Tikrit university

Collage of Engineering Shirqat

Department of Electrical Engineering

Fourth Year

Control Engineering

Chapter 1

Introduction

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1. Introduction

Automatic control is essential in any field of engineering and science. Automatic control is an important and integral part of space-vehicle systems, robotic systems, modern manufacturing systems, and any industrial operations involving control of temperature, pressure, humidity, flow, etc. It is desirable that most engineers and scientists are familiar with theory and practice of automatic control.

Advantages of Control Systems: With control systems we can move large equipment with precision that would otherwise be impossible. We can point huge antennas toward the farthest reaches of the universe to pick up faint radio signals; controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. We alone could not provide the power required for the load and the speed; motors provide the power, and control systems regulate the position and speed.

2.Definitions

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

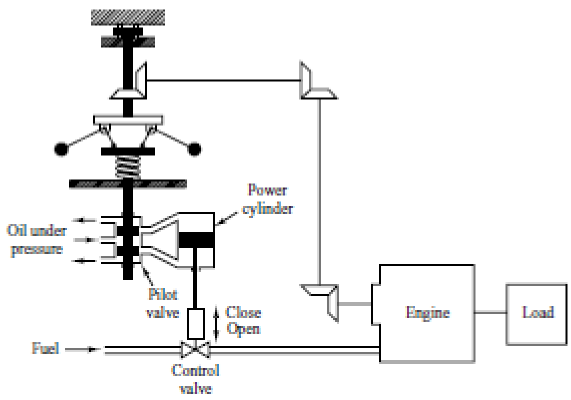
- **Controlled Variable** is the quantity or condition that is measured and controlled.
- **Control signal** is the quantity or condition that is varied by the controller so as to affect the value of the controlled variable. Normally, the controlled variable is the output of the system.
- **Control** means measuring the value of the controlled variable of the system and applying the control signal 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.
- **Systems**. A system is a combination of components that act together and perform a certain objective. A system need not be physical. 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.

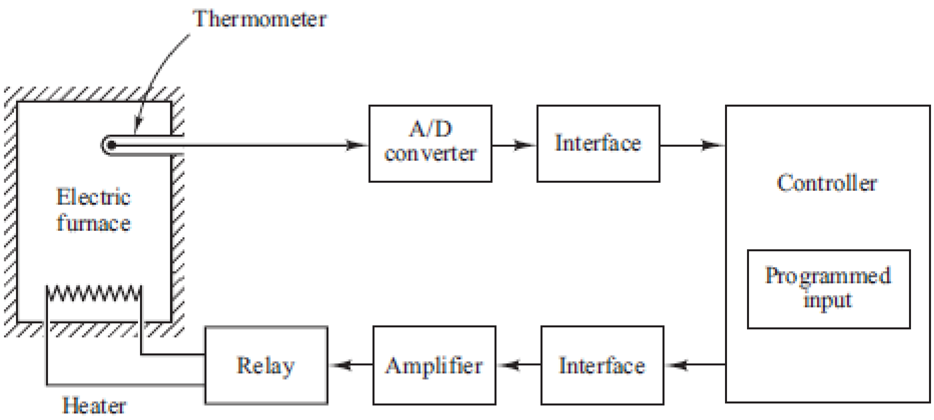
- **Plant or process:** The part or component of a system that is required to be controlled.
- **Disturbances**. A disturbance is a signal that tends to adversely affect the value of the output of a system. If a disturbance is generated within the system, it is called internal, while an external disturbance is generated outside the system and is an input.
- **Feedback Control**. Feedback control refers to an operation that, in the presence of disturbances, tends to reduce the difference between the output of a system and some reference input and does so on the basis of this difference. Here only unpredictable disturbances are so specified, since predictable or known disturbances can always be compensated for within the system.
- **Sensor.** is a device that provides a measurement of a desired external signal. For example, resistance temperature detectors (RTDs) are sensors used to measure temperature.
- **Actuator** is a device employed by the control system to alter or adjust the environment. An electric motor drive used to rotate a robotic manipulator is an example of a device transforming electric energy to mechanical torque

3. Examples of Control Systems

Speed Control System. The basic principle of a Watt's speed governor for an engine is illustrated in the schematic diagram of Figure below. The amount of fuel admitted to the engine is adjusted according to the difference between the desired and the actual engine speeds. The sequence of actions may be stated as follows: The speed governor is adjusted such that, at the desired speed, no pressured oil will flow into either side of the power cylinder. If the actual speed drops below the desired value due to disturbance, then the decrease in the centrifugal force of the speed governor causes the control valve to move downward, supplying more fuel, and the speed of the engine increases until the desired value is reached. On the other hand, if the speed of the engine increases above the desired value, then the increase in the centrifugal force of the governor causes the control valve to move upward. This decreases the supply of fuel, and the speed of the engine decreases until the desired value is reached. In this speed control system, the plant (controlled system) is the engine and the controlled variable is the speed of the engine. The difference between the desired speed and the actual speed is the error signal. The control signal (the amount of fuel) to be applied to the plant (engine) is the actuating signal. The external input to disturb the controlled variable is the disturbance. An unexpected change in the load is a disturbance.



