ENERGY NORTHWEST

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Proprietary – Withhold under 10 CFR 2.390. Attachments 1 through 6, 13, and Enclosure 1 of Attachment 12 contain PROPRIETARY information.

July 31, 2012
GO2-12-105

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Subject: **COLUMBIA GENERATING STATION, DOCKET NO. 50-397 SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION**

References:
1) BJ Sawatzke (Energy Northwest) to NRC, "License Amendment Request to Change Technical Specifications in Support of PRNM / ARTS / MELLLA Implementation," January 31, 2012 (ADAMS Accession No. ML1120400144)

2) Digital I&C-ISG-06, "Task Working Group #6: Licensing Process Interim Staff Guidance," January 19, 2011 (ADAMS Accession No. ML110140103)

3) Letter GNRO-2011/00039 Entergy Operations, Inc. to NRC, "Responses to NRC Requests for Additional Information Pertaining to License Amendment Request for Power Range Neutron Monitoring System (TAC No. ME2531)," May 26, 2011 (ADAMS Accession No. ML111460590)

Dear Sir or Madam:

In Reference 1, Energy Northwest submitted to the Nuclear Regulatory Commission (NRC) a license amendment request (LAR) which proposes to revise the Columbia Generating Station (CGS) Technical Specifications (TS) to reflect the installation of the digital General Electric – Hitachi (GEH) Power Range Neutron Monitoring (PRNM) system. Included in this submittal was a commitment to provide the remainder of the Phase 2 information to support a Reference 2 defined Tier 2 review. Enclosed herein is the requisite Phase 2 information.

The following table provides a roadmap to the Phase 2 information as identified in Enclosure B, "Information to be Provided in Support of a Digital I&C Upgrade License Amendment Request," of Reference 2:

When Attachments 1 through 6, 13, and Enclosure 1 of Attachment 12 are removed from this letter, the letter and remaining Attachments and Enclosures are NON-PROPRIETARY.

A001
NRR

Table - CGS PRNM ISG-06 Conformance Documentation Roadmap

ISG-06 Encl B Item #	Title	Phase 2 Document
2.1	Safety Analysis (D.4.4.2.1)	The Technical Design Reviews as delineated by GEH procedure CP-03-04 are being performed as part of the software development process as described in Sections 4.4.1.9 and 4.4.2.1 of NEDC-33685P, "Digital I&C-ISG-06 Compliance for Columbia Generating Station NUMAC Power Range Neutron Monitoring Retrofit Plus Option III Stability Trip Function," Revision 1, January 2012. NEDC-33685P was previously provided in Reference 1 as Attachment 2 of Enclosure 2. As identified in NEDC-33685P, the review summary reports are available for NRC review at the GEH office.
2.2	V&V Reports (D.4.4.2.2)	Attachment 12 The information provided in this document has previously been reviewed by the NRC as part of a response to a Grand Gulf Nuclear Station request for additional information regarding the PRNM (Reference 3).
2.3	As-Manufactured, System Configuration Documentation (D.4.4.2.3)	
2.4	Test Design Specification (D.4.4.2.4)	Attachment 5
2.5	Summary Test Reports (Including FAT) (D.4.4.2.4)	
2.6	Summary of Test Results (Including FAT) (D.4.4.2.4)	
2.7	Requirement Traceability Matrix (D.9.4.2)	
2.8	FMEA (D.9.4.2.1.1)	Attachment 1

Table (continued) - CGS PRNM ISG-06 Conformance Documentation Roadmap

ISG-06 Encl B Item #	Title	Phase 2 Document
2.9	System Build Documents (D.4.4.3.5)	Attachment 12 The information provided in this document has previously been reviewed by the NRC as part of a response to a Grand Gulf Nuclear Station request for additional information regarding the PRNM (Reference 3).
2.10	Intentionally Blank	N/A
2.11	Qualification Test Methodologies (D.5.2)	Previously provided in Reference 1 as Attachment 2 of Enclosure 2.
2.12	Summary of Digital EMI, Temp., Humidity, and Seismic Testing Results (D.5.2)	
2.13	As-Manufactured Logic Diagrams (D.9.2)	Previously provided in Reference 1 as Attachment 5 of Enclosure 2.
2.14	System Response Time Confirmation Report (D.9.4.2.4)	Attachment 6
2.15	Reliability Analyses (D.9.4.2.15, D.10.4.2.15)	Attachment 2
2.16	Setpoint Calculations (D.9.4.3.8)	Attachment 3 - for Average Power Range Monitor, and Attachment 4 - for Rod Block Monitor
2.17	Software Tool Analysis Report (D.10.4.2.3.2)	Attachment 10
	Commercial Grade Dedication Report(s) (D.10.4.2.4.2)	Not applicable as described in Section 10.3.4.2 of Reference 1 Attachment 2 of Enclosure 2.

In addition to the Phase 2 information described above, this letter also contains a revision to one of the documents which was provided as part of the Phase 1 information in Reference 1. In Reference 1, as Attachment 5 to Enclosure 2, GEH document NEDC-33696P had been identified as being entirely proprietary. Upon further review, GEH has identified portions of this document that do not contain proprietary information. Included with this letter, as Attachment 13, is a revised proprietary version of this document with the only changes being the demarcations as to which information is considered proprietary information. Attachment 14 is the non-proprietary version (NEDO-33696) of this report.

The No Significance Hazards Determination and the Environmental Consideration provided in Reference 1 are not impacted by this supplemental submittal.

There are no new commitments identified in this letter.

The following documents are included as Attachments to this letter:

1. NEDC-33750P, Revision 0, "Columbia Generating Station Power Range Neutron Monitoring System Failure Mode and Effects Analysis," June 2012 - (Proprietary)

2. NEDC-33751P, Revision 2, "Columbia Generating Station Power Range Neutron Monitoring System Reliability Analysis," June 2012 – (Proprietary)

3. NEDC-33753P, Revision 0, "Columbia Generating Station Instrument Limits Calculation Average Power Range Monitor (NUMAC ARTS-MELLLA)," June 2012 – (Proprietary)

4. NEDC-33754P, Revision 0, "Columbia Generating Station Instrument Limits Calculation Rod Block Monitor (NUMAC ARTS-MELLLA)," June 2012 – (Proprietary)

5. NEDC-33756P, Revision 1, "Columbia Generating Station Power Range Neutron Monitor V&V Test Summary Report," June 2012 – (Proprietary)

6. NEDC-33758P, Revision 0, "Columbia Generating Station Power Range Neutron Monitoring System Response Time Confirmation Report," June 2012 – (Proprietary)

7. NEDO-33750, Revision 0, "Columbia Generating Station Power Range Neutron Monitoring System Failure Mode and Effects Analysis," June 2012 - (Non-Proprietary)

8. NEDO-33753, Revision 0, "Columbia Generating Station Instrument Limits Calculation Average Power Range Monitor (NUMAC ARTS-MELLLA)," June 2012 – (Non-Proprietary)

9. NEDO-33754, Revision 0, "Columbia Generating Station Instrument Limits Calculation Rod Block Monitor (NUMAC ARTS-MELLLA)," June 2012 – (Non-Proprietary)

10. NEDO-33755, Revision 0, "Columbia Generating Station Power Range Neutron Monitoring System Software Tools Summary Report," June 2012 – (Non-Proprietary)

11. NEDO-33758, Revision 0, "Columbia Generating Station Power Range Neutron Monitoring System Response Time Confirmation Report," June 2012 – (Non-Proprietary)

12. Letter GE-MS-CT-106244-JC14 from Jamie Creech (GEH) to James Snyder (Energy Northwest), "CGS DI&C-ISG-06 Enclosure B, Phase 2 Items 2.2, 2.3, and 2.9," dated June 12, 2012. Included with this letter are the following Enclosures:

    1. DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station - (Proprietary)

    2. DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station - (Non-Proprietary)

    3. Affidavit

13. NEDC-33696P, Revision 1, "Columbia Generating Station Power Range Neutron Monitoring System Architecture & Theory of Operations Report," July 2012 - (Proprietary)

14. NEDO-33696, Revision 1, "Columbia Generating Station Power Range Neutron Monitoring System Architecture & Theory of Operations Report," July 2012 - (Non-Proprietary)

GEH considers certain information contained in Attachments 1 through 6, 13, and Enclosure 1 to Attachment 12 to be proprietary and, therefore, requests that these be withheld from public disclosure in accordance with 10 CFR 2.390. Non-proprietary versions of Attachments 1, 3, 4, 6 and 13 are provided as Attachments 7, 8, 9, 11 and 14 respectively.

A non-proprietary version of Attachment 12 Enclosure 1 is included as Attachment 12 Enclosure 2. Because the vast majority of information provided in Attachments 2 and 5 are considered proprietary, non-proprietary versions would be of no value; therefore, redacted versions of these documents are not being provided.

Attachments 1 through 6, and 13, also contain the associated affidavits, within the first few pages of each document, for the requests to be withheld from public disclosure. The affidavit for Attachment 12 Enclosure 1 is provided in Enclosure 3 of Attachment 12.

In Reference 1 Energy Northwest identified the intent to install the PRNM and ARTS / MELLLA improvements during the next planned refueling outage after NRC approval is received (with the earliest opportunity being in the spring 2013). Based on outage schedules and resource loading, the scheduled implementation of PRNM and ARTS / MELLLA improvements has been moved to the subsequent refueling outage (spring 2015). As such, approval of the LAR is requested by January 30, 2014 to support the proposed installation schedule.

In accordance with 10 CFR 50.91, a copy of this supplemental submittal, with attachments, is being provided to the designated Washington State Official.

Should you have any questions or require additional information regarding this matter, please contact Mr. ZK Dunham, Licensing Supervisor, at (509) 377-4735.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the date of this letter.

Respectfully,

BJ Sawatzke
Vice President, Nuclear Generation & Chief Nuclear Officer

Attachments and Enclosures: As described herein

cc: Regional Administrator – NRC RIV
Project Manager – NRC NRR
NRC Senior Resident Inspector/988C
A.J. Rapacz – BPA/1399
W.A. Horin – Winston & Strawn
J.O. Luce – EFSEC
R.R. Cowley – WDOH

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 7

NEDO-33750, Revision 0

Columbia Generating Station
Power Range Neutron Monitoring System
Failure Mode and Effects Analysis

June 2012

(Non-Proprietary)

HITACHI

GE Hitachi Nuclear Energy

NEDO-33750
Revision 0
DRF Section 0000-0144-7420 R1
June 2012

Non-Proprietary Information – Class I (Public)

COLUMBIA GENERATING STATION
POWER RANGE NEUTRON MONITORING SYSTEM
FAILURE MODE AND EFFECTS ANALYSIS

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33750P, Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

The design, engineering, and other information contained in this document are furnished for the purposes of supporting a license amendment request by Energy Northwest for a power range neutron monitoring system upgrade in proceedings before the U.S. Nuclear Regulatory Commission. The use of this information by anyone other than Energy Northwest, or for any purpose other than that for which it is intended, is not authorized; and, with respect to any unauthorized use, GEH makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

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Acronyms and Abbreviations

Term	Definition
APRM	Average Power Range Monitor
CGS	Columbia Generating Station
CP	Common Procedure
D3	Diversity and Defense-in-Depth
DI&C	Digital Instrumentation and Control
FMEA	Failure Mode and Effects Analysis
GEH	GE Hitachi Nuclear Energy
IEEE	Institute of Electrical and Electronics Engineers
ISG	Interim Staff Guidance
LAR	License Amendment Request
LPRM	Local Power Range Monitor
LTR	Licensing Topical Report
NRC	Nuclear Regulatory Commission
NUMAC	Nuclear Measurement Analysis and Control
OPRM	Oscillation Power Range Monitor
PRNMS	Power Range Neutron Monitoring System
RBM	Rod Block Monitor
RG	Regulatory Guide
RPS	Reactor Protection System
SE	Safety Evaluation

1. Introduction

This report addresses Digital Instrumentation and Control (DI&C) Interim Staff Guidance (ISG)-06 (Reference 1) Section D.9.4.2.1.1 and provides an assessment of the effects of single failures.

2. Overview

The Nuclear Regulatory Commission (NRC) previously reviewed the design of the Nuclear Measurement Analysis and Control (NUMAC) Power Range Neutron Monitoring System (PRNMS) retrofit design against Institute of Electrical and Electronics Engineers (IEEE) Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations" (Reference 2), and the NRC staff found that "(the PRNMS design) provides the required isolation and physical independence to ensure acceptable defense against Single-Failures." See Section 3.1 of the NRC Safety Evaluation (SE) (Reference 3). The present discussion reviews and reaffirms the basis for concluding the design is adequate.

