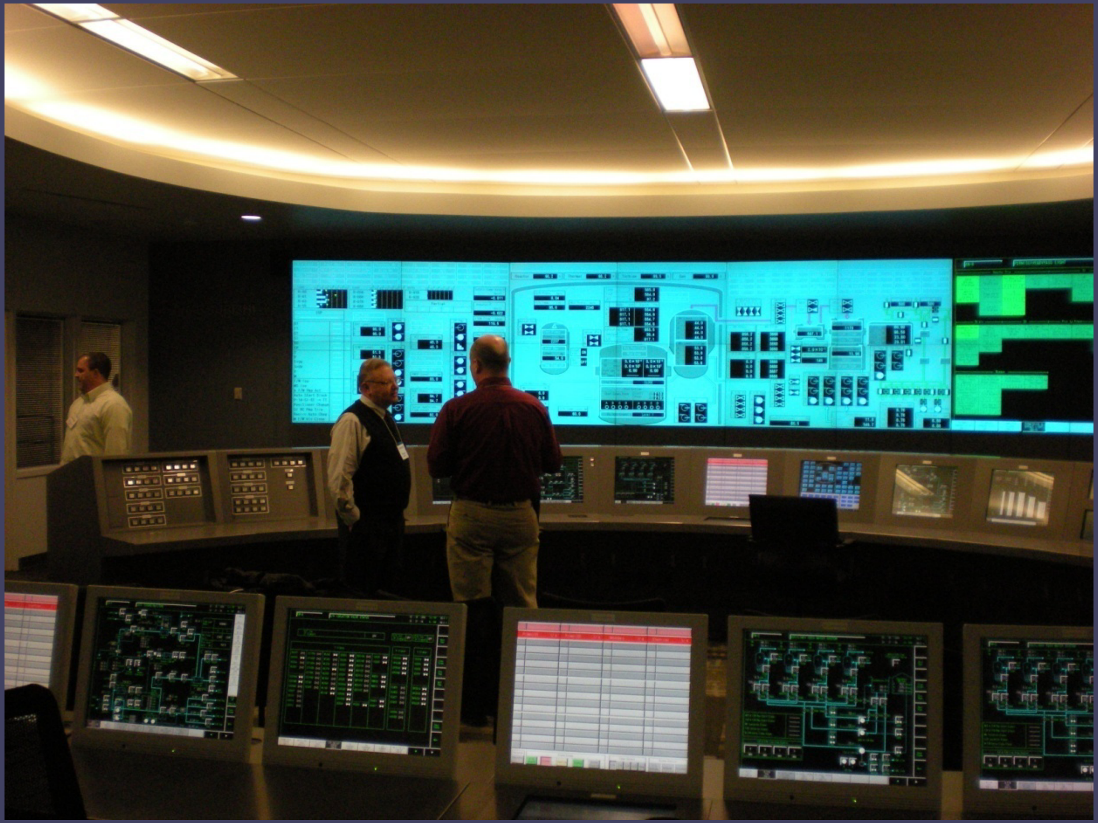
United States Nuclear Regulatory Commission
Protecting People and the Environment

Instrumentation & Control Systems

US-APWR Technology Chapter 8.0



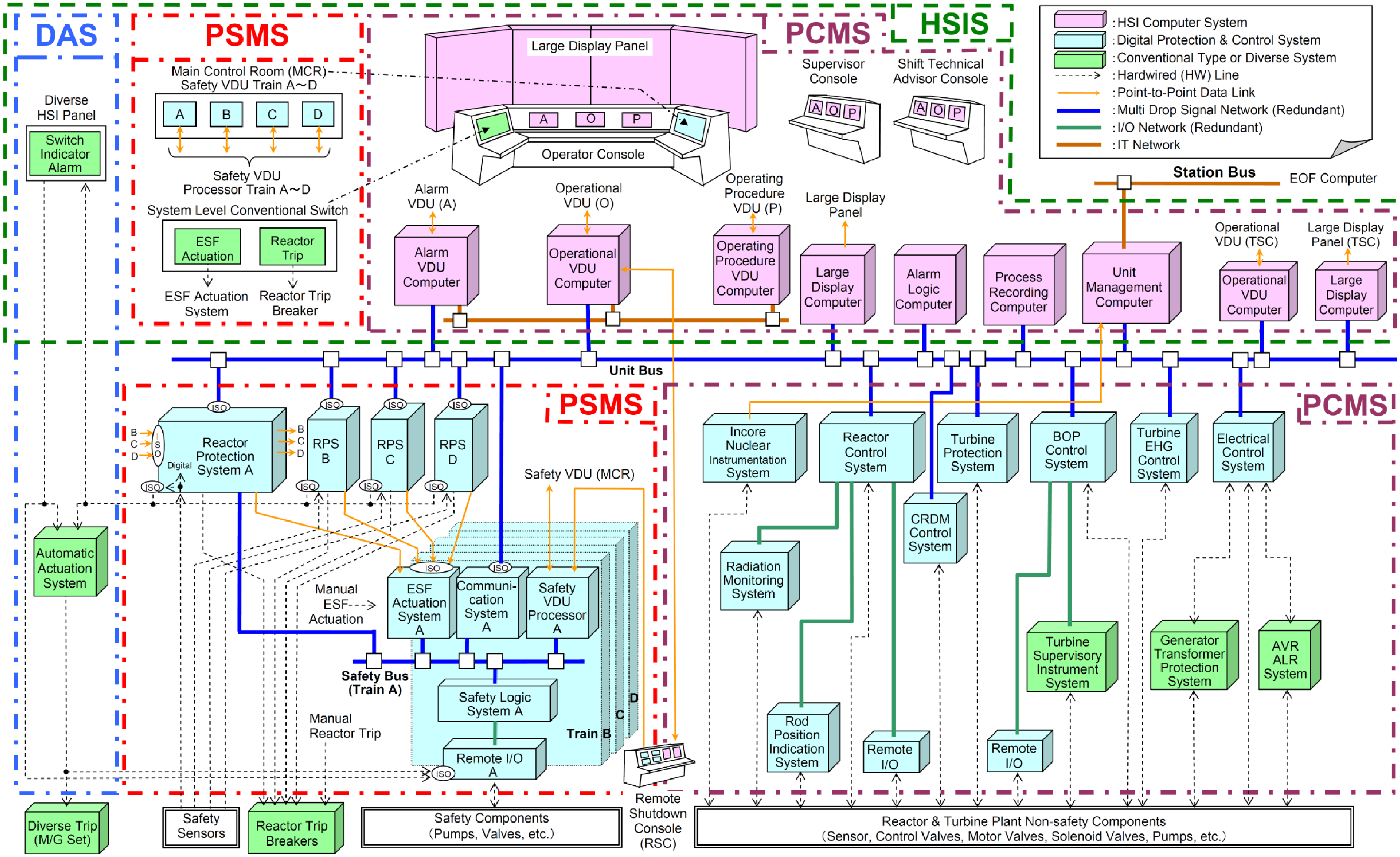
Human Resources Training & Development

Learning Objectives:

1. State the purposes of the following:
   a. Protection and Safety Monitoring System
   b. Reactor Trip System
   c. Engineered Safety Features Actuation System
   d. Plant Control and Monitoring System
   e. Diverse Actuation System

2. Describe the major differences between the control and instrumentation design of the US-APWR and those of currently operating PWRs.

