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Subject: **Topical Report NEDO-33288 – APPLICATION OF NUCLEAR MEASUREMENT ANALYSIS AND CONTROL (NUMAC) FOR THE ESBWR REACTOR TRIP SYSTEM**

The purpose of this letter is to provide the basic structure and overview of the Reactor Trip System (RTS) architecture for the ESWBR as referenced in General Electric letter MFN 07-004, dated January 20, 2007.

GE intends to apply the NUMAC architecture for the ESBWR Reactor Trip System. The basic structure and overview of this architecture is provided in GE Topical Report NEDO-33288, Revision 0. Please note that NEDO-33288 is being submitted as a non-proprietary document. Also, the title has changed from "NEDC-33288P-Application of Nuclear Measurement Analysis and Control for a New BWR (NUMAC Platform Architecture)" as referenced in MFN 07-004.

Planned revisions to Design Control Document (DCD) Subsections (see Markup Index Table in Enclosure 1) reflecting references to this report and changes to be consistent with this LTR will be included in DCD, Tier 2, Revision 4, as shown in Enclosure 1. NEDO-33288, Revision 0 is provided in Enclosure 2.

If you have any questions or require additional information, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey

D068

Project Manager, ESBWR Licensing

Reference:

1. MFN 07-004, Letter to U.S. Nuclear Regulatory Commission from Jim Kinsey, *Schedule for Submitting ESBWR Instrumentation and Control Licensing Topical Reports*

Enclosures:

1. MFN 07-160, RTS Topical Report NEDO-33288 – Markup Index Table and Chapter 7 DCD Tier 1 and Tier 2, Proposed Markups for DCD Revision 4
2. MFN 07-160, RTS Topical Report NEDO-33288 – NUMAC Platform Architecture – NEDO-33288

cc: AE Cubbage USNRC (with enclosures)
GB Stramback GE/San Jose (with enclosures)
B.E. Brown GM Regulatory Affairs (with enclosures)
eDRF 0065-4975

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Enclosure 1

Markup Index Table and Chapter 7 DCD Tier 1 and Tier 2, Proposed Markups for DCD Revision 4

Markup Index Table		
Tier	**Section**	**Item**
1	2.2.5	5th paragraph, 4th sentence
1	2.2.5	11th, 12th, 13th paragraphs, last sentences
1	Table 2.2.5-1	8th item, Design Commitment wording
1	Figure 2.2.5-1	Altered figure
1	Figure 2.2.5-2	Altered figure
1	Figure 2.2.7-1	Altered notes
1	2.2.10	1st paragraph, 1st sentence
1	2.2.12	4th Paragraph, 3rd sentence
1	Table 2.2.14-1	9th item, Design Commitment and Acceptance Criteria wording
2	Abbreviation List	RPS/RTIF entry
2	7.1.2	First bulleted item
2	7.1.2.8.1	1st paragraph, 1st Sentence.
2	7.1.2.8.1	4th paragraph, 2nd sentence
2	7.1.2.8.3.5	Last sentence
2	7.1.2.8.3.6	1st paragraph, last sentence
2	7.1.2.8.3.6	2nd paragraph, first sentence
2	7.1.2.8.3.8	2nd paragraph, last sentence
2	7.1.2.8.4.1	Last sentence
2	7.1.6.6.1.18	1st paragraph, last sentence
2	7.1.8	Revised reference 7.1-6
2	7.2.1.2.4.1	3rd paragraph, 9th sentence
2	7.2.2.1	Last paragraph, 3rd sentence
2	7.2.2.2.4.3	1st paragraph, 11th sentence
2	7.2.2.2.4.6	1st paragraph, 4th sentence
2	7.2.2.2.4.6	1st paragraph, 7th sentence
2	7.2.2.2.4.7	3rd sentence
2	7.2.2.2.6.1	Last sentence
2	7.2.2.2.6.6	1st paragraph, 3rd and 4th sentences
2	7.2.2.2.6.6	2nd paragraph, 3rd sentence
2	7.2.2.2.6.7	1st sentence
2	7.2.2.2.7.1	Last sentence
2	7.2.2.2.7.4	3rd paragraph, first sentence
2	7.2.2.6.2	5th paragraph, last sentence
2	7.2.2.6.2	6th paragraph, 3rd and last sentences
2	7.2.2.6.2	8th paragraph
2	7.2.2.6.2	9th paragraph (significant re-wording throughout)
2	Figure 7.2-1	Altered Notes
2	Figure 7.2-4	Altered Figure

Markup Index Table		
Tier	**Section**	**Item**
2	Figure 7.2-5	Altered Figure
2	Table 7.2-6	Wording under Action column for OPRM Oscillation Detection
2	7.3.3	Last sentence
2	7.3.3.2	1st paragraph, last sentence
2	7.3.3.4.1	3rd paragraph
2	7.3.5.5	3rd paragraph, 4th sentence
2	7.7.2.2.1, Emergency Rod Insertion Control Panel (ERICP) section	3rd sentence

2.2.5 Neutron Monitoring System

Design Description

The Neutron Monitoring System (NMS) monitors thermal neutron flux and supports the Reactor Protection System. The functions of the system are to:

(1) Monitor the thermal neutron flux in the reactor core;

(2) Provide trip signals to the Reactor Protection System (RPS);

(3) Provide plant power and power distribution information to the operator and plant control systems;

(4) Provide permissives to ATWS and SSLC; and

(5) Provide permissive inhibit to ADS.

The startup range neutron monitor (SRNM), the local power range monitor (LPRM), and the average power range monitor (APRM) are classified as safety-related. The automated incore instrument calibration system (automated fixed in-core probe) and the rod block monitoring function (multi-channel rod block monitor [MRBM]) are classified as nonsafety-related. The NMS safety-related components and associated electrical equipment, which are classified as safety-related are Seismic Category I.

The SRNM monitors neutron flux from the source range to 15% of the rated power. The SRNM has multiple channels, each with one detector, with the multiple channels distributed throughout the reactor core and assigned to four divisions. The SRNM detector is a fixed in-core sensor. Detector cables are separated according to different divisional assignment, connected to their designated preamplifiers located in the Reactor Building. The detector signals are then transmitted to signal processing electronic units in the Control Building.

The LPRM monitors local neutron flux in the power range up to 125% of the rated power, and overlaps part of the SRNM range. LPRM detector assemblies are distributed in the core, with four sensors per each LPRM assembly, to monitor local neutron flux level throughout the core. The LPRM assembly also contains space for the automated fixed in-core calibration detector. The LPRM detector outputs are connected to the APRM signal conditioning units, where the signals are processed and amplified. LPRM detector signals are divided and assigned to four APRM channels corresponding to four divisions. LPRM signals in each APRM channel are averaged and normalized to form an APRM signal, which represents the core average power.

The oscillation power range monitor (OPRM) is part of the APRM. Each OPRM receives the identical LPRM signals from the corresponding APRM channel as inputs, and forms many OPRM cells to monitor the neutron flux behavior of all regions of the core. The LPRMs signals assigned to each cell are averaged to provide an OPRM signal for this cell. The OPRM trip protection algorithm detects thermal hydraulic instability and provides trip output to the RPS if the trip setpoint is exceeded. The OPRM bypass is controlled by the bypass of its associated APRM channel.

The automated fixed in-core instrument calibration system provides local power information at various core locations that correspond to LPRM locations. The automated fixed in-core instrument calibration system uses its own set of in-core detectors for local power measurement and provides local power information for three-dimension core power determination and for the calibration of the LPRMs. The measured data are sent to the plant computer for such calculation and LPRM calibration.

The Rod Control and Information System (RC&IS) uses LPRM signals to detect local power change during the rod withdrawal. If the averaged LPRMs signal exceeds a preset rod block setpoint, a control rod block demand is issued.

Figures 2.2.5-1 and 2.2.5-2 show the configuration of each SRNM division and APRM division.

Each of the four divisions of the SRNM, LPRMs and APRMs instruments is powered by its respective divisional safety-related power supplies. In the NMS outside the primary containment, independence is provided between safety-related divisions, and between the safety-related divisions and nonsafety-related equipment.

The SRNM and APRM trip signal outputs are in four divisions. The SRNM trip and the APRM trip logic are independent from each other. The SRNM generates a high neutron flux trip or a short period trip signal. Any single SRNM channel trip causes a trip in its division. The APRM generates a high neutron flux trip, a simulated thermal power trip signal, or a core power oscillation trip signal. The NMS provides these trip signals to the RPS.

The SRNM trip functions are in effect when the RPS mode switch is <u>not</u> in the RUN position (Non-Coincidence Mode). The SRNM upscale trip setpoint is lowered in the NMS Non-Coincidence Mode (RPS Mode switch in RUN). SRNM trips shall be active only when the reactor mode switch is not in the RUN position.

The SRNM and APRMs are fail-safe in the event of loss of electrical power to any division of their logic ~~equipment~~. A loss of power to any division results in a divisional trip being provided ~~to the RPS~~. DELETE

The NMS bypass function is performed within the NMS. Within the NMS, the bypass functions of the SRNM and the APRMs are separate and independent from each other. The SRNM channels are grouped into four bypass groups. Individual SRNM channels can be bypassed, with one channel being able to be bypassed at any time within each bypass group. At any one time, up to four SRNM channels can be bypassed. At any one time, only one APRM channel can be bypassed. ~~A single~~ bypassed SRNM channel or a bypassed APRM channel does not cause a trip output ~~sent to the RPS~~. DELETE

The NMS provides SRNM flux permissive signal to feedwater runback logics within the Safety System Logic and Control (SSLC), and an APRM flux permissive signal to the Nuclear Boiler System (NBS) logic within SSLC as part of the anticipated transient without scram (ATWS) logics. The SRNM and APRM flux permissive signals from the NMS indicate when the reactor power level is above or below the setpoint in order to allow or disallow the initiation of ATWS mitigation features, such as Automatic Depressurization System (ADS) inhibit (in NBS).

The NMS has the following displays and controls in the main control room:

- SRNM, LPRM, and APRM neutron flux and period displays;
- Trip and bypass status displays; and
- Bypass control devices including SRNM bypass switches (one per bypass group) and APRM bypass switch.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
a trip initiation by requiring coincident trip of at least two divisions out of four to cause the trip output as described in Subsection 2.2.5.	simulated inputs to cause trip conditions in two, then three, and then four divisions at a time of the system	in all test conditions, the system output trip change state, per the system logic design, and thereby provide a trip initiation by coincident trip of at least two divisions out of four to cause the trip output as described in Subsection 2.2.5.
5. The SRNM and PRNM power supplies are provided by the four 120VAC UPS buses.	5. Tests will be conducted after installation.	5. The installed safety-related equipment is powered from the four divisional safety-related UPS.
6. The bypass logics of the SRNM subsystem and the APRMS subsystem are as described in Subsection 2.2.5 and are separate and independent of each other.	6. SRNM and APRMS Bypass functions will be tested by using simulated signals.	6. The as-built SRNM and APRMS bypass logics are in accordance with Subsection 2.2.5.
7. The NMS is designed with channel bypass provisions for on-line test and repair during plant operation. When a channel is placed in by-pass condition, the NMS logic changes from two-out-of-four to two-out-of-three trip.	7. Tests will be conducted with a division in the NMS placed in bypass, and a simulated signal is initiated to cause a trip condition in each of the un-bypassed channels in this system.	7. Report(s) exist(s) and conclude(s) that all output channels change state when at least two out of three un-bypassed channels of remaining divisions of the system have tripped by the simulated signal and the channel under bypass did not change state. The trip condition remains until manually reset.
8. The NMS logic is designed fail-safe such that loss of electrical power to a division of RPS results in a trip output from that division.	8. Tests will be conducted by disconnecting electrical power to one division of NMS at a time, to verify that each division provides a trip output to RPS.	8. Report(s) exist(s) and conclude(s) that the NMS logic is designed fail-safe such that, loss of electrical power to a division of NMS, results in a trip output to RPS.

