Westinghouse Technology Systems Manual

Section 12.2

Reactor Protection System – Reactor Trip Signals

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12.2 REACTOR PROTECTION SYSTEM - REACTOR TRIP SIGNALS

Learning Objectives:

1. Given a list of reactor trips, explain the purpose (basis) of each.

2. Given a list of Reactor Protection System (RPS) interlocks, explain the purpose of each.

3. Given a list of control-grade interlocks, explain the purpose of each.

12.2.1 Introduction

The purposes of the reactor trip signals are to initiate a reactor trip if safe operating limits are exceeded. The safe operating limits bounded by these trips are monitored by sensors and are compared to preselected bistable setpoints. If a processed parameter exceeds its associated setpoint, a reactor trip occurs. The specific functions of all reactor trips are discussed in the following sections.

12.2.2 Reactor Trip Functions

The philosophy of the reactor protection system is to define an area of permissible operation in terms of power, flow, axial power distribution, and primary coolant temperature and pressure, so that the reactor is tripped when the limits of a selected area of concern are approached. When the protection system receives signals indicative of an approach to an unsafe operating condition, the system actuates alarms, prevents control rod withdrawal (if applicable), initiates a turbine runback (if applicable), and/or opens the reactor trip breakers. The overpower ΔT (OPΔT) and overtemperature ΔT (OTΔT) reactor trips provide core protection for situations in which:

- The transient is slow with respect to coolant piping delays from the core to the temperature sensors, and
- Pressure is within the range between the high and low pressure reactor trips.

Other reactor trips shown in Figure 12.2-1, such as the low coolant flow and high nuclear flux trips, provide core protection for accidents in which the loop ΔT signal does not respond quickly enough. Additional reactor trips, such as the high pressurizer water level and low feedwater flow trips, are provided primarily for equipment protection. Finally, some reactor trips, such as those produced by a turbine trip or reactor coolant pump circuit breaker opening, are provided to anticipate probable plant transients and tominimize the resulting thermal transient on the reactor coolant system (RCS). Descriptions of the reactor trips are provided in section 12.2.3 and in Table 12.2-1.

Protection-grade interlocks (designated as P-n), also known as permissives, and control-grade interlocks (designated as C-n) are also described in this section. An interlock blocks certain actions and permits others. Rod withdrawal stops are

examples of control-grade interlocks; they are provided to prevent abnormal conditions which could result in a trip in response to excessive control rod withdrawal initiated by either a control system malfunction or a violation of administrative procedures by the operator. Descriptions of interlocks are provided in sections 12.2.3 and12.2.4 and in Tables 12.2-2 and 12.2-3.

A reactor trip is initiated by interrupting power to the rod cluster control assemblies (RCCAs). Power is delivered to the RCCAs from the rod drive motor generator sets through two series-connected trip breakers. Opening either trip breaker removes power to the rods. Each breaker is designed to trip open by spring action when a small undervoltage coil in the breaker assembly is de-energized. When this coil is de-energized, it allows a mechanical latch to move, allowing the spring to open the trip breaker. The undervoltage coil to reactor trip breaker (RTB) “A” is powered by protection train “A,” and that of RTB “B” is supplied by protection train “B.” Therefore, either protection train is capable of initiating a reactor trip, regardless of the action by the opposite train.

12.2.3 Trip Signal Functions

Reactor trip signals are provided by the RPS to protect the plant during various analyzed transients or accidents. The reliability of the RPS is assured by providing more than one trip function to protect the plant against the same event. The following provides a brief description of each of the various reactor trip signals.

12.2.3.1 Manual Trip

The manual actuating devices (reactor trip switches) are independent of the automatic trip circuitry, and are not subject to the types of failures which may render a portion of the automatic circuitry inoperable. Actuating either of the two manual reactor trip switches located in the control room initiates a reactor trip and a turbine trip.

12.2.3.2 High Neutron Flux Trip - Source Range

This trip, Figure 12.2-2, occurs when at least one of the two source range channels indicates greater than 10^5 cps. The source range trip provides protection against reactivity excursions and startup accidents. This trip may be manually blocked when at least one of the two intermediate range channels exceeds the P-6 setpoint value of 10^{-10} amps, and the trip function is automatically reinstated when both intermediate range channels decrease below the P-6 setpoint.

When this trip is manually blocked, power is removed from the source range neutron detectors, de-energizing both channels. The operator can manually restore power to the source range detectors by momentarily placing the BLOCK-RESET switches to reset. When the P-10 permissive setpoint (10% power on the power range instruments) is exceeded, the altered reset logic prevents the operator from inadvertently energizing the source range detectors. Applying a high voltage to these detectors in the presence of a high neutron flux could damage the detectors.

12.2.3.3 High Neutron Flux Trip - Intermediate Range

This trip, Figure 12.2-3, occurs when the current output from at least one of the two intermediate range channels indicates greater than the equivalent of 25% power. The intermediate range trip, which provides protection against reactivity excursions and startup accidents, can be manually blocked if at least two of the four power range channels exceed 10% of full power (P-10). If at least three of four (3/4) power range channels fall below the P-10 setpoint value, the trip function is automatically reinstated.

12.2.3.4 High Neutron Flux Trip - Power Range

This trip, Figure 12.2-4, occurs when at least two of the four (2/4) power range channels indicate greater than the trip setpoint. Two independent trips are provided: a high setting at 109% and a low setting at 25%. The high trip setting provides protection against overpower during normal power operations. The low setting, which provides protection against reactivity excursions and startup accidents, can be manually blocked when at least two of the four power range channels indicate greater than 10 percent of full power (P-10).

If at least three of the four power range channels drop below 10 percent power, the low power trip function is automatically reinstated. The high trip setting is always active (cannot be blocked). Before reactor power reaches the 109% trip setpoint, a signal is generated to block automatic and manual rod withdrawal. This action occurs if at least one of the four power range channels exceeds 103% power (the C-2 interlock).

12.2.3.5 Positive Neutron Flux Rate Trip - Power Range

This trip, Figure 12.2-5, occurs when an abnormal rate of increase in nuclear power (+5% with a 2 second time constant) occurs in at least two of the four power range channels. This trip provides protection for rod ejection accidents and cannot be bypassed or blocked. A rate trip in a particular RPS channel “seals in”; it remains in effect until the operator resets the trip at the appropriate nuclear instrument drawer.

12.2.3.6 Negative Neutron Flux Rate Trip - Power Range

This trip, Figure 12.2-5, occurs when an abnormal rate of decrease in nuclear power (-5% with a 2 second time constant) occurs in at least two of the four power range channels. This trip provides protection against dropped rod accidents and cannot be bypassed or blocked. A rate trip in a particular RPS channel “seals in”; it remains in effect until the operator resets the trip at the appropriate nuclear instrument drawer.

12.2.3.7 Overtemperature ΔT Reactor Trip

The OTΔT trip, Figure 12.2-6, is designed to protect against departure from nucleate boiling (DNB), which causes a large decrease in the heat transfer coefficient between the fuel rods and the reactor coolant, resulting in high fuel clad temperatures. In each of the four reactor protection channels, the calculated loop

ΔT, a measure of reactor power, is compared with a continuously calculated trip setpoint. This setpoint is a function of T_{avg}, pressurizer pressure, and axial flux difference.(Separate inputs of T_{avg}, pressurizer pressure, and axial flux difference are used in each reactor protection channel.) If the calculated ΔT equals the calculated trip setpoint, the affected channel is tripped. If two or more channels are simultaneously tripped, the reactor is automatically tripped. The equation for the calculation of the OTΔT setpoint is:

$$\text{OT}\Delta\text{T setpoint} = \Delta T_0 \left[K_1 - K_2\left(\frac{1 + \tau_1 S}{1 + \tau_2 S}\right)(T - T') + K_3(P - P') - f_1(\Delta I)\right]$$

where:

ΔT_0 = indicated ΔT at rated thermal power, in terms of percent reactor power.
T = measured RCS average temperature (T_{avg}), °F.
T' = nominal T_{avg} at rated thermal power, 584.7°F.
P = pressurizer pressure, psig.
P' = nominal RCS operating pressure, 2235 psig.
S = Laplace transform operator, sec^{-1}.

$\frac{1 + \tau_1 S}{1 + \tau_2 S}$ = function generated by the lead-lag controller for T_{avg} dynamic compensation.

τ_1 = lead time constant, sec.
τ_2 = lag time constant, sec.
K_1 = manually adjusted preset bias that sets the steady-state trip setpoint when other parameters are at their rated values.
K_2, K_3 = manually adjusted preset gains.
$f_1(\Delta I)$ = function of axial flux difference.

The T_{avg} term in the equation acts to lower the trip point when T_{avg} is greater than the normal full power T_{avg}. This correction is necessary because the increased average temperature reduces the margin to DNB. The pressure signal reduces the ΔT setpoint when pressure is lower than rated, since this condition also reduces the margin to DNB. The $f_1(\Delta I)$ term reduces the value of the trip setpoint to reflect an increase in the hot channel factors which could result in localized DNB. Generally, the ΔI function does not affect the OTΔT trip setpoint (the function value is set to 0) when core power is evenly or fairly evenly distributed axially; it dramatically reduces the OTΔT trip setpoint for very large positive or negative values of axial flux difference. This correction ensures that DNB is not approached even for highly skewed power distributions. The OTΔT trip ensures a DNBR of not less than 1.30 at the time of the reactor trip if:

- The transient is slow with respect to piping transient delays from the core to the temperature detectors and
- The reactor coolant pressure is within the bounds set by the high and low pressure trips.

Prior to the actual ΔT reaching the OTΔT trip setpoint, both automatic and manual control rod withdrawal is inhibited, and a cyclic turbine runback is initiated, as long

as the overtemperature condition exists. This action occurs if the calculated ΔT values in at least two of the four protection channels are within 3% of the trip setpoint.

12.2.3.8 Overpower ΔT Reactor Trip

The OPΔT trip, Figure 12.2-7, is designed to protect against a high fuel rod power density (excessive kw/ft) and subsequent fuel melt and fuel rod cladding failure. Fuel melt is avoided by limiting the fuel centerline temperature to less than 4700°F, which is significantly below the actual UO_2 melting temperature. In each of the four reactor protection channels, the calculated loop ΔT, a measure of reactor power, is compared with a continuously calculated trip setpoint that is automatically calculated as a function of T_{avg} and axial flux difference. (Separate inputs of T_{avg} and axial flux difference are used in each reactor protection channel.) If the ΔT signal exceeds the calculated setpoint, the affected channel is tripped. If two or more channels are simultaneously tripped, the reactor is automatically tripped. A turbine runback occurs and automatic and manual rod withdrawal is inhibited when, in at least two protection channels, the ΔT value reaches 3% below the trip setpoint. Since core thermal power is not precisely proportional to ΔT due to the effects of changes in coolant density and heat capacity, a compensating term, a function of average temperature, is used. Similarly, since the prescribed overpower limit may not be adequate for highly skewed axial power distributions, a compensating term related to ΔI is used. The setpoint equation is:

$$\text{OP}\Delta\text{T setpoint} = \Delta T_0 \left[K_4 - K_5\left(\frac{\tau_3 S}{1 + \tau_3 S}\right)T + K_6(T - T') - f_2(\Delta I)\right]$$

where:

ΔT_0 = indicated ΔT at rated thermal power, in terms of percent reactor power.
T = measured RCS average temperature (T_{avg}), °F.
T' = nominal T_{avg} at rated thermal power, 584.7°F.
S = Laplace transform operator, sec^{-1}.