I & C Architecture – Fig. 8-1

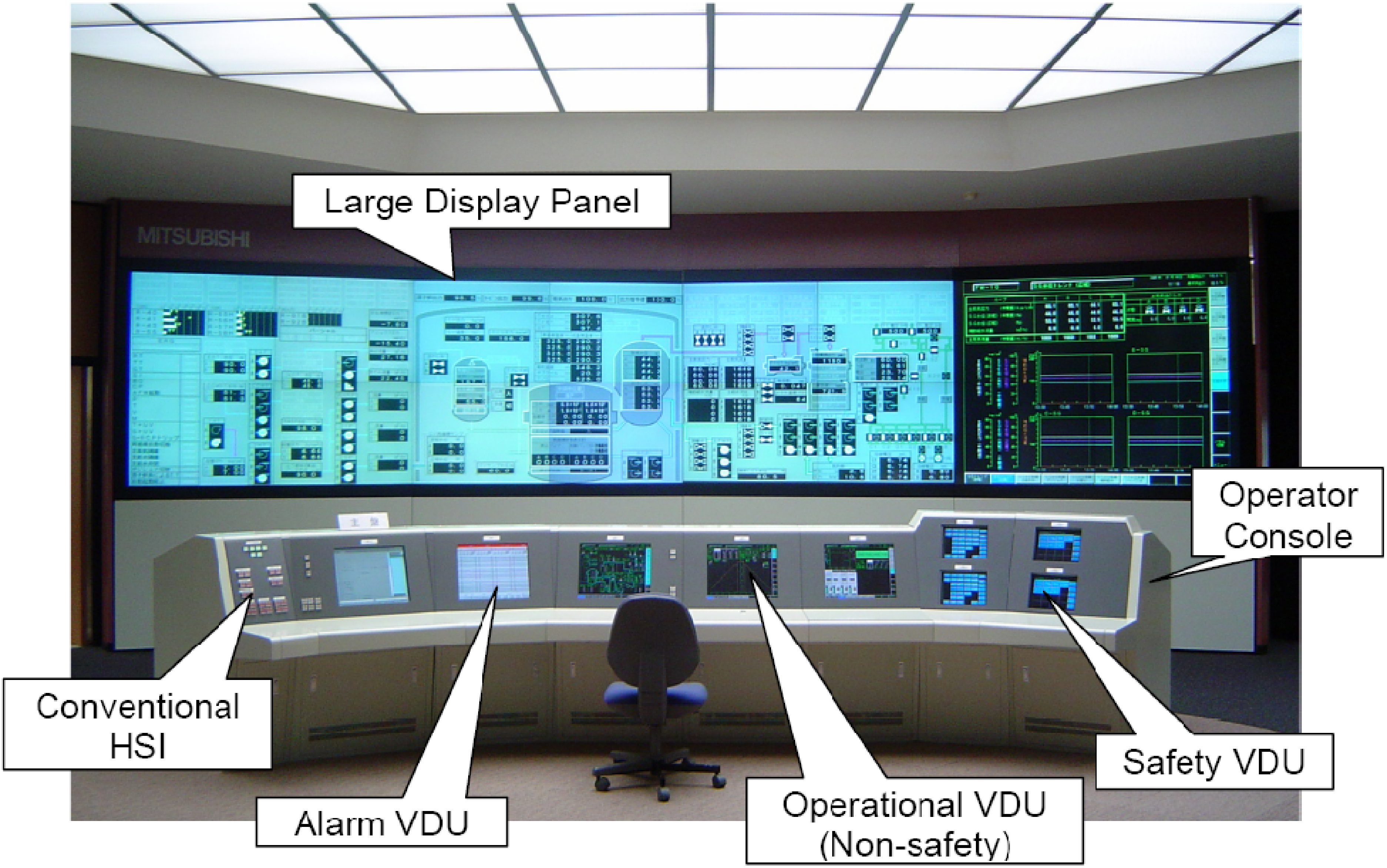


DAS : Diverse Actuation System PSMS : Protection and Safety Monitoring System HSIS : Human System Interface System PCMS : Plant Control and Monitoring System