More recent regulatory guidance and industry standards updated the definition of the Single-Failure Criterion. Namely, Regulatory Guide (RG) 1.153, "Criteria for Safety Systems" (Reference 4) endorses IEEE Standard 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations" (Reference 5), and RG 1.53, "Application of the Single-Failure Criterion to Safety Systems" (Reference 6) endorses IEEE Standard 379-2000, "IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems" (Reference 7). These two IEEE standards provide an updated Single-Failure Criterion that is somewhat different from the one in IEEE Standard 279-1971 (Reference 2) because they include some additional considerations in three sub-clauses. The present discussion evaluates the NUMAC PRNMS design against the updated definition of the Single-Failure Criterion, and explains why the design is adequate.

3. Technical Evaluation

As discussed in the original NUMAC PRNMS licensing topical report (LTR, Reference 8) Section 4.4.1.1.2, [[

]]

The updated definition of the Single-Failure Criterion, as found in IEEE Standard 379-2000 (Reference 7) and IEEE Standard 603-1991 (Reference 5), includes additional considerations in three sub-clauses. The following discussion addresses each of these sub-clauses and shows that the PRNMS design satisfies them.

The first sub-clause requires that the system perform its safety functions in the presence of a single failure concurrent with all identifiable but non-detectable failures. As discussed above, in connection with IEEE Standard 279-1971 Clause 4.2, the NUMAC PRNMS continues to perform its safety function in the presence of a single failure. The system also meets the additional consideration of "identifiable but non-detectable failures" mainly through self-testing. As explained in Section 6.3.5 of the PRNMS LTR (Reference 8), [[

]] See Section 3.6.2 of the NRC SE (Reference 3).

As discussed in Section 2.4.11 of Reference 9, a Technical Design Review was conducted in accordance with GE Hitachi Nuclear Energy (GEH) Common Procedure (CP)-03-04, Technical Reviews (Reference 10). These reviews require a Failure Mode and Effects Analysis (FMEA) as one of the deliverables. During the CGS PRNMS project, the findings in the NUMAC PRNMS LTR and SE were confirmed. Specifically, identified failure modes that could impair a trip function were detectable.

Additionally, it should be noted that the NUMAC PRNMS will continue to perform its safety function even in the presence of a second random failure. [[

]] The PRNMS design meets the first sub-clause.

The second sub-clause requires that the system perform its safety function in the presence of all failures caused by the single failure. As discussed above in connection with IEEE Standard 279-1971, the redundant channels are independent and isolated. Other clauses in the industry standards address this aspect of system design, and were included as attachments to Enclosure 2 of the License Amendment Request (LAR, Reference 11) demonstrating that the PRNMS design is acceptable. See Section 4.4.1.1.6 of the NUMAC LTR (Reference 8), Section 3.5 of the NRC SE (Reference 3), and Section 9.2.6 of the NEDC-33685P (Reference 9).

Besides physical and electrical isolation, another related aspect is inter-division communication. The PRNMS inter-division communication is discussed in NEDC-33697P (Reference 12), which

addresses D.7.2 of DI&C-ISG-06 (Reference 1) and includes the DI&C-ISG-04 (Reference 13) compliance matrix. Collectively, the PRNMS isolation and the acceptable inter-division communication ensure that a credible fault or failure in one channel will not cascade to and impair another channel. Therefore, the effects of the Single-Failure are confined to that single channel, and with only one channel impaired, a scram occurs when any two of the remaining three APRM channels detect a trip condition. The PRNMS design meets the second sub-clause.

The third sub-clause requires that the system perform its safety functions for a design basis event in the presence of all failures and spurious system actions that cause or are caused by the design basis events requiring the safety function. The CGS PRNMS Diversity and Defense-in-Depth (D3) Analysis (Reference 14) Section 4.2 tabulates all the CGS design basis events and identifies the credited trip signal. Based on a review of these events, those that require a PRNMS trip signal clearly will not also impair the PRNMS. Additionally, the NUMAC PRNMS equipment is qualified, as discussed in Sections 4.4.1.1.5 and 4.4.2 in the NUMAC LTR (Reference 8) and Section 5 of NEDC-33685P (Reference 9). Thus, the design meets the third sub-clause.

4. Summary and Conclusion

In summary, the retrofit NUMAC PRNMS system satisfies the Single-Failure Criterion, as it is defined in References 2, 5, and 7.

5. References

1. DI&C-ISG-06, "Task Working Group #6: Licensing Process," Revision 1, January 19, 2011 (ADAMS Accession No. ML110140103).
2. IEEE Standard 279, "Criteria for Protection Systems for Nuclear Power Generating Stations," 1971.
3. Letter, NRC to Mr. David W. Reigel (GE), "Acceptance of Licensing Topical Report NEDC-32410-P, Nuclear Measurement Analysis and Control Power Range Neutron Monitor (NUMAC-PRNMS) Retrofit Plus Option III Stability Trip Function (TAC No. M90616)," September 5, 1995.
4. NRC RG 1.153, "Criteria for Safety Systems," Revision 1, June 1996.
5. IEEE Standard 603, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," 1991.
6. NRC RG 1.53, "Application of the Single-Failure Criterion to Safety Systems," Revision 2, November 2003.
7. IEEE Standard 379, "IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems," 2000.
8. GE Nuclear Energy, "Nuclear Measurement Analysis and Control Power Range Neutron Monitor (NUMAC PRNMS) Retrofit Plus Option III Stability Trip Function," NEDC-32410P-A, Volume 1, October 1995.
9. GE Hitachi Nuclear Energy, "Digital I&C-ISG-06 Compliance for Columbia Generating Station NUMAC Power Range Neutron Monitoring Retrofit Plus Option III Stability Trip Function," NEDC-33685P, Revision 1, January 2012 (ADAMS Accession No. ML12040A074).
10. CP-03-04, Technical Reviews.

11. Letter, B.J. Sawatzke (CGS) to NRC Document Control Desk, "Columbia Generating Station, Docket No. 50-397, License Amendment Request to Change Technical Specifications in Support of PRNM/ARTS/MELLLA Implementation," GO2-12-017, January 31, 2012 (ADAMS Accession No. ML12040A072).
12. GE Hitachi Nuclear Energy, "Columbia Generating Station Power Range Neutron Monitoring System Design Analysis Report," NEDC-33697P, Revision 1, January, 2012 (ADAMS Accession No. ML12040A077).
13. DI&C-ISG-04, "Task Working Group #4: Highly Integrated Control Rooms-Communications Issues," Revision 1, March 6, 2009 (ADAMS Accession No. ML083310185).
14. GE Hitachi Nuclear Energy, "Columbia Generating Station Power Range Neutron Monitoring System Diversity and Defense-in-Depth (D3) Analysis," NEDC-33694P, Revision 0, November 2011 (ADAMS Accession No. ML12040A076).

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 8

NEDO-33753, Revision 0

Columbia Generating Station
Instrument Limits Calculation
Average Power Range Monitor
(NUMAC ARTS-MELLLA)

June 2012

(Non-Proprietary)

HITACHI GE Hitachi Nuclear Energy

NEDO-33753
Revision 0
DRF Section 0000-0148-3954 R0
June 2012

Non Proprietary Information – Class I (Public)

COLUMBIA GENERATING STATION

INSTRUMENT LIMITS CALCULATION

AVERAGE POWER RANGE MONITOR

(NUMAC ARTS-MELLLA)

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33753P, Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

The design, engineering, and other information contained in this document are furnished for the purposes of supporting a license amendment request by Energy Northwest, for a power range neutron monitoring system upgrade in proceedings before the U.S. Nuclear Regulatory Commission. The use of this information by anyone other than Energy Northwest, or for any purpose other than that for which it is intended, is not authorized; and, with respect to any unauthorized use, GEH makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

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ACRONYMS AND ABBREVIATIONS

Term	Definition
AGAF	APRM Gain Adjustment Factor
AL	Analytical Limit
ALT	As Left Tolerance
APEA	Primary Element Accuracy-Accuracy Error
APRM	Average Power Range Monitor
ARTS	Average Power Range Monitor, Rod Block Monitor Technical Specification Improvement Program
AV	Allowable Value
CGS	Columbia Generating Station
CLTP	Current Licensed Thermal Power
CP	Common Procedure
D3	Diversity and Defense-in-Depth
DI&C	Digital Instrumentation & Control
dP	Differential Pressure
DPEA	Primary Element Accuracy-Drift Error
EMI	Electromagnetic Interference
FMEA	Failure Mode and Effects Analysis
FS	Full Scale
FT	Flow Transmitter
GEH	GE Hitachi Nuclear Energy
HP	High Pressure
IEEE	Institute of Electrical and Electronics Engineers
LAT	Leave Alone Tolerance
LER	Licensing Event Report
LP	Low Pressure
LPRM	Local Power Range Monitor
M&TE	Maintenance and Testing Equipment
MELLLA	Maximum Extended Load Line Limit Analysis
NIST	National Institute of Standards and Technology
NTSP	Nominal Trip Setpoint
NUMAC	Nuclear Measurement Analysis and Control
OL	Operational Limit

Term	Definition
P/C	Process Computer
PEA	Primary Element Accuracy
PMA	Process Measurement Accuracy
RB	Rod Block
RFI	Radio Frequency Interference
RTP	Rated Thermal Power
SLO	Single-Loop Operation
SP	Calibrated Span
STA	Spurious Trip Avoidance
STP	Simulated Thermal Power
TID	Total Integrated Dose
TLO	Two-Loop Operation
TS	Technical Specifications
URL	Upper Range Limit
VA	Vendor Accuracy
VD	Vendor Drift

EXECUTIVE SUMMARY

This document is a supplement analysis data sheet to Reference 1. Included in this document in sequential order are:

- the setpoint functions for the system,
- the setpoint function analyses inputs and the source reference of the inputs,
- the devices in the setpoint function instrument loop,
- the component analysis inputs and input sources,
- the calculated results,
- input comments and result recommendations,
- references.

System: Average Power Range Monitor (APRM)

The following setpoint functions are included in this document:

- Flow Biased "Simulated Thermal Power - High" (Scram) (two-loop operation (TLO) and single-loop operation(SLO))
- APRM Flow Biased "Simulated Thermal Power – High" (Rod Block (RB)) (TLO and SLO)

Note: The titles from the Technical Specifications (TS) are shown above within quotation marks.

1. FUNCTION: APRM FLOW BIASED SIMULATED THERMAL POWER SCRAMS AND ROD WITHDRAWAL BLOCKS

Setpoint Characteristics:	Definition	Reference(s)
Event Protection:	Limiting event for the setpoint **Scram:** This function is not credited in any plant Safety Analyses. The TS identify that this function is required for Mode 1. **Rod Block:** This function avoids conditions that would require Reactor Protection System action if allowed to proceed. The APRM High RB is set below the APRM Flow Biased Thermal Power - High Scram, and as an operational safeguard, initiates a RB before the APRM Fixed Neutron Flux-High Scram. This function is not a TS limit.	Ref. 3.1 Bases Section B 3.3.1.1 Ref. 3.1 Bases Section B 3.3.1.1, Ref. 3.2 Section 7.7.1.2.2.2.b.2(a)
Function After Earthquake	☐ Required ☒ Not Required for Flow Transmitter	Comment 18
Setpoint Direction • Flow Biased Simulated Thermal Power (STP) Scram (TLO and SLO) • Flow Biased STP Rod Block (TLO and SLO)	☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing	
Single or Multiple Channel	☐ Single ☒ Multiple	
Licensing Event Report (LER) Calculation Basis if Multiple Channel	Standard (Conservative) LER Calculation ☒, or Configuration Specific LER Calculation ☐	Ref. 1 Section 5.3, Ref. 2 Section 1.2.3
Trip Logic for Configuration Specific LER Calculation	N/A	

Plant Data:	Value	Sigma if not 2	Reference(s)
Flow Element Primary Element • Accuracy (APEA) • Drift (DPEA)	± 3.3% FS loop flow; n/a		
Flow Process Measurement Accuracy (PMA) • PMA (Flow noise) • PMA (Flow transmitter (FT) taps-static head)	± 1% rated Recirc flow 0.0%		

1. **Function: APRM Flow Biased Simulated Thermal Power Scrams and Rod Withdrawal Blocks (cont'd)**