$\frac{\tau_3 S}{1 + \tau_3 S}$ = function generated by the rate-lag controller for T_{avg} dynamic compensation.

τ_3 = rate-lag time constant, sec.
K_4 = manually adjusted preset bias that sets the steady-state trip setpoint when other parameters are at their rated values.
K_5, K_6 = manually adjusted preset gains.
$f_2(\Delta I)$ = function of axial flux difference.

The (T - T') term effectively imposes an upper limit for the setpoint based on full power. Since it is possible for the average temperature to exceed the programmed full power average temperature, the setpoint must be reduced to take into account the increase in the heat capacity of the reactor coolant at higher temperatures. This term can only decrease the OPΔT trip setpoint from its normal full power value.

Prior to the actual ΔT reaching the OPΔT trip setpoint, both automatic and manual control rod withdrawal is inhibited, and a cyclic turbine runback is initiated, as long as the overpower condition exists. This action occurs if the calculated ΔT values in at least two of the four protection channels are within 3% of the trip setpoint.

12.2.3.9 Pressurizer Low Pressure Trip

The pressurizer low pressure trip, Figure 12.2-8, protects against excessive core steam voids and limits the range of required protection afforded by the OTΔT trip. The reactor trips when at least two of four pressurizer pressure signals fall below 1865 psig. This trip is automatically blocked when turbine first-stage pressure or reactor power is less than 10 percent power (P-7 permissive).

12.2.3.10 Pressurizer High Pressure Trip

The pressurizer high pressure trip protects against reactor coolant system overpressure, thereby protecting the RCS pressure boundary. As shown in Figure 12.2-9, the reactor trips when two of four high pressurizer pressure signals exceed 2385 psig. This trip is always in service and cannot be bypassed or blocked.

12.2.3.11 Pressurizer High Water Level Trip

The pressurizer high water level trip, shown in Figure 12.2-10, protects against overpressurization of the RCS resulting from rapid thermal expansions of reactor coolant which fill the pressurizer. In addition, if the pressurizer fills completely with water, relieving water instead of steam could be damaging to the relief and safety valves. The reactor is tripped when two of three pressurizer water level signals exceed 92%. This trip is automatically blocked below 10 percent power (P-7).

12.2.3.12 Low Reactor Coolant Flow Trips

The low flow reactor coolant flow trips protect the core from DNB following a loss of coolant flow. The means of generating a low flow are shown in Figure 12.2-11 and described below:

1. Low primary coolant flow trip: A low loop flow signal is generated by two-out-of-three low flow signals per loop. Above the P-7 setpoint (approximately 10% of full power), a low flow in two or more loops results in a reactor trip. Above the P-8 setpoint (39% of full power) low flow in any single loop results in a direct reactor trip.

2. Reactor coolant pump breaker position trip: A contact associated with each reactor coolant pump power supply breaker supplies a signal to the logic section of the reactor protection system. The reactor trips if at least two reactor coolant pump breakers open.

3. RCP bus under-voltage trip: The RCP under-voltage trip anticipates, and improves the response of the RPS to, a complete loss of reactor coolant flow. Each of the two RCP busses is equipped with two under-voltage sensors. An

under-voltage condition, as sensed by one of two (1/2) devices on an individual bus, must exist on two of two (2/2) RCP busses to produce a reactor trip.

4. RCP bus under-frequency trip: An under-frequency condition on the RCP busses reduces the speed of the pumps (with a subsequent reduction in flow). This is undesirable because it reduces the coastdown time of the pumps if power is lost to the busses. Each of the two RCP busses is equipped with two under-frequency sensors. An under-frequency condition, as sensed by one of two devices on an individual bus, must exist on two of two RCP busses to produce a reactor trip. In addition to tripping the reactor, satisfaction of the under-frequency trip logic also trips the RCPs.

All the reactor coolant low flow trips are automatically blocked below the P-7 setpoint (10% power).

12.2.3.13 Low Feedwater Flow Trip

The low feedwater flow trip, Figure 12.2-12, protects the reactor from a loss of heat sink (steam generator secondary inventories). The trip is actuated by the logic of a steam flow greater than feed flow mismatch signal (1/2) coincident with a steam generator low level (1/2) in at least one steam generator. This trip is anticipatory in that a steam generator's level has not yet reached the low-low level setpoint (see the next section) but is trending toward it.

12.2.3.14 Low-Low Steam Generator Water Level Trip

This trip (Figure 12.2-13) protects the reactor against a loss of heat sink. The setpoint of this trip is 11.5%, as indicated by the narrow-range steam generator level instruments. The trip logic is satisfied by two of three (2/3) levels below the low-low setpoint in at least one steam generator.

12.2.3.15 Safety Injection Actuation Trip

If a reactor trip has not already been generated by any other trip signal, the safety injection (SI) actuation signal initiates a trip when the RPS senses any condition which initiates safety injection. The SI actuation trip protects the core in the event of a loss of coolant accident or a steam line break accident.

The safety injection actuation signals are discussed in Section 12.3.

12.2.3.16 Reactor Trip on Turbine Trip

The turbine trip - reactor trip signal, Figure 12.2-14, protects the reactor coolant system from a thermal transient (overpressure or overtemperature) when the energy removal from the coolant abruptly diminishes. This trip occurs for power levels greater than 10% (P-7), or in plants with the P-9 permissive, for levels greater than 50%. The signals used to sense that the turbine has tripped are:

1. Four of four (4/4) turbine throttle (stop) valves fully closed, or

2. Two of three low turbine electrohydraulic control system trip header fluid pressures (setpoint: 800 psig) for a General Electric turbine, or two of three low auto-stop oil pressures (setpoint: 45 psig) for a Westinghouse turbine.

See Sections 11.3 and 11.5 for additional details.

12.2.4 Interlocks

Various signals are generated throughout the plant for the purpose of:

1. Automatically prohibiting and/or allowing the actuation of certain protective functions and the operation of certain control systems, and
2. Allowing the operator to manually prohibit certain protective actions.

The interlocks are divided into two broad categories, designated as protection-grade (P) interlocks (permissives) and control-grade (C) interlocks. Protection-grade interlocks are developed within the solid-state protection system. Control-grade interlocks are developed within the process instrumentation racks (with the exception of C-8). Although not part of the protection system, the control-grade interlocks are discussed here for the sake of completeness.

12.2.4.1 Control-Grade Interlocks

An interlock is a signal or equipment status that prevents or allows an action or a function when a certain set of conditions exist. Listed below are the control-grade interlocks (designated by the C-n convention) employed in most Westinghouse reactor plants. The “C” designation differentiates them from RPS permissives (“P” designation), as previously discussed.

C-1: High Neutron Flux Rod Stop Interlock

At least one of two intermediate range detector currents exceeding the equivalent of 20% power generates a rod withdrawal stop for both automatic and manual rod control. The rod stop may be blocked with reactor power (power range) at or above the P-10 setpoint (2/4 coincidence), but it is automatically reinstated when power drops below the P-10 setpoint (3/4 coincidence).

C-2: Overpower Rod Stop Interlock

If at least one of the four excore power range flux detectors indicates a power output of greater than 103%, an automatic and manual rod withdrawal stop is actuated. This interlock may be bypassed by the operator to allow for continued operation with one inoperable power range channel.

C-3: OTΔT Rod Stop and Turbine Runback Interlock

When the calculated loop ΔT in at least two of four protection channels is within three percent of the OTΔT trip setpoint, automatic and manual rod withdrawal is blocked, and a turbine runback is initiated.

C-4: OPΔT Rod Stop and Turbine Runback Interlock

When the calculated loop ΔT in at least two of four protection channels is within three percent of the OPΔT trip setpoint, automatic and manual rod withdrawal is blocked, and a turbine runback is initiated.

C-5: Low Power Interlock

The setpoint for this interlock is 15% load, as sensed by turbine impulse pressure. If load drops below 15%, automatic rod withdrawal is inhibited. The C-5 interlock is supplied by a particular turbine impulse pressure sensor that cannot be changed by the operator.

C-7: Loss of Load Interlock

This interlock is actuated by a reduction in turbine load of sufficient severity; it arms the steam dump control system (allows steam dump valves to open if an open demand exists). C-7 senses must be manually reset. It is actuated by a turbine load decrease larger in magnitude than a 10% step drop or a 5%/min ramp decrease.

C-8: Turbine Tripped Interlock

When the C-8 interlock is actuated, the steam dump control system (if in the T_{avg} mode of control) shifts from the load-rejection controller to the turbine-trip controller. Permissive C-8 requires:

1. Four of four (4/4) turbine throttle (stop) valves fully closed, or
2. Two of three low turbine electrohydraulic control system trip header fluid pressures (setpoint: 800 psig) for a General Electric turbine, or two of three low auto-stop oil pressures (setpoint: 45 psig) for a Westinghouse turbine.

In addition, C-8 arms the steam dumps. The C-8 interlock is not installed in Westinghouse-designed units that have the P-9 permissive.

C-9: Condenser Available Interlock

The condenser must be available in order to allow steam dump operation. To actuate C-9, one of two (1/2) circulating water pump breakers must be shut AND two of two condenser vacuum switches must be shut (< 5 in. Hg backpressure). If backpressure in the condenser increases to 7.6 in. Hg, then the C-9 interlock is removed.

C-11: Control Bank D Rod Withdrawal Limit Interlock

This signal prevents misalignment of rod position step counters by blocking automatic withdrawal of control bank D when the bank D position has reached 223 steps.

12.2.4.2 Protection-Grade Interlocks

During controlled plant evolutions, certain protection signals are not required for plant safety and may be blocked to prevent inadvertent reactor trips or engineered safety features (ESF) actuations. These signals are disabled automatically by the RPS or manually by the operator. The mechanisms for blocking these trips are the protection-grade interlocks, or permissives. The protection system is designed so that any signal which had been blocked is automatically reinstated whenever the conditions allowing that block (a satisfied permissive) are no longer met (This design convention is required by IEEE Std. 279-1971). The following provides brief descriptions of the various permissives.

