LESSON 1:
BASICS OF CONTROL SYSTEMS

Learning Objectives

- Describe control system
- Describe types of control system
- Describe open loop and closed loop control system

An Overview

Dear students, in very starting lecture we discuss about , what is system? Which are the different types of systems? And discuss more about open loop and closed loop system.

Introduction

Before to start with this subject we must be familiar with the fact that what is the need of this subject? Since from morning we wake up, we are in contact with so many instruments. Some of them are operated manually while other are operating automatically. Say for example water heater, which automatically becomes on and off as temp. of water crosses some limit. In such manner so many instruments are there which we directly and indirectly handle. E.g. fan, washing machines, electric iron etc. Now question arises how these instruments are being operated directly and indirectly?

Answer is so simple; we have to go for this subject. As far as you electronics engineer are concerned you have to think about to control each physical parameter. In instrumentation we know how to measure the different physical parameter. But in this subject now we have to think how to control these parameters. So in first unit we try to get familiar with

- What is system?
- What is control system?
- How control systems can be classified?
- Which are basic components of control system ?

Definitions

To understand the meaning of the word control system, first we will define the word system first and then we will try to define the word control system.

System

A system is a combination or an arrangement of different physical components, which act together as a entire unit to achieve certain objective.

Every physical object is actually a system. So what you think Is class room itself acts as a system? Yes ,a classroom is a good example of physical system. A room along with a combination of benches, blackboard, fans, lighting arrangements etc. can be called as elementary system.

Consider another example of a system is a lamp. A lamp is made up of a glass and filament is a physical system. Similarly a kite made up of a paper and sticks is an example of a physical system. Similarly system can be of any type i.e. physical ecological, biological etc. Now once we have defined the term system, let us define the term control system.

Control System

So my question is “What is control?” so expected answer from your side is to control means to regulate, to direct or to command. Hence a control system is an arrangement of different physical elements connected in such a manner so as to regulate, direct or command itself or some other system.

For example if in a classroom, I am delivering a lecture, the combination becomes a control system as; I tries to regulate, direct or command the students in order to achieve the objective which is to input good knowledge to the students. Similarly if lamp is switched ON or OFF using a switch, the entire system can be called as a control system

When a child plays with the kite, he tries to control it with the help of string and entire system can be considered as a control system.

In short, a control system is in the broadest sense, an interconnection of the physical components to provide a desired function, involving some kind of controlling action in it.

Now let us define some important terms related to control.

Plant

The portion of a system, which is to be controlled or regulated, is called as the plant or the Process.

Controller

The element of the system itself or external to the system which controls the plant or the process is called as controller.

For each system, there must be excitation and system accepts it as an input. And for analyzing the behavior of system for such input, it is necessary to define the output of a system.

Input

It is an applied signal or an excitation signal applied to control system from an external energy source in order to produce a specified output.

Output

It is the particular signal of interest or the actual response obtained from a control system when input is applied to it.

Disturbances

Distrbance is a signal, which tends to adversely affect the value of the output of a system. If such a disturbance is generated within the system itself, it is called as internal disturbance. The disturbance generated outside the system acting as an extra input to the system in addition to its normal input, affecting the output adversely is called as an external disturbance.

Control systems may have more than one input or output. From the information regarding the system, it is possible to well define all the inputs and outputs of the systems.

Classification of Control Systems

Now let us discuss about different control systems.

Broadly control systems can be classified as,

Natural Control Systems

The Biological systems, systems inside human being are of natural type.

Ex.1 : The perspiration system inside the human being is a good example of natural control system. This system activates the secretion glands, secreting sweat and regulates the temperature of human body.

Manmade Control Systems

The various systems, we are using in our day to day life are designed and manufactured by human beings. Such systems like vehicles, switches, various controllers etc. are called as manmade control systems.

Ex.2 : An automobile system with gears, accelerator, braking system is a good example of manmade control system.

Combinational Control Systems

Combinational control system is one, having combination of natural and manmade together i.e. driver driving a vehicle. In such system, for successful operation of the system, it is necessary that natural systems of driver along with systems in vehicles, which are manmade, must be active .

Time Varying and Time-Invariant Systems

Time varying control systems are those in which parameters of the systems are varying with time. It is not dependent on whether input and output are functions of time or not. For example, space vehicle whose mass decreases with time, as it leaves earth. The mass is a parameter of space vehicle system. Similarly in case of a rocket, aerodynamic damping can change with time as the air density changes with the altitude. As against this if even though the inputs and outputs are functions of time but the parameters of system are independent of time, that is not varying with time and are constants, then system is said. to be time invariant system. Different electrical networks consisting of the elements as resistances; inductances and capacitances are time invariant systems as the values of the elements of such system are constant arid not the functions of time. The complexity of the control system design increases considerably if the control system is of the time varying type.

But for the engineering analysis, control systems can be classified in many ways. Some of the classifications are given below.

