output, desired performance at a specific input.

So, each component will have certain input certain output. This output will go in some another component as a input. And then, that system subsystem will give certain output. So, we for each of the component we will make a block diagram functional block diagram. Here there is a difference between block diagram and functional block diagram. So, this is a functional block diagram.

We will name the component and it is function. So, here the name of the component and it is function. What is it is function? We will write like this. And we will represent this physical system in terms of as a continued continuous assemblage of the functional block diagram..

So, the next system so, then here second system, then function what is it is function and so on. We will make this block this functional block diagram. Then the step 3 a schematic diagram. So, from the physical system, for each component we will make a schematic diagram. So, what is a schematic diagram? So, we know that a component can be a mechanical component. It can be electrical component or electronics component.

So, mechanical component such as it would be a spring, damper, some mass, inertia. Electrical component it can be a motor a potentiometer, some electronic component it can be a amplifier or power amplifier some controller. So, each of these components we will make a schematic diagram. Means, we will represent it as a mass inertia, resistance if there is a resistance we will represent as a resistance, inductance.

So, we are going to more entering into the inside that component. And representing the actual elements of that component. Now when we make a schematic diagram, in the first diagram of the design process, we can make a simple schematic diagram. For example, if we have some potentiometer, know that potentiometer has certain friction or inertia. We can neglect this in the beginning.

We can assume that potentiometer is functioning instantaneously giving the voltage without any inertia without any friction. And we will get that a schematic diagram, and similarly for other components. Once this schematic diagram is made. From this schematic diagram, we will come to mathematical modeling. Because we have defined each component in terms of it is basic elements. And each basic with certain assumptions we have neglected some non-linearity we have neglected some mass, inertia.

We are neglected some friction. So, we have a simple schematic diagram, and for each of these elements, there is some mathematical models, mathematical functions. And so, we will do mathematical modeling. And the mathematical modeling is this mathematical modeling can be done in various ways.

So, these mathematical modeling, we can use the differential equations . So, we can use differential equations. If there is a mechanical system we can apply newtons second law, and we can get the differential equations for for this system. If there is electrical component we can apply Kirchhoff's laws of current and voltage. And we can get again the differential equations for the system. Or we can use frequency domain approach like transfer functions or block diagram. Because block diagrams, if we convert these in a block diagram we will represent here the transfer function in this block .

So, this is transfer function. So, this is block diagram, that contains the transfer function of the system. We will discuss transfer function in detail in the in some next lecture. But here you we should understand that we convert in this step 4 the mathematical model, we can make either by differential equation with transfer function block diagram. Or some state space approach, it is state space model.

So, this is the these transfer functions approach is valid for linear time invariant systems. But if state space approach or state space model is valid for also for non-linear and time varying systems. So, these are few models modeling approach, we can use any of these. So, here we will use transfer function or block diagram approach in the beginning of this course. As it is much intuitive approach, it gives more information, more graphical information's and quick information.

So, this is schematic diagram from we get the block diagram. Now this system can have several blocks. Because one block for each component. And so, there could be several blocks. And these several blocks there should be one main input, and the last system will give the final output. The last component to output will be the final output of the system, and the first components input will be the main input of the system a specific input.

So, these several block diagrams, we can reduce in a single block diagram, in step number 5. So, we can reduce these block diagrams in a single block diagram. And that has this input and this has this output. So, it means this block diagram is for complete system. And so, we know that this is the input we are giving and this is the output. We are via this is a specific input that we give to the system. And this is the output that we are going to get from that system. And so, this is the step number 5.

Now, analysis design taste redesign. The last step 6 we do analysis, we said that analysis is a process through which systems of performance is assessed. So, we give input and we get output, and we see what is the response of the system.