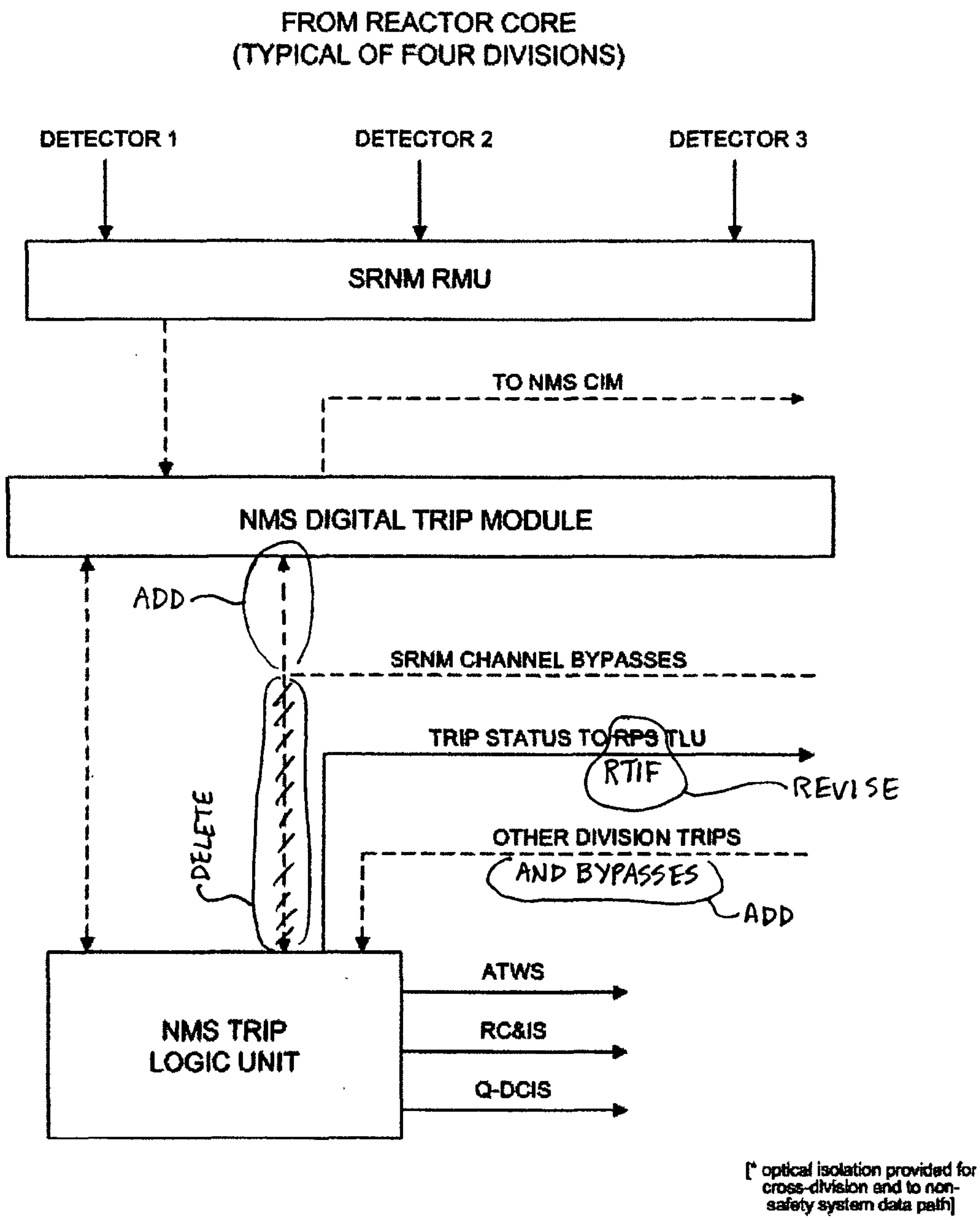

Figure 2.2.5-1. Basic Configuration of a Typical SRNM Division (Subsystem)

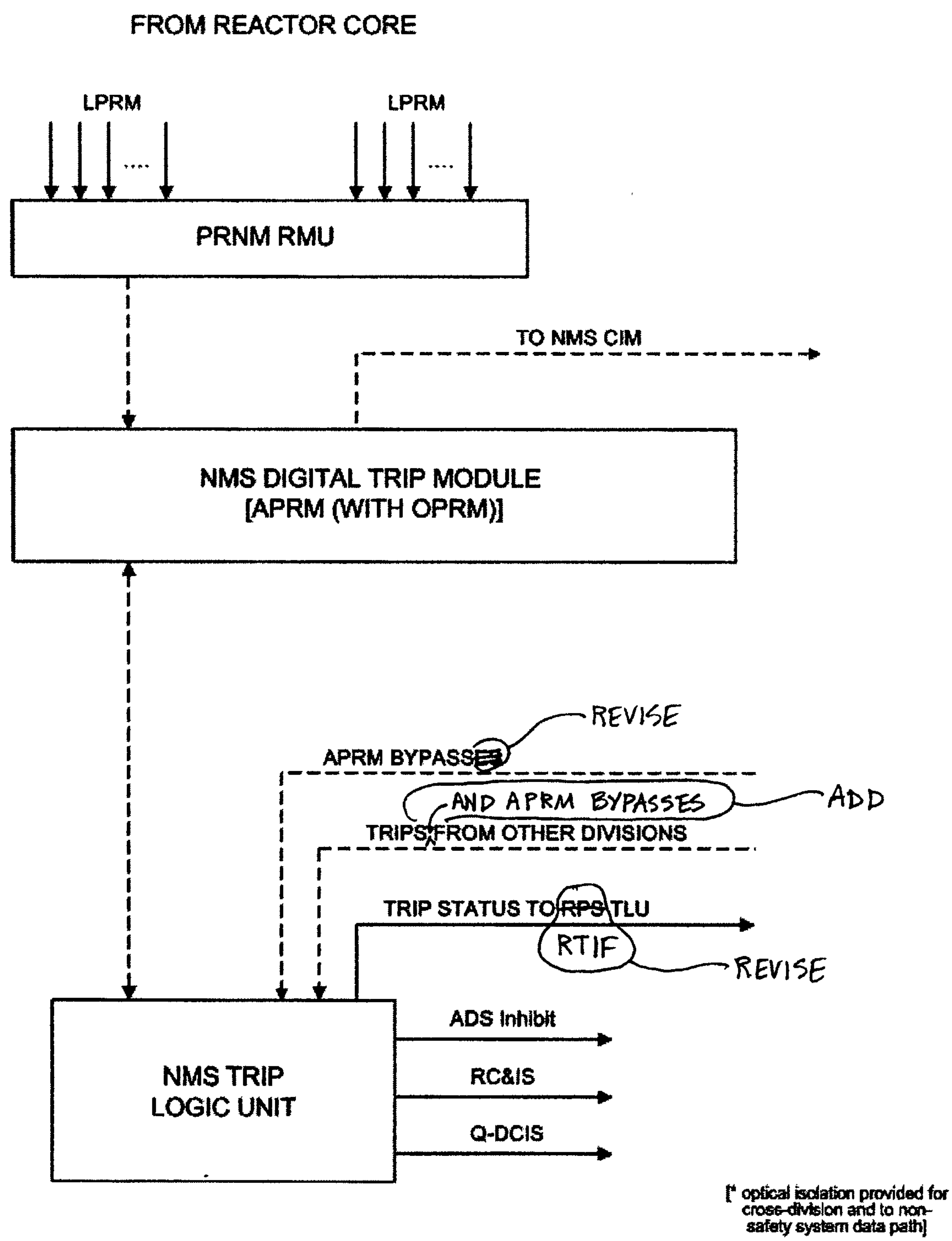

Figure 2.2.5-2. Basic Configuration of a Typical PRNM Division (Subsystem)

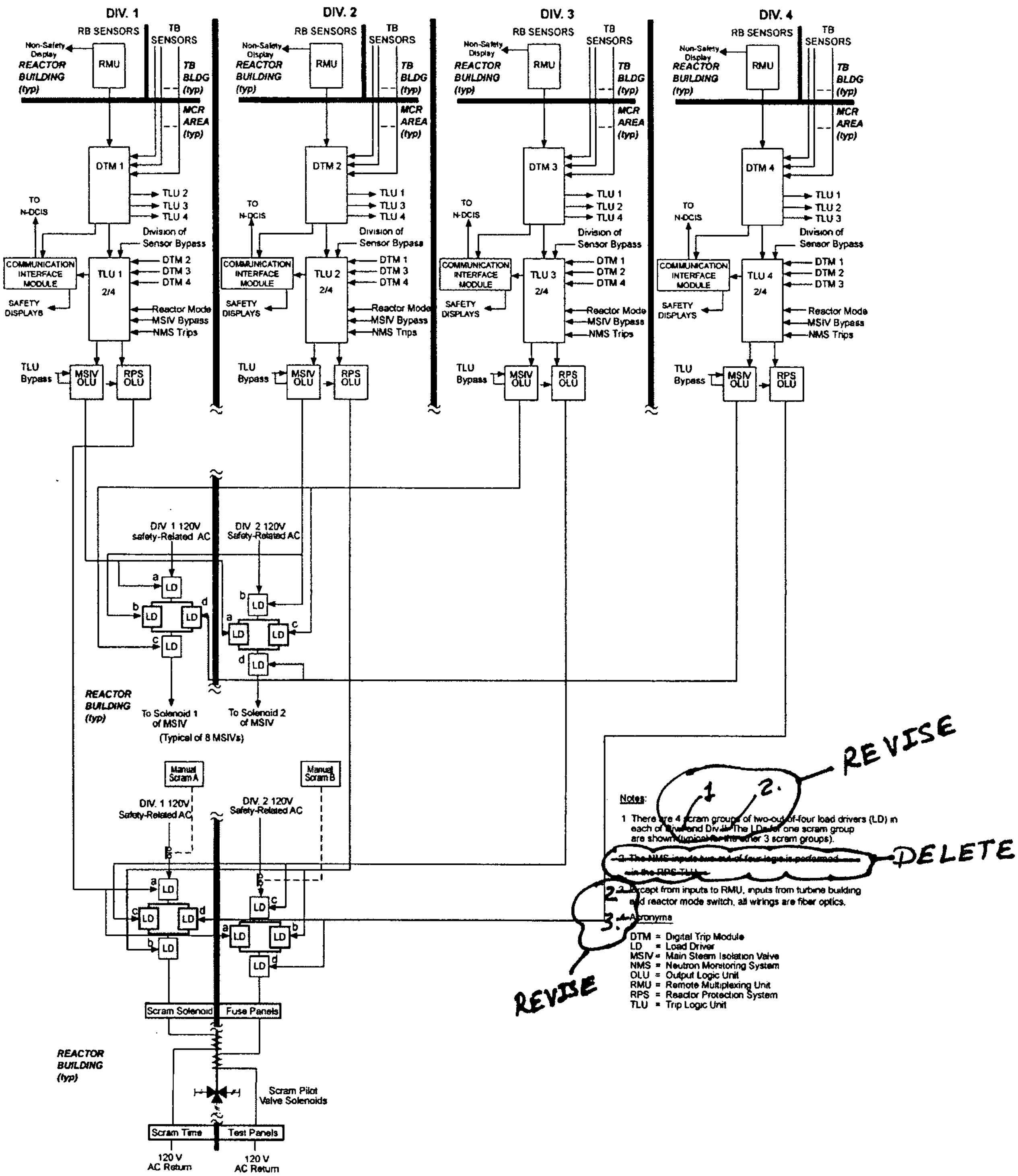

Figure 2.2.7-1. Reactor Protection System Basic Configuration Block Diagram

2.2.10 Safety-Related Distributed Control and Information System

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Design Description

The Safety-Related Distributed Control and Information System (Q-DCIS) is the designation given to the collection of hardware and software that comprise the Reactor Trip and Isolation Function (RTIF) ~~Protection System (RPS)~~, Neutron Monitoring System (NMS), and SSLC/ESF Systems and several other systems and/or functions that have safety-related components (post accident monitoring, containment monitoring, process radiation monitoring, control room habitability). The safety-related portions of the instrumentation, controls, and monitoring systems and/or functions that comprise Q-DCIS are listed in Table 2.2.10-1. The generic functions of the Q-DCIS include:

- Acquisition of data needed for a system to function;
- Provision of a logic platform to implement system functions;
- Provision of an operator interface to allow control and monitoring;
- Output of manual and automatic calculations and commands to system actuators;
- Communication between divisions; and
- Communication between Q-DCIS and Nonsafety-Related Distributed Control and Information System (N-DCIS).

