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NRW-FPGA-Based PRM System Qualification Project

Document Title

Equipment Requirement Specification of FPGA based Units

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PROJECT NAME	NRW-FPGA-Based PRM System Qualification Project
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Table of Contents

1. Scope

This document describes the equipment requirements of the Non Rewritable (NRW)-Field Programmable Gate Array (FPGA) based units for the Power Range Monitor (PRM).

The equipment requirements consist of specific functional and design requirements of the hardware and FPGA logic, including any detailed logic requirements. The Equipment Requirements Specification (ERS) also specifies qualification requirements.

This ERS is prepared specifically for the NRW-FPGA-Based PRM System Qualification Project.

The scope of the PRM System described in this specification includes units performing the functions of the LPRM, APRM and flow measurement, plus the interconnecting cables between units. The scope does not include requirements for external interfacing components such as the in-core detectors and differential pressure transmitters.

2. Applicable Documents

2.1. Supporting and Supplemental Documents

2.1.1. Supporting Documents

The latest revision is applicable about following documents.

2.1.1.1. EPRI TR-107330
Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants

2.1.1.2. RS-5114010
PRM System Design Specification for Japanese Plants

2.1.1.3. FPGA-based PRM Unit Equipment Design Specifications (for Commercial Product):
5G8HA385 PRM Unit Equipment Design Specification
5G8HA386 LPRM/APRM Unit Design Equipment Specification
5G8HA381 Flow Unit Design Equipment Specification

2.1.1.4. FPGA-based PRM Unit Equipment Users Manual (for Commercial Product):
6E8H7301 Instructions for TOSDIA LPRM (HNU100)
6E8H7302 Instructions for TOSDIA APRM (HNU200)
6E8H7306 Instructions for TOSDIA FLOW (HNU300)

2.1.1.5. FPGA-based PRM Module Equipment Design Specification (for Commercial Product):
5G8HA382 SQ-ROOT Module Equipment Design Specification

5G8HA390	APRM Module Equipment Design Specification
5G8HA391	LPRM Module Equipment Design Specification
5G8HA393	TRN Module Equipment Design Specification
5G8HA394	RCV Module Equipment Design Specification
5G8HA395	DIO Module Equipment Design Specification
5G8HA396	AO Module Equipment Design Specification
5G8HA439	FLOW Module Equipment Design Specification
5G8HA466	LVPS Module Equipment Design Specification
5G8HA475	STATUS Module Equipment Design Specification

2.1.1.6. FPG-PLN-A70-0001
Project Quality Assurance Manual

3. Applicable Regulations, Codes and Standards

3.1. Applicable Documents

3.1.1. Electric Power Research Institute (EPRI)

3.1.1.1. TR-102323-R2
Guidelines for Electromagnetic Interference Testing in Power Plant Equipment, November 2000

3.1.1.2. TR-100516
Equipment Qualification Reference Manual, November 1992

3.1.1.3. TR-107330
Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety related Applications in Nuclear Power Plants

3.1.2. Institute of Electrical & Electronics Engineers (IEEE)

3.1.2.1. IEEE Std 7-4.3.2-2003
IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations

3.1.2.2. IEEE Std 323-1983, Standard for Qualifying of Class 1E Equipment for Nuclear Power Generating Stations

3.1.2.3. IEEE Std 344-1987, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

3.1.2.4. IEEE Std 379-2000
Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems

3.1.2.5. IEEE Std 383-1974
IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

3.1.2.6. IEEE Std 384-1992

IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits

3.1.2.7. IEEE Std 603-1991
IEEE Standard for Safety Systems for Nuclear Power Generating Stations

3.1.2.8. IEEE Std 730-2002
IEEE Standard for Software Quality Assurance Plans

3.1.2.9. IEEE Std 828-1990
Standard for Software Configuration Management Plans

3.1.2.10. IEEE Std 1012-1998
Standard for Software Verification and Validation Plans

3.1.2.11. IEEE Std 1074-1995
IEEE Standard for Developing Software Life Cycle Processes

3.1.2.12. IEEE Std 352-1987
Guide for General Principles of Reliability Analysis of Nuclear Power Generating Stations

3.1.2.13. IEEE Std 1050-1996
Guide for Instrumentation Control Equipment Grounding in Generating Stations

3.1.2.14. IEEE Std 338-1987
IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety System

3.1.2.15. IEEE Std 498-1990
IEEE Standard Requirements for the Calibration and Control of Measuring and Test Equipment Used in Nuclear Facilities

3.1.3. Other Documents

3.1.3.1. ISA-S67.04-1994
Setpoints for Nuclear Safety related Instrumentation Used in Nuclear Power Plants

3.1.3.2. ANSI N45.2.2-1982
Packing, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants

3.1.3.3. MIL-HDBK 217F
Reliability Prediction of Electronic Equipment

3.1.3.4. MIL-STD-461E
Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

3.1.3.5. IEC61000-4-2-1995
Testing and measurement requirement techniques-Section 2: Electrostatic discharge immunity test

3.1.3.6. IEC61000-4-4-1995
Testing and measurement requirement techniques-Section 4:Electrical fast

transient/burst immunity test

3.1.3.7. IEC61000-4-5-1995
Testing and measurement techniques-Section 5: Surge immunity test

3.1.3.8. IEC61000-4-12-1995
Testing and measurement techniques-Section 5: Oscillatory waves immunity test, Basic EMC publication

3.1.3.9. Toshiba Energy Systems & Solutions Corporation 4401-4 "Nuclear Energy QA Program Description" (Latest Revision)

3.2. Information Documents

3.2.1. U.S. Nuclear Regulatory Commission (NRC) Regulatory Guides (RG)

3.2.1.1. RG 1.22, Feb. 1972
Periodic Testing of Protection System Actuation Functions

3.2.1.2. RG 1.29, Rev 3, Sep. 1978
Seismic Design Classification

3.2.1.3. RG 1.47, Rev 0, May. 1973
Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems

3.2.1.4. RG 1.53,Rev 2, Nov. 2003
Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems

3.2.1.5. RG 1.75,Rev 2, Sep. 1978
Physical Independence of Electric Systems

3.2.1.6. RG 1.89, Rev 1, Jun. 1984
Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants

3.2.1.7. RG 1.152, Rev 2, Jan. 2006
Criteria for Programmable Digital Computer System Software in Safety related Systems of Nuclear Power Plants

3.2.1.8. RG 1.153, Rev 1, Jun. 1996
Criteria for Safety Systems

3.2.1.9. RG 1.168, Rev.1, Feb. 2004
Verification, Validation, Reviews and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants

3.2.1.10. RG 1.169, Sept 1997
Configuration Management Plans for Digital Computer Software Used in Safety Systems of Nuclear Power Plants

3.2.1.11. RG 1.170, Sep. 1997
Software Test Documentation for Digital Computer Software Used in Safety Systems

of Nuclear Power Plants

3.2.1.12. RG 1.171, Sep. 1997
Software Unit Testing for Digital Computer Software Used in Safety Systems of Nuclear Power Plants

3.2.1.13. RG 1.172, Sep. 1997
Software Requirements Specifications for Digital Computer Software Used in Safety Systems of Nuclear Power Plants

3.2.1.14. RG 1.173, Sep. 1997
Developing Software Life Cycle Processes for Digital Computer Software Used in Safety Systems of Nuclear Power Plants

3.2.1.15. RG 1.180 Rev 1, Oct. 2003
Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety related Instrumentation and Control Systems

3.2.1.16. RG 1.100 Rev2, Jan. 1988
Seismic Qualification of Electric Equipment for Nuclear Power Plants

3.2.2. Other Documents

3.2.2.1. NUREG-0800
Standard Review Plan for the Safety Analysis Reports for Nuclear Power Plants

4. System Overview

This section describes the PRM System applied for existing typical US BWR 5 nuclear power plants having following system features:

- Input signal from172 LPRM Detectors.
- Six APRM channels, two LPRM channels.
- Two RBM channels and four Flow channels.
- The Reactor Protection System (RPS) logic is one out of two taken twice for Locking Piston CRD system.
- Interconnection to an OPRM System (a protection system for reactor power oscillation).

Requirements for this system are obtained from the following sources:

- EPRI TR-107330
- PRM System Design Specification for Japanese Nuclear Plant
- IEEE Std 603-1991 and IEEE Std 7-4.3.2-2003

Section 5 of this document provides detailed design requirements for the units and interfacing cables that make up the test specimen for the qualification project.

Requirements from the Japanese Nuclear Plant System Design Specification, and from the IEEE standards, are summarized in Section 4 of this ERS.

4.1. Functions

4.1.1. Design Basis Event

Following design basis events that require safety functions of the PRM System specified in Section 4.1.2 are postulated:

- Anticipated Operational Occurrences whose result might occur to exceed acceptable fuel design limits, specified in NUREG-0800 Chapter 15
- Plant Design Basis Accidents specified in NUREG-0800 Chapter 15
- Reactor Power Oscillation specified in NUREG-0800 Chapter 15.9

For design basis events, the postulated initial condition of these events is that reactor power is at 100% rated power plus power measurement uncertainty.

4.1.2. Safety-related Functions

The PRM has the following safety-related functions:

1. Generate signals that represent:
   a. Local neutron flux
   b. Spatially averaged neutron flux
   c. Spatially averaged heat flux (Simulated Thermal Power Level)
   d. Recirculation flow

2. Provide the following trips to the Reactor Protection System (RPS) - Divisional APRM trips shall be initiated by any of the following:
   a. APRM Upscale (High-High) Trip
   b. Simulated Thermal Power Upscale Trip
   c. APRM Inoperable Trip

4.1.3. Non Safety-related Functions

The PRM has the following non-safety-related functions:

1. Provide data signals, including recording transient data, and trip indications to the Process Computer.

2. Provide a rod withdrawal block signal to the Reactor Manual Control System (RMCS), if any one of the following occurs:
   a. APRM Upscale (High) Trip
   b. APRM Inoperable Trip
   c. APRM Downscale Trip
   d. Recirculation Flow Upscale / Inoperable Trip
   e. RBM upscale Trip
   f. RBM downscale Trip
   g. RBM Inoperable Trip
   h. Recirculation Flow comparison Abnormal Trip

4.2. Summary System Description

The PRM is designed to provide information used for monitoring the average power level of the reactor core, monitoring the local power density distribution associated with the withdrawal or insertion of a control rod, and for protecting the core against local and full-core power transients when the reactor power is in the power range, i.e., above approximately 10 percent of rated power. It provides trip signals to initiate reactor scrams under excessive neutron flux conditions or fast increasing neutron flux conditions. It provides alarms to the operator warning of the impending and actual occurrence of these trips. It also provides power information to the operator and performs the rod block monitoring function.

The PRM has following subsystems:

a. Local Power Range Monitor (LPRM) Subsystem
b. Average Power Range Monitor (APRM) Subsystem
c. Recirculation Flow Measurement Subsystem
d. Rod Block Monitor (RBM) Subsystem

The LPRM Subsystem continuously monitors the local neutron flux distribution in the core. In the PRM System considered in this project, the LPRM subsystem contains 172 neutron detectors distributed throughout the reactor core. The LPRM Subsystem provides LPRM levels indication and reading of this information to other systems for operation and control. It also provides alarms when preset levels are reached. The LPRM detectors provide measurement of core local power from 1% to 125% of the rated power.

The APRM Subsystem provides APRM levels by averaging the output signals from the selected LPRM signal. Typically, the APRM Subsystem consists of six channels. The LPRM signals are divided and assigned to the APRM channels. The APRM Subsystem issues trip signals for generating reactor trip and alarm functions.

Signals from the Recirculation Flow Measurement Subsystem are available for the APRM Subsystem and RBM trip setpoint determination.

The LPRM, APRM and Recirculation Flow signals are displayed for operators at the Main Operator Console (MOC).

The RBM Subsystem is not part of the qualification effort. Therefore, its functions are not described in this document. However, the interfaces of the LPRM, the APRM and the Recirculation Flow Measurement Subsystems with the RBM Subsystem are described.

These subsystems include varistors and noise filters in power supply lines of each unit to prevent surge voltage. Specific requirements are described in Section 5.2.4.7.

4.3. Detailed System Description

4.3.1. System Equipment, Arrangement and Location

This section provides a detailed explanation of the system configuration of the PRM System. Specific requirements for the PRM hardware components are described in Section 5.2.

The LPRM subsystem receives signals from the 43 LPRM detector assemblies, each with four fission chamber detectors (i.e. LPRM detectors) evenly spaced at four axial positions along the fuel bundle in the vertical direction. These are called the A, B, C, and D detectors positions. The assemblies are distributed throughout the whole core in evenly spaced locations such that each assembly is located at every fourth intersection of the water channels around fuel bundles

not containing a control rod. The LPRM subsystem also includes cables, electrical penetrations and LPRM signal processing.

Each detector assemblies are housed in and fitted at the incore housing with penetrations at the bottom of the RPV.

Each LPRM signal is provided to either an APRM channel or an LPRM channel.

- LPRM detector signals provided to an LPRM channel. The LPRM subsystem consists of two LPRM channels, one of which is connected to 21 detectors, and the other of which is connected to 22 detectors. The LPRM subsystem function is to provide indication and reading of the local neutron flux information to other systems for operation and control. It also provides alarms when preset levels are reached.

- LPRM signals provided to an APRM channel. There are six APRM channels that monitor the average reactor power. Each APRM channel has two functions: the function of LPRM subsystem, as described above; and the function of APRM subsystem, to average the selected LPRM signals, provide the average reactor power to other systems for operation and control, and issue trip signals.

The APRM subsystem is designed to include redundancy in order to maintain the system safety functions in the event of a single failure.

Each APRM channel (Channel A through F) receives signals from two Flow channels. All flow channels (Channels A through D) are identical in design and independent of each other. The assignment of Flow channels to APRM channels is shown below:

Assignment of Flow Channels to APRM Channels				
FLOW channel	A	B	C	D
APRM channel	A,C,E	B,D,F	A,C,E	B,D,F

The assignment of the APRM channels to the one out of two taken twice type RPS is presented below.

Assignment of the APRM Channels to the Reactor Protection System Divisions				
RPS division	A		B	
RPS trip channel	A1	A2	B1	B2
APRM channel	A, E	C, E	B, F	D, F

Three APRM channels are associated with each of the Reactor Protection System division. Two of the six APRM channels are shared between the RPS trip channels, i.e. APRM E is associated with the RPS trip channels A1 and A2, and APRM F is associated with trip channels B1 and B2.

APRM channels A, C, and E average the output signals from 21 LPRM signals. APRM channels B, D, and F average the output from 22 LPRM signals.

The LPRM cables are grouped by associated RPS trip channel (A1, A2, B1 and B2) under the reactor vessel. Each group of the LPRM cables is routed to the control room in a separate conduit, with a separate containment electrical penetration, to maintain separation. The assignment of the APRM and the LPRM channels to the four electrical penetrations (A through F) is presented below.

Assignment of APRM and LPRM Channel to Electrical Penetrations				
Electric Penetration	A	B	C	D
APRM & LPRM Channel	APRM E LPRM B	APRM A APRM B	APRM C APRM D	APRM F LPRM A

The LPRM detector assignments to each to each APRM channel and LPRM channel are specified in Table 4-1

Table 4-1 Assignment of the LPRM Inputs to the APRM Channels

LPRM	LEVEL	CHANNEL APRM A	APRM C	APRM E	LPRM A
24-57	A	X			
	B		X		
	C			X	
	D				X
40-57	A			X	
	B				X
	C	X			
	D		X		
16-49	A		X		
	B			X	
	C				X
	D	X			
32-49	A				X
	B	X			
	C		X		
	D			X	
48-49	A		X		
	B			X	
	C				X
	D	X			
08-41	A	X			
	B		X		
	C			X	
	D				X
24-41	A			X	
	B				X
	C	X			
	D		X		
40-41	A	X			
	B		X		
	C			X	
	D				X
56-41	A			X	
	B				X
	C	X			
	D		X		
16-33	A				X
	B	X			
	C		X		
	D			X	
32-33	A		X		
	B			X	
	C				X
	D	X			
48-33	A				X
	B	X			
	C		X		
	D			X	
08-25	A			X	
	B				X
	C	X			
	D		X		
24-25	A	X			
	B		X		
	C			X	
	D				X
40-25	A			X	
	B				X
	C	X			
	D		X		
56-25	A	X			
	B		X		
	C			X	
	D				X
16-17	A		X		
	B			X	
	C				X
	D	X			
32-17	A				X
	B	X			
	C		X		
	D			X	
48-17	A		X		
	B			X	
	C				X
	D	X			
24-09	A			X	
	B				X
	C	X			
	D		X		
40-09	A	X			
	B		X		
	C			X	
	D				X

LPRM	LEVEL	CHANNEL APRM B	APRM D	APRM F	LPRM B
16-57	A			X	
	B				X
	C	X			
	D		X		
32-57	A	X			
	B		X		
	C			X	
	D				X
08-49	A				X
	B	X			
	C		X		
	D			X	
24-49	A		X		
	B			X	
	C				X
	D	X			
40-49	A				X
	B	X			
	C		X		
	D			X	
16-41	A	X			
	B		X		
	C			X	
	D				X
32-41	A			X	
	B				X
	C	X			
	D		X		
48-41	A	X			
	B		X		
	C			X	
	D				X
08-33	A		X		
	B			X	
	C				X
	D	X			
24-33	A				X
	B	X			
	C		X		
	D			X	
40-33	A		X		
	B			X	
	C				X
	D	X			
56-33	A				X
	B	X			
	C		X		
	D			X	
16-25	A			X	
	B				X
	C	X			
	D		X		
32-25	A	X			
	B		X		
	C			X	
	D				X
48-25	A			X	
	B				X
	C	X			
	D		X		
08-17	A				X
	B	X			
	C		X		
	D			X	
24-17	A		X		
	B			X	
	C				X
	D	X			
40-17	A				X
	B	X			
	C		X		
	D			X	
56-17	A		X		
	B			X	
	C				X
	D	X			
16-09	A	X			
	B		X		
	C			X	
	D				X
32-09	A			X	
	B				X
	C	X			
	D		X		
48-09	A	X			
	B		X		
	C			X	
	D				X

Each of the two Recirculation loops has four pressure differential measurements, for a total of eight pressure differential measurements. Each of the four Recirculation Flow Measurement subsystem channels takes inputs from the two differential pressure transmitters: one from Recirculation Loop A, and the other from Recirculation Loop B. Each channel calculates a flow signal by processing differential pressure signals from each of the two Recirculation loops and summing up them, to provide an output that is representative of the total core flow rate value.

Assignment of differential pressure transmitter signals to Recirculation Flow Measurement channels and APRM channels is shown below.