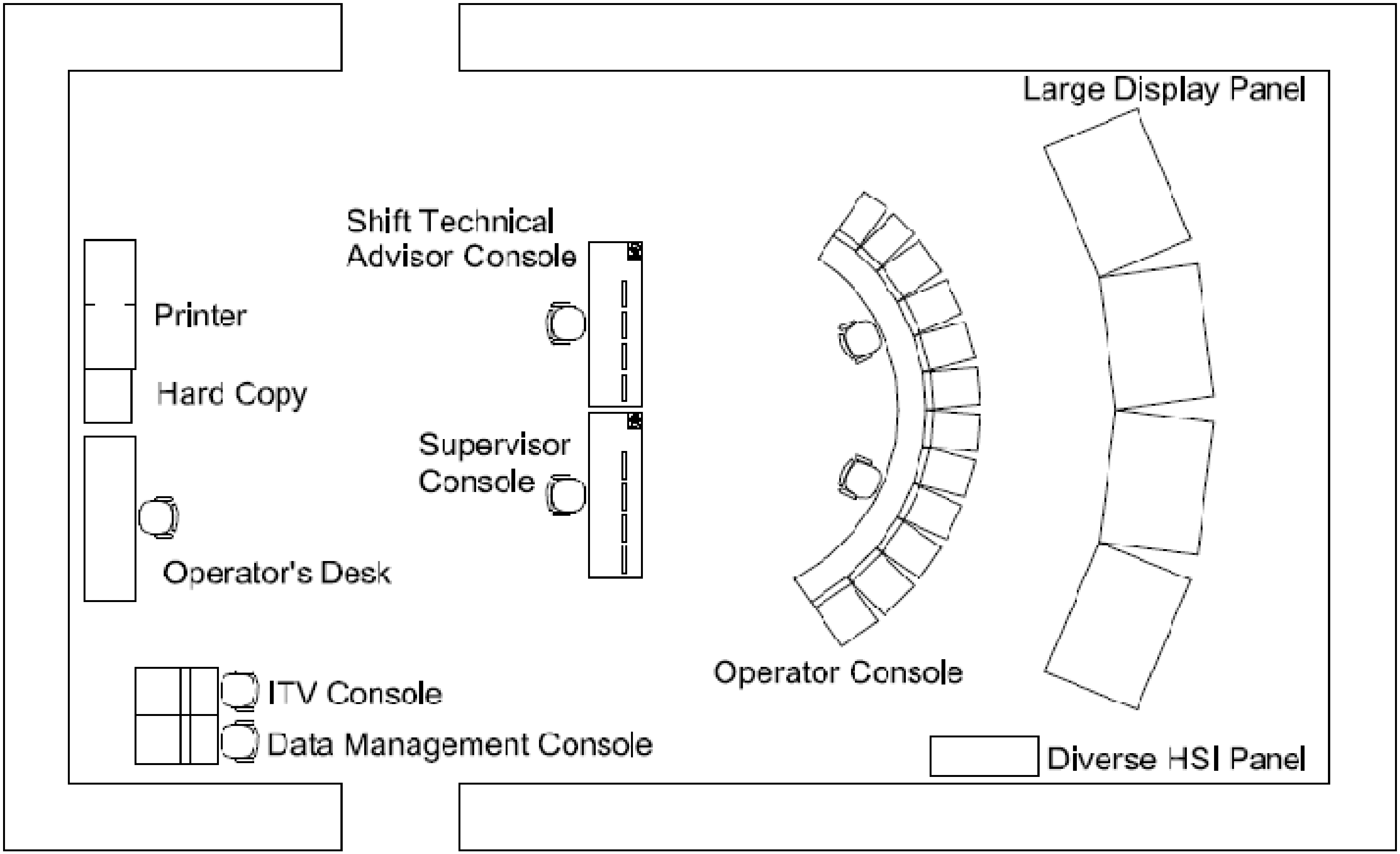
I & C Architecture

- Both control (PCMS) & safety (PSMS) are based on the MELTAC digital platform.
- No, not ALF's home planet. MELTAC = Mitsubishi ELectric Total Advanced Controller.

CR Arrangement – Fig. 8-2



CR Arrangement – Fig. 8-2 (cont'd)



PSMS Overview

PSMS subsystems include:

- Reactor Protection System (RPS)
- Engineered Safety Features Actuation System (ESFAS)
- Safety Logic System (SLS)
- Conventional train-level actuation switches
- Safety-related Visual Display Units (VDUs), including post-accident monitoring

Table 8-1 Reactor Trips

Actuation Signal	Number of Sensors, Switches, or Signals	Division Trip Actuation Logic	Permissives and Bypasses (See Table 7.2-4)	Logic Diagram Figure 7.2-2
High Source Range Neutron Flux	2 Neutron Detectors	1/2	P-6, P-10	Sheet 3
High Intermediate Range Neutron Flux	2 Neutron Detectors	1/2	P-10	Sheet 3
High Power Range Neutron Flux (low setpoint)	4 Neutron Detectors	2/4	P-10	Sheet 3
High Power Range Neutron Flux (high setpoint)		2/4	None	Sheet 4
High Power Range Neutron Flux Positive Rate		2/4	None	Sheet 4
High Power Range Neutron Flux Negative Rate		2/4	None	Sheet 4
Over Temperature Δ T	1 Composite Signal per RCS Loop	2/4	None	Sheet 5
Over Power Δ T	1 Composite Signal per RCS Loop	2/4	None	Sheet 5

Table 8-1 Reactor Trips (cont'd)

Actuation Signal	Number of Sensors, Switches, or Signals	Division Trip Actuation Logic	Permissives and Bypasses (See Table 7.2-4)	Logic Diagram Figure 7.2-2
Low Reactor Coolant Flow	4 Flow Sensors per RCS Loop	2/4 per RCS Loop	P-7	Sheet 5
Low RCP Speed	1 Speed Sensor per RCP	2/4	P-7	Sheet 5
Low Pressurizer Pressure	4 Pressure Sensors	2/4	P-7	Sheet 5
High Pressurizer Pressure		2/4	None	Sheet 6
High Pressurizer Water Level	4 Level Sensors	2/4	P-7	Sheet 6
Low SG Water Level	4 Level Sensors per SG	2/4 per SG	None	Sheet 7
High-High SG Water Level		2/4 per SG	P-7	Sheet 9
Manual Reactor Trip	1 Switch per Train	1/1	None	Sheet 2
ECCS Actuation	Valid Signal	N/A	None	Sheet 11
Turbine Trip	Valid Signal	N/A	P-7	Sheet 13