Electrical power is from redundant safety-related sources of the DC Power Supply and Uninterruptible AC Power Supply.

Inspections, Tests, Analyses and Acceptance Criteria

The inspections, tests, and/or analyses, together with associated acceptance criteria for Q-DCIS are contained within the ITAAC tables for the systems in Table 2.2.10-1. The Q-DCIS power supplies and their ITAACs are described in Subsections 2.13.3 (DC Power Supply) and 2.13.5 (Uninterruptible AC Power Supply).

2.2.12 Leak Detection and Isolation System

Design Description

The Leak Detection and Isolation System (LD&IS) detects and monitors leakage from the containment, preventing the release of radiological leakage from the reactor coolant boundary to the environment. The system initiates safety isolation functions by closure of inboard and outboard containment isolation valves. The LD&IS interfaces are shown in Figure 2.2.12-1.

The following functions are supported by the LD&IS:

- Containment isolation following a LOCA event;
- Main steamlines and drain lines isolation;
- Isolation Condenser System process lines isolation;
- RWCU/SDC system process and sampling lines isolation;
- Fuel and Auxiliary Pools Cooling system suction lines from the GDCS pools isolation;
- Chilled Water System lines to DW coolers isolation;
- Drywell sumps liquid drain lines isolation;
- Containment purge and vent lines isolation;
- Reactor Building HVAC (RBVS) air exhaust ducts isolation;
- Feedwater system process lines isolation;
- Monitoring of identified and unidentified leakages in the drywell;
- Monitoring of condensate flow from the drywell air coolers; and
- Monitoring of the vessel head flange seal leakage.

The LD&IS monitors plant parameters such as flow, temperature, pressure, water level, etc., which are used to alarm and initiate the isolation functions. The LD&IS transfers the Table 2.2.12-1 signals to electronic processors for use in isolation logic, alarms and indication.

At least two parameters are monitored for an isolation function. The LD&IS functions are performed in two separate safety-related platforms. The Main Steam Isolation Valve (MSIV) isolation logic functions are performed in the RPS/RTIF system platform, while all other containment isolation logic functions are performed in the SSLC/ESF system. REVISE

The LD&IS safety-related functions have four divisional channels of sensors for each parameter. Two-out-of-four coincidence voting within a channel is required for initiation of the isolation function. The control and decision logic are of fail-safe design, such that loss of electrical power to one LD&IS divisional logic channel initiates a channel trip. The logic is energized at all times and de-energizes to trip for isolation functions. The divisional LD&IS logic channels and associated sensors are powered from safety-related divisional power.

Loss of one divisional power or one monitoring channel does not cause inadvertent isolation of the containment. Different divisional isolation signals are provided to the inboard and outboard

Table 2.2.14-1

ITAAC For Diverse Instrumentation and Controls

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
9. Failure Modes and Effects Analysis (FMEA) per NUREG/CR-6303 of safety-related protection system platforms (RTIF~~RPS~~ and SSLC/ESF) completed to validate the DPS diverse protection function.	9. Complete FMEA per NUREG/CR-6303 to validate the DPS protection functions described in LTR NEDO-33251.	9. Report(s) exist(s) and conclude(s) that the completed FMEA (which address NUREG/CR-6303 Type 1-3 failures) for the RTIF~~RPS~~ and SSLC/ESF safety-related platforms have been addressed in the DPS design scope.

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Abbreviations And Acronyms List

Term	Definition
RAT	Reserve Auxiliary Transformer
RB	Reactor Building
RBC	Rod Brake Controller
RBCC	Rod Brake Controller Cabinet
RBS	Rod Block Setpoint
RCIC	Reactor Core Isolation Coolant
RC&IS	Rod Control and Information System
RCCWS	Reactor Component Cooling Water System
RCPB	Reactor Coolant Pressure Boundary
RDC	Resolver-to-Digital Converter
RFI	Radio Frequency Interference
RFP	Reactor Feed Pump
RG	Regulatory Guide
RMS	Root Mean Square
RMU	Remote Multiplexer Unit
ROM	Read-only Memory
RPS	Reactor Protection System
RPSM	Reactor Protective System Monitoring
~~RPS/RTIF~~	~~Reactor Protection System/Reactor Trip and Isolation Function(s)~~ DELETE
RPV	Reactor Pressure Vessel System
RRPS	Reference Rod Pull Sequence
RSM	Rod Server Module
RSPC	Rod Server Processing Channel
RSS	Remote Shutdown System
RSSM	Reed Switch Sensor Module
RTIF	Reactor Trip and Isolation Function(s)
RTS	Reactor Trip System
RWCU/SDC	Reactore Water Cleanup and Shutdown Cooling
RWM	Rod Worth Minimizer
S/DRSRO	Single/Dual Rod Sequence Restriction Override
SAD	Software Architecture Description
SAG	Severe Accident Guideline
SAS	Service Air System
SB&PC	Steam Bypass and Pressure Control
SBO	Station Blackout
SCM	Software Configuration Management
SCMP	Software Configuration Management Plan
SCRRI	Selected Control Rod Run-in
SCWS	Stator Cooling Water System

Figure 7.1-2, which is a functional representation of the current design. The final DCIS design may alter equipment locations and actual hardware components depending on the chosen DCIS vendors.

Q-DCIS and N-DCIS architectures, their relationships, and their acceptance criteria are further described in this section.

Both Q-DCIS and N-DCIS functions are implemented with diverse power and sensors as indicated in Figure 7.1-3 and diverse hardware and software architectures as shown in Figure 7.1-4 that are fully discussed in Reference 7.1-4 which is the Licensing Topical Report (LTR) entitled, "ESBWR I&C Defense-In-Depth And Diversity Report", NEDO-33251.

Q-DCIS and N-DCIS will be designed and developed in accordance with Appendix 7B, which describes the software quality program for DCIS and addresses the NRC review guidance described in the SRP.

7.1.2 Q-DCIS General Description Summary

Q-DCIS comprises the safety-related portion of the ESBWR DCIS, which performs the safety-related control and monitoring functions. Q-DCIS is organized into four physically and electrically isolated divisions. Each division is segmented into systems; segmentation allows, but does not require, the systems to operate independently of each other. The Q-DCIS major systems and ~~functions are:~~

- Reactor Trip and Isolation Function (RTIF) ~~Protection System (RPS)~~ which includes ~~Reference Section 7.2.1~~:
  - Reactor Trip Functions (Reference Section 7.2.1)
  - Main Steam Isolation Valve (MSIV) Functions of the Leak Detection And Isolation System (LD&IS) (Reference Section 7.3.3)
  - ~~Anticipated Transient Without Scram (ATWS)/Standby Liquid Control (SLC) Functions~~ Suppression Pool Temperature Monitoring Functions (Reference Section 7.2.3)
- Neutron Monitoring System (NMS) which includes (Reference Section 7.2.~~1.3~~ 2):
  - Startup Range Neutron Monitor (SRNM) Functions
  - Power Range Neutron Monitor (PRNM) Functions

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  i. Local Power Range Monitor (LPRM) Functions
  ii. Average Power Range Monitor (APRM) Functions
  iii. Oscillation Power Range Monitor (OPRM) Functions
- Safety System Logic and Control/Engineered Safety Features (SSLC/ESF) System which includes Reference Section 7.3.5:
  - Emergency Core Cooling System (ECCS) Functions
  iv. Automatic Depressurization System (ADS) Functions

7.1.2.8.1 Reactor Protection System (RPS) Description Summary

The RPS ESBWR implements the reactor trip and MSIV LD&IS functions. The RPS is the overall complex of instrument channels, trip logics, trip actuators, manual controls and scram logic circuitry that initiates rapid insertion of control rods to shut down the reactor for situations that could result in unsafe reactor operations. This action prevents or limits fuel damage, limits system pressure excursions and thus minimizes the release of radioactive material.

The RPS also establishes appropriate logic for different reactor operating modes, provides monitoring and control signals to other systems and actuates alarms.

The RPS overrides selected operator actions and process controls and is based on a fail-safe design philosophy. The RPS design provides reliable, single-failure-proof capability to automatically or manually initiate a reactor scram, while maintaining protection against unnecessary scrams resulting from single failures. This is accomplished through the combination of fail-safe (and fault tolerant) equipment design and a two-out-of-four voting logic algorithm.

The RPS sensors, hardware and logic are diverse from SSLC/ESF logic, ATWS Mitigation logic and Diverse Protection System (DPS) logic. The RPS cabinet houses the equipment that performs the Suppression Pool Temperature Monitoring functions for the Containment Monitoring System (CMS) discussed in Section 7.5.2.

7.1.2.8.2 Neutron Monitoring System (NMS) Description Summary

The NMS monitors neutron flux in the reactor core from the startup source range to beyond rated power. The NMS provides logic signals to the RPS to automatically shut down the reactor when a condition necessitating a reactor scram is detected. The system provides indication of neutron flux, which can be correlated with thermal power level for the entire range of flux conditions that can exist in the core. The NMS comprises the following systems:

- SRNM System - The SRNM system monitors neutron flux levels from very low average power levels to a power level well above 15% at which the monitoring function is overlapped with LPRM/APRM to assure continuous monitoring of neutron flux levels. However, the SRNM channel still can provide local power information up to 100%. The SRNMs generate trip signals to prevent fuel damage resulting from abnormal positive reactivity insertions under conditions that are not covered by the APRMs. The SRNMs generate both a high neutron flux trip and a high rate of neutron flux increase trip.

- PRNM System - The PRNM system includes the LPRM, the APRM, and the OPRM functions. The LPRM System provides the average power level of the reactor core, and the OPRM System provides monitoring of neutron flux and core thermal hydraulic instabilities. In the low end of the power range (for example., from 1% to 15% reactor power), the SPRM and PRNM monitoring function overlap.

- Automatic Fixed In-core Probe (AFIP) – This is a nonsafety-related component of the NMS system and has no connections to the Q-DCIS; its function is to calibrate the LPRMs by providing flux information to 3D MONICORE.

- Automatically initiate the GDCS to prevent fuel cladding temperatures from reaching their limits.
- Respond to a need for emergency core cooling, following reactor depressurization.
- Be completely automatic in operation (for example., no operator action required). Manual initiation of GDCS is possible at any time providing a protective permissive has been satisfied.
- Prevent the inadvertent actuation of the deluge valves thus preventing inadvertent draining of the GDCS pools.

