Automatic Control.
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Lecture – 02
Performance Specifications

Welcome to the lecture on automatic control system. In this lecture, we will discuss about performance specifications. So, we saw the definition of the control system that, a control system should give a desired output with desired performance for any specific input. So, your desired performance, when we say desired performance, there should be certain parameters that measures the performance.

So, whenever we design a control system or we analyze a control system, we should have certain objectives. So, what is your design of control system? So, in a design of a control system, we create systems of performance. So, design is what? We want the system to give certain performance, and we are going to design a system for that. So therefore, a design is a process through which system's performance is created or changed. Changed means, if we have already an existing system and we know that, the system is not going to give the desired performance, then we need to change the design of the system so that, it is going to give an improved performance or desired performance. So, we are going to change the design.

In contrary analysis, analysis is a process through which we determine the systems performance; means, once we design a system, with the objective that the system that it designs will give the performance that we define at the beginning of the design. Now, whether it is going to give that or not, this is done by analysis. So, analysis is a process through which the systems of performance is determined.

So, every control system, there are certain analysis and design objectives. When we go to design a system, we should have certain objectives that the system should achieve. We know that, from the response of the elevator, that an elevator response with time. This is the input and this is the output or response. So, this is the transient part, this is transient and this is steady state. And there is the error; this is the steady state error.

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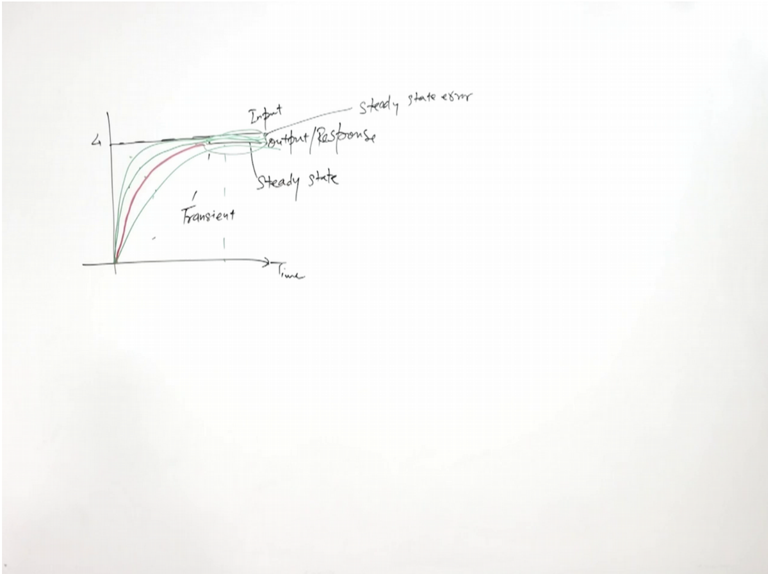

So, we see that this part, which is transient and steady state. Therefore, we should have certain design objectives for a control system. Whenever we try to design a control system, we should define the objectives of the design. So, objective of the design should be based on 3 main characteristics. First, is the transient response; we should achieve desired transient response. Because, the control system to definition is, we should achieve the desired output with desired performance.

So, we should get the desired transient response, we should get the desired steady state response. And then the third parameter that we are going to add is the stability. And therefore, based on these 3 design objectives, we have the performance specifications. These are the parameters through which the systems performance can be assessed. We can talk about the system’s performance in terms of these 3 parameters; that is, transient response, steady state error and stability.

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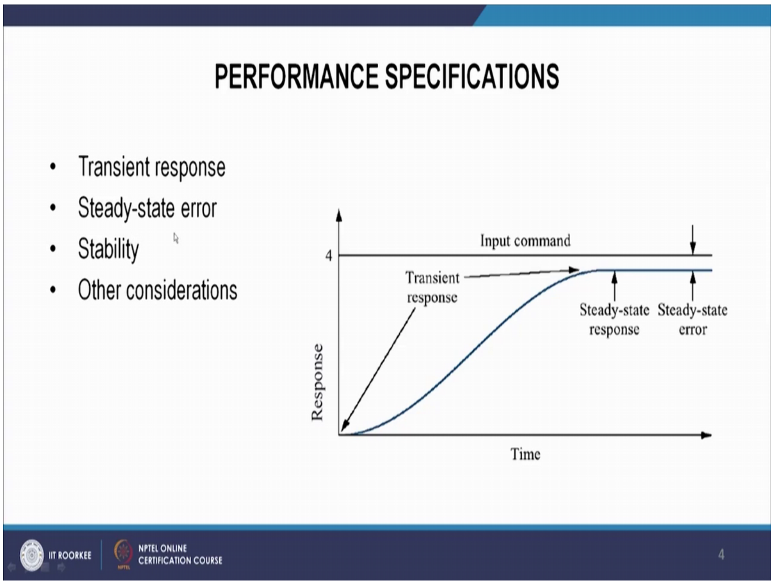

So now we understand that, these 3 things come into the design, and they are going to appear in the performance. So, that is why we call it performance specifications. Because, from the response we are going to decide whether the system, based on these 3 parameters, systems performance is correct or desired. There could be some other considerations that we will discuss.

