CHAPTER 7: OVERALL UNIT CONTROL

MODULE 1: UNIT CONTROL CONCEPTS

MODULE OBJECTIVES:

At the end of this module, you will be able to:

1. **Sketch and label a block diagram which illustrates the gross energy balance of a typical CANDU generating station.**
2. **State the five major control systems necessary for maintaining the overall energy balance while maintaining stable plant control.**
3. **Briefly, explain in writing, the major differences between Reactor Leading and Reactor Lagging modes of control in response to a change in unit power output.**

Energy Balance

A typical generating station can be considered as a series of energy sources and sinks which together provide an overall energy balance.

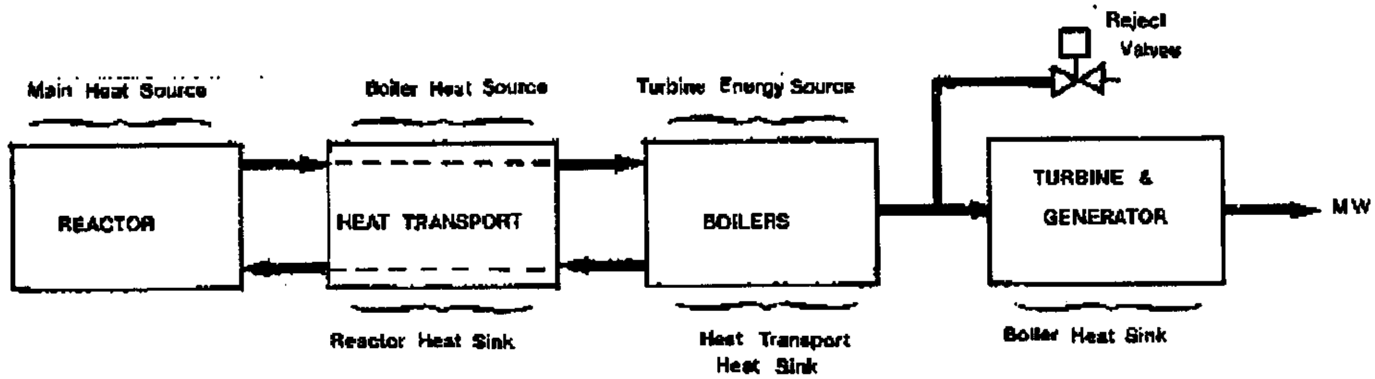

Figure 1: Gross Energy Balance of a Generating Station.

- The reactor provides the heat energy input for the system.
- The heat generated, by the fission process, is carried to the boilers by the heat transport system.
- The boilers convert this transported heat to a source of steam which is used to drive the turbines.
- The turbine drives the generator to provide electrical power to the grid system.
- An alternative final heat sink, in the form of reject valves, is provided in the event that the turbine is not available.

Maintaining the Energy balance

This operation is stable as long as no part of the energy chain is broken. If one portion of the chain is disturbed the system interaction will likely cause control corrections to be necessary in other areas. For example consider a loss in boiler feed water. The boilers now appear as a smaller heat sink for the HTS and less heat will be extracted from it. The pressure, and therefore temperature, of the heat transport system will increase and action must be taken to relieve pressure in the heat transport system possibly by removing the heat source, i.e., reactor.

In all of the control situations which we shall discuss an upset condition will be controlled by:

- re-establishing stable control at the present power level.
- re-establishing stable control at a lower power level.

Overall Unit Control Concepts

There are two methods of overall unit control used in nuclear generating stations. The choice is dictated by the station design and its intended mode of operation. These control modes are usually referred to as:

- reactor leading (turbine following)
- reactor lagging (turbine leading)

Reactor Leading (Turbine Following)

This is the mode used for most base-load stations. Essentially the station electrical output is determined by the reactor power set-point. Changes in electrical output will first require a change in reactor output. The electrical output change will follow the change in reactor power. This mode of control may be necessitated for units having limited dynamic response of their Heat Transport Feed and Bleed Pressure control systems.