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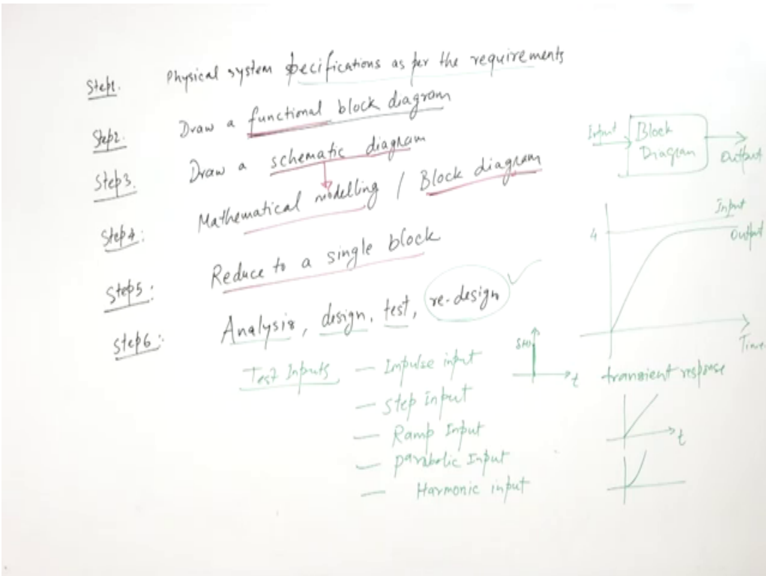

So, we are going to get the response of the system. So, from this response, we are going to give input and we are getting the response. From this response we will see whether we are going to get the desired response and the desired specifications that we required. The specifications that we required are we going to get these specifications or not.

Now, here in the design process, we should understand that in the design process we do not know exactly what input we will get from the in the practical applications. So, there are certain test inputs, that we must use. So, the test inputs. So, that could be impulse input, there could be step input , there could be ramp input , or parabolic input or harmonic input .

So, there are certain test inputs. Like, impulse input, step input, ramp input, parabolic input, harmonic input. And these different inputs give different performances specification, information of the different specifications like impulse input. So, we give some impulse at this time t equal to 0, we gave some delta t very high value. And it will give the transient response. Impulse will give the transient response of the system and so, the information about the transient response transient specification of the system.

Similarly, step input this is the step input. We give certain constant value. And so, it will give the transient response as well as a steady state response both information. This step input. Similarly, ramp input, ramp it input with time. So, ram will give the information about steady state error or a steady state response. Similarly, this parabolic input will give also the steady state error. And harmonic input that is if we give sin omega t a sin omega t as the input. It will give us both the transient as well as a steady state response information.

So, we can give these inputs and we can see the outputs. And we can see that whether the system is going to give the specification that we required or not. So, we analyzed this is analysis we are doing. Reality design, and we test because we are we giving test inputs. If not, we will redesign, how we will redesign if not, because this block diagram will contain each components parameters. Because this block diagram is coming from the functional block diagram, that each component had has some parameters. And so, if we change that parameter what will be the change in the output.

So, in this way we will be able to redesign the system. Now we take one example and we will discuss this process. So, here let us take an example of antenna azimuth position control system.

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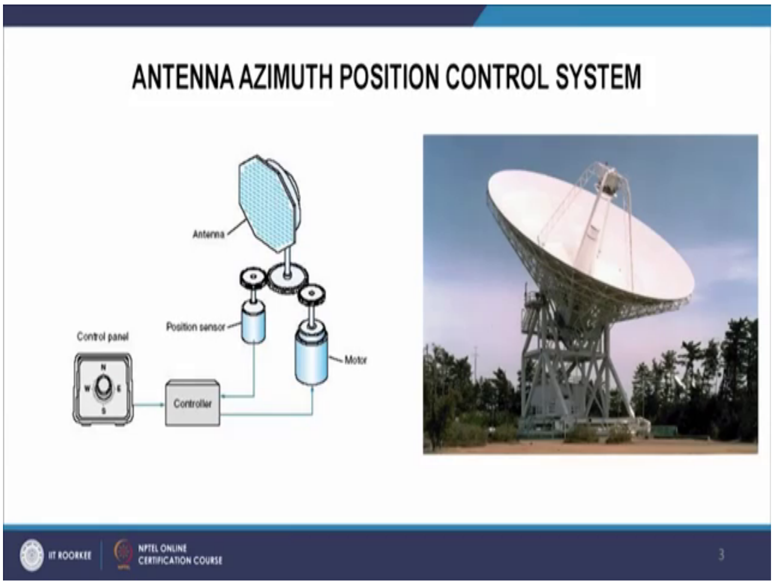

So, this is a radio telescope antenna, and this is your physical system. We have certain requirement of the performance specifications of this system. Suppose, this is a system we want to see the effect of a particular system parameter on the performance of the system.

