Chapter 8

Introduction to Control Systems

8.1 Some Basic Definitions

8.1.1 What is a system?

A collection of components that interact with one another and with their environment.

Some examples of systems. Human beings, mechanical devices, an electrical switch, plants, animals, the atmosphere, the stock market, the political system, etc. As aerospace engineers we may consider some aerospace systems like aircraft, helicopters, missiles, avionics, rocket engines, and so on.

8.1.2 What is a control system?

A control system is a collection of components that is designed to drive a given system (plant) with a given input to a desired output.

Examples.

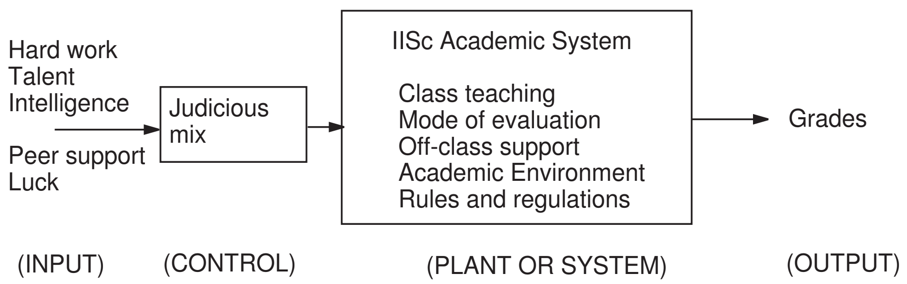

Figure 8.1: *The IISc academic system*

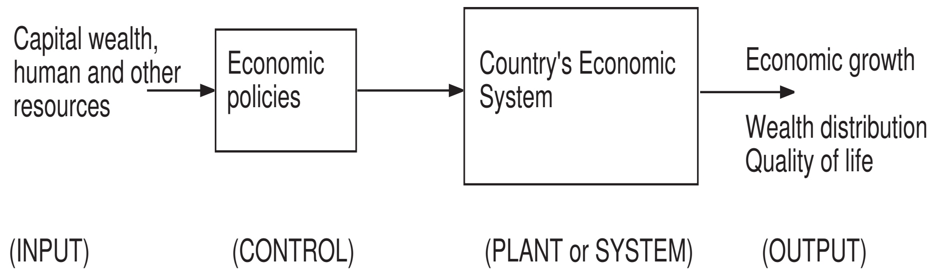

Figure 8.2: *The economic system of a country*

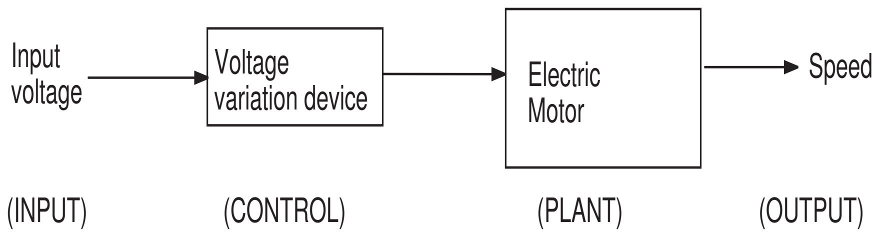

Figure 8.3: *Speed control of an electric motor*

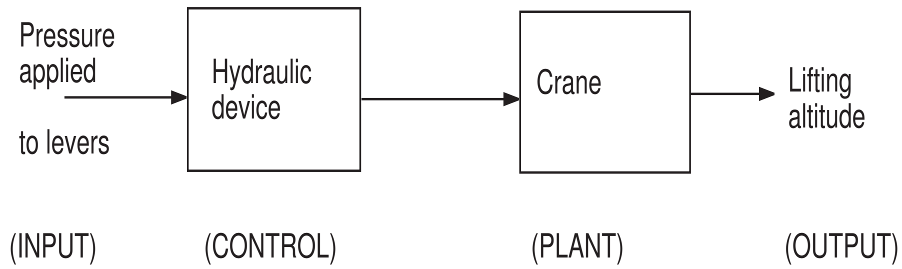

Figure 8.4: *Control of a hydraulic crane*

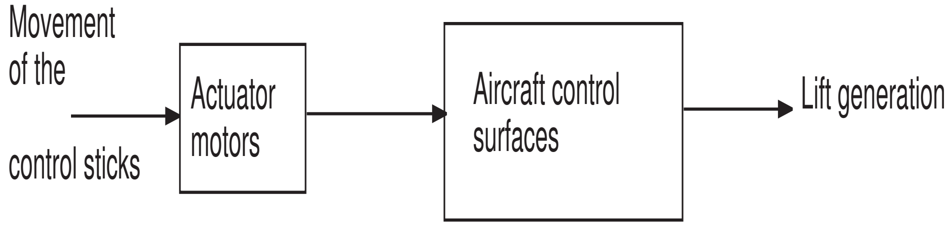

Figure 8.5: *Lift generation in an aircraft*

8.2 Control Problem

Let us be a little more specific about what constitutes a control problem and what are the different types of control problems. In Table 8.1 we consider an aircraft control problem as an example.

