7.9 RECIRCULATION FLOW CONTROL SYSTEM

7.9.1 Power Generation Objective

The objective of the Recirculation Flow Control System is to control reactor power level over a limited range by controlling the flow rate of the reactor recirculating water.

7.9.2 Power Generation Design Basis

The Recirculation Flow Control System is designed to allow manual control of reactor power by adjusting the flow rate of the recirculation water.

7.9.3 Safety Design Basis

The Recirculation Flow Control System shall function so that no operational transient resulting from a malfunction in the Recirculation Flow Control System can result in fuel damage or in a violation of the nuclear system pressure limit.

7.9.4 Description

7.9.4.1 General

The Recirculation Flow Control System adjusts the flow rate of the recirculating pumps by adjusting the frequency and voltage supplied to the pump motors. The change in flow, then effects changes in reactor power.

An increase in recirculation flow temporarily reduces the void content of the moderator by increasing the flow of coolant through the core. Due to the higher moderator density, the core reactivity, and thus power level, is increased. At this higher power level (higher heat flux), the steam volume in the core increases with a subsequent decrease in core reactivity. A new steam void equilibrium is subsequently attained at the higher recirculation flow rate, which establishes a new steady-state power level. When the recirculation flow is reduced, the power level is reduced in the reverse manner.

When both reactor recirculation pumps are operating (Unit 2 only), one equalizer valve between the two recirculation pump discharge lines is opened and the other equalizer valve is closed. The motive power to the valves is removed. This prevents pressure buildup between the equalizer valves due to ambient and conduction heating of the water. Units 1 and 3 have a different recirculation pump discharge piping arrangement which does not have equalizing valves.

7.9.4.2 Variable Frequency Drive (Units 1, 2, and 3)

Units 1, 2, and 3 - Each variable frequency drive (VFD) supplies power to its associated recirculating pump motor. Each of the two VFDs and its controls are identical; therefore, only one description is given. The VFD can continuously supply power to the pump motor at any frequency between approximately 11.5 Hz and 57.5 Hz. The VFD is capable of starting the pump and accelerating it from standstill to the desired operating speed when the pump motor thrust bearing is fully loaded by reactor pressure acting on the pump shaft.

Units 1, 2, and 3 - The main components of the VFD are transformers, power cells and control center to adjust the output speed.

7.9.4.2.1 VFD Transformers (Units 1, 2, and 3)

Units 1, 2, and 3 - The VFD transformers supplies 3-phase voltages to the output power cells. The normal AC power for each transformer is supplied from that unit's associated unit station service transformer, and the alternate AC power is supplied from a different bus.

7.9.4.2.2 Power Cells (Units 1, 2, and 3)

Units 1, 2, and 3 - The VFD power cells provide output power to the recirculation pump motor.

7.9.4.3 Speed Control Components

Units 1, 2, and 3 - The speed control system is a fault tolerant digital control system. This system is configured to provide for individual VFD control and common master manual control. This control system is comprised of various I/O and processor modules with operator control stations in the main control room. The VFD has a master control center that interfaces with each VFD's speed control system. All control and limiting functions are performed via software operating on the processor modules.

7.9.4.3.1 Master Control

Units 1, 2, and 3 - The master control station allows for varying the speed of both recirculation pumps simultaneously.

7.9.4.3.2 Speed Demand Limiter

Units 1, 2, and 3 - The VFDs are equipped with a frequency change limiter. This limiter provides a limit to the rate of change of frequency for the VFD.

7.9.4.3.3 Manual Control Station (Units 1, 2, and 3)

Units 1, 2, and 3 - Each VFD is provided with an individual control station to allow individual manual control, and a parallel master control station with the capability of manually varying the speed of both recirculation pumps simultaneously.

7.9.4.3.4 Speed Controller (One for each VFD - Units 1, 2, and 3)

Units 1, 2, and 3 - The software implemented speed controller provides the signal that adjusts the VFD speed control.