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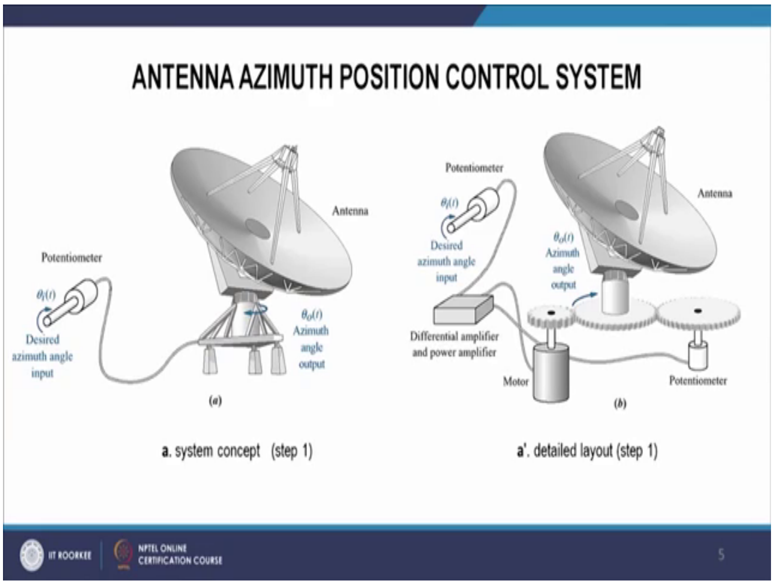

So, we have a physical system, now you see in this antenna, we are giving a input, that is desired azimuth angle input at the input of the potentiometer. So, there is a potentiometer shaft and and that shaft we are rotating. We are giving some angular input. And we want to get the output, angular output that is the positioning of the antenna. So, that output we want to get eye space desired output. That if we give certain specific input that antenna should give the desired output angular output.

Now, how to analyze, how to design this system using the design process of the control system. So, here we can see the first step. The system concept physical system. We have to define some specifications of the system as per requirement. So, we assume that we know there is some specifications for this type of system. So, if we have this physical system, we have to see what are the components of the physical system. Because this system is made of certain components. So, you can see here we have potentiometer here is potentiometer then amplifier a differential amplifier and power amplifier. Then there is a motor then there are the gear systems. And this gear system is connected to the shaft that rotates the antenna. And so, the output is coming at this shaft of this middle gear.

From this gear, there is another shaft that is connected to potentiometer and giving the feedback to this amplifier. So, this is the step one we try to understand the physical system. We try to express the system as a components physical components. Now the step 2 is functional block diagram. Now because you can see here we have made the functional block diagram.

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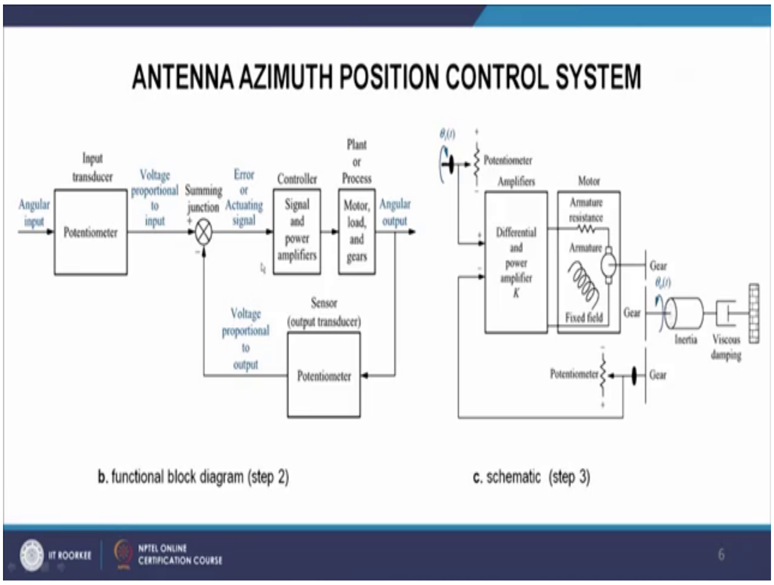

We have made the component and there funks the function.

So, here is angular input that we are giving to potentiometer. And there is some it is transducer that converts this angular input to a voltage proportional to the input. Then there should be some junction that is getting the error or activating signal. This signal is going to controller; that is, signal and power amplifier, and this controller now it gives this is our processor plant. That is motor load and gears. These are them the power is going to run these system. It is going to run the power motor.

