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4 REACTOR REGULATING SYSTEM

Learning Objectives:

1. State the purpose of the reactor regulating system (RRS).
2. List the input signals to the RRS.
3. List the RRS system interfaces.
4. Explain the effect of a given instrument failure on the RRS and its interface systems.

4.1 Introduction

The purpose of the Reactor Regulating System (RRS) is to sense the operating condition of the reactor and provide the following control signals:

1. pressurizer level control system programmed level setpoint,
2. analog output signal for atmospheric steam dump valve control,
3. ADV and Turbine bypass valve (TBV) quick - open signal,
4. $T_{avg} - T_{ref}$ alarm, and
5. a total error (power error plus temperature error) signal to provide an automatic control capability for the regulating groups of control element assemblies (CEAs).

There are two independent RRS systems installed in the plant. Either RRS may be selected.

In order to minimize the inherent decrease in steam pressure associated with the U-tube steam generator, a linear ramp of T_{avg} from 532°F at 0% power to 572.5°F at 100% power is used. The RRS is designed to maintain actual T_{avg} on the curve by withdrawing or inserting the CEA control groups.

At Calvert Cliffs, automatic CEA control is disabled due to concerns with local power peaking.

4.2 RRS Inputs

4.2.1 Temperature Inputs

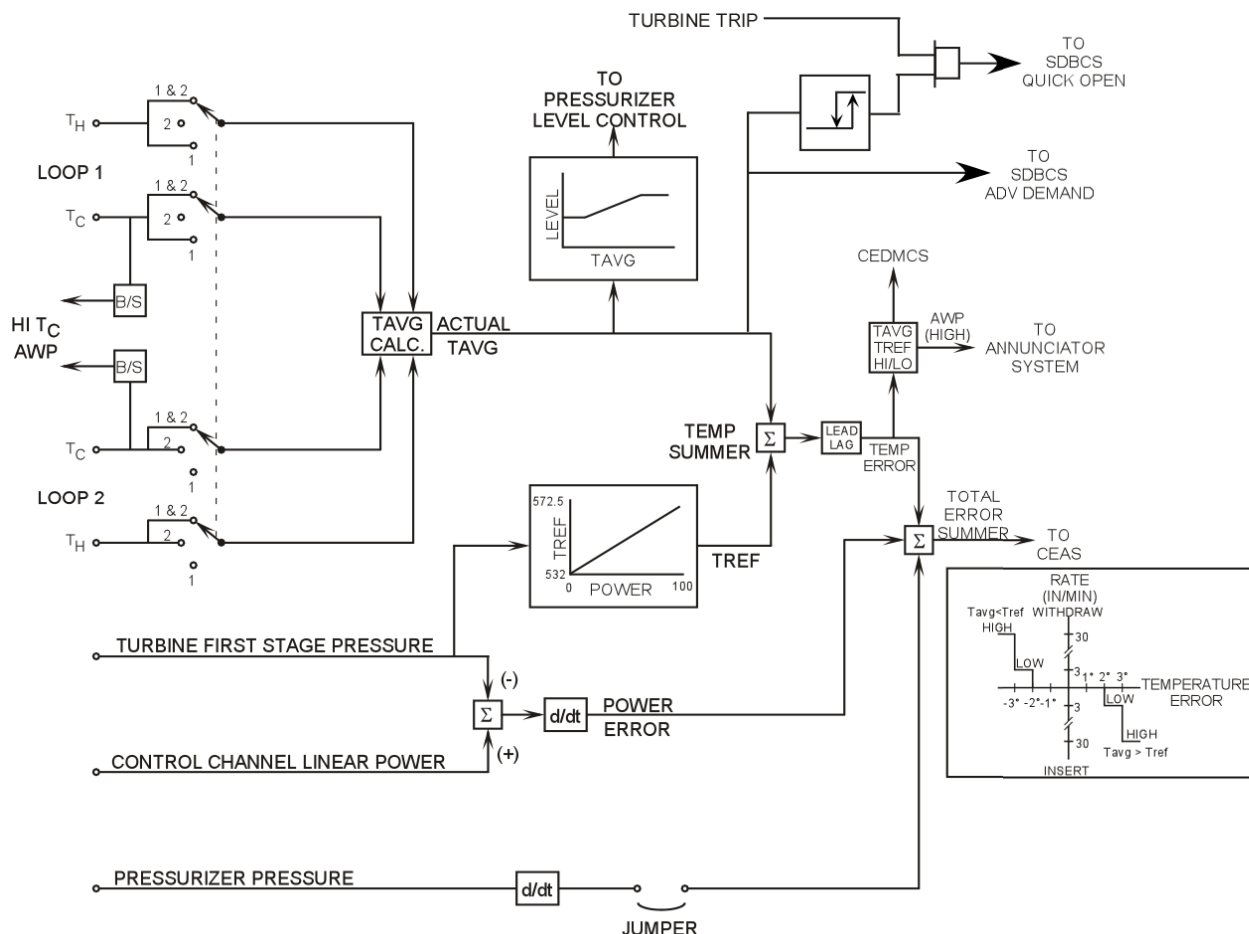


Figure 4-1 Reactor Regulating System

As shown in Figure 4-1, the RRS receives an input of hot (T_h) and cold (T_c) leg temperatures from each RCS loop. These outputs are routed to a selector switch that is used to determine the inputs that are used in the calculation of T_{avg} . The selector switch provides the operator with the option of choosing either loop 1, loop 2, or both loops as inputs to the calculation of T_{avg} . Both loops are normally selected to minimize the error associated with failure of one RTD. If both reactor regulating systems are selected to the 1 & 2 positions, both channels of the RRS will be identically affected by a temperature detector failure, i.e. selecting the other RRS will not restore proper operation of the RRS.