Different aspects of the control problem	*Example*
The Plant	Aircraft
Control Inputs	Control surface deflections
Disturbance Inputs	Wind gusts
Outputs	Vehicle Translation and rotation, position and velocities
Goals of Control – Performance criteria, design criteria, control specifications	Speed of achieving commanded output, handling qualities, stability

Table 8.1: *Constituents of a control problem (aircraft example)*

In Table 8.1 note that 'input' and 'output' are defined with respect to a plant. So, output of one plant can be the input to another plant.

In Table 8.2 we give some standard classification terms used in describing a control system.

Open loop	Closed loop
Dynamic	Static
Linear	Non-linear
Time-variant	Time-invariant
Continuous	Discrete-time
Stochastic	Deterministic

Table 8.2: *Classification of control problems*

8.2.1 What is an open loop control system?

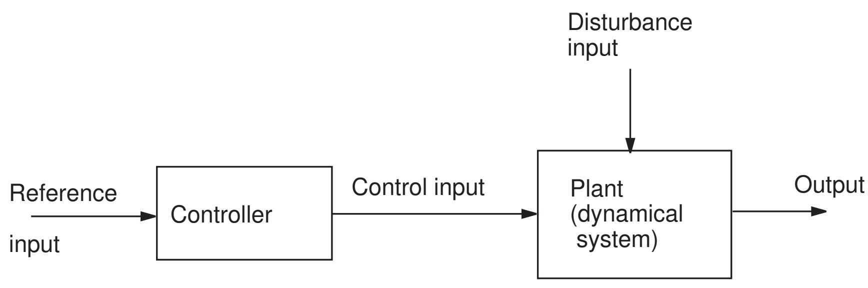

Figure 8.6: *A general open-loop control system*

Example. Electronic Fan Switch

Reference input: Switch on the fan (that is, press the switch and 230 V is applied). So, the reference input is the 230 V signal.

Controller: The electronic voltage controller (that is, turn the knob to the desired position). The effect is to reduce/change the voltage to the appropriate value. We may have approximately 230 V (= full speed) and 115 V (half-speed), and so on.

Once the speed is set there is nothing else that needs to be done. But suppose you have three fans. Even if you give their knobs the same amount of turn, the speeds are likely to be slightly different. This may happen due to inaccuracy in the settings, inconsistency in ball bearings performance, imperfect setting of the fan blades causing different amount of drag on the blades, or maybe due to non-standard performance of the electronic components.

So, essentially an open loop system is one where there is no way to correct the error between the desired output and the actual output.

8.2.2 What is a closed loop control system?

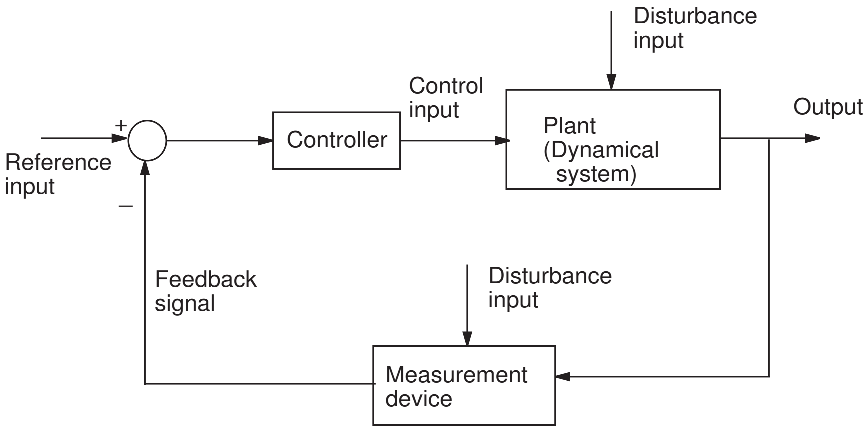

Figure 8.7: *A general closed-loop control system*

Consider the same electronic fan control switch. Assume that you are looking at the fan blades to make sure that the speed is right. If it isn't, then you turn the knob continuously till the desired speed is achieved. The block diagram in Figure 8.7 is not an exact representation of this, but it conveys the idea in a broad sense.

Closed loop systems have different characteristics when compared to open-loop systems.

1. They are more accurate.
2. They are less sensitive to disturbances.
3. They are less sensitive to system characteristics/parameter variations.
4. However, they have a tendency to oscillate.

8.2.3 What are the objectives of controller design?

The main objective is to meet system specifications in the presence of large input disturbances and plant variations. Generally controller design goals are characterized by,

- Speed
- Accuracy
- Stability

8.3 General input-output relationships

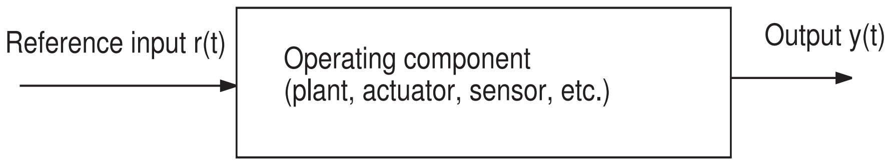

Figure 8.8: *An input-output model of a system*

A *model* is a mathematical relationship between the input and the output of a system. It is an approximation of the physical system.

A model may be described by differential equations (continuous-time systems) or difference equations (discrete-time systems), or a combination of both (hybrid systems).