Control Systems

Part 1: Basics of Control Systems

Learning objectives

- To state the basic concept of feedback control
- To differentiate sensors from the actuators
- To clarify the roles that sensors, actuators and controllers play in a feedback control loop.

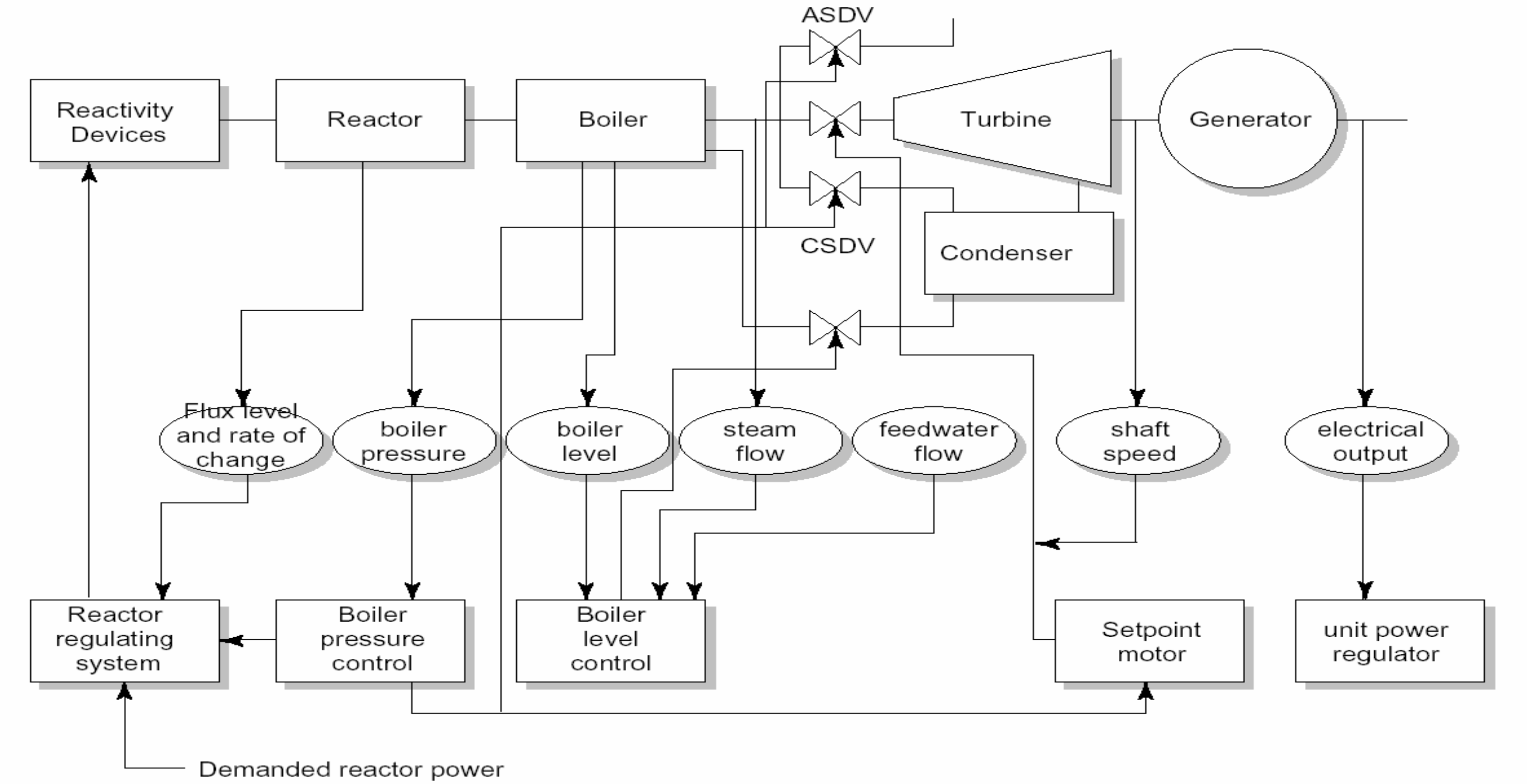
Motivations for control engineering

Feedback control has a long history which began with the early desire of humans to harness the materials and forces of nature to their advantage.

It involves the use of sensed environmental information to aid in the manipulation of system inputs to achieve the desired system behaviours.

Modern industrial plants, such as a nuclear power plant, have sophisticated control systems which are crucial to their successful operation.