The output range of the T_{avg} calculator is 515°F to 615°F which is the same range as the individual temperature detector inputs. The output of the T_{avg} calculator is used to generate the pressurizer level setpoint, the steam dump quick open signal, the analog signal for ADV control, and is also supplied to the temperature summer where it is compared with the reference temperature that is calculated from turbine first stage pressure (T_{ref}).

4.2.2 Turbine First Stage Pressure

Since the purpose of the RRS is to maintain T_{avg} at the desired value for efficient turbine operation, it is logical to use a turbine load related parameter as an input. Turbine first

stage pressure varies linearly as turbine load changes and is used in two different ways by the RRS. First, the first stage pressure input is used to generate the variable T_{avg} setpoint called reference temperature (T_{ref}). T_{ref} is compared with actual T_{avg} in the temperature summer and the difference between the temperature values is used to determine rod motion. The second use of turbine first stage pressure is in the development of power error.

As previously stated, first stage pressure is directly proportional to turbine load or power. This turbine power signal is compared with reactor power in the power summer and is used as an anticipatory signal for CEA motion demand.

The output of the power summer is supplied to a rate unit (d/dt). If there is a rate of change of turbine power with respect to reactor power, the rate unit will have an output.

4.2.3 Reactor Power Input

The RRS reactor power input is supplied from the control channel associated with each RRS cabinet. The control channel input is used in the development of the power error signal. The non-safety related control channel signal has a range of 0 to 120% power.

4.2.4 Pressurizer Pressure

This signal was designed to provide an anticipatory indication of RCS temperature changes, but is removed at Calvert Cliffs with a jumper.

4.3 RRS Circuitry

4.3.1 Temperature Lag Circuit

The output of the temperature summer is supplied to a lead/lag unit that functions to correct system response for measurement time delays.

4.3.2 Total Error Summer

The total error summer receives inputs from the temperature summer, the power summer, and pressurizer pressure (if used). The output signal is a temperature error signal that has been modified by the rate of change of power. The summer output will be used in determining CEA speed and direction.