Motor is going to run the gears, and gears are going to run the shaft of the antenna to position it at the desired angle. Now there is a feedback loop. This is a closed loop system you can see we the angular output is going to be feedback through potentiometer and back to the summing junction here. And this error again is going to feed in the controller. So, this is a function block diagram showing then the name and function of the diagram and flow of the signal. Now step 3 we are going to make the schematic diagram.

So, you can see here we are representing each component as the basic element like potentiometer. There is some resistance then power amplifier that is simply the gain. Then there is a motor here potentiometer we neglect the inertia or friction in motor there is armature armature may have also resistance and inductance. But we are neglecting the inductance of the armature. Then there is the fixed field here the gear we are representing this lines, gear as a lines, and these 2 gears. Then inertia and damping.

You see the antenna will have certain inertia. Because we are going to rotate to position the antenna. And there is some friction and this friction is represented as viscous damping, equivalent viscous damper. Again, this gear is connected to the gear through potentiometer giving feedback, that how much angle actually is rotated this system. So, this is step number 3 we have got the schematic.

Now, come to the mathematical modelling. Here we use the transfer function the block diagram. So, here is the block diagram. So, each component of the each component of the system is represented as a block. And inside the block is the transfer function of that system we will discuss transfer function in next class next some classes.

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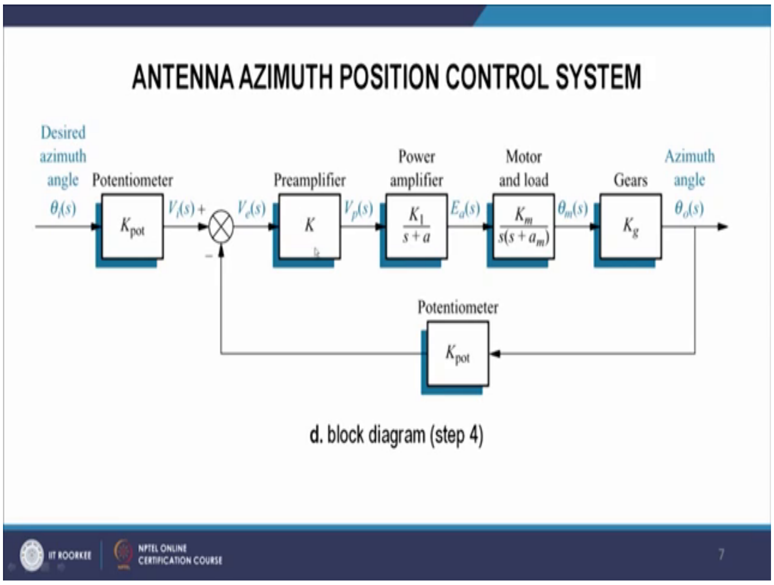

And so, there is transfer function each block has certain input, certain output. And that summing junction then input output. So, these each component can be represented as input output block diagrams.

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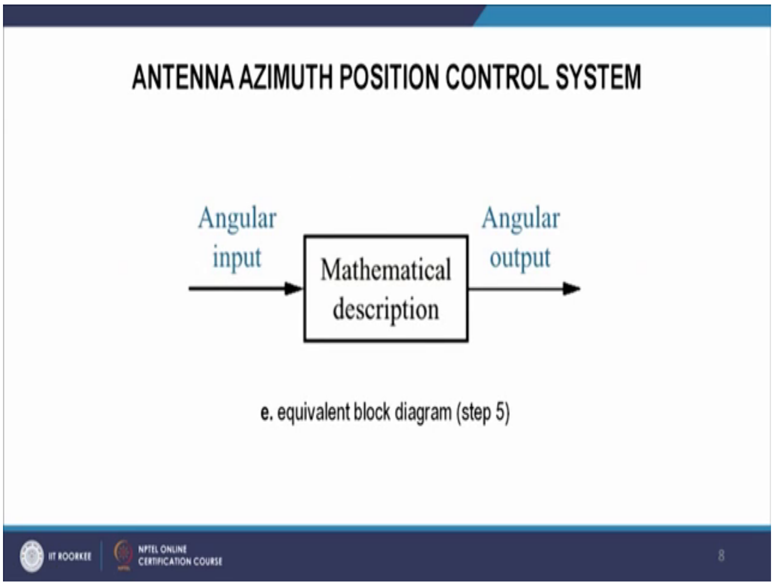

Now, this is step number 4. So, each step number 5 we reduce to a single block. So, we are going to get the equivalent block diagram, that represent the complete systems block diagram, complete systems transfer function in that block. So, here we only give input we are going to get output. Now this system we can and use for the analysis. Because this block diagram the transfer function will contain the parameters of the individual systems. And we can change a parameter we can see what is the what is the variation in the output.

