General Electric Advanced Technology Manual

Chapter 6.7

Balance of Plant System

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6.7 BALANCE OF PLANT SYSTEM

Learning Objectives:

1. Explain how water level is controlled with motor driven feedwater pumps.

2. Explain how and why pump runout protection is provided for motor driven feedwater pumps.

3. Explain how some of the feedwater control systems minimize level overshoot.

4. List the major differences found in condensate and feedwater systems.

6.7.1 Introduction

The discussion in this section is directed toward the condensate and feedwater system and the feedwater control system. Keeping in mind that the condensate and feedwater system is designed by the architectural engineer in concurrence with the utility; very few are the same. However, you will discover that all systems must have a means of delivering the water at sufficient pressure and volume to maintain reactor vessel water level during normal system operation. In addition, the condensate and feedwater system will cleanup and preheat the water prior to delivering it to the reactor vessel.

The feedwater control systems consist of two basic types with small variations to account for the specific condensate and feedwater system being controlled.

6.7.2 Condensate and Feedwater System

The two most common condensate and feedwater systems used differ in the type of feed pumps, feedwater heater arrangement, and the means of filtering and cleaning up the water.

6.7.2.1 Early Condensate and Feedwater System

The condensate and feedwater system, Figure 6.7-1, is an integral part of the plants conventional regenerative steam cycle. The steam exhausted from the three low pressure turbines is condensed in the main condenser and collected in the condenser hotwell, along with various equipment drains. The condensate is removed from the hotwell by three of the four condensate pumps. The fourth pump is a standby pump with an automatic start feature if one of running pumps should trip. The condensate pumps provide the driving force for the condensate which flows through the steam jet air ejector (SJAE) condensers and gland seal leak off (GSLO) condensers; to perform a heat removal function. At this point the condensate is directed to the condensate demineralizers to filter and demineralize the condensate. After the demineralizers, booster pumps increase the driving force for the condensate flowing through three parallel strings of low pressure feedwater heaters.

Each heater string is rated for 33% flow. Isolation of a string requires routing the flow through the bypass line around the heater string. This type of heater string arrangement yields a large and sudden decrease in feedwater temperature following heater string isolation. Decreasing feedwater temperature will cause reactor power to increase and the power distribution to peak in the bottom of the core.

The motor driven feedwater pumps take the preheated water and further increases the pressure to a value above reactor pressure. The amount of feedwater flowing to the reactor vessel is controlled by varying the position of the feedwater regulating valves.

The discharge of the feedwater regulating valves is directed to the high pressure feedwater heater strings for the final stage of feedwater heating. Two feedwater lines penetrate the primary containment and further divide into a total of four lines. Each of the four supply lines provides feedwater to its respective sparger. The feedwater spargers distribute the flow of feedwater within the vessel annulus area.

6.7.2.2 New Condensate and Feedwater System

The condensate and feedwater system, shown in Figure 6.7-2, is an integral part of the plant's conventional regenerative steam cycle. The steam exhausted from the three low pressure turbines is condensed in the main condenser and collected in the condenser hotwell along with various equipment drains. The condensate is removed from the hotwell by three condensate pumps. The condensate pumps provide the driving force for the condensate which flows through the (SJAE) condensers, steam packing exhauster condenser, and offgas condensers to perform a heat removal function. At this point the condensate is directed to the condensate demineralizers and through the process of ion exchange, impurities are removed. After the demineralizers, booster pumps increase the driving force of the condensate flowing through strings of low pressure feedwater heaters. The turbine driven, variable speed, feedwater pumps take the condensate and increase the pressure to a value above reactor pressure.

The amount of feedwater flowing to the reactor vessel is controlled by varying the speed of the turbine driven reactor feed pumps. The discharge of the feedwater pumps is directed to the high pressure feedwater heater strings for the final stage of feedwater heating. Two feedwater lines penetrate the primary containment and then further divide into a total of six lines which penetrate the reactor vessel. Each line supplies feedwater to its respective feedwater sparger. The feedwater spargers distribute the flow of feedwater within the vessel annulus area.

6.7.3 Feedwater Control System

The feedwater control system regulates the flow of feedwater to the reactor vessel in order to maintain reactor water level within the normal range during all modes of plant operation. The regulation of feedwater flow is accomplished by modulating the position of feedwater regulating valves or feed pump turbine speed. The feedwater control system measures and uses total steam flow, total feedwater flow, and reactor vessel water level signals to carry out its function.

Discussion of the two basic types of feedwater control systems are given in the paragraphs that follow.