7.1.2.8.3.4 Isolation Condenser System (ICS) Description Summary

The primary function of the ICS is to limit reactor pressure and prevent SRV operation following an isolation of the main steam lines. The ICS, together with the water stored in the RPV, provides sufficient reactor coolant volumes to avoid automatic depressurization caused by low reactor water level. The ICS passively removes excess sensible and core decay heat from the reactor, with minimal loss of coolant inventory from the reactor, when the normal heat removal system is unavailable. The ICS is a safety-related system that removes reactor decay heat following reactor shutdown and isolation. It also prevents unnecessary reactor depressurization and operation of the ECCS, which can also perform this function. The IC logic resides on the SSLC/ESF portion of Q-DCIS.

7.1.2.8.3.5 Standby Liquid Control (SLC) System Description Summary

The SLC system performs dual functions. It provides additional coolant inventory to respond to a LOCA, and is a backup method to bring the nuclear reactor to subcriticality and to maintain subcriticality as the reactor cools (discussed in the SLC Subection 7.4.1). The SLC logic resides on the SSLC/ESF and ATWS/SLC ~~(RPS)~~ portions of Q-DCIS.

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7.1.2.8.3.6 Leak Detection and Isolation System (LD&IS) Description Summary

The LD&IS monitors leakage sources from the reactor coolant pressure boundary, and automatically initiates closure of the appropriate valves that isolate the source of the leak if monitored system variables exceed preset limits. This action limits coolant release from the reactor coolant pressure boundary and the release of radioactive materials to the environment. ~~The LD&IS logic for the non-MSIV isolation valves resides on the SSLC/ESF and the MSIV isolation valve logic resides on the RPS portions of Q-DCIS.~~

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The MSIV isolation logic of the LD&IS is performed as part of the ~~RPS~~ logic platform. The non-MSIV isolation logic of the LD&IS is performed as part of the SSLC/ESF logic platform.

7.1.2.8.3.7 Control Room Habitability System (CRHS) Description Summary

The primary function of the CRHS is to provide a safe environment for the operators to control the nuclear reactor and its auxiliary systems during normal and abnormal conditions. The CRHS monitors the Control Room Habitability Area (CRHA) inlet ventilation air and actuates logic to isolate and filter the CRHA on detection of hazardous environmental conditions. The CRHS logic resides on the SSLC/ESF portion of Q-DCIS.

7.1.2.8.3.8 Anticipated Transient Without Scram Mitigation/Standby Liquid Control (ATWS/SLC) Description Summary

The ATWS mitigation logic provides a diverse means of reducing power excursions from certain transients and a diverse means of emergency shutdown. The ATWS mitigation logic, which uses the soluble boron injection capability of the SLC system as a diverse means of negative reactivity insertion, is implemented as safety-related logic (designated as ATWS/SLC). The ATWS/SLC logic also provides a feedwater run-back signal to attenuate power excursions.

In the event that the control rods cannot provide sufficient negative reactivity insertion, the SLC system provides the capability of an orderly and safe shutdown by a diverse means. SLC is sized to counteract the positive reactivity effect of shutting down from rated power to a cold shutdown condition. The SLC system may be initiated manually, or automatically via the ATWS mitigation logic or the SSLC/ESF logic as an ECCS function. The SLC logic resides on the SSLC/ESF and ATWS/SLC ~~(RPS)~~ portions of Q-DCIS.
DELETE

The nonsafety-related ATWS mitigation logic is implemented in the Diverse Protection System (DPS). (See Subsection 7.8.1.1.3)

7.1.2.8.3.9 Passive Containment Cooling System (PCCS) Description Summary

The PCCS functions to cool the containment following a rise in containment pressure and temperature without requiring any component actuation. The PCCS needs no electric power and does not have instrumentation, control logic, or power actuated valves. The PCCS is only briefly discussed here for completeness.

7.1.2.8.4 Containment Monitoring System (CMS) Description Summary

CMS provides the functions identified in the following Subsections. Refer to Subsection 7.5.2 for additional information.

7.1.2.8.4.1 Suppression Pool Temperature Monitoring System Function Description Summary

The safety-related Suppression Pool Temperature Monitoring of the Containment Monitoring System is part of CMS and monitors suppression pool temperatures under all operating accident conditions. The system operates continuously during reactor operation. Should the suppression pool temperature exceed established limits, the Suppression Pool Temperature Monitoring of the Containment Monitoring System provides input for both a reactor scram and for automatic initiation of the suppression pool cooling mode of the Fuel Auxiliary Pool Cooling System (FAPCS) operation. The RTIF cabinet houses the equipment that performs the Suppression Pool Temperature Monitoring functions for the Containment Monitoring System (CMS) ~~diss~~ discussed in section 7.5.2.

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7.1.6.6.1.17 Automatic (IEEE Std. 603, Sections 6.1 and 7.1)

The ESBWR RPS and SSLC/ESF logic is designed to automatically initiate reactor scram trip and actuate the engineered safety features to mitigate the consequences of AOOs and DBEs. Such automatic protection actions are implemented via two-out-of-four voting logic whenever one or more process variables (monitored and measured by each of the RPS and SSLC/ESF divisions) reach the scram or ESF actuation setpoint.

Plant-specific setpoint analyses evaluate whether the protection systems' precision is adequate and thus ensure that the systems' real-time performance is deterministic and known. ESBWR instrument setpoints are determined by setpoint and safety-related analyses described in the GE Setpoint Methodology Licensing Topical Report, NEDC 31336P-A (See Reference 7.1-9). The GE Setpoint Methodology uses plant-specific setpoint analyses to ensure that the characteristics of the instruments (that is, range, accuracy and resolution) meet the performance requirements assumed for the safety-related control system components and systems of the safety-related I&C analyses in Chapter 15. The response times of the I&C systems are assumed in the safety-related analyses and verified by plant specific surveillance testing or system analyses.

7.1.6.6.1.18 Manual Control (IEEE Std. 603, Sections 6.2 and 7.2)

The ESBWR design provides for manual initiation of each protective action at the system level in conformance with RG 1.62, and at the division level in conformance with IEEE Std. 603, Sections 6.2 and 7.2. The manual initiation must satisfy divisional rules for independence and separation; two manual actions, each in a separate division, are required to satisfy the two-out-of-two system logic or the two-out-of-four division logic that initiates reactor trip ~~and isolation functions (RTIF)~~ in the RPS and ESF functions in the ESF system.

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The operator can manually initiate the ESF functions by actuating manual switches in two-out-of-four divisions; thus, satisfying the two-out-of-two system initiation logic. The ESF functions that use squib valves use a redundant two-step arm and fire sequence to prevent single failures from firing or inhibiting the firing of the squib valves, that is, the GDCS pool injection valves, the suppression pool injection valves, the GDCS deluge valves, the ADS depressurization valves (DPV), and the SLC injection valves. To initiate the GDCS short-term injection and long-term injection systems manually, a low pressure signal must be present in the RPV; this prevents inadvertent manual initiation of the system during normal reactor operation.

The operator can manually initiate reactor emergency shutdown with control rods (that is, reactor trip), by any of three different methods using redundant or diverse controls. The reactor trip will occur independently of the automatic trip logic and sensor status.

The two manual scram switches, the reactor mode switch, and each of the four divisional manual trip switches (per protective system) are located in the MCR and are easily accessible to the operator.

The two MCR manual scram switches, the RSS manual scram switches, and the ATWS diverse protection system (DPS) manual scram switches share a minimum of equipment with the automatic controls. The MCR and RSS manual scram switches are directly connected to the power feed for the load drivers that are, in turn, connected directly to the scram pilot valve generators or off-site power. This allows for operation of the Q-DCIS when one power supply is in maintenance bypass. Further discussion of the safety-related power supplies is provided in Chapter 8.

7.1.6.6.1.28 Cyber Security (IEEE Std. 7-4.3.2)

The security requirements included in RG 1.152 are evaluated and incorporated in the Q-DCIS design and include both plant hardware and software security measures. The software development process plans will be developed with the security requirements incorporated for actual detailed design implementation.

The comprehensive cyber security program plan identifies security risks and outlines appropriate procedures to ensure that hardware, controls, and data networks comprising the control network cannot be disrupted, interrupted or negatively impacted by unauthorized users or external systems. It also documents the design commitments meeting the applicable requirements of RG 1.152, Section C.2, and Positions 2.1 through 2.9.

Inspections, tests, analyses, and acceptance criteria (ITAAC) associated with the cyber-security program plan are provided in ESBWR DCD, Tier 1 together with the software development plan.

7.1.7 COL Information

None.

7.1.8 References

7.1-1 USNRC, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants,” NUREG-0800.

7.1-2 General Electric Company, “General Electric Environmental Qualification Program,” NEDE-24326-1-P, Revision 1, Class III (proprietary), January 1983.

7.1-3 Electric Power Research Institute (EPRI) TR-102323 (TR-1003697), "Guidelines for Electromagnetic Interference Testing of Power Plant Equipment", Revision 3.

7.1-4 GE Energy Licensing Topical Report (LTR) entitled, “ESBWR I&C Defense-In-Depth and Diversity Report.” NEDO-33251, Class I (Non-proprietary), Revision 0, July 2006.

7.1-5 GE Energy, “ESBWR Safety Criteria for Instrumentation & Control Systems.” NEDO-33294, Class I (Non-proprietary), Revision 0.

7.1-6 GE Energy, “Application of Nuclear Measurement Analysis and Control for ~~a new BWR (NUMAC Platform Architecture.)~~” NEDE-33288P, Class III (Proprietary), ~~Revision 0~~

7.1-7 GE Energy, “SSLC/ESF Licensing Topical Report (Platform Architecture.)” Class III (Proprietary), Revision 0

7.2.1.2.4.1 Arrangement

The RPS-related equipment is divided into four redundant divisions of sensor (instrument) channels, trip logics and trip actuators, and two divisions of manual scram controls and scram logic circuitry. The sensor channels, divisions of trip logic, divisions of trip actuators, and associated portions of the divisions of scram logic circuitry together constitute the RPS automatic scram and air header dump (backup scram) initiation logic. The divisions of manual scram controls and associated portions of the divisions of scram logic circuitry together constitute the RPS manual scram and air header dump initiation logic. The automatic and manual scram initiation logics are independent of each other and use diverse methods and equipment to initiate a reactor scram. Equipment arrangement is shown in Figure 7.2-1.

Sensor Channels - Equipment within a sensor channel consists of sensors (transducers or switches), Digital Trip Module (DTM) and multiplexers. The sensors within each channel monitor for abnormal operating conditions and send analog (or discrete) output either directly to the RPS cabinets or to the Reactor Trip and Isolation Function (RTIF) Remote Multiplexer Units (RMUs) within the associated division of safety-related DCIS. The RMU within each division performs analog-to-digital and signal processing, then sends the digital or digitized analog output values of the monitored variables to the DTM for trip determinations within the associated RPS sensor channel in the same division. The DTM in each sensor channel compares individual monitored variable values with trip setpoint values and for each variable sends a separate trip/no trip output signal to the functional Trip Logic Units (TLU) in the four divisions of trip logic. DTM signals sent from one division to other divisions are optically isolated using fiber optic links. The DTMs and TLUs are microprocessor-based modules of the RPS. The software associated with RPS channel trip and trip system coincident logic decisions that are installed in these modules are RPS unique. The number of channels utilized in the functional performance of RPS is shown in Table 7.2-1 (IEEE Std. 603, Section 4.4).