Assignment of the Flow Transmitter Signals to the Flow Channels and Corresponding APRM Channels								
Transmitter Signal	A	E	B	F	C	G	D	H
Flow Channel	A		B		C		D	
APRM Channel	A, C, E		B, D, F		A, C, E		B, D, F	

As stated above, the PRM System must provide outputs for the RBM subsystem as follows:

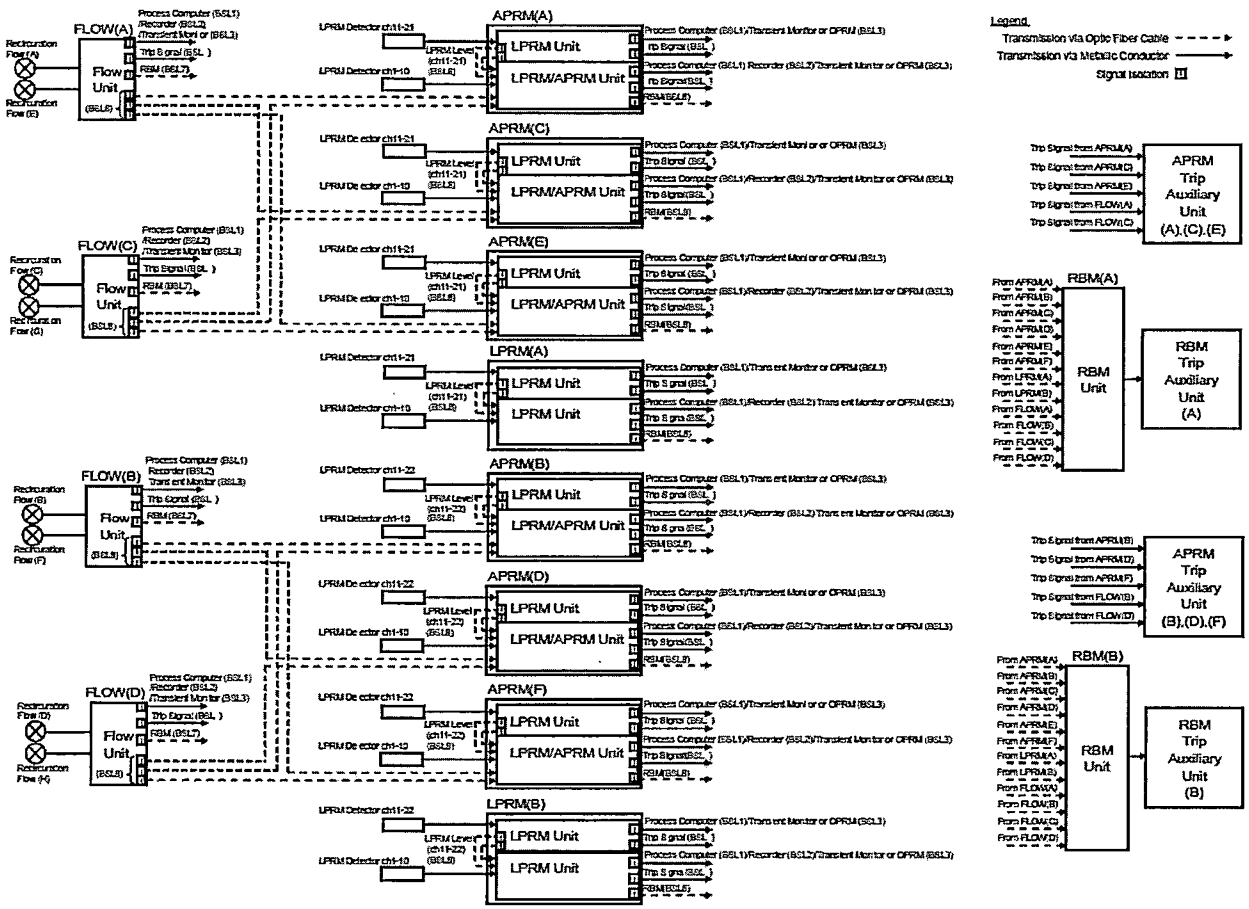
- LPRM Subsystem: Provides the LPRM levels to the RBM subsystem.
- APRM Subsystem: Provides the APRM levels, and the Simulated Thermal Power Levels, from each of the six APRM channels to the RBM subsystem.
- Flow Subsystem: Provides the Recirculation flow rate value from each of the four flow channels to the RBM subsystem.

All digital signals from these subsystems are transmitted to the RBM subsystem through optical cables.

To provide the trip signals from the PRM System to the RPS, relays are used.
The requirements for the relays are as follows:

(a) Connectable to the RPS.
(b) Response time shall satisfy the system requirements shown in Section 5.1.3.1, where response time requirement for relay is described as the requirement for trip auxiliary unit.
(c) Already qualified for US nuclear safety-related purpose

The PRM System configuration showing the subsystem interfaces is given in Figure 4-1.



*"(A)" in the figure denotes "A" channel. For example, LPRM(A) means the LPRM A channel.

Figure 4-1 PRM System Configuration Diagram

4.3.2. Safety Features

The following safety features are included in the PRM:

1. The PRM System is safety-related and, thus, is qualified for Class 1E applications per the requirements of IEEE Std 323-1983 and IEEE Std 344-1987.
2. The delay time from the instant in which a step change is made in the LPRM detector signal, to the instant in which a state change occurs in the trip circuit (in the RPS and OPRM system) is designed to be equal to or less than 40 milliseconds.
3. Each LPRM, APRM, and Flow channel is entirely redundant and identical in design, and independent of each other.
4. PRM equipment is protected from electric power transients and disturbances by using fuses, analog isolators, optical couplers and, fiber optic cables.
5. The safety-related subsystems of the PRM System are single-failure-proof and conform to IEEE Std 379-2000 endorsed by RG 1.53. The safety-related systems shall perform all required safety functions for a design basis event in the presence of the following:
    - Any single detectable failure within the safety systems concurrent with all identifiable, but non-detectable failures.
    - All failures caused by the single failure.
    - All failures and spurious system actions that cause, or are caused by, the design basis event requiring the safety function.
6. [Deleted]
7. When any one channel is bypassed, the fact shall be indicated in the control room. The design is to conform to R.G. 1.47.
8. Equipment that is used for both safety and non-safety functions shall be classified as part of the safety systems. Isolation devices used to affect a safety system boundary shall be classified as part of the safety system. No credible failure on the non-safety side of an isolation device shall prevent any portion of a safety system from meeting its minimum performance requirements during and following any design basis event requiring that safety function.
9. The Class 1E equipment and circuits comply with IEEE Std 384-1992 for independence.
10. In order to provide assurance that the requirements in the specification can be applied during the design, construction, maintenance, and operation of the plant, the requirements of Section 5.11 of IEEE Std 603-1991 are met.
11. The allowance for uncertainties between the process analytical limit and the device setpoints is determined in accordance with ISA-S67.040-1994. Design of multiple setpoints for adequate protection for a particular mode of operation or set of operating conditions provides positive means of ensuring that the more restrictive setpoint is used when required.
12. The PRM reliability requirements are specified in Section 5.1.7.
13. Digital equipment is designed in accordance with Section 5.3, 5.5 and 5.6 of IEEE Std 7-4.3.2-2003. ERS Section 5.3 defines these requirements.
14. System initialization requirements are specified in ERS Section 5.1.2.
15. The points in time or the plant conditions for which the protective actions of the safety system shall be initiated are specified in ERS Section 5.1.3.
16. The points in time or the plant conditions that allow returning a safety system to

normal are specified in ERS Section 5.1.4.
17. Auxiliary features (ex. Cooling fun, Power supply) comply with IEEE 603-1991.

4.3.3. System Availability

Loss of an APRM channel due to bypass or inoperability does not result in loss of the PRM System safety function, because the LPRM detectors are distributed throughout the core, at various distances from the core center, various azimuths, and various elevations, and the LPRM detectors connected to each APRM channel are grouped so that each APRM channel provides an average power level that is representative of the spatial average power throughout the core.

Loss of individual LPRM signals due to bypass or inoperability does not result in loss of the APRM safety function, because each APRM channel receives and averages 21 or 22 LPRM signals. APRMs can function with loss of multiple LPRMs.

Any failure in the interconnection between units shall not defeat the ability of signal transfer of information between the units.
Loss of power in any units shall not defeat the ability of signal transfer between the units.

4.3.4. Environmental Consideration

All safety-related PRM equipment has the ability to operate under the normal and accident conditions specified in Section 5.5. These conditions must bound condition under the anticipated Operating Occurrences and the Design base accidents at the rated power operation.

All safety-related PRM equipment is qualified to minimize both susceptibility to, and generation of, electromagnetic interference (EMI) and radio frequency interference (RFI). The PRM Units are subjected to test for EMI, RFI, and surge conditions that conform to guidelines given in RG 1.180 Rev. 1.

All safety-related PRM components are qualified to IEEE Std 323-1983 and IEEE Std 344-1987.

4.3.5. Maintenance Provisions

The PRM equipment design provides the replacement capability of all modules. All modules performance is readily measurable.

4.3.6. Self-Testing

The self-test functions are described in the Section 5.1.6.

4.3.7. Surveillance Testing

The PRM System provides the following functions for surveillance testing:

a. LPRM gain adjustment (See 4.4.3.)
b. APRM gain adjustment (See 4.4.3.)
c. LPRM trip test
d. APRM trip test
e. Flow trip test

4.4. Operation

4.4.1. Operation

The PRM System operates continuously during reactor operation. The accuracy of the APRM channels can be verified by cross-comparison of the other redundant channels within the two redundant divisions. The bypass of one channel of three APRM channels for one RPS division is allowable, because of the one out of two taken twice type RPS trip logic. The PRM System fully meets the requirements stated in R. G. 1.22.

4.4.2. Operating Bypasses

The PRM System uses an operational bypass that changes the reactor trip setpoint and rod withdrawal setpoint depending on two inputs: reactor mode and recirculation flow rate. Specifically, the operational bypass functions as follows:

- When the reactor operating mode switch is in the "RUN", the APRM reactor trip and the rod withdrawal block setpoints are dependent upon the recirculation flow rate.
- When the reactor operating mode switch is NOT in the "RUN", the APRM is still capable of issuing trips and the rod withdrawal block signals, but at a lower fixed setpoint.

4.4.3. Calibration

(1) LPRM gain adjustment
LPRM calibration is performed for each APRM channel and LPRM channel. The operator bypasses the APRM channel to be calibrated (this process is not executed for LPRM channel). The operator places the LPRM mode switch in the "CAL" position and enters a new gain adjustment value. After entering new gain adjustment value, the operator places the LPRM mode switch in the "OP" position. The operator then

removes the bypass of the channel. This process is repeated for each LPRM (except for channel bypass process for LPRM channel), or APRM channel.

(2) APRM gain adjustment
APRM calibration is performed for each APRM channel (this process is not executed for LPRM channel). The operator bypasses the APRM channel to be calibrated and places the APRM mode switch in the "CAL" position and enters new gain adjustment values. After entering new gain adjustment values, the operator places the APRM mode switch in the "OP" position and removes the bypass.
An analysis shall be prepared to provide the information needed to support an application specific setpoint analysis per ISA-RP 67.04. The analysis shall include:

a. Calibrated accuracy, including hysteresis and non-linearity, of the analog inputs.
b. Repeatability of the analog inputs.
c. Temperature sensitivity of the analog inputs.
d. Drift with time of the analog inputs.
e. Power supply voltage fluctuation effects on the analog inputs.

In addition, the qualification process shall identify components, if any, on analog input modules as follow:

a. Components where vibration during seismic testing could affect accuracy.
b. Components where radiation exposure could affect accuracy.
c. Component where relative humidity over the range given in Section 5.5 could affect accuracy.

(3) Flow Calibration
Flow calibration is performed for each Flow channel. The operator bypasses the Flow channel to be calibrated and adjust the output signal to the test current input signal.

4.4.4. Unit and Detector Bypass

Each LPRM, APRM or Flow channel can be individually bypassed for maintenance bypass. Restrictions as to the total number and distribution of bypassed channels (at one time) must be adhered rigidly to avoid reactor trip due to inoperable PRM channels.

The APRM equipment allows the operator to bypass any one of the 3 APRM channels for one RPS division during normal plant operation. The APRM channel bypassed status is displayed on the PRM front panel and provided to the MOC complying with R.G 1.47.

All PRM bypass logic control functions are located within the PRM, none are located in RPS.

Each LPRM modules allows to be bypassed within the permissive numbers to retain the PRM Safety function. The LPRM module (including LPRM detector) bypass status is displayed on the PRM front panel.

4.5. System Interface

The PRM System has interfaces to other systems, described in the following sections. Of

these interfaces, Table 4.2 summarizes the PRM System discrete outputs.

4.5.1. Reactor Manual Control System (RMCS)

The PRM System provides discrete signals to RMCS as follows:

The discrete signals from the PRM to the RMCS through the trip auxiliary unit:

APRM Inoperable	OR of all APRM channels
APRM Upscale (High)	OR of all APRM channels
APRM Downscale	OR of all APRM channels
Recirculation Flow Upscale	OR of all FLOW channels
Recirculation Flow Inoperable	OR of all FLOW channels

These discrete output signals are used as the rod withdrawal block signals.

4.5.2. Reactor Protection System (RPS)

Each APRM channel provides the trip signal to the RPS as described in Section 4.3.1.

The RPS provides the PRM System with the position and control information of the reactor mode switch, e.g. RPS provides the signal indicating if the mode switch is in the "RUN" position.

Discrete signals from the RPS to the PRM:

Reactor Mode signal
APRM Bypass signal

Discrete signals from the PRM to the RPS through the trip auxiliary unit:

APRM Upscale (High-High)	Each APRM channel
Simulated Thermal Power Upscale	Each APRM channel
APRM Inoperable	Each APRM channel

These signals are used to initiate the reactor scram.

4.5.3. Process Computer System (PCS)

PRM provides data signals, trip indications and operation status to the PCS.

Analog signals from the PRM to the PCS:

LPRM levels	0 to 160 mV signal for 0 to 125%
APRM levels	0 to 160 mV signal for 0 to 125%
APRM Upscale (High) setpoints	0 to 160 mV signal for 0 to 125%
Simulated Thermal Power Levels	0 to 160 mV signal for 0 to 125%
Simulated Thermal Power Upscale setpoints	0 to 160 mV signal for 0 to 125%
Loop Flow values	0 to 160 mV signal for 0 to 125%

Differential Pressure values	32 to 160 mV signal for 4 to 20 mA
Recirculation Flow values	0 to 160 mV signal for 0 to 125%

Discrete signals from the PRM to the PCS through the trip auxiliary unit:

APRM Upscale (High-High)	Each APRM channel
Simulated Thermal Power Upscale	Each APRM channel
APRM Upscale (High)	Each APRM channel
APRM Inoperable	Each APRM channel
APRM Downscale	OR of all APRM channels
APRM Bypass	Each APRM channel
Recirculation Flow Upscale	OR of all Flow channels
Recirculation Flow Inoperable	OR of all Flow channels

4.5.4. Oscillation Power Range Monitor (OPRM)

The PRM System can provide the analog signals of the LPRM levels to the OPRM system. The analog signals are identical to the signals that are provided to the transient monitor.

If an LPRM module is bypassed or becomes inoperable, it continues sending the last LPRM level to the OPRM, so the OPRM may identify the inoperable LPRM by detecting the constancy of the LPRM levels.

4.5.5. Main Operator Console (MOC)

Discrete signals from the PRM System to the MOC through the trip auxiliary unit:

LPRM Unit Minor failure	Each LPRM Unit
LPRM/APRM Unit Minor failure	Each LPRM/APRM Unit
APRM Upscale (High-High)	Each APRM channel
APRM Inoperable	Each APRM channel
APRM Upscale (High)	Each APRM channel
Simulated Thermal Power Upscale	Each APRM channel
APRM Downscale	Each APRM channel
APRM Minor Failure	Each APRM channel
APRM Bypass	Each APRM channel
Recirculation Flow Upscale	Each FLOW channel
Recirculation Flow Inoperable	Each FLOW channel

4.5.6. Annunciator (ANN)

Discrete output from the PRM System to the ANN through the trip auxiliary unit:

LPRM Upscale	OR of all LPRM modules*
LPRM Downscale	OR of all LPRM modules*
APRM Upscale (High-High)	Each RPS trip system
Simulated Thermal Power Upscale	Each RPS trip system
APRM Inoperable	Each RPS trip system

APRM Upscale (High)	OR of all APRM channels
APRM Downscale	OR of all APRM channels
APRM Minor Failure	OR of all LPRM Unit Minor Failure, APRM Minor Failure and FLOW Unit Minor Failure
Recirculation Flow Upscale	OR of all Flow channels
Recirculation Flow Inoperable	OR of all Flow channels

*See Section 5.2.3.2 about LPRM module

4.5.7. Recorder

Analog output from PRM System to the Recorder:

APRM levels	0 to 1 V signal for 0 to full scale
APRM Upscale (High) setpoints	0 to 1 V signal for 0 to 125%
Recirculation Flow values	0 to 1 V signal for 0 to 125%

Table 4-2 Discrete Output from the PRM System

Type of Output	Destination of Output		
	RMCS	RPS	a,c
LPRM Upscale	—	—	
LPRM Downscale	—	—	
LPRM Unit Minor Failure	—	—	
LPRM/APRM Unit Minor Failure	—	—	
APRM Upscale (High-High)	—	○	
Simulated Thermal Power Upscale	—	○	
APRM Inoperable	◎	○	
APRM Upscale (High)	◎	—	
APRM Downscale	◎	—	
APRM Minor Failure	—	—	
APRM Bypass	—	—	
Recirculation Flow Upscale	◎	—	
Reciculation Flow Inoperable	◎	—	
FLOW Unit Minor Failure	—	—	

○:each channel ●:each RPS trip system ◎:or of all channels △:each unit

X: or of all LPRM modules (See Section 5.2.3.2 about LPRM module)

* OR of all LPRM Unit Minor Failure, all LPRM/APRM Unit Minor Failure, all APRM Minor Failure and FLOW Unit Minor Failure

5. Design Requirements

This section specifies the detailed functional requirements for the hardware and software components of the system (Section 5.1), the hardware requirements for each hardware component (Section 5.2), and generic software requirements for all logic (Section 5.3).

5.1. Functional Requirements

5.1.1. Basic Design Requirements

The PRM System shall be designed to provide adequate flux monitoring information from 1% through 125% reactor power. In order to allow this PRM system measurement, the LPRM indication shall be adjusted not to exceed 86% at the rated power. Note that the PRM System can accept 138.9% flux value at maximum, and if the flux value exceeds the limit, it is clamped to the 138.9%.

The PRM System shall provide trip functions for required safety protection. It shall also provide continuous and reliable reactor power performance data to the various output interfaces.

The PRM System shall be able to compare the signal input to the setpoints, and generate alarms or trip signals.

The PRM System shall be capable of latching alarm signals and resetting the signals based on alarm reset conditions. The display for the PRM units (e.g., LPRM Display) shall provide a manual reset button to perform this action.

The PRM System shall be capable of monitoring its operability and showing operability external to the PRM System (i.e., using a discrete output to activate a LED), so that the operator can visually confirm the PRM System is currently operating.

These functions specified in this section shall be performed by logic in the equipment.

5.1.2. System Initialization Requirements

When power is applied to the PRM equipment, the equipment shall be initialized by the power on reset function.

All trip and alarm outputs shall remain tripped until the initialization process has completed (about 470 ms). After initialization, the trip and alarm outputs shall assume the states indicated by calculations and bypass settings.

The power on reset function shall also be executed and maintained when the power supply low voltage is detected.

The modules that have FPGAs are provided with a power supply monitoring IC, which provides about 150 ms or 470 ms reset action and initial startup of the FPGAs at the time when the module is energized. In addition, it executes a reset action when the power supply voltage lowers, i.e. if the power supply low voltage continues to be low, the module shall remain in initialization state, and keep all trip and alarm outputs tripped.

Note: The TRN module has about 470ms reset time while other modules have about 150 ms reset time.

The PRM System shall be capable of performing run time diagnostics.

5.1.3. Nominal System Setpoints

The PRM trip setpoints shall be adjustable by a technician during equipment maintenance or an operator during periodic surveillance service. The PRM System shall support setpoint adjustments of equipment on the front panel. Adjustments shall include increase and decrease of the setpoint.

Table 5-1 and Table 5-2 show the recommended LPRM and APRM trip setpoints respectively.

The LPRM gain shall be adjusted 400 µA/100% or 2400 µA/100% as long as there are no special requirements in testing and shipping.