6.7.3.1 Regulation of Feed Flow with Feedwater Regulating Valves

The feedwater control system (Figure 6.7-3) used to regulate the flow of feedwater via feedwater regulating valves has four modes of operation, each with a specific purpose.

Manual Operation

Used for feedwater control at low powers or for a water level problem.

Single-Element Operation

Used to control the low flow feedwater regulating valve and the normal feedwater regulating valves.

Three-Element Operation

Used to control the feedwater regulating valves.

Runout Flow Control

Allows the maximum feedwater flow possible without overloading or tripping the motor driven reactor feedwater pumps.

During normal operation the feedwater control system regulates reactor vessel water level by measuring different parameters:

- mass flow rate leaving the reactor vessel (steam),
- mass flow rate returning to the vessel (feedwater), and

- the mass inventory of water in the reactor vessel (level).

The three parameters are combined to develop a signal that is used to modulate the opening of the feedwater regulating valves.

During startups, shutdowns, and low power operation the rate of feedwater flow to the vessel is controlled by the low flow feedwater regulating valve.

6.7.3.1.1 Component Description

The components of this system are discussed in the paragraphs that follow.

Reactor Water Level Instrumentation

Reactor water level is measured by two independent level transmitters with a range of 0 to 60 inches. Only one of the two instruments may provide level signals to the FWCS at a time. Selecting either level A or level B instrument is accomplished via a level selector switch.

Total Steam Flow

Steam flow is calculated in each of the four steam lines by measuring the differential pressure across a flow restrictor. The calculated steam flow signals are sent to a four input summer which develops a total steam flow signal. The total steam flow signal is used as an input to the steam flow/feed flow summer, rod worth minimizer system and steam leak detection system.

Total Feedwater Flow

Feedwater flow is measured by venturi flow elements located in the two feedwater lines penetrating the drywell. The output signals from the flow transmitters are sent to a feedwater flow summer that generates a total feedwater flow signal. The total feedwater flow signal is used as an input to the steam flow/feed flow summer, flow integrator, RFC System, and the runout flow controller.

Steam Flow/Feed Flow Summer

The feedwater flow summer output (- signal) and steam flow summer output (+ signal) are sent to the steam flow/feed flow summer where they are summed to produce a base signal for the FWCS. If steam flow and feed flow are not equal, this summer will produce a signal either greater than or less than the base signal. The algebraic signs are such that when steam flow exceeds feedwater flow, the output signal will modify the level signal to indicate the need for additional feedwater flow. Thus, an anticipatory signal is developed which will correct for projected changes in level due to process flow changes. This anticipatory signal corrects feedwater flow to lessen the effect of changes on reactor level due to a change in steam demand.

Level/Flow Summer

The output of the steam flow/feed flow summer, a flow error signal, is compared with the selected reactor water level signal to produce an output signal referred to as the modified level signal. The flow error signal provides anticipation of the change in the reactor vessel water level that will result from a change in load. The level signal provides a reference for any mismatch between the steam flow and feed flow that causes the level to rise or fall.

Master Level Controller

The master level controller is provided to control either or both feedwater regulating valves to achieve the desired feedwater flow. Both single element and three element control modes of operation are available as determined by the mode selector switch.

Feedwater Regulating Valve Control

The feedwater regulating valves are positioned by valve operators. Air is supplied by a valve positioner to both the top and bottom on the valve operator diaphragm. Increasing the air pressure to the top and decreasing the air pressure on the bottom of the diaphragm causes the valve to close. The positioner output is controlled by a 3-15 psig air signal from the E/P converter. The E/P converter output is controlled, in turn, by an electrical signal from the FWCS controllers.

Runout Operation

The runout flow control network is provided to prevent tripping a reactor feed pump on overcurrent or low suction pressure due to an abnormally high flow. The flow through each of the three RFPs is monitored by devices called alarm units. If one or more RFPs exceed the alarm unit setpoint (5.6×10^6 lbm/hr), a RFP runout relay is energized. The runout relays control the AA solenoid and is energized only when two RFPs are running. The BB solenoid is energized if a runout condition is sensed by the runout relay.

Energizing the BB solenoid removes the M/A transfer station(s) from control and places the runout flow controller in the control circuit. The runout relay also causes the feedwater regulating valve bypass valve to close.