P-4: Reactor Trip Permissive

This permissive is derived from the status of "b" contacts on the reactor trip breakers (RTBs). (Each contact is closed when the associated RTB is open, and open when the RTB is closed). The permissive is satisfied whenever an RTB is open. It performs the following functions:

1. Actuates a turbine trip,
2. Initiates main feedwater isolation with RCS temperature below 564°F,
3. Inputs to the SI actuation block-reset logic, and
4. Prevents opening of the main feedwater isolation valves which had been closed by an SI actuation signal or high-high steam generator level (P-14).

Permissive P-4 (and P-14, as discussed below) is not a permissive signal in the classic sense, in that it does not enable or reinstate some switch or function. It does not have associated status lights on protection system bistable status panels in the control room.

P-6: Source Range Block Permissive

Permissive P-6 enables the source range block-reset switches on the main control board. The operator can then place the switches in the “block” position to remove power from the source range detectors, thereby blocking the source range high flux trip. During a power increase when at least one of two intermediate range channels is greater than 10^{-10} amps, permissive P-6 is in effect. During a power decrease when BOTH intermediate range channel outputs drop below 10^{-10} amps, permissive P-6 is removed.

P-7: At-Power Permissive

At-power permissive P-7 is in effect below 10% power and automatically blocks the at-power trips listed below:

- Two-loop low reactor coolant flow trip,
- RCP power supply breaker trip,
- RCP bus under-voltage trip,
- RCP bus under-frequency trip,

- Pressurizer low pressure trip,
- Pressurizer high level trip, and
- Reactor trip on turbine trip (except at plants with P-9).

During a power increase, when either the turbine load (P-13) or the reactor power (P-10) is greater than 10%, permissive P-7 is removed, and the at-power trips are automatically enabled. During a power decrease, both the turbine load (2/2) and the reactor power (3/4, power range) must be below 10% to enable permissive P-7 and disable the at-power trips.

P-8: Three Loop Flow Permissive

Permissive P-8 is in effect below 39% reactor power. The permissive allows the loss of flow in one reactor coolant loop without generating a direct reactor trip signal. When at least two of four power range channels indicate that reactor power is greater than 39%, a loss-of-flow signal in any single loop initiates a reactor trip signal.

P-9: Turbine Trip/Reactor Trip Permissive

Permissive P-9 is in effect below 50% power (note: not all Westinghouse units use this permissive). This permissive allows the reactor to remain in operation if the turbine trips. Facilities with this permissive have demonstrated that, for turbine trips from 50% power or less, sufficient steam dump capacity is available for excess energy removal until the plant is brought to no-load conditions.

P-10: Nuclear At-Power Permissive

Inputs to the P-10 permissive circuit are from each of the four power range channels. The P-10 setpoint is 10%. When at least two of the channels indicate greater than or equal to this setpoint, the operator may block the intermediate high flux trip, the power range low setpoint high flux trip, and the high neutron flux rod stop (C-1). When 3/4 power range channels drop below the P-10 setpoint, the functions previously mentioned are automatically reinstated. The following is a list of functions provided by P-10:

1. Allows the operator to manually block the intermediate range high flux trip and the C-1 rod stop,
2. Allows the operator to manually block the low setpoint power range high flux trip,
3. Automatically restores intermediate range trip and C-1 rod stop when power falls below the P-10 setpoint,
4. Automatically restores the low setpoint power range high flux trip when power falls below the P-10 setpoint,
5. Provides an input to the P-7 circuit, and
6. Serves as a backup to P-6 by preventing the operator from inadvertently re-energizing the source range high voltage.

P-11: Low Pressurizer Pressure SI Block Permissive

Permissive P-11 is in effect below 1915 psig. When two of three pressurizer pressure channels indicate less than 1915 psig, the block switches for the low pressurizer pressure safety injection actuation signal are enabled, and the operator may block the actuation signal before the low pressure SI setpoint of 1807 psig is reached.

With pressure increasing, when two of three channels indicate greater than 1915 psig, the block is automatically removed. In addition, the removal of this permissive (pressurizer pressure greater than the permissive setpoint) provides a confirmatory open signal to all cold-leg accumulator motor-driven isolation valves. (The accumulator isolation valves are unlikely to open automatically; power to the valves is removed except when operators are manually opening or closing them.)

P-12: High Steam Flow SI Block Permissive

Permissive P-12 is in effect below 553°F. If two of four loop T_{avg} signals are below the low-low Tavg value of 553°F, the block switches for the high steam line flow safety injection actuation is enabled, and the operator can block this signal. This signal is blocked during a controlled plant cooldown to prevent an automatic initiation of the ESF equipment. Permissive P-12 also automatically blocks steam dump operation and thereby prevents an uncontrolled cooldown caused by an instrumentation malfunction. Operators can bypass the block for only one bank of three steam dump valves. This permissive is automatically removed when three of four (3/4) T_{avg} channels indicate greater than 553°F. The removal automatically makes the remaining nine steam dump valves available for operation and removes the block of the high steam line flow SI actuation signal.

P-13: Turbine At-Power Permissive

Permissive P-13 is enabled when both turbine impulse chamber pressures indicate that turbine load is less than 10%. P-13 and P-10 are the two inputs to at-power permissive P-7.

P-14: Steam Generator High Level Override

The P-14 setpoint is enabled when at least two of three steam generator narrow-range levels exceed 69% for at least one steam generator. When this permissive is actuated the following actions occur:

1. The turbine trips,
2. All main feedwater pumps trip,
3. All main feedwater regulating and bypass valves shut, and
4. All main feedwater isolation valves shut.

Permissive P-14, like P-4, is not a permissive signal in the classic sense, in that it does not enable or reinstate some switch or function. Individual bistable lights for the high-high level turbine trip function are on the reactor trip bistable status panel.

12.2.5 Summary

Many reactor trip signals are generated to ensure that the reactor is operated within safe limits. Some trip functions are enabled or blocked in accordance with the status of associated permissives (protection-grade interlocks). Control-grade interlocks, discussed in this section for completeness, are also provided for certain plant control functions.

Table 12.2-1
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
1. Source Range High Neutron Flux	1/2	10^5 cps	Manual block permitted by P-6; power to source range detectors is removed when manual block is initiated. Power to detectors cannot be turned on when power is above P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident
2. Intermediate Range High Neutron Flux	1/2	Current equiva-lent to 25% power level	Manual block permitted by P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident
3. Power Range High Neutron Flux - low setpoint	2/4	25%	Manual block permitted by P-10.	Prevents an inadvertent power rise (excursion). A trip will occur unless the operator deliberately blocks the trip.	Reactivity addition accidents such as: a. Uncontrolled rod withdrawal from subcritical or low power condition, b. Inadvertent boron dilution, or c. Excessive heat removal caused by steamline break or feedwater addition accident

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
4. Power Range High Flux - high setpoint	2/4	109%	No Interlocks	Limits maximum power level to prevent damage to fuel clad and to protect against centerline melting.	Inadvertent power excursions such as: a. Excessive load increase, b. Excessive heat removal, c. Boron dilution accident, d. Inadvertent rod withdrawal, or e. Rod ejection accident
5. High Positive Rate Neutron Flux	2/4	+5% change with a 2-sec time constant	No Interlocks	Limits power excursions. Prevents unacceptable power distribution.	Rod Ejection Accident
6. High Negative Rate Neutron Flux	2/4	-5% change with a 2-sec time constant	No Interlocks	Prevents unacceptable power distribution. Limits power overshoot from rod withdrawal in response to a dropped rod.	Dropped Rod
7. OTΔT	2/4	Variable (cal-culated)	No Interlocks	Prevents operation with DNBR <1.30.	Relatively slow transients such as: a. Uncontrolled rod withdrawal at power, b. Uncontrolled boron dilution, c. Excessive load increase, or d. Depressurization of the RCS

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
8. OPΔT	2/4	Variable (calculated)	No Interlocks	Prevents excessive power density (kw/ft).	Relatively slow transients such as: a. Uncontrolled rod withdrawal at power, b. Uncontrolled boron dilution, c. Excessive load increase, or d. Steamline break
9. Pressurizer Low Pressure	2/4	1865 psig (rate compensated)	Disabled below P-7 (10%)	Prevents operation with DNBR <1.30. Limits required range of OTΔT trip.	Depressurization of RCS due to: a. LOCA, b. Steamline break, or c. SG tube rupture
10. Pressurizer High Pressure	2/4	2385 psig	No Interlocks	Protects integrity of RCS pressure boundary.	Uncontrolled rod withdrawal at power, loss of electrical load, or turbine trip
11. Pressurizer High Water Level	2/3	92%	Disabled below P-7 (10%)	Prevents "solid-water" operations, prevents discharge of high energy water through relief and safety valves.	Uncontrolled rod withdrawal at power, loss of electrical load, or turbine trip
12. Low Reactor Coolant Flow	2/3 per loop	<90% of rated flow	<P-8 (39%): loss of flow in one loop, no direct trip. <P-7 (10%): loss of flow in two or more loops, no direct trip.	Ensures adequate loop flow to remove core heat. DNBR considerations.	Loss of coolant flow events such as: a. Partial loss of RCS flow, b. Complete loss of forced RCS flow, or c. Loss of off-site power to station auxiliaries.
13. Reactor Coolant Pump Bus Under-Voltage	1/2 on 2/2 buses	68.6% of nominal bus voltage	Disabled below P-7 (10%)	Redundant to low flow trip	Redundant to low flow trip

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
14. Reactor Coolant Pump Bus Under-Frequency	1/2 on 2/2 buses	57.7 Hz	Disabled below P-7 (10%); trips open the pump motor breakers when actuated to preserve pump coastdown time.	Redundant to low flow trip	Redundant to low flow trip
15. Reactor Coolant Pump Breaker	1/1 on 2/4 RCPs	Breaker open	Disabled below P-7 (10%)	Redundant to low flow trip	Redundant to low flow trip
16. Steam Generator Low-Low Level	2/3 on 1/4 SGs	11.5%	No Interlocks	Prevents loss of heat sink.	Loss of normal feedwater
17. Low Feedwater Flow	1/2 flow mis-match + 1/2 low level on 1/4 SGs	25.5% SG level AND $1.5x10^6$ lbm/hr mismatch (W_s>W_f)	No Interlocks	Anticipates loss of heat sink.	Partial loss of normal feedwater
18. Turbine Trip	2/3 low pres-sure or 4/4 throttle valves closed	Westing-house: 45 psig auto-stop oil press. GE: 800 psig trip header press.	Disabled below P-7 (10%)	Removes heat source if steam load is lost to SGs.	Turbine trip, loss of load

Table 12.2-1 (cont'd)
Summary of Reactor Trips

Trip	Coinc.	Setpoint	Interlocks	Purpose	Accident/Event
19. SI Actuation	1/2 trains		No Interlocks		Any accident requiring a safety injection actuation signal
20. Manual	1/2 manual push-buttons		No Interlocks	Operator initiated backup to all trips	Any condition requiring a reactor trip
21. SSPS General Warning	2/2	General Warning		The SSPS has a self-check feature that will trip the reactor if both protection trains develop trouble.	