Control loops in a nuclear power plant



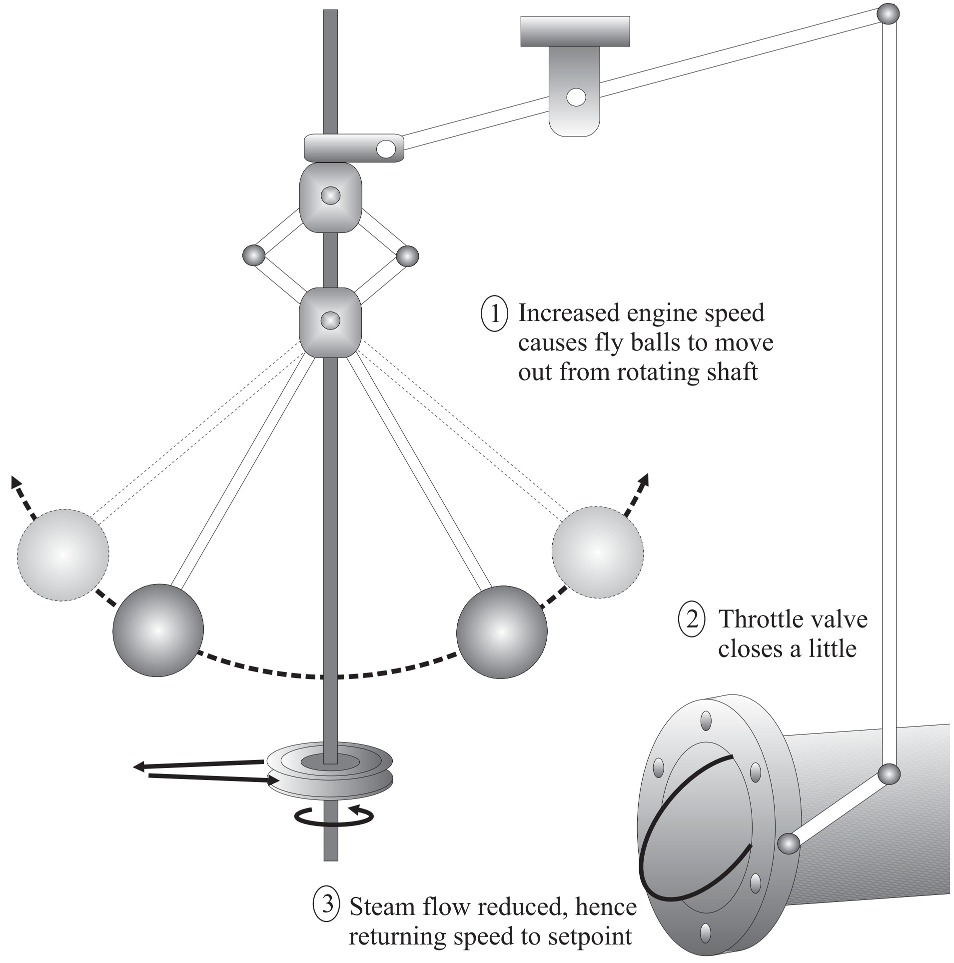
Impact of control systems

Control Engineering has had a major impact on society.

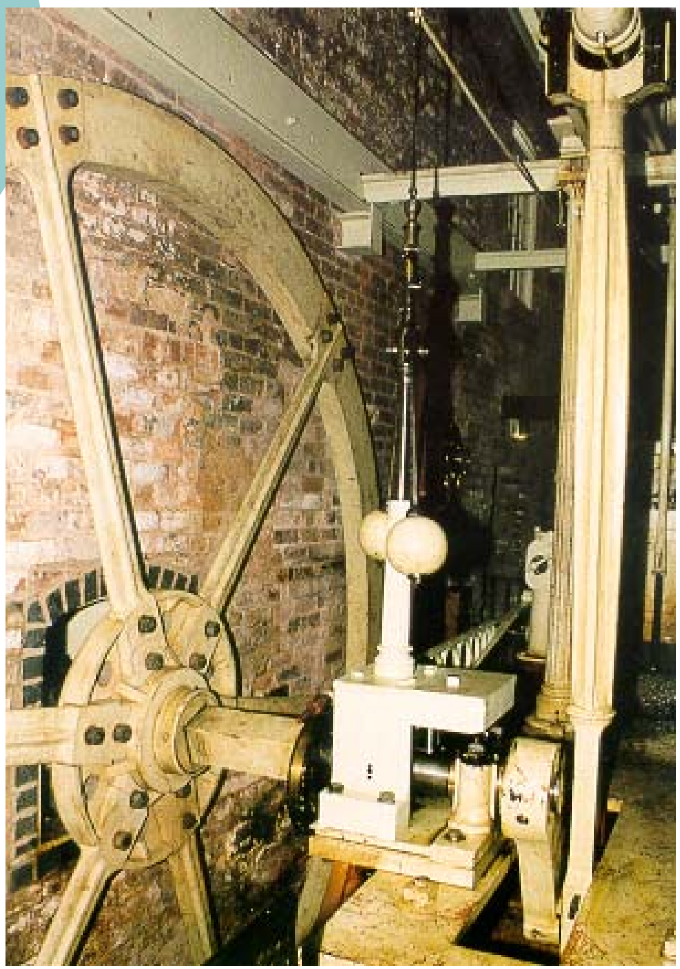
For example, Watt's Fly Ball Governor had a major impact on the industrial revolution.