The runout flow controller compares a fixed setpoint with the total feedwater flow. If the total feedwater flow is greater than the fixed setpoint, a negative error signal is generated. The integrator output decreases and the feed regulating valves close until the feedwater flow matches the maximum setpoint allowed. The runout relay resets automatically when level indication increases to 20 inches. Manual reset of the runout relay is allowed if level is below 20 inches provided that the runout condition is not present.

Scram Response Operation

Feedwater systems with feedwater regulating valves or slow responding turbine driven feedwater pumps tend to over fill the reactor vessel following a scram. To counteract this effect, the FWCS reduces the level demand signal by 50% following a scram. The master controller output is returned to its normal demanded value upon resetting the reactor scram.

6.7.3.2 Regulation of RFPTs

The FWCS controls reactor water level low enough to minimize carryover, a condition that entrains moisture in the steam leaving the reactor vessel. Conversely, the FWCS controls water level high enough to minimize carryunder, a condition in which steam is entrained in the reactor vessel annulus water.

Reactor water level is measured by three independent sensing networks, each consisting of a differential pressure transmitter connected to a water reference condensing chamber leg located in the drywell. Feedwater mass flow rate is measured by flow transmitters coupled across flow elements in the feedwater lines. Total feedwater flow rate, as used by this system, is the sum of the signals from the feedwater lines. Steam mass flow rate through each of the steam lines is measured by differential pressure transmitters connected across the steam flow elbow tap in each steam line. The steam flow signals are summed before being used by the feedwater control circuit.

The FWCS, Figure 6.7-4, generates a signal that is used to regulate the position of the turbine speed control steam supply valves; thereby controlling the pumping effort of the turbine driven reactor feed pumps. The FWCS also generates the control signal that is used to position the reactor fill valve and the discharge throttle valve bypass (DTVB) during low power operation.

6.7.4 Summary

Condensate and feedwater systems are designed by the architectural engineer in concurrence with the utility; very few are the same. However, all systems must have a means of delivering the water at sufficient pressure and volume to maintain reactor vessel water level during normal system operation. In addition, the condensate and feedwater system will cleanup and preheat the water prior to delivering it to the reactor vessel.

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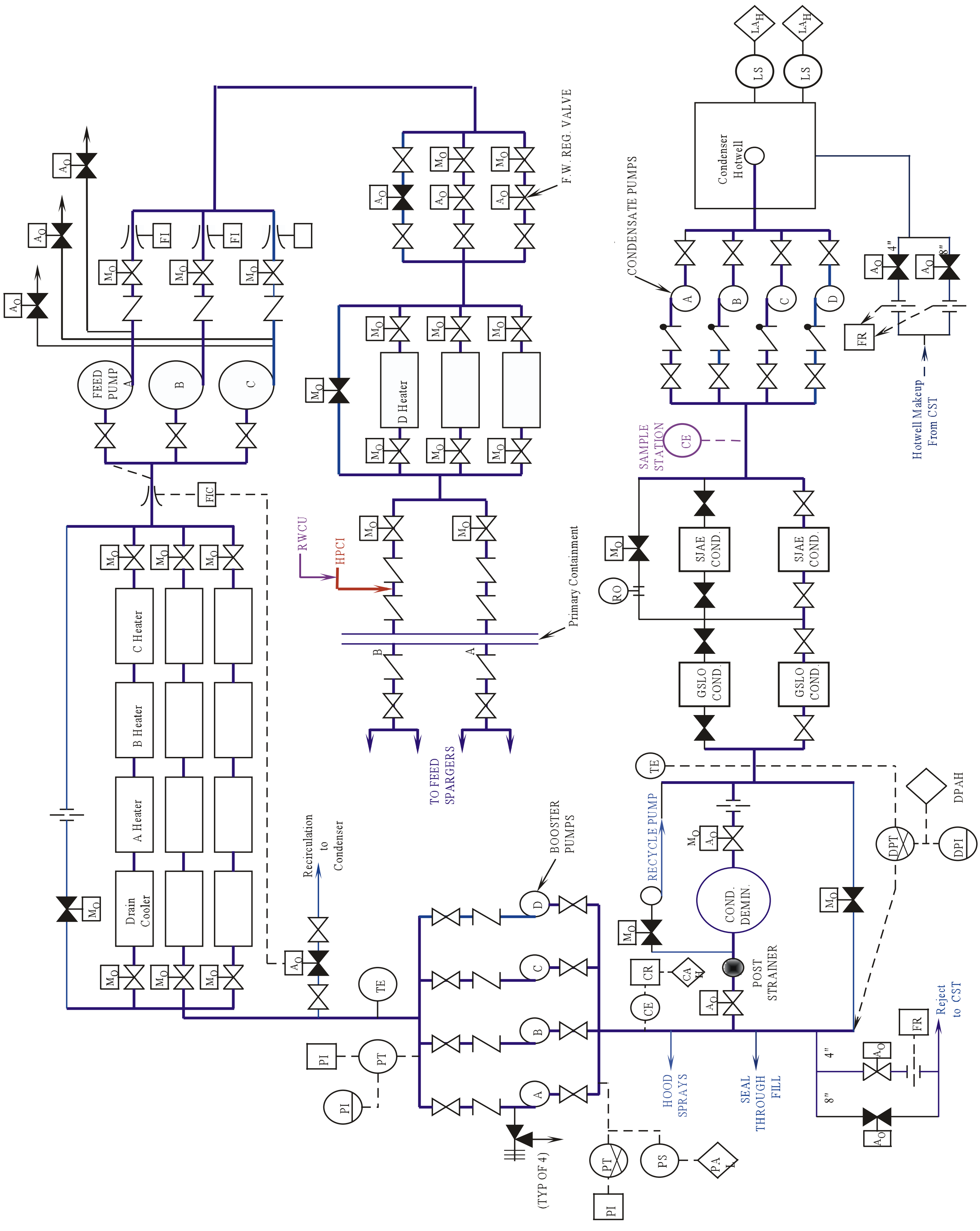

