1. WESTINGHOUSE RPS SYSTEM DESCRIPTION

1.1 System Operation

The Westinghouse RPS is a complex control system comprising numerous electronic components that combine to provide the ability to produce an automatic or manual rapid shutdown of the nuclear reactor, known as a reactor trip or scram. In spite of its complexity, the Westinghouse RPS can be roughly divided into four segments—rods, trip breakers, logic cabinet (containing the two trains of the RPS), and instrumentation rack—as shown in Figure 1. The rods segment includes the rod control cluster assemblies (RCCAs) and control rod drive mechanisms (CRDMs). Westinghouse RPSs typically have 40 to 60 RCCAs and associated CRDMs. The trip breaker segment includes the reactor trip breakers and associated undervoltage devices and shunt trip devices. Most of the Westinghouse RPSs have DB-50 type reactor trip breakers, while some of the newer plants have DS-416 versions. For the logic cabinet, approximately 70% of the RPSs have solid state logic termed the Solid State Protection System (SSPS), while the remaining 30% have analog logic. Finally, for the instrumentation rack approximately 85% of the RPSs have analog systems to process the signals, while the remaining 15% have converted to the Eagle-21 solid state system.

RPS Segments			
Instrumentation Rack	Logic Cabinet	Trip Breakers	Rods
Generally, 3 channels for 3-loop plants, 4 channels for 2- and 4-loop plants; analog (Analog Series 7300 or earlier) or Eagle-21 signal processing (note that the sensors are located within containment rather than in the instrumentation racks)	2 trains; SSPS or analog logic	2 reactor trip breakers (and 2 bypass breakers); DB-50 or DS-416 design; automated shunt trip and undervoltage trip	40 to 60 RCCAs and associated CRDMs

Figure 1. Segments of Westinghouse RPS.

The analysis of the Westinghouse RPS is based on a four-loop plant with either an Eagle-21 or Analog Series 7300 sensor processing system and an SSPS for the logic cabinet. This configuration has been used in generic analyses of Westinghouse RPSs as representative of most designs. A simplified diagram of the SSPS/Analog Series 7300 design is presented in Figure 2. The SSPS/Eagle-21 modification is shown in Figure 3. The following discussions concerning system operation and system testing refer to the SSPS/Analog Series 7300 RPS design. The SSPS/Eagle-21 design is covered in Section 2.1.3.

In Figure 2, there are two RPS trains in the logic cabinet, trains A and B. These trains receive trip signals from the channels, process the signals, and then open the reactor trip breakers (RTBs) given appropriate combinations of signals from the channels. The channel portion of the RPS includes many different types of trip signals, as indicated in Table 1. The trip signals include various neutron flux indications, pressurizer pressure and level, reactor coolant flow, steam generator level, and others.

Several of the signals involve measurements in each of the four loops of the reactor, with a trip signal being generated if at least two of the four loop measurements exceed a setpoint. Shown in the simplified RPS diagram in Figure 2 are sensor/transmitters and signal processing modules associated with the overpower ΔT and pressurizer high pressure trip signals. (These two signals, along with others, protect the plant from uncontrolled rod withdrawal transients while at power.) For each loop there are cold leg and hot leg coolant temperature sensor/transmitters that combine to determine the loop ΔT and $T_{average}$. This information, along with flux information (not shown in Figure 2), is converted by the processing module and sent to the associated bistable, which trips if the bistable setpoint is reached. Similarly, there are four pressure sensor/transmitters for the pressurizer, one for each channel. The pressure processing module converts the pressure signal and sends it to the associated bistable.

The logic cabinet or SSPS in Figure 2 includes two trains. When a bistable in the instrumentation rack trips, it actuates associated relays in both of the trains. The solid state logic module, or universal card, for that trip parameter (one in each train) then determines whether sufficient relays have actuated (i.e., two of four for pressurizer high pressure). If so, a trip signal is sent to the undervoltage driver card (one in each train), which then opens the RTB associated with that train.

In Figure 2, there are two normally-closed RTBs and two normally-open bypass trip breakers. The bypass trip breakers are used only when testing the reactor trip breakers. Train A of the RPS logic actuates RTB-A and train B of the logic actuates RTB-B. Opening of either RTB disconnects AC power from the rod control motor generator sets to the rod drive power cabinets, which results in the RCCAs dropping into the reactor core and shutting down the nuclear reaction. During plant operation, the normally-energized undervoltage coil maintains the RTB in a closed position. The shunt trip coil is normally de-energized. An undervoltage driver card trip signal results in de-energization of the undervoltage coil and energizing (through the auto shunt trip relay) of the shunt trip coil, either of which will open the RTB.