Table 5-1 Recommended LPRM trip setpoints

TRIP FUNCTION	REACTOR MODE	ACTION	SETPOINT	TRIP RANGE
LPRM Upscale	--	Light and annunciator	100%	5 to 125%
LPRM Downscale	--	Light and annunciator	5%	0 to 10%

Table 5-2 Recommended APRM trip setpoints

TRIP FUNCTION	REACTOR MODE	ACTION	TRIP POINT	
			SET VALUE	ADJUSTABLE RANGE
APRM Upscale (High-High)	Only in "RUN" mode	Scram	120%	40 to 125%
APRM Upscale (High-High)	Not in "RUN" mode	Scram	15%	6 to 20%
Simulated Thermal Power Upscale	--	Scram	0.62 W+62% (Max 115%)	Clamp: 60 to 125% Slope : 0.40 to 1.50 Offset: 20 to 125%
APRM Upscale (High)	Only in "RUN" mode	Rod Block	Varied with flow 0.62 W+55% (Max 108)	Clamp: 60 to 125% Slope :0.40 to 1.50 Offset: 0 to 125%
APRM Upscale (High)	Not in "RUN" mode	Rod Block	12%	6 to 20%
APRM Downscale	Only in "RUN" mode	Rod Block	2%	2 to 10%
APRM Inoperable (LPRM bypass number)	--	Scram and Rod Block	Operative LPRM Number<14	14 to 22
Simulated Thermal Power Upscale (SRI)	--	Selected Rod Insertion	35%	0 to 40%
Recirculation Flow Downscale (SRI)	--	Selected Rod Insertion	42%	35 to 70%
Recirculation Flow Upscale	--	Rod Block	120%	90 to 125%
Recirculation Flow Inoperable	--	Rod Block	--	--

5.1.3.1. Response Time Requirements

For the APRM trip signals, Rod withdrawal Block signals, and LPRM signals, the response times shall be measured as the delay time from an input signal change to the corresponding output signal change.

The PRM System shall be capable of transferring data between units.
The actual response time of each module in the PRM System shall be determined during qualification testing.

1. APRM Trip signal

(1) APRM Upscale (High-High)

The response time, which is measured as the total delay time from a step change of the LPRM input current to the change of the APRM trip auxiliary unit output, shall be equal to or less than 40 milliseconds.

The step change shall be made in the following condition:

LPRM input:	[ ]a,c %→[ ]a,c % step change
LPRM gain :	[ ]a,c μA/100%
APRM gain:	[ ]a,c (Although monitoring range of the APRM level is 0 to 125%, the APRM module can accept signals up to 138.9%)
APRM Upscale (High-High) set value:	120%

An expected response time for modules and units shall be as follows:

Item	Time
LPRM module	[ ]a,c ms*2 or less
Transmission between units *1	[ ]a,c ms*2 or less
APRM module	[ ]a,c ms*2 or less
DIO module	[ ]a,c ms*2 or less
(APRM trip auxiliary unit)	[ ]a,c ms*2 or less
Total	40 ms*2 or less

*1: Transmission from LPRM unit to the LPRM/APRM unit
*2 : Milliseconds

(2) Simulated Thermal Power Upscale

Simulated Thermal Power Level is calculated from APRM output with 6 seconds time constant delay.
The response time shall be measured by either of the following methods:

a) Method 1

The response time shall be measured as the total delay time from when a step change is made in the LPRM input current until the APRM trip auxiliary unit outputs the Simulated Thermal Power Upscale trip. The response time shall be equal to or less

than [ ]a,c milliseconds ([ ]a,c milliseconds* + 40 milliseconds**) at the following condition.

* Time that Simulated Thermal Power, which has [ ]a,c seconds time constant delay reach TPM Upscale set value at the following condition.
**Time from Simulated Thermal Power reaches TPM Upscale set value to the change of state of the trip circuit (to RPS).

LPRM input:	[ ]a,c %→[ ]a,c % step change
Time constant:	[ ]a,c seconds
LPRM gain:	[ ]a,c µA/100%
APRM gain:	[ ]a,c (Although monitoring range of the APRM level is 0 to 125%, the APRM module can accept signals up to 138.9%)
TPM Upscale set value:	115%

An expected response time for modules and units shall be as follows:

Item	Time
LPRM module	[ ]a,c ms*2 or less
Transmission between units *1	[ ]a,c ms*2 or less
APRM module	[ ]a,c ms*2 or less
DIO module	[ ]a,c ms*2 or less
(APRM trip auxiliary unit)	[ ]a,c ms*2 or less
Total	40 ms*2 or less

*1: Transmission from the LPRM unit to the LPRM/APRM unit
*2 : Milliseconds

b) Method 2
The response time shall be measured by following 2 steps:

- Step 1
  The interval time is measured from when a step change is made in the LPRM input current until the APRM trip auxiliary unit outputs the APRM Upscale (High-High) trip. The interval time shall be equal to or less than 40 milliseconds at the following condition:

LPRM input:	[ ]a,c %→[ ]a,c % step change
Time constant:	[ ]a,c second
LPRM gain:	[ ]a,c µA/100%
APRM gain:	[ ]a,c
TPM Upscale set value	115%

- Step 2
  The interval time is measured from when the Simulated Thermal Power Level analog output starts rising to the instant when it reaches the 79% level. The interval time shall be within 6.0±0.5 seconds at the following condition:

LPRM input: [ ]a,c %→[ ]a,c % step change
Time constant: [ ]a,c seconds
LPRM gain: [ ]a,c μA/100%
APRM gain: [ ]a,c

2. Rod withdrawal block signal
   The response time is measured as the total delay time from when a step change is made in the LPRM input current until the RBM trip auxiliary unit outputs the Rod withdrawal block trip. The response time shall be equal to or less than 150 milliseconds.

   The step change should be made in the following condition:

   LPRM input: [ ]a,c %→[ ]a,c % step change
   LPRM gain: [ ]a,c μA/100%
   APRM gain: [ ]a,c
   APRM Upscale (High) set value: 108% (in "RUN" mode)
   12% (not in "RUN" mode)

   The LPRM unit and LPRM/APRM unit response time to the RBM should be:

Item	Time
LPRM module	[ ]a,c ms*4 or less
Transmission between units *1	[ ]a,c ms*4 or less
APRM module	[ ]a,c ms*4 or less
Transmission within unit*2	[ ]a,c ms*4 or less
RBM unit transmission *3	[ ]a,c ms*4 or less
(RBM unit)	[ ]a,c ms*4 or less
(RBM trip auxiliary unit)	[ ]a,c ms*4 or less
Total	100 ms*4 or less

*1: Transmission from LPRM unit to LPRM/APRM unit
*2: Transmission from APRM module to TRN module
*3: Transmission from LPRM/APRM unit to RBM unit
*4: Milliseconds

3. LPRM signal
   The response time is measured as the total delay time from when a step change is made in the LPRM input current until the AO module outputs the change. The response time shall be equal to or less than 100 milliseconds.

   The step change should be made in the following condition:

   LPRM input: [ ]a,c %→[ ]a,c % step change
   LPRM Gain: [ ]a,c μA/100%

The expected response time of the LPRM analog output signal is based on a step change into the LPRM and LPRM/APRM units propagating to the LPRM analog output signal used by Transient Monitor system. This should be as follows:

Item	Time
LPRM module	[ ] a,c ms or less
AO module	[ ] a,c ms or less
Total	43 ms or less

5.1.4. Drift and Accuracy Requirements

1. LPRM function
   a. The LPRM drift over a period of two weeks shall not exceed ±1.0 % full scale (FS) at control room environmental conditions.
   b. The LPRM input-and-output linearity (inaccuracy) shall be within ±2.0% FS, at control room environmental conditions.

   Note: 1. FS is from 0% to 125% reactor power.
   2. The LPRM drift and linearity are measured from the LPRM input current to the LPRM output through the AO module.

2. APRM function
   a. The APRM drift over a period of two weeks shall not exceed ±1.0 %FS at control room conditions.
   b. The APRM input-and-output linearity (inaccuracy) shall be within ±2.0% FS.
   c. The APRM function shall be so designed that, at control room environmental conditions, trip accuracy shall be as follows:
      Scram signal:
         Within ±2.0% FS
      Rod withdrawal signals:
         Within ±3.0% FS (FLOW: 0 to 50%)
         Within ±2.0% FS (FLOW: 50 to 125%)
   d. The trip reset point shall be –1.25% below trip set point.

   Note: 1. FS is from 0% to 125% reactor power.
   2. The APRM drift, linearity and trip accuracy are measured from the LPRM input current to the APRM output through the AO module.

3. FLOW function
   a. The FLOW function shall be so designed that, at control room environmental conditions, the drift over a period of two weeks shall not exceed ±1.0 %FS.
   b. The FLOW function shall be so designed that the input-and-output linearity (inaccuracy) and the trip accuracy at control room environmental conditions is as follows.
         Within ±3.0% FS (FLOW: 0 to 50%)
         Within ±2.0% FS (FLOW: 50 to 125%)

c. The trip reset point shall be –1.25% below trip set point.

Note: 1. FS is from 0% to 125% recirculation flow.
2. The FLOW drift and linearity are measured from the FLOW unit input current to the FLOW output through the AO module.

The actual uncertainty of the PRM System shall be determined during qualification testing and setpoint analysis.

5.1.5. Instrument Modes

(1) LPRM module
The mode switch of the LPRM module shall select the one of the following operation modes.

a. OP	Performing normal measurement
b. STAND BY	-Used for LPRM gain calibration and alarm test -Providing LPRM inoperability signal -Providing LPRM level signal in the same way as in the OP mode.
c. BYP	-Disconnected from the detector (the detector signal is ignored, and the detector bias power supply is turned off). -Allowing alarm testing -Suspending LPRM Upscale alarm and LPRM Downscale alarm -Providing LPRM inoperability signal. -Providing LPRM level signal of zero value -Allowing calibration current input

The APRM module shall exclude the LPRM modules with inoperability signal, i.e. the LPRM modules that are not in the "OP" mode, from the APRM calculation.

The LPRM module mode switch shall be a key switch.

(2) APRM module

The mode switch of the APRM module shall select the one of the following operation modes.

a. OP	Performing normal data processing
b. STANDBY	Providing APRM inoperability signal Data processing continues in the same way as in the OP mode.
c. CAL	-Allowing APRM gain calibration -Allowing trip testing -Providing APRM inoperability signal Data processing continues in the same way as in the OP mode using the injected calibration signal.

APRM inoperable signal shall be provided at the times other than "OP" mode.

The APRM module mode switch shall be a key switch.

(3) FLOW module

The mode switch of the FLOW module shall select the one of the following operation modes.

a. OP	Performing normal measurement
b. CAL1 FLOW	-Allowing trip testing with the total recirculation-flow-rate values entered from the FLOW unit front panel -Providing inoperability signal to the LPRM/APRM unit and other external equipment -Providing the entered Flow value to the LPRM/APRM unit and other external equipment.
c. CAL2 LOOP	-Allowing checking of the total-flow-rate values entered from the variable resister of the front panel of the SQ-ROOT module -Providing inoperability signal to the LPRM/APRM unit and other external equipment -Providing the entered Flow value to the LPRM/APRM unit and other external equipment.

The FLOW module inoperable signal shall be provided at the times other than "OP" mode.

The FLOW module mode switch shall be a key switch.

5.1.6. Failure Detection and Self Test Requirements

The FPGA equipment shall have diagnostic functions as follows:

(a) Monitoring of the Low Voltage Power Supply module
The Low Voltage Power Supply (LVPS) module shall monitor its output voltage. If the voltage of the LVPS becomes lower than the setpoint [ ]a,c% [ ]a,c% in either of the LVPS module, the STATUS module front panel shall provide the indication.

(b) Monitoring Low Voltage Supply for each module
The LPRM, APRM, SQ-ROOT, FLOW, TRN, RCV, and STATUS modules shall monitor the input voltage from the LVPS modules. If the input voltage becomes lower than the setpoint, the module shall be reset.

(c) Monitoring of the FPGAs with a watchdog
A watchdog timer shall monitor each FPGA that operates periodically. A group of FPGAs that operates serially may be monitored by [ ]a,c watchdog timer, as long as the watchdog timer can detect the [ ]a,c. If a [ ]a,c, the module containing the FPGA shall generate an inoperable signal. The failure of the [ ]a,c shall not generate an inoperable signal, but a Minor Failure Alarm, except for the LPRM module. The watchdog timers shall be external, and not built into the FPGA logic, nor shall the watchdog timer depend on the clock signal used by the FPGA.

(d) [Deleted]

(e) Checking data transmission between units via fiber optic cables
The module receiving data from the other unit shall verify the periodic occurrence of the data transmissions, and the validity of transmitted data between units over fiber optic cables. The validity of data shall be verified by parity checks for each [ ]a,c bit word in the transmitted data frame. A later revision of the module receiving data performs a CRC check of each message.

(f) Checking data transmission from the modules in a same unit
The APRM module shall check the periodic transmission of the data frame from the TRN modules and the RCV modules in the same unit. If a [ ]a,c occurs, a Minor Failure signal shall be generated.

(g) Checking constants stored in Rewritable ROM
Every Rewritable ROM storing constants used for the signal processing shall protect its value with parity bits or dual storage. If an error is detected, a Minor Failure alarm shall be generated.

(h) Checking the voltage of the LPRM High Voltage Power Supply
The LPRM module shall monitor the voltage of the High Voltage Power Supply. If the voltage becomes lower than the setpoint, the LPRM shall be inoperable. A single

inoperable LPRM module does not affect the Safety-Related function.

(i) Checking the input value of the SQ-ROOT module
The SQ-ROOT module shall perform range check for the input current value after digital conversion. If the input current value meets either of the following conditions, the SQ-ROOT module shall output failure signal:
Input Current Value < Setpoint[ ]a,c% FS (FLOW:[ ]a,c to [ ]a,c%)
Input Current Value < Setpoint[ ]a,c% FS (FLOW:[ ]a,c to [ ]a,c%)

Note: 1. FS is from 0% to 125% recirculation flow.
2. The FLOW drift and linearity are measured from the FLOW unit input current to the FLOW unit output through the AO module.

5.1.7. Availability/Reliability Requirements

1. The overall availability of the PRM units shall be 0.99. An availability calculation shall be prepared in the manner that conforms to IEEE Std 352-1987. The availability analysis shall include random hardware failure rates only for the units and components that constitute the PRM System.

2. The availability of the units shall be calculated for the combination of units to be part of one channel, e.g., 1 LPRM/APRM unit, 2 FLOW units, cables, and the power supplies.

3. Each unit shall have an availability goal of 0.99 on the condition that Mean Time To Repair (MTTR) is 24 hours.
The availability analysis shall include a calculation of the surveillance interval required to support the availability goal for those failures that are only detectable by periodic surveillance testing. In addition, the availability resulting from 6 months surveillance intervals shall be calculated.

4. The mean time between failures (MTBF) of each subcomponent shall be calculated using the reference given in MIL-HDBK 217F.

5. A Failure Modes and Effects Analysis (FMEA) shall be performed in accordance with IEEE Std 352-1987. For each component that constitutes the modules, the analysis shall evaluate its failure modes and effects on the PRM unit performance. The FMEA shall also identify the following items:

   a. Those faults that will be detected by the run-time diagnostics.
   b. Faults that can only be detected by surveillance testing.
   c. For redundant components, e.g., LVPS modules
      i) States that result from one or more failures where the system remains operable as well as where it is not operable.
      ii) States where undetected failures have occurred.

iii) States where a failure in a single component has caused the PRM System to fail.
iv) State where failures reduce the effectiveness of self-diagnostics.

5.1.8. Test Circuit Requirements

Any built-in test circuits in a modules or FPGA shall not have adverse effects on the safety functions of the PRM system.

5.2. Hardware Requirements

5.2.1. Unit Configuration Requirements

5.2.1.1. Assignment of Units for Subsystem

Each APRM channel contains one LPRM unit and one LPRM/APRM unit. Each LPRM Channel contains two LPRM units. Each Recirculation Flow Measurement channel contains one FLOW unit. Therefore, the equipment specified in this document consists of ten LPRM units, six LPRM/APRM units, and four FLOW units.

1. The LPRM/APRM unit has functions of the APRM subsystem, which are receiving two recirculation flow signals from the two FLOW units, averaging all the LPRM detector signals in the division to provide the APRM level and the Simulated Thermal Power Level, and providing appropriate readout and alarms for operator action or attention.

2. The LPRM unit and the LPRM/APRM unit have functions of the LPRM subsystem, which are providing local power level information of the reactor core and providing appropriate readout and alarms for operator action or attention.

3. Each LPRM detector shall be assigned to one LPRM module in an LPRM unit or an LPRM/APRM unit.

4. The FLOW unit shall provide total recirculation flow information and provide appropriate readout and alarms for operator action or attention.

   The FLOW unit assignments are described in Section 4.3.

5.2.1.2. Unit Hardware Hierarchy

Modules are placed inside a chassis, to form a unit. Each module contains one or more Printed Circuit (PC) boards, which mounts FPGAs containing embedded logic. The logic of the FPGAs is implemented using functional elements, which are discrete programming elements containing simple logic.

5.2.1.3. LPRM Unit and Module Configuration

Table 5-3 and 5-4 show module configuration of the LPRM unit.

5.2.1.4. LPRM/APRM Unit Module Configuration

Table 5-5 and 5-6 show module configuration of the LPRM/APRM unit.

5.2.1.5. FLOW Unit and Module Configuration

Table 5-7 and 5-8 show module configuration of the FLOW unit.

5.2.2. Unit Input/Output Requirements

The PRM System consists of the LPRM units, the LPRM/APRM units, and the FLOW units. The input and output requirements for these units are described in the following.

5.2.2.1. LPRM Unit

The LPRM unit shall have following Analog inputs, Analog outputs, and Discrete outputs:

Analog input:
- From LPRM detector
  - 11 LPRM signals — for division A
  - 12 LPRM signals — for division B

Communication and analog outputs:

(a) To LPRM/APRM unit — digital optical data transmission
  - 11 LPRM signals — for APRM channels A, C, E
  - 12 LPRM signals — for APRM channels B, D, F
  - LPRM Inoperable information

(b) To Process Computer — 0 to 160 mV signal for 0 to 125%
  - LPRM level

(c) To Transient Monitor — 1 to 5 V signal for 0 to 125%
  - LPRM level

Discrete outputs:
- To trip auxiliary unit
  - LPRM Upscale — OR of 11 or 12 LPRM detector channels
  - LPRM Downscale — OR of 11 or 12 LPRM detector channels
  - LPRM Inoperable — OR of 11 or 12 LPRM detector channels
  - Unit Minor Failure

5.2.2.2. LPRM/APRM Unit

Communication and analog inputs:

(a) From LPRM unit — digital optical data reception
- 11 LPRM signals — for APRM channels A, C, E
- 12 LPRM signals — for APRM channels B, D, F
- LPRM Inoperable information

(b) From LPRM detectors
- 10 LPRM signals

(c) From FLOW unit — digital optical data reception
- Individual Recirculation Flow values
- Recirculation Flow inoperable
- Flow Bypass

Discrete inputs:

- From Trip Auxiliary unit
  - Reactor Mode signal
  - APRM bypass signal
    - Notice: APRM channels shall be designed to allow bypass one of three APRM channels that send the trip signals to one RPS division.
  - 2 Flow bypass signals

Communications and analog outputs:

(a) To Rod Block Monitor — digital optical data transmission
- LPRM level
- APRM level
- Simulated Thermal Power Level

(b) To Process Computer — 0 to 160 mV signal for 0 to 125%
- LPRM level
- APRM level
- Simulated Thermal Power Level
- APRM Upscale (High) setpoint
- Simulated Thermal Power Upscale setpoint
- Selected Recirculation Flow value*

(c) To Transient Monitor — 1 to 5 V signal for 0 to 125%
- LPRM level
- APRM level
- Selected Recirculation Flow value*

(d) To Recorder — 0 to 1 V signal for 0 to 125%
- APRM level
- APRM Upscale (High) setpoint

Selected Recirculation Flow value*

*The lower of the two Recirculation Flow values received from the Flow units.