Figure 6.7-1 Condensate and Feedwater System BWR/3

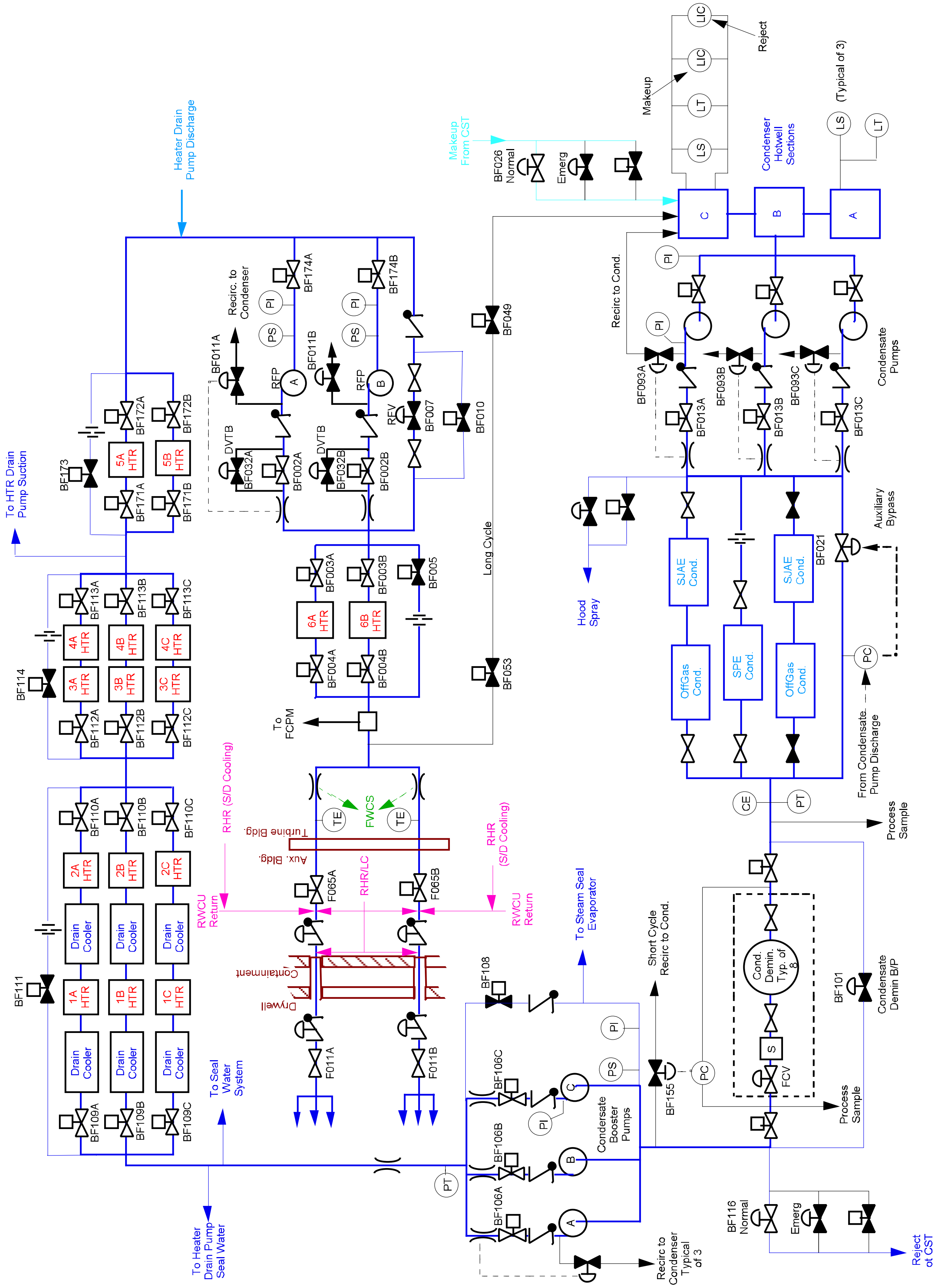

Figure 6.7-2 Condensate