Q-DCIS equipment within a single division of sensor channels are powered from the safety-related power source of the same division. However, different pieces of equipment may be powered from separate low voltage dc power supplies within the panels belonging to the same division. Within a sensor channel, the sensors themselves may belong to the RPS or may be components of another system. Signal conditioning and distribution performed by the RMUs are functions of the Q-DCIS. Components within each of the four RPS sensor channels are totally separated physically and independent from components of other sensor channels, satisfying the independence requirement of IEEE Std. 603, Section 5.6. The RPS equipment is independent and physically separated from other safety or nonsafety systems satisfying the requirements of IEEE Std. 603, Section 5.6. Any necessary signal communication between the RPS and other systems is through optical isolation devices such as fiber optic cables, via the communication interface module (CIM) of the RPS. There are no signal inputs from other systems that will affect the safety function of the RPS. The application of this non-safety to safety interface is described in detail in the GE NUMAC Licensing Topical Report (NEDOC-33288P). This Topical Report explains the CIM function, communication data link, data flow and isolation requirements of IEEE-603. The CIM has two-way fiber optic communication/data links and provides electrical isolation when passing data from non-safety related subsystems to safety-related systems

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7.2.2 Neutron Monitoring System

7.2.2.1 System Design Bases

The Neutron Monitoring System (NMS) monitors thermal neutron flux from the startup source range to beyond rated power. The NMS is comprised of the following subsystems:

- Startup Range Neutron Monitor (SRNM)
- Power Range Neutron Monitor (PRNM)
- Automatic Fixed In-Core Probe (AFIP)
- Multi-Channel Rod Block Monitor (MRBM)

The PRNM subsystem includes the local power range monitor (LPRM), average power range monitor (APRM) functions, and the oscillation power range monitor (OPRM).

The SRNM and PRNM subsystems are safety-related and are discussed below. The nonsafety-related AFIP Subsystem and the MRBM are addressed in Subsection 7.7.6. The application of this non-safety to safety interface is described in detail in the GE NUMAC Licensing Topical Report (~~NEDC~~NEDO-33288~~P~~). This Topical Report explains the CIM function, communication data link, data flow, and isolation requirements of IEEE Std. 603. The CIM has two-way fiber optic communication data links and provides electrical isolation when passing data from non-safety related subsystems to safety-related systems.

7.2.2.1.1 Startup Range Neutron Monitor (SRNM) Subsystem

7.2.2.1.1.1 Trip Functions

The SRNM scram trip functions are discussed in Subsection 7.2.1.3, and rod block trip functions are discussed in Subsection 7.7.2.2. The SRNM channels also provide trip bypass. The trip setpoints are adjustable. The SRNM trips are shown in Table 7.2-2 (IEEE Std. 603, Section 6.8). A short period signal (the period withdrawal permissive) inhibits continuous control rod withdrawal such that the reactor scram (due to the short reactor period caused by excessive rod withdrawal) can be avoided.

- The trip signals provided in the SRNM design are shown in Table 7.2-3.
- SRNM trips are active only when the reactor mode switch is not in the Run position. When the NMS Coincidence/Non-Coincidence switch position is in Non-Coincidence, any one of the SRNMs trip can be generated. When the Reactor Mode is in Run, the NMS trip is in the coincidence mode. For each division, the three SRNM scram trip signals are combined to form a divisional SRNM trip signal, and then combined with the divisional APRM trip signal before sending to the RPS.
- Trips dependent upon signal magnitude have setpoints adjustable in the instrument range.

7.2.2.2.4 Startup Range Neutron Monitor (SRNM) Subsystem

7.2.2.2.4.1 General Description

The SRNM monitors neutron flux from the source range (approximately 1×10^3 nv) to approximately 1.5×10^{13} nv. The SRNM subsystem has twelve SRNM channels, each having one fixed in-core regenerative fission chamber sensor.

7.2.2.2.4.2 Power Sources

SRNM channels are powered as listed below:

- A, E, J: 120 VAC Div. UPS Bus A (Division 1)
- B, F, K: 120 VAC Div. UPS Bus B (Division 2)
- C, G, L: 120 VAC Div. UPS Bus C (Division 3)
- D, H, M: 120 VAC Div. UPS Bus D (Division 4)

As previously described, each SRNM cabinet is redundantly powered with two uninterruptible divisional 120 VAC power sources from the appropriate division; either source of power can support system operation.

7.2.2.2.4.3 Physical Arrangement

The 12 SRNM detectors are located at a fixed elevation about the mid-plane of the fuel region, and are evenly distributed throughout the core. The SRNM locations in the core, together with the neutron source locations, are shown in Figure 7.2-6. Each detector is contained within a pressure barrier dry tube inside the core, with signal output exiting the bottom of the dry tube under-vessel. Detector cables are separately routed to the appropriate containment penetration according to divisional assignment. They are connected to their designated preamplifiers located in the different divisional quadrants of the reactor building. The SRNM preamplifier signals are transmitted to the SRNM digital processing equipment units, which provide algorithms for signal processing and calculation to provide neutron flux, power calculations, period trip margin, period calculations, and provide various outputs for local and control console displays, recorders, and to the plant computer function. As shown in Figure 7.2-4, the individual SRNM channel trips are combined to form a SRNM divisional trip in the NMS Trip Logic Unit function. This SRNM divisional trip is sent to the RPS via a safety-related network interface. (This is the logic in Coincidence Mode. Further discussion of SRNM trip logic is included in Subsection 7.2.2.5.2.) ~~alarm~~ Alarm and trip outputs are also provided for both high flux and short period trip or alarm conditions. Such outputs also include the instrument inoperative trip. The electronics for the startup range neutron monitors and their designated bypass units are located in four separate cabinets, one in each of the four divisional reactor building quadrants and in each of the control building divisional equipment room locations. The SRNM satisfies the IEEE Std. 603, Section 5.1 single failure criterion that the failure of each individual SRNM channel will not affect the protection function of the SRNM through channel bypasses discussed in the following paragraph (with any three of the four divisions of safety-related power available). It also satisfies the IEEE Std. 603, Section 5.6 independence requirement.

7.2.2.2.4.4 Signal Processing

Over the 10-decade power monitoring range, two monitoring methods are used: (1) the counting method for the lower ranges, which covers from lowest counting range (approximately 1×10^3 nv) to approximately 1×10^9 nv; and (2) the Campbelling technique (mean square voltage, MSV) for the higher ranges, which cover from 1×10^8 nv to 1×10^{13} nv of neutron flux. In the counting range, the discrete pulses produced by the sensors are applied to a discriminator after pre-amplification. The discriminator, together with other digital noise-limiter features, separates the neutron pulses from gamma radiation and other noise pulses. The neutron pulses are counted. The reactor power is proportional to the count rate. In the MSV range, where it is difficult to distinguish the individual pulses, a DC voltage signal proportional to the mean square value of the input signal is produced. The reactor power is proportional to this mean square voltage. In the mid-range overlapping region, where the two methods are changed over, the SRNM calculates a neutron flux value based on a weighted interpolation of the two flux values calculated by both methods. A continuous and smooth flux reading transfer is achieved in this manner. There is also the calculation algorithm of the period-based trip circuitry that generates trip margin setpoint for the period trip protection function.

7.2.2.2.4.5 Trip Functions

The SRNM scram trip functions are discussed in Subsection 7.2.2.1.1, and rod block trip functions are discussed in Subsection 7.7.2.2. The SRNM channels also provide trip bypass. The trip setpoints are adjustable. The SRNM trips are shown in Table 7.2-2 (IEEE Std. 603, Section 6.8). A short period signal (the period withdrawal permissive) inhibits continuous control rod withdrawal such that the reactor scram (due to a shorter reactor period caused by excessive rod withdrawal) can be avoided.

7.2.2.2.4.6 Bypasses and Interlocks

The twelve SRNM channels are divided into four bypass groups. A joystick switch allows only one SRNM at a time to be bypassed in each bypass group; this scheme allows up to four SRNM channels to be bypassed at any one time. There is no additional SRNM bypass capability at the divisional level. However, it is possible to bypass all three SRNMs that belong to the same division. For SRNM calibration or repair, the bypass can be done for each individual channel separately through these SRNM bypasses without putting the whole division out of service. The SRNM subsystem satisfies the repair requirement of IEEE Std. 603, Section 5.10. Note that bypassing any of the SRNM sensors within a division does not affect the ability of the ~~RPS~~ NMS to perform 2-out-of-4 trip determination using the trip decisions from the SRNM divisions (with any three of the four divisions of safety-related power available). The SRNM subsystem satisfies the IEEE Std. 603, Section 5.1 single failure criterion. The SRNM bypass switches are mounted on the control room panel. Bypass functions for the SRNM and the APRM in the NMS are separate (that is, there is no single NMS divisional bypass that affects both the SRNM and the APRM). Any APRM bypass does not force a SRNM bypass. The individual SRNM power

; when this occurs, a divisional bypass allows that division's NMS DTM to be bypassed while in the startup range (when SRNM trips are active).

signals are not combined and averaged to form a divisional SRNM power signal. Also, all NMS bypass logic control functions are located within the NMS, not in the RPS.

The SRNM has several major interlock logics. The SRNM trip functions are in effect when the RPS mode switch is not in the Run position. The SRNM upscale trip setpoint is lowered (IEEE Std. 603, Section 6.8) in the NMS Non-Coindence mode (Table 7.2-2). The SRNM ATWS Permissive signals are sent to the ATWS/SLC system as a permissive signal to control initiation of Standby Liquid Control system boron injection and associated functions (for example, feedwater runback).

7.2.2.2.4.7 Redundancy and Diversity

The signal outputs from the twelve SRNM channels are arranged such that each of the four divisions includes a different set of designated SRNM channels that cover different regions of the core. The SRNM monitoring and protection function is individual channel based. Failure of an un-bypassed single SRNM channel causes an inoperative trip to only one of the four divisions, whereas a full scram requires divisional trips in two-out-of-four divisions within the ~~RPS~~NMS. Bypassing a single SRNM channel does not cause a trip output to the related SRNM division and would not prevent proper operation of the remaining SRNM channels to perform their safety-related functions (Subsection 7.2.1.2).

7.2.2.2.4.8 Environmental Considerations

The wiring, cables, and connectors located within the drywell are designed for continuous duty in the conditions described in Appendix 3H.

The SRNM instruments are designed to operate under the expected environmental conditions. Environmental qualification is discussed in Section 3.11. Additional information on equipment qualification with respect to environmental considerations is in Reference 7.1-5, Reference 7.1-6, and Reference 7.1-7.

7.2.2.2.5 Local Power Range Monitor

7.2.2.2.5.1 General Description

The Local Power Range Monitor (LPRM) monitors local neutron flux in the power range. The LPRM provides input signals to the APRM (Subsection 7.2.2.6), to the RC&IS (Subsection 7.7.2), and to the plant computer function of the N-DCIS (Subsection 7.1.5).

7.2.2.2.5.2 Uninterruptible Power Supply (UPS)

Alternating current power for the LPRM circuitry is supplied by four pairs of redundant divisional 120 VAC UPS buses (A, B, C and D) that correspond to the four safety-related divisions; the various cabinets can perform their function with either of the redundant power sources. Each division supplies power to one-fourth of the detectors. Each LPRM detector is provided with a DC power supply, housed in the designated divisional APRM instrument, which furnishes the detector polarizing potential.

7.2.2.2.5.5 Trip Functions

The LPRM channels provide trip and status signals indicating when an LPRM is upscale, downscale, or bypassed.