Indeed, most modern systems (aircraft, high speed trains, CD players, ...) could not operate without the aid of sophisticated control systems.

Watt's fly ball governor



Watt's fly ball governor



This photograph shows a flyball governor used on a steam engine in a cotton factory near Manchester in the United Kingdom.

Of course, Manchester was at the centre of the industrial revolution. Actually, this cotton factory is still running today.

Watt’s fly ball governor

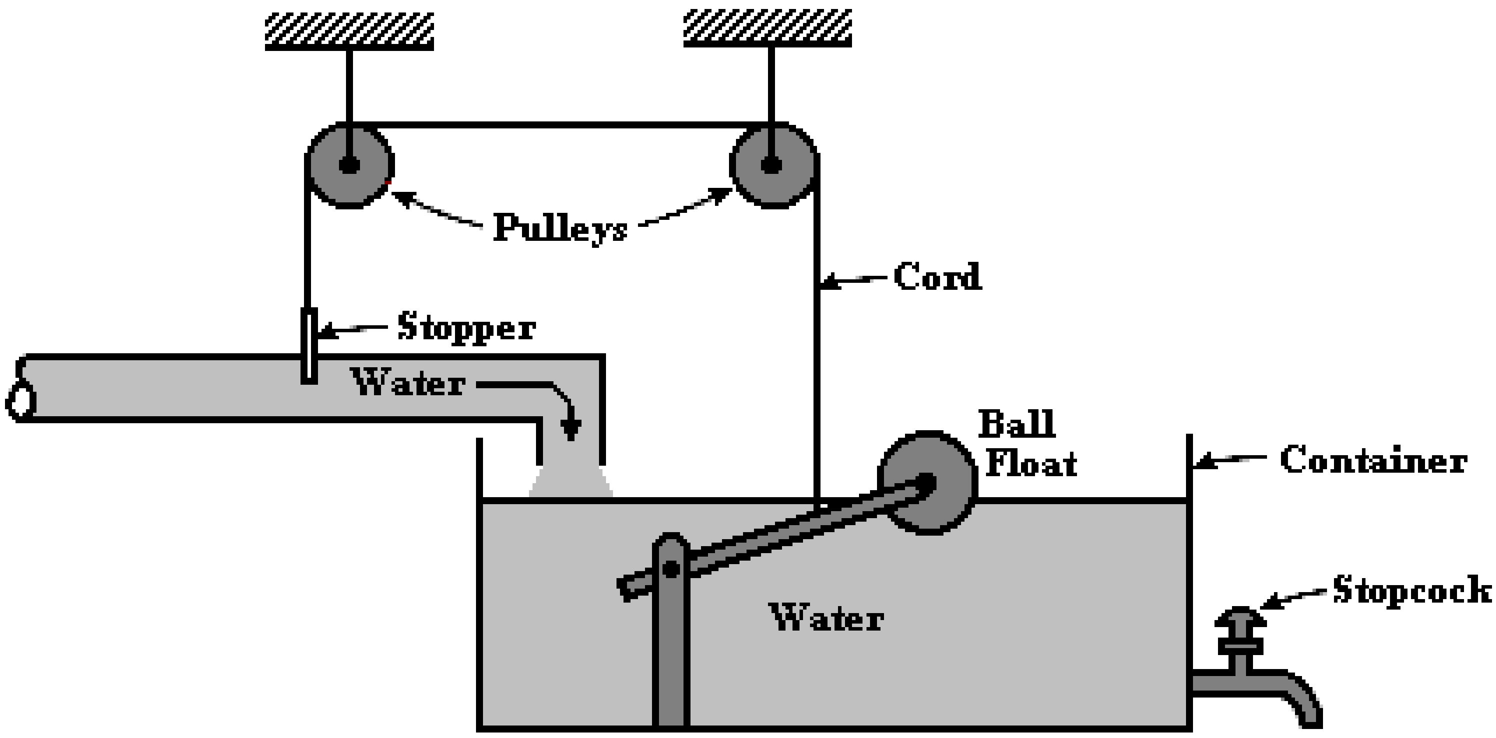
This flyball governor is in the same cotton factory in Manchester.
However, this particular governor was used to regulate the speed of a water wheel driven by the flow of the river. The governor is quite large as can be gauged by the outline of the door frame behind the governor.