Discrete outputs:

(a) To trip auxiliary unit

LPRM Upscale	OR of 10 LPRM detector channels
LPRM Downscale	OR of 10 LPRM detector channels
LPRM Inoperable	OR of 10 LPRM detector channels
APRM Upscale (High-High)	Each APRM channel
Simulated Thermal Power Upscale	Each APRM channel
APRM Inoperable	Each APRM channel
APRM Upscale (High)	Each APRM channel
APRM Downscale	Each APRM channel
LPRM/APRM Unit Minor Failure	Each APRM channel
Simulated Thermal Power Upscale	Each APRM channel
Simulated Thermal Power Upscale (for SRI)	Each APRM channel
Flow Downscale (SRI)	Each APRM channel

5.2.2.3. FLOW Unit

Analog inputs:

- From the differential pressure transmitters

  Individual differential pressure transmitter signals

Discrete inputs:

- From FLOW bypass switch
  FLOW bypass signal
  Note: The FLOW unit allows bypassing one of channel A or C, and one of channel B or D.
- From Trip auxiliary unit
  Inoperable Bypass

Communication and analog outputs:

(a) To Rod Block Monitor — digital optical data transmission
Recirculation Flow value

(b) To Recorder

Loop Flow value	0 to 1 V signal for 0 to 125%
Differential Pressure value	0.2 to 1 V signal for 4 to 20 mA
Recirculation Flow value	0 to 1 V signal for 0 to 125%

(c) To Process Computer — 0 to 160 mV signal for 0 to full scale

Loop Flow value	0 to 160 mV signal for 0 to 125%
Differential Pressure value	32 to 160 mV signal for 4 to 20 mA
Recirculation Flow value	0 to 160 mV signal for 0 to 125%
(d) To LPRM/APRM unit	digital optical data transmission
Recirculation Flow value	
(e) To Transient Monitor	
Loop Flow value	0 to 5 V signal for 0 to 125%
Differential Pressure value	1 to 5 V signal for 4 to 20 mA
Recirculation Flow value	0 to 5 V signal for 0 to 125%

Communication and discrete outputs:

(a) To Trip auxiliary unit
Recirculation Flow Upscale
Recirculation Flow Inoperable
Flow Unit Minor Failure

(b) To Rod Block Monitor (digital optical data transmission)
Recirculation Flow inoperable
Flow Bypass

(c) To LPRM/APRM Unit — digital optical data transmission
Recirculation Flow inoperable
Flow Bypass

5.2.2.4 Data transmission through fiber optic cable

The units transmit data through fiber optic cables. The fiber optic transmission has the following redundant configuration:

i) The LPRM unit has two optical serial transmission ports to the LPRM/APRM unit to provide redundant transmission.
ii) The LPRM/APRM unit has two optical serial transmission ports to two RBM units, and two serial transmission ports from two FLOW units.
iii) The FLOW unit has five optical serial transmission ports to communicate to three LPRM/APRM units and two RBM units.

5.2.2.5 Module Configuration of each Unit

The following tables provide the module configurations of each unit. Figure 5-1 shows the FLOW channel and APRM channel configuration of the PRM System.

Table 5-3 LPRM unit module configuration - Front slot (for 12 LPRM Detector Signals)

Slot ID (Front)	Module Name	Description
FSL1	LPRM Module	LPRM function for LPRM Detector CH 11
FSL2	LPRM Module	LPRM function for LPRM Detector CH 12
FSL3	LPRM Module	LPRM function for LPRM Detector CH 13
FSL4	LPRM Module	LPRM function for LPRM Detector CH 14
FSL5	LPRM Module	LPRM function for LPRM Detector CH 15
FSL6	LPRM Module	LPRM function for LPRM Detector CH 16
FSL7	LPRM Module	LPRM function for LPRM Detector CH 17
FSL8	LPRM Module	LPRM function for LPRM Detector CH 18
FSL9	LPRM Module	LPRM function for LPRM Detector CH 19
FSL10	LPRM Module	LPRM function for LPRM Detector CH 20
FSL11	LPRM Module	LPRM function for LPRM Detector CH 21
FSL12	LPRM Module	LPRM function for LPRM Detector CH 22
FSL13	BLANK Module	Dummy LPRM module (See Section 5.2.3.12)
FSL14	STATUS Module	Power-supply-voltage-monitoring status indication

Table 5-4 LPRM unit module configuration - Back slot (for 12 LPRM Detector Signals)

Slot ID (Back)	Module Name	Description
---	LVPS Module	+5 V and ±15 V power supply to each module
BSL1	AO Module	Analog output of LPRM levels (Ch. 11 to 22) to the process computer (0 to +160 mV / 0 to 125%).
BSL2	---	Blank panel
BSL3	AO Module	Analog output of LPRM levels (Ch. 11 to 22) to the Transient Monitor (+1 to +5 V/ 0 to 125%).
BSL4	DIO Module	Digital output of LPRM Upscale, Downscale, and Inoperable signal by OR of Ch. 11-22 to the trip auxiliary unit
BSL5	---	Blank Panel
BSL6	---	Blank Panel
BSL7	---	Blank Panel
BSL8	TRN Module	Optical data transmission of LPRM level (Ch.11-22), Inoperable and LVPS failure information to LPRM/APRM unit
---	LVPS Module	+5 V and ±15 V power supply to each module

Table 5-5 LPRM/APRM unit module configuration - Front slot

Slot ID (Front)	Module Name	Description
FSL1	LPRM Module	LPRM function for LPRM Detector CH 1
FSL2	LPRM Module	LPRM function for LPRM Detector CH 2
FSL3	LPRM Module	LPRM function for LPRM Detector CH 3
FSL4	LPRM Module	LPRM function for LPRM Detector CH 4
FSL5	LPRM Module	LPRM function for LPRM Detector CH 5
FSL6	LPRM Module	LPRM function for LPRM Detector CH 6
FSL7	LPRM Module	LPRM function for LPRM Detector CH 7
FSL8	LPRM Module	LPRM function for LPRM Detector CH 8
FSL9	LPRM Module	LPRM function for LPRM Detector CH 9
FSL10	LPRM Module	LPRM function for LPRM Detector CH 10
FSL11	APRM Module	APRM function
FSL13	---	Blank Panel
FSL14	STATUS Module	Data reception status, power-supply-voltage-monitoring status indications.

Table 5-6 LPRM/APRM unit module configuration - Back slot

Slot ID (Back)	Module Name	Description
----	LVPS Module	+5 V and ±15 V power supply to each module
BSL1	AO Module	Analog outputs of LPRM levels (Ch. 1 to 10), APRM level, APRM Upscale (High) setpoint, Simulated Thermal Power level, and Simulated Thermal Power Upscale setpoint to the process computer (0 to 160 mV / 0 to 125%)
BSL2	AO Module	Analog outputs of APRM level and APRM Upscale (High) setpoint to the recorder (0 to +1V / 0 to 125%)
BSL3	AO Module	Analog outputs of LPRM levels (Ch. 1 to 10) and APRM level to the Transient Monitor (1 to +5V / 0 to 125%)
BSL4	DIO Module	Digital outputs of LPRM Upscale, Downscale, Inoperable, and various APRM trip signals to the trip auxiliary unit Digital inputs of reactor mode and APRM bypass signal.
BSL5	RCV Module	Optical data reception of the recirculation flow values from the FLOW units Optical data reception of LPRM levels (Ch. 11 to 22), Inoperable, and LVPS failure information from the LPRM unit
BSL6	----	Blank panel
BSL7	----	Blank panel
BSL8	TRN Module	Optical data transmission of LPRM level (Ch. 1 to 22), APRM level, Recirculation FLOW values, Simulated Thermal Power level, APRM Upscale (High) setpoint and Simulated Thermal Power Upscale setpoint to RBM unit
---	LVPS Module	+5 V and ±15 V power supply to each module

Table 5-7 FLOW unit module configuration - Front slot

Slot ID (Front)	Module Name	Description
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
---	Blank Panel	---
FSL10	SQ-ROOT Module	Square root arithmetic function for Loop "a"
FSL11	SQ-ROOT Module	Square root arithmetic function to Loop "b"
FSL12	FLOW Module	Recirculation-flow calculation, trip and alarm functions
FSL14	STATUS Module	FLOW unit status indication function

Table 5-8 FLOW unit module configuration - Back slot

Slot ID (Back)	Module Name	Description
PSSL1	LVPS Module	+5 V and ±15 V power supply to each module
BSL1	AO Module	Analog outputs to the process computer.
BSL2	AO Module	Analog outputs to the recorders.
BSL3	AO Module	Analog outputs to the transient monitor.
BSL4	DIO Module	Digital outputs of the trip signals to the trip auxiliary unit. Digital input of Bypass signal. Digital input of Inoperable Bypass signal.
BSL5	Blank	---
BSL6	Blank	---
BSL7	TRN Module	Optical serial transmission to RBM unit
BSL8	TRN Module	Optical serial transmission to APRM unit
PSSL2	LVPS Module	+5 V and ±15 V power supply each module

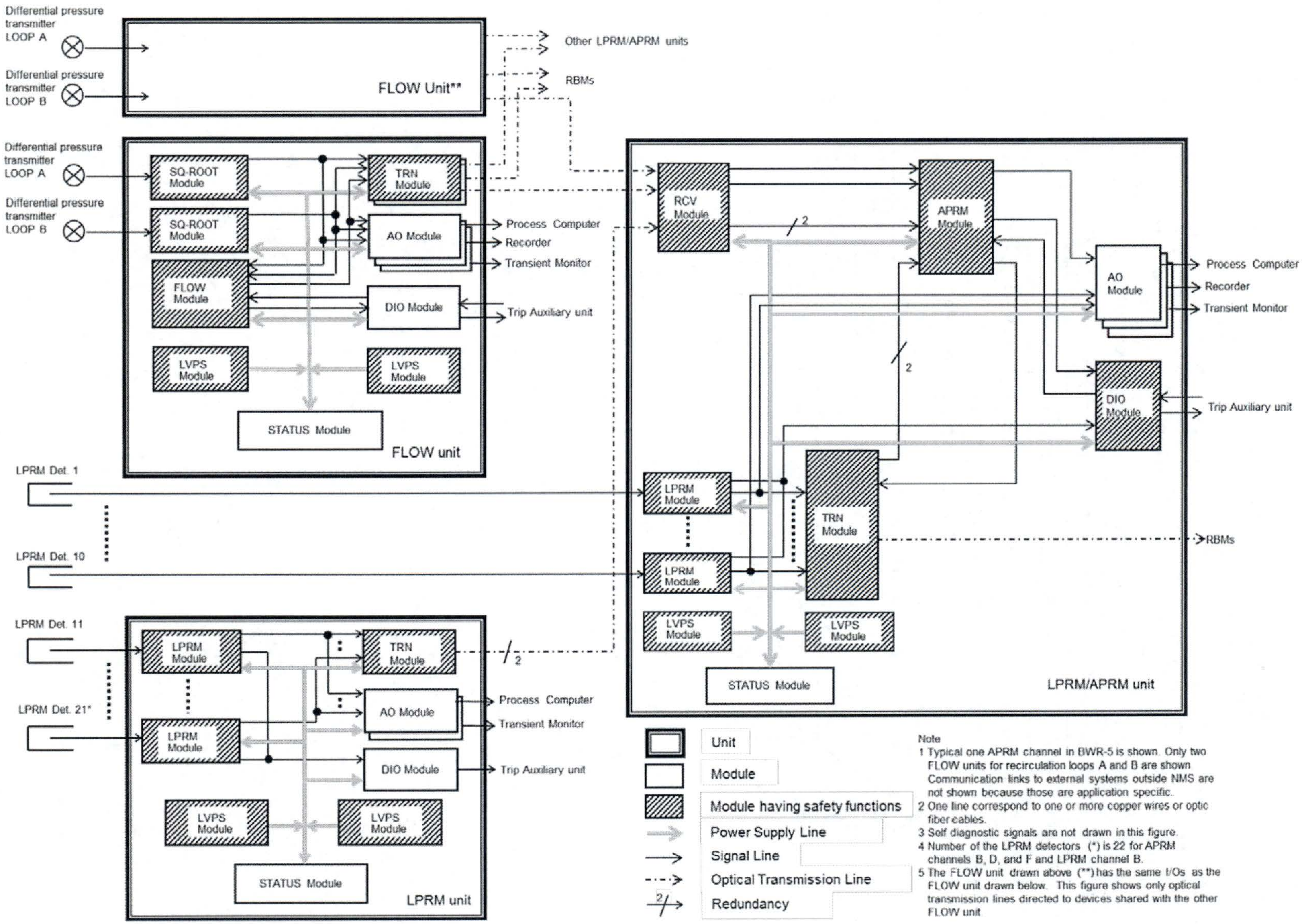


Figure 5-2 Flow channel & APRM channel Configuration

5.2.3. Module Requirements

5.2.3.1. General

All modules/units shall meet or support the general requirements described in Section 5.2.1 and 5.2.2.

The following sections describe the requirements for each module type.

5.2.3.2. LPRM module

Each LPRM module generates an LPRM level, which is proportional to the neutron flux level at the detector location in the reactor core.

The LPRM module shall be capable of accepting a 0 to 3 mA current signal from the detector, and convert the electric current signal to a voltage signal. Then, the LPRM module shall apply a low pass filter for anti-aliasing and high frequency noise rejection to the voltage signal. The low pass filter has the following characteristics:

Type: [ ]a,c
Stopband: [ ]a,c Hz ±[ ]a,c %

The filtered voltage signal is converted to a digital value, a moving average digital filter shall be applied to eliminate the power supply noise. The digital filter has the following characteristics:

Passband: [ ]a,c Hz
Passband Fluctuation: [ ]a,c dB
Stopband: above [ ]a,c Hz
Stopband Attenuation: more than [ ]a,c dB
more than [ ]a,c dB for [ ]a,c Hz
Number of Samples for averaged group: [ ]a,c
Sampling Cycle: [ ]a,c microseconds
Output Cycle: [ ]a,c milliseconds

LPRM gain compensation shall be provided for each LPRM input. It shall be possible to enter the simulated "LPRM gain" value manually from the LPRM module front panel, where LPRM gain is LPRM detector current at 100% power (40 to 2400μA).

Full design input range of the LPRM current shall be 0 to 125%.

The LPRM module shall supply power to the LPRM detectors at least 3 mA at 100 VDC.

The LPRM module shall be designed to generate the following signals:

(a) LPRM level
LPRM level signals are transmitted to the APRM module.
(b) LPRM Upscale

The LPRM module shall be designed to provide an upscale alarm when the LPRM level exceeds the user defined setpoint.
The setpoint shall be adjustable over the range corresponding to the 5.0% up to 125.0% flux.

(c) LPRM Downscale
The LPRM module shall be designed to provide a downscale alarm when the LPRM level falls below user defined setpoint.
The setpoint shall be adjustable over the range of 0.0 to 10.0% flux.

(d) LPRM inoperable signal
The LPRM module shall generate the LPRM inoperable signal if any of the following occur:

- The operation mode is not "OP"
- The LPRM module is being initialized
- One or more FPGAs halt
- An error detected in the memory storing LPRM gain value
- High voltage power supply fails

The LPRM module front panel shall display following signals:

a LPRM level
b LPRM Upscale
c LPRM Downscale
d LPRM Inoperable

When the LPRM module mode switch is in the "OP" position, the following, as minimum, shall be displayed when requested by the user:

a [Deleted]
b The LPRM gain
c High Voltage monitoring value, Input current monitoring value
d Alarm setpoints

When the LPRM module mode switch is not in the "OP" position, the following, as minimum, shall be displayed when requested by the user:

a Apply the LPRM gain adjustments
b Alarm trip checks (LPRM alarm outputs)

The operation clock of each LPRM module is [ ] [a,c] MHz.

5.2.3.3 APRM module

The APRM module receives data from the LPRM modules mounted in the same LPRM/APRM unit through the TRN module, and from the LPRM modules mounted in the LPRM unit, as well as the FLOW modules through the RCV module.

The dual electrical communication links are used in the data transmission from the TRN and RCV modules. The link consists of the primary link and the secondary link. The APRM module receives data though the primary link usually, and when the primary link is marked as failed, the APRM module uses the secondary link.

The APRM module shall verify that the periodic data transmissions occur in the electrical communication links to determine if the links are failed. In addition, for each data transmission over the fiber optic cables, the APRM module receives alarms from the RCV module if a failure occurs, and uses this alarm to determine if the links are failed.

The APRM module calculates the APRM level in the reactor core based on the LPRM levels.

If the APRM level exceeds any setpoint, the APRM module generates trip signals corresponding to each setpoint.

APRM module shall be designed to generate the following signals:

(a) APRM level
The APRM module shall calculate the APRM level using the following formula:

$$APRM\_level = \frac{\sum_i LPRM\_level_i}{LPRM\_COUNT} \times APRM\_GAIN$$

Where,

APRM_level:	Average power level	0.0 - 125.0%
LPRM_level$_i$:	i-th LPRM level	0.0 - 125.0%
APRM_GAIN:	APRM gain	1.00 - 3.00
LPRM_COUNT:	Number of operable LPRM modules. The APRM module calculates this value from each LPRM's inoperable signal.	

The APRM gain shall be adjusted by entering the APRM gain value manually from the APRM module front panel.
The APRM level and the APRM_GAIN shall be displayed on the APRM module front panel if requested.

(b) Simulated Thermal Power Level
The APRM module shall calculate the Simulated Thermal Power Level of the reactor core as the first order lag of the APRM level by applying 0.00 - 9.99 second time constant. The time constant can be set with a rotary switch and shall be stored in the dual storage.

The Simulated Thermal Power Level and the time constant shall be displayed on the APRM module front panel if requested.

(c) Average Power Level for APRM Upscale (High)
The APRM module shall calculate the Average Neutron Flux for APRM Upscale (High) alarm as the first order lag of the APRM level by applying 0.00 - 9.99 second time constant. The time constant can be set with a rotary switch and shall be stored in the dual storage.

(d) Flow biased Simulated Thermal Power Upscale Setpoint
The flow biased Simulated Thermal Power Upscale setpoint shall be calculated as follows:

Simulated Thermal Power Upscale Setpoint = (Slope × Flow) + Offset

Where,

Slope	Slope of the Power/Flow level line, 0.40 - 1.50
Flow	Recirculation flow, 0.0 - 125.0% (The lower of the two Flow values received from the two FLOW units.
Offset	flux offset at zero flow, 20.0 to 125.0%

When the calculated Simulated Thermal Power Upscale setpoint exceeds 115%, the setpoint is clamped to 115%.

The slope, offset, and the clamp value shall be displayed on the APRM module front panel if requested.

(e) Flow biased APRM Upscale (High) Setpoint
When the reactor mode switch is in the "RUN" position, the flow biased APRM Upscale (High) shall be calculated as follows:

APRM Upscale (High) Setpoint = (Slope× Flow) + Offset

Where,

Slope	Slope of the Power/Flow level line, 0.40 to 1.50
Flow	Recirculation flow, 0.0 - 125.0%
Offset	flux offset at zero flow 0.0 to 125.0%

When the calculated APRM Upscale (High) setpoint exceeds 108%, the setpoint clamped to 108%.

The slope, offset, and the clamp value shall be displayed in the APRM module front panel if requested.