and Feedwater System BWR/4

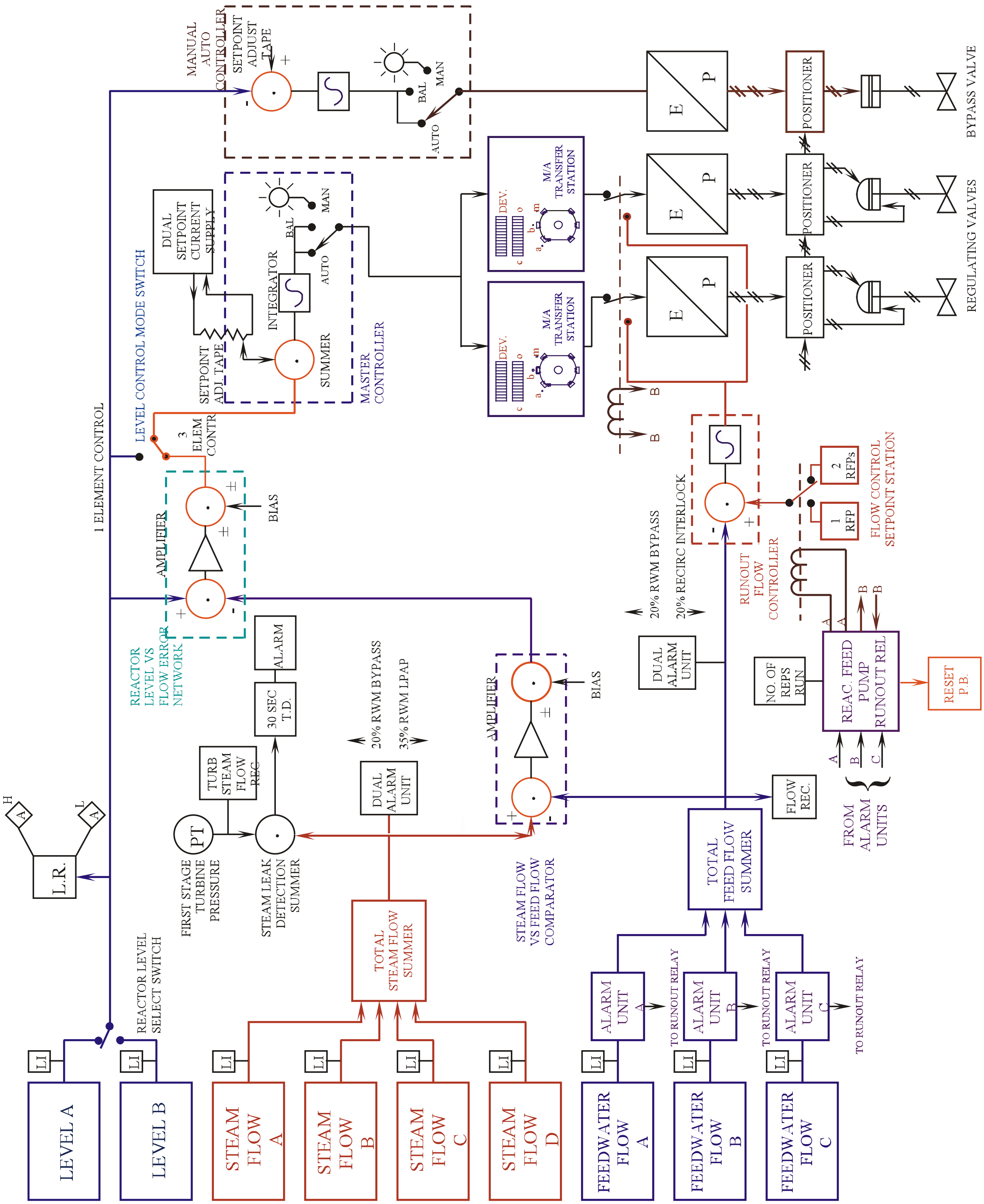

Figure 6.7-3 Feedwater Control System for Motor Driven Feed Pumps