Plant Data:	Value	Sigma if not 2	Reference(s)
Local Power Range Monitor (LPRM) Detector (APRM PEA) (% power) $APEA_{Accuracy}$ $APEA_{PowerSupplyEffect}$ DPEA	 ± 1%; bias 0.49% negligible ± 0.2% / 7 days; bias 0.33% / 7 days		Ref. 2, Comment 6
LPRM Detector (APRM PMA) (% power) • Tracking • Noise (STP flow-biased setpoints)	 ± 1.11% n/a		

Components (or Devices) in Setpoint Function Instrument Loop:

- Flow Element
- LPRM Detector
- Flow Transmitter
- NUMAC Chassis:
  - Instrument Loop Flow Electronics (Recirculation Flow Monitor System)
  - Instrument Loop Power Electronics (LPRM, APRM, Trip Circuit)

1.1 APRM Flow Biased "Simulated Thermal Power - High" (Scram) Two-loop Operation

Current Function Limits:	Value/Equation		Reference(s)	
	Current Licensed Thermal Power (CLTP) (% RTP)	ARTS-MELLLA Condition (% RTP)		
Analytical Limit (AL)	n/a	n/a	n/a	n/a
TS Allowable Value (AV)	$0.58W_d + 62\%$	$0.63W_d + 64\%$		
Nominal Trip Setpoint (NTSP)	$0.58W_d + 59\%$	Results provided in Section 3		
Operational Limit (OL)	None provided	$0.63W_d + 58.1\%$		Ref. 1, Ref. 2, Comment 14

1.2 APRM Flow Biased "Simulated Thermal Power - High" (Scram) Single-loop Operation

Current Function Limits:	Value/Equation		Reference(s)	
	CLTP (% RTP)	ARTS-MELLLA Condition (% RTP)		
Analytical Limit	n/a	n/a	n/a	n/a
TS Allowable Value	$0.58W_d + 62\%$ (Same as TLO)	$0.63(W_d\text{-}\Delta W) + 64.0\%$ $0.63W_d + 60.8\%$		
Nominal Trip Setpoint	$0.58W_d + 59\%$ (Same as TLO)	Results provided in Section 3		
Operational Limit	None provided	n/a		Ref. 1, Ref. 2, Comment 11

* $\Delta W = 5$.

1.3 APRM Flow Biased Simulated Thermal Power - High (Rod Block) Two-loop Operation

Current Function Limits:

	Value/Equation		Reference(s)	
	CLTP (% RTP)	ARTS-MELLLA Condition (%RTP)		
Analytical Limit	n/a	n/a	n/a	n/a
TS Allowable Value	$0.58W_d + 53\%$	$0.63W_d + 60.1\%$		
Nominal Trip Setpoint	$0.58W_d + 50\%$	Results provided in Section 3		
Operational Limit	None provided	n/a		Ref.1, Ref. 2, Comment 14

1.4 APRM Flow Biased Simulated Thermal Power - High (Rod Block) Single-loop Operation

Current Function Limits:

	Value/Equation		Reference(s)	
	CLTP (% RTP)	ARTS-MELLLA Condition (%RTP)		
Analytical Limit	n/a	n/a	n/a	n/a
TS Allowable Value	$0.58W_d + 53\%$ (Same as TLO)	$0.63(W_d - \Delta W) + 60.1\%$ $0.63W_d + 56.9\%$		
Nominal Trip Setpoint	$0.58W_d + 50\%$ (Same as TLO)	Results provided in Section 3		
Operational Limit	None provided	n/a		Ref. 1, Ref. 2, Comment 11

* $\Delta W = 5$.

1.5 APRM STP Scram Clamp

Current Function Limits:

	Value/Equation		Reference(s)	
	CLTP (% RTP)	ARTS-MELLLA Condition (%RTP)		
Analytical Limit	117%	n/a		n/a
Allowable Value	114.90%	114.9%		
Nominal Trip Setpoint	113.50%	Results provided in Section 3		
Operational Limit	n/a	109.0%	Ref. 1, Ref. 2, Comment 14, Comment 23	

1.6 APRM STP Rod Block Clamp

Current Function Limits:	Value/Equation		Reference(s)	
	CLTP (% RTP)	ARTS-MELLLA Condition (%RTP)		
Analytical Limit	n/a	n/a	n/a	n/a
Allowable Value	n/a	111%		
Nominal Trip Setpoint	n/a	Results provided in Section 3		
Operational Limit	n/a	n/a	Ref. 1, Ref. 2, Comment 14	

2. COMPONENTS

2.1 Flow Transmitter

Component Information:	Value/Equation	Reference(s)
Plant Instrument ID No.	RRC-FT-14A (B35-N014A)	
Instrument vendor	Rosemount	
Model ID No. (including Range Code)	1153DB5PA	
Plant Location(s)	E-IR-P006, elevation 471', column 4.1/R5	
Process Element	Flow Element (Flow Elbow)	

Inputs:

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Top of Scale	362.4 inWC 20mA		
Bottom of Scale	0 inWC 4 mA		
Upper Range Limit (URL)	750 inWC		
Accuracy	0.25% SP	3	Ref. 4.6
Temperature Effect	(0.75% URL + 0.5% Span)/100F	3	Ref. 4.6
Seismic Effect	0.5% URL at 4g		Ref. 4.4 Section 6, Comment 18
Radiation Effect	±8.0% URL during and after exposure to 2.2×10^7 rads Total Integrated Dose (TID)		Ref. 4.4 Section 6, Comment 17

2.1 Flow Transmitter (cont'd)

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Humidity Effect	negligible		Comment 4
Power Supply Effect	0.02% SP <0.005% of output span per volt		
RFI/EMI Effect	included in accuracy		Comment 4
Insulation Resistance Effect	0.0%		
Over-pressure Effect	± 1% URL (Maximum zero shift after 2,000 psi overpressure).	3	Ref. 4.4, Ref. 4.6
Static Pressure Effect (psid) • Zero Effect • Range Span Effect	 ± 0.2% URL per 1000 psi (calibrated out) ± 0.5% of input reading/1,000 psi (calibrated out)	3	Ref. 4.4, Ref. 4.6, Comment 16
Mounting Position Effect • Zero Shift • Span Effect	 Up to 1.5 InH_20 (calibrated out) None	3	Ref. 4.4 (page 6-5) Ref. 4.6

Plant Data:	Value	Reference(s)
Calib Temperature Range	70 to 104 °F	
Normal Temperature Range	40 to 104 °F	
Trip Temperature range	40 to 104 °F	Comment 20
Plant seismic value	0.5g	
Plant Radiation value	2.07 x 10^6 rads TID	
Plant Humidity value	20 to 90% RH	
Power Supply Variation value	24Vdc ± 2.0 Vdc	
RFI/EMI value	Negligible	
Over-pressure value	1375 psig	
Static Pressure value	1039 psig	

2.1 Flow Transmitter (cont'd)

Drift:	**Value**	**Sigma if not 2**	**Reference(s)**
Current Calib. Interval	184 days ☐Includes extra 25%		Ref. 3.1, Table 3.3.1.1-1, Item 2.b., SR 3.3.1.1.9
Desired Calib. Interval	24 months ☐Includes extra 25%		Comment 3
Drift Source	☒Vendor ☐Calculated		Ref. 1, Ref. 2
Drift Value	± 0.2% URL /30 months		Ref. 4.4 Section 6, Comment 12

Calibration:	**Value / equation**	**Sigma if not 3**	**Reference(s)**
As Left Tolerance (ALT)	± 0.07% SP		
Leave Alone Tolerance (LAT)	± 0.07% SP		

Input Calibration Tool:	Pressure gauge (Wallace & Tiernan or equivalent)		
Accuracy	± 1.0 inWC Minimum approx. ± 0.28% SP		Comment 10
Resolution / Readability	approx. ± 0.07% SP		
Minor Division	0.5 inWC		
Upper Range			
Temperature Effect			
Input Calibration Standard:	NIST		
Accuracy	= ¼ Tool accuracy ± 0.071108% SP		Comment 10
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			

2.1 Flow Transmitter (cont'd)

	Value / equation	Sigma if not 3	Reference(s)
Output Calibration Tool:	Fluke 45		
Accuracy	± 0.013 mAdc = ± 0.08125% SP		Comment 10
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Standard:	NIST		
Accuracy	= ¼ Tool Accuracy ± 0.020313% SP		Comment 10
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			

2.2 Flow Electronics (Recirculation Flow Monitor System)

Component Information:	Value/Equation	Reference(s)
Plant Instrument ID No.	Not provided	Comment 2
Instrument vendor	GEH	Ref. 4.2
Model ID No. (including Range Code)	NUMAC	Ref. 4.2
Plant Location(s)	Control Room	
Process Element	n/a	

Inputs:

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Top of Scale	125% loop flow 10Vdc 20mAdc		Ref. 4.2 Sections 4.3.5.3, 4.3.5.4, 4.6.2
Bottom of Scale	0% loop flow 0Vdc 4 mAdc		Ref. 4.2 Sections 4.3.5.3, 4.3.5.4, 4.6.2
Upper Range Limit	n/a		Ref. 4.2 Sections 4.3.5.3, 4.3.5.4, 4.6.2
Accuracy	± 0.122 mAdc (where 16 mAdc input span from FT corresponds to 125% flow)		Comment 21
Temperature Effect	included in accuracy		Ref. 4.5, Section 4.6.2
Seismic Effect	included in accuracy		Ref. 4.5 Section 4.1.1 and Section 4.2.6, Comment 4
Radiation Effect	Included in accuracy		Ref. 4.5 Section 4.2.4, Comment 4.
Humidity Effect	included in accuracy		Ref. 4.5 Section 4.2.2, Comment 4
Power Supply Effect	included in accuracy		Comment 4
RFI/EMI Effect	negligible		Ref. 4.5 Section 4.2.5, Comment 4
Insulation Resistance Effect	negligible		Comment 4
Over-pressure Effect	n/a		Comment 5
Static Pressure Effect	n/a		Comment 5

Plant Data:	Value	Sigma if not 2	Reference(s)
Calib Temperature Range	70 to 104 °F		
Normal Temperature Range	40 to 104 °F		
Trip Temperature range	40 to 104 °F		Comment 20

2.2 Flow Electronics (cont'd)

Plant Data:	**Value**	**Sigma if not 2**	**Reference(s)**
Plant seismic value	0.7g		
Plant Radiation value	n/a		
Plant Humidity value	10 to 60% RH		
Power Supply Variation value	Not provided		Comment 2
RFI/EMI value	Not provided		Comment 2
Over-pressure value	n/a		Comment 5
Static Pressure value	n/a		Comment 5

Drift:	**Value**	**Sigma if not 2**	**Reference(s)**
Current Calib. Interval	184 days ☐Includes extra 25%		Ref. 3.1, Table 3.3.1.1-1, Item 2.b., SR 3.3.1.1.9
Desired Calib. Interval	24 months ☐Includes extra 25%		Comment 3
Drift Source	☐Vendor ☒Calculated		Ref. 1, Ref. 2
Drift Value • (% rated drive flow)	[[ ]] = ± 0.122 mAdc / 6 months		Ref. 1 Section 3.3, Ref. 2

2.2 Flow Electronics (cont'd)

Calibration:	Value / equation	Sigma if not 3	Reference(s)
As Left Tolerance	n/a		
Leave Alone Tolerance	n/a		
Input Calibration Tool:	Internal to NUMAC		
Accuracy	± (1.1)*0.192% units on 125% scale		Comment 15
Resolution / Readability	included in accuracy		
Minor Division	included in accuracy		
Upper Range	125%		
Temperature Effect	included in accuracy		
Input Calibration Standard:	included in calibration tool		
Accuracy	n/a		
Resolution / Readability	n/a		
Minor Division	n/a		
Upper Range	n/a		
Temperature Effect	n/a		
Output Calibration Tool:	n/a		
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Standard:	n/a		
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			

2.3 Power Electronics (LPRM, APRM, Trip Circuit)

Component Information:	Value/Equation	Reference(s)
Plant Instrument ID No.	Not provided	Comment 2
Instrument vendor	GEH	Ref. 4.2
Model ID No. (including Range Code)	NUMAC	Ref. 4.2
Plant Location(s)	Control Building	
Process Element	Neutron detector - LPRMs: NA250 and NA300	Ref. 4.2 Sections 1.5 & 3.2

Inputs:

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Top of Scale	FS = 125%		Ref. 4.2 Section 4.3.2
Bottom of Scale	0%		Ref. 4.2 Section 4.3.2
Upper Range Limit	n/a %		Ref. 4.2 Section 4.3.2
Accuracy • LPRM Detector • LPRM Electronics	 See APRM PEA (Section 1) ± 0.943% (% local power)		$A_{LPRM\ Detector}$ = APRM PEA per Ref. 1 & Ref. 2
Temperature Effect	included in accuracy		
Seismic Effect	included in accuracy		Ref. 4.5 Section 4.1.1, Comment 4
Radiation Effect	Included in accuracy		Ref. 4.5 Section 4.2.4, Comment 4
Humidity Effect	included in accuracy		Ref. 4.5 Section 4.2.2, Comment 4
Power Supply Effect (Detector)	See APRM PEA		
RFI/EMI Effect	negligible		Ref. 4.5 Section 4.2.4, Comment 4
Insulation Resistance Effect	negligible		Comment 4
Over-pressure Effect	n/a		Comment 5
Static Pressure Effect	n/a		Comment 5

2.3 Power Electronics (LPRM, APRM, Trip Circuit) (cont'd)

Plant Data:	Value	Reference(s)
Calib Temperature Range	70 to 104 °F	
Normal Temperature Range	40 to 104 °F	
Trip Temperature range	40 to 104 °F	Comment 20
Plant seismic value	0.7g	
Plant Radiation value	n/a	
Plant Humidity value	10 to 60% RH	
Power Supply Variation value	Not provided	Comment 2
RFI/EMI value	Not provided	Comment 2
Over-pressure value	n/a	Comment 5
Static Pressure value	n/a	Comment 5

Drift:	Value		Sigma if not 2	Reference(s)
Current Calib. Interval	7 days	☐Includes extra 25%		Ref. 3.1 Table 3.3.1.1-1 SR 3.3.1.1.2
Desired Calib. Interval	7 days	☐Includes extra 25%		Ref. 3.1 Table 3.3.1.1-1 SR 3.3.1.1.2
Drift Source	☐Vendor	☒Calculated		Ref. 1, Ref. 2
Drift Value (% power)	± 0.5% FS / 700 hours	± 0.5% SP / 8.75 days		Ref. 4.3 Section 4.3.3.3, Comment 9

2.3 Power Electronics (LPRM, APRM, Trip Circuit) (cont'd)

Calibration:	**Value / equation**	**Sigma if not 3**	**Reference(s)**
	Included in APRM calibration		
As Left Tolerance	AGAF		Comment 7
Leave Alone Tolerance	= ALT		Comment 7
Input Calibration Tool:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Input Calibration Standard:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Tool:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Standard:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			

Application Specific Input:	**Value**	**Sigma if not 2**	**Reference(s)**
Minimum no. of LPRMs per APRM Channel	20 of 43		Ref. 4.1 Section 4.1.5, Comment 25
APRM Gain Adjustment Factor	± 2% RTP	3	

3. SUMMARY RESULTS

Calculated Values

Setpoint Function $^{\tau}$	Allowable Value (AV) (% ARTS-MELLLA RTP)	Nominal Trip Setpoint (NTSP) (% ARTS-MELLLA RTP)	Meets LER Avoidance Criteria	Meets Spurious Trip Avoidance Criteria (Comment 13)
APRM STP Scram Clamp	114.9%	112.9%	Y	Y
APRM STP RB Clamp	111.0%	108.0% (Comment 23)	Y	n/a
Flow Biased STP-High Scram - TLO	$0.63W_d + 64.0\%$	$0.63W_d + 62.0\%$	Y	Y
Flow Biased Neutron Flux-High RB - TLO	$0.63W_d + 60.1\%$	$0.63W_d + 58.1\%$	Y	n/a
Flow Biased STP-High Scram - SLO (Comment 22, Comment 24)	$0.63(W_d - \Delta W) + 64.0\%$ $0.63W_d + 60.8\%$	$0.63(W_d - \Delta W) + 60.2\%$ $0.63W_d + 57.1\%$ $0.63(W_d - SLO_{SettingAdj}) + 62.0\%$	Y	n/a
Flow Biased Neutron Flux-High RB - SLO (Comment 22, Comment 24)	$0.63(W_d - \Delta W) + 60.1\%$ $0.63W_d + 56.9\%$	$0.63(W_d - \Delta W) + 56.3\%$ $0.63W_d + 53.2\%$ $0.63(W_d - SLO_{SettingAdj}) + 58.1\%$	Y	n/a

τ "W_d" in the APRM flow-biased equations is defined, as the % Recirculation drive flow, where 100% drive flow is that required to achieve 100% core power and flow. The AL equations that include ΔW were derived as part of the ARTS-MELLLA setpoint calculation. The TLO ΔW is 0% and the SLO ΔW is 5% (Comment 8).

Application Specific Setpoint Adjustments

Function	Example Equation	$SLO_{SettingAdj}$	
TLO to SLO Setting Adjustment for NUMAC setpoints	[[ ]]	7.8%	Comment 19
	TLO AV to NTSP	SLO AV to NTSP (Comment 22)	
Minimum Required Margins (% RTP)	2.000	3.700	

4. COMMENTS AND RECOMMENDATIONS

1. Unless specifically identified as "bias" errors in this document, all instrument uncertainty errors will be considered to be random in nature, even when the "±" symbol is not shown.
2. Some plant specific information has not been provided in the current CGS setpoint calculation(s) and is considered unnecessary because the impact of this information is included within the instrument accuracy values, or considered negligible.
3. Calibration interval of 24 months is used in the analysis. The plant is on a 24 month cycle, but there is no verified input to that effect. 24 months used in the drift analysis is conservative even if the calibration is done on an 18 month cycle.
4. Seismic effect, radiation effect, humidity effect, power supply effect, RFI/EMI effect, and insulation resistance effect errors are marked "negligible" or "included in accuracy" and are considered to have negligible impact on the manufacturer's accuracy terms when they are not identified separately.
5. Per Reference 1 and Reference 2, overpressure effects are only applicable to pressure measurement devices (e.g., differential pressure transmitters), and static pressure effects are only applicable to differential pressure measurement devices. These effects are marked "n/a" for other devices.
6. [[ ]] (Reference 2 Section 4.5.3)
7. The APRM subsystem is calibrated on-line weekly (Reference 3.1) using the APRM Gain Adjustment Factor (AGAF) process, where the gain of the APRMs is adjusted to read the Core Thermal Power (CTP) determined by the Process Computer (P/C), within a specified ALT. [[ ]]
   Thus, the only calibration error to consider for the APRM electronics sub-loop is the As Left Tolerance specified by the AGAF process.
8. "W_d" in the APRM flow-biased equations is defined as the % Recirculation drive flow, where 100% drive flow is that required to achieve 100% core power and flow. The effective drive flow correction term, ΔW, corresponds to the difference in percent flow between the TLO and SLO drive flow at the same core flow. The TLO ΔW is 0% by definition. For these setpoint calculations, the SLO ΔW is 5%.
9. A conservative value for the design drift value of ± 0.5%SP/8.75 days is applied based on the equipment surveillance interval of 7 days plus 25%.
10. For the FTs, the Calibration Tools are used two times to calibrate the two FTs. Therefore, the calibration accuracy terms need to be considered for both uses. (Reference 1)
11. An spurious trip avoidance (STA) evaluation is not performed for SLO due to the rarity of plant operation in this configuration; thus, the OL is not applicable.
12. The current approach in GEH setpoint calculation methodology treats the Drift for this instrument to be a 2 sigma value.
13. Per GEH Setpoint methodology (Reference 1 and Reference 2), the criteria for STA [[ ]]. This corresponds to a $Z_{STA} = 1.65$.

14. For the APRM flow-biased Scrams, the OLs for TLO are set equal to the corresponding TLO setpoints for the APRM flow-biased RBs. This is consistent with GEH setpoint methodology and with ensuring a RB occurs prior to reaching a Scram for the same function. STA evaluations were performed for Scrams, but not for Rod Blocks or permissives per GE setpoint methodology (Reference 1 and Reference 2), such as the APRM Flow-biased RBs.

15. Complete inputs are unavailable for the Flow Electronic calibration errors for all Maintenance and Testing Equipment (M&TE) to be used at the plant. Therefore, the Flow Electronics calibration errors are based on using errors that are 10% higher than the errors for assumed calibration tools.

16. The FT zero bias error is usually considered to be zero due to the installation and calibration of the differential pressure (dP) transmitter nozzle taps on the Recirculation pipes. However the installation of the dP transmitter nozzle taps on the Recirculation flow pipe must be evaluated and a PMA bias error included if the low pressure (LP) nozzle is at a higher elevation than the high pressure (HP) nozzle, and this static head dP is not accounted for in the transmitter calibration process. This error is calibrated out, and is considered zero.

17. The vendor data uncertainty value is after or during an accident radiation level. In a non-accident condition, the environment in which the transmitter is located will never approach that level, and the transmitter is not required to function after an accident. Therefore, the radiation effect for the FTs does not need to be considered.

18. The flow-biased APRM Flow Biased STP-High (Scram) setpoint does not perform a protective function credited in the safety analysis. Therefore, the Seismic Effect for the FTs does not need to be considered.

19. [[

]] The resulting SLO NTSP would then be 0.63 (W_d – 7.8) + 62.0%. Because the Setting Adjustment is programmed into the NUMAC equipment to one decimal place, each calculated number is rounded up to one decimal place for conservatism. This adjustment may be used in the implementation of the new NUMAC equipment.

20. The Neutron Monitoring System performs its trip functions before accident temperatures are reached, so temperatures for trip and normal conditions are assumed to be the same.

21. The accuracy of the flow electronics is not given in the NUMAC specifications, [[

]] The combined error for the loop flow electronics is ± 0.122 mA at 2σ.

22. For the SLO NTSPs, the results use current GEH setpoint methodology, where a higher SLO error exists because of equipment errors in the idle loop upstream of the flow electronics.

23. The APRM STP RB Clamp NTSP calculated NTSP is 109.0 % RTP, and this number is conservatively used as the OL for the APRM STP Scram Clamp, as it would be more restrictive. The STA evaluation for the APRM STP Scram Clamp met the STA avoidance criteria with the higher OL. An NTSP value of 108.0 % RTP was conservatively chosen to meet RB operating margin requirements at rated power. This 108.0 % RTP reflects the original overpower design basis for this RB setpoint function, and is consistent with other ARTS-MELLLA projects.

24. Each of the SLO NTSP equations are equivalent to each other, but could provide slightly different results because of rounding. Each SLO NTSP equation has been rounded conservatively to one decimal place, that is, further away from the AV.

25. Reference 4.1 specifies that 20 LPRMs per APRM channel must be operable. Based on a total of 43 LPRMs, 23 LPRMs per LPRM channel can be bypassed.

5. REFERENCES

1. GE Nuclear Energy, "General Electric Methodology for Instrumentation Technical Specification and Setpoint Analysis," NEDC-32889P, Revision 3, November 2002.

2. GE Nuclear Energy, "General Electric Instrument Setpoint Methodology," NEDC-31336P-A, dated September 1996.

3. Columbia Generating Station Licensing and related documents:

   3.1. Columbia Generating Station Technical Specifications and Bases, as revised through Amendment 212.

   3.2. Columbia Generating Station Final Safety Analysis Report (FSAR), as revised through Amendment 57, December 2007.

4. Vendor Specifications:

   4.1. GEH 24A5221TC, "PRNM Requirements Specification," Data Sheet, Columbia Generating Station, Revision 4, December 7, 2009.

   4.2. GEH 24A5221, "NUMAC Power Range Neutron Monitor (PRNM)," Requirements Specification, Revision 17, July 21, 2008.

   4.3. GEH 25A5916, "NUMAC Average Power Range Monitor (APRM)," Performance Specification, Revision 5, February 28, 2005.

   4.4. Rosemount Reference Manual 00809-0100-4302, Rev. BA, Model 1153 Series B Alphaline® Pressure Transmitter, January 2008.