So, let us discuss these 3 parameters, 3 specifications one by one. So, the first design objective should be the transient response. The first design objective of a control system is a transient response. We know that, if this transient response is very fast. If the transient response is very fast for this elevator, it could be uncomfortable or it can also physically damage some person or some parts of the system.

And if this is very slow, it will sacrifice the person's patience who are in the lift or elevator. So therefore, when we set the design objective, we should in the beginning, define what is quantitatively, that what is the transient response objective. How fast I want the response, what should be the characteristics of the transient response.

For example, this system, how fast we want, when we want to reach this, and this transient response. Because, this transient response can be also like this or it could be this. So, whether we want this, or this, or this, or this? So, you see in this case, the tangent response is very fast, suddenly the lift is rising; the elevator is rising to follow the input and it is very risky as well.

However, this takes much time, this transient response, so it increases the waiting time. So therefore, quantitatively we should define that, how much this time, in terms of time are some other parameters. Because, these parameters will depend on the type of the system, whether it is a first order system, second order system or higher order system. So, these systems have different parameters for this transient response.

And so, these parameters should be defined quantitatively and then, if we have a new system, we should set these parameters and we should go for the designing of that system. Or if it is an existing system, then we should decide that, how much change we should do in the system to get this particular transient response. And then, once we have set the objective of the transient response, we will adjust our parameters or we will change the parameters of this system so that, it will yield a desired transient response.

So, the system has it is own parameters and we change the parameter that transient response will change. So, once we have these objective that, this much change in the transient response I want or this much transient response I want to generate, we will change the design, we will change the parameters so that, the system is going to give that particular transient response. So, this is the first design objective.

Now the second design objective is, the steady state response; this part is the second part. So now, this steady state response is what that remains after the transient part has been decayed. So, you see, once transient is, this is transient, then when transient is gone, what we get is the steady state response. So, steady state response, how it affects the functioning of a system.

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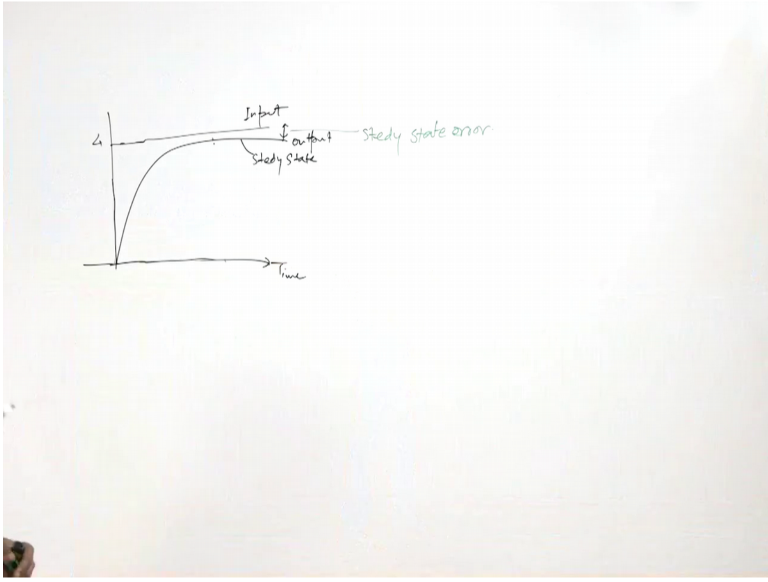

So, you saw that in case of an elevator, let me redraw this diagram. So, we can see that, this steady state response, this difference is a steady state error. And this steady state error means that, there is a difference between the labeling of this floor and the actual floor we are reaching through the elevator. So, this difference is more means, we are away from the floor that much.

So, the steady state error should be minimum and that is the good response if the steady state error range is minimum. So, steady state error is one parameter that can be allowed to control or that could be a design objective. So, we should define that, when we want to design a control system, we should define that, quantitatively how much steady state error we want, what should be the range of the steady state error of the response of our system.

So, once we have defined this steady state error, we should analyze if we have a new system, it is ok, we go on. So that, we can get this steady state error value. But, if it is an existing system, we should check what is the steady state error of the current system and then, how we can change the system so that, we could get the desired steady state error. And so, this steady state error is the second design objective and as well as this is one of the performance specifications.