How the output is changing? For example, we can see one example. You can see that the gain, gain of the amplifier.

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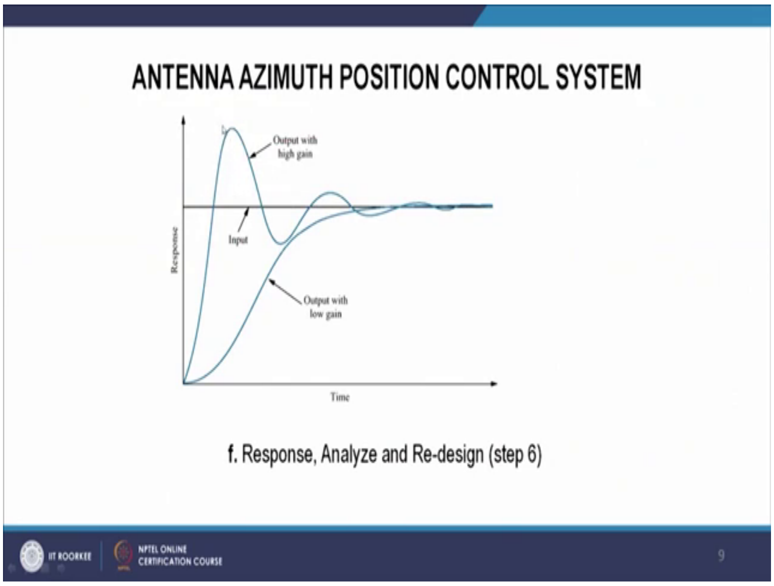

You can see if we have high gain this is our function the output, and if we have low gain. So, here gain means you can see here this is the amplifier gain k. So, this k we are changing if we are going to give high gain we are getting this. And if we have low gain we are getting this. So, why it is like, because if we have high gain means the, if there is error function coming multiplying to high gain. So, motor is running faster in this. And so, when motor runs the starts and runs faster it overshoots. The values it goes higher due to the inertia, and then it later it catches to the steady state value. But if the amplifier is gain is low, that you multiply the error between the input and output with this lower gain.

So, there is no value for the motor, and the motor will run slower. And so, it will not overshoot, but it will follow this curve. So now, you can understand that depending on we can measure the steady state error the transient response. And we can change the value of k and see the effect of the gain parameter on the response of the system. And so, if we are not satisfied with the response we can redesign, we can change the amplifier and we can redesign the system. So, again this we refer the books of Norman s nise and k ogata for this course.

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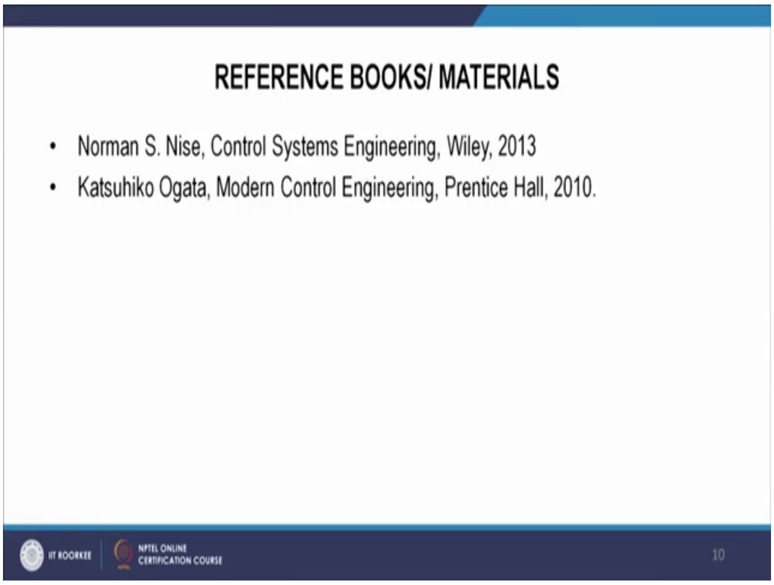

Thank you for your attention, and let us see in the next lecture.

Thank you.