   4.5. GEH 23A5082, "NUMAC Requirements Specification," Design Spec, Revision 1, August 9, 1995.

   4.6. Facsimile from G. Hanson of Rosemount to Daniel Gould of GE, "3-Sigma Compliance," February 26, 1999.

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 9

NEDO-33754, Revision 0

Columbia Generating Station
Instrument Limits Calculation
Rod Block Monitor
(NUMAC ARTS-MELLLA)

June 2012

(Non-Proprietary)

HITACHI

GE Hitachi Nuclear Energy

NEDO-33754
Revision 0
DRF Section 0000-0148-3954 R0
June 2012

Non Proprietary Information – Class I (Public)

COLUMBIA GENERATING STATION

INSTRUMENT LIMITS CALCULATION ROD BLOCK MONITOR (NUMAC ARTS-MELLLA)

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33754P, Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

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ACRONYMS AND ABBREVIATIONS

Term	Definition
AL	Analytical Limit
ALT	As Left Tolerance
APEA	Primary Element Accuracy-Accuracy Error
APRM	Average Power Range Monitor
ARTS	Average Power Range Monitor, Rod Block Monitor Technical Specification Improvement Program
AV	Allowable Value
CGS	Columbia Generating Station
DPEA	Primary Element Accuracy-Drift Error
EMI	Electromagnetic Interference
FS	Full Scale
GEH	GE Hitachi Nuclear Energy
HPSP	High Power Setpoint
HTSP	High Power Trip Setpoint
IEEE	Institute of Electrical and Electronics Engineers
IPSP	Intermediate Power Setpoint
ITSP	Intermediate Power Trip Setpoint
LAT	Leave Alone Tolerance
LER	Licensing Event Report
LP	Low Pressure
LPRM	Local Power Range Monitor
LPSP	Low Power Setpoint
LTSP	Low Power Trip Setpoint
M&TE	Maintenance and Testing Equipment
MELLLA	Maximum Extended Load Line Limit Analysis
NIST	National Institute of Standards and Technology
NTSP	Nominal Trip Setpoint
NUMAC	Nuclear Measurement Analysis and Control
OL	Operational Limit
P/C	Process Computer
PEA	Primary Element Accuracy

Term	Definition
PMA	Process Measurement Accuracy
RB	Rod Block
RFI	Radio Frequency Interference
RTP	Rated Thermal Power
SP	Calibrated Span
STA	Spurious Trip Avoidance
STP	Simulated Thermal Power
TS	Technical Specifications

EXECUTIVE SUMMARY

This document is a supplement analysis data sheet to Reference 1. Included in this document in sequential order are:

- The setpoint functions for the system,
- The setpoint function analyses inputs and the source reference of the inputs,
- The devices in the setpoint function instrument loop,
- The component analysis inputs and input sources,
- The calculated results,
- Input comments and result recommendations,
- References.

System: Rod Block Monitor (RBM)
The following setpoint functions are included in this document:

- Low Power Trip Setpoint (LTSP)
- Intermediate Power Trip Setpoint (ITSP)
- High Power Trip Setpoint (HTSP)
- Low Power Setpoint (LPSP)
- Intermediate Power Setpoint (IPSP)
- High Power Setpoint (HPSP)

1. FUNCTION: RBM ROD WITHDRAWAL BLOCKS

Setpoint Characteristics:	Definition	Reference(s)
Event Protection:	Limiting event for the setpoint: The RBM is designed to prevent fuel damage during a Rod Withdrawal Error (RWE) event during high power operation.	Ref. 2, Section 3.19 Ref. 3 Bases B 3.3.2.1
Function After Earthquake	☐ Required ☒ Not Required	Ref. 2 Section 3.19.2 Ref. 3 Bases B3.3.2.1, Comment 9
Setpoint Direction: • Low Power Trip Setpoint (LTSP) • Intermediate Power Trip Setpoint (ITSP) • High Power Trip Setpoint (HTSP) • Low Power Setpoint (LPSP) • Intermediate Power Setpoint (IPSP) • High Power Setpoint (HPSP)	☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing ☒ Increasing ☐ Decreasing	Ref. 3 Bases Section 3.3.2.1
Single or Multiple Channel	☒ Single ☐ Multiple	Ref. 3 Bases Section 3.3.2.1, Ref. 4.2 Section 4.1.6
LER Calculation Basis if Multiple Channel	Standard (Conservative) LER Calculation ☒, or Configuration Specific LER Calculation ☐	Ref. 1, Ref. 2
Trip Logic for Configuration Specific LER Calculation	n/a	

Plant Data:	Value	Sigma if not 2	Reference(s)
Power Primary Element (LPRM Detector) (% Power)			
$APEA_{Accuracy}$	± 1%; bias 0.49%		
$APEA_{PowerSupplyEffect}$	negligible		Ref. 2, Comment 6
DPEA			
• Trip Setpoints	negligible		
• Power Setpoints	± 0.2% / 7 days; bias 0.33% / 7 days		

1. FUNCTION: RBM ROD WITHDRAWAL BLOCKS (CONT'D)

Plant Data:	Value	Sigma if not 2	Reference(s)
Power Process Measurement Accuracy (PMA)			
• Tracking - Trip Setpoints	± 1%	3	
• Tracking - Power Setpoints	± 1.11%		
• Noise - Trip Setpoints	± 2.0%		
• Noise - Power Setpoints	0.0%		

Components (or Devices) in Setpoint Function Instrument Loop:

- LPRM Detector
- NUMAC Chassis: Instrument Loop Power Electronics (LPRM, APRM, RBM, Trip Circuit)

1.1 RBM Low Power Trip Setpoint

Current Function Limits:	Value/Equation			Reference(s)	
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% Reference Level) unfiltered	filtered		
Analytical Limit	$0.58\ W_d + 38$	127.0	125.8		
Technical Specification (TS) Allowable Value	$0.58\ W_d + 35.0$	Results provided in Section 3			
Nominal Trip Setpoint	$0.58\ W_d + 32.0$	Results provided in Section 3			
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3	

1.2 RBM Intermediate Power Trip Setpoint

Current Function Limits:	Value/Equation			Reference(s)	
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% Reference Level) unfiltered	filtered		
Analytical Limit	$0.58\ W_d + 46$	122.0	121.0		
TS Allowable Value	$0.58\ W_d + 43.0$	Results provided in Section 3			
Nominal Trip Setpoint	$0.58\ W_d + 40.0$	Results provided in Section 3			
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3	

1.3 RBM High Power Trip Setpoint

Current Function Limits:	Value/Equation			Reference(s)	
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% Reference Level) unfiltered	filtered		
Analytical Limit	$0.58\ W_d + 54$	117.0	116.0		
TS Allowable Value	$0.58\ W_d + 51.0$	Results provided in Section 3			
Nominal Trip Setpoint	$0.58\ W_d + 48$	Results provided in Section 3			
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3	

1.4 RBM Low Power Setpoint

Current Function Limits:	Value/Equation			Reference(s)
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% RTP) unfiltered	filtered	
Analytical Limit	n/a	30	30	
TS Allowable Value	n/a	Results provided in Section 3		
Nominal Trip Setpoint	n/a	Results provided in Section 3		
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3

1.5 RBM Intermediate Power Setpoint

Current Function Limits:	Value/Equation			Reference(s)
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% RTP) unfiltered	filtered	
Analytical Limit	n/a	65	65	
TS Allowable Value	n/a	Results provided in Section 3		
Nominal Trip Setpoint	n/a	Results provided in Section 3		
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3

1.6 RBM High Power Setpoint

Current Function Limits:	Value/Equation			Reference(s)
	Present Value/Equation (% RTP)	ARTS-MELLLA Condition (% RTP) unfiltered	filtered	
Analytical Limit	n/a	85	85	
TS Allowable Value	n/a	Results provided in Section 3		
Nominal Trip Setpoint	n/a	Results provided in Section 3		
Operational Limit	n/a	n/a		Ref. 1, Ref. 2, Comment 3

2. COMPONENTS:

2.1 Power Electronics (LPRM, APRM, RBM, Trip Circuit)

Component Information:	Value/Equation	Reference(s)
Plant Instrument ID No.	Undefined	Comment 2
Instrument vendor	GE / Reuter-Stokes	Ref. 4.1
Model ID No. (including Range Code)	NUMAC	Ref. 4.1
Plant Location(s)	Control Bldg	Ref. 4.1 Section 4.2.1 and Appendix C
Process Element	LPRMs: NA250/NA300	Ref. 4.2 Sections 1.5 and 3.2

Inputs:

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Top of Scale	FS = 125%	n/a	Ref. 4.2 Sections 4.3.2 and 4.7.2
Bottom of Scale	0%	n/a	Ref. 4.2 Sections 4.3.2 and 4.7.2
Upper Range Limit	n/a	n/a	Ref. 4.2 Sections 4.3.2 and 4.7.2
Accuracy • LPRM Detector • LPRM Electronics	 See Section 1 ± 0.943% (% local power)		Ref. 1 & Ref. 2
Temperature Effect	included in accuracy		
Seismic Effect	included in accuracy		Ref. 4.4 Section 4.1.1, Comment 4
Radiation Effect	included in accuracy		Ref. 4.1 Section 5.2, Comment 4
Humidity Effect	included in accuracy		Ref 4.1 Section 5.2, Comment 4
Power Supply Effect (Detector)	See Section 1		
RFI/EMI Effect	included in accuracy		Ref. 4.4 Sections 4.1.1, and 4.2.5, Comment 4
Insulation Resistance Effect	Negligible		Comment 4
Over-pressure Effect	n/a		Comment 5
Static Pressure Effect	n/a		Comment 5

2.1 Power Electronics (LPRM, APRM, RBM, Trip Circuit) (cont'd)

Plant Data:	Value	Reference(s)
Calibration Temp Range	70 to 104 ^{0}F	Comment 15
Normal Temperature Range	40 to 104 ^{0}F	
Trip Temp Range	40 to 104 ^{0}F	Comment 16
Humidity Operating Range	10 to 60% RH	
Plant Radiation value	n/a	
Plant seismic value	0.7g	Comment 9
Power Supply Variation value	Negligible	Comment 4
RFI/EMI value	n/a	Comment 4
Over-pressure value	n/a	Comment 5
Static Pressure value	n/a	Comment 5

Drift:	Value		Sigma if not 2	Reference(s)
Current Calib. Interval	7 days	☐Includes extra 25%		Ref. 3 Table 3.3.1.1-1 SR 3.3.1.1.2
Desired Calib. Interval	7 days	☐Includes extra 25%		Ref. 3 Table 3.3.1.1-1 SR 3.3.1.1.3
Drift Source	☒Vendor Trip Setpts	☒Calculated Power Setpts		Ref. 1, Ref. 2
Drift Value (Trip Setpoints)	± 0.3% FS / 4 hours (% RBM power)			Ref. 4.2 Section 4.7.2.9, Comment 8
Drift Value (Power Setpoints) (% power)	± 0.5% FS / 700 hours	± 0.5% SP / 8.75 days		Ref. 4.3 Section 4.3.3.3.5, Comment 14

2.1 Power Electronics (LPRM, APRM, RBM, Trip Circuit) (cont'd)

Calibration:	Value / equation	Sigma if not 3	Reference(s)
	Included in APRM calibration		
As Left Tolerance	Trip setpoints: 0 Power setpoints: AGAF		Comment 7
Leave Alone Tolerance	Trip setpoints: = ALT Power setpoints: = ALT		Comment 7
Input Calibration Tool:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Input Calibration Standard:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Tool:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			
Output Calibration Standard:	n/a		Comment 7
Accuracy			
Resolution / Readability			
Minor Division			
Upper Range			
Temperature Effect			

Application Specific Input:	Value	Sigma if not 2	Reference(s)
Minimum no. of LPRMs per RBM Channel (Trip Setpoints)	4 of 8		Ref. 4.2 Section 4.7.9.4.2, 4.8.2
Minimum no. of LPRMs per APRM Channel (Power Setpoints)	20 of 43		Ref. 4.1 Section 4.1.5, and Section 3.1.1. Comment 13
APRM Gain Adjustment Factor (AGAF)	± 2% RTP	3	

3. SUMMARY RESULTS:

Calculated Values

Setpoint Function	Analytic Limit (from Section 1) (%RTP)		Allowable Value (%RTP)		Nominal Trip Setpoint (%RTP)		Meets LER Avoid-ance Criteria	Meets Spurious Trip Avoidance Criteria
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered		
Low Power Setpoint (LPSP)	30	30	28.0	28.0	26.0	26.0	Y	n/a
Intermediate Power Setpoint (IPSP)	65	65	63.0	63.0	61.0	61.0	Y	n/a
High Power Setpoint (HPSP)	85	85	83.0	83.0	81.0	81.0	Y	n/a

Setpoint Function	Analytic Limit (from Section 1) (% Reference Level)		Allowable Value (% Reference Level)		Nominal Trip Setpoint (% Reference Level)		Meets LER Avoid-ance Criteria	Meets Spurious Trip Avoidance Criteria
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered		
Low Power Trip Setpoint (LTSP)	127.0	125.8	124.6	123.4	124.2	123.0	Y	n/a
Intermediate Power Trip Setpoint (ITSP)	122.0	121.0	119.6	118.6	119.2	118.2	Y	n/a
High Power Trip Setpoint (HTSP)	117.0	116.0	114.6	113.6	114.2	113.2	Y	n/a

Application Specific Setpoint Adjustments

Setpoint Function				
Low Power Setpoint (LPSP) - setting adjustment	NTSP 26.0% RTP (from above)	Deadband 1.1% RTP	Actual Instrument Setting 24.9% RTP	Ref. 4.2 Section 4.7.9.1.2 and Section 4.8.2.4, Comment 10

4. COMMENTS AND RECOMMENDATIONS:

1. Unless specifically identified as "bias" errors in this document, all instrument uncertainty errors will be considered to be random in nature, even when the "±" symbol is not shown.