4.3.3 CEA Rate Circuit

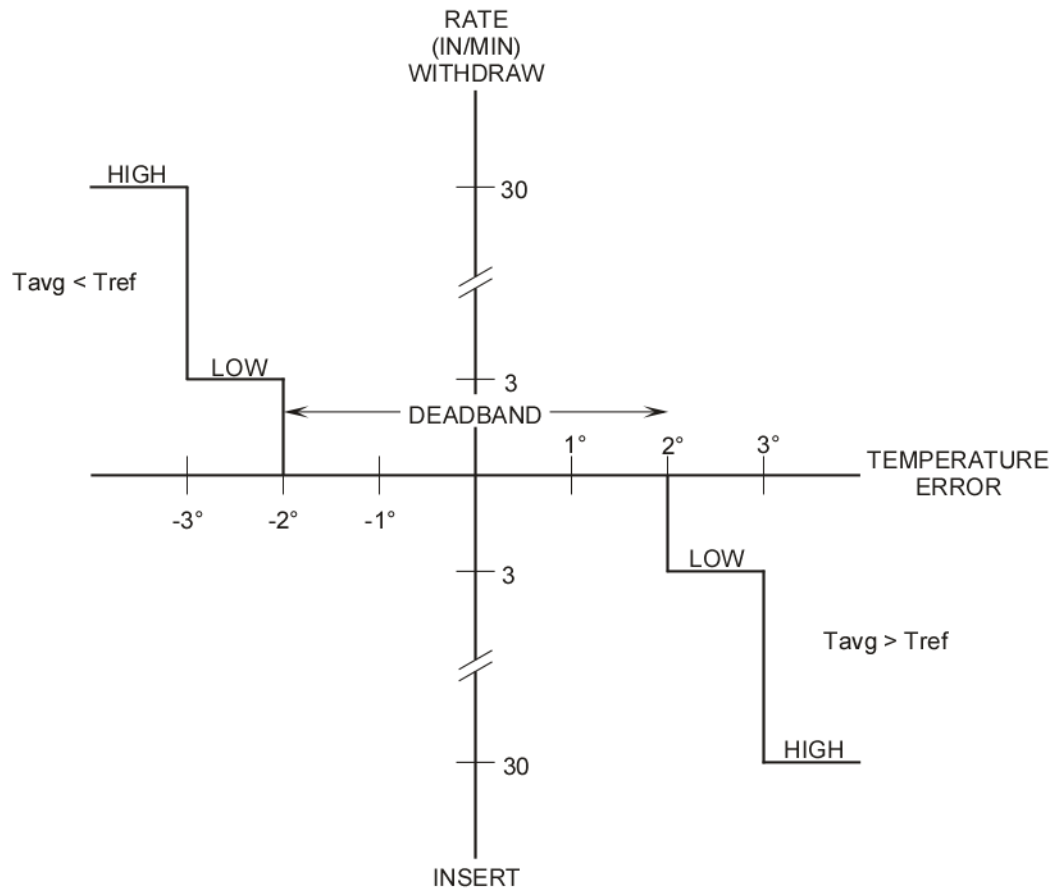


Figure 4-2 CEA Rates and Direction

The modified temperature error signal from the output of the total error summer is used in determining the speed of CEA movement. As shown on Figure 4-2, equivalent temperature errors of 2°F result in low rate CEA motion while errors of 3°F result in high rate CEA motion. Low rates of CEA insertion or withdrawal occur at three inches per minute. High rates of CEA insertion or withdrawal occur at 30 inches per minute. Since automatic CEA movement is disabled at Calvert Cliffs, low rate CEA motion is not possible.

4.3.4 CEA Direction Circuit

The output of the total error summer is also supplied to the CEA direction circuit which is used to determine the need for CEA insertion or withdrawal. When the temperature error is less than $\pm 2^\circ\text{F}$, no CEA motion will be demanded in either direction. This 2°F deadband prevents unnecessary CEA motion. When the error exceeds $+2^\circ\text{F}$ ($T_{avg} > T_{ref}$) inward CEA motion will be demanded at the rate determined by the CEA rate circuit. When the temperature error exceeds -2°F ($T_{avg} < T_{ref}$), CEA withdrawal will be demanded at the rate determined by the CEA rate circuit. These values and directions are shown on Figure 4-2.

4.4 RRS Indications

The following is a listing of RRS indications that are available for use by the control room operator:

1. T_{avg}/T_{ref} recorder - One (1) two (2) pen recorder per RRS. One pen indicates T_{avg} , while the second pen registers the value of T_{ref} .
2. T_{avg} indication indicates the value of T_{avg} from the selected RRS.
3. A level setpoint provides indication of the calculated pressurizer level setpoint.
4. On the Calvert Cliffs simulator, CEA status lamps (5) provide the following indication:
 - a. High rate CEA withdrawal,
 - b. Low rate CEA withdrawal,
 - c. Hold,
 - d. High rate CEA insertion and
 - e. Low rate CEA insertion.

These lamps have been removed at the Calvert Cliffs plant, but are still functional on the TTC CE simulator.

