Automatic Control Systems

Lecture-1

Description of Control Systems

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Outlines

- General Introduction
- Why do we need to study control systems
- Syllabus
- Targeted Audience

General Introduction

Recently, automatic control systems have shown tremendous development and advancement of modern technology. These are found in both domestic and industrial applications.

Domestically, automatic controls in heating and air conditioning systems regulate the temperature and humidity of modern homes for comfortable living.

Industrially, automatic control systems are found in numerous applications, such as quality control of manufactured products, automation, machine tool control, etc.

Advantages of using Control Systems

We build control systems for 4 primary reasons

- Power amplification
- Remote control
- Convenience of input form
- Compensation for disturbances

Syllabus

1. Description of control systems
2. Laplace transform and their properties
3. Solving linear differential equations
4. Modeling electrical systems
5. Modeling mechanical systems
6. System block diagrams and block diagram reduction techniques
7. Represent systems using Signal flow graph
8. Analyze response of first order systems
9. Analyze response of second order systems
10. Analyze system stability using Routh Hurwitz Criterion
11. Describe types of system compensators
12. Describe types of system controllers

Target audience

Engineering students and other passionates in engineering field.

Lecture-1: Description of control systems

Session Objectives

By the end of this session, you should be able to:

- Explain/define basic terms used in control systems
- Differentiate types of control systems

Content

- Basic definitions
- Classification of control systems
- References

Basic definitions

- **A system:** According to Smarajit Gosh, a system is defined as an arrangement or combination of different physical components that are connected together to form an entire unit to achieve a certain objective.
- **Control:** The meaning of control is to regulate, direct or command a system so that a desired objective is achieved.
- **Plant**: It is defined as a portion of the system which is to be controlled or regulated. It is also called a process.
- **Controller:** It is the element of the system itself or may be external to the system. It controls the plant or the process.

Smarajit Gosh (2007), Control systems, Pearson Education, Page 1

Basic definitions(cont’d)

- **Input:** The applied signal or excitation signal that is applied to a control system to get a specified output is called input.
- **Output:** The actual response that is obtained from a control system due to the application of the input is termed as output.
- **Disturbance:** The signal that has some adverse effect on the value of the output of a system is called disturbance. We have internal disturbance and external disturbance.
- **Control system:** a system which consists of a number of components connected together to perform a specific function, in which the output is controlled by input.

Smarajit Gosh (2007), Control systems, Pearson Education, Page 1

Automatic Control Systems

Think:

List down various control systems that you come across in your day today life.

Classification of Control Systems

- Natural control systems
- Manmade control systems
- Combinational systems
- Manual and automatic control systems
- Time varying and time Invariant systems
- Continuous time and discrete time control systems
- Deterministic vs Stochastic systems
- Lumped and Distributed Parameter Control Systems
- Multivariable systems (SISO & MIMO)
- Linear and Non-linear systems
- Open loop and closed loop systems

Natural Control Systems

- The systems inside a human being or a biological system are known as natural control systems
- Universe
- 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 vehicle, bicycle, switches, various controllers etc are called manmade control systems.
- Airplanes
- Chemical process

Combinational Control Systems

The combination of a natural control system and a manmade control system is an example of combinational control systems

Example: Driver driving a car.

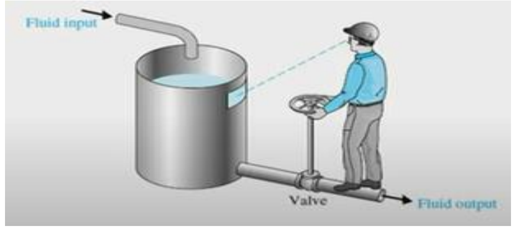
Smarajit Gosh (2007), Control systems, Pearson Education, Page 2

Manual and Automatic Control Systems

Manual Control Systems

A control system in which human operator is necessary is called manual control system

- Room temperature control via Electric Fan
- Automobile system with gears
- Water level control



Automatic control Systems

A control system in which a human operator is not at all required, the system is known as automatic control systems.

- Room temperature control via A.C
- Water level control with float valve.

Time Varying and Time Invariant Systems

Time varying Systems

Time varying systems are those in which one or more parameters of the systems are varying with time. It is not dependent on whether input and output are functions of time or not.

$$y(t) = 2u(t) - 3t$$

Systems that are represented by differential equations whose coefficients are functions of time

Time Invariant Systems

In time invariant systems, the inputs and outputs are functions of time but the parameters of system are independent of time, which are not varying with time and are constants.

$$y(t) = 2u(t) + 1$$

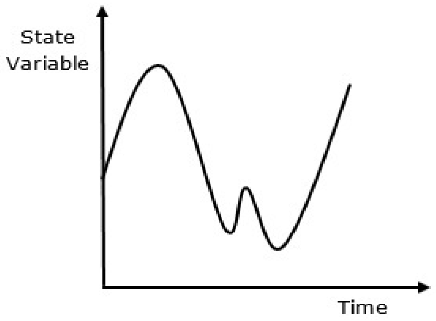
Electrical network elements i.e resistance, inductance and capacitance are time invariant systems as the values of such systems are constant and not the function of time.

Continuous time vs Discrete time Systems

Continuous time systems

A *continuous system* is one in which the state variable(s) change continuously over time.