(f) APRM Upscale (High-High)
The APRM module shall be designed to provide an APRM Upscale (High-High) trip signal to the RPS when the APRM level exceeds the user defined setpoint.
There are two setpoints depending on the position of the reactor mode switch.
One setpoint shall be adjustable over the range of 40.0 to 125.0% APRM level when the reactor mode switch is in the "RUN" position.
The other setpoint shall be adjustable over the range of 6.0 to 20.0% APRM level, when the reactor mode switch is not in the "RUN" position.

Both setpoints shall be displayed on the APRM module front panel if requested.

(g) Simulated Thermal Power Upscale
The APRM module shall be designed to provide an Simulated Thermal Power Upscale trip signal to the RPS when the Simulated Thermal Power Level exceeds the setpoint described in (d) of this section.

(h) APRM Upscale (High)
The APRM module shall be designed to generate an APRM Upscale (High) alarm signal intended to be used as a rod block when the APRM level exceeds the APRM Upscale (High) setpoint described in (e) and the reactor mode switch is in the "RUN" position.

The APRM Upscale (High) alarm signal is generated when APRM level exceeds the user defined setpoint and the reactor mode switch in not in the "RUN" position. The alarm setpoint shall be adjustable over the range of 6.0 to 20.0% APRM level.

(i) APRM Downscale
The APRM module shall be designed to generate a downscale alarm signal intended to be used as a rod block when the APRM level falls below a user defined setpoint.
The alarm setpoint shall be adjustable over the range of 2.0 to 10.0% APRM level.

The setpoint shall be displayed on the APRM module front panel if requested.

(j) APRM Inoperable
The APRM module shall provide an inoperable trip signal to the RPS when any of the following conditions occur:

a. One or more signal processing FPGAs halt
b. The APRM module's mode switch is not in the "OP" position
c. The APRM module is being initialized
d. The number of operable LPRM modules is less than the set value

"The minimum number of LPRM modules" set value shall be displayed on the APRM module front panel if requested.

(k) Selected Rod Insertion (SRI) Simulated Thermal Power Upscale
The APRM module shall be designed to generate a SRI Thermal Power Upscale Trip signal intended to be used as a SRI signal when the Simulated Thermal Power Level exceeds a user defined setpoint.
The alarm setpoint shall be adjustable over the range of 0.0 to 40.0% thermal power.

The setpoint shall be displayed on the APRM module front panel if requested.

(l) SRI Recirculation Flow Downscale
The APRM module shall be designed to generate a SRI Recirculation Flow Downscale Trip signal to be used as a SRI signal when the Recirculation Flow value falls below a user defined setpoint.
The alarm setpoint shall be adjustable over the range of 35.0 to 70.0% flow.

The setpoint shall be displayed on the APRM module front panel if requested.

(m) APRM Minor Failure
The APRM module shall generate a Minor Failure alarm when any one of the following conditions occurs:

a. An error is detected in the EEPROM storing the APRM gain.
b. A time-out error is detected in the data transmission from the TRN module.
c. A time-out error is detected in the data transmission from the LPRM units.
d. A time-out error is detected in the data transmission from the FLOW units.
e. One or more Human Machine Interface (HMI) FPGAs halt.

The APRM module front panel shall display the following signals:

- Trip and Alarm signals of (f), (g), (h), (i), (j), (k), (l), and (m)
- Chronological order of an APRM Upscale (High-High) trip and a Simulated Thermal Power Upscale trip
- Reactor mode switch status, i.e. if the mode switch is in "RUN" position

When the APRM module mode switch is in the "CAL" position, the following, as a minimum, shall be made available when requested by the user:

- APRM gain adjustment
- Trip and Alarm checks
- Setting of trip setpoints

The operation clock of APRM module is [ ][a,c] MHz.

5.2.3.4 SQ-ROOT module

The SQ-ROOT module calculates the recirculation loop flow from the differential pressure value obtained from the differential pressure transmitter.

The SQ-ROOT module shall provide at least 20 mA at 24 VDC to the differential pressure transmitter.

The SQ-ROOT module shall be designed to generate the following signals:

(a) Differential Pressure Value
The SQ-ROOT module shall receive a 4-20 mA differential pressure signal from the differential pressure transmitter, and applying the analog-to-digital converter and the first order lag filter. The time constant of the filter is adjustable in the range 0.00 - 9.99 seconds.

(b) Loop Flow Value
The SQ-ROOT module shall calculate the recirculation loop flow from the filtered differential pressure value as follows:

$$Flow = 125.0 \times \sqrt{\frac{(\Delta P - Ib)}{If}}$$

Where,

Flow:	Loop Flow Value. It is normalized in the range 0 to 125%
ΔP:	Differential Pressure Value calculated in (a)
Ib	Offset corresponding to 4 mA input signal
If	Constant corresponding to 16 mA input signal

(c) Input signal low alarm
The SQ-ROOT module shall generate the input signal low alarm if the differential pressure value calculated in (a) falls below the setpoint.

(d) SQ-ROOT inoperable signal
The SQ-ROOT module shall generate the inoperable signal if the following occur:
- Input signal low alarm is generated
- One or more signal processing FPGAs halt

(e) SQ-ROOT Minor Failure alarm
The SQ-ROOT module shall generate the Minor Failure alarm if the HMI FPGA halts.

The SQ-ROOT module front panel shall display the following signals.
- Differential pressure value
- Loop Flow value
- Operation mode

- Inoperable signal
- Minor failure signal alarm

It shall be possible to enter simulated differential pressure signals to the SQ-ROOT module for calibration.

The operation clock of SQ-ROOT module is [ ][a,c] MHz.

5.2.3.5 FLOW module

The FLOW module computes a recirculation flow value from the two SQ-ROOT modules, one of which measures the recirculation loop A, and the other measures the recirculation loop B. The range of the recirculation flow value is 0 to 125%. The computed total recirculation flow value is transmitted to the LPRM/APRM units and the RBM units. When the recirculation flow value exceeds the setpoint, the FLOW module shall generate the recirculation flow value high alarm.

(a) Recirculation flow value
The FLOW module shall calculate the total recirculation flow value using the following equation:

$$\text{FLOW} = (\text{Flow-A} + \text{Flow-B}) \times \text{FLOW GAIN}$$

Where,

FLOW	Recirculation flow value
Flow-A	Loop-A flow value
Flow-B	Loop-B flow value
FLOW GAIN	Gain 0.5 to 2.0

(b) Recirculation Flow Upscale
The Flow module generates the recirculation flow upscale alarm when the total recirculation flow rate exceeds the user defined setpoint.
The setpoint shall be adjustable over the range of 90.0 to 125.0% flow.

(c) Recirculation Flow Inoperable
The FLOW module shall provide the recirculation flow inoperable signal if any of the following conditions occur:
- The FLOW module mode switch is not in the "OP" position.
- Either of the SQ-ROOT modules is inoperable.
- One or more signal processing FPGAs halt.

(d) FLOW module Minor Failure alarm
The FLOW module shall provide the FLOW module Minor Failure alarm if any of the following occur:

- HMI FPGA halts
- Either of the SQ-ROOT modules emits the Minor Failure alarm
- A time-out error is detected in the transmission from either of the SQ-ROOT modules.

The FLOW module front panel display shall display the following signals:

- Total flow rate value (see (a).)
- Bypass status
- Operation mode
- Inoperable signal (see (c).)
- Minor failure alarm (see (d).)

The operation clock of the FLOW module is [ ][a,c] MHz.

5.2.3.6 AO module

The AO module has up to 16 analog output ports. The AO module receives digital data from the unit middle plane, converts the digital data to analog data. Photo couplers and isolated-type DC/DC converters isolate the unit from the output ports.

There are eight types of AO modules:

5.2.3.6.1 AO module 1

This type of the AO module shall be mounted in the LPRM unit, and provide the analog signals to Process Computer as described in Section 5.2.2.1.

5.2.3.6.2 AO module 2

This type of the AO module shall be mounted in the LPRM/APRM unit, and provide the analog signals to Process Computer as described in Section 5.2.2.2.

5.2.3.6.3 AO module 3

This type of the AO module shall be mounted in the LPRM/APRM unit, and provide the analog signals to Recorder as described in Section 5.2.2.2.

5.2.3.6.4 AO module 4

This type of the AO module shall be mounted in the LPRM Unit, and provide the analog signals to Transient Monitor as described in Section 5.2.2.1.

5.2.3.6.5 AO module 5

This type of the AO module shall be mounted in the LPRM/APRM unit, and provide the analog signal to Transient Monitor as described in Section 5.2.2.2.

5.2.3.6.6 AO module 6

This type of AO module shall be mounted in the FLOW unit, and provide the analog signal to Process Computer as described in Section 5.2.2.3.

5.2.3.6.7 AO module 7

This type of AO module shall be mounted in the FLOW unit, and provide the analog signal to Transient Monitor as described in Section 5.2.2.3.

5.2.3.6.8 AO module 8

This type of AO module shall be mounted in the FLOW unit, and provide the analog signal to Recorder as described in Section 5.2.2.3.

5.2.3.7 DIO module

The discrete input and output module has 16 output ports and 4 input ports. The DIO module receives discrete signals from the unit middle plane in the unit and transmits them to external equipment, and receives discrete signals from external equipment.

Photo couplers isolate the unit and other modules from the output and input ports.

There are two types of the DIO module.

5.2.3.7.1 DIO module 1

This type of the DIO module is mounted in the LPRM unit, and provides the discrete outputs described in Section 5.2.2.1 to the trip auxiliary unit.

5.2.3.7.2 DIO module 2

This type of the DIO module is mounted in the LPRM/APRM unit, and provides the discrete outputs to the trip auxiliary unit, and receives discrete inputs as described in Section 5.2.2.2.

5.2.3.7.3 DIO module 3

This type of the DIO module is mounted in the FLOW unit, and provides the discrete outputs to the trip auxiliary unit, and receives discrete inputs as described in Section 5.2.2.3.

5.2.3.8 TRN module

The TRN module collects digital signals from other modules in the unit, multiplexes them in the defined frame format, and transmits the frame to the LPRM/APRM unit or external equipment through the fiber optical cables. The TRN modules are mounted in the FLOW unit and APRM units.

Each TRN module has two separate, independent data processing paths. Each of the data processing paths has two outward communication links, transmitting identical data. One of the links is used as the primary, and the other is used as the secondary.

The TRN module has the two watchdog timers that monitor the periodic operation of the FPGAs. If the watchdog timer detects the failure of the FPGAs, the front panel LED shall be turned off for each data processing path.

The operation clock of TRN module is [ ][a,c] MHz.

The TRN module has three operational modes corresponding to the unit type on which it is mounted.

5.2.3.8.1 In the LPRM unit

The TRN module collects LPRM levels and the LPRM inoperable signals, and transmits them to the LPRM/APRM unit as described in Section 5.2.2.1.

5.2.3.8.2 In the LPRM/APRM unit

When the TRN module is mounted in the LPRM/APRM unit, it has following two functions:

- The TRN module collects the LPRM levels and the LPRM inoperable signals from the LPRM modules in the LPRM/APRM unit, and transmits them to the APRM module over the middle plane wiring.
- The TRN module collects signals and transmits them to the Rod Block Monitor as described in Section 5.2.2.2.

5.2.3.8.3 In the FLOW Unit

The TRN module collects signals and transmits them to the LPRM/APRM unit as described in Section 5.2.2.3.

5.2.3.9 RCV module

The RCV module is mounted in the LPRM/APRM unit. The RCV module receives the data from the TRN modules in the LPRM unit, and provides them to the APRM module.

An RCV module has four separate, independent optical receivers, each of which receives serial data at 1 megabit per second (Mbps) every [ ][a,c] milliseconds from a TRN module by a one way

fiber optic cable. The RCV module sends the received data in the same frame format over the copper lines inside the unit.

The RCV module checks for the periodic data transmission through each fiber optic cable. If the RCV module fails to receive the three consecutive data frame for [ ]a,c millisecond per cycle ([ ]a,c millisecond cycle time plus some margin), the RCV module marks the link failed.

The RCV module checks for the parity bit on every [ ]a,c bit word in the received data through each fiber optic cable. A later revision of the module receiving data performs a CRC check of each message.

The RCV module has one watchdog timer that monitors the periodic operation of the FPGAs. The watchdog timer detects a failure of the FPGAs and the RCV module sends the failure detection signal to the STATUS module and the APRM module.
The operation clock of RCV module is [ ]a,c MHz.

5.2.3.10 LVPS module

The LVPS module supplies +5 VDC, ±15 VDC to the other modules in the unit.

5.2.3.11 STATUS module

The STATUS module displays the status of other modules on the front panel. There are two types for LPRM unit, LPRM/APRM unit and FLOW unit.

The STATUS module has a watchdog timer that monitors the periodic operation of its HMI FPGA. If the watchdog timer detects the failure of the FPGA, it shall be indicated on the front panel.

The operation clock of STATUS module is [ ]a,c MHz.

5.2.3.11.1 STATUS module 1

This type of the STATUS module is mounted in the LPRM/APRM unit and displays the following:

- LVPS alarm: Indicate that either of the LVPS modules is failed.
- Fail: Indicate if either of the LVPS modules is failed, or any one of the LPRM or FLOW module fails, or the FPGA of the STATUS module halts.
- LINE status: Status of the following data transmission:
  (a) From the TRN module in the LPRM/APRM unit to the APRM module
  (b) From the LPRM unit to the LPRM/APRM unit
  (c) From the FLOW units to the LPRM/APRM unit

(a) and (b) are dual transmission.

5.2.3.11.2 STATUS module 2

This type of the STATUS module is mounted in the LPRM or FLOW units, and displays the followings:

- LVPS alarm — Indicate that either of LVPS modules is failed.
- Fail — Indicate if the FPGA of the STATUS module halts, or both of the LVPS modules are failed.

5.2.3.12 BLANK Module

The BLANK module shall be mounted in the LPRM unit or the LPRM/APRM unit as a dummy LPRM module. The BLANK module provides the mock normal signals for the LPRM Inoperable signal, the LPRM Upscale alarm, and the LPRM Downscale alarm, in order to prevent false alarms, because the LPRM or LPRM/APRM unit generates an alarm by ORing all LPRM modules and the BLANK modules for those alarms.

5.2.4. General Design

5.2.4.1. Chassis Requirements

Chassis that are used as the enclosure of the units must be suitable for mounting in a standard 19 inch rack, and must have adequate strength and provide positive hold down for the modules. Chassis are fixed in the rack with 4 screws in the front side and 8 screws in the backside. The torque to tighten the screws in the front side is 2.6 - 3.4 N·m and in the backside is 1.3 – 1.7 N·m.

Outline dimension (Excluding protrusion)	177.0 mm	Height
	482.6 mm	Width
	440.8 mm	Depth
Weight (Excluding built-in)	19 kg or less	
Material	Aluminum	

The use of extender is permitted and, if needed, shall be included as part of the qualification testing.

The side plate of chassis must have sufficient strength and to meet seismic requirements specified in Section 5.5.2.

5.2.4.2 System Cables and Connectors

1. The PRM System shall include all cabling and wiring necessary to connect and operate the units (and the system).
2. All cables and connectors shall not contain any polyvinylchloride (PVC).
3. [Deleted]
4. All cables shall be suitable for UL Class 2 service. Specifically, withstand rating shall be more than 3 times the signal level voltage or 150 volts.
5. Temperature rating shall be 60 °C or greater.

5.2.4.3 Data Retention Capability Requirements

Any EEPROM used for field modifiable constants shall be capable of at least 100,000 write cycles.

5.2.4.4 Transferring information between modules in the same unit

1. Each unit of the PRM System shall be capable of transferring information between modules in the same unit.
2. Failures of other units shall not defeat the concerned unit's capability to transfer data in the concerned unit.
3. Loss of power to one module shall not defeat the capability of other modules in the same unit.
4. [Deleted]
5. Surge withstand capability shall be included as given in Section 5.5.4.

5.2.4.5 Grounding/Shielding Requirements

The PRM System shall meet IEEE Std 1050 and EPRI TR-102323 grounding requirements. This includes supporting connection to single point, multi-point and floating ground systems, and providing a ground connection point on each chassis.

The PRM System shall meet IEEE Std 1050 and R.G. 1.180 shielding requirements. This includes providing shielding connection points for the I/O module field terminations.

5.2.4.6 Termination Requirements

Features shall be provided to substitute test signals or monitoring instruments for field connections.
Any connectors and terminations to the units shall be included in qualification testing.

5.2.4.7 Requirements for the power supply lines

Varistors and noise filters shall be inserted in the power supply lines of each LPRM, LPRM/APRM, and FLOW unit as provisions for surge withstand. The following varistors and noise filters shall be applied:

- Varistor (between line for AC connection and ground): [ ][a,c] [ ][a,c] or equivalent.
- Varistor (between neutral for AC connection and ground): [ ][a,c] [ ][a,c] or equivalent.
- Varistor (between line and neutral for AC connection): [ ][a,c] [ ][a,c] or equivalent.
- Noise Filter (between line and neutral for AC connection): [ ][a,c] or equivalent.

5.3 Software Requirements

1. The baseline configuration of the qualified units shall be controlled by NED. All modules and units shall be marked with an identifier that includes revision level.
2. The Software Integrity Level required for the safety-related functions of the units shall be level 4.
3. FPGA based units application logic shall be designed in VHDL, which is a hardware description language.
4. Application logic shall be modular in structure and shall employ structured programming.
5. The logic capacity of FPGA shall be sufficient to execute application logic.
6. The application logic contained in the FPGA shall not be rewritable. Therefore, non-rewritable FPGA type shall be used.
7. As long as the system is normal, the non-rewritable FPGA shall retain the logic.
8. NICSD shall specify the FPGA availability.
9. Functional Elements (FE) shall be used to program the FPGA. Only FEs that are completely tested (by exhaustive pattern testing), shall be used in the FPGA design.
10. Any memory used for field modifiable constants shall be capable of at least 100,000 write cycles.
11. The application logic shall provide the features required for the satisfactory system performance.
12. The self-test function shall determine the specific failures of any module within the system for its replacement.
13. Verification and Validation Requirements:
    A. NICSD shall have a V&V Plan for the PRM logic design.
    B. NICSD shall take a life cycle approach to PRM logic design development, with V&V activities performed throughout the life cycle.
    C. The PRM logic design requirements shall be documented to be reviewable for completeness, correctness and consistency.
    D. NICSD shall provide traceability of software requirements throughout the life cycle.
    E. There shall be both functional and structural testing of the PRM logic design.

F. NED shall evaluate the NICSD's V&V program plan against the following documents:
   (1) Section 5.3.4 of IEEE Standard 7-4.3.2
   (2) IEEE Standard 1012
   (3) NED's V&V Plan
G. If NICSD's V&V processes do not meet requirements applicable to Nuclear Power Plants, then compensatory measures shall be implemented.

14. Commercial digital equipment shall be controlled in accordance with applicable commercial grade dedication process.
15. Software tools shall be identified within the logic design development process. V&V tasks of witnessing, reviewing, and testing are not required for software tools, but are provided for the software that is produced using the tools is subject to V&V activities that will detect flaws introduced by the tools. Software tools shall be identified and controlled under configuration management.
16. Digital equipment qualification testing shall be performed with each required functions and each diagnostic functions as specified in Section 5.1.6.
17. The test and calibration as specified in Section 5.1.6 shall not adversely affect the ability which the digital equipment performs its safety function as specified in Section 4.1.2.
18. Data communication between units or with other safety and non-safety systems shall not inhibit the performance of the safety function as specified in 4.1.2.
19. The PRM System application logic shall be developed to meet all software standards and codes in accordance with the design process specified in the Software Quality Assurance Plan (SQAP).
20. NICSD shall ensure upward compatibility, maintain the same or enhanced level of rigor in the processes.
21. NICSD shall ensure to maintain continuously the same versions of software tools, or capability to reconstruct same functionality with the revised tools.