4.5 RRS Interfaces

In addition to supplying the pressurizer level control system with its setpoint, the RRS also interfaces with the CEDS and SDBCS. The CEDS interface consists of CEA rate, CEA direction, and automatic withdrawal prohibit (AWP) signals. AWP signals prevent CEA withdrawal if a high T_c or a large T_{avg}/T_{ref} error exists. For the SDBCS, the demand signal to the atmospheric steam dump valves and the quick opening signal to all SDBCS valves is generated by the selected RRS.

4.6 Instrument failures

Any failure that causes the selected T_{avg} to be inaccurate can affect the pressurizer level control system (PLCS) and the steam dump and bypass control system (SDBCS).

Since the pressurizer level program is a function of selected T_{avg} , any failures involving selected T_{avg} will cause program level to change in accordance with figure 6.2-1.

T_{avg} is interlocked with the turbine trip signal in the SDBCS. Any failures of selected T_{avg} will cause improper SDBCS operation following a turbine trip. This will affect modulation of the atmospheric dump valves and the quick open of all bypass and dump valves.

Since CEAs are operated in manual at Calvert Cliffs, failures of control channel linear power or turbine first stage pressure cannot result in spurious CEA motion. Only the CEA status lights can be affected on the TTC CE simulator.

A high failure of an RTD could cause a spurious AWP on high T_{cold} or high $T_{avg}-T_{ref}$.

4.7 Summary

The RRS is installed to maintain the desired ramp of T_{avg} as power is increased. The ramp in T_{avg} minimizes the reduction in steam pressure which, in turn, improves turbine efficiency. The RRS receives inputs from T_{avg} , turbine first stage pressure, and linear control channel reactor power. In addition to controlling T_{avg} , the RRS also supplies

signals to the pressurizer level control system and the steam dump and bypass control system.