Reactor Lagging (Turbine Leading)

This is the preferred mode of operation from the point of view of the bulk electric power system operator. The unit will respond to requested changes in electrical power production directly, with the change in reactor power necessitated by the electrical output change being handled by the unit's control system in the form of a requested reactor power change. In many cases it is not desirable to have frequent changes in reactor output, this can be ensured by having other (non nuclear) units on the bulk electric system that respond more quickly to changes in demand.

Operation of Reactor Leading Mode

Consider a requirement for an increase in unit output. The operator will increase the setpoint of the Unit Power Regulator (UPR). An error will be created between the existing unit output and the new requested unit output. This error signal becomes the new setpoint for the Reactor Regulating System (RRS).

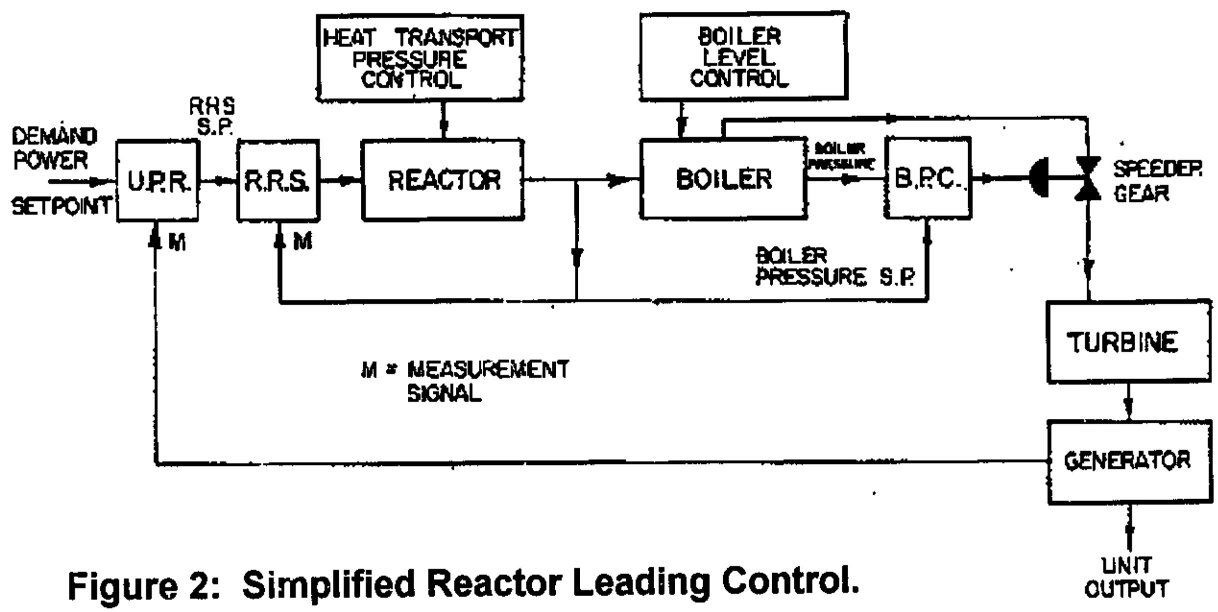

Figure 2: Simplified Reactor Leading Control.

This new RRS. setpoint will cause an increase in the thermal output of the reactor. This additional heat energy output will attempt to increase the pressure of the Heat Transport System which in turn elicits a response from the Heat Transport System Pressure Control to maintain the pressure at the setpoint.

The increased heat energy is fed to the Boilers where a control response from the Boiler Level Control may be necessary to maintain the correct boiler water levels. It can also be seen from the diagram that boiler pressure is also measured and that the boiler pressure setpoint is a function of reactor output power.

Any boiler pressure deviation from the setpoint will cause the speeder gear (and hence the governor valve) to be adjusted, in the case of a power increase the steam flow will be increased, i.e., boiler pressure is held at the setpoint by manipulating steam flow.

The increased turbine output will result in an increased electrical output. It can be seen that the overall unit control loop is closed by a feedback path from the generator to the UPR. . Control action will continue, i.e., reactor power increases, until the measured output of the unit is equal to the new UPR setpoint.

Operation of Turbine Leading Mode

- Consider a request to increase unit power output.
- A setpoint increase will be input to the Unit Power Regulator (UPR).
- The ensuring error between the setpoint and the actual power output will cause an adjustment of the speeder gear to increase steam flow to the turbine thus increase the unit's electrical output.
- Once the actual power output meets the new demanded setpoint speeder gear operation will be held steady.