2. Some plant specific information has not been provided or is not currently available in the current plant setpoint document, but is considered unnecessary because the effects of this information are included within the instrument accuracy values or are not necessary for setpoint evaluation.

3. Spurious trip avoidance (STA) evaluations are not performed for rod blocks or permissives per GEH setpoint methodology (Reference 1 and Reference 2), such as the RBM Rod Blocks. Therefore, the Operational Limits are not applicable.

4. Seismic effect, radiation effect, humidity effect, power supply effect, Radio Frequency Interference/ Electromagnetic Interference (RFI/EMI) effect, and insulation resistance effect errors are marked "negligible" or "included in accuracy" and are considered to have negligible impact on the manufacturer's accuracy terms when they are not identified separately.

5. Per Reference 1 and Reference 2, overpressure effects are only applicable to pressure measurement devices (e.g., differential pressure transmitters), and static pressure effects are only applicable to differential pressure measurement devices. These effects are marked "n/a" for other devices.

6. [[ ]] (Reference 2 Section 4.5.3)

7. The APRM subsystem is calibrated on-line weekly (Reference 3, SR 3.3.1.1) using the AGAF process, where the gain of the APRMs is adjusted to read the Core Thermal Power (CTP) determined by the Process Computer (P/C), within a specified As Left Tolerance. [[ ]] Thus, the only calibration error to consider for the APRM electronics sub-loop is the As Left Tolerance specified by the AGAF process.

8. The Power Electronics Drift for the RBM Trip setpoints uses the 4-hour drift error specification. The only drift error would be the drift in the several hours after control rod selection and nulling, and before the control rod is motion. This is estimated to be a few hours, so the 4-hour drift interval is used.

9. The RBM Rod Block limits control rod withdrawal if localized neutron flux exceeds a pre-determined setpoint during control rod manipulations. However, the RBM system is not essential for the safety of the plant. Hence, the RBM rod withdrawal block setpoint does not perform a protective function. Therefore, the Seismic Effect for the RBM does not need to be considered.

10. As described in the Technical Specifications (Reference 3 Section 3.3.2.1), the LPSP is considered as an automatic "enable" feature when thermal power is above the LPSP, and the AV and NTSP are calculated accordingly. The enable feature occurs as Reactor power increases past the LPSP. The vendor documents for the RBM equipment treat the LPSP as an automatic "bypass" feature (Reference 4.2, Section 4.8.2.4) when below the LPSP. The bypass feature occurs as Reactor Power decreases below the LPSP. These two descriptions are not interchangeable/equivalent; there is a need in the equipment logic for an instrument setting "deadband". Therefore, the equipment instrument setting for the LPSP NTSP must include the 1.1% Rated Thermal power deadband (i.e., hysteresis of 1.0% and an accuracy of 0.1%). The deadband does not apply to the AV. The equipment instrument setting is equal to the NTSP for the other RBM setpoint functions.

11. For the RBM Downscale Trip Setpoint (DTSP), no credit is taken for it in the RWE analyses. Choice of this setpoint is an operational issue to be decided by the plant. There is no AL for this setpoint. A value of 95% is recommended, but it can be lowered if operational problems are encountered.

12. Per Reference 1 and Reference 2, the difference between the AL and AV and the difference between the AL and NTSP are independent of the number for the AL. This applies for all of the Power and Trip setpoint functions.

13. Reference 4.1 specifies that up to 23 LPRMs per APRM channel can be bypassed. Based on a total of 43 LPRMs, this is the basis for a minimum of 20 LPRMs per LPRM channel.

14. A conservative value for the design drift value of ± 0.5%SP/8.75 days is applied based on the equipment surveillance interval of 7 days plus 25%.

15. Calibration temperature range is conservatively chosen to be between 70°F and 104°F. Energy Northwest's setpoint calculation provided a calibration temperature of 70°F; a max temperature of 104°F, which corresponds to the maximum normal temperature is assumed.

16. The Trip temperature range was chosen to be between 40°F to 104°F, which is equal to the normal temperature range. This is because the RBM is used for transient states, and not for accident trips. The temperature range is expected to be normal when the trip is required.

17. Transfer functions used in this calculation:

RBM Power Electronics:	Output is proportional to the average of the inputs, and multiplied by a gain adjustment, calculated relative to a constant arbitrary reference equivalent to 100% RTP.
APRM Power Electronics:	Output is proportional to the average of the inputs.

5. REFERENCES:

1. GE Nuclear Energy, "General Electric Methodology for Instrumentation Technical Specification and Setpoint Analysis," NEDC-32889P, Revision 3, November 2002.

2. GE Nuclear Energy, "General Electric Instrument Setpoint Methodology," NEDC-31336P-A, September 1996.

3. Columbia Generating Station Technical Specifications and Bases, as revised through Amendment 212.

4. Vendor Specifications:

   4.1. GE 24A5221TC, "PRNM Requirements Specification," Data Sheet, Columbia Generating Station, Revision 4, December 7, 2009.

   4.2. GE 24A5221, "NUMAC Power Range Neutron Monitor (PRNM)," Requirements Specification, Revision 17, July 21, 2008.

   4.3. GE 25A5916, "NUMAC Average Power Range Monitor (APRM)," Performance Specification, Revision 5, February 28, 2005.

   4.4. GE 23A5082, "NUMAC Requirements Specification," Design Specification, Revision 1, August 9, 1995.

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 10

NEDO-33755, Revision 0

Columbia Generating Station
Power Range Neutron Monitoring System
Software Tools Summary Report

June 2012

(Non-Proprietary)

GE HITACHI

GE Hitachi Nuclear Energy

NEDO-33755
Revision 0
DRF Section 0000-0145-5270 R1
June 2012

Non-Proprietary Information – Class I (Public)

COLUMBIA GENERATING STATION

POWER RANGE NEUTRON MONITORING SYSTEM

SOFTWARE TOOLS SUMMARY REPORT

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

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Table 1 GEH I&C Software Development Software Tool Reports 3

ACRONYMS AND ABBREVIATIONS

Term	Definition
ASP	Automatic Signal Processor
CGS	Columbia Generating Station
COTS	Commercial Off the Shelf
CPU	Central Processing Unit
DI&C	Digital Instrumentation and Control
DSP	Digital Signal Processor
eDRF	Electronic Design Record File
GEH	GE Hitachi Nuclear Energy
I&C	Instrumentation and Controls
ICE	In-Circuit Emulator
IEEE	Institute of Electrical and Electronics Engineers
ISG	Interim Staff Guidance
NRC	Nuclear Regulatory Commission
NUMAC	Nuclear Measurement Analysis and Control
PDMS	Product Data Management System
PDS	Previously Developed Software
PL/M or PLM	Programming Language for Microcomputers
PRNM	Power Range Neutron Monitor
SCMP	Software Configuration Management Plan
VAX	Virtual Address eXtension
VMS	Virtual Memory System

1. INTRODUCTION

This Software Tools Summary Report identifies the target platforms, purpose, acceptance criteria, issues, methods, and results of third party Commercial Off the Shelf (COTS) tools used for software development and debugging on Columbia Generating Station (CGS) Nuclear Measurement Analysis and Control (NUMAC) Power Range Neutron Monitor (PRNM) safety and non-safety classified software applications.

This summary defines the acceptance criteria and conclusions for tools used in the software development and debugging of CGS NUMAC PRNM software applications to evaluate and identify COTS products. The acceptance criteria, methods used for the evaluation, and the results and conclusions are described within this report, as required per Institute of Electrical and Electronics Engineers (IEEE) Standard 7-4.3.2 (Reference 1), Section 5.3.2 and Digital Instrumentation and Control (DI&C)-Interim Staff Guidance (ISG)-06 (Reference 2), Section D.10.4.2.3.2.

The approved tool reports (Table 1) provide assurance that the necessary features of the software tools are adequate for their intended use for both safety and non-safety classified CGS NUMAC PRNM software applications.

2. TOOL IDENTIFICATION

The tools evaluated by this report are as follows:

1. **Intel In-Circuit Emulator (ICE-386SX)**
    a) Intel ICE-386SX Emulator Revision 1.0
    b) ICE-376 Software Revision 1.0 (Referred collectively as the Intel ICE-386SX)
2. **Stability Automatic Signal Processor (ASP) Developmental Tools**
    a) Motorola Digital Signal Processor (DSP)56000 Simulator, Version 6.30
    b) Motorola DSP56000 Optimizing C Compiler/Assembler, C Compiler Version 1.29 GNU 1.37.1, and Assembler Version 6.30
3. **iSystem Z80180 Central Processing Unit (CPU) Emulation Tools**
    a) iSystem iC1000 Power Emulator, V09.01
    b) iSystem Z180 Power POD, Revision C
    c) winIDEA 2011 Integrated Development Environment, Build 9.11.82 2/28/2012
4. **Intel Programming Language for Microcomputers (PLM) and C Software Tools**
    a) Intel Virtual Address eXtension (VAX)/Virtual Memory System (VMS) iC-386 Compiler, V4.5

b) Intel VAX/VMS PL/M-386 Compiler, V3.4

c) Intel VAX/VMS 386™ Macro Assembler, V4.0

d) Intel VAX/VMS 386™ Binder, V1.5VX

e) Intel VAX/VMS 386™ System Builder, V1.6VX

f) Intel VAX/VMS 386™ Mapper, V1.3VX

g) Intel 386™ Object to Hex (OH386) Converter, V1.1

h) VAX/VMS Checksum / Prom Drawings Program CHKSUM, Revision 5.3

5. HP64000 PASCAL Compiler, Assembler, and Linker

a) HP Model 64823 Z80/NSC800 PASCAL Compiler

b) HP Model 64864A/AR Version 1.01 Assembler

c) HP Model 64864A/AR Version 1.01 Linker

3. APPLICATION

All verification tests were conducted in a controlled environment inside the Services Instrumentation and Controls (I&C) engineering department at the GE Hitachi Nuclear Energy (GEH) facilities in Wilmington, North Carolina.

4. TOOLS DESCRIPTION

The tools identified in this report are controlled under the GEH Software Configuration Management Plan (SCMP, Reference 3) and the storage location of each tool is specifically stated within its respective tool report, as identified in Table 1. The HP64000 PASCAL Compiler, Assembler, and Linker is a stand-alone non-PC based tool and is archived via means of physical media (optical disk backup) and stored in the secured Services I&C software development lab.

Table 1 identifies each tool report relative to all individual software development and debugging tools evaluated for the CGS PRNM software applications. Each tool report is archived in eMatrix or the GEH Product Data Management System (PDMS) and is identified by title in Table 1.