RPS Configuration – Fig. 8-3

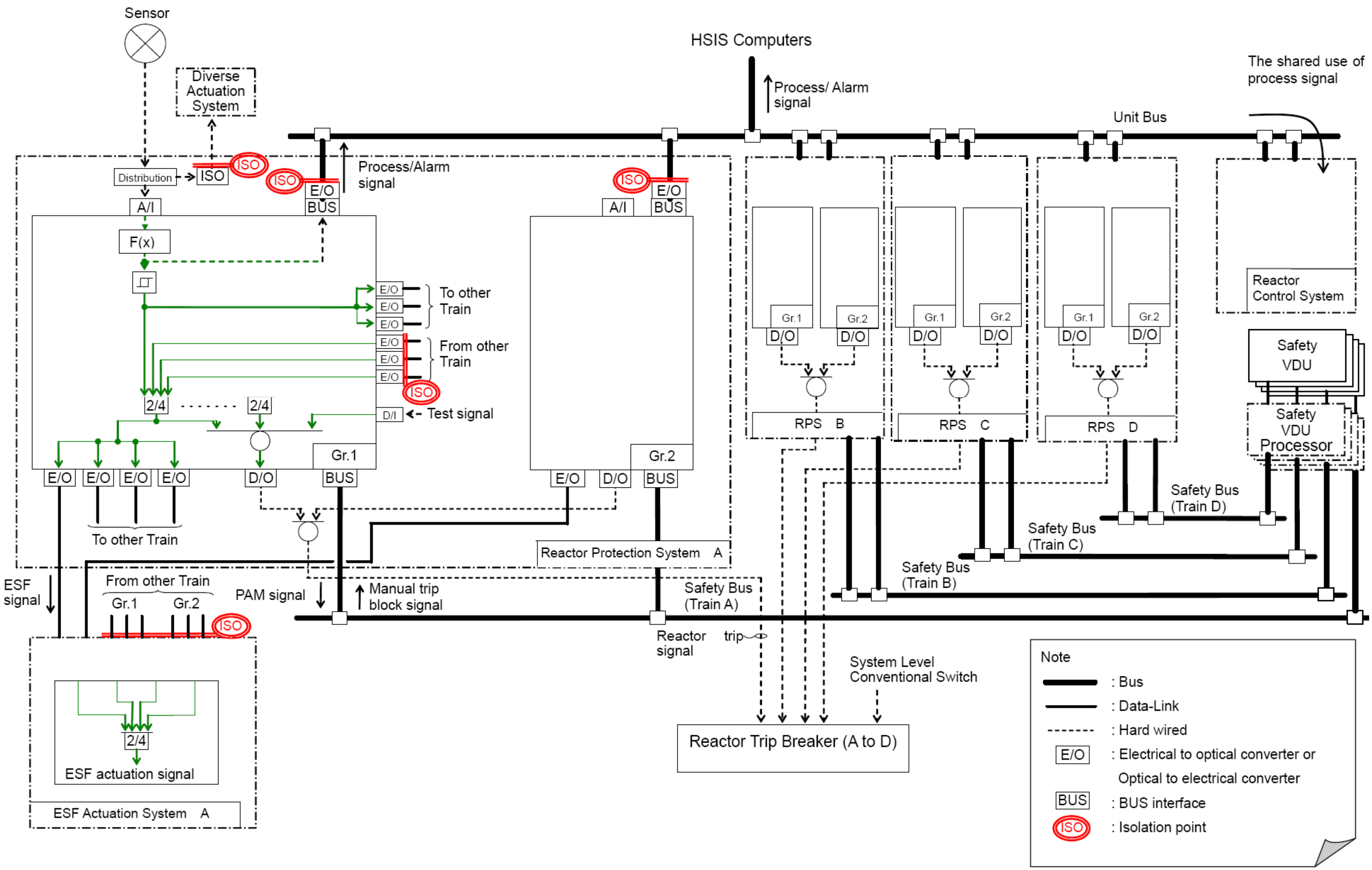


Table 8-4 Diverse Parameter Groups

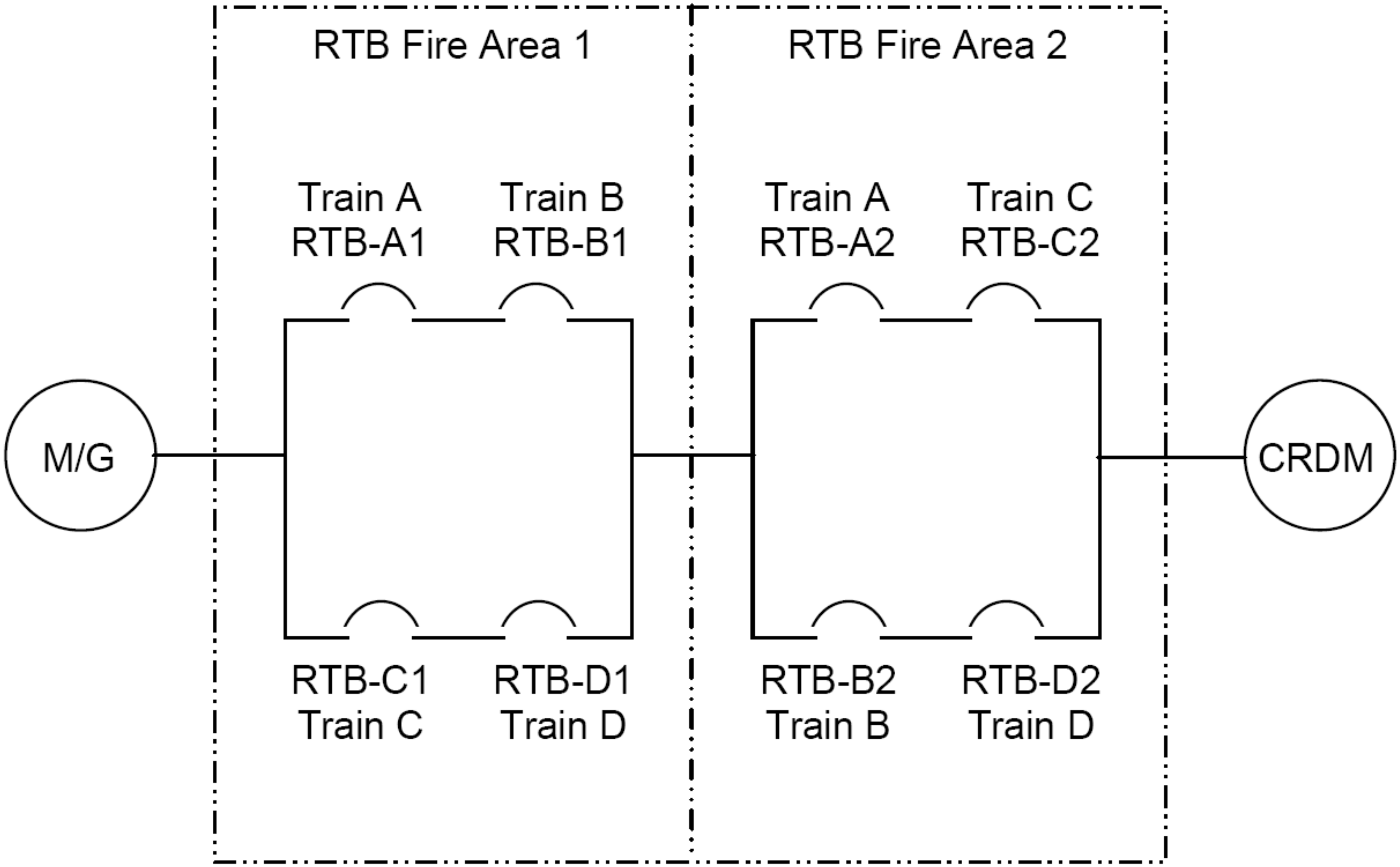
Table 8-4 Diverse Parameters in Two Separate Controller Groups

Group 1	Group 2	Remark
Over Power Δ T*6 High Power Range Neutron Flux Rate	High Power Range Neutron Flux	Over Power Protection*1
Low RCP Speed Over Temperature Δ T	Low Reactor Coolant Flow Low Pressurizer Pressure	Core Heat Removal Protection*2
Low SG Water Level High Pressurizer Water Level	High Pressurizer Pressure	Loss of Heat Sink Protection*3
High Source Range Neutron Flux High Intermediate Range Neutron Flux	High Power Range Neutron Flux (Low Setpoint)	Nuclear Startup Protection*4
High Pressurizer Water Level	High Pressurizer Pressure	Primary Over Pressure Protection*5

Note:

1. Example of design basis event in the safety analysis is "Uncontrolled Control Rod Assembly Withdrawal at Power."
2. Example of design basis event in the safety analysis is "Loss of Forced Reactor Coolant Flow Including Trip of Pump Motor."
3. Example of design basis event in the safety analysis is "Feedwater System Pipe Break Inside and Outside Containment."
4. Example of design basis event in the safety analysis is "Uncontrolled Control Rod assembly Withdrawal from a Subcritical or Low Power Startup Condition, or Spectrum of Rod Ejection Accident."
5. Example of design basis event in the safety analysis is "Loss of External Electrical Load or Turbine Trip."
6. Overpower ΔT also has a function of Core Heat Removal Protection in conjunction with Overtemperature ΔT, although the primary function of Overpower ΔT is Overpower Protection.