Units 1, 2, and 3 - The individual VFD speed control setpoint signal is adjusted from the master control station during master manual control, and from the individual VFD control stations during individual VFD manual operation. A preset startup setpoint is input during pump startup.

7.9.4.3.5 Startup Signal Generator (One for Each VFD - Units 1, 2, and 3)

Units 1, 2, and 3 - A software startup signal generator will supply an output to the VFD control to provide for an approximate 11.5 hertz frequency of the recirculation pump motor.

7.9.4.3.6 Speed Limiter Two for Each VFD - Units 1, 2, and 3)

Units 1, 2, and 3 - The two speed limiters are implemented in software. Speed limiter No. 1 automatically limits the recirculation pump speed to 28 percent of rated speed if the recirculation pump main discharge valve is not fully open, or if the total feedwater flow is less than 19 percent of rated flow. Without this speed limiter, the recirculation pump could overheat if the recirculation pump discharge valve is partly closed. This speed limiter also prevents cavitation in the recirculation or jet pumps, if the feedwater flow drops below 19 percent of rated flow.

Speed limiter No. 2 automatically limits the recirculation pump speed to 75 percent of rated flow if one of the three feedwater pumps is at low flow and, coincidentally, the reactor water level is below the low-level alarm setpoint. This reduction of the recirculation pump speed reduces the reactor power to a level within the capacity of the remaining feedwater pumps flow, thus preventing plant shutdown due to a low-water-level scram. Units 2 and 3 - Speed limiter No. 2 is also initiated on a reactor scram signal to limit the recirculation pump speed to 75 percent of rated flow to mitigate the magnitude of reactor water level transients from a scram.

There are three operator initiated manual runbacks. Two runbacks are based on total steam flow (for an approximation of reactor power), and one based on total core flow.

7.9.4.4 System Operation

7.9.4.4.1 Recirculation Loop Starting Sequence (Units 1, 2, and 3)

Each recirculation loop is independently put into operation by operating the controls of each recirculation loop as follows:

a. The starting sequence is manually initiated by placing the VFD start switch for one VFD in the start position. The VFD supply breaker closes provided that:

   1. The recirculation loop suction valve is fully open.

   2. The recirculation loop discharge valve is fully closed.

   3. RPT breaker closed.

   4. VFD lockout relay is reset.

   5. 4160V Recirculation Board lockout relay is reset.

b. After recirculation pump start is sensed by a differential pressure switch, the jogging circuit initiates the pump discharge valve open sequence.

c. Recirculation flow is initially increased during startup to a preset value providing all control system permissives are met.

d. After startup, the master control station can control both recirculation loops or the individual VFD control stations can control their respective recirculation loop.

e. Recirculation flow is increased by manually increasing pump speed.

7.9.4.5 Recirculation Pump Trip (RPT) Control System

7.9.4.5.1 Description

The recirculation pump trip (RPT) is the recirculation control system that trips the recirculation pump motors from their power supplies in response to a turbine-generator trip, load rejection, or an Anticipated Transient Without Scram (ATWS). Its function is to reduce the severity of the thermal transients on the fuel due to the turbine-generator trip and load rejection events by tripping the recirculation pumps early in the event, and to reduce reactor power during an ATWS event. The rapid core-flow reduction increases void content and thereby reduces reactivity in conjunction with the control rod scram. See FSAR Section 7.19 for a description of the ATWS RPT system.

The RPT system is not classified as safety-related but is designed to Class 1E standards (IEEE 279). The RPT breakers and trip logic are designed as seismic Category 1, Class 1E equipment and are expected to remain functional in the event of a design basis earthquake. Input to the RPT trip logic is from relays in the reactor protection system (RPS).

The major components of the RPT system are RPS relays which trip on turbine control valve fast closure and stop valve position, RPS relays which respond to reactor output power level, separate division logic, and two circuit breakers for each pump motor.

The RPT System does not need to be operable until reactor thermal power is greater than or equal to 30 percent rated thermal power. It may remain inoperable above this power level if the minimum critical power ratio limits specified by the Core Operating Limits Report (COLR) for the RPT out-of-service condition are met.