Each tool report contains the following detailed description for every tool evaluated:

- Electronic Design Record File (eDRF) Section Identification
- Tool Location
- Description
- Application

- Known Issues
- Safety Application Classification
- Evaluation Methods
- Evaluation Results
- Conclusions

The following GEH I&C software development software tool reports are available for Nuclear Regulatory Commission (NRC) review:

Table 1 GEH I&C Software Development Software Tool Reports

Report Title	Tools Evaluated
Intel In-Circuit Emulator (ICE-386SX) Tool	• Intel ICE-386SX Emulator Revision 1.0 • ICE-376 Software Revision 1.0 (Referred collectively as the Intel ICE-386SX)
Stability ASP Developmental Tools	• Motorola DSP56000 Simulator, Version 6.30 • Motorola DSP56000 Optimizing C Compiler/Assembler, C Compiler Version 1.29 GNU 1.37.1, and Assembler Version 6.30
iSystem Z80180 CPU Emulation Tools	• iSystem iC1000 Power Emulator, V09.01 • iSystem Z180 Power POD, Revision C • winIDEA 2011 Integrated Development Environment, Build 9.11.82 2/28/2012
Intel PLM and C Software Tools	• Intel VAX/VMS iC-386 Compiler, V4.5 • Intel VAX/VMS PL/M-386 Compiler, V3.4 • Intel VAX/VMS 386™ Macro Assembler, V4.0 • Intel VAX/VMS 386™ Binder, V1.5VX • Intel VAX/VMS 386™ System Builder, V1.6VX • Intel VAX/VMS 386™ Mapper, V1.3VX • Intel 386™ Object to Hex (OH386) Converter, V1.1 • VAX/VMS Checksum / Prom Drawings Program CHKSUM, Revision 5.3
HP 64000 PASCAL Compiler, Assembler, and Linker	• HP Model 64823 Z80/NSC800 PASCAL Compiler • HP Model 64864A/AR Version 1.01 Assembler • HP Model 64864A/AR Version 1.01 Linker

5. SUMMARY REPORT CONCLUSION

All tools identified in Section 2 of this report are acceptable for use in any CGS NUMAC PRNM software development project, previously developed software (PDS) or new, safety or non-safety software application. The intended functionality and limitations of applicability for all software tools are documented within their respective tool reports.

It has been concluded from review of all of the software tool reports, issues, and their conclusions that all tools can be successfully used for software development and debugging on all CGS NUMAC PNRM software development projects to the safety level in which they were approved.

6. REFERENCES

1. IEEE Standard 7-4.3.2, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations," 2003.

2. DI&C-ISG-06, "Task Working Group #6: Licensing Process," Revision 1, January 19, 2011 (ADAMS Accession No. ML110140103).

3. "Software Configuration Management Plan," 23A5161, Revision 4.

NEDO-33758, Revision 0

Columbia Generating Station
Power Range Neutron Monitoring System
Response Time Confirmation Report

June 2012

(Non-Proprietary)

HITACHI

GE Hitachi Nuclear Energy

NEDO-33758
Revision 0
DRF Section 0000-0148-5422 R1
June 2012

Non Proprietary Information – Class I (Public)

COLUMBIA GENERATING STATION
POWER RANGE NEUTRON MONITORING SYSTEM
RESPONSE TIME CONFIRMATION REPORT

PROPRIETARY INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33758P, Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

PLEASE READ CAREFULLY

The design, engineering, and other information contained in this document are furnished for the purposes of supporting a license amendment request by Energy Northwest for a power range neutron monitoring system upgrade in proceedings before the U.S. Nuclear Regulatory Commission. The use of this information by anyone other than Energy Northwest, or for any purpose other than that for which it is intended, is not authorized; and, with respect to any unauthorized use, GEH makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

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Table 1 Safety Function Response Times 1

Acronyms and Abbreviations

Term	Definition
APRM	Average Power Range Monitor
BTP	Branch Technical Position
CGS	Columbia Generating Station
DI&C	Digital Instrumentation and Controls
FDDI	Fiber Direct Data Interface
GGNS	Grand Gulf Nuclear Station
ISG	Interim Staff Guidance
LPRM	Local Power Range Monitor
NUMAC	Nuclear Measurement Analysis and Control
OPRM	Oscillation Power Range Monitor
PRNMS	Power Range Neutron Monitoring System
STP	Simulated Thermal Power
V&V	Validation and Verification

1. Introduction

This report evaluates the Response Time of the Columbia Generating Station (CGS) Nuclear Measurement Analysis and Control (NUMAC) Power Range Neutron Monitoring System (PRNMS) versus the safety analysis requirements and standard criteria for digital instrumentation and controls as per (Reference 1). This evaluation demonstrates compliance with the criteria of Branch Technical Position (BTP) 7-21 (Reference 2) and Staff Positions 1.19 and 1.20 of Digital Instrumentation and Controls (DI&C)-Interim Staff Guidance (ISG)-04 (Reference 3).

2. High Flux Trip Test Results

Tests were performed during PRNMS Validation and Verification (V&V) testing to confirm the CGS PRNMS configuration meets the response time requirement. All of the High Flux Trips follow the same logic path with the addition of the six second simulated thermal power (STP) filtering constant in the STP High Flux Trip path. Therefore only one test is needed to verify the High Flux Trip response times.

Testing was performed on production (non-development) equipment manufactured in accordance with the CGS design documentation.

The calculated and actual PRNMS response times presented in Table 1 meet the requirement of a response time analysis report as stated in Section D.9.4.2.4 of DI&C-ISG-06 (Reference 4).

Table 1 Safety Function Response Times

PRNM Safety Function	PRNM Response Time Requirement (mSec)	PRNM Calculated Response Time (mSec)	PRNM Actual Response Time (mSec)
APRM Neutron Flux – High Trip	40	[[	
APRM STP – High Trip	40		
APRM Neutron Flux – High (Setdown) Trip	40		
OPRM Instability Detect-and-Suppress Trip	400		]]

3. Data Error Rate Test Results

Data error rate testing was performed on a similar PRNM system for Grand Gulf Nuclear Station (GGNS) during integration testing. The GGNS testing is considered applicable to CGS because the communication links from the Local Power Range Monitor (LPRM) to the Average Power Range Monitor (APRM) and from the APRM to the 2-Out-Of-4 Logic module are identical for the two systems. Therefore, the data error rates observed for the GGNS communication paths will be representative of the rates which would be observed for the CGS system. Data error rate testing monitors the number of errors on the Fiber Direct Data Interface (FDDI) link from the LPRM instrument to the APRM instrument and on the broadcaster link from the APRM instrument to the 2-Out-Of-4 Logic Module. The tests were performed for a sufficient time period to conclude that the actual data error rate is lower than the established data error rate used for the safety system response time calculations.

The communication link that supports the trip response time is a fixed message size irrespective of the application software that uses it and because the error data rate analysis depends only on the data message size and the expected bit error rate, the testing and analysis that was done for GGNS is applicable to CGS. Data error rate testing of the GGNS PRNM software was performed and passed with no anomalies.

4. Test Anomaly/Observation and Disposition

No anomalies, observations, or issues were identified by the tester during testing.

5. Conclusion

This report confirms the evaluation of the response time of the CGS PRNMS versus the safety analysis requirements and standard criteria for DI&C. This confirmation demonstrates compliance with the criteria of References 2 and 3.

6. Applicable Documents

1. GE Hitachi Nuclear Energy, "Columbia Power Range Neutron Monitoring System Response Time Analysis Report," NEDC-33690P, Revision 0, November 2011 (ADAMS Accession No. ML12040A75).
2. Standard Review Plan, BTP 7-21, "Guidance on Digital Computer Real-Time Performance," Revision 5, March 2007 (ADAMS Accession No. ML070550070).
3. DI&C-ISG-04, "Task Working Group #4: Highly-Integrated Control Rooms-Communications Issues," Revision 1, dated March 6, 2009 (ADAMS Accesssion No. ML083310185).
4. DI&C-ISG-06, "Task Working Group #6: Licensing Process," Revision 1, dated January 19, 2011 (ADAMS Accesssion No. ML110140103).

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 12

GE-MS-CT-106244-JC14

CGS DI&C-ISG-06 Enclosure B, Phase 2 Items 2.2, 2.3, and 2.9

June 12, 2012

Enclosures:

Enclosure 1 - DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station – (Proprietary)

Enclosure 2 - DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station – (Non-Proprietary)

Enclosure 3 - Affidavit

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Proprietary Notice
This letter transmits proprietary information in accordance with 10 CFR 2.390. Upon the removal of Enclosure 1, the balance of the letter may be considered non-proprietary.

Date: June 12, 2012

GE-MS-CT-106244-JC14 Response Required? Yes ☐ No ☒

Response Requested by: N/A
Contains Engineering Requirements/Design Inputs? Yes ☒ No ☐
If Yes, Requirements/Design Inputs Verified? Yes ☒ No ☐
If Yes, Design Record File: 0000-0148-9680

Mr. James Snyder
CGS - Energy Northwest
Mail Drop PE29
PO Box 968
Richland, WA 99352-0968

Subject: **CGS DI&C-ISG-06 Enclosure B, Phase 2 Items 2.2, 2.3, and 2.9**

Reference:
1) ENW Contract 328791 dated May 4, 2009
2) ENW Contract 328791 Amendment 1, May 15, 2009
3) ENW Purchase Order 329043 dated May 19, 2009
4) GEH Acceptance Letter 0509-020-VMA, GE Hitachi, May 21, 2009

Dear Mr. Snyder:

This letter provides the following DI&C-ISG-06 Enclosure B deliverables in support of Columbia Generating Station's Nuclear Measurement Control and Analysis Power Range Neutron Monitor (NUMAC PRNM) upgrade:

DI&C-ISG-06 Enclosure B Item	Title
2.2	Verification & Validation Reports (D 4.4.2.2)
2.3	As-Manufactured, System Configuration Documentation (D 4.4.2.3)
2.9	System Build Documents (D 4.4.3.5)

If you have any questions concerning this transmittal, please contact me at your earliest convenience.

Sincerely yours,

Jamie Creech

Enclosures:
1. DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station, GEH Proprietary Information-Class III (Confidential)
2. DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station, Non-Proprietary Information-Class I (Public)
3. Affidavit

ENCLOSURE 2

GE-MS-CT-106244-JC14

DI&C-ISG-06 Phase 2 Items 2.2, 2.3, and 2.9 for Columbia Generating Station

Non-Proprietary - Class I (Public)

NON-PROPRIETARY NOTICE

This is a non-proprietary version of the Enclosure 1 of GE-MS-CT-106244-JC14 which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

In support of Columbia Generating Station's Nuclear Measurement Control and Analysis Power Range Neutron Monitor (NUMAC PRNM) upgrade, the following DI&C-ISG-06 Enclosure B deliverables are addressed:

2.2 Verification & Validation (V&V) Reports (D 4.4.2.2)

2.3 As-Manufactured, System Configuration Documentation (D 4.4.2.3)

2.9 System Build Documents (D 4.4.3.5)

The following information was previously provided to the NRC as part of a response to Grand Gulf Nuclear Station (GGNS) RAI #1 within Entergy Letter, "Responses to NRC Requests for Additional Information Pertaining to License Amendment Request for Power Range Neutron Monitoring System (TAC No. ME2531)," GNRO-2011/000039, dated May 26, 2011 (ADAMS Accession No. ML111460590).

V&V Analysis and Reports (DI&C ISG-06 D.4.4.2.2)

[[

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The V&V records for all baseline configuration items, as well as the baseline review records that show that verification tasks were successfully accomplished at each design phase in the life cycle, are maintained in the Product Data Management System (PDMS) where they are available for review by the NRC staff at the GEH office.

Configuration Management Activities (DI&C ISG-06 D.4.4.2.3)

The Product Data Management System is the primary configuration management tool for all engineering controlled documentation, including software for NUMAC products.

[[

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The PDMS provides unique identification of each configurable item by document identification number, title, and revision. [[

]] Revision history of all baseline configuration items is tracked and reported by the PDMS.

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The configuration management records for all baseline configuration items, as well as the baseline review records that establish and document the configuration at each design phase in the life cycle, are maintained in the PDMS where they are available for review by the NRC staff at the GEH office.

<u>System Build Documents (DI&C ISG-06 D.4.4.3.5)</u>

[[

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The firmware release descriptions and firmware drawings are maintained in the PDMS where they are available for review by the NRC staff at the GEH office.

SUBMITTAL OF PHASE 2 INFORMATION IN SUPPORT OF LICENSE AMENDMENT REQUEST TO CHANGE TECHNICAL SPECIFICATIONS IN SUPPORT OF PRNM / ARTS / MELLLA IMPLEMENTATION
Attachment 14

NEDO-33696, Revision 1

Columbia Generating Station
Power Range Neutron Monitoring System
Architecture & Theory of Operations Report

July 2012

(Non-Proprietary)

HITACHI

GE Hitachi Nuclear Energy

NEDO-33696
Revision 1
DRF Section 0000-0139-4769 R2
July 2012

Non-Proprietary Information – Class I (Public)

Columbia Generating Station Power Range Neutron Monitoring System Architecture & Theory of Operations Report

INFORMATION NOTICE

This is the non-proprietary version of the document NEDC-33696P, Revision 1, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of and analysis of previously developed software for the Nuclear Measurement Analysis and Control Power Range Neutron Monitoring (NUMAC PRNM) System and to demonstrate adequacy for use in the Columbia Generating Station PRNM application. The only undertakings of GEH with respect to information in this document are contained in the contract between Energy Northwest and GEH, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than Energy Northwest, or for any purpose other than that for which it is intended, is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

Revision Summary

Revision No.	Content
0	N/A
1	Added proprietary markings to NEDC-33696P and created public version of NEDC-33696P (NEDO-33696).