RTB Configuration – Fig. 8-4



M/G: Motor-Generator Set
CRDM: Control Rod Drive Mechanism

RPS Functions Fig. 8-5

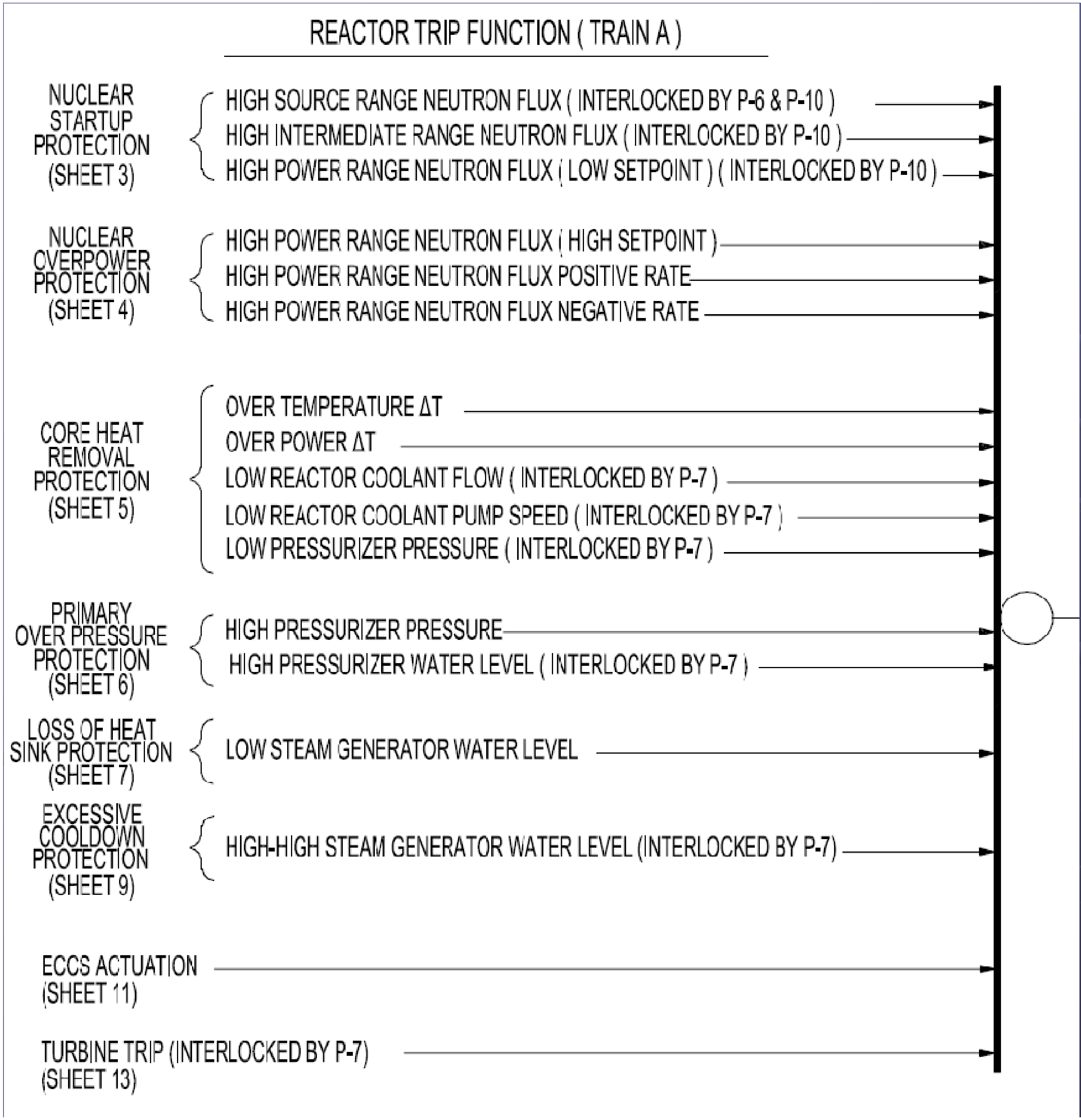


Table 8-5 ESF Actuations

Actuation Signal	Number of Sensors, Switches, or Signals	Actuation Logic	Permissives and Bypasses For Permissives and Bypasses Refer Table 7.2-4
1. Emergency Core Cooling System - Logic diagram Figure 7.2-2 Sheet 11			
Low Pressurizer Pressure	4 Pressure Sensors (Shared with RT)	2/4	Operating bypass permitted while P-11 is active, automatically unbypassed by inactive P-11.
Low Main Steam Line Pressure	4 Pressure Sensors per Steam Line	2/4 per Steam Line	Operating bypass permitted while P-11 is active, automatically unbypassed by inactive P-11.
High Containment Pressure	4 Pressure Sensors	2/4	None
Manual Actuation	1 Switch per Train	1/1	Can be manually reset to block re-initiation of ECCS signal while P-4 is active. This block is automatically removed when P-4 becomes inactive.
2. Containment Spray - Logic diagram Figure 7.2-2 Sheet 12			
High-3 Containment Pressure	4 Pressure Sensors (Shared with ECCS)	2/4	None
Manual Actuation	2 Switches per Train	2/2	None
3. Main Control Room Isolation - Logic diagram Figure 7.2-2 Sheet 12			
MCR Outside Air Intake Radiation	2 Gas Radiation Detectors	1/2	None
	2 Iodine Radiation Detectors	1/2	None
	2 Particulate Radiation Detectors	1/2	None
ECCS Actuation	Valid ECCS Signal	1/1	None
Manual Actuation	1 Switch per Train	1/1	None

Table 8-5 ESF Actuations (cont'd)

Actuation Signal	Number of Sensors, Switches, or Signals	Actuation Logic	Permissives and Bypasses For Permissives and Bypasses Refer Table 7.2-4
4. Containment Purge Isolation - Logic diagram Figure 7.2-2 Sheet 12			
Containment High Range Area Radiation	4 Radiation Detectors	2/4	None
ECCS Actuation	Valid ECCS signal	1/1	None
Manual Containment Isolation	1 Switch per Train	1/1	None
Manual CS Actuation	2 Switches per Train	2/2	None
5. Containment Isolation Phase A - Logic diagram Figure 7.2-2 Sheet 12			
ECCS Actuation	Valid ECCS Signal	1/1	None
Manual Actuation	1 Switch per train	1/1	None
6. Containment Isolation Phase B - Logic diagram Figure 7.2-2 Sheet 12			
High-3 Containment Pressure	4 Pressure Sensors (Shared with ECCS)	2/4	None
Manual CS Actuation	2 Switches per train	2/2	None