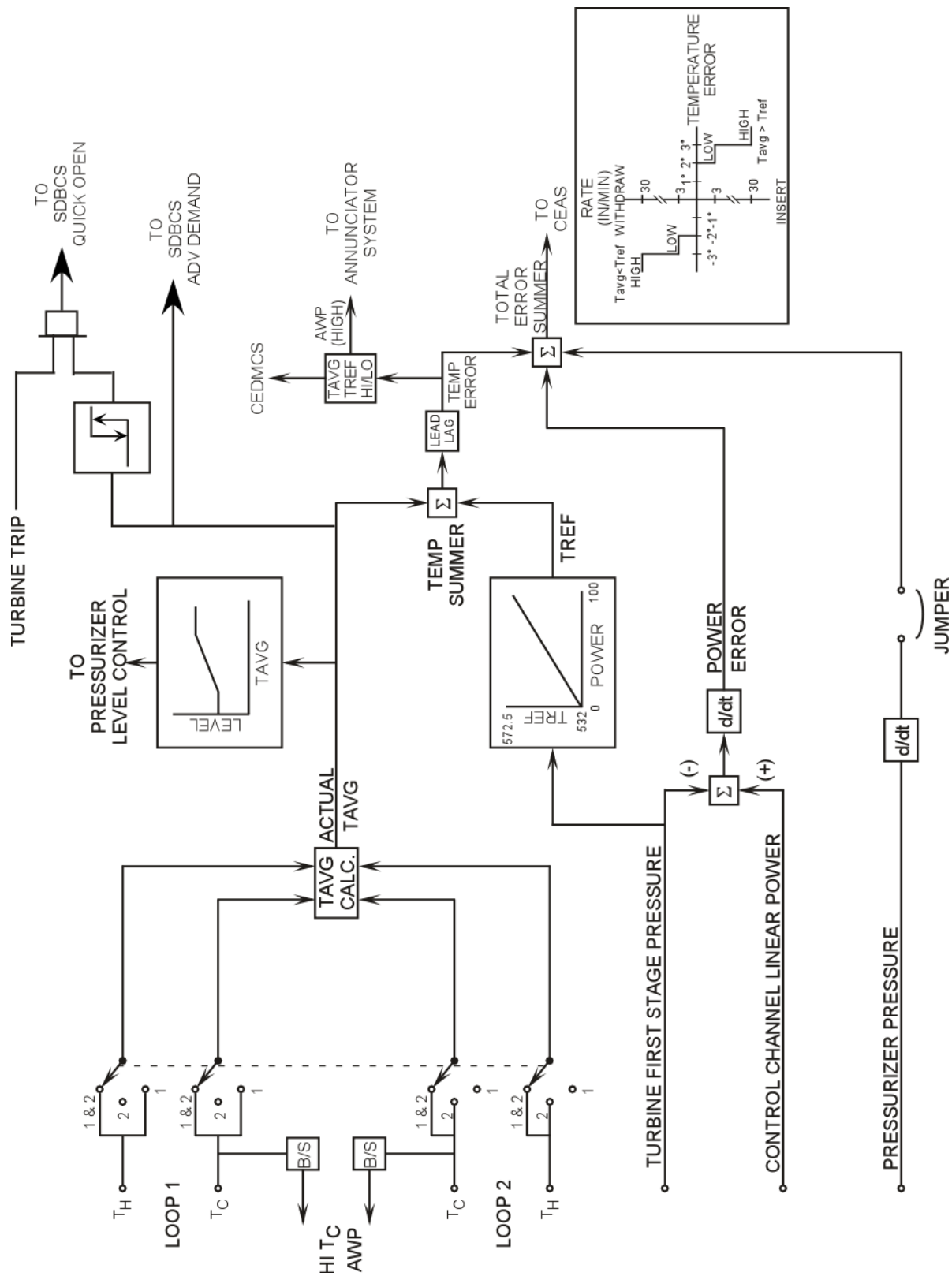


Figure 4-1 Reactor Regulating System

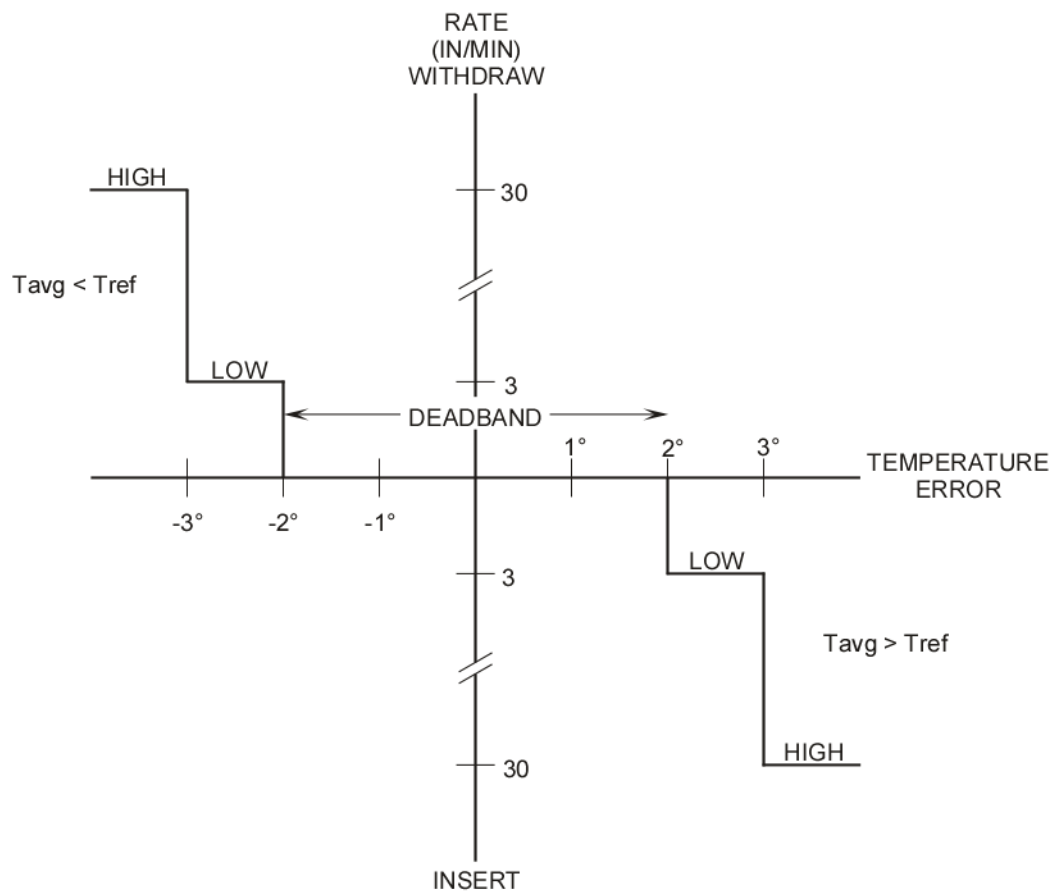


Figure 4-2 CEA Rates and Direction