Table 12.2-2
Summary of Protection-Grade Interlocks

Number	Name	Setpoint	Coincidence	Functions
P-4	Reactor Trip Breaker Contact	Open if trip breaker is closed. Closed if trip breaker is open.	Trip breaker and its bypass breaker both open	1. Trips main turbine. 2. Isolates main feedwater with T_{avg} <564°F in 2/4 loops. 3. Input to SI block and reset logic. 4. If main feed regulating and bypass valves are closed by SI or SG high level, P-4 seals in the isolation.
P-6	Source Range Block Permissive	Intermediate range power > 10^{-10} amps.	1/2	Enables BLOCK/RESET switches to allow the operator to block SR high flux trip.
P-7	At-Power Permissive	Power < 10%	Power range power <10% (P-10 cleared) and turbine power (impulse pressure) <10% (P-13)	Automatically blocks the “at-power” trips: 1. Pressurizer low pressure, 2. Pressurizer high level, 3. All RCS low flow, and 4. Turbine tripped
P-8	3-Loop Flow Permissive	Power range power < 39%	3/4	Automatically blocks the single loop low flow reactor trip.
P-9 (Not on all plants)	Turbine Trip/Reactor Trip Permissive	Power range power < 50%	3/4	Blocks reactor trip on turbine trip below 50%.
P-10	Nuclear At-Power Block Permissive	Power range power > 10%	2/4	1. Opens contacts to SR high voltage power supply. 2. Enables BLOCK switches to allow the operator to block IR high flux trip and rod stop. 3. Enables BLOCK switches to allow the operator to block PR high flux - low setpoint trip. 4. Input to P-7.

Table 12.2-2 (cont'd)
Summary of Protection-Grade Interlocks

Number	Name	Setpoint	Coincidence	Functions
P-11	Low Pressurizer Pressure SI Block Permissive	Pressurizer pressure < 1915 psig	2/3	Enables BLOCK switches to allow the operator to block low pressurizer pressure ESF actuation. Removal of permissive provides open signal to accumulator isolation valves.
P-12	High Steam Flow SI Permissive	T_{avg} < 553°F	2/4	1. Enables BLOCK switches to allow the operator to block high steam flow ESF actuation. 2. Input to high steam flow ESF actuation logic. 3. Removes arming signal for steam dump operation. Operator may bypass the interlock on the three cooldown valves.
P-13	Turbine At-Power Permissive	Turbine power (impulse pressure) < 10%	2/2	Input to P-7
P-14	SG High Level Override	Steam generator narrow-range level > 69%	2/3 per SG on 1/4 SGs	1. Closes main feedwater regulating and bypass valves. 2. Trips all main feed pumps. 3. Trips main turbine. 4. Closes all main feedwater isolation valves.

Table 12.2-3
Summary of Control-Grade Interlocks

Number	Name	Setpoint	Coincidence	Interlocks	Functions
C-1	Intermediate Range High Flux Rod Stop	Intermediate range power > current equivalent to 20% power	1/2	Blocked when IR trip is blocked. Bypassed when IR trip is bypassed.	Stops control rod outward motion (manual & automatic).
C-2	Power Range High Flux Rod Stop	Power range power > 103%	1/4	Individual channel can be bypassed at local cabinet.	Stops control rod outward motion (manual & automatic).
C-3	OTΔT Rod Stop & Runback	Loop ΔT > (OTΔT reactor trip setpoint - 3%)	2/4	None	Stops control rod outward motion (manual & automatic) and initiates a turbine runback.
C-4	OPΔT Rod Stop & Runback	Loop ΔT > (OPΔT reactor trip setpoint - 3%)	2/4	None	Stops control rod outward motion (manual & automatic) and initiates a turbine runback.
C-5	Low Power Interlock	Turbine power (impulse pressure) < 15%	1/1 (one channel assigned)	None	Stops control rod outward motion in automatic only.
C-7	Loss of Load	Turbine power (impulse pressure) reduction > 10% step or 5%/min ramp	1/1 (one channel assigned)	Seals in. Must be reset.	Arms steam dumps in T_{avg} mode (loss-of-load controller).
C-8 (Plant with P-9 does not have)	Turbine Tripped	1. Throttle valves closed, or 2.a Westinghouse: auto-stop oil pressure <45 psig 2.b GE: trip header pressure < 800 psig	1. 4/4 2.a, b 2/3	Reactor trip (see function 2) disabled if P-7 satisfied.	1. Arms steam dumps in T_{avg} mode (turbine-trip controller). 2. Trips reactor.

Table 12.2-3 (cont'd)
Summary of Control-Grade Interlocks

Number	Name	Setpoint	Coincidence	Interlocks	Functions
C-9	Condenser Available Interlock	1. Condenser vacuum > 22 in. Hg, and 2. Condenser circulating water pump breaker closed	1. 2/2 2. 1/2	None	Ensures condenser is available for steam dump operation.
C-11	Control Bank D Withdrawal Interlock	Control bank D pulse-to-analog converter output >223 steps	1/1	None	Stops outward rod motion in automatic only.