7.2.2.2.5.6 Bypasses and Interlocks

Each LPRM channel may be individually bypassed. When the maximum allowed number of bypassed LPRMs for each APRM has been exceeded, an inoperative trip is generated by the affected APRM channel.

7.2.2.2.5.7 Redundancy

The LPRM detectors are assigned in four divisional APRM channels, with 64 LPRM detector signals in each APRM channel. The redundancy criteria are met such that, in the event of a single failure under permissible APRM bypass conditions, the safety-related protection function can still be performed as required (with any three of the four divisions of safety-related power available).

7.2.2.2.5.8 Environmental Considerations

The LPRM detector and detector assembly are designed to operate up to a gauge pressure of approximately 8.62 MPa (1250 psig) at an ambient temperature of approximately 315°C. The wiring, cables, and connector located within the drywell are designed for continuous duty at drywell ambient conditions. The LPRMs are capable of functioning during and after design basis events, including earthquakes and anticipated operational occurrences (Sections 3.10 and 3.11). Additional information on equipment qualification with respect to environmental considerations is in Reference 7.1-5 and Reference 7.1-7.

7.2.2.2.6 Average Power Range Monitor (APRM)

7.2.2.2.6.1 General Description

The APRMs perform a safety-related function. There are four APRM channels, one per division. Each APRM channel receives 64 LPRM signals through fiber cables from the reactor building as primary inputs, averages the inputs and normalizes the result to provide an APRM value that corresponds to the average ~~core thermal power signal. One APRM channel is associated with each division of the RPS. Each of the divisional NMS trip signals is also sent to the other three RPS divisions through optical isolation.~~

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7.2.2.2.6.2 Power Sources

APRM channels are powered as listed below:

- A: Redundant 120 VAC Div UPS Bus A (Division 1)
- B: Redundant 120 VAC Div UPS Bus B (Division 2)

- C: Redundant 120 VAC Div UPS Bus C (Division 3)
- D: Redundant 120 VAC Div UPS Bus D (Division 4)

Either of the two redundant divisional power sources will support APRM operation. The bypass units and LPRM detectors associated with each APRM channel receive power from the same power sources as the APRM channel.

7.2.2.2.6.3 Physical Arrangement

The APRM subsystem consists of four independent and separate instrument channels. Each APRM channel consists of 64 LPRM signal inputs. The assignment of individual LPRM sensors to each of the four APRM channel is performed such that an even and uniform selection of LPRM sensors from the whole core is realized for each APRM channel. In this manner, the average value of the 64 LPRM signals from the whole core represents the average core power value. The LPRM signals within the APRM channel are averaged and normalized to form an average core power APRM signal. The LPRM assignment to APRM channels is shown in Figure 7.2-9.

7.2.2.2.6.4 Signal Conditioning

The APRM channel electronic equipment averages the output signals from 64 LPRM detectors to form an APRM signal for this channel. The averaging circuit automatically corrects for the number of un-bypassed LPRM input signals. The APRM channel electronics unit includes the capabilities for LPRM and APRM calibrations and diagnostics. The APRM has signal output interface units in order to send signals to other systems. A simplified PRNM block diagram is shown in Figure 7.2-5. Individual APRM channel trips are routed to the RPS directly. The APRM satisfies the IEEE Std. 603, Section 5.1 single failure criterion that the failure of each individual APRM channel will not affect the protection function of the APRM through channel bypasses discussed in the following paragraph (with any three of the four divisions of safety-related power available). It also satisfies the IEEE Std. 603, Section 5.6, independence requirement, as the redundant portions of the NMS equipment are independent of and physically separated from each other, and that the NMS equipment is separated from other systems.

7.2.2.2.6.5 Trip Function

The APRM scram trip function is discussed in Subsection 7.2.1.3. The APRM rod block trip function is discussed in Subsection 7.7.2.2. The APRM channels also provide trip and status signals indicating when an APRM channel is upscale, downscale, bypassed, or inoperative. The trip setpoints are adjustable. APRM system trips are summarized in Table 7.2-4.

7.2.2.2.6.6 Bypasses and Interlocks

One APRM channel out of four channels may be bypassed at any one time for repair during plant operation while still maintaining the required APRM functions. This satisfied the repair requirement of IEEE Std. 603, Section 5.10. When one APRM channel is bypassed, the trip logic in the ~~RPS~~ becomes two-out-of-three instead of two-out-of-four (with any three of the four

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divisions of safety-related power available). Each divisional trip signal is sent to all four RPS divisions. All four RPS channels continue to perform the trip logic even if the RPS channel is in the same division as the bypassed APRM input. The bypass of APRM channels is accomplished with a joystick type switch with mutually exclusive positions. The APRM bypass switch is located on the control room panel. Access to the panel and the switch is under administrative control. When a bypass is active, the input from the bypassed APRM/OPRM channel (APRM or OPRM trip function) will be bypassed by removing it from the vote. The remaining signals are voted with a two-out-of-three logic, thus retaining the ability to withstand a single channel failure. The final separate check of the signals, performed independently by each voter channel, assures that no single failure will cause an inadvertent bypass. The bypass function uses physical means and independent logic to assure that no more than one channel is bypassed at a given time.

There are no automatic bypasses for the APRM trip function. The APRM trip setpoint is automatically changed to a lower value (setdown) when the manually operated reactor mode switch is not in Run. When any APRM (or OPRM) channel output to the RPS is bypassed, the bypass is indicated on the plant operator's panel. The same channel bypass bypasses both the OPRM and APRM channel.

The APRM ATWS Permissive signals are sent to the ATWS/SLC system as a permissive signal for the ADS initiation inhibit function.

7.2.2.2.6.7 Redundancy

Four independent channels of the APRM monitor neutron flux, each channel being associated with one RPS division but with its trip signal being sent to the other three RPS divisions through optical isolation. The redundancy criteria are met such that in the event of a single failure under permissible APRM bypass conditions, the safety-related protection function can still be performed as required (with any three of the four divisions of safety-related power available).

7.2.2.2.6.8 Environmental Considerations

Chapter 3 describes the APRM operating environments. The APRM is capable of functioning during and after the design basis events in which continued APRM operation is required (Sections 3.10 and 3.11). Additional information on equipment qualification with respect to environmental considerations is in Reference 7.1-5 and Reference 7.1-7.

7.2.2.2.7 Oscillation Power Range Monitor

7.2.2.2.7.1 General Description

The Oscillation Power Range Monitor (OPRM) consists of four independent safety-related channels. The OPRM channel utilizes the same set of LPRM signals used by the associated APRM channel in which this OPRM channel resides. Each OPRM receives the identical LPRM signals from the corresponding APRM channel as inputs, and forms many OPRM cells to monitor the neutron flux behavior of all regions of the core. Assignment of LPRMs to the four OPRM channels are as shown in DCD Figure 7.2-10. The OPRM channel consists of OPRM cells that are formed by grouping LPRM inputs (maximum 4). The OPRM cell signal is the average of all grouped LPRM input signals for detecting thermal hydraulic instability of the reactor core. The LPRM signals assigned to each cell are summed and averaged to provide an OPRM signal for that cell. The OPRM trip protection algorithm detects thermal hydraulic instability ~~(flux~~ oscillation with unacceptable amplitude and frequency) and provides a trip output ~~to the RPS~~ if the trip setpoint is exceeded. [DELETE]

7.2.2.2.7.2 Power Sources

OPRM function resides in the APRM equipment and receives the same redundant APRM power.

7.2.2.2.7.3 Signal Conditioning

The OPRM function resides in its associated APRM channel equipment. Assignment of LPRMs to the four OPRM channels is shown in Figure 7.2-10. The OPRM channel consists of OPRM cells that are formed by grouping LPRM inputs. Each OPRM cell signal is the average of all grouped LPRM input signals for this cell, for detecting thermal hydraulic instability of the reactor core.

7.2.2.2.7.4 Trip Function

The OPRM trips are combined with the APRM trips of the same APRM channel, and sent to RPS. The OPRM function generates an inoperative alarm for an OPRM channel when there is an insufficient number of operating OPRM cells. If the number of operating LPRM inputs to an OPRM cell is less than the minimum required, the cell is considered to be inoperable. Similarly the channel is inoperable if it does not have enough operating cells. Any cell can result in an OPRM channel alarm or trip condition.

The OPRM channel monitors OPRM cell signal responses and provides alarm and trip signals based on the oscillation detection algorithm to be defined in detailed hardware and software design specification document. ~~Any cell can result in an OPRM channel alarm or trip condition.~~

~~The OPRM trips are combined with the APRM trips of the same APRM channel, and sent to RPS.~~ ~~The OPRM channel trips are sent to the RPS. The OPRM function shall not generate an inoperative~~ trip, but shall generate an inoperative alarm for an OPRM channel when there is an insufficient number of operating OPRM cells. (An inoperative OPRM cell is defined as a cell that has insufficient number of operating LPRM inputs).

[DELETE. Redundant to 1st paragraph]

The OPRM alarms and trips are bypassed in all reactor operation modes except Run, and when operating below the required power level (typically 30%). The OPRM channel bypass is controlled by the APRM channel in which it resides. Bypass of the APRM channel also bypasses the OPRM trip function within this APRM channel.

A summary of OPRM trip functions is provided in Table 7.2-6.

7.2.2.2.7.5 Bypasses and Interlocks

The OPRM alarms and trips are bypassed in all reactor operation modes except Run, and when operating below a preset required power level. The OPRM bypass is controlled by the APRM

SRNM, LPRM, OPRM or APRM channel can be individually bypassed. Restrictions as to the total number and distribution of bypassed channels (at one time) must be adhered to in order to avoid reactor trip due to inoperative NMS channels.

In the case of SRNM channels, each of the twelve channels belongs to one of the four bypass groups. Each group has one "multiple position" selector switch, so that only one SRNM channel in each group may be bypassed at a time. The SRNM channel bypassed status is displayed on the NMS user interface.

The APRM equipment allows the operator to bypass any one of the four APRM channels during normal plant operation. The ~~APRM~~ channel bypassed status is displayed on the NMS user interface. The trip logic at the ~~RPS~~ NMS becomes two-out-of-three instead of two-out-of-four.

There are separate bypass functions for the SRNM and the APRM in the NMS (that is, there is no single NMS divisional bypass which will affect both the SRNM and the APRM). An APRM ~~bypass will not force an SRNM bypass. The~~ SRNM and APRM bypasses are separate logics ~~to RPS, each interfacing with RPS independently.~~ ~~All NMS bypass logic control functions are located within NMS but none are located in RPS.~~ Use of SRNM and APRM bypasses does not adversely affect the ATWS Permissive and ADS Inhibit output functions.

Individual LPRM channels are bypassed by first confirming, for a given APRM channel, that the minimum LPRM input requirement is still met after the bypasses are completed. The operator has to input the LPRM designator to be bypassed and then can switch it into bypass. The LPRM channel bypassed status is displayed on NMS user interface. When the maximum allowed number of bypassed LPRMs associated with any APRM channel has been exceeded, an inoperative trip is automatically generated by that APRM channel.

~~A failure that causes a~~ channel to become inoperative causes a channel trip output ~~to the Reactor Protection System (RPS)~~.

When the reactor mode switch is in Run mode, this equates to a "Coincident" mode for the NMS. When the reactor mode switch is NOT in Run mode, this equates to a "Non-Coincident" mode for the NMS. ~~The SRNM upscale trip setpoint is lowered in the NMS Non-Coincidence mode (RPS Mode switch in Run).~~ SRNM trips are active only when the reactor mode switch is not in the Run position. If the manual Coincident/Non-Coincident switch is in the "Non-Coincident" position when the reactor mode switch is placed in the Run position, then an alarm is generated in the Main Control Room. When the NMS ~~Coincidence/Non-Coincidence switch position~~ is in Non-~~Coincidence~~Coincident Mode, any one of the SRNMs channel trips can cause a reactor scram; in the ~~c~~Coinciden~~ce~~t ~~m~~Mode, at least two-out-of-four divisions must be tripped in order to activate the reactor scram.