7.9.4.5.2 System Design

The RPT system design is based on two separate trip divisions; each has equipment for each measured variable. This system is designed to meet the single-failure criterion such that any single trip channel (sensor and associated equipment) or system component failure does not prevent the system from performing its intended function.

Electromechanical relays are used, as the logic elements within the RPT system and the RPT system logic are of the fail-safe type (i.e., trip on loss of electrical power). A switch is provided to reset the RPT system manually after pump trip.

The total delay time from start of "Turbine Stop Valve Closure," or "Turbine Control Valve Fast Closure," to complete suppression of the electric arc between the fully open contacts of the circuit breaker is less than 175 milliseconds at 80 percent of rated pump motor speed.

The start of the "Turbine Stop Valve Closure" event is defined as the beginning of turbine stop valve motion from its original full-open position.

The start of the "Turbine Control Valve Fast Closure" event is defined as the beginning of turbine control valve fast closure motion. If this event signal is not available as a time measurement reference, the control-valve hydraulic-pressure-switch change-of-state can be used as a substitute. This can be done only if it can be demonstrated that the hydraulic-pressure-switch change-of-state occurs before or within 30 milliseconds after the beginning of control valve fast closure motion.

When either of the end-of-cycle (EOC) recirculation pump breakers trips, the VFD breaker (Units 1, 2, and 3) is then tripped. This is accomplished through automatic logic control.

Both of the EOC breakers must be closed for the VFD breaker (Units 1, 2, and 3) to be closed. The interlock is accomplished through automatic logic control.

7.9.4.5.3 Equipment

Individual components were procured to specifications which satisfy the operational and environmental conditions. Manufacturer and plant startup test data, or reasonable engineering extrapolation based on test data, are available to verify that equipment which must operate to provide protection system action meets, on a continuing basis, the performance requirements determined to be necessary for achieving the system requirements.

Primary Logic Elements and Sensors

The primary trip channels and division logic elements are fast-response, high-reliability-type relays which are compatible with those relays used for the Reactor Protection System. Sensors and associated equipment are highly reliable, and the components are of a quality consistent with minimum maintenance requirements and low failure rate.

Circuit Breakers

Each pump motor has two circuit breakers in series. The circuit breakers are designed, built, and supplied with quality assurance to Class 1E equipment.

One circuit breaker trip coil is used exclusively for the RPT system. Separate division control power supply is provided for each of the series-connected circuit breakers.

All control and information circuits for each breaker, except for the trip coil used for the RPT system, is provided with approved isolation devices (isolation relays or other devices per IEEE-Standard 384) to permit interfacing with non-Class-1E external control and information circuits.

Cables

Wiring for the two-pump RPT system requires special isolation, routing, and protection considerations and is in accordance with the design criteria, “Physical Independence of Electrical Systems."

Equipment Components

The equipment components which form a part of the recirculation pump trip control system are listed below, along with their function and operating requirements.

Circuit Breaker	Operating Requirements
a. Normal Range (a)	Pump motor current at 30 percent to 100 percent rated speed
b. Accuracy (b, c)	N/A
c. Number of Trip Coils	Two
d. Interrupting Time follows:	Linear from 60 Hz to 15 Hz as

System Frequency (Hz)	Reactor Power (% NBR) (e)	Pump Motor Speed (% Rated)	VFD (Units 1, 2, & 3) Frequency (Hz)	Breaker Interrupting Time (Milliseconds)
60	100	80	44.8	<135
60	30	30	16.8	<360

"Turbine Stop Valve Closure" Sensor

a. Normal Range (a)	Fully open to fully closed
b. Accuracy (b, c)	N/A
c. Trip Setting	A fixed valve position less than or equal 90 percent open
d. Response Time (d)	N/A

"Turbine Control Valve Fast Closure" Sensor

a. Normal Range (a)	Fully open to fully closed
b. Accuracy (b, c)	N/A
c. Trip Setting	Low Emergency Trip System (ETS) Fluid Pressure

d. Response Time (d) N/A

Recirculation Pump Trip System Bypass Switch

a. Normal Range (a) N/A

b. Accuracy (b, c) ± 3 percent rated power (e)

c. Bypass Setting 30 percent or less of rated power (e, f)

d. Response Time (d) N/A

Notes:

(a) Prudent, steady-state operational limits of the measured variable.