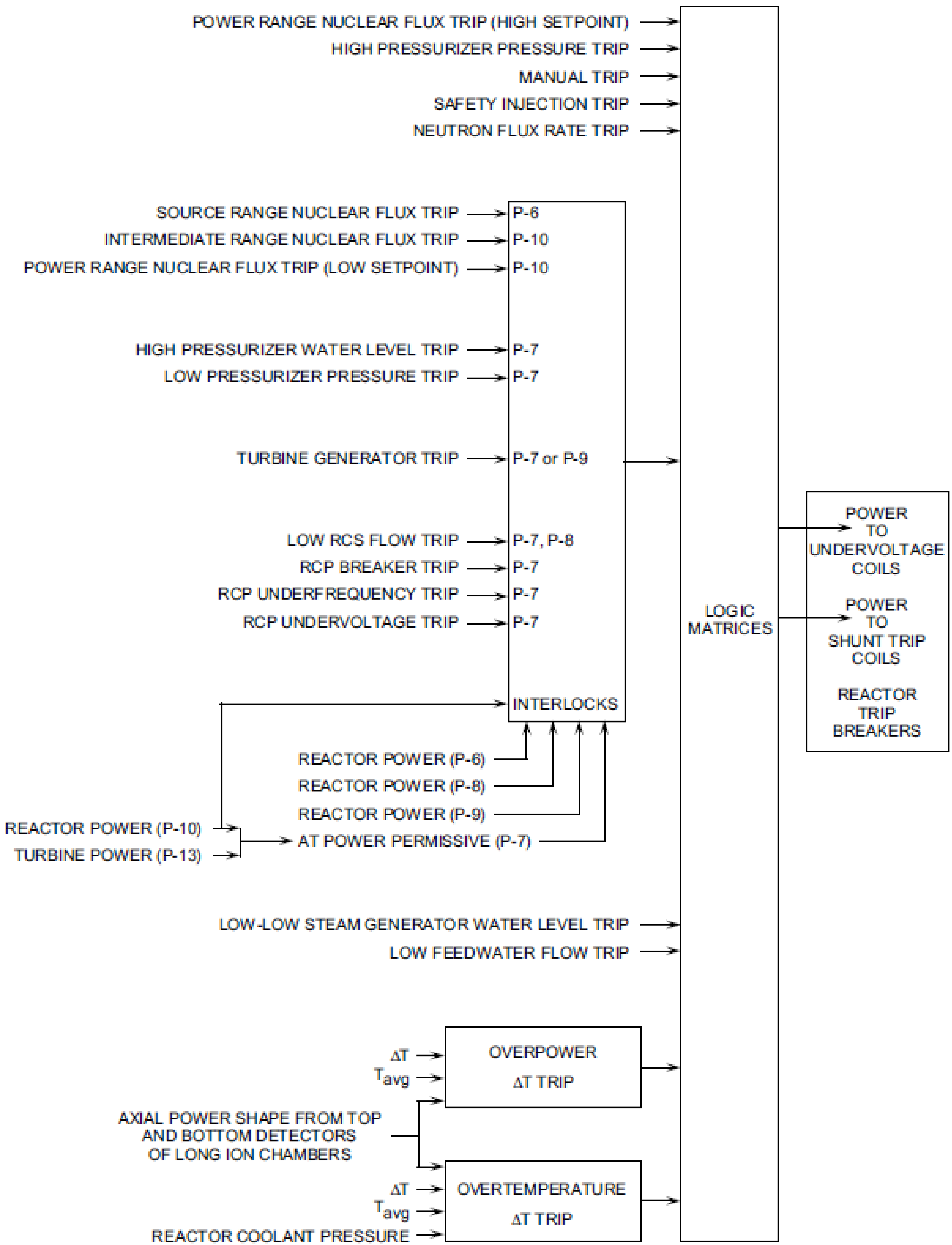

Figure 12.2-1 Reactor Protection System, Block Diagram

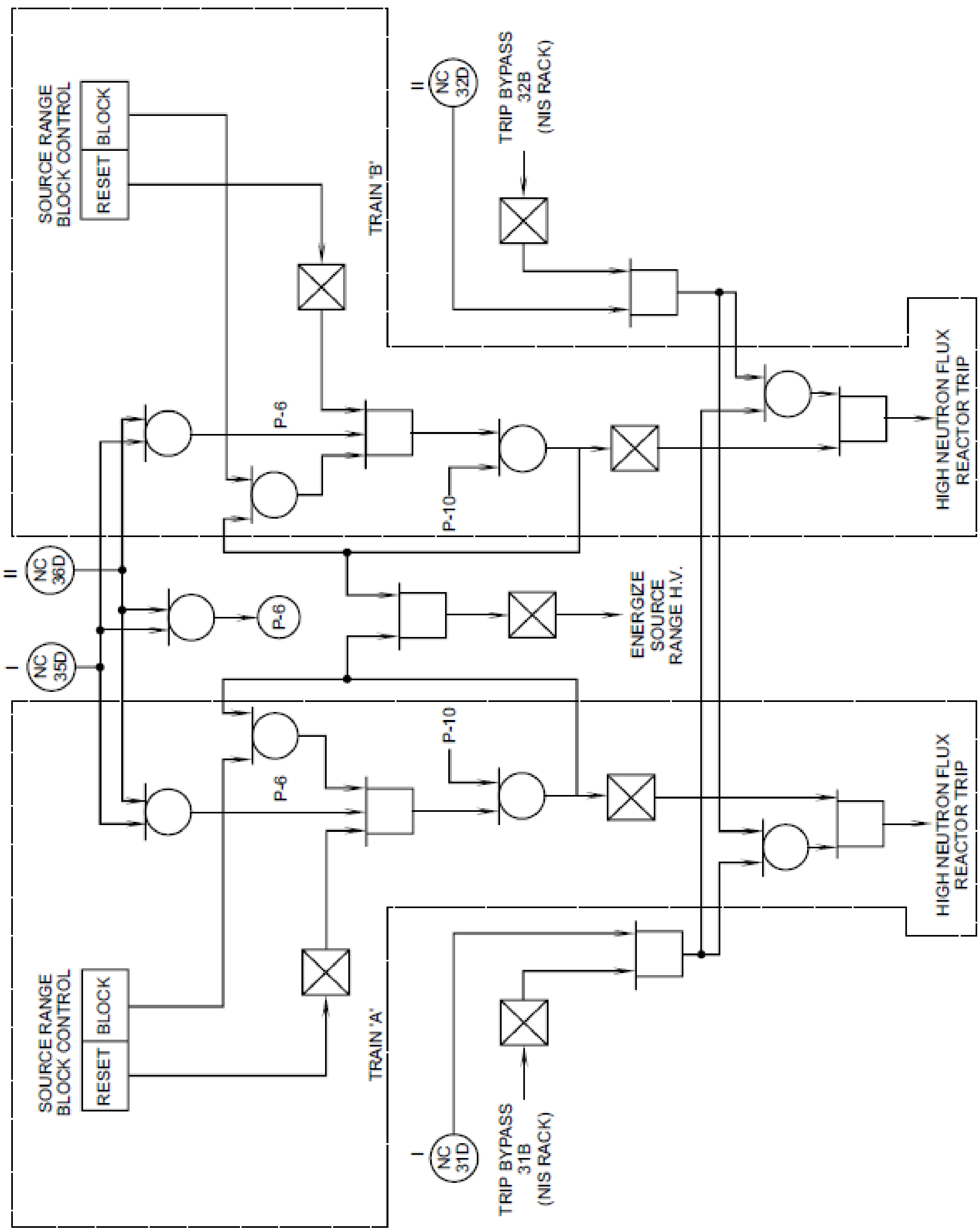

Figure 12.2-2 Source Range Reactor Trip Logic

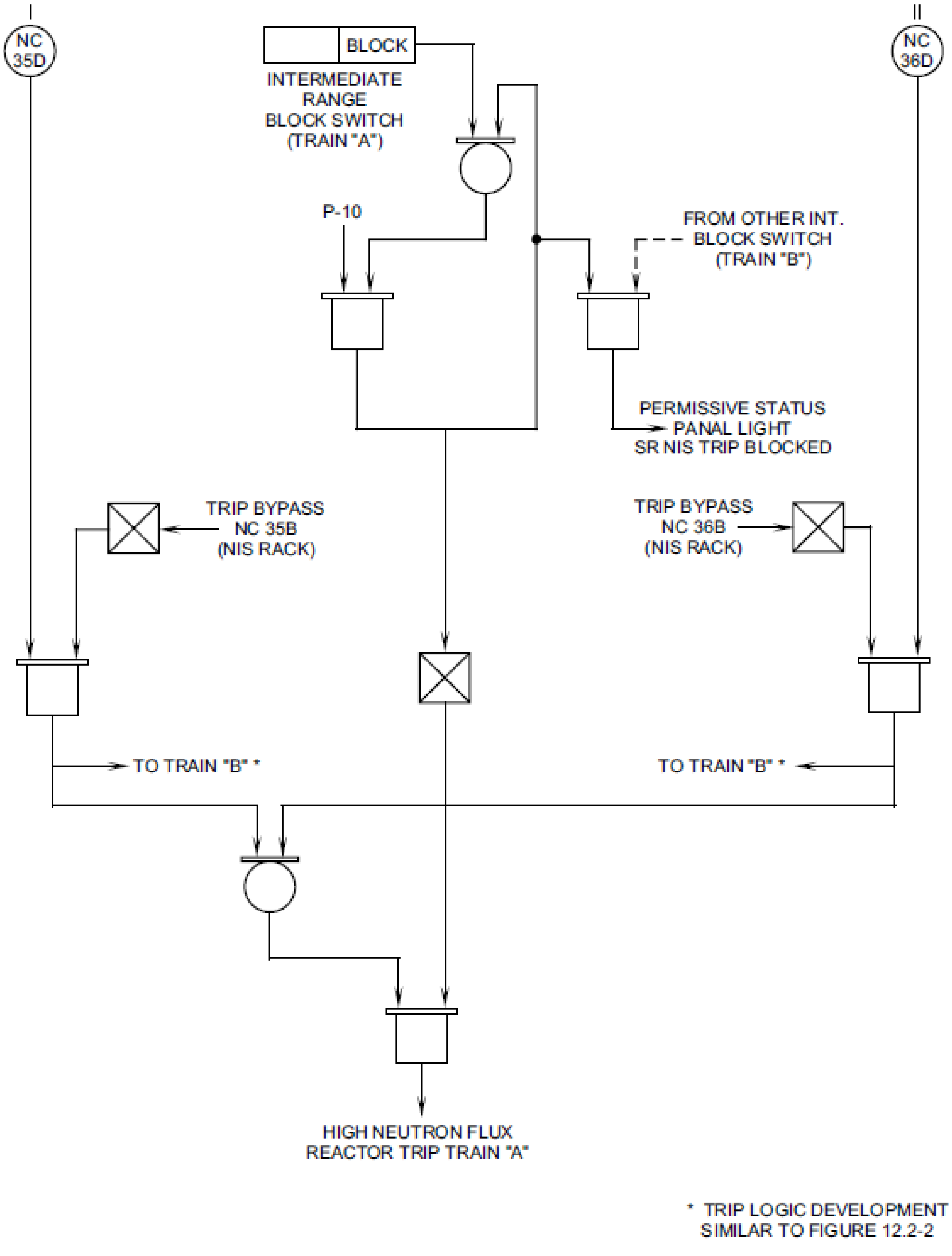

Figure 12.2-3 Intermediate Range Reactor Trip Logic

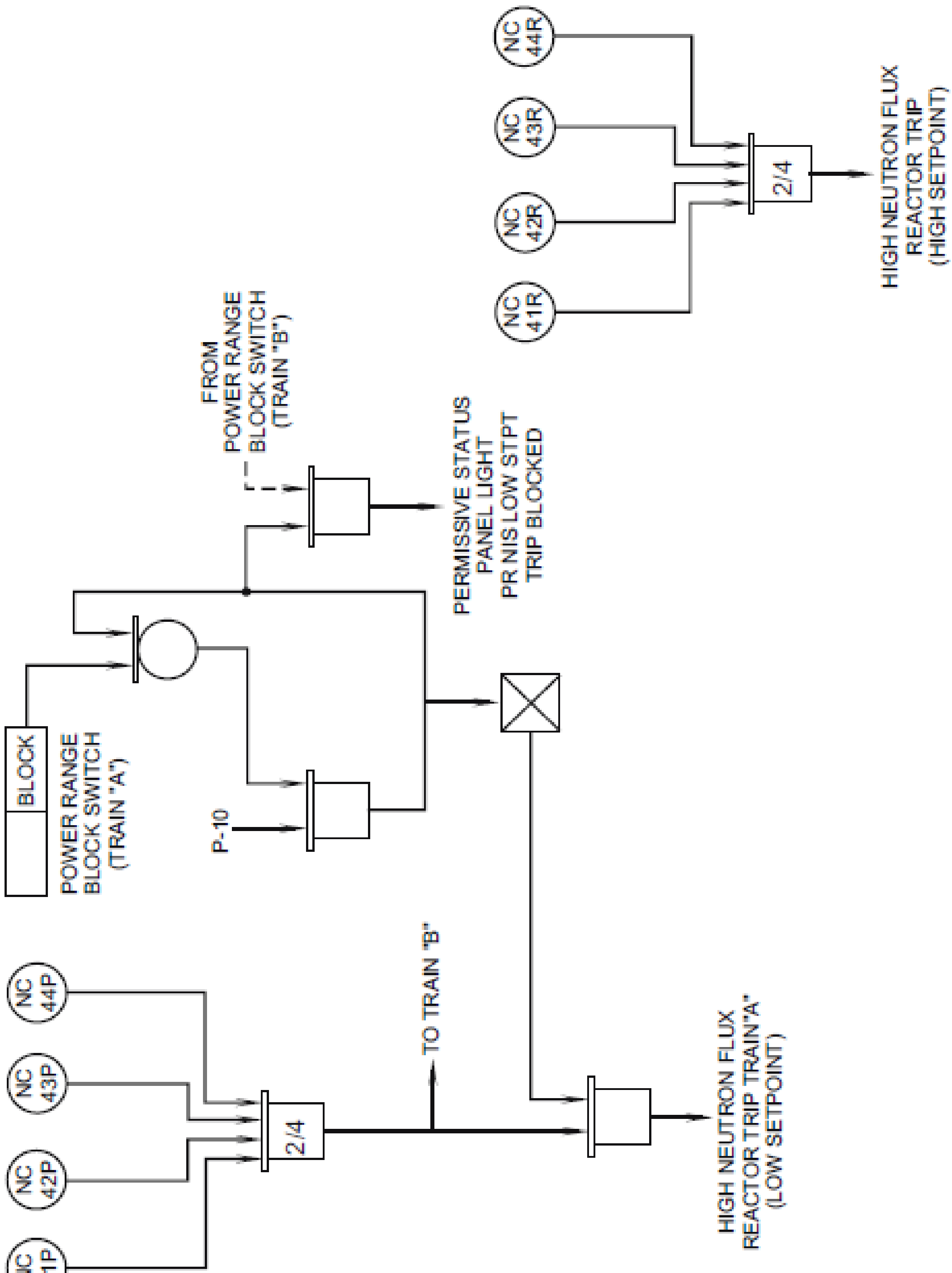