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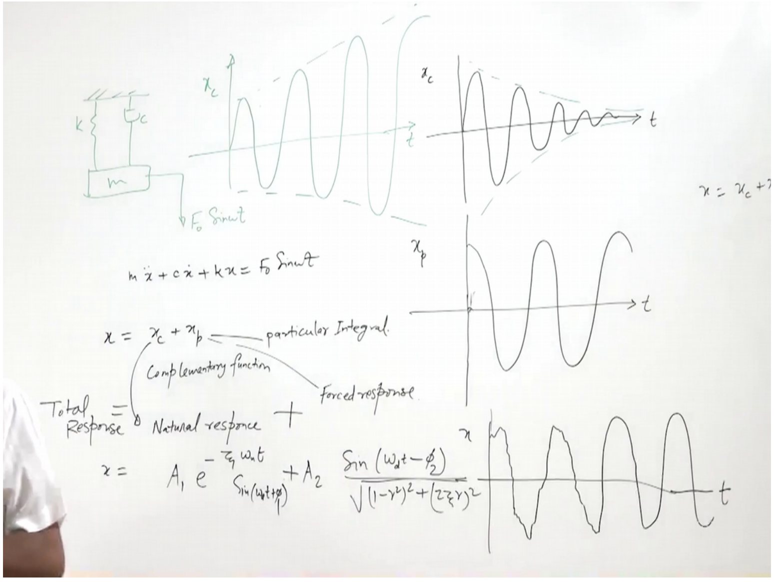

Now, we come to the third design objective and that is, stability. Now, what is stability? So, let us discuss what is stability. So, stability, you know that, if we have a system like this. So, if we have a system like this, spring mass damper system and it is subjected to some certain input that is, a harmonic force, we will get the differential equations, mx double dot plus cx dot plus kx equal to F 0 sin omega t.

When you solve this equation, so this x will be xc plus x p, that is complementary function and this is particular integral. So, this xc is your component that is also called natural response and this is a response due to the applied input, that is force response and this x is the total response.

So, what we see that for a dynamic system, if there is some input some force or any other type of input, the systems response is of 2 components, that is natural response and forced response. Now, why we call it natural response? Because, this response depends on the property of the system.

So, if we try to plot for this system the response, let us assume that this damping c is under damped system, so c is less than critical damping. So, this is an under damped system. For under damped system, if we give this response, this is xc and this is time t. So, this is the natural response. Now, xp or force response. So, this expression, x is given as A 1 e power minus.

So now, we can understand from this x, this is a solution of this and this is xc and this is xp. So, we can see that, here it is exponentially decaying and with harmonic functions. So, this is a harmonic function and the amplitude is decaying exponentially so, this is xc. Now, this is a sin curve. So, this is a sin because, this is a sin function.

Now, when we will get the x with time. So, x will be the xc plus xp. And so, this is the superposition of these 2 functions, so we add them and we will get something like this. So, in this you can see that, this sinusoid is when we add it, it is not the pure sinusoid, it is disturbed due to this part. Once this part is decayed to 0, we are going to get what is the xp. So, x is equal to xp, after certain time when this x is decayed to 0.

So here, when we talk stability, we talk in terms of the natural response, this is natural response. So, a system is stable if, with time it is natural response approaches to 0 and after certain time, the total response of the system will be the forced response. Suppose, the natural response is not decaying to 0, but it is like this.

So, with time, this natural response is growing. You see, the amplitude is growing. Here, it is decreasing but, there it is growing. So, it means, natural response is growing. And so, if you will superimpose this force part to this, this response will be again, growing without any limits, without any bound essence.

So, this is the instable condition. So, if you have you are in an elevator and the elevator's response is growing very fast and growing with amplitude, the elevator can hit the floor, below the ground floor or it could hit the ceilings. It can go out of the ceiling server, breaking this. So, if a system is, it will crash to the floor or ceiling. So therefore, if a system is unstable, it is very dangerous, it can make certain damage.

And so, if stability is the third design objective and it is a very important objective, very much important, because if the system is not stable, there is no use of talking the steady state error or transient response. Because, the system will not follow the input, because system is out of control, due to it is own internal characteristic. And therefore, there is no meaning of talking the steady state error of this type of system.

So, when we talk about a third design objective stability, we should be clear that, the natural response of the system should approach to 0, after initial time from the starting of the response and then only the system is stable. And, the system will reach to the steady state value; otherwise, if it is not stable we cannot expect any steady state value, steady state response.