(b) The maximum-allowable error (based on full range) or the measurement at the point of switch actuation.

(c) The maximum-allowable error (based on full range) in the trip setpoint for repetitive switch actuation.

(d) The maximum-allowable time from when the variable being measured just exceeds the trip setpoint for opening the trip channel sensor contact during a transient event.

(e) Rated power defined as the main turbine power that corresponds to the reactor operation at 100 percent power with 100 percent recirculation flow.

(f) If the setpoint of the RPT is different for TSV closure and control-valve fast-closure scram bypass in the RPS, the setpoint for TSV closure and control-valve fast-closure scram bypass govern.

7.9.4.5.4 Reliability

The system is designed to accomplish the desired protection function and to minimize the effect of this additional system on plant availability.

The logic design does not cause the inadvertent trip of more than one pump, given a single component failure in the system. Each trip division is clearly identified to reduce the possibility of inadvertent trip of the recirculation pump during routine maintenance and test operations.

Redundant sensor circuits in each division (sensors, wiring, transmitter, amplifiers, etc.) are electrically, mechanically, and physically independent, so that they are unlikely to be disabled by a common cause except for an electrical power failure.

7.9.4.5.5 Testability

Capability is provided for testing the system logic and calibrating instrument channels once per refueling outage. Channel functional testing is performed once per quarter to ensure continued operability of the RPT function.

Provisions allow closure of stop valve and fast closure of turbine control valve separately, at least one valve at a time (for normal routine valve test purposes), without causing a pump motor trip.

The system input sensors and the division logic are capable of being checked one channel or division at a time. The sensors and system logic test or calibration during power operation does not initiate pump trip action at the system level.

Annunciators for operating bypasses are provided in the control room. The annunciators are activated when the sensor or division logic has been bypassed or deliberately rendered inoperative for testing or repair purposes. Failure to restore normal signals to the sensors, or removal of bypass after test, is guarded against by making such failure conspicuous to the operating personnel and by ensuring that adequate checkoff, locking, and sealing procedures are followed.

7.9.4.5.6 Maintainability

The RPT system is designed to facilitate the recognition, location, replacement, repair, or adjustment of setpoint and malfunctioning components or modules. Most failing components in the system can be repaired or replaced during reactor operation without initiating the pump trip action at system level.

7.9.4.5.7 Operation Information

The RPT system is designed to provide the operator with accurate, complete, and timely information pertinent to the system status. Indicators and annunciators are provided for system input trip signals, initiation signal at system level, the status of trip coils, and the mechanical position of the circuit breakers.

7.9.4.5.8 System Interaction

The RPT system is separated from other recirculation control systems to the extent that failure of any single component in those systems does not prevent the system from performing its intended function.

7.9.4.5.9 Performance

The RPT system design meets the maximum time delay requirement such that rapid reactivity reduction is achieved early during turbine-generator trip or generator load-rejection event transients.

7.9.5 Safety Evaluation

Units 1, 2, and 3 - The Recirculation Flow Control System is designed with a VFD System instead of the MG Set System. The VFD does not add inertia for coastdown time.

Transient analyses described in Section 14.0, "Plant Safety Analysis," show that no malfunction in the Recirculation Flow Control System can cause a transient sufficient to damage the fuel barrier or exceed the nuclear system pressure limits, as required by the safety design basis.

7.9.6 Inspection and Testing

Units 1, 2, and 3 - The VFDs and their controls are functioning during normal power operation. Any abnormal operation of these components can be detected during operation. The components which do not continually function during normal operation can be tested and inspected during scheduled plant shutdowns. Recirculation Flow Control System components are tested and inspected according to good maintenance practice and based on component manufacturer’s recommendations.