Linear and Nonlinear Systems

A control system is said to be linear if superposition principle applies to it. For linear systems the response to several forcing functions can be calculated by considering one forcing function at a time and adding the results.

The system is said to be linear if it satisfies following two properties.

i. Additive property that is for any x and y belonging to the domain of the function f, we have

$$f(x + y) = f(x) + f(y)$$

ii. Homogeneous property that is for any x belonging to the domain of the function f and for any scalar constant a, we have.

$$f(a\,x) = a\,.\,f(x)$$

These two properties together constitute a principle of superposition.

Continuous Time and Discrete Time Control Systems

In a continuous time control system all system variables are the functions of a continuous time variable ‘t’. The speed control of a d.c. motor using a tachogenerator feedback is an example of continuous data system. At any time ‘t’ they are dependent on time. In discrete time systems one or more system variables are known only at certain discrete intervals of time. They are not continuously dependent on the time. Microprocessor or computer based systems use such discrete time signals. The reasons for using such signals in digital controllers are

1. Such signals are less sensitive to noise.
2. Time sharing of one equipment with other channels is possible.
3. Advantageous from point of view of size, speed, memory, flexibility etc.

The systems using such digital controllers or sampled signals are called as sampled data systems.

Deterministic and Stochastic Control Systems

A control system is said to be deterministic when its response to input as well as behavior to external disturbances is predictable and repeatable. If such response is unpredictable, system is said to be stochastic in nature.

Lumped Parameter and Distributed Parameter Control Systems

Control system that can be described by ordinary differential equations is called as lumped parameter control system. For example electrical networks with different parameters as resistance, inductance, etc. are lumped parameter systems. Control systems that can be described by partial differential equations are called as distributed parameter control systems. For example, transmission line having its parameters resistance and inductance totally distributed along with it. Hence description of transmission line characteristics is always by use of partial differential equations.

Single Input Single Output (SISO) and Multiple Input

Multiple Output (MIMO) Systems

A system having only one input and one output is called as single input single output system. For example a position control system has only one input (desired position) and one output (actual output position). Some systems may have multiple type of inputs and multiple outputs, these are called as multiple input multiple output systems.

Up till now we have discussed about the classification of control system. Now let us discuss in detail open loop and closed loop system in detail.

Open loop and Closed Loop Systems

This is another important classification. The features of both types are discussed as follows.

Open Loop System

Definition

So from the name itself tell me first "What do you mean by open loop?" As the name suggests to us, A system in which output is dependent on input but controlling action or input is totally independent of the output or changes in output of the system, is called as Open Loop System.

As shown in following figure if feedback signal is not applied then that will results into a open loop control system. Reference input [R(t)] is applied to the controller which generates the actuating signal (u) required to control the process which is to be controlled. Process is giving out the necessary desired controlled output C(t). this system may have some advantages as well as some disadvantages which we can describe as follows

Advantages

1. Such systems are simple in construction.
2. Very much convenient when output is difficult to measure.
3. Such systems are easy from maintenance point of view.
4. Generally these are not troubled with the problems of stability.
5. Such systems are simple to design and hence economical.

Disadvantages

1. Such systems are inaccurate and unreliable because accuracy of such systems are totally dependent on the accurate precalibration of the controller.
2. Such systems give inaccurate results if there are variations in the external environment i.e. cannot sense environmental changes.
3. Similarly they cannot sense internal disturbances in the system, after the controller stage.
4. To maintain the quality and accuracy, recalibration of the controller is necessary, time to time.

Now you will have clear idea that why we are now going with closed loop system. To overcome all above disadvantages generally in practice closed loop systems are used.

For example, an electric switch, this is open loop because output is light and switch is controller of lamp. Any change in light has no effect on the ON-OFF position of the switch, i.e. its controlling action. Similarly automatic washing machine, Here output is degree of cleanliness of clothes. But any change in this output will not affect the controlling action or will not decide the operation time or will not decide the amount of detergent, which is to use. Some other examples are traffic signal, automatic toaster system etc.

Illustrations

Following are the very common examples with which we are very much familiar.

Sprinkler Used to Water a Lawn

The system is adjusted to water a given area by opening the water valve and observing the resulting pattern. When the pattern is considered satisfactory, the system is "calibrated" and no further valve adjustment is made.

Stepper Motor Positioning System

The actual position in such system is usually not monitored. The motor controller commands a certain number of steps by the motor to drive the output to a previously determined location.

Automatic Toaster System

In this system, the quality of toast depends upon the time for which the toast is heated. Depending on the time setting, bread is simply heated in this system. The toast quality is to be judged by the user and has no effect on the inputs.

Traffic Light Controller

A traffic flow control system used on roads is time dependent. The traffic on the road becomes mobile or stationary depending on the duration and sequence of lamp glow. The sequence and duration are "controlled by relays which are predetermined and not dependent on the rush on the road.