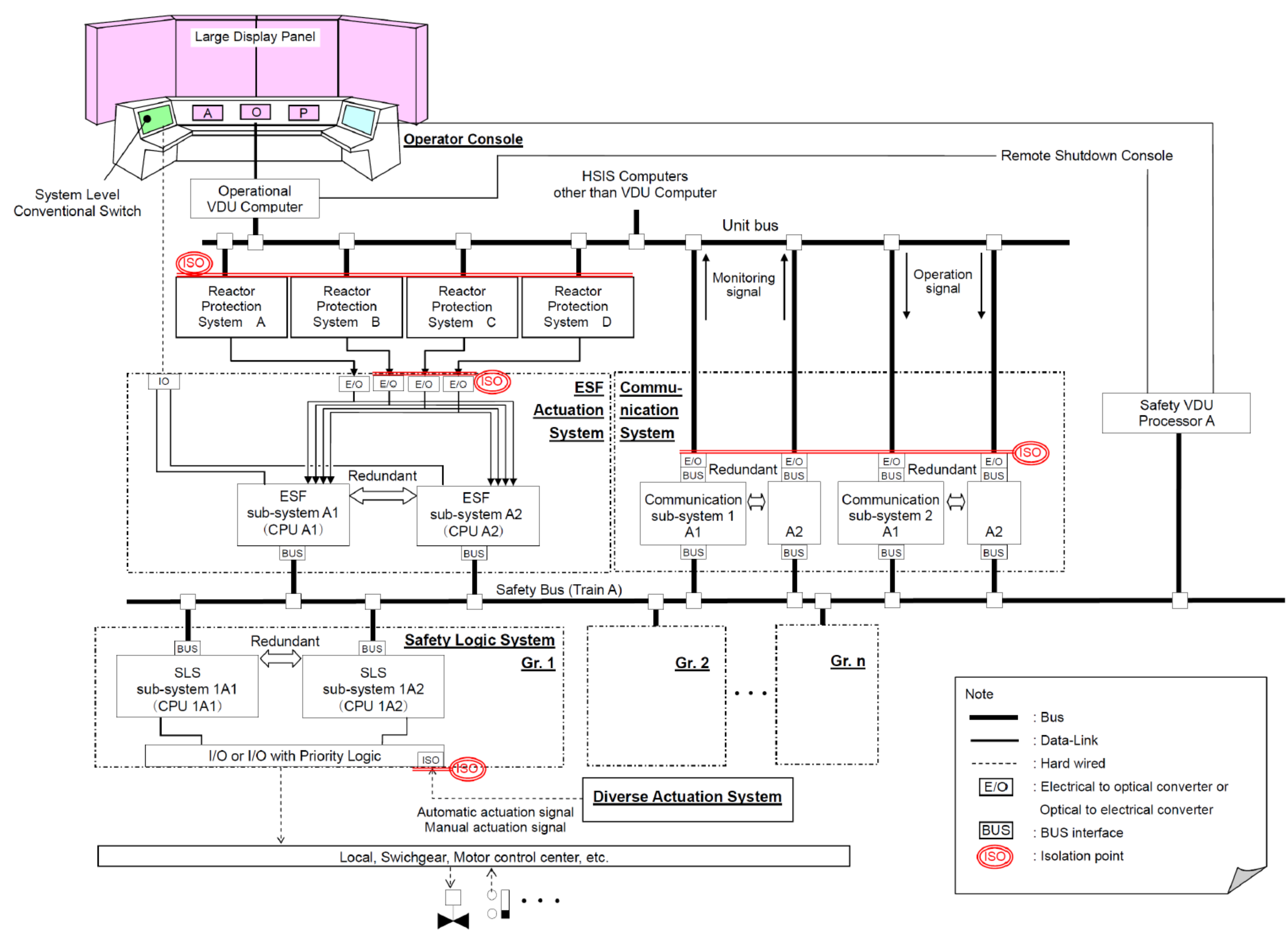
Table 8-5 ESF Actuations (cont'd)

Actuation Signal	Number of Sensors, Switches, or Signals	Actuation Logic	Permissives and Bypasses For Permissives and Bypasses Refer Table 7.2-4
7A. Main Feedwater Regulation Valve Closure Figure 7.2-2 Sheet 10			
Low T_{avg} coincident with RT (P-4)	4 Temperature Sensors (T_{avg}) (Shared with RT)	2/4	None
	1Signal per Train (P-4)	1/1	None
7B. Main Feedwater Isolation Figure 7.2-2 Sheet 10			
High-High SG Water Level	4 Level Sensors per SG (Shared with RT)	2/4 per SG	None
ECCS Actuation	Valid ECCS signal	1/1	None
Manual Actuation	2 Switches	1/2 per Valve	None
8. Main Steam Line Isolation - Logic diagram Figure 7.2-2 Sheet 9			
Low Main Steam Line Pressure	4 Pressure Sensors per Steam Line (Shared with ECCS)	2/4 per Steam Line	Operating bypass permitted while P-11 is active, automatically unbypassed by inactive P-11.
High Main Steam Line Pressure Negative Rate		2/4 per Steam Line	Operating bypass of unblock permitted while P-11 is active, automatically blocked by inactive P-11.
High-High Containment Pressure	4 Pressure Sensors (Shared with ECCS)	2/4	None
Manual Actuation	2 Switches	1/2 per Valve	None