Procedure for control system design

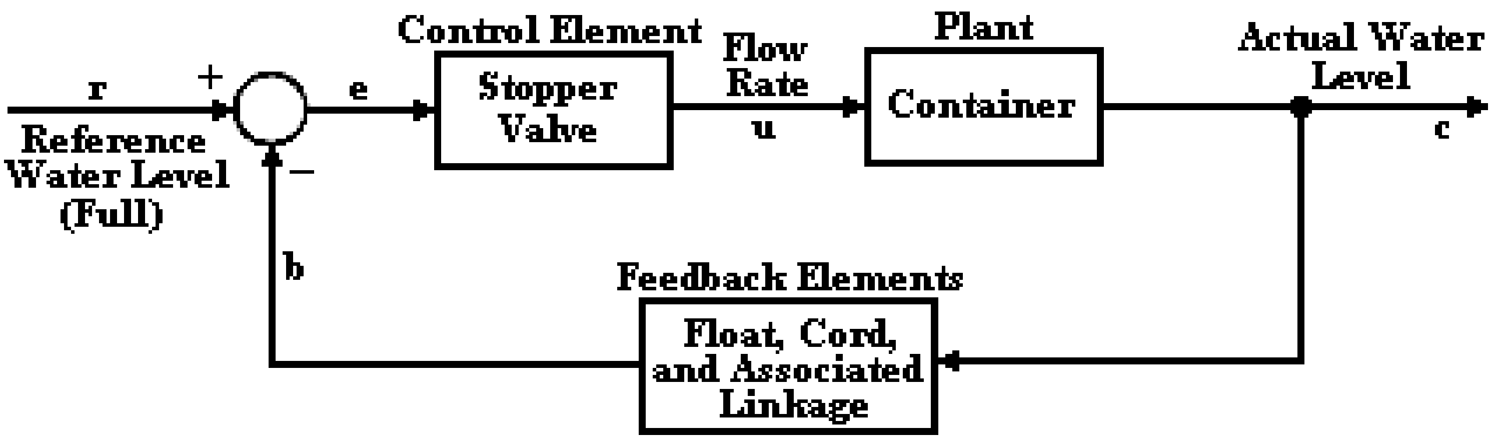
Design of a practical control system usually takes several different stages and each requires a slightly different approach.

- Initial "grass roots" design
- Commissioning and Tuning
- Refinement and Upgrades
- Forensic studies

Simple water level control system



Block diagram representation



Control system integration

Success in control engineering needs to examine the following issues:

- plant, i.e. the process to be controlled
- objectives
- sensors
- actuators
- communications
- computing
- architectures and interfacing
- algorithms
- accounting for disturbances and uncertainty

Plant: The process to be controlled

The physical layout of a plant is an intrinsic part of control problems. Thus a control engineer needs to be familiar with the "physics" of the process under study.

This includes a rudimentary knowledge of the basic energy balance, mass balance and material flows in the system.

Control design objectives

Before selecting sensors, actuators or controller architectures, it is important to know the goal of the closed-loop control system: for example,

- what does one want to achieve (energy reduction, yield increase,...)
- what variables need to be controlled to achieve these objectives
- what level of performance is necessary (accuracy, speed,...)

Sensors

Sensors are the *eyes* of control enabling one to *see* what is going on.

Indeed, one statement that is sometimes made about control is:

If you can measure it, you may be able to control it.

Actuators

Once sensors are in place to report on the *state* of a process, then the next issue is the ability to affect, or actuate, the system in order to move the process from the current state to a desired state.

Controller architecture and algorithm

Finally, we come to the real *heart* of control engineering i.e. the algorithms that connect the sensors to the actuators. One should never underestimate this final aspect of the problem.

As a simple example from our everyday experience, consider the problem of playing tennis at top international level. One can readily accept that one needs good eye sight (sensors) and strong muscles (actuators) to play tennis at this level, but these attributes are not sufficient. Indeed eye-hand coordination (i.e. control) is also crucial to success.

In summary, one can say that:

Sensors provide the eyes and actuators the muscle, but control science provides the finesse.

- **Better Sensors**

  Provide better *Vision*

- **Better Actuators**

  Provide more *Muscle*

- **Better Control**

  Provides more finesse by combining *sensors* and *actuators* in more intelligent ways