Automatic Door Opening and Closing System

In this system, photo sensitive devices are used. When a person interrupts a light, photo device generates actuating signal which opens the door. When person passes through the door, light becomes continuous closing the door. The opening and closing of the door is the output which has nothing to do with the inputs, hence an open loop system.

Closed Loop System

Definition

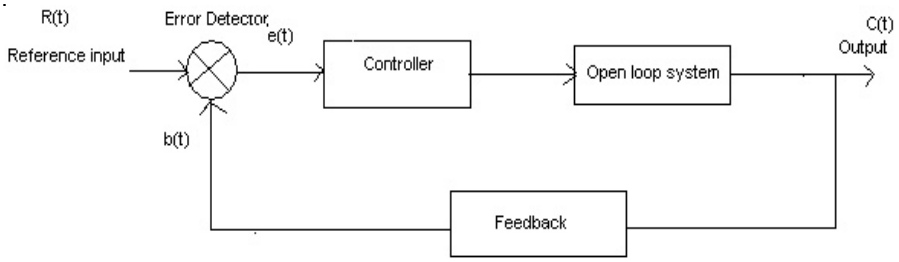
We have already defined the open loop control system.So from taking the idea about the previous definition of open loop control system let me tell now the definition of closed loop control system. Expected answer from your side will be that a system in which the controlling action or input is somehow independent on the output or changes in output is called as closed loop system. To have dependence of input on the output, such system uses the feedback property.

Feedback

Feedback is a. property of the system by which it permits the output to be compared with the reference input so that appropriate controlling action can be decided.

In such system output or part of the output is feedback to the input for comparison with the reference input applied to it. It is not possible in all the systems that available signal can be applied as input to the system. Depending upon nature of controller and plant it is required to reduce it or amplify it or to

change its nature i.e. making it discrete from continuous type of



signal etc. This changed input as per requirement is called as reference input which is to be generated by using reference transducer. The main excitation to the system is called as its command input which is then applied to the reference transducer to generate reference input.

The part of output, which is to be decided by feedback element is fed back to the reference input. The signal which is output of feedback element is called as feedback signal' b(t).

It is then compared with the reference input giving error signal

$$e(t) = r(t) +\_ b(t)$$

When feedback sign is positive, systems are called as positive feedback systems and if it is negative systems are called as negative feedback systems.

This error signal is then modified by controller and decides the proportional manipulated signal for the process to be controlled.

This manipulation is such that error will approach to zero. This signal then actuates the actual system and produces an output. As output is controlled one, it is called as controlled output c(t).

Advantages

1. Accuracy of such system is always very high because controller modifies and manipulates the actuating signal such that error in the system will be zero.
2. Such system senses environmental changes, as well as internal disturbances and accordingly modifies the error.

In such system, there is reduced effect of nonlinearities and distortions.

Bandwidth of such system i.e. operating frequency zone for such system is very high.

Disadvantages

1. Such systems are complicated and time consuming from design point of view and hence costlier.
2. Due to feedback, system tries to correct the error time to time. Tendency to overcorrect the error may cause oscillations without bound in the system. Hence system has to be designed taking into consideration problems of instability due to feedback.

Illustrations

Human Being

If you sre now familiar with open loop and closed loop then I think you yourselves are best example . If a person wants to reach for a book on the table, position of the book is given as the reference. Feedback signal from eyes, compares the actual position of hands with reference position. Error signal is given to brain. Brain manipulates this error and gives signal to the hands, This process continues till the position of the hands get achieved appropriately

Home Heating System

In this system, the heating system is operated by a valve. The actual temperature is sensed by a thermal sensor and compared with the desired temperature. The difference between the two, actuates the valve mechanism to change the temperature as per the requirement.

Comparison of open loop and closed loop control system

	Open loop		Closed loop
1	Feedback does not exists	1	Use of feedback
2	Output measurement is not required for operation of system.	2	Output measurement is necessary.
3	Feedback element is absent.	3	Feedback element is present.
4	Error detector is absent	4	Error detector is necessary.
5	It is inaccurate and unreliable	5	Highly accurate and reliable.
6	Highly sensitive to the disturbances.	6	Less sensitive to the disturbances.
7	Highly sensitive to the enviournmental changes.	7	Less sensitive.
8	Bandwidth is small.	8	Bandwidth is large
9	Simple to construct and cheap	9	Complicated to design and hence costly
10	Generally are stable in nature	10	Stability is the major consideration while designing.
11	Highly affected by nonlinearities.	11	Reduced effect of nonlinearities

Summary

The major objective of this chapter has been the introduction of the terminology and different classification of control system. A control system is an arrangement of different physical elements connected in such a manner so as to regulate, direct or command itself or some other system. Broadly, control systems are classified as natural, manmade and combinational control systems.

Supplementary Readings

Feed back Control system by Bhide and Bakshi.

Web sites.