5.4 Design Life

The design goal of the qualified life for the system shall be 15 years.

The material and equipment selection for the system components are based on a 15 year design life, with appropriate provisions for maintenance and replacement. Reparability is enhanced by the modular design of PRM electronic equipment. Channel redundancy and bypass capabilities are provided in PRM design; hence, failed components can be replaced with little or no effect on system operation.

The safety-related components are repaired or replaced as they fail but completed within the times allowed by the plant Technical Specifications. All PRM instruments (not including sensors) in the Main Control Room are designed such that they can be maintained, tested and calibrated during normal plant operation without the adverse plant shutdown or scram.

A periodic surveillance and maintenance interval shall be determined per IEEE Std 323 to account for any significant aging mechanisms.

5.5 Environmental Conditions

5.5.1 Environmental Requirements

The PRM System shall operate within the normal environmental condition in the located area, and within the abnormal environmental conditions of anticipated transients and accidents, in order to preserve the safety system functions.

The PRM System will be located in a mild environment such as the main control room, so only mild environment condition is considered in this specification. Table 5-9 shows the environmental conditions.

Table 5-9 Environmental Conditions

	Normal Environmental	Abnormal Environmental
Temperature Range	16 to 40 °C	4 to 50 °C
Humidity Range	40 to 95% (non-condensing)	10 to 95% (non-condensing)
Radiation Exposure*	Up to 10 Gy	Up to 10 Gy

EPRI TR-107330 requirements

* Section 6.3 (Table 6.6) of EPRI TR-100516, Nuclear Power Plant Equipment Qualification Reference Manual, provides a basis for the specified 1 kRAD or 10 Gy radiation exposure level. Section 6.3 of EPRI TR-100516 further defines the 1 kRAD exposure level as the gamma 40-year dose from normal/abnormal service (approximately 2.9 millirem per hour). In this specification, SI units should be used. So here, 10 Gy radiation exposures is shown.

Radiation exposure is a rate phenomenon, so the difference of the exposure rate will cause the different aging effects on the test specimen even if the integral doses were the same. However, the radiation exposure rate as shown in TR-100516 is too low to be simulated during the qualification testing.

The higher-level exposure rate will cause the more severe aging effects to the test specimen. So the higher level exposure rate will provide the safety side simulation of the radiation aging. Hence we provide only the integral exposure level here, because the exposure times in any realistic qualification tests are shorter than 40 year.

The environmental qualification shall follow the requirement of RG 1.89 and IEEE Std 323 to assure that the instrument is able to complete its safety function under the those conditions of Table 5-9.

PRM units shall operate for the temperature/humidity profile given in Figure 5-2.

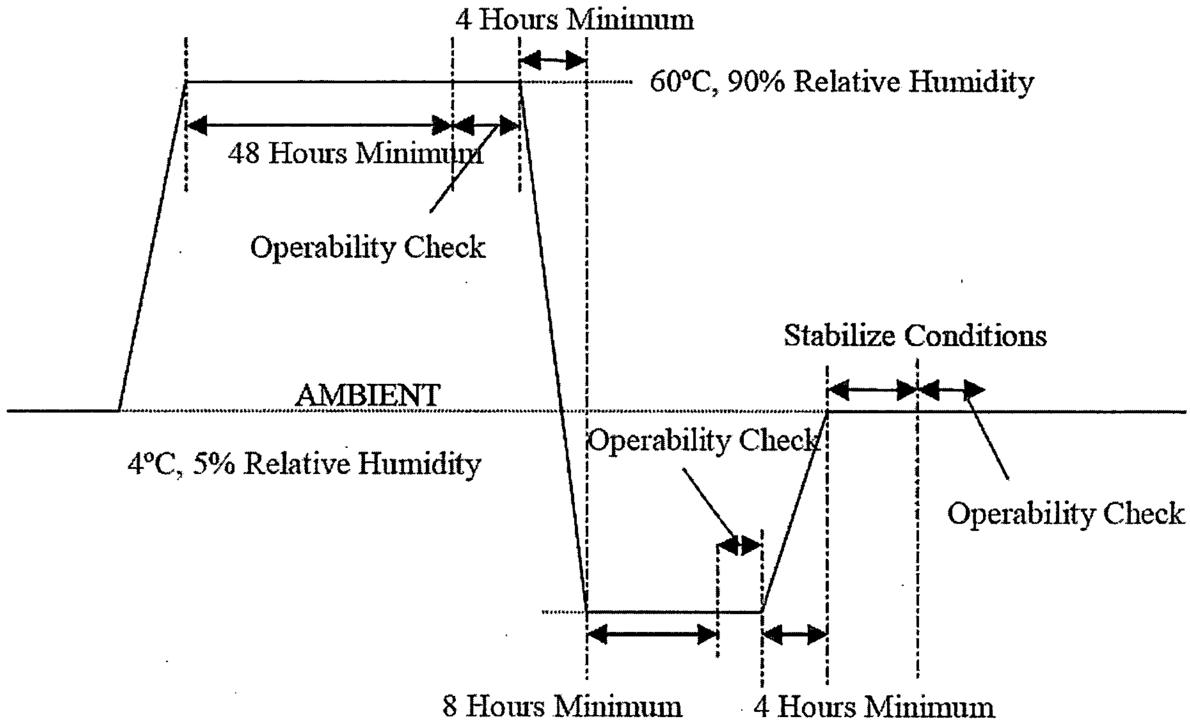


Figure 5-2 Temperature and Humidity Profile

5.5.2 Seismic Requirements

The PRM safety-related equipment shall be designed to operate during and after seismic events.
The qualification shall be implemented in accordance with the requirements of IEEE Std 344 and RG 1.29. The PRM System shall be suitable for qualification as a Category 1 Seismic device. The PRM System shall meet performance requirements during and after exposure to the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) levels (Figure 5-3).

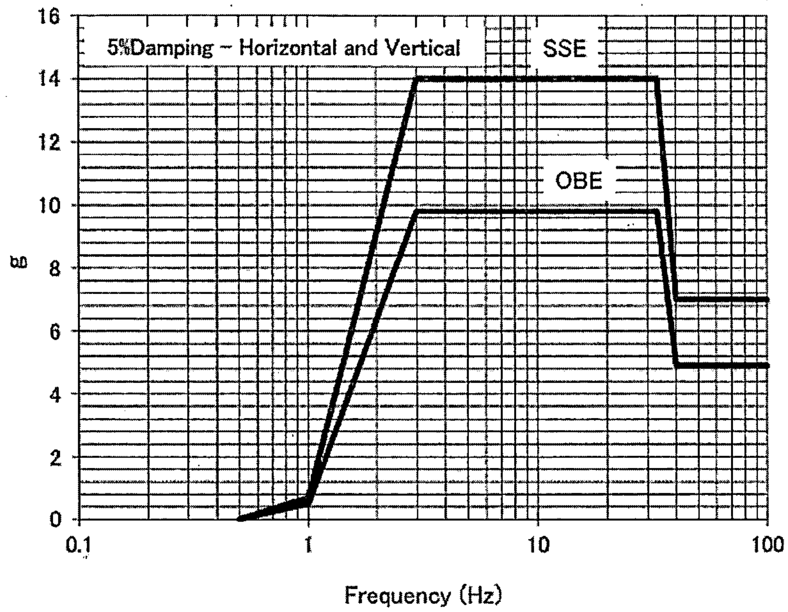


Figure 5-3 Requirement Response Spectrum

5.5.3 EMI/RFI Requirements

The PRM units shall be design to minimize susceptibility to, and generation of the electromagnetic interference (EMI) and radio frequency interference (RFI).
The PRM units shall be subjected to test for EMI/RFI conditions that conform to the guidelines given in RG 1.180.

When subjected to this level of EMI/RFI, any PRM unit shall continue to function as follows:

a. The transfer of I/O data shall not be disrupted.
b. The emissions shall not cause the discrete I/O to change state.
c. Analog I/O levels shall not vary more than 2 %.

For convenience, Figure 5-4 through 5-10 has been reproduced in this document from original RG 1.180 requirement, therefore it is required to consult the originals when these tests are executed.

5.5.3.1 Low-Frequency Conducted Susceptibility Testing got AC Power Leads (CS101)

The PRM units shall not be susceptible to a test signal with levels as specified in Figure 5-4 that complies with RG. 1.180 Section 4.1.1. This test is performed for evaluating the conducted electromagnetic transients injected on power input leads over a frequency range from 30 Hz to 150 kHz for DC power leads, and from the second harmonic of the power line frequency and extending to 150 kHz for AC power leads. The PRM uses AC power leads. This test shall be performed in accordance with MIL-STD-461E, CS101.

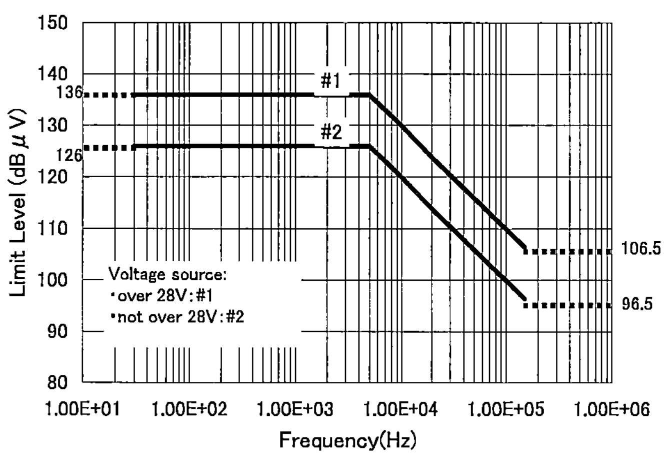


Figure 5-4 Low-Frequency Conducted Susceptibility Operating Envelopes (R.G. 1.180 CS101)

5.5.3.2 High-Frequency Conducted Susceptibility Testing for AC Power Leads (CS114)

The PRM units shall not be susceptible to a test signal with levels as specified in Figure 5-5 that complies with R.G. 1.180 Section 4.1.2. This test is performed for evaluating the conducted electromagnetic transients injected on power input leads over a frequency range from 10 kHz to 30 MHz. This test shall be performed in accordance with MIL-STD-461E, CS114.

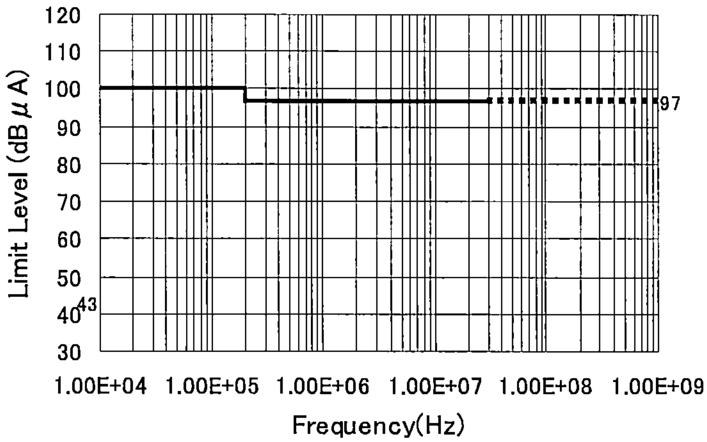


Figure 5-5 High-Frequency Conducted Susceptibility Operating Envelopes for Power Leads (R.G.1.180 CS114)

5.5.3.3 High Frequency Conducted Susceptibility Testing for Signal Cable (CS114, CS115, CS116)

The PRM units shall be designed to withstand radio frequency interference coupled onto the instrument cabling, and shall be tested by following the measurement procedure CS114, CS115 and CS116 of MIL-STD-461E to meet the requirement of being subjected to a test signal levels 91dBμA (frequency range from 10 kHz to 30 MHz) (CS114), 2A (CS115) and 5A(frequency range from 10kHz to 100MHz)(CS116).

5.5.3.4 Radiated Susceptibility, Magnetic Fields (RS101)

The PRM instruments shall not be susceptible to the electromagnetic field levels as specified in Figure5-6 that complies with R.G. 1.180 Section 4.3.1. This test is performed in the frequency range of 30 Hz to 100 kHz. This test shall be performed in accordance with the MIL-STD-461E RS101.

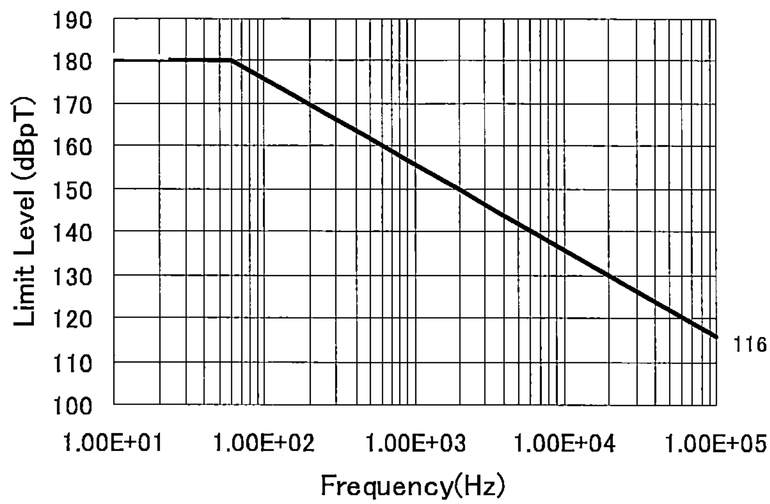


Figure 5-6 Low-Frequency Radiated Susceptibility Envelopes (R.G.1.180 RS101)

5.5.3.5 Radiated Susceptibility, Electric Fields (RS103)

The PRM instruments shall not be susceptible to the electromagnetic field strength of 10 V/m. This test shall be performed at frequency range of 30 MHz to 1 GHz. This test shall be performed in accordance with MIL-STD-461E, RS103.

5.5.3.6 Low-Frequency Conducted Emissions (CE101)

The PRM units shall not be susceptible to the electromagnetic emissions specified in Figure 5-7 that complies with R.G.-1.180 Section 3.1. Since the PRM uses less than 1KVA of AC power, this test shall be performed using the appropriate curve in Figure 5-7, with frequencies from 60 Hz to 10 kHz. This test shall be performed in accordance with MIL-STD-461E, CE101.

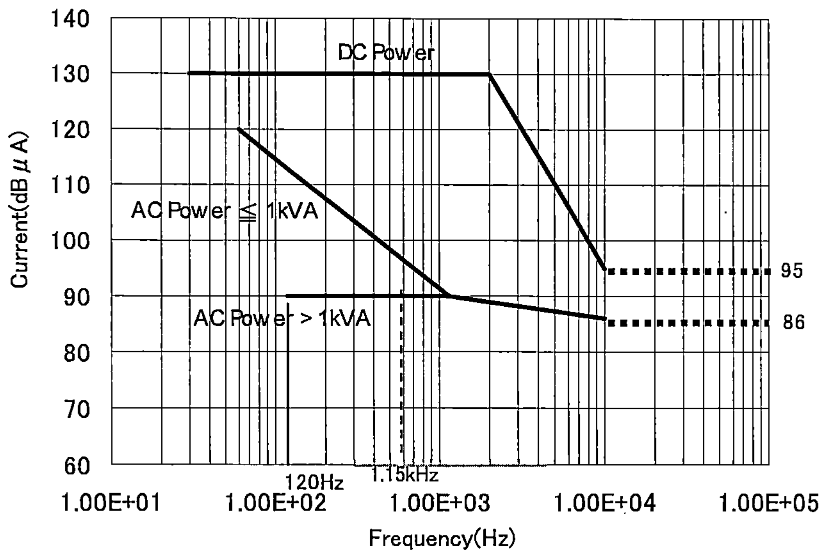


Figure 5-7 Low-Frequency Emissions Envelopes (R.G.1.180 CE101)

5.5.3.7 High-Frequency Conducted Emissions (CE102)

The high-frequency conducted emissions from the PRM units on power leads shall be tested. Conducted emissions on power leads should not exceed the applicable values shown in Figure 5-8 that complies with R.G. 1.180 Section 3.2. This test shall be performed at the frequency from 10 kHz to 2 MHz. This test shall be performed in accordance with MIL-STD-461E, CE102.

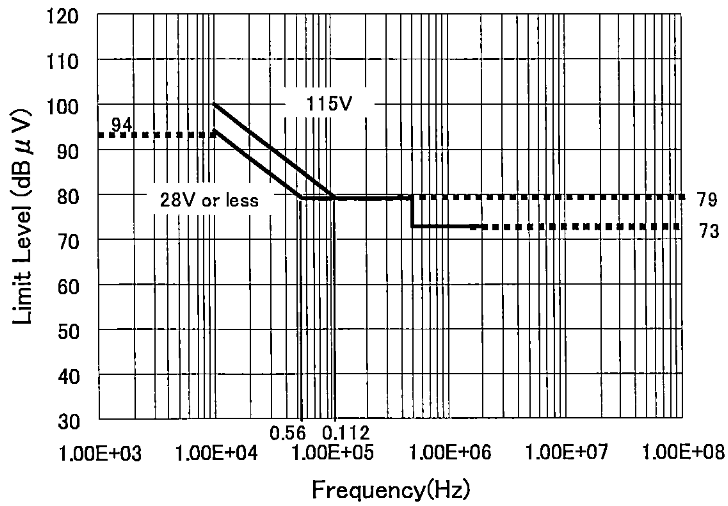


Figure 5-8 High-Frequency Conducted Emissions Envelopes (RG 1.180 CE102)

5.5.3.8 Radiated Emissions, Magnetic Field (RE101)

The radiated magnetic field emissions from the PRM units shall be tested. Magnetic field emissions should not be radiated in excess of the levels shown in Figure 5-9 that complies with R.G. 1.180 Section 3.3. This test shall be performed at the frequency from 30 Hz to 100 kHz. This test shall be performed in accordance with MIL-STD-461E, RE101.

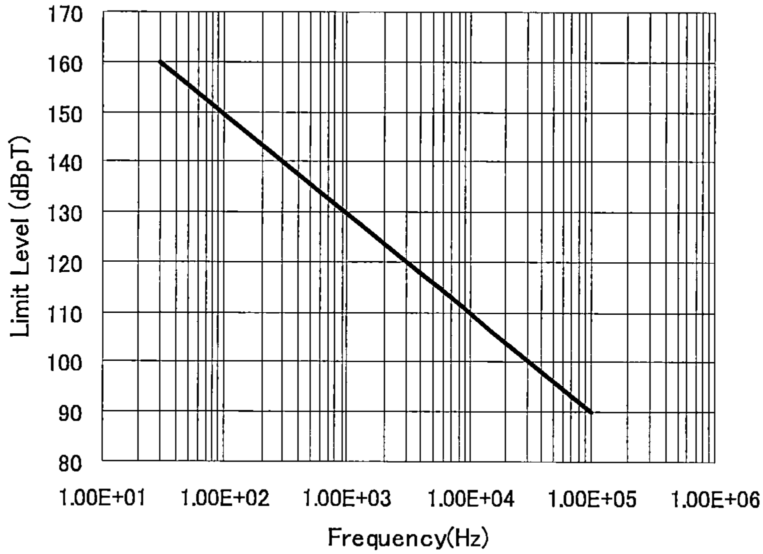


Figure 5-9 Magnetic-Field Radiated Emissions Envelope (R.G.1.180 RE101)

5.5.3.9 Radiated Emissions, Electric Fields (RE102)

The radiated electric field emissions from PRM units shall be tested. Electric field emissions should not be radiated in excess of the RMS values shown in Figure 5-10 which complies with R.G. 1.180 Section 3.4. This test shall be performed at the frequency from 2 MHz to 1000 MHz. This test shall be performed in accordance with MIL-STD-461E, RE102.