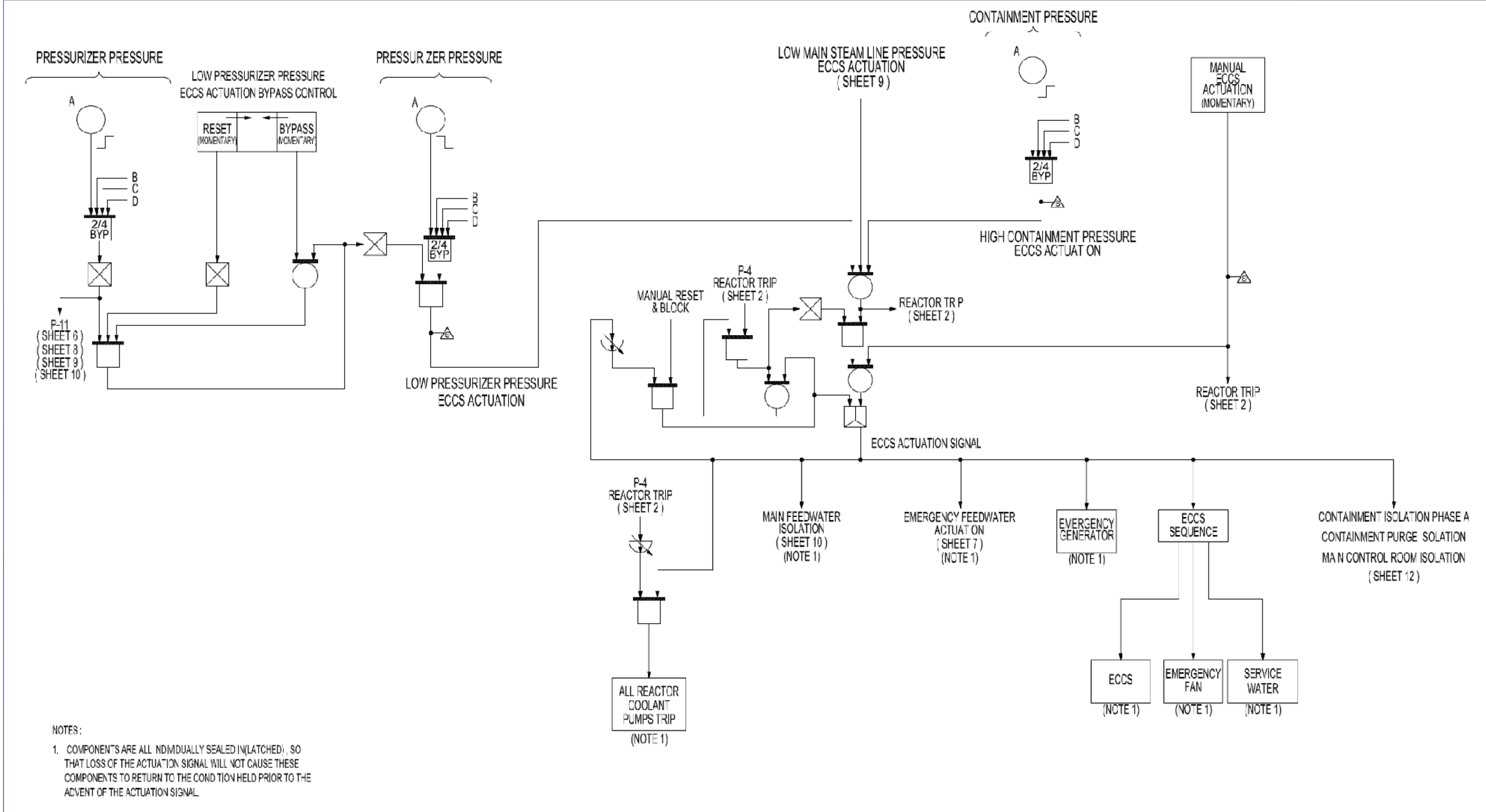
Table 8-5 ESF Actuations (cont'd)

Actuation Signal	Number of Sensors, Switches, or Signals	Actuation Logic	Permissives and Bypasses For Permissives and Bypasses Refer Table 7.2-4
9. Emergency Feedwater Actuation - Logic diagram Figure 7.2-2 Sheet 7			
Low SG Water Level	4 Level Sensors per SG (Shared with RT)	2/4 per SG	None
ECCS actuation	Valid ECCS signal	1/1	None
LOOP signal	Valid Blackout signal	1/1	None
MFW Pumps tripped	All pumps trip signal	1/1	None
Manual Actuation	1 Switch per train	1/1	None
10 Emergency Feedwater Isolation - Logic diagram Figure 7.2-2 Sheet 8			
High SG Water Level	4 Level Sensors per SG (Shared with RT)	2/4 per SG	Permitted while P-4 is active Automatically blocked while steam line pressure is low Operating bypass permitted while P-11 is active, automatically unbypassed by inactive P-11.
Low Main Steam Line Pressure	4 Pressure Sensors per Steam Line (Shared with ECCS)	2/4 per Steam Line	Automatically blocked while EFW Isolation signal from other SG is initiated.
Manual Actuation	2 Switches per SG	1/2 per SG	None
11. CVCS Isolation - Logic Diagram Figure 7.2-2 Sheet 6			
High Pressurizer Water Level	4 Level Sensors (Shared with RT)	2/4	Operating bypass permitted while P-11 is active, automatically unbypassed by inactive P-11.
Manual Actuation	1 Switch per train	1/1	None

ESFAS, SLS Configuration – Fig. 8-6



ECCS Actuation – Fig. 8-7



Diverse Actuation System (DAS)

- Nonsafety diverse I&C system designed to cope with simultaneous disabling of PSMS, PCMS
- Conventional analog equipment totally diverse & independent from MELTAC platform
- Auto actuations for critical functions required within 10 min of event initiation
- Manual actions credited after 10 min