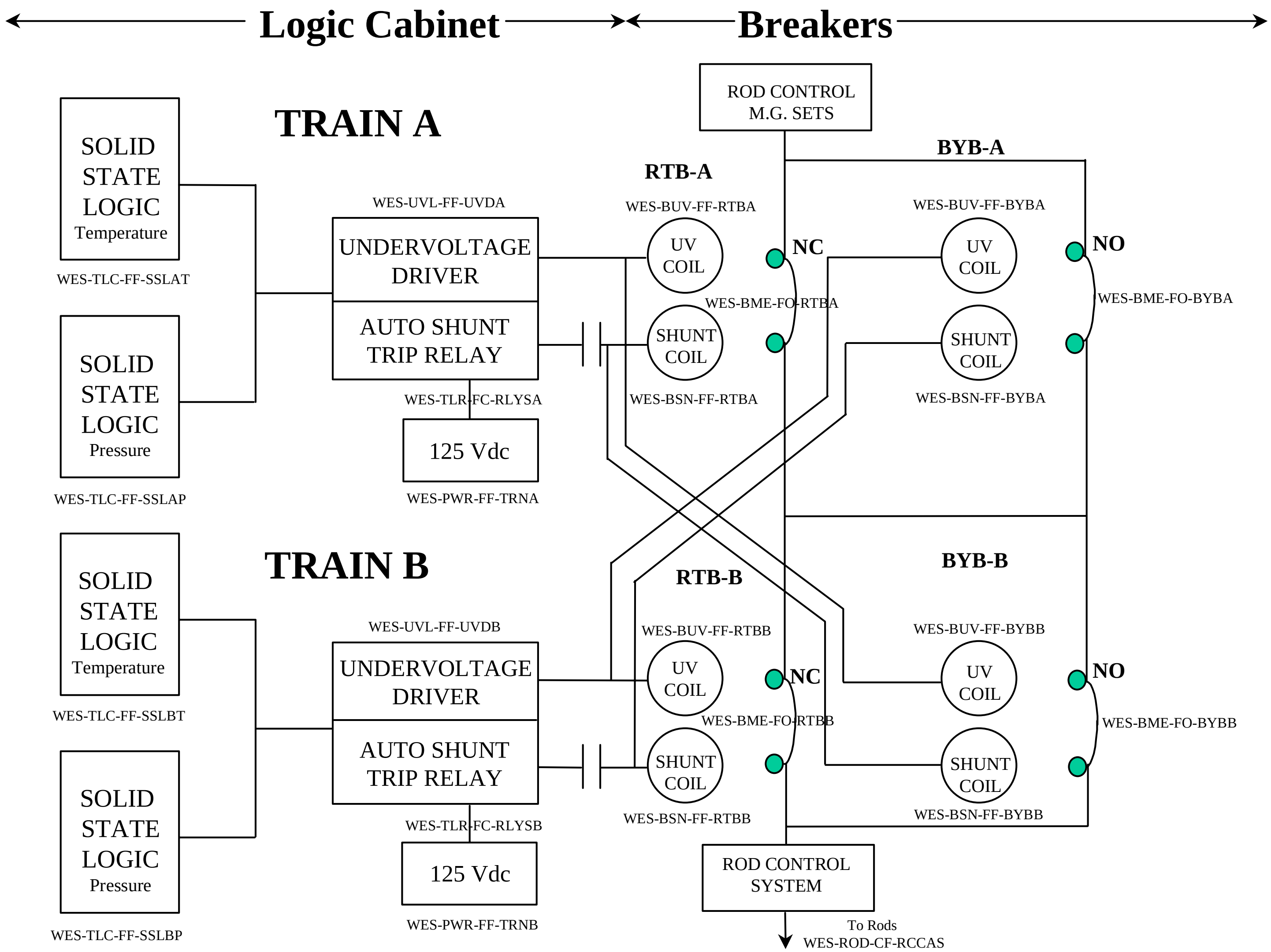

Figure 2. Westinghouse RPS simplified diagram (Analog Series 7300).

