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المرحلة الرابعة

Control and Measuring Systems I

Unit 1: Control Engineering Systems I

INTRODUCTION

Automatic control has played a vital role in the advance of engineering and science. In addition to its extreme importance in space-vehicle systems, missile-guidance systems, robotic systems, and the like, automatic control has become an important and integral part of modern manufacturing and industrial processes.

For example, automatic control is essential in the numerical control of machine tools in the manufacturing industries, in the design of autopilot systems in the aerospace industries, and in the design of cars and trucks in the automobile industries.

It is also essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries. Since advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity, relieving the drudgery of many routine repetitive manual operations, and more, most engineers and scientists must now have a good understanding of this field.

Definitions

Before we can discuss control systems, some basic terminologies must be defined.

The **controlled variable** is the quantity or condition that is measured and controlled.

Normally, the controlled variable is the output of the system.

The **manipulated variable** is the quantity or condition that is varied by the controller to affect the value of the controlled variable.

Control means measuring the value of the controlled variable of the system and applying the manipulated variable to the system to correct or limit deviation of the measured value from a desired value.

In studying control engineering, we need to define additional terms that are necessary to describe control systems.

Automatic Control:

Simple definition: Automatic control is the science of controlling processes.

The control of an industrial process (manufacturing, production, and so on) by automatic rather than manual means is often called **automation**.

Plants. A plant may be a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation. In this unit we shall call any physical object to be controlled (such as a mechanical device, a heating furnace, a chemical reactor, or a spacecraft) a plant.

Processes: The Merriam-Webster Dictionary defines a process to be a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled actions or movements systematically directed toward a particular result or end.

In this unit we shall call any operation to be controlled a process. Examples are chemical, economic, and biological processes.

Systems: A system is a combination of components that act together and perform a certain objective.

A system is not limited to physical ones. The concept of the system can be applied to abstract, dynamic phenomena such as those encountered in economics.

The word system should, therefore, be interpreted to imply physical, biological, economic, and the like, systems.

Disturbances: A disturbance is a signal that tends to adversely affect the value of the output of a system. If a disturbance is generated within the system, it is called internal, while an external disturbance is generated outside the system and is an input.

Feedback Control: A feedback control system often uses a function of a prescribed relationship between the output and reference input to control the process.

Often the difference between the output of the process under control and the reference input is amplified and used to control the process so that the difference is continually reduced.

In general, the difference between the desired output and the actual output is equal to the **error**, which is then adjusted by the controller. The output of the controller causes the actuator to modulate the process in order to reduce the error.

Classification of control system

1- **Natural control systems**: the biological systems, systems inside human being are natural type.

   Ex: the perspiration system inside the human being, this system activate the secretion glands, secreting sweat and regulates the temperature of human body.

2- **Manmade control systems**: we are using in our day-to-day life are designed and manufactured by human being. Such systems like vehicles, switches controllers etc.

3- **Combinational control systems**: it is one having Combinational of natural and manmade together i.e. driver driving a vehicle.

4- **Time varying** and **Time – Invariant systems**: Time varying control systems are those in which parameters of the systems are varying with time.

   Ex.: space vehicle whose mass decreases with time, as it leaves earth.

   As against this if, the parameters of the systems are not varying with time and constant then the system is said to be Time Invariant system.

   Ex.: resistance, capacitance, inductances …

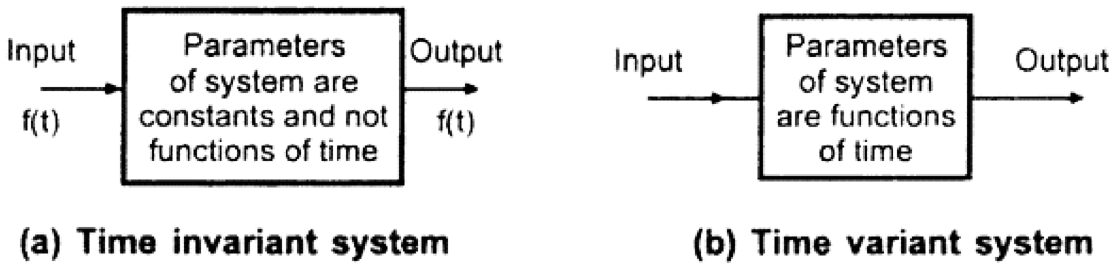


Fig.1-1: Time varying and Time – Invariant systems

5- **Linear** vs. **Nonlinear Control System**: A Control System in which output varies linearly with the input is called a linear control system.