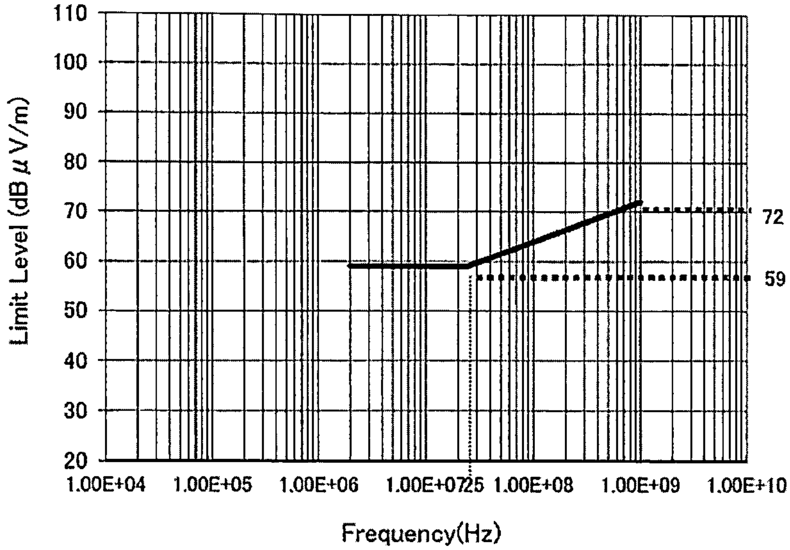


Figure 5-10 Electric-Field Radiated Emissions Envelopes (RG 1.180 RE102)

5.5.4 Surge Withstand Capability Requirements

The PRM instruments shall be qualified to withstand surge voltages from switching and lightning effects as specified in IEC61000-4-5 and IEC61000-4-12. Category B/Low exposure level of R.G. 1.180 shall be applied.

The withstand level shall be as follows:

A. Surge (Ring Wave) (R.G. 1.180 rev. 1. --IEC 61000-4-12.)

Limits (Applied peak voltage)
- Voltage = 2 kV for secondary or derived power distribution systems

Pulse Shape
- 100 kHz, ring wave (0.5 μs rise time, 10 μs pulse width)

Number of tests
- At least five positive and five negative at the selected points

B. Surge (Combination Wave) (R.G. 1.180 rev.1. -- IEC 61000-4-5, severity level: Level 3.

Limits (Applied peak voltage)
- Voltage = ±2 kV for secondary or derived power distribution systems

Pulse Shape

- Impulse of 1.2 μs (±30 %) rise time, 50 μs pulse width, open circuit, double exponential
- Impulse of 8 μs (±20 %) rise time, 20 μs pulse width, short circuit, double exponential

Number of tests

- At least five positive and five negative at the selected points

Surges withstand capability shall include surge applied to following points, if exist:

A. Between line and neutral for AC connections to the power supplies.
B. Between line and AC ground for AC connections to the power supplies.
C. Between neutral and AC ground for AC connections to the power supplies.

Applying the specified level of surge to the specified points does not damage any other module or device or cause disruption of the operation that could result in a loss of the safety-related function.
If there is more than one module or input that are the same type of modules or inputs, surges can be applied to only one representative module for each type.

5.5.5 EFT/B Withstand Requirements

The PRM instruments shall be qualified to perform when they are subjected to repetitive Electrically-Fast Transient/Burst (EFT/B) as specified in IEC 61000-4-4 on supply, signal or control lines.

The withstand level shall be as follows:

A. EFT/B Level (Section C\5.3 of R.G. 1.180 Rev.1-- IEC 61000-4-4, severity level: Level 3 (low exposure))

   Limits (Applied peak voltage)

   - Voltage = ±2 kV for secondary or derived power distribution systems (Level 3)

   Pulse Shape

   - Impulse of 5 ns (±30 %) rise time, 50 ns pulse width, double exponential

   Repetition

   - Repetition rate = 5 kHz (±2 kVp-p)
   - Burst duration = 15 ms
   - Burst period = 300 ms

EFT/B pulses shall be applied to following points, if exist:

A. Between line and neutral for AC connections to the power supplies.
B. Between line and AC ground for AC connections to the power supplies.
C. Between neutral and AC ground for AC connections to the power supplies.

5.5.6 ESD Withstand Requirements

The PRM instruments shall be qualified to cope with electrostatic discharges at a severity of Level 4 as specified in IEC 61000-4-2. (EPRI TR-107330 Section 4.3.8. and EPRI TR-102323, Appendix B, Section 3.5).
The withstand level shall be as follows:

A. ESD Level (IEC 61000-4-2 Level 4)

Pulse Wave Shape:	Specified as current output from 150 pF storage capacitor through a 330 ohm discharge resistance into a specific load defined in each Referenced standard
Pulse Rise Time:	Equal or less than 1 ns
Pulse Decay Time:	Approximately 30 ns at 50% height
Pulse Amplitude:	Specified as charge voltage to simulator. For uncontrolled ambient temperature, pressure, and humidity
Air discharge:	±15kV
Contact discharge:	±8kV
Pulse repetition:	Apply minimum of ten simulations for each polarity at each test point while the digital system is operating
Relative Humidity:	Between 30% RH and 60% RH

Test Points should be selected on the basis of accessibility during operation.

Subjecting the PRM equipment to this level of ESD shall not disrupt operation or cause any damage.

5.5.7 Isolation Requirements

1. Isolation capability of Class 1E/Non-Class 1E is shown at least 600 VAC and 250 VDC applied for 30 seconds. Applying a signal within the specified range for the time shall not disrupt the operation of any other module. AO modules connected to non-class 1E equipment shall be qualified under the condition specified in Section 5.5.1.
2. The group-to-group isolation of DIO module shall be shown at least 40 volts peak, which means that applying this level to an input shall not disrupt operation or cause any damage of any other input channel on the module.
3. TRN modules shall be isolated to non-class 1E equipment through the one way fiber optic cable.

5.5.8 Power Supply

The power supply to the PRM System shall be from 120 VAC class 1E uninterrupted power sources and Low Exposure levels described in R.G. 1.180 Section 5.

The PRM System shall operate for AC source range of 90 to 150 VAC and frequency range of 57 to 63 Hz (EPRI TR-107330 Section 4.6.1).
Sources shall be capable of supplying 1.2 times bus loading for a fully loaded main chassis.

The supply modules shall operate over the temperature and humidity range given in Section 5.5.1.

Each PRM unit has two LVPS modules that operate in parallel. Each LVPS module has enough capacity to supply power to all modules mounted in the chassis.

During Hold up time for AC power sources (40 ms), digital I/Os shall not change and the change of analog I/Os shall be within 5% of full scale (EPRI TR-107330 Section 4.6.1).

Failure of one of the redundant power supplies for more than 2 ms shall not cause the discrete I/O to change state, the analog I/O signals shall not change more than 5%, and the application logic shall continue to operate.

Redundant power supply modules shall be protected so that undervoltage and overvoltage, shorts to ground, and other faults in one power supply do not prevent operation of the alternate power supply.

5.5.9 [Deleted]

5.6 Classification

The PRM Units are classified as safety-related. The PRM units shall be designed to meet all requirements of IEEE Std 603.

5.7 [Deleted]

5.8 Maintenance Requirements

1. Corrective maintenance of any hardware component shall not be required more frequently than every 14 days over the entire design life.
2. Repair of equipment shall normally be accomplished by simple modular replacement in the field as specified in Section 5.2.4.6.
3. No activity associated with expected maintenance or repair of the equipment shall prevent any plant safety or protection system from fulfilling its required function. In addition, the systems shall be designed to permit expected maintenance, to the greatest extent practical, while the plant is on power.
4. The PRM safety-related instruments shall be designed to allow periodic testing and calibration in accordance with the requirements of IEEE Std 338.
5. The modules shall be designed for easy access of removal and installation.
6. The design baseline of the qualified units shall be maintained as NED activities.
7. The information necessary to fulfill tasks specified in Item 6 above shall be obtained from NICSD.

5.9 Design Method

Equipment shall be designed accordance with this requirement specification.

5.10 Material requirements

If any hazardous materials are used as part of the system equipment, then Material Data Sheets (MDSs) shall be provided for these materials.

5.11 Requirements for Third Party/Sub-Vendor Items

All items provided by sub-vendors or third parties shall be subjected to all applicable requirements and tests. Compatibility of operation with the FPGA-based unit shall be demonstrated through tests.

6 Fabrication Requirements

The PRM System is a safety-related system. Therefore, the design and fabrication of the PRM System shall satisfy this specification and the required codes and standards stated herein.

The design and fabrication of the PRM System shall be made in accordance with the requirements of the US Nuclear Regulations and the Toshiba Corporation, Power Systems Company, Nuclear Energy (PSNE) QA Program.

7 Test Requirements

This section describes the test requirements for the PRM System. The Test Specimen Requirements are specified in 7.3.1.

The following tests shall be performed:

- Unit and Module Tests
- Pre-Qualification Tests
- Qualification Tests

Before performing the tests, detailed test procedures shall be issued.

In addition to these tests, the system validation testing shall be performed. For the system validation testing, refer to the V&V Plan.

7.1 Unit and Module Test

Unit and Module test shall be performed by NICSD to provide evidence that the units meet the design requirements.

Unit test shall include the following:

A. Visual and Dimensional Inspection
The dimension of the module and unit shall be inspected to verify that they are fabricated in accordance with the applicable drawings.

B. Insulation Resistance test
Insulation resistance of the units shall be measured before the withstand voltage test.

C. [Deleted]

D. FPGA Tests
All FPGAs shall be tested adequately to verify their functions.

E. Performance Test
The module and unit shall be tested to verify their performance which meets the requirements in the applicable requirements specification.

7.2 Pre-Qualification Test and Test Requirements

This section describes the requirements for the pre-qualification test that are performed as the first category of the qualification test, to demonstrate that the Test Specimen operates as intended, and provides a baseline for the qualification test.

This test shall be performed before the qualification test in order to ensure the correct

operation of the system and to provide baseline performance data on operation of the Test Specimen.

The following tests are performed as pre-qualification test and generally described in Section 7.2.1.

A. System Set-up and Check-out Test
B. Burn-in Test
C. Operability Test
D. Prudency Test
E. Power Quality Tolerance Test

7.2.1 Pre-Qualification Test

This test shall include the following items:
More detail explanation for item D is shown in Section 7.2.2 and for item E is shown in Section 7.2.3.

A. System Set-up and Check-out Test

Wiring Inspection
All wiring shall be inspected through a point-to-point continuity check per Electrical Cable Wiring Diagram (ECWD). All errors or omissions shall be corrected before proceeding with further testing. Incorrect wiring shall be completely removed from the test system.

Initial Calibration
The instrumentation measuring and test equipment used for this test was calibrated by equipment traceable to the National Institute of Standard and Technology (NIST) or the National Metrology Institute of Japan (NMIJ). Both NIST and NMIJ are signatories to the Bureau International des Poids et Mesures (BIPM). The AS LEFT data is used as a baseline for qualification testing. The acceptance criteria are that the equipment accuracy meets the requirements specified in Section 5.1.4.

System Integration
The system integration testing portion of the V&V phase in the digital system life cycle shall be performed during system validation testing. The acceptance criteria for these tests shall be based on the requirements specification for the test specimen specified in Section 4.1.2.
The setpoint variation test shall also be performed during system testing. The acceptance criteria for setpoint variation shall be in accordance with Section 5.1.3.

B. Burn-in Test
A minimum 352 hours burn-in test shall be performed on the Test Specimen. The objective of this test is to detect any early hardware failures that might otherwise impact the subsequent qualification test activities. The acceptance criteria are that Test

Specimen shall pass the operability test following the burn-in test. If any failure occur, the failed component shall be replaced and the replaced, items shall be burned in and retested.

C. Operability Test
The operability test and its requirement is described in Section 7.2.2. The operability test shall be performed during pre-qualification test, and during qualification test as described in Section 7.2.4.
This test establishes the Test Specimen baseline performance and verifies the suitability of the operability test procedure to be used for later qualification test.

D. Prudency Test
The prudency test and its requirement is described in Section 7.2.3. The prudency test shall be performed during pre-qualification test, and during qualification test as described in Section 7.2.4.
This test establishes the Test Specimen baseline performance and verifies the suitability of the prudency test procedure to be used for later qualification test.

E. Power Quality Tolerance Test
Power quality tolerance test to the given input voltage and frequency range shall be performed during pre-qualification test, and during qualification test. The power source requirements are given in Section 5.5.8.
In addition, the testing shall include the decreasing the source voltage to meet the minimum voltage requirement specified in Section 5.5.8.

Redundant power supply module shall be tested with the same AC power supply connected to both modules during the testing in accordance with Section 5.5.8.

7.2.2 Operability Test Requirements

Operability test shall cover the following items:

A. Accuracy
Accuracy checks shall be performed for safety-related functions defined in Section 4.1.2 for analog inputs and outputs.
Minimum five point linearity checks shall be made on the analog inputs and outputs. The test shall be performed on at least one channel of each type of analog inputs and /outputs in the qualification envelope.

Trip accuracy and trip reset accuracy shall be checked on the DIO module. The test shall be performed on at least one channel of each type of DIO module in the qualification envelope.
The acceptance criterion is to meet the requirements given in Section 5.1.4.

B. Response Time

The response time between receiving an analog input and generating a digital output for safety-related functions, and the response time between receiving a digital input and generating a digital output for safety-related functions defined in Section 4.1.2 shall be measured in such a way that the repeatable results can be obtained. The acceptance criteria are that the measured response time for the baseline testing shall be equal to or less than the response time given in Section 5.1.3.1. Toshiba considers that the absolute response time criteria established for the PRM as application specific requirements are more important and applicable for the FPGA system than the plus minus 10% change criteria addressed in the Section 5.3B of EPRI TR-107330 which Toshiba interprets as the requirements for PLC based systems.

C. Discrete Input Operability

The discrete inputs shall be tested for their ability to detect changes for safety-related functions defined in Section 4.1.2. These tests shall be performed on at least one channel of each type of discrete input module. The acceptance criteria is that the operational modes of safety-related functions shown in Section 4.1.2 shall be changed according to discrete input within the unit and module requirements given in Section 5.2.2.2 and 5.2.2.3.

D. Discrete Output Operability

The discrete outputs for safety-related functions defined in Section 4.1.2 shall be tested for their ability to implement the required functionality. The test shall be performed on at least one channel of each type of discrete output in the qualification envelope. The acceptance criteria are that the discrete output of safety-related function which is shown in Section 4.1.2 shall be changed within the unit and module requirements given in Section 5.2.2.1, 5.2.2.2, and 5.2.2.3.

E. Failure Detection and Self-Test

The functions to detect failures shall be tested. The acceptance criteria for detecting the failure shall meet the requirements of Section 5.1.6 (except (e), (f), (g). These functions should be qualified by the vendor.)

F. Loss of Power Test

The AC power source shall be shut off for at least 30 seconds and reapplied. The acceptance criteria are that all output for safety-related functions shown in Section 4.1.2 shall turn to the power off default and power on default states and normal operation shall resume after the restoration of power.

G. Power Interruption Test

The AC power source shall be interrupted for 40 ms.

The acceptance criteria are that the Discrete Outputs for safety-related functions as shown in Section 4.1.2 shall not change, and the PRM System shall not be reset.

7.2.3 Prudency Test Requirements

This test shall be applied as specified in Section 7.2.4. The prudency test shall include the following tests:

A. Burst of Events Test
   This test consists of actions as follows:
   (1) Simultaneously toggling all +24 V discrete inputs at 1 second ±10% interval (if sampling interval of PRM modules is shorter than 0.1 s, interval for toggling is 1 second ± one sampling interval) for at least one minute.

   The acceptance criteria are as follows:
   - APRM High-High Trip occurs within 40 ms after the Reactor Operation Mode DI is changed to OFF.
   - The number of the toggles of Reactor Operation Mode DI and the number of APRM High-High Trips are the same.

   (2) Simultaneously driving all inputs from 0 to 125% at 1 Hz ±10% interval (if sampling interval of the PRM System is shorter than 0.1 s, interval should be 1 Hz ± one sampling interval) for at least one minute.

   The acceptance criterion is as follows:
   APRM High-High Trip occurs within 28 ms after APRM AO outputs exceed 120.0% level. This criterion is based on the expected response time of the PRM to the input change above.

B. [Deleted]

C. [Deleted]

D. Fault Simulation Test
   Failure of one of the redundant LVPS module shall be simulated. The system successfully detects the failure (using self-diagnosis) and transfers to another LVPS module, and continues normal operation. The acceptance criteria are follows:

   1. Trips for the safety-related functions as shown in Section 4.1.2 do not occur.
   2. The discrete outputs of the safety-related functions in Section 4.1.2 do not change.
   3. The analog outputs of safety-related functions in Section 4.1.2 do not change more than 5%.

   Note that this item is same as Item E of Section 7.2.2 applied for the Section 5.1.6 Item (b).

7.2.4 Operability and Prudency Test Applicability

The operability test of Section 7.2.2 and prudency test of Section 7.2.3 shall be performed at the points given in the following table.

		Operability Test	Prudency Test
Pre-Qualification Test		Conduct	Conduct
Radiation Exposure		-	-
Environmental Test	Before High Temperature and High Humidity Exposure	Conduct for specific scope (Note 1)	-
	During High Temperature and High Humidity Exposure	-	-
	After High Temperature and High Humidity Exposure	Conduct for specific scope (Note 1)	Conduct for specific scope (Note 3)
	During Low Temperature Exposure	-	-
	After Low Temperature Exposure	Conduct for specific scope (Note 1)	-
	During Low Humidity Exposure	-	-
	After Low Humidity Exposure	Conduct for specific scope (Note 1)	-
	After all Environmental	Conduct for specific scope (Note 1)	-
Seismic Test	Before Seismic Test	-	-
	During Seismic Test	-	-
	After Seismic Test	Conduct	-
Replacement of Modules (LPRM Modules were replaced with HNS013 from HNS011. AO Modules were replaced with HNS515/516/517/518 from HNS511/512/513/514.			
EMC Test	Before EMC Test	Conduct for specific scope (Note 2)	-
	During EMC Test	-	-
	After EMC Test	-	-
Isolation Test(Class 1E to Non 1E Test)		-	-
Post Qualification Test(Before re-replacement of modules)		Conduct for specific scope (Note 2)	-
Re-Replacement of Modules (LPRM Modules were replaced with HNS011 from HNS013. AO Modules were replaced with HNS511/512/513/514 from HNS515/516/517/518.			
Post-Qualification Test(After re-replacement of modules)		Conduct	Conduct

Notes for this table are listed in the next page.

The Operability Test and the Prudency Test to be conducted in the Pre-Qualification Test and the Post-Qualification Test (After re-replacement of modules) include the following Tests.

Operability Test:

(1) Linearity test for APRM level, TPM level, and LPRM level at the LPRM gains 40μA/100%

(2) Linearity test for APRM level, TPM level, and LPRM level at the LPRM gains 400μA/100%

(3) Linearity test for APRM level, TPM level, and LPRM level at the LPRM gains 2400μA/100%

(4) APRM Upscale (High-High) trip and TPM Upscale trip response time test at the LPRM gains 40μA/100%

(5) APRM Upscale (High-High) trip and TPM Upscale trip response time test at the LPRM gains 400μA/100%

(6) APRM Upscale (High-High) trip and TPM Upscale trip response time test at the LPRM gains 2400μA/100%

(7) Linearity test for FLOW level
(8) APRM Inoperable trip function test
(9) DI function test
(10) Low voltage power supply failure test for LPRM unit
(11) Low voltage power supply failure test for LPRM/APRM unit
(12) Low voltage power supply failure test for FLOW unit
(13) Watchdog function test for LPRM unit
(14) Watchdog function test for LPRM/APRM unit
(15) Watchdog function test for FLOW unit
(16) Current value test of Square Root module in FLOW unit
(17) Loss of power test
(18) Power interruption test

Prudency Test:
(19) DI Toggling test
(20) AI Toggling test
(21) Failure simulation test

Note 1: Toshiba did not conduct (1), (3), (4), (6), (8), (10), (11), (12), (13), (14), (15).
Note 2: Toshiba did not conduct (2), (3), (5), (6), (13), (14), (15), (16), but Toshiba conducted watchdog timer function test for the LPRM module inserted Slot1 of LPRM and LPRM/APRM units.