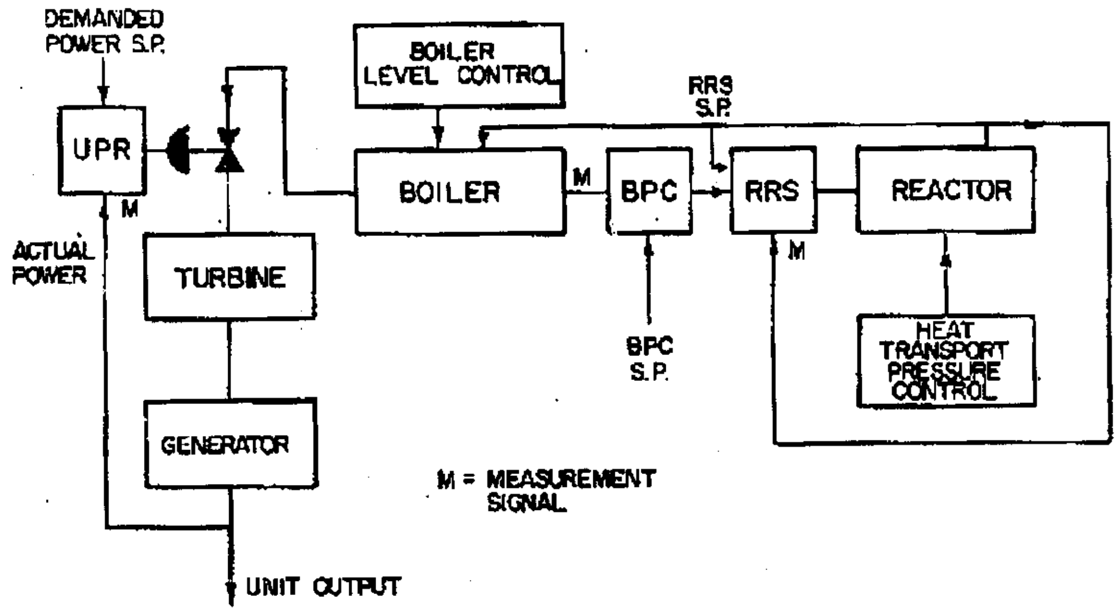

Figure 3: Simplified Reactor Lagging Control

- The increased steam demand will cause a decrease in boiler pressure.
- The resulting error signal from the BPC becomes the new setpoint signal for the Reactor Regulating System.
- The RRS will now increase reactor power until boiler pressure is restored.
- The unit is once again in a stable condition.
- It can be seen that a similar control response would occur as the result of a variation in load from the grid. In this case the demanded setpoint would remain constant and the error generated, which adjusts the speeder gear setting, would be as a result of the load change.

Two points should be remembered about overall unit control.

(1) The basic unit control functions are performed by five control loops. These are:

(a) Unit Power Regulator (UPR) controls the overall unit power output. It is a primary interface between the operator and the control system.

(b) Reactor Regulating System (RRS) controls the power and rate of change of power of the reactor.

(c) Boiler Pressure Control (BPC) controls the boiler pressure via the speeder gear (and hence governor valves) and via the steam reject valves. Note that in the Reactor Leading mode the Boiler Pressure Setpoint is a function of Reactor Power, i.e., a variable setpoint.

(d) Boiler Level Control (BLC) controls the boiler level as a function of unit output power.

(e) Heat Transport System Pressure Control regulates heat transport system pressure and therefore HTS temperature. A pressurizer and/or feed and bleed are the methods for pressure regulation.

(2) All CANDU generating stations are designed to be run under automatic control. The operator's normal function is to initiate a change of operating conditions or to intercede if automatic control action is impaired for any reason, e.g., equipment failure or during run up and run down operations.

Assignment

1. Sketch and label a simple block diagram which illustrates the energy transfer in a typical CANDU generating station.

2. Overall plant control is maintained by five major control loops. List the loops and state their principle function.

3. Briefly explain the control responses to a request for an increase in station power output for:

   (a) A Reactor Leading Unit
   (b) A Reactor Lagging Unit.