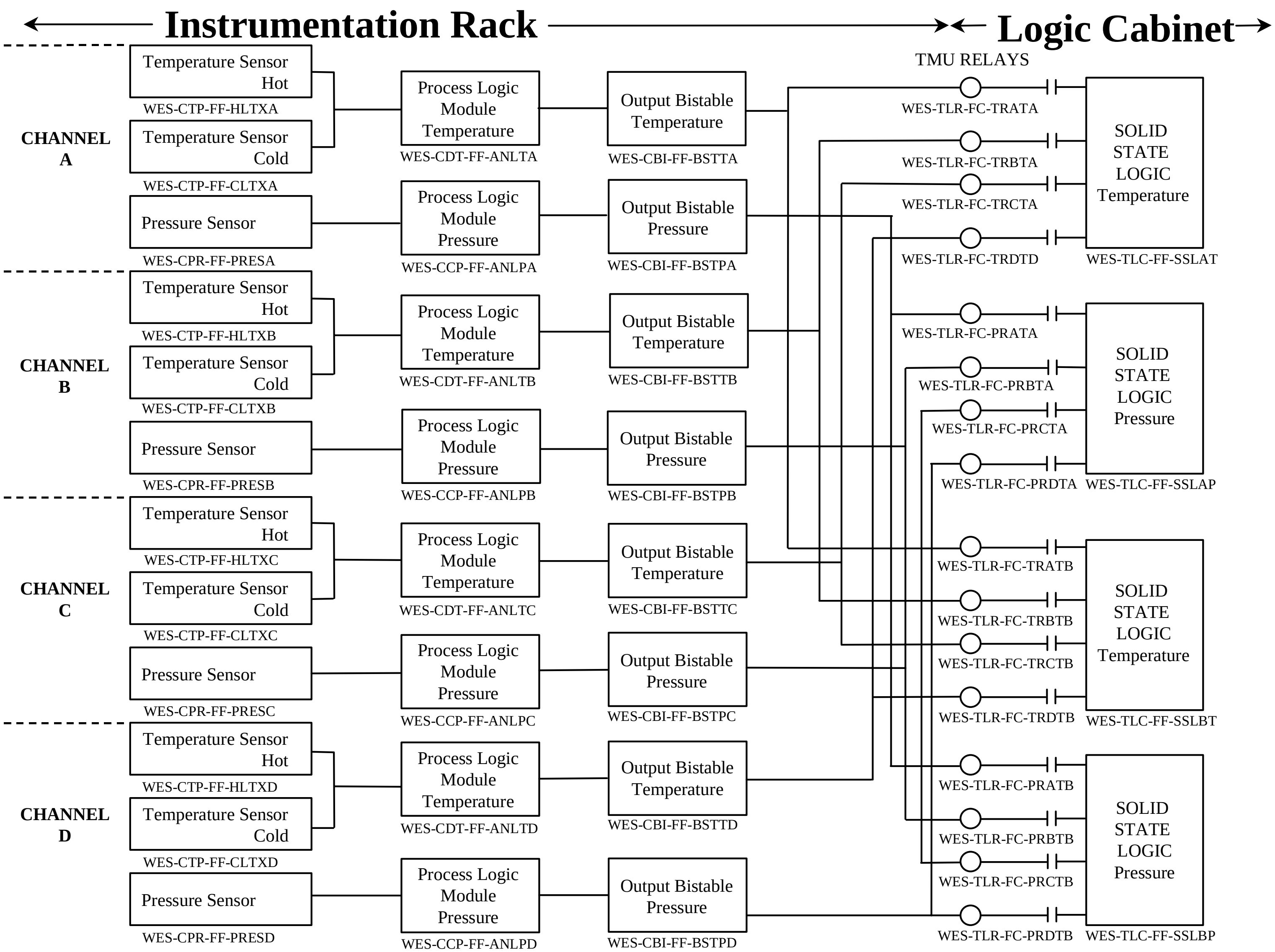

Figure 2. (continued).