$$y(t) = 3u(t) + 5$$

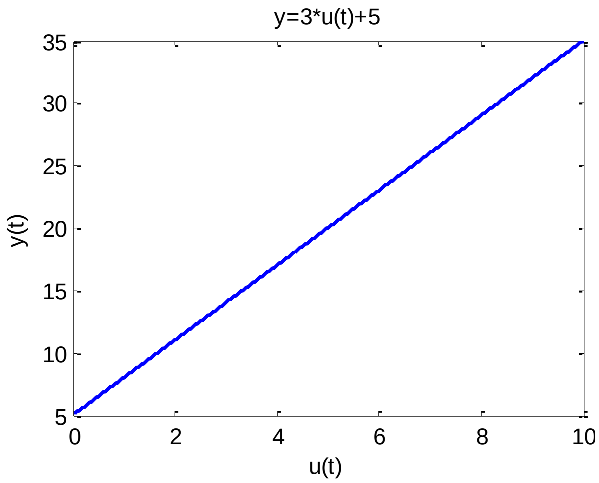


Fig.1-2: linear control system

When the input and output has nonlinear relationship, the system is said to be nonlinear.

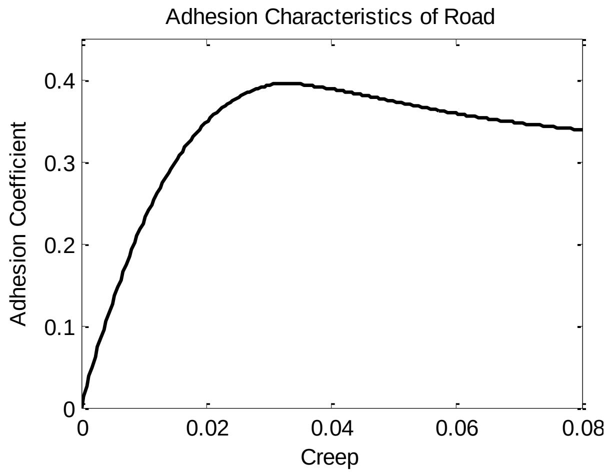


Fig.1-3: Nonlinear control system

A linear system is a mathematical model of a system based on the use of a linear operator. Linear systems typically exhibit features and properties that are much simpler than the nonlinear case. As a mathematical abstraction or idealization,

Linear systems find important applications in automatic control theory, signal processing, and telecommunications.

For example, the propagation medium for wireless communication systems can often be modeled by linear systems.

A Control System is said to be linear if it satisfies the following properties:

1- The principle of ***superposition*** is applicable to the system.

   This mean the response to several input can be obtained by considering one input at a time.

   Mathematically expressed by two conditions:

   i) **Additive**: $F(x+y) = f(x) + f(y)$

   ii) **Homogeneous**: $f(\alpha x) = \alpha f(x)$

2- The differential eq. of the system is linear having its coefficient as constant.

3- Practically the ***output*** response varies ***linearly*** with the ***input***.

Ex.:

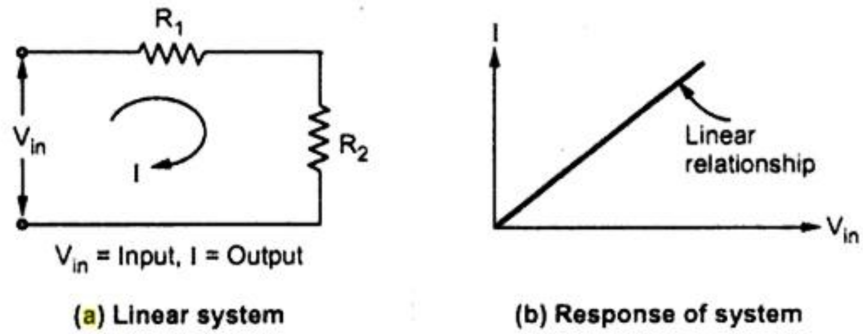


Fig.1-4: Ex. of linear system

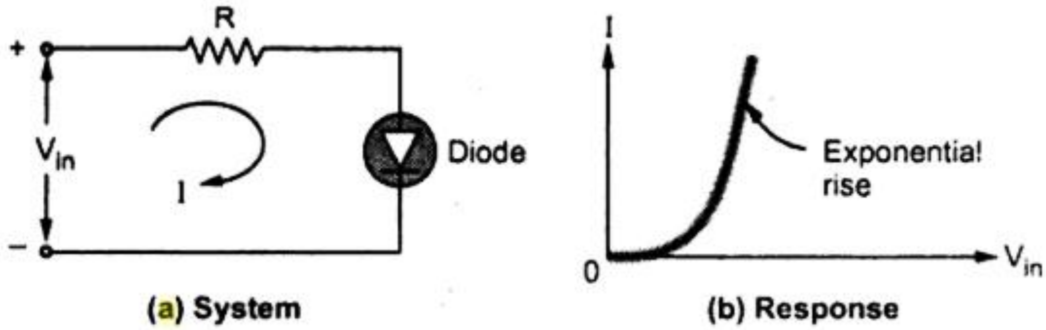


Fig.1-4: Ex. of nonlinear system

6- **Continuous Time** and **Discrete time Control System**: In a CTCS [Continuous time Control System] all variables are functions of (t). The speed control of a d.c, motor using a tachogenerator feedback is an ex. of Continuous time Control System.

In DTCS [Discrete time Control System] one or more variables are known only at a certain discrete interval of time. Computers based system used such DT 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) Useful in speed, size, memory, flexibility etc.

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

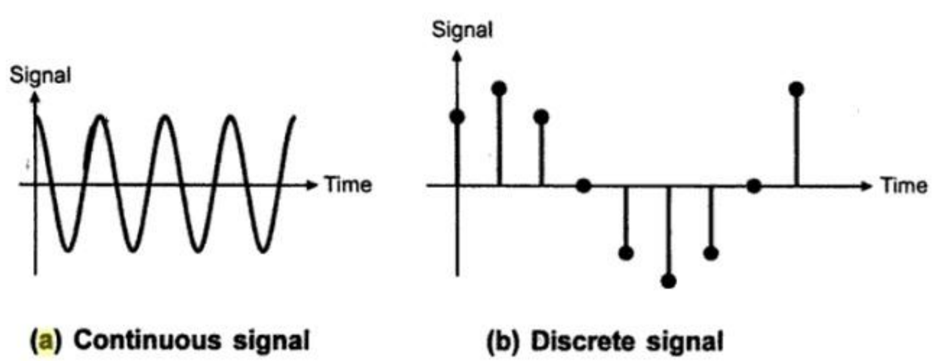


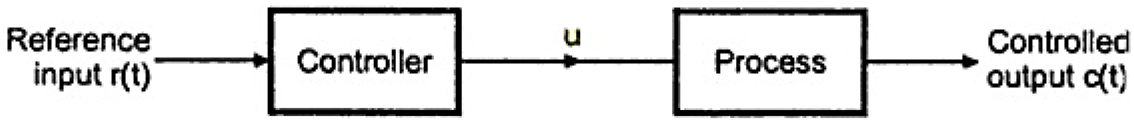
Fig.1-5: CTS and DTS

7- **Deterministic** and **Stochastic Control System**: 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.

8- **Lumped parameter** and **Distributed parameter Control System:** Control System that can be described by ordinary differential equations is called *Lumped parameter Control System.* For example electrical networks with resistance, capacitance, inductance etc. Control System that can be described by partial differential equations is called *Distributed parameter Control System.* For example transmission line having its parameter resistance and inductance totally distributed along it. The Lumped parameters are physically separable.