Figure 12.2-4 Power Range Reactor Trip Logic

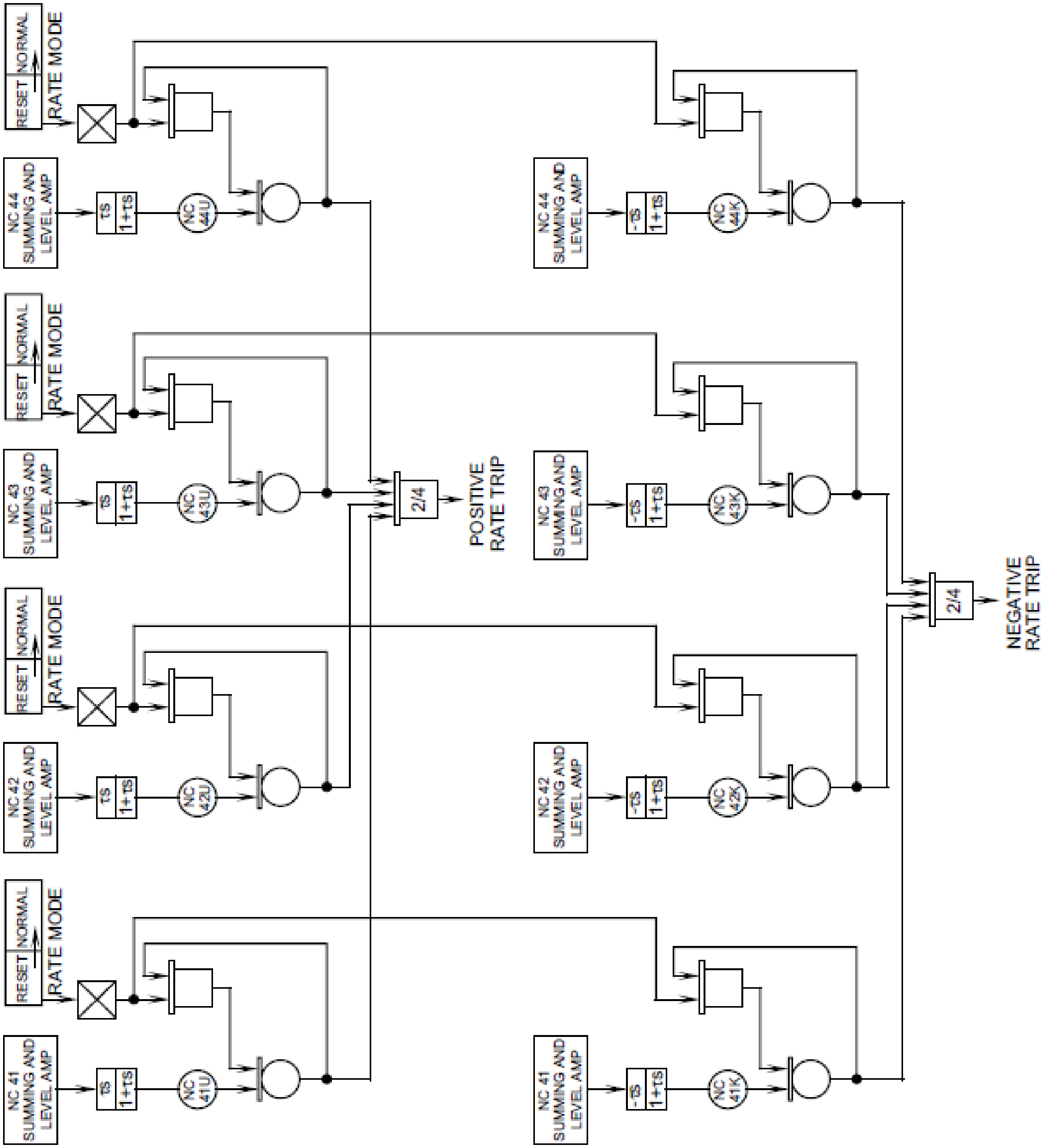

Figure 12.2-5 Power Range Flux Rate Trips

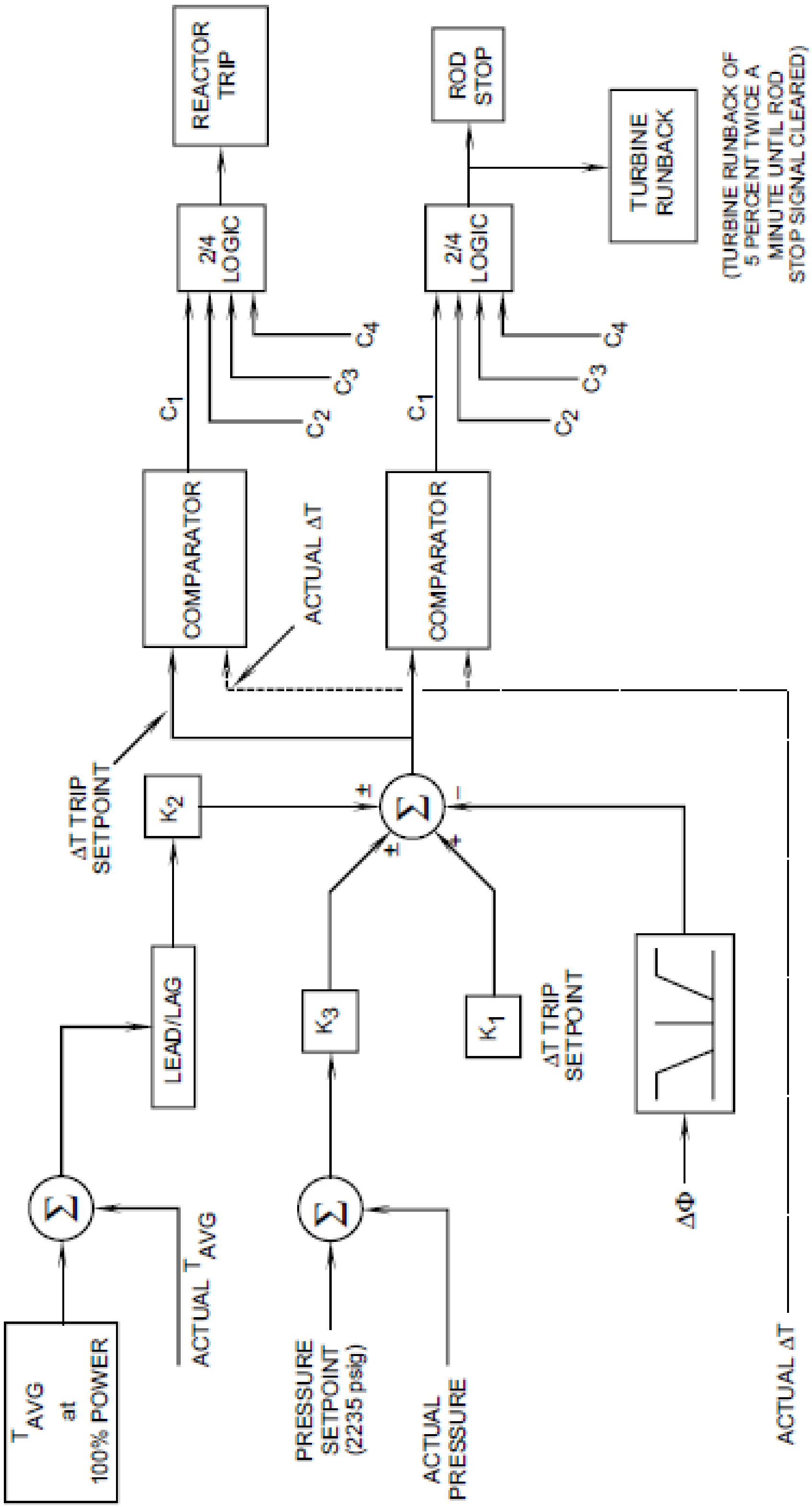

Figure 12.2-6 Overtemperature ΔT Channel Block Diagram

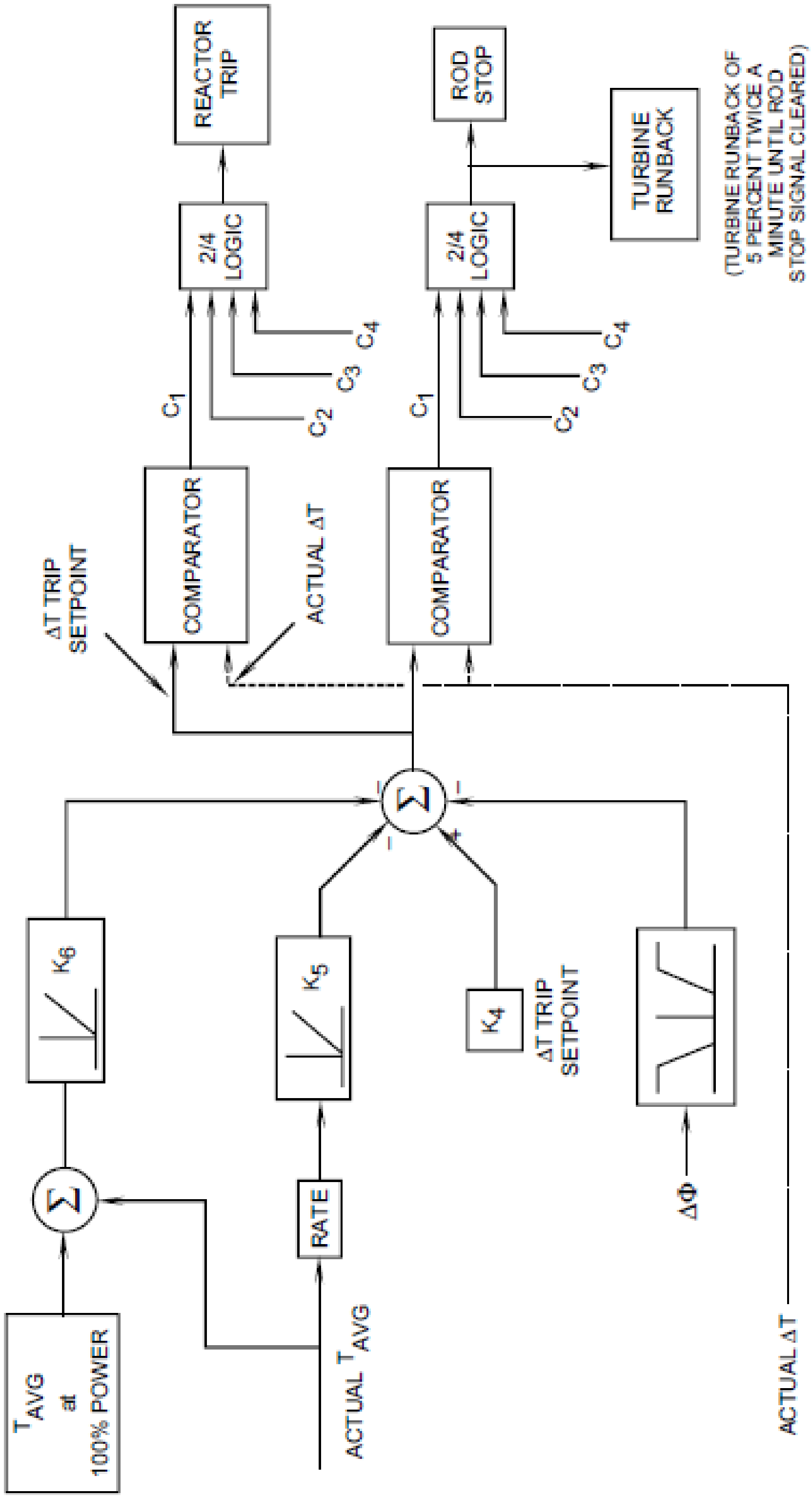

Figure 12.2-7 Overpower ΔT Channel Block Diagram