7.3 Qualification Tests

This section describes the qualification tests to be performed on the test specimen. The following two categories of qualification tests shall be performed:

(1) Qualification Tests
Qualification Tests for Environmental test and post SSE test shall be performed in order to confirm that the Test Specimen meet the requirements provided in this ERS. In addition, these tests shall be performed to operate of the Test Specimen under the subjected stress conditions.

Qualification Tests shall be performed on the Test Specimen after successfully performing the pre-qualification Test.

The following tests are performed as part of the Qualification Tests:

A. System Set-up and Check-out Test
This test is performed before the each step at B through H. If the test location is changed, this test is performed prior to any new test.
B. Environmental Test
C. Seismic Test
(Resonance Search Test and tri-axial Seismic Withstand Test)
D. EMI / RFI Test
E. Surge Withstand Test
F. EFT/B Test
G. ESD Test

H. Class 1E to Non-Class 1E Isolation Test

(2) Performance-Proof Test
This test shall be performed on the qualification tested Test System as a final demonstration of acceptable system performance.

The following tests are performed as part of the performance-proof tests:

A. System Set-up and Check-out Test
B. Operability Test
C. Prudency Test

7.3.1 Test Specimen Requirements

7.3.1.1 Test Specimen Hardware Configuration and Arrangement Requirements

The hardware configuration of the Test Specimen shall conform to the PRM System configuration specified in Section 5.2.1. The Test Specimen is a part of the PRM System; the Test Specimen includes one LPRM/APRM Unit, one LPRM Unit, and one FLOW unit. LPRM unit shall include 12 LPRM modules.

7.3.1.2 Test Specimen Software Requirements

The Test Specimen shall include the FPGAs in which the application logic have been embedded.

7.3.1.3 Test Support Equipment Requirements

The test support equipment to support test shall be provided in accordance with EPRI TR-107330 Section 6.2.3.
The supporting equipment included is:

- Panels or other devices for connecting to the inputs and outputs, which contains procedures for connecting, simulating inputs and monitoring outputs.
- Test and measurement equipment shall have the accuracy needed to support the test acceptance criteria.
- Any special tools and devices needed to support testing.
- All test equipment shall be controlled per IEEE 498.

In addition, the following requirements shall be met.

- Relays used in the Test Equipment that generates the simulated output signals to the RPS shall comply with the relay requirements shown in Section 4.3.1.
- Input signal specification for relays used in the Test Equipment that generates the

simulated output signals to the RPS shall comply with the output signal specification for DIO module shown in Section 5.2.3.1.

7.3.2 Qualification Tests and Analysis requirements

Qualification tests shall be performed as described in the following sections.
All testing shall be performed on the calibrated PRM System with setpoint values adjusted to nominal values.

7.3.2.1 Aging Requirements

The following tests represent the aging factors that the PRM System will be exposed to during qualification tests:

(1) Environmental (Abnormal Temperature and Humidity)
(2) Seismic
(3) EMI/RFI
(4) Surge Withstand
(5) ESD
(6) EFT/B Test

The environmental test must be performed before the other tests. The order of the other five tests is permutable.

7.3.2.2 EMI/RFI Test Requirements

EMI/RFI test shall be performed to the level and for the emission types specified in Section 5.5.3.

The acceptance criteria are specified in Section 5.5.3.
If the Test Specimen does not satisfy the acceptance criteria for each test in the application of the specified level, the reduced susceptibility tests shall be additionally performed.

7.3.2.3 EMI/RFI Test Mounting Requirements

Test Specimen shall be connected to ground. The grounding used for these tests shall meet grounding and shielding requirements specified in Section 5.2.4.5.

7.3.2.4 Environmental Test Requirements

Environmental test shall be performed to the environmental withstand requirements given in Section 5.5.1 to assure that the PRM System does not have fail its performance due to service conditions of temperature and humidity.

Abnormal environmental test shall be performed using the profile given in Figure 5-2 with power supply that maximum dissipate heat into the PRM System.

7.3.2.4.1 Environmental Test Mounting Requirements

The Test Specimen shall be mounted in the environmental chamber on a simple structured rack that does not enclose the chassis. The environmental air shall be monitored at the bottom of the chassis. No additional cooling fan should be included in the chamber.

7.3.2.5 Seismic Test Requirements

The Test Specimen shall meet its performance requirements for the seismic loads specified in Section 5.5.2. All seismic tests shall conform to IEEE Std 344. Tri-axial, random, multi-frequency shaking table shall be used for seismic withstand capability.

The vibration aging shall use the five OBEs with the Required Response Spectrum (RRS) as shown in Figure 5-3 followed by an SSE with the RRS as shown in Figure 5-3.

7.3.2.5.1 Seismic Test Mounting Requirements

The Test Specimen shall be mounted on a structure that shall be stiff enough so that there are no resonances below 100 Hz with the Test Specimen mounted on it. Each unit should be fixed to the shaking table.

7.3.2.6 Seismic Test Measurement Requirements

The relay contact monitor shall be connected to all relay output channels in the Test Specimen. During seismic test, the relay contacts should be capable of changing state from energized to de-energized and de-energized to energized. Any spurious change of state should be not exceeding 2 milliseconds for both energized and de-energized relays.

In addition to the control accelerometer, one or more response accelerometer for Test Specimen shall be mounted on each chassis (the Test Specimen consist of four chassis). The additional accelerometers shall be located to establish the maximum acceleration that occurs in each chassis.

7.3.2.6.1 Seismic Test Performance Requirements

The following tests shall be performed in the order shown:

(1) Resonance Search
(2) Five tri axial OBEs
(3) A tri-axial SSE
(4) Operability Test

7.3.2.6.2 Seismic Test Spectrum Analysis Requirements

In addition to reporting the test response spectrum from the control and specimen response accelerometers at the damping given in Figure 5-3 (5%), the spectrum is also reported for 1/2, 1, 2 and 3% damping.

7.3.2.7 Surge Withstand Capability Test Requirements

Surge withstand capability test shall be performed per the requirement of Section 5.5.4. The surge shall be applied to the points indicated in that section. For the AO module and the DIO module, the surge needs to be applied to representative points for a given type of module. The test shall be conducted in accordance with IEC61000-4-5 and IEC61000-4-12.

7.3.2.7.1 Surge Withstand Capability Test Mounting Requirements

The Test Specimen shall be connected to ground. The grounding and shielding shall meet the requirements specified in Section 5.2.4.5.

7.3.2.8 Class 1E to Non-Class 1E Isolation Test Requirements

The Class IE to Non-Class 1E isolation capability test shall be performed per requirements specified in Section 5.5.7. The test only needs to be applied to representative points for AO module, DIO module, and TRN modules.

7.3.2.8.1 Class 1E to Non-Class 1E Isolation Test Mounting Requirements

The Test Specimen shall be connected to ground. The grounding and shielding shall meet the requirements specified in Section 5.2.4.5.

7.3.2.9 EFT/B Test Requirements

EFT/B withstand capability test shall be performed per the requirements of Section 5.5.5. For the AO module and the DIO module, the EFT/B test needs to be applied to representative points for a given type of module. The test shall be conducted in accordance with IEC61000-4-4.

7.3.2.10 ESD Test Requirements

ESD test shall be performed to assure that the Test Specimen does not fail due to service condition for the ESD level specified in Section 5.5.6. The Test Specimen shall be connected to ground. The grounding and shielding shall meet requirements specified in Section 5.2.4.5. The acceptance criteria following application of the ESD are given in Section 5.5.6.

7.3.2.10.1 ESD Test Mounting Requirements

Test Specimen shall be connected to ground. The grounding and shielding shall meet the requirements specified in Section 5.2.4.5.

7.3.2.11 Power Quality Tolerance Requirements

The power source requirements are listed in Section 5.5.8. Power Quality Tolerance test to the input voltage range given in Section 5.5.8 shall be performed (1) during the system validation test, (2) at the end of the elevated temperature in the environmental test while the Test Specimen is still at high temperature, and (3) after the Seismic test.
The test shall include reducing the source to a level sufficient to test the requirement per Section 7.2.1.

Redundant power supply module shall be tested with the same AC power supply connected to both modules during the test.

7.3.3 Requirements for Compliance to Specifications

The Test Plan shall define the acceptance criteria of the Qualification Test conforming to the requirements in Section 6.4.4 of EPRI TR-107330.

8 Packaging and Shipping

Packaging and shipping shall be in accordance with ANSI N45.2.2 Level A.

8.1 Packaging Requirements

Packing requirements shall be provided by NICSD. Requirements shall include:

a. Items shall be packaged to avoid damage or degradation due to various environmental and handling factors which may be encountered during shipping and storage.
b. Packaging shall include desiccant materials as required.
c. Items shall be inspected for cleanliness prior to packaging. Items not immediately packaged shall be protected from contamination.
d. Cushioning shall be provided to protect against shock and vibration.
e. Items and containers shall be marked with appropriate identification.
f. Copies of packing lists shall be included with each carton shipped.
g. ESD sensitive items shall be appropriately packaged, handled and marked.
h. Packaging shall be suitable for movement using hand trucks.
i. Special handling or storage requirements shall be marked on the containers.

8.2 Shipping Requirements

Shipping requirements shall be provided by NICSD. Requirements shall include use of fully enclosed vehicles, special handling and stacking instructions as necessary, and container markings and protective covers.

The means of transportation shall be consistent with the protection classification of the item and with the packaging methods employed.

Transportation shall be by use of fully enclosed vehicles from reputable shipping firms to minimize the possibility of theft and vandalism during shipment of items.

Where special care is deemed necessary to avert damage, written instructions covering the located and stacking limit of the crates or boxes on the transport vehicle shall be specified; these shall be marked on the container.

Identification and marking on the outside of packages shall be maintained during shipping.

8.3 Storage Requirements

Storage shall be in accordance with ANSI N45.2.2 Level A.
Storage requirements shall be provided for all items by the manufacturer. Requirements for storage shall include temperature, humidity, and any static control requirements.

9 Documentation Requirements

9.1 Equipment Documentation Requirements

The following documents shall be prepared.

9.1.1 Equipment General Overview Documentation

The system documentation shall include an overview of the generally qualified the PRM System. The overview should include the Equipment Design Specification and the Electrical Cable Wiring Diagram.

The Equipment Design Specification shall include the following information:

A. Description of the equipment structure
B. [Deleted]
C. Installation information
   1. Any variations in mounting.
   2. Information on torques to use for any mounting screws.

3. Any requirements or limitations on the structure on which the PRM System can be mounted on, including space and clearance requirements
4. Any limitations on distance between the equipment and other components.
5. Requirements and specification for any user-supplied hardware required for mounting and connection to the PRM System.
6. Any special handling restriction while installing the units and modules.
7. Grounding and shielding requirements

D. Handling and storage requirements
E. A description of the self-diagnostics and redundancy features.

The Electrical Cable Wiring Diagram (ECWD) shall include information on the types of the interconnections to be used between units based on Figure 4-1.

9.1.2 (Deleted)

9.1.3 Users Manual

The Users Manuals shall include the following information:

A. Information on the operation of the units
- Significance of any status indication
- Any special procedures that should be used for operation
- The use of any switches or controls that are part of a module
- Operation and use of any redundancy feature included in the units

B. Information on the maintenance of the modules and the units
- Any hardware configuration item for each module
- Information for calibration
- Information for troubleshooting
- Information for maintenance
  (Measuring and Test Equipment connection,)
- Information for preventive maintenance
  (i.e. air filter cleanliness, terminations checks, power supply checks, and instrument ground checks)
- [Deleted]
- Trouble shooting, errors, and self-diagnostics messages

9.2 Final Documentation Requirements

All documentations supporting the qualification of the PRM System shall be provided. The requirements for documents to define and record the qualification process include programmatic items to meet Sections 4 and 8 of IEEE Std 323 plus the technical items and acceptance criteria. The items that are to be covered in the documentation are given in the following Subsections.

9.2.1 Programmatic Documentation.

The following items are required to document all aspects of the qualification process.

A. Master Test plan that include:

1. Pre-Qualification test plan
2. Environmental qualification test plan
3. Seismic qualification test plan
4. Surge withstand capability qualification test plan
5. Class 1E to Non-1E isolation qualification test plan
6. EMI/RFI qualification test plan
7. EFT/B test plan
8. ESD test plan
9. Test Performance proof test plan

B. Following test procedures :

1. System Set-up and Check-out test procedure
2. Burn-in test procedure
3. Operability Test procedure
4. Prudency test procedure
5. Environmental test procedure
6. Seismic test procedure
7. Surge withstand capability test procedure
8. Class 1E to Non-Class 1E isolation test procedure
9. EMI/RFI test procedure
10. ESD test procedure

C. Test report
Test report shall include reports that correspond to each of the plans described in item A.

D. Report on all audits
Report on all audits shall include the findings and observations from the audits, and document the closure of any open issues resulting from the audits.

E. Reports on design evaluations
Reports on design evaluations shall address requirements that cannot be reasonably addressed by test.

9.2.2 Technical Items

The documentation of technical items is used to establish and document the Test Specimen, describe the environmental conditions to be tested, design life determination, and pre-aging requirement.

This ERS includes following technical items:

A. Test specimen requirements
B. Test specimen purchasing records
C. Test specimen documentation, see Section 9.2.6, 9.2.7, 9.2.8, 9.2.9, 9.2.10
D. Test document per Section 9.2.11

9.2.3 Application Guide

The Application Guide shall describe the qualification envelop in detail, and provide all of the configuration information needed for guidance in applying the FPGA-based Units to the PRM System.

The Application Guide shall include:

A. The results of the environmental operability tests shall be evaluated and the performance measurements and other suitable information used to describe the qualification envelope for accuracy, response time, and etc. The sufficient detail information to permit comparing the test results to the needs of the particular safety system shall be described.
B. The applied seismic level from the test response spectrum where the PRM System met the requirements per Section 5.5.2 shall be reported as the seismic withstand capability. The seismic withstand capability shall be reported for all damping value used in the test data analysis. The spectrum for the Test Specimen accelerometers as well as the control accelerometers shall be included. Mounting screw requirements and torques shall be provided.
C. The Class 1E to Non-Class 1E isolation level used in the test shall be reported as the qualification value for this parameter.
D. The surge withstand capability level used in the test shall be reported as the qualification value for this parameter.
E. The performance of the PRM System during EMI/RFI test shall be reported for all test levels including the performance of each unit.
F. The actual variation of the PRM System performance during power supply quality test shall be included.
G. A complete description of the PRM System configuration and detail test configuration of each module shall be provided.
H. The configuration information shall include mounting, grounding, and shielding methods used during the tests.
I. The summary of the FMEA and availability analysis shall be included for each unit in the qualification shall be provided.
J. Setpoint analysis support information produced per Section 5.1.3.

K. Information from the surveys and audits of the manufacturer's process that are applicable to future purchasing shall be included.
L. A description of the redundancy features included in the qualification.
M. A description of external devices applied by the qualification or needed to meet any requirement applicable to the qualified equipment.
N. A description of the configuration management
O. [Deleted]
P. Any special practical mounting methods that were used to meet the seismic requirements.
Q. A definition of qualification envelops for specific modules that are different from the overall envelope.
R. A description of any application hardware or software features that are assumed in order to meet qualification requirements.

9.2.4 Supporting Analyses Documentation

A. An FMEA report that is specific to the qualified PRM shall be provided.
B. An Availability/Reliability Analyses report that is specific to the PRM configuration shall be provided.
   The analysis includes the basis for values used in the analysis including the use of operating experience (if used).

9.2.5 V&V Documentation

The following documents are needed to support the V&V process and related software quality processes.

A. Unit and Module specification
B. FPGA specifications
C. Software V&V plan
D. Software V&V report
E. Users Manuals

9.2.6 Test System Description

The Equipment Design Specification describes the Test Specimen hardware and software shall be provided. The contents should be similar to that of the hardware design description.

9.2.7 Critical Characteristics

The Preliminary Technical Evaluation Report shall include a definition of the critical characteristics covered by the qualification Test Specimen and qualification test including pre-qualification test.

9.2.8 Test System Drawing

As part of the generic qualification, a set of documents sufficient to define the Test Specimen shall be provided.

The document shall include:

A. Electrical Cable Wiring Diagram containing a schematic of the Test Specimen, including the external devices to create inputs of the PRM and capture outputs of the PRM, and Test Specimen wiring, power distribution and grounding
B. Layout of Test Specimen chassis and qualification test fixtures
C. Test Specimen mounting and mounting fixtures, including special installation requirement.

9.2.9 System Software/Hardware Configuration Document

Software and hardware configuration used for pre-qualification and qualification test shall be documented. This includes:

A. The identification and revision of the application logic
B. The serial numbers of the hardware

9.2.10 System Setup/Calibration/Checkout Procedure

All of the system setup, calibration and checkout procedures for pre-qualification and qualification test shall be included in the qualification document.

9.2.11 System Test Documentation

The System Validation Test Plan and the Test Report shall be provided. The documents shall include:

A. Test requirements
B. Acceptance criteria for all acceptance, and qualification test. The acceptance criteria are developed from the system requirements, configuration, and test instrumentation
C. Sequence of test
D. Vehicles for recording the test results
E. Requirements for Test Equipment, including the required instruments list and a performance specification for each instrument. These requirements shall conform to IEEE Std 498.

A Test Report summarize the test results.

10 Abbreviations

AI	Analog Input
AO	Analog Output
APRM	Average Power Range Monitor

BWR	Boiling Water Reactor
DI	Discrete Input
DO	Discrete Output
ECWD	Electrical Cable Wiring Diagram
EEPROM	Electrically Erasable Read Only Memory
EFT/B	Electrically-Fast Transient/Burst
EMI	Electro-Magnetic Interference
EPRI	Electric Power Research Institute
ERS	Equipment Requirements Specification
ESD	Electrostatic Discharge
FE	Functional Element
EMI	Electromagnetic Interference
FMEA	Failure Modes and Effects Analysis
FPGA	Field-Programmable Gate Array
FS	Full Scale
HMI	Human Machine Interface
IEEE	Institute of Electrical and Electronic Engineers
LED	Light Emitting Diode
LPRM	Local Power Range Monitor
LVPS	Low Voltage Power Supply
MDS	Material Data Sheet
MTTR	Mean Time To Repair
NED	Nuclear Energy systems & services Division
NICSD	Nuclear Instrumentation & Control Systems Department, Fuchu Complex
NIST	National Institute of Standard and Technology
NRC	Nuclear Regulatory Commission
NRW-FPGA	Non-Rewritable Field Programmable Gate Array
OBE	Operating Basis Earthquake
PRM	Power Range Monitor
PRS	Problem Reporting Sheet
PSNE	Toshiba Corporation, Power Systems Company, Nuclear Energy
RCV	Receiver
RFI	Radio Frequency Interference
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RRS	Requirement Response Spectrum
SSE	Safe Shutdown Earthquake
SIL	Software Integrity Level
SQAP	Software Quality Assurance Plan
SQ-ROOT	Square Root
TRN	Transmit
VHDL	Very high speed integrated circuit Hardware Description Language
V&V	Verification and Validation

Attachment A-1 [Deleted]

Attachment A-2 [Deleted]

Attachment B [Deleted]