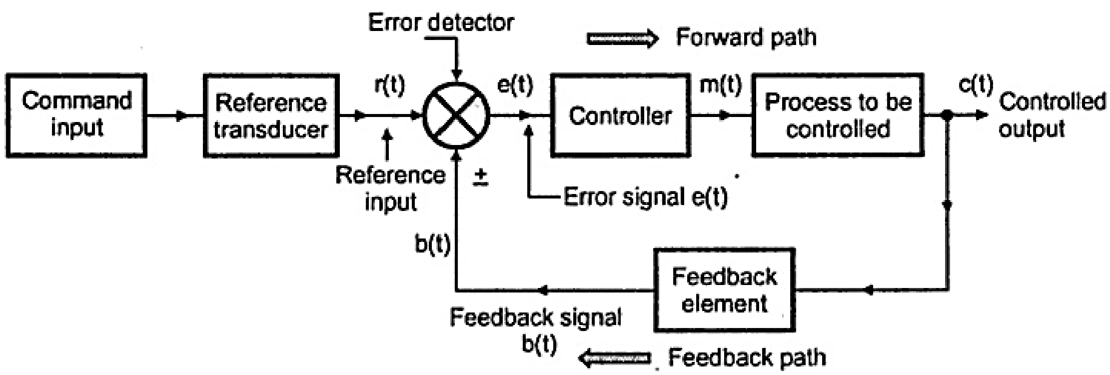
9- **Single Input Single Output (SISO)** and **Multiple Input Multiple Output (MIMO):** Ex.: a position Control System has only one input (desired position) and one output (actual output position). Some systems have multiple type of inputs and multiple outputs; these are called Multiple Input Multiple Output (MIMO) systems.

10- Open and closed loop systems: An open-loop system is a system without feedback or input is totally independent of the output. In contrast to an open-loop control system, a closed-loop control system utilizes an additional measure of the actual output to compare the actual output with the desired output response. The measure of the output is called the feedback signal.



u = Actuating signal

Fig.1-6: OLCS



Representation of closed loop control system

The various signals are,

r(t) = Reference input	e(t) = Error signal	
c(t) = Controlled output	m(t) = Manipulated signal	b(t) = Feedback signal

Fig.1-7: CLCS

When Feedback sign is positive systems called positive Feedback systems and if it is negative systems called negative Feedback systems.

Advantages

The advantages of closed loop system are,

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.
3) In such system, there is reduced effect of nonlinearities and distortions.
4) Bandwidth of such system i.e. operating frequency zone for such system is very high.

Disadvantages

The disadvantages of closed loop system are,

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 from 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. The stability problems are severe and must be taken care of while designing the system.

Ex.:

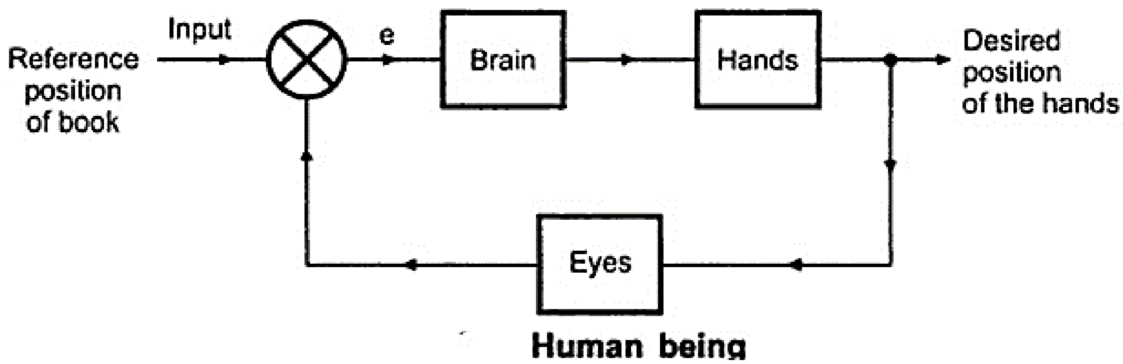


Fig.1-8: CLCS example 1

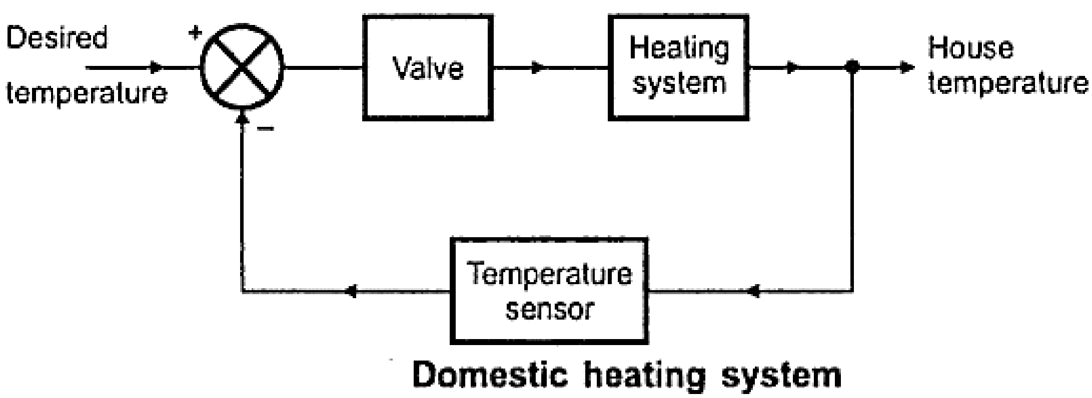


Fig.1-9: CLCS example 2

Comparison between OLCS & CLCS

Sr. No.	Open Loop	Closed Loop
1.	Any change in output has no effect on the input i.e. feedback does not exists.	Changes in output, affects the input which is possible by use of feedback.
2.	Output measurement is not required for operation of system.	Output measurement is necessary.
3.	Feedback element is absent.	Feedback element is present.
4.	Error detector is absent.	Error detector is necessary.
5.	It is inaccurate and unreliable.	Highly accurate and reliable.
6.	Highly sensitive to the disturbances.	Less sensitive to the disturbances.
7.	Highly sensitive to the environmental changes.	Less sensitive to the environmental changes.
8.	Bandwidth is small.	Bandwidth is large.
9.	Simple to construct and cheap.	Complicated to design and hence costly.
10.	Generally are stable in nature.	Stability is the major consideration while designing
11.	Highly affected by nonlinearities.	Reduced effect of nonlinearities.

An Ideal Control System

An ideal system of control is that which makes the controlling function easy, effective and smooth.

1. Suitability:

The control system should be appropriate to the needs, kind of activity and circumstances of an enterprise. Control is executed through managerial position.

2. Simplicity:

To be effective, control system must be clear, easy to understand and operate. Unless the control system is understood properly by those responsible for its implementation it cannot succeed.

A complex system will not only create hurdles in the performance of activities, but it will also not bring the results expected of it.

3. Objectivity:

The fixation of standards, measurement of performance and corrective action must be objective and impersonal.

Subjective and arbitrary control cannot be effective. It is essential that the standards to judge the actual performance are clear, definite and stated in numerical terms.

4. Economical:

The systems of control must be worth their costs. They must justify the expenses involved. The cost of control system should not exceed the possible savings from its use. The complicated control system should be avoided to keep a check on the costs of control.

It, therefore, becomes essential to concentrate the control system on factors which are important to keep the costs down and make the system economical.

5. Flexibility:

The system of control must be flexible, i.e., workable even if the plans have to be changed. A good control system must keep pace with the continuously changing pattern of a dynamic business world.

It must be responsive to changing conditions. Control system should be flexible so that it can be adjusted to any modification or alteration in a plan.

6. Quick Reporting:

Time is an important element in enforcing a control system.

Subordinates should inform their superiors quickly with actual results and all deviations from standards.

Delays in reporting of information will make control ineffective. Promptness is also needed in initiating the corrective action. Quick reporting helps in the timely disposal of deviations.

7. Suggestive:

A control system should not only measure performance and detect deviations; it should suggest remedial measures as well. In other words, good control system should be self-correcting. In fact,

A control system can be effective only when it is considered as part of the internal working and not as a mechanism, operating from outside.

8. Forward-Looking:

The control system should be directed towards future. In fact, the control system can at times be so devised as to anticipate possible deviations or problems.

It should be preventive and not merely corrective Ideal control is spontaneous. Cash forecasts and cash control is an example where a financial manager can forecast the future cash needs and provide for in advance.

9. Individual Responsibility:

Control can be effective when it focuses on individuals rather than on jobs or works.

10. Strategic Point Control:

All deviations from standards are not of equal importance. Hence, to control all deviations is not desirable. Therefore, the control system should focus on key, critical or strategic points which require management attention. Effective and efficient control is control by exception. Uncontrollable deviations need not be given much care and thought.

11. Self-Control:

Different departments may be asked to control themselves. If a department can have its own control system, much of the detailed controls can be handled within the department. These sub-systems of self-control can then be tied together for an overall control system.

12. Feedback:

It means information on previous performance. For effective control, regular flow of information regarding the actual performance is necessary. Feedback can be supplied through personal contact, observation or reports. Automatic feedback assists in taking corrective action at the right time or in adjusting future operations.

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3. Feedback and Control Systems, Joseph J. Distefano, Allen R. Stubberud and Ivan J. Williams, Tata McGraw Hill Publishing Co. Ltd., New Delhi.

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