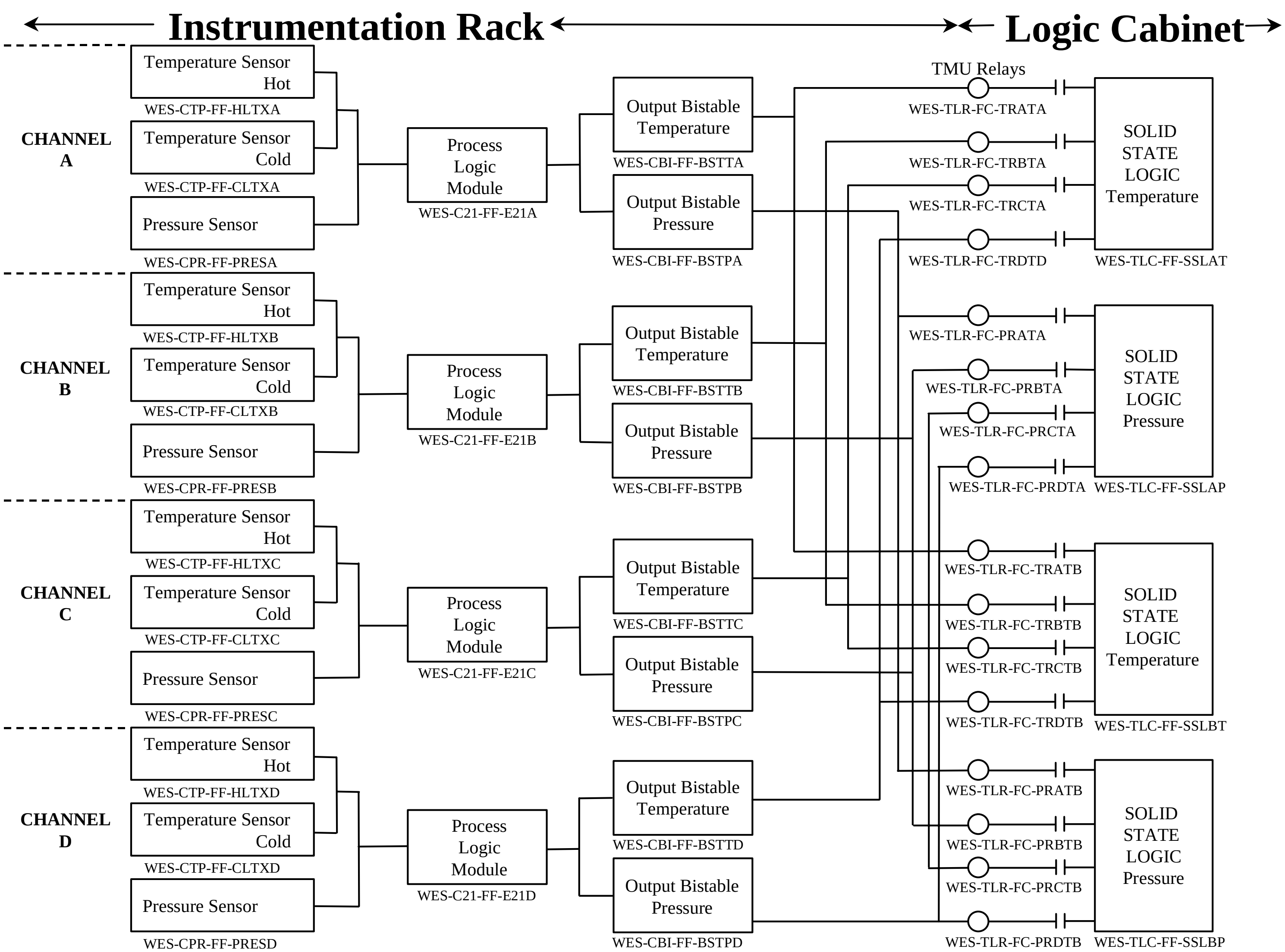

Figure 3. Westinghouse RPS simplified diagram (Eagle-21).

Table 1. Representative Westinghouse RPS trip signals.

Trip Signal	Trip Logic[a]	Purpose of Trip
1. Source range high neutron flux	1 of 2 sensors	Prevent an inadvertent power increase while subcritical or at low power
2. Intermediate range high neutron flux	1 of 2 sensors	Prevent an inadvertent power increase at low power
3. Power range high neutron flux (low setpoint)	2 of 4 sensors	Prevent an inadvertent power increase while at power
4. Power range high neutron flux (high setpoint)	2 of 4 sensors	Limit maximum power level
5. High positive rate, neutron flux	2 of 4 sensors	Limit power excursions
6. High negative rate, neutron flux	2 of 4 sensors	Prevent unacceptable power distributions
7. Overtemperature ΔT	2 of 4 overtemperature ΔT signals (one for each loop)	Prevent operation with a DNBR < 1.30[c]
8. Overpower ΔT[b]	2 of 4 overpower ΔT signals (one for each loop)	Prevent excessive power density
9. Pressurizer low pressure	2 of 4 sensors	Prevent DNBR < 1.30[c]
10. Pressurizer high pressure[b]	2 of 4 sensors	Protect integrity of reactor coolant system pressure boundary
11. Pressurizer high water level	2 of 3 sensors	Prevent solid water operations
12. Low reactor coolant flow	2 of 3 sensors in any one of four loops	Ensure adequate loop flow to remove core heat
13. Reactor coolant pump undervoltage	2 of 4 buses	Ensure adequate loop flow to remove core heat
14. Reactor coolant pump underfrequency	2 of 4 buses	Ensure adequate loop flow to remove core heat
15. Steam generator low water level (mismatch with steamflow/feedflow)	1 of 2 level sensors coincident with 1 of 2 mismatches in the same steam generator (four steam generators)	Anticipate loss of heat sink
16. Turbine trip	2 of 3 low autostop oil pressure or 4 of 4 turbine stop valves shut	Remove heat source if steam load is lost to steam generators

a. A four-loop reactor design is assumed.

b. These two signals are modeled in the RPS fault tree used for this study.

c. DNBR = departure from nucleate boiling ratio