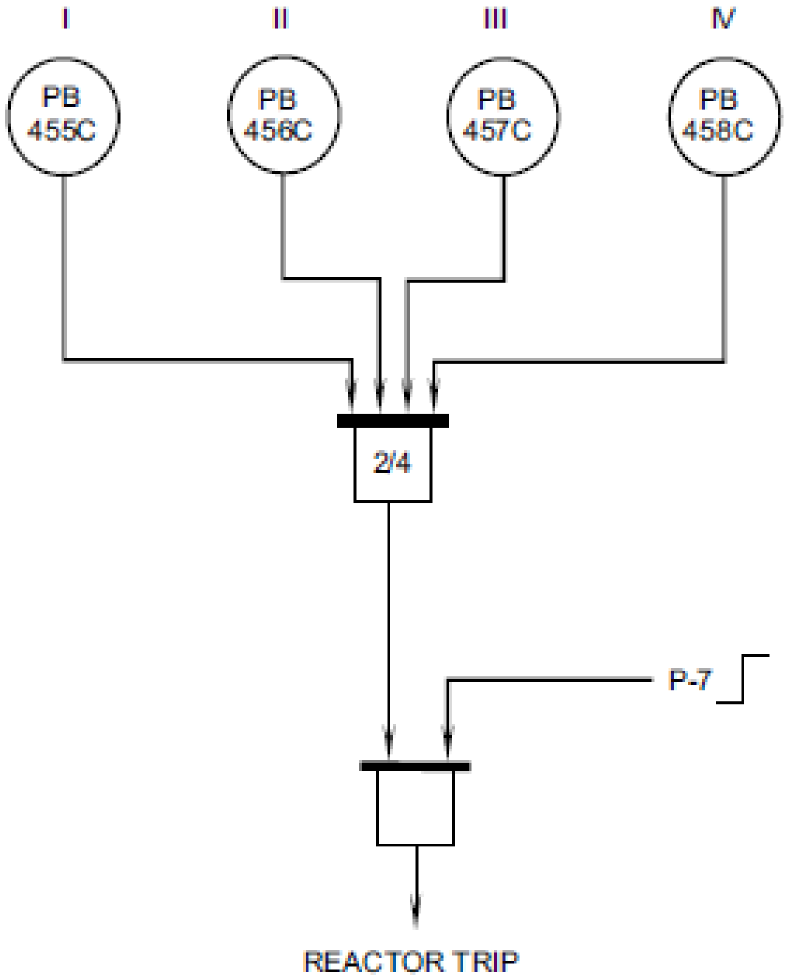

Figure 12.2-8 Pressurizer Low Pressure Reactor Trip

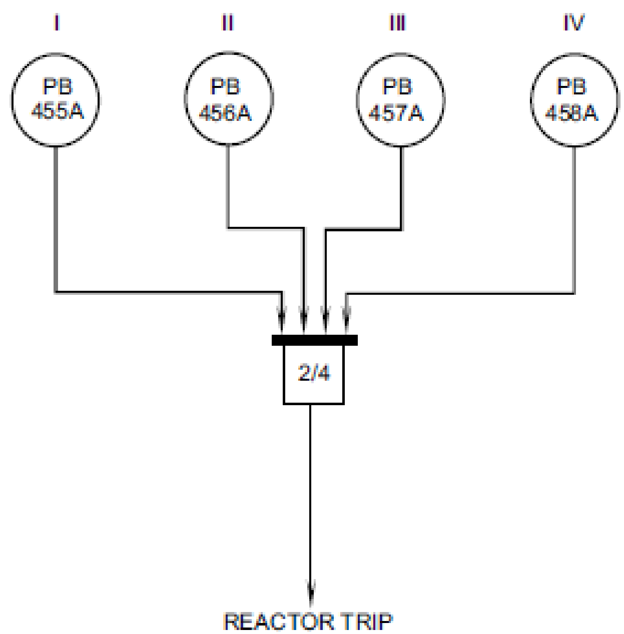

Figure 12.2-9 Pressurizer High Pressure Reactor Trip

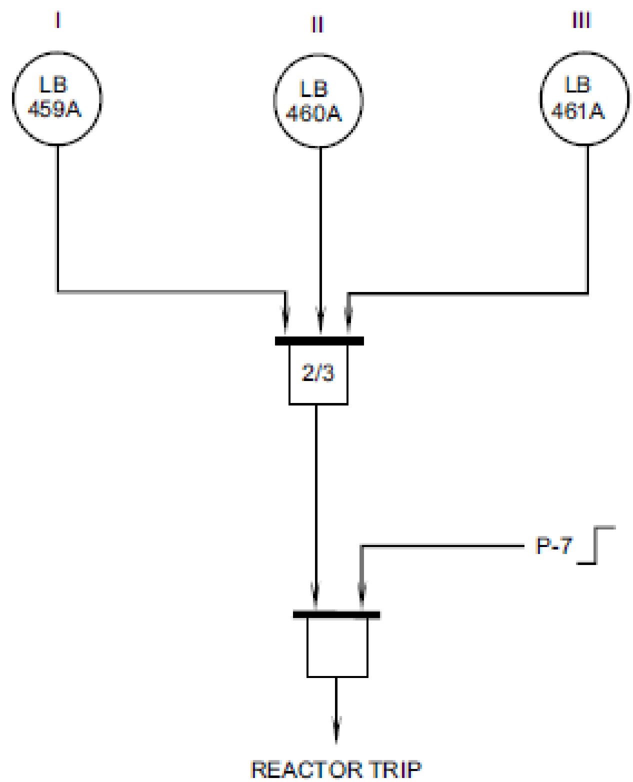

Figure 12.2-10 Pressurizer High Water Level Reactor Trip

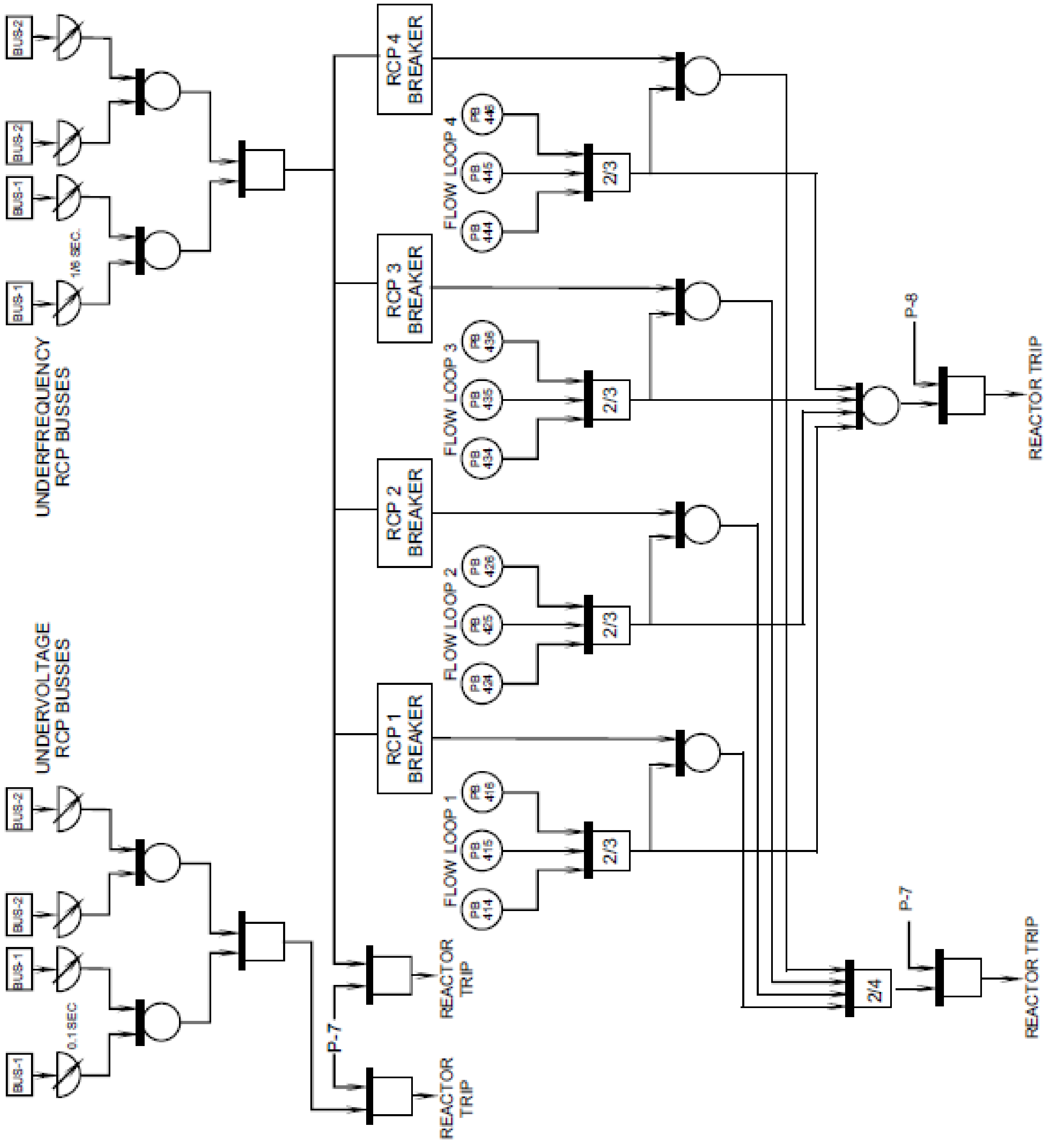