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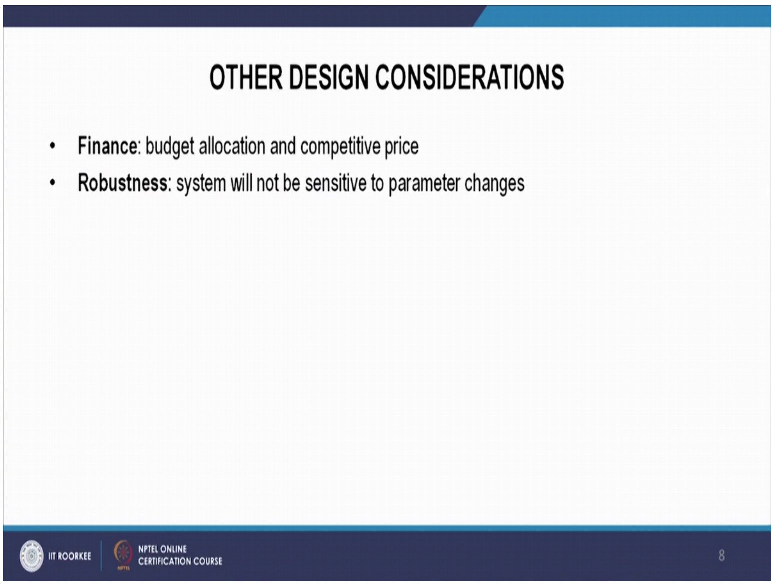

Now, some other design considerations that we should discuss. So, other design considerations. The first one could be the finance. Finance means, the budget that is allocated to design that product, that control system and the competitive prices, the product that will emerge to the market, whether it is competitive to the already available products or not. If it is not competitive and it has not some advantageous features, some advantage then, this control system is not going to be sold out.

Therefore, it is important to consider this finance as another design consideration; any design should have certain limited cost. The last one is, robustness. So, what is robustness? So, you know that, when we design certain system and we are going to actually manufacture that system, there is some difference between what we design and what we get from manufacturing.

Because, there is certain limitations of the manufacturing processes that, they cannot produce exactly what is designed; there should be some differences. Some difference in tolerance, some difference in material properties and some other parameters. Therefore, we are not going to get the same parameters that we have designed. We will, if we design for some values that, there is some spring and spring constant should be one thousand kilo Newton per meter, but it could be, maybe one thousand and ten, one thousand and fifty, something like this.

If there is some little change in the parameter, the control systems of performance should not be affected. It should be not so much sensitive to change little in the parameter. Therefore, a robust system is the system that has less sensitiveness when there is some change in parameter. Suppose, it is design for some room temperature, 27 degree Celsius and if temperature goes to 40 degree Celsius, it is not giving the desired output or desired response.

So, this system is not robust. A system is robust, if it is designed for 30 degree, it can add the same performance, at nearby temperature values. So that is why, this robustness is another consideration that, a designer should consider in it is design objective. So, what we learned that, this design objective should account the transient response parameters, a steady state response parameter and stability parameters for their design and the same thing for the performance specifications. Because, that you will get after the analysis of the system or after the system is designed.

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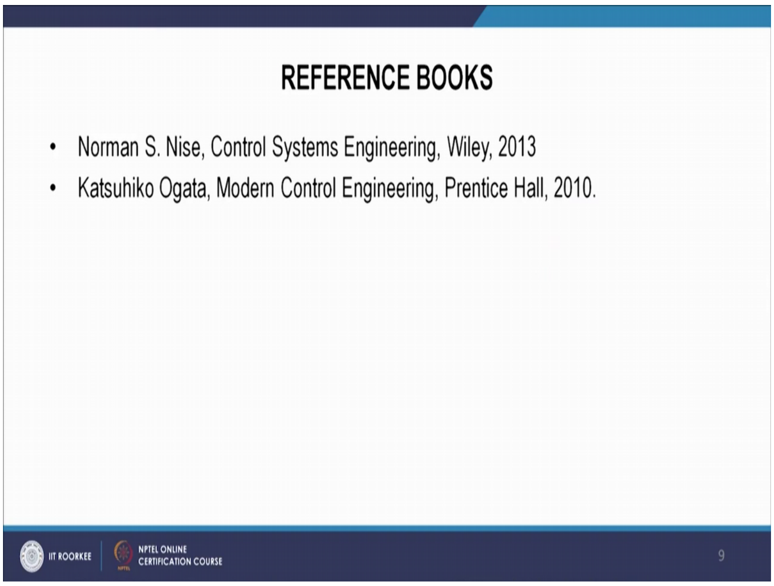

So here again, the reference books we are following is, Norman S Nise from control system engineering and K Ogata from modern control engineering. So, I thank you for this lecture and let us see in some next lecture.

Thank you.