Temperature Control System. Figure below shows a schematic diagram of temperature control of an electric furnace. The temperature in the electric furnace is measured by a thermometer, which is an analog device. The analog temperature is converted to a digital temperature by an A/D converter. The digital temperature is fed to a controller through an interface. This digital temperature is compared with the programmed input temperature, and if there is any discrepancy (error), the controller sends out a signal to the heater, through an interface, amplifier, and relay, to bring the furnace temperature to a desired value.



4. Classification of Control Systems

Time-Varying and Time-Invariant Control Systems:

If the parameters of a control system vary with time, the control system is termed as time-varying control system. If the parameters of a control system are not varying with time, it is termed as time-invariant control system. A space vehicle leaving earth is an example of time-varying system. The elements of an electrical network such as resistance, inductance and capacitance are not time varying; this is an example of the time-invariant system.

Linear and Non-linear Systems: A control system is known as linear if it satisfies the additive property as well as the homogeneous property.

(a) Additive Property: If *x* and *y* belong to the domain of the function/, we can write

$f(X + y) = f(X) + f(y)$

(b) Homogeneous Property: Homogeneous Property: For any x belonging to the domain of the function f and for any scalar constant a, we can write $f(ax) = a f(x)$

Continuous-Time and Discrete-Time Control Systems: If all the system variables of a control system are functions of time, it is termed as a continuous-time control system. If one or more system variables of a control system are known at a certain discrete time, it is termed as a discrete-time control system. The speed control of a dc motor with tacho-generator feedback is an example of continuous-time control systems. The micro-processor- or computer-based system is an example of discrete-time control systems.

Single-Input-Single-Output and Multiple-Input-Multiple-Output Systems: If a control system has one input and one output, it is termed as single-input-single output (SISO) system. If a control system has multiple input and multiple output, it is known as multiple-input-multiple output (MIMO) system.

Open-loop and Closed-loop Systems: This is another classification of control systems. Both types are given

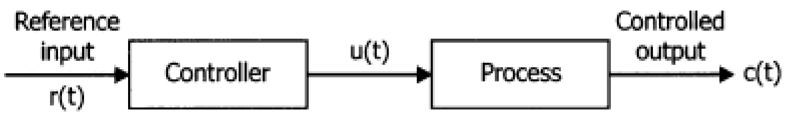
in details in the following section.

4. OPEN-LOOP AND CLOSED-LOOP SYSTEMS

Any control system can be classified as (a) open-loop or (b) closed-loop system depending on the relation of control of action with output.

4.1 Open-loop System

A system in which control action does not depend on output is known as open-loop system. Fig. below shows an open-loop system.



Examples of open-loop systems are automatic washing machines, bread toaster, electric hand dryer, automatic milk server, automatic coffee server, traffic signals, etc. Advantages and disadvantages of open-loop system

Advantages:

- Simple design and easy to construct
- Economical
- Easy for maintenance
- Highly stable operation

Dis-advantages:

- Not accurate and reliable when input or system parameters are variable in nature
- Recalibration of the parameters are required time to time

4.2 Closed-loop control system:

It is a control system where its control action depends on both of its input signal and output response as shown in Figure below

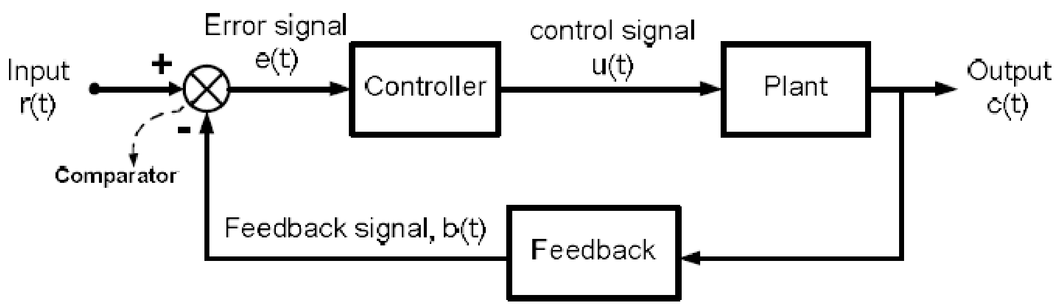
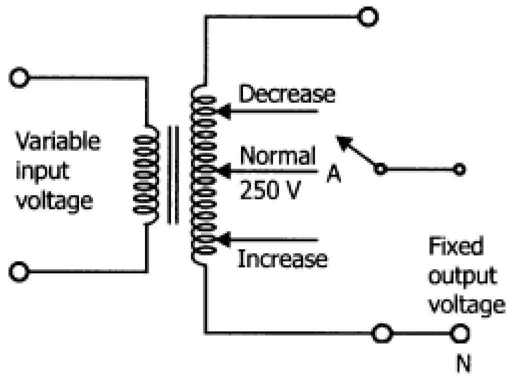