Figure 12.2-11 Low Flow Trips

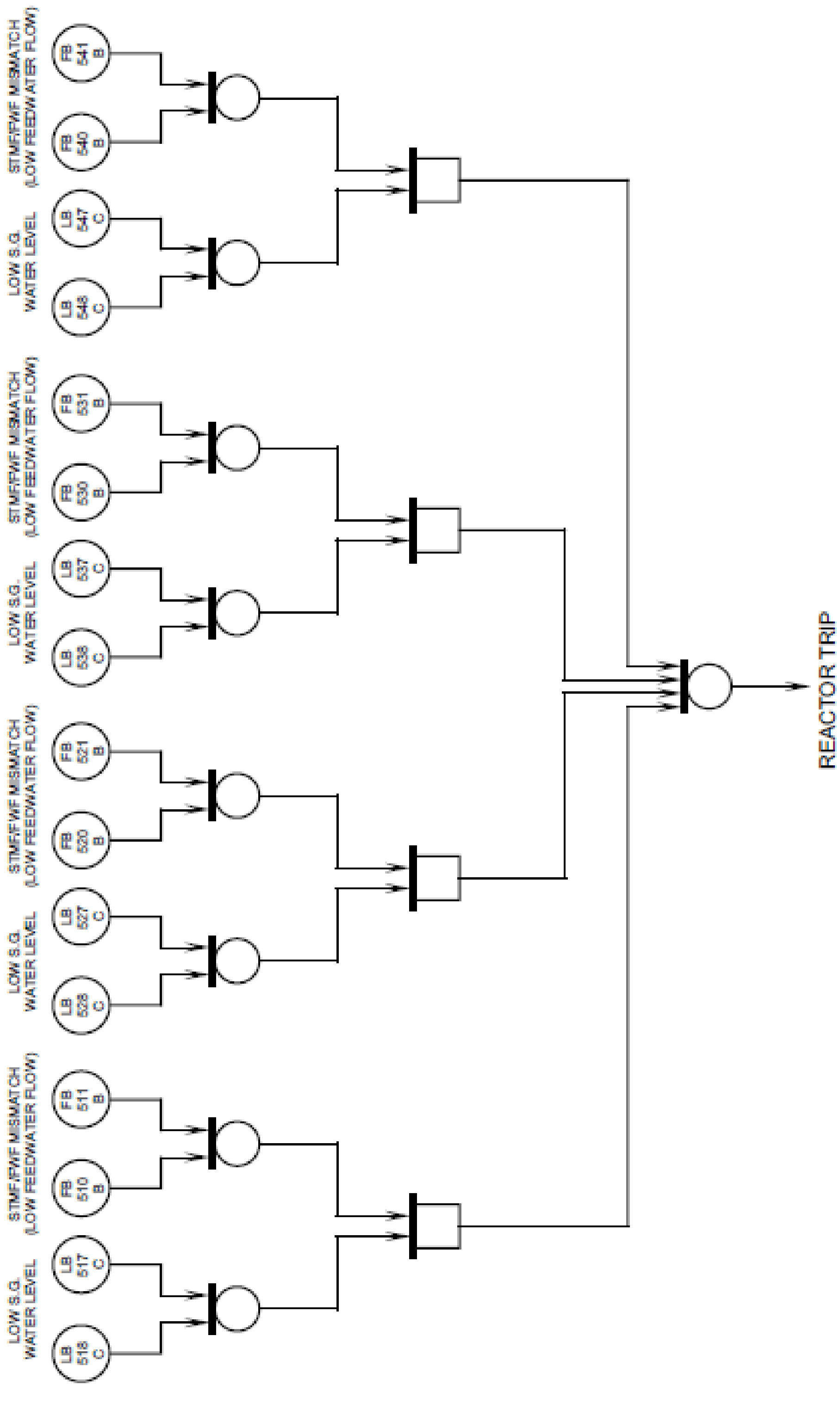

Figure 12.2-12 Low Feedwater Flow Reactor Trip

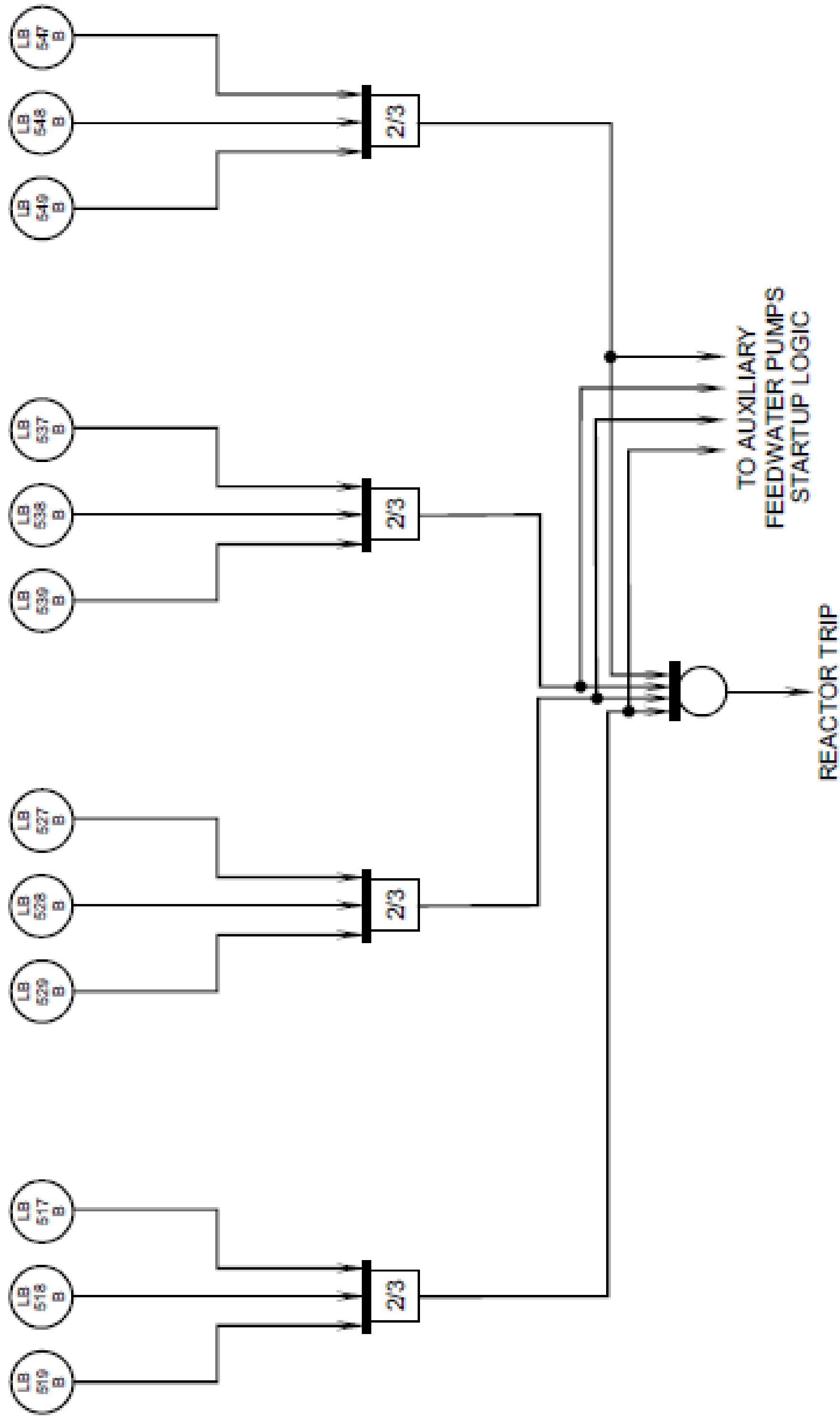

Figure 12.2-13 Steam Generator Low-Low Water Level Reactor Trip

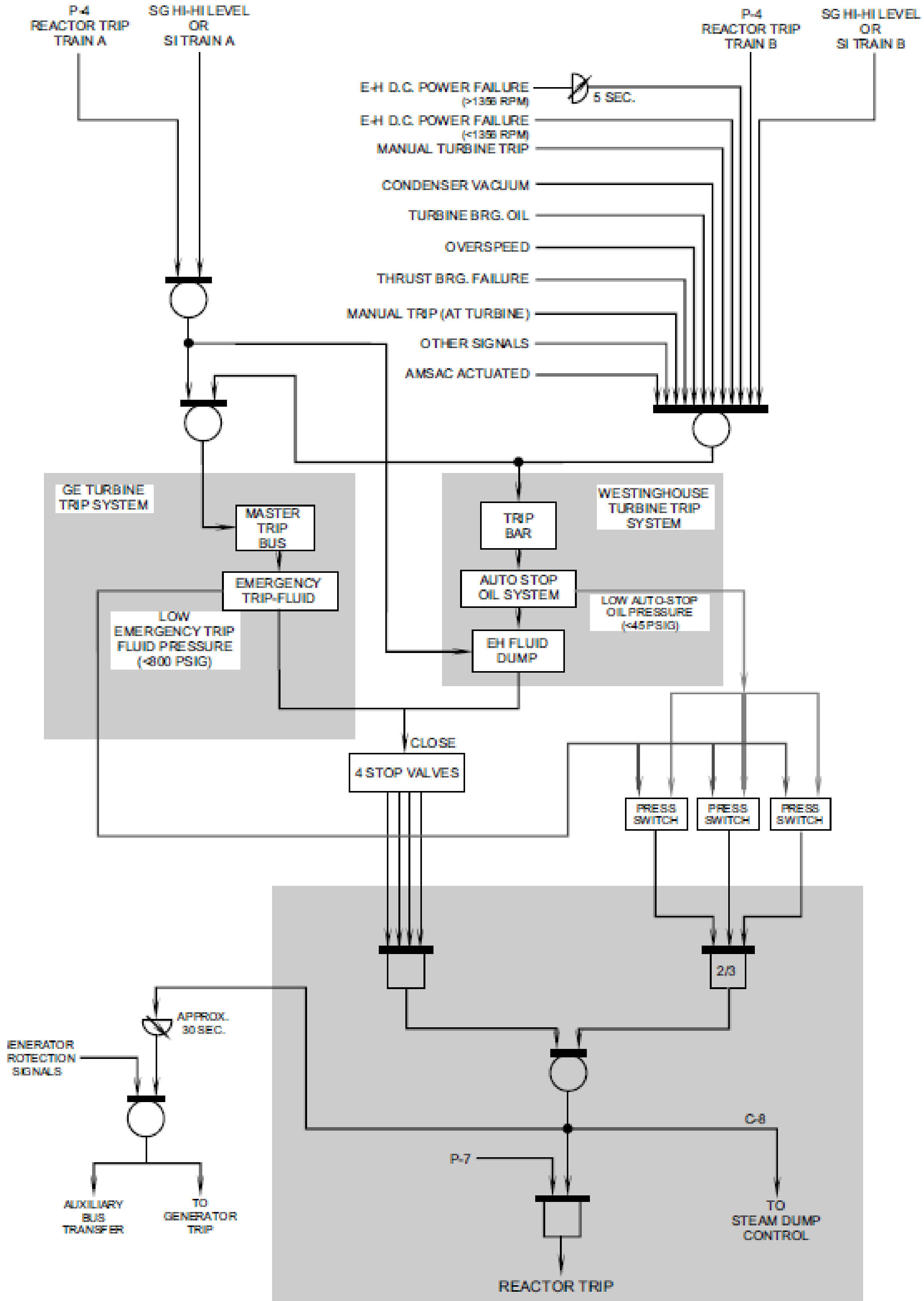

Figure 12.2-14 Turbine Trip - Reactor Trip