7.2.2.6.3 Basic Instrument Arrangement Requirements

NMS instruments and equipments are located in appropriate areas in the control building and reactor building, with appropriate divisional physical and electrical separation. Any NMS instruments located in the reactor building are in clean areas.

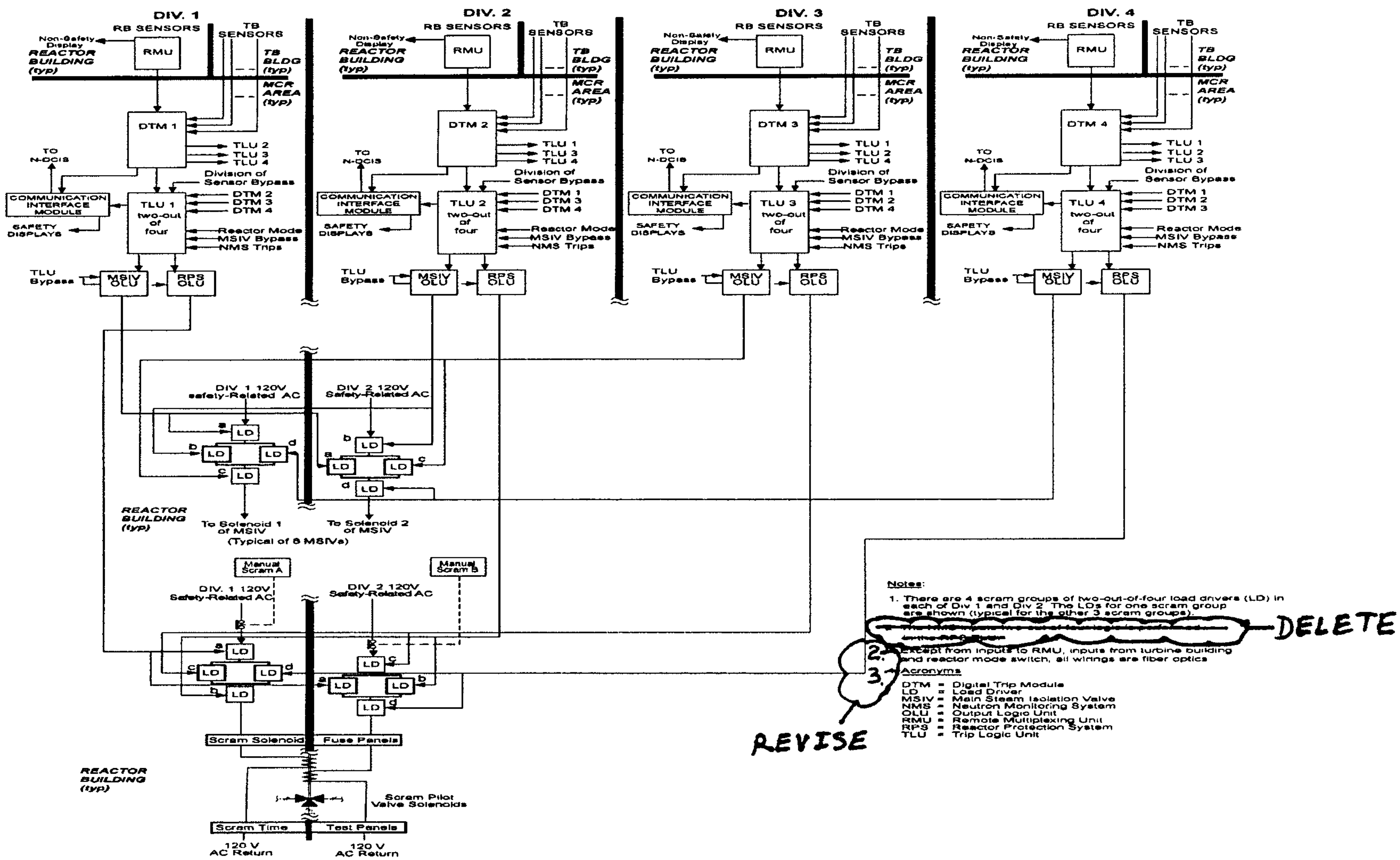

Figure 7.2-1. RPS Functional Block

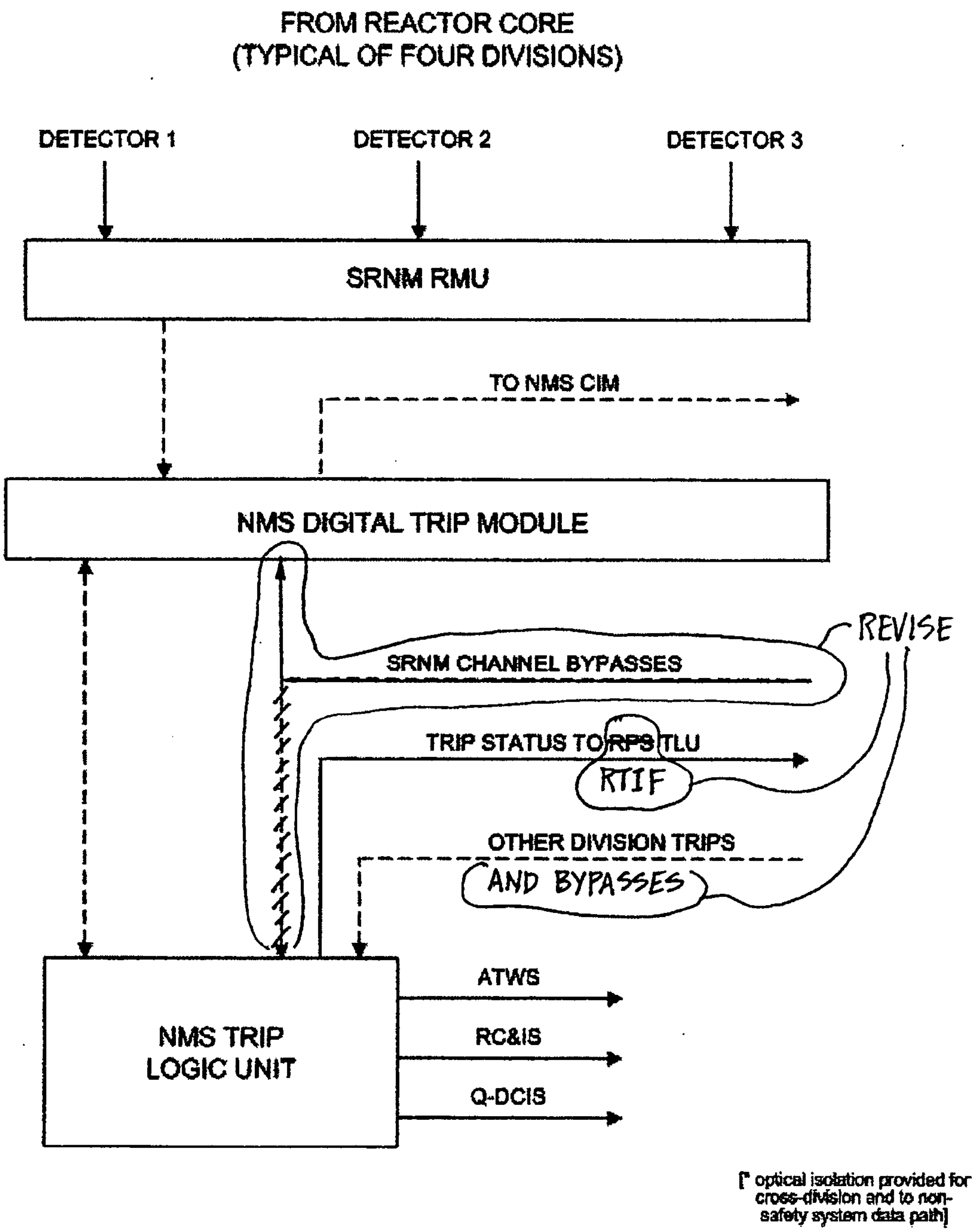

Figure 7.2-4. Basic Configuration of a Typical SRNM Subsystem

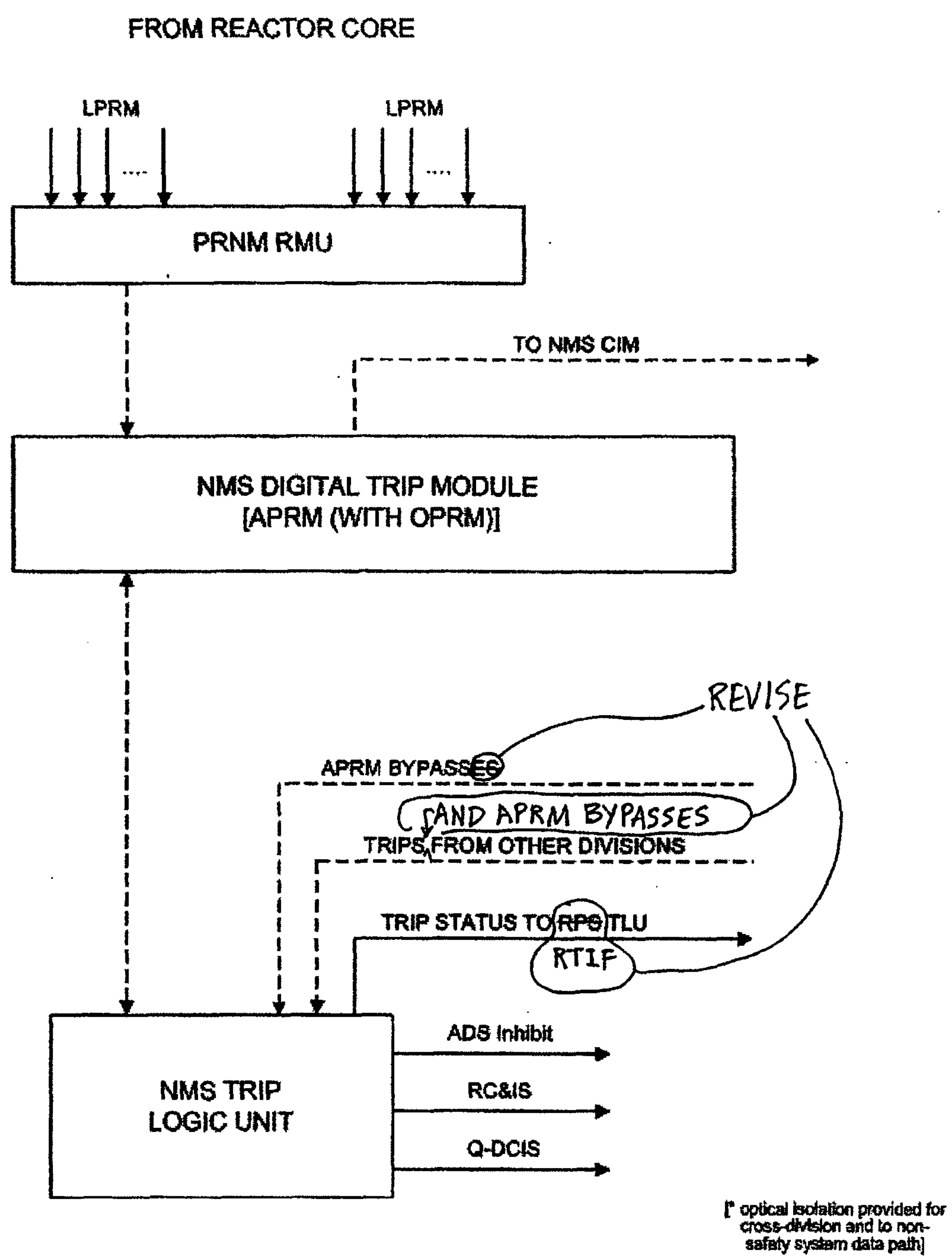

Figure 7.2-5. Basic Configuration of a Typical PRNM Subsystem

Table 7.2-6

OPRM Trip Function Summary

Trip Function	**Analytical Limit For Trip Setpoint** (Note 1)	**Action**
OPRM Inoperative	LPRM inputs too few	OPRM Cell/Channel Alarm
OPRM Oscillation Detection	Bypassed below 30% and when not in Run	Channel Trip ~~to RPS~~ DELETE
OPRM Oscillation Detection	Bypassed below 30% and when not in Run	Channel Alarm
OPRM Bypass	N/A	Controlled by APRM bypass

1. Instrument setpoint accuracy will be determined by safety analyses using GE instrument setpoint methodology of Reference 7.2-1.

instrumentation, control logic, or power-actuated valves, and does not need or use electrical power for its operation. Other information on the PCCS is given in Subsection 6.2.2.