Figure below shows the closed-loop control of a voltage stabilizer. It is expected that the output voltage will be 230 V for a single-phase system. When input decreases, the output switch will be connected above A. On the other hand, if input increases, the output switch will be connected below *A.*



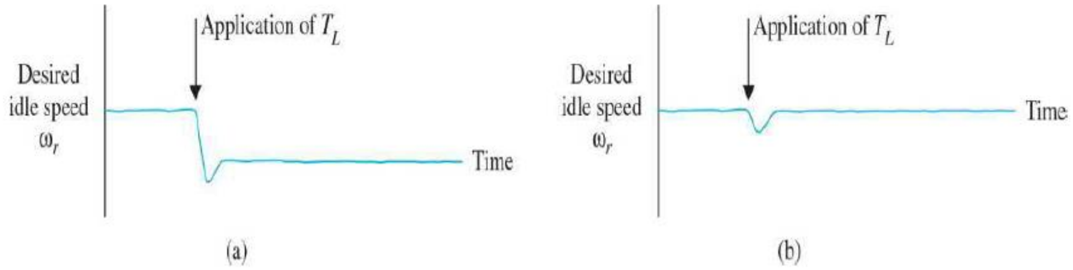
Advantages:

- More accurate operation than that of open-loop control system
- Can operate efficiently when input or system parameters are variable in nature
- Less nonlinearity effect of these systems on output response
- High bandwidth of operation

- Time to time recalibration of the parameters are not required

Dis-advantages:

- Complex design and difficult to construct
- Expensive than that of open-loop control system
- Complicate for maintenance
- Less stable operation than that of open-loop control system.

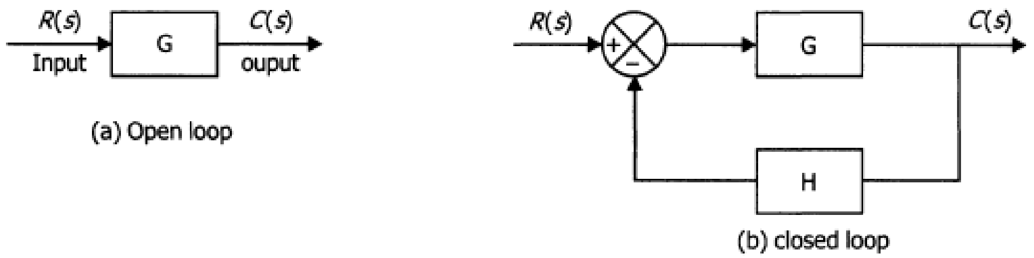


(*a*) Typical response of the open-loop idle-speed control system.

(b) Typical response of the closed-loop idle speed control system.

4.3 Effects of Feedback

The error between the system input and output can be reduced by using a feedback system as shown in figure below



The effects of feedback are as follows:

(i) Gain is reduced by a factor $\frac{1}{1+G(S)H(s)}$

(ii) There is improvement in sensitivity.

(iii)There may be reduction of stability

Note: The disadvantages of reduction of gain and reduction of stability can be over-come by gain amplification and good design, respectively.

5. Analysis and Design Objectives

Analysis is the process by which a system's performance is determined. For example, we evaluate its transient response and steady-state error to determine if they meet the desired specifications. Design is the process by which a system's performance is created or changed. For example, if a system's transient response and steady-state error are analyzed and found not to meet the specifications, then we change parameters or add additional components to meet the specifications

5.1Transient Response

Transient response is important. In the case of an elevator, a slow transient response makes passengers impatient, whereas an excessively rapid response makes them uncomfortable. If the elevator oscillates about the arrival floor for more than a second, a disconcerting feeling can result. Transient response is also important for structural reasons: Too fast a transient response could cause permanent physical damage.

Steady-State Response

Another analysis and design goal focuses on the steady-state response. As we have seen, this response resembles the input and is usually what remains after the transients have decayed to zero. For example, this response may be an elevator stopped near the fourth floor or the head of a disk drive finally stopped at the correct track. We are concerned about the accuracy of the steady-state response. An elevator must be level enough with the floor for the passengers to exit, and a read/write head not positioned over the commanded track results in computer errors. An antenna tracking a satellite must keep the satellite well within its beamwidth in order not to lose track. In this text we define steady-state errors quantitatively, analyse a system's steady-state error, and then design corrective action to reduce the steady-state error—our second analysis and design objective.