Table 8-8 Diverse Actuation Signals

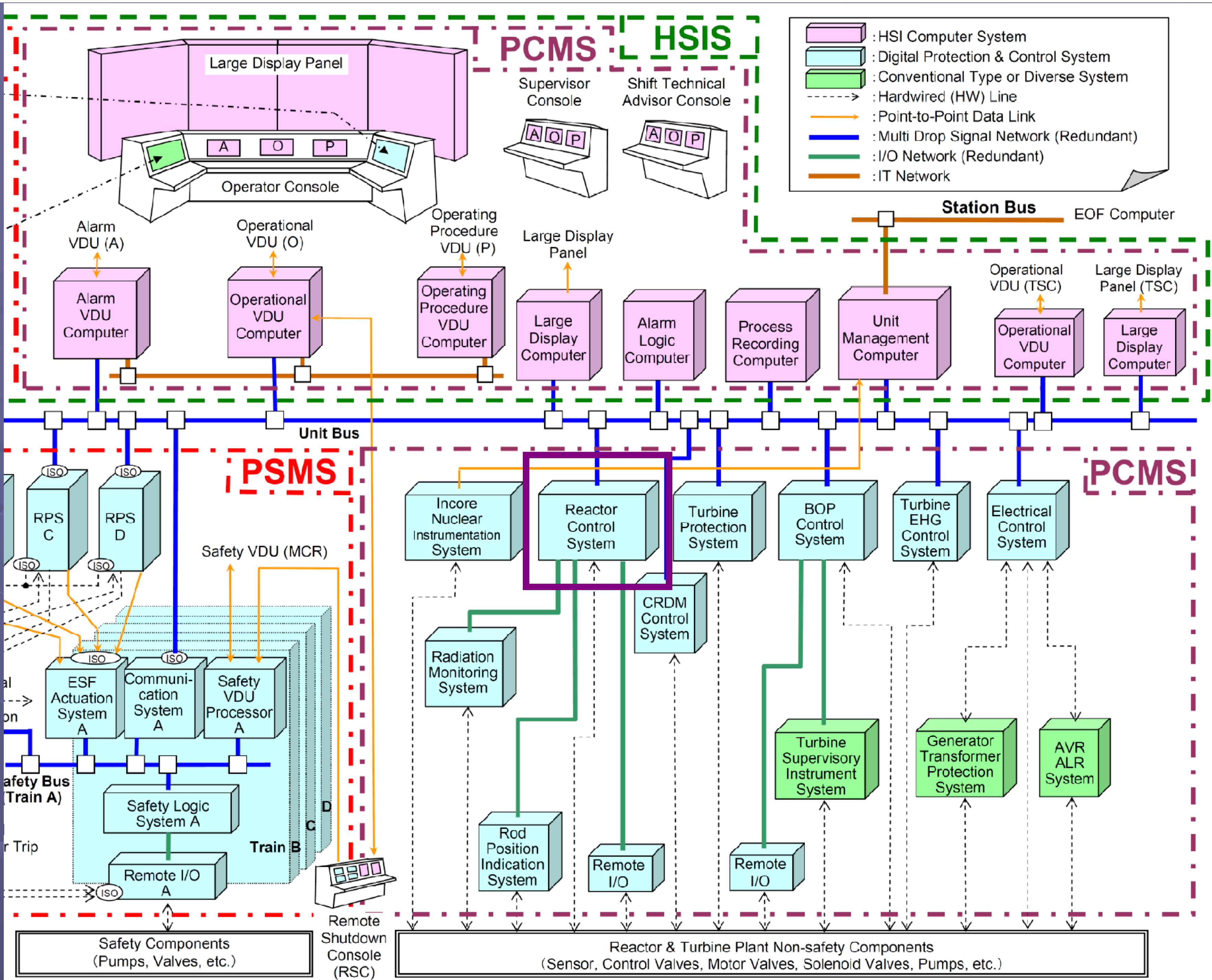
Actuation Signal	Number of Sensors or Switches	Actuation Logic	Permissives and Bypasses
1. Reactor Trip, Turbine Trip and MFW Isolation			
Low Pressurizer Pressure	4 Pressure Sensors	2/4	Manually bypassed by the actuation of a dedicated hardwired switch on the OC during plant startup and shutdown. Blocked by P-4.
High Pressurizer Pressure	4 Pressure Sensors	2/4	Manually bypassed by the actuation of a dedicated hardwired switch on the OC during plant startup and shutdown. Blocked by P-4.
Low SG Water Level	1 Level Sensor per SG) (Shared with EFW Actuation)	2/4	Manually bypassed by the actuation of a dedicated hardwired switch on the OC during plant startup and shutdown. Blocked by P-4.
Manual Actuation	1 Switch	1/1	None
2. Emergency Feedwater Actuation			
Low SG Water Level	1 Level Sensor per SG (Shared with reactor trip, turbine trip and MFW isolation)	2/4	Manually bypassed by the actuation of a dedicated hardwired switch on the OC during plant startup and shutdown. Blocked by 2-out-of-4 signal of EFW Pump operation signals.
Manual actuation	1 Switch	1/1	None
3. ECCS Actuation			
Manual Actuation	1 Switch	1/1	None
4. Containment Isolation			
Manual actuation	1 Switch	1/1	None
5. Open/Close Emergency Feedwater Control Valves			
Manual Actuation	1 Switch per SG	1/1	None
6. Open/Close Safety Depressurization Valve			
Manual Actuation	1 Switch	1/1	None
7. Open/Close Main Steam Depressurization Valves			
Manual Actuation	1 Switch per SG	1/1	None

Control System (PCMS)

- Establishes and maintains plant operating conditions within prescribed limits.
- Minimizes frequency of protective responses.
- Relieves operator of routine tasks.
- Regulates conditions in the plant automatically in response to changing plant conditions and changes in plant load demand.

Design Capability

- ±10% step load change in 15 – 100% range
- ± 5% ramp load change in 15 – 100% range
- 100% load rejection without reactor trip, handled by:
  - Immediate full closure of governor valves
  - Full opening of turbine bypass valves
  - Automatic insertion of control rods


PCMS
HSIS
Large Display Panel
A
O
P
Operator Console
Supervisor Console
Shift Technical Advisor Console
: HSI Computer System
: Digital Protection & Control System
: Conventional Type or Diverse System
: Hardwired (HW) Line
: Point-to-Point Data Link
: Multi Drop Signal Network (Redundant)
: I/O Network (Redundant)
: IT Network
Station Bus
EOF Computer
Alarm VDU (A)
Operational VDU (O)
Operating Procedure VDU (P)
Large Display Panel
Operational VDU (TSC)
Large Display Panel (TSC)
Alarm VDU Computer
Operational VDU Computer
Operating Procedure VDU Computer
Large Display Computer
Alarm Logic Computer
Process Recording Computer
Unit Management Computer
Operational VDU Computer
Large Display Computer
Unit Bus
PSMS
PCMS
ISO
RPS C
RPS D
Safety VDU (MCR)
Incore Nuclear Instrumentation System
Reactor Control System
Turbine Protection System
BOP Control System
Turbine EHG Control System
Electrical Control System
CRDM Control System
Radiation Monitoring System
ESF Actuation System A
Communi-cation System A
Safety VDU Processor A
Safety Bus (Train A)
Safety Logic System A
Train B
C
D
Remote I/O A
Trip
Turbine Supervisory Instrument System
Generator Transformer Protection System
AVR ALR System
Rod Position Indication System
Remote I/O
Remote I/O
Remote Shutdown Console (RSC)
Safety Components (Pumps, Valves, etc.)
Reactor & Turbine Plant Non-safety Components (Sensor, Control Valves, Motor Valves, Solenoid Valves, Pumps, etc.)

PCMS – Normal Plant Control

- Reactor Control System
  - Rod Control System
    - CRDM Control System
    - Rod Position Indication System
  - Pressurizer Pressure Control System
  - Pressurizer Water Level Control System
  - Steam Generator Water Level Control System
  - Turbine Bypass Control System

- Turbine Electrohydraulic Governor Control System

NRC Concerns w/ US-APWR I&C

- Interdivision data communication
  - Compliance with regulatory guidance for independence of safety systems (from non-safety systems)
  - Conformance to ISG-04 (Interim Staff Guidance for highly integrated control rooms) – initially limited to basic MELTAC platform
- Quality assurance
  - Compliance of QA program for MELTAC w/ App. B
  - Demonstration that MELTAC has been commercially dedicated
  - Compliance with NRC guidance for software life cycle processes

MHI has commitments for addressing all concerns.