7.3.3 Leak Detection and Isolation System

The primary function of the Leak Detection and Isolation System (LD&IS) is to detect and monitor leakage from the reactor coolant pressure boundary and to initiate the appropriate safety action to isolate the source of the leak from the containment. The system is designed to automatically initiate the isolation of certain designated process lines that penetrate the containment to prevent release of radiological leakage from the reactor coolant pressure boundary. The initiation of the isolation functions results in the closure of the appropriate containment isolation valves. The LD&IS functions are performed in two separate safety-related platforms. The Main Steam Isolation Valve (MSIV) isolation logic functions are performed in the ~~RPS/~~RTIF system ~~platform,~~ while all other containment isolation logic functions are performed in the SSLC/ESF system. REVISE

7.3.3.1 System Design Bases

The following system design criteria are applicable to the design of LD&IS (IEEE Std. 603, Sections 5.1, 5.6 and 6.1):

- The LD&IS is engineered as a safety system, Seismic Category 1, and conforms to the regulatory codes and standards listed in Table 7.1-1 for this system.
- The LD&IS logic design is fail-safe, such that loss of electrical power to one LD&IS divisional logic channel initiates a channel trip.
- Isolation is initiated with precision and reliability once leakage has been detected from the reactor coolant pressure boundary.
- The divisional LD&IS logic channels and associated sensors are powered from safety-related divisional power. The loss of one divisional logic power source or one monitoring channel does not cause inadvertent isolation of any containment valves.
- Once isolation is initiated, the isolation action goes to completion. Deliberate operator action is required to return the system to normal and to reopen the isolation valves.
- The LD&IS design meets the single-failure criteria; no single-failure within the system, with any three of the four divisions of safety-related power available, initiates inadvertent isolation or prevent isolation when required.
- Automatic isolation is initiated on a coincidence vote of any two-out-of-four channel trips as appropriate for each monitored variable.
- Electrical, communication, and physical independence is maintained between safety-related divisions and nonsafety-related equipment (see Subsection 7.1.3.3).
- The LD&IS design incorporates provisions to permit bypass of a single division of sensors at any one time.

- LD&IS instrumentation utilizes a diversity of sensed parameters and redundant channels for initiation of containment isolation.
- Manual isolation capability is provided for diversity to the automatic logic.
- The containment leak detection methods that are described in RG 1.45 are adopted in the LD&IS system design.
- Identified and unidentified leakages within the containment are monitored separately for quantifying the flow rates.
- The LD&IS provides different divisional isolation signals to the containment isolation valves.
- The control and isolation logic for the main steamline isolation valves (MSIVs) are provided in the LD&IS system design. The MSIV control logic for each pilot solenoid valve is shown in Figure 7.2-1.

7.3.3.2 System Description

The LD&IS is a four-divisional system designed to detect and monitor leakage from the reactor coolant pressure boundary (RCPB), and, in certain cases, isolate the source of the leak by initiating closure of the appropriate containment isolation valves. The LD&IS control and isolation logic utilizes two-out-of-four coincidence voting channels for each monitored plant variable for containment isolation. Various plant variables are monitored, such as flow, temperature, pressure, RPV water level, and radiation, and these are used in the logic to initiate alarms and the required control signals for containment isolation. Two or more diverse leakage parameters are monitored for each specific isolation function. The LD&IS logic functions reside in the framework of the RTIF ~~RPS~~ and the SSLC/ESF system~~platforms~~ where the trip signals are generated to initiate the isolation functions of the LD&IS. REVISE

The following control and isolation functions are implemented by the LD&IS:

- Containment isolation following a LOCA event;
- Main steamlines and drain lines;
- ICS process lines;
- RWCU/SDC System process and sampling lines;
- Fuel and Auxiliary Pools Cooling System suction lines from the GDCS pools;
- Chilled Water System lines to drywell coolers;
- Drywell sumps liquid drain lines;
- Containment purge and vent lines;
- Reactor Building area air supply and exhaust ducts;

- BTP HICB-18 - Guidance on the Use of PLC in Digital Computer-Based Instrumentation and Control Systems
- BTP HICB-19 - Guidance for Evaluation of Defense-in-Depth and Diversity in Digital Computer-Based Instrumentation and Control Systems
- BTP HICB-21 - Guidance on Digital Computer Real-Time Performance

Conformance: The LD&IS complies with the above HICBs. Discussion of HICBs 14, 17, 18, 19, and 21 are addressed in conjunction with the SSLC/ESF in Subsection 7.3.5.3, and in Subsection 7.1.6.

7.3.3.3.6 TMI Action Plan Requirements

In accordance with the SRP for 7.3 and with Table 7.1-1, 10 CFR 50.34(f)(2)(v) (I.D.3) and 10 CFR 50.34(f)(2)(xiv) (II.E.4.2) apply to the LD&IS. The LD&IS complies with the requirements as indicated above. However, TMI action plan requirements are addressed in Appendix 1A.

7.3.3.4 Testing and Inspection Requirements

7.3.3.4.1 In-service & Surveillance Tests

In-service testing of the leak detection and monitoring channels is performed periodically to verify operability during normal plant operation and to assure that each tested channel can perform its intended design function. The surveillance tests include as required instrument channel checks, functional tests, verification of proper sensor and channel calibration, and response time tests in accordance with the established test procedures.

The LD&IS instrument channels utilize conventional sensors for leak detection and monitoring, and require no special or unique testing methods.

The setpoint verifications, the trip logic tests, and the channel integrity tests for the safety-related functions of LD&IS are processed and tested by the RTIF ~~RPS~~ and SSLC/ESF systems.

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7.3.3.4.2 MSIV Closure Tests

The LD&IS design provides manual capability and incorporates logic provisions to test closure of each of the MSIVs during normal reactor operation (IEEE Std. 603, Sections 5.7 and 6.5). To verify MSIV closure capability, each MSIV is periodically tested for partial closure while in service without causing a plant outage (IEEE Std. 603, Section 6.5).

7.3.3.4.3 Testing and Maintenance in the Bypass Mode

Testing, calibration, and maintenance are performed in accordance with established procedures on the equipment during the time when the channel is out of service or has been deliberately bypassed.

7.3.5.5 Instrumentation and Control Requirements

The SSLC/ESF equipment uses microprocessor-based programmable logic and control instrument, with standardized modules interchangeable with similar modules. Discrete solid-state logic is also used when applicable.

Control programs for each microprocessor-controlled instrument are in the form of software residing in non-volatile memory. The storage medium is in general Programmable Read-Only Memory (PROM). Programs are under the control of a real-time operating system residing in non-volatile memory. The equipment is qualified with verification and validation program conforming to applicable codes and standards.

Logic and controls for SSLC/ESF are located on each divisional SSLC/ESF cabinet in the equipment room in the Control Building, with key controls and system operating status available on the operator interface Section in the main control room. The SSLC/ESF controls are used infrequently. Such controls normally do not require operator action during plant operation or during accident or transient conditions, and mainly are used for test and maintenance purposes. However, conditions such as equipment failure, maintenance, or testing, may require the operator to manually bypass a division of sensors or, ~~(for RPS/MSIV,)~~ a division of trip logic. Under the bypass status, SSLC/ESF continues to run in automatic mode using the unaffected logic in the remaining divisions.

DELETE

The following minimum required SSLC/ESF displays are provided in the Main Control Room (per division):

- Division-of-sensors in bypass;
- SSLC/ESF controller inoperative (DTM or VLU); and
- Communication Interface Module (CIM) inoperative.

7.3.6 COL Information

None.

7.3.7 References

None.

The ERICP is located in the back-panel area of the MCR. It serves as an additional logic panel to contain relays (or solid-state equivalent) hardware needed to transmit discrete output signals to the emergency rod insertion panels in the RB. The discrete output signals are activated based upon input signals received from the RPS ~~portion of the SSLC panels~~ (that indicate a scram-follow function is active or based upon input signals received from the N-DCIS) that indicate a ARI function or automatic SCRRI function is active or by input signals from the two manual SCRRI pushbuttons on the MCRP.

DELETE

Emergency Rod Insertion Panels (ERIPs)

The ERIPs are located in the Reactor Building and provide discrete output signals to the IMCs in the IMCCs. The discrete output signals are activated based upon input signals received from the ERICP that indicate the scram-follow function, the ARI function or the SCRRI function is active.

Scram Time Recording Panels (STRPs)

The STRPs, located in the RB, monitor the FMCRD position reed switch status using Reed Switch Sensor Modules (RSSMs) and communicate this information to the RAPI via the RC&IS multiplexing network. Also, the STRPs automatically record and time tag FMCRD scram timing position reed switch status changes either: 1) after initiation of an individual HCU scram test at the RPS Scram Time Test Panel, or 2) after a full-core reactor scram has been initiated. The recorded scram timing data can be transmitted to the scram time recording and analysis panel in the MCR back-panel area.

Scram Time Recording and Analysis Panel (STRAP)

The STRAP, located in the MCR back-panel area, receives scram timing position information from the STRPs and performs scram timing performance analysis against the applicable Technical Specification requirements. The recorded performance information can also be transmitted to the N-DCIS equipment for further data analysis and archiving.

RAPI Auxiliary Panels

RAPI Auxiliary Panels, located in the Reactor Building, provide output signals to open a purge water valve whenever either FMCRD associated with the corresponding HCU receives an insertion command from RAPI subsystem. These panels also monitor scram valve position status as well as the HCU accumulator water pressure and level status (that is, normal or abnormal). Communication of this information to and from the RAPI subsystem is achieved via the N-DCIS equipment. Two (or more) of the non-safety remote multiplexing unit cabinets of the N-DCIS equipment scope are used as the RAPI auxiliary panels (that is, the RAPI Auxiliary Panels are physically not part of RC&IS equipment scope, even though they provide for the RC&IS related functions described above).

7.7.2.2.2 RC&IS Multiplexing Network

The RC&IS multiplexing network consists of two separate channels. Fiber-optic communication links are used in this multiplexing network to handle communication between the RACS and the RSPCs in the RCCs (via the FCMs), communication between the STRPs and the RACS, and communication between the STRPs and the STRAP. Communication between the RAPI

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Enclosure 2

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