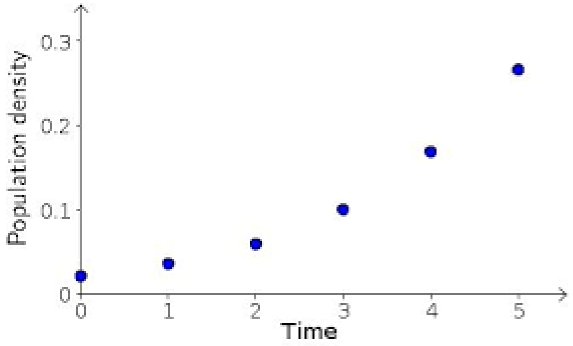
Ex: The amount of water flow over a dam.



Discrete time response

A *discrete system* is one in which the state variable(s) change only at a discrete set of points in time.

Ex: customers arrive at 3:15, 3:23, 4:01



Deterministic vs Stochastic Systems

Deterministic Systems

A control system is deterministic if the response to input is predictable and repeatable.

or

A *deterministic* system is a system in which no randomness is involved in the development of future states of the system.

Stochastic Systems

A stochastic system has a random probability distribution or pattern that may be analyzed statistically but may not be predicted precisely.

Lumped and Distributed Parameter Control Systems

Lumped Parameter Control Systems

If a control system can be represented by an ordinary differential equations, such a control system is called lumped parameter control system.

This is the case of electrical network parameters like resistance, inductance and capacitance.

Distributed Parameter Control Systems

If a system can be described by a partial differential equations, such a control system is known as distributed parameter control system

This is the case of a transmission line where resistance and inductance are totally distributed along it.

Linear vs Non-linear Systems

Linear System

A system is known as linear system if it satisfies the laws of additivity and Homogeneity. A linear system holds the superposition principle

$$x_1(t) \rightarrow y_1(t)$$
$$x_2(t) \rightarrow y_2(t)$$
$$x_1(t) + x_2(t) \rightarrow y_1(t) + y_2(t)$$
$$a\,x_1(t) \rightarrow a y_1(t)$$

Non Linear System

Otherwise

Multivariable Systems (SISO &MIMO)

SISO

A system having only one input and one output is called single input single output system

MIMO

Systems having multiple type of inputs and multiple outputs those are called multiple input multiple output systems.

Open Loop and Closed Loop systems

1. Open Loop Control Systems
a) Definition

A control system in which the control action is totally independent of the output of the system then it is called an open loop control system

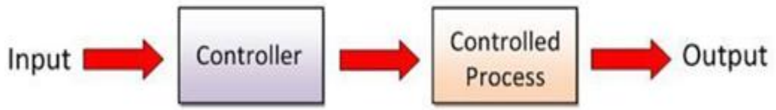


Fig: Open Loop Control Systems

Benjamin C. Kuo (1975), Automatic Control Systems, 3rd Edition, Prentice Hall, Page 2

b) Advantages of Open Loop Control System

- Simple in construction and design
- Economical
- Easy to maintain
- Generally stable

c) Disadvantages of open loop control system

- They are inaccurate
- They are unreliable
- Any change in output cannot be corrected automatically

d) Examples of open loop control systems

- Automatic washing machine
- Light switch
- Timer based clothes drier

2. Closed Loop Control System
a) Definition

Control system in which the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated is called a closed loop control system.

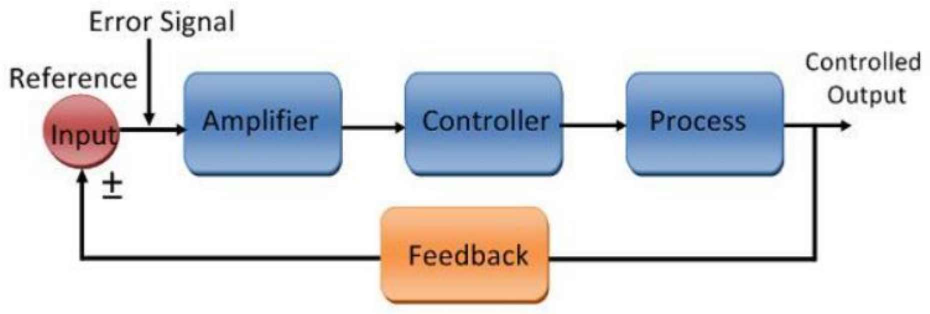


Figure: Closed Loop Control System

Benjamin C. Kuo (1975), Automatic Control Systems, 3rd Edition, Prentice Hall, Page 5

Feedback:

- Feedback is a key tool that can be used to modify the behavior of a system
- Feedback compares output signal with input signal in order to generate error signal to achieve or generate desired output.

b) Advantages of closed loop control system

- The closed loop control systems are more accurate.
- The bandwidth range is large i.e high operating frequency zone
- Facilitates automation
- This system is less affected by noise

c) Disadvantages of Closed Loop Control System

- They are costlier
- They are complicated to design
- Required more maintenance
- The systems may be unstable

d) Examples of Closed Loop Control Systems

- Automatic electric iron
- Water level controller
- An air conditioner
- Cooling system in a car

Open Loop vs Closed Loop Control Systems

Open Loop Control System

- The feedback element is absent
- An error detector is not present
- It is a stable one
- Easy to construct
- It is economical
- Having a small bandwidth
- It is inaccurate
- Less maintenance
- It is unreliable

Closed Loop Control System

- The feedback element is always present
- An error detector is always present
- It may become unstable
- Complicated construction
- It is costly
- Having a large bandwidth
- It is accurate
- More maintenance
- It is reliable

References

1. Smarajit Gosh (2007), Control systems, Pearson Education.
2. Benjamin C. Kuo (1975), Automatic Control Systems, 3rd Edition, Prentice Hall.

THANK YOU!