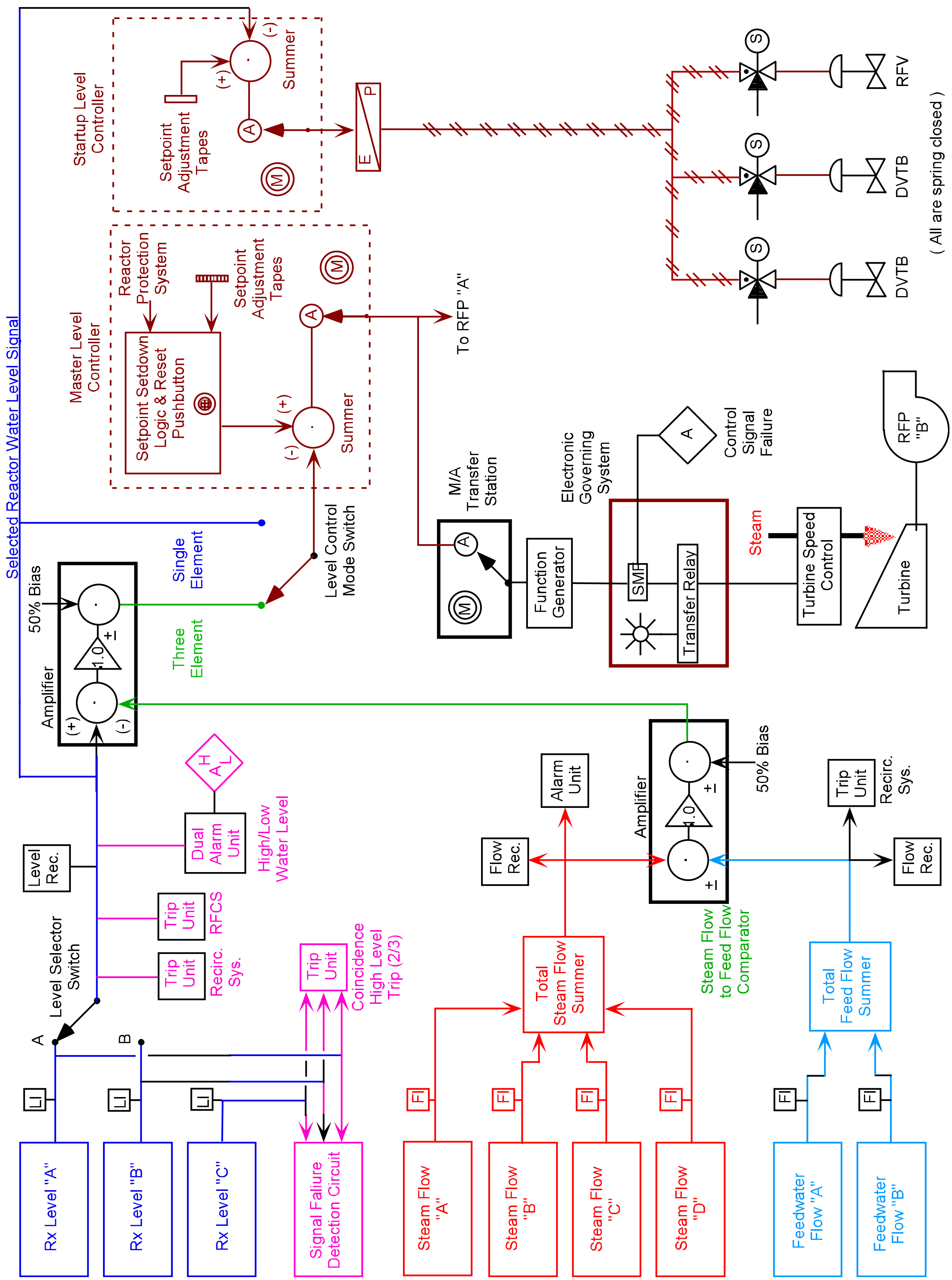

Figure 6.7-4 Feedwater Control System for Turbine Driven Pump