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ACRONYMS AND ABBREVIATIONS

Term	Definition
ADC	Analog to Digital Converter
APRM	Average Power Range Monitor
ASP	Automatic Signal Processor
BTP	Branch Technical Position
CGS	Columbia Generating Station
CPU	Central Processing Unit
CTP	Core Thermal Power
DI&C ISG-06	NRC's Interim Staff Guidance, *Digital I&C-ISG-06*
ENW	Energy Northwest
FDDI	Fiber Direct Data Interface
FIR	Finite Impulse Response
FSAR	Final Safety Analysis Report
GEH	GE-Hitachi Nuclear Energy Americas LLC
GGNS	Grand Gulf Nuclear Station
IEEE	Institute of Electrical and Electronics Engineers
I&C	Instrumentation & Control
I/O	Input/Output
ISG	Interim Staff Guidance
ISR	Interrupt Service Routine
LPRM	Local Power Range Monitor
NUMAC	Nuclear Measurement Analysis and Control
NIC	NUMAC Interface Computer
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Commission Regulation
ODIO	Open Drain Input/Output
OPRM	Oscillation Power Range Monitor
PLD	Programmable Logic Device
PPC	Primary Plant Computer
PRNMS	Power Range Neutron Monitoring System
RAI	Request for Additional Information

Term	Definition
RAM	Random Access Memory
RMCS	Reactor Manual Control System
RPS	Reactor Protection System
STP	Simulated Thermal Power
T/H	Track-and-Hold
V&V	Verification & Validation
VME	VERSA Module Eurocard

1. Introduction

This report describes the System Architecture & Theory of Operations of Nuclear Measurement Analysis and Control Power Range Neutron Monitoring (NUMAC PRNM) as specifically configured for Energy-Northwest's (ENWs) Columbia Generating Station (CGS).

The NRC's Interim Staff Guidance, Digital Instrumentation & Control-ISG-06 revision 1 (DI&C-ISG-06), identifies the following items – in the sections noted – as individual Phase 1 submittals:

- System Description (D.1.2, D.9.2, D.10.2)
- Hardware Architecture Descriptions (D.1.2)
- Software Architecture Descriptions (D.3.2, D.4.4.3.2)
- Theory of Operations (see sub-section 1.3 for list of ISG-06 sections)

This report has been designed and structured to address these items within the context of the integrated NUMAC PRNM System Architecture[1]. The purpose, scope, and basis for this report are described within following sub-sections.

Sub-section 1.1, Purpose and Scope, identifies the primary objective and scope of this System Architecture & Theory of Operations Report.

Sub-section 1.2, System Architecture, discusses the basis and rationale for addressing the System Description, Hardware Architecture Description, and Software Architecture Descriptions within a single report.

Sub-section 1.3, Theory of Operations, addresses the primary function of the Theory of Operations as defined in DI&C ISG-06 Enclosure F, "Glossary," and identifies the DI&C ISG-06 sections assigned to the Theory of Operation.

Sub-section 1.4, Report Structure & Content, describes the overall structure of this report, identifies the individual sections – and their content, within the remainder of this report.

1.1. Purpose and Scope

The objective of this document is to not only describe the NUMAC Power Range Neutron Monitoring System Architecture, but more importantly, to demonstrate how the integrity of that architecture ensures that Safety Functions are reliably performed, and that faults and failures do not compromise or inhibit the actuation of safety functions.

This document addresses safety-related and non-safety-related portions of the NUMAC PRNM System including internal and external interfaces.

The scope for the safety-related portions of the NUMAC PRNM System includes detailed examinations of the sub-systems, interfaces to non-safety sub-systems, and the hardware and

[1] *System Architecture*, within this report, refers to the structures, interfaces, software & hardware components, and the interactions between and within those structures, interfaces and components which implement system functions.

software architectures within each sub-system. These examinations address timing, accuracy, mechanisms to address vulnerabilities, and response to faults, failures, and degraded conditions.

The scope for the non-safety-related portions of the NUMAC PRNM System is limited to the identification of sub-systems, interfaces, and examining aspects of hardware and software architectures for vulnerabilities which could potentially threaten, inhibit, or adversely affect the actuation of safety functions.

1.2. System Architecture

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Unlike those platform-based systems, NUMAC systems are uniquely and explicitly designed to perform specific plant functions – and only those functions. And unlike those platform-based systems, there are no distinctions between the application and the system and sub-system design and architecture. [[

]]

1.3. Theory of Operations

The primary function of a Theory of Operations, as defined in Enclosure F of DI&C-ISG-06, is to provide a:

"Description of how systems and components work together to accomplish the specified functions."

The hierarchical structure of this report describes these interactions at the system-level, sub-system level, module level, and between the hardware and software architectures within those modules.

Particular attention has been given to addressing the specific topics identified in the following ISG-06 sections as they relate to how systems and components work together to accomplish the specified functions:

- D.9.4.2.8 IEEE Standard 603, Clause 5.8, Information Displays
- D.9.4.2.9 IEEE Standard 603, Clause 5.9, Control of Access
- D.9.4.2.14 IEEE Standard 603, Clause 5.14, Human Factors Considerations
- D.9.4.3.2 IEEE Standard 603, Clause 6.2, Manual Control
- D.9.4.3.5 IEEE Standard 603, Clause 6.5, Capability for Testing and Calibration
- D.9.4.3.6 IEEE Standard 603, Clause 6.6, Operating Bypass
- D.9.4.3.7 IEEE Standard 603, Clause 6.7, Maintenance Bypass
- D.9.4.4 IEEE Standard 603, Clause 7, Execute Features

As noted above, these items are discussed within the context of the integrated CGS NUMAC PRNM System Architecture.

1.4. Report Structure & Content

This document is structured to describe the PRNM System in a hierarchical manner from the overall NUMAC Product-Line, to the PRNM System-Level Architecture, to the sub-system architecture, and finally, the modules, hardware components, software components, and the software and hardware architecture within each safety-related sub-system.

The contents of this report are divided into the following sections:

- Section 1 – Introduction (this section)
- Section 2 – NUMAC Products Versus Digital I&C Platforms
- Section 3 – NUMAC PRNM System Overview
- Section 4 – PRNM Sub-System Architecture Overview
- Section 5 – APRM/LPRM
- Section 6 – Two Out of Four Logic Module

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2. NUMAC Products Versus Digital I&C Platforms

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2.1. Intended Purpose and Design Approach Comparison

Commercial Digital I&C Platform Families

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NUMAC Product Family

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2.2. NUMAC Standard Components Versus Standard Platform Modules

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Figure 1 NUMAC Standard 21-Slot Chassis Component

2.3. Summary Conclusion

The differences identified above have significant ramifications in terms of how the PRNM System Architecture is reviewed and evaluated.

In platform-based systems, the application is implemented and resides within the architecture of the platform itself. The platform architecture can be viewed and evaluated as an independent entity - separate and distinct from the application.

The NUMAC PRNM System Architecture has no platform which can be viewed or evaluated independent of the application. [[

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3. NUMAC PRNM System Overview

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3.1. PRNM System Functions

This section describes the system-level safety-related functions performed by the PRNM System.

The primary safety-related function of the PRNM system is to assert a trip output upon detection of any of the following events:

- Neutron flux obtained by averaging the flux values from all operative LPRMs meets or exceeds the Flux Upscale Trip Setpoint
- Simulated thermal power obtained by applying a six second time constant infinite impulse response filter to the average neutron flux meets or exceeds the Simulated Thermal Power Upscale Trip Setpoint.
- Core power fluctuations detected by the OPRM stability function meet applicable criteria for a channel trip

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Figure 2 PRNM System Functions

Input Processing Description

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Figure 3 LPRM Signal Input and Data Processing

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PRNM calculation functions

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Figure 4 PRNM Calculation Functions

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3.2. PRNM System Interfaces

As shown in Figure 5 PRNM System Interfaces, the PRNM system has five external system interfaces:

- LPRM Detectors
- Recirculation Flow
- Plant Process Computer
- Reactor Manual Control System
- Reactor Protection System (RPS)

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Figure 5 PRNM System Interfaces

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3.3. PRNM System-Level Architecture

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Figure 6 PRNM System-Level Architecture

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4. PRNM Sub-System Architecture Overview

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4.1. NUMAC Interface Computer (Non-Safety-Related)

The NIC does not perform any safety-related functions. [[

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4.1.1. NIC Overview Description

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4.1.2. NIC Interfaces

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Figure 7 NIC Interface with PPC, RBM A, and RBM B

<u>NIC/PPC Communication</u>

The NIC communicates with the PPC over two [[ ]] ports residing on the main central procession unit (CPU) module.

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<u>NIC/RBM Communication</u>

The NIC communicates with the RBM channels over fiber-optic links residing on a GEH-designed Fiber Optic board.

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4.1.3. NIC Computer Layout

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Figure 8 NIC Computer Layout

4.2. Rod Block Monitor (Non-Safety-Related)

The RBM does not perform any safety-related functions. [[

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4.2.1. RBM Overview Description

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4.2.2. RBM Interfaces

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Figure 9 Rod Block Monitor Subsystem Interfaces

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4.2.3. RBM Instrument Layout Diagram

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Figure 10 RBM Instrument Layout

4.3. APRM/LPRM (Safety-Related)

This section provides a high level overview of the APRM / LPRM subsystem. Details of this subsystem are discussed in Section 6.

4.3.1. APRM / LPRM Overview Description

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4.3.2. APRM / LPRM Interfaces

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Figure 11 APRM / LPRM Subsystem Interfaces

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4.3.3. APRM / LPRM Block Diagram

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Figure 12 APRM / LPRM Overview Block Diagram

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4.3.4. APRM/LPRM Instrument Layout Diagram

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Figure 13 APRM/LPRM Instrument Layout

4.4. Two Out of Four Logic Module (Safety-Related)

Each 2-Out-of-4 Logic module is responsible for monitoring trip state information from all four APRM channels and bypass status of the other three 2-Out-Of-4 Logic modules to determine if PRNM trip conditions exist, and if so, issue a trip signal to the RPS.

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Figure 14 2-Out-Of-4 Logic Module and Bypass Switch

4.5. NUMAC Display Units

The Operator Display Assembly (ODA) units installed in the control room are part of the HICR console for the PRNM system. The PRNM system HICR console includes APRM operator displays and RBM operator displays. [[

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Figure 15 APRM Operator Display Overview

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5. APRM/LPRM

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[2] [[ ]]

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Figure 16 APRM / LPRM Instrument

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5.1. Functional CPU Module Software Architecture

The Functional Controller software, operating on the 386SX Module, [[

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Three of the tasks perform the primary functions involved in generating a PRNM system trip to the RPS.

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Figure 17 APRM Instrument Functional CPU Software Architecture for Trip Functions

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Figure 18 LPRM Instrument Functional CPU Software Architecture for Trip Functions

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5.2. APRM Trip Signal Path

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Figure 19 APRM Trip Signal Path Components

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5.2.1. 5-Channel LPRM Module

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Figure 20 5-Channel LPRM Module

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5.2.2. Automatic Signal Processor (ASP) Scanning / Stability Module

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Figure 21 Automatic Signal Processor Module

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5.2.3. Functional CPU Module

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5.2.4. FDDI Communication Module

Transfer of LPRM detector data from the LPRM instrument to its associated APRM instrument are carried by an FDDI link connecting the two instruments. [[

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Figure 22 One of Two Channels of the FDDI Module

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5.2.5. Broadcaster Module

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Figure 23 Broadcaster Module

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5.3. APRM Anti-Aliasing

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Figure 24 Anti-Aliasing Filtering in APRM / LPRM Instrument

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5.3.1. ASP Stability Data Processing

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5.3.2. Scanning ASP Module Software Architecture

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5.3.3. Scanning ASP Module – Interrupt Service Routine

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Figure 25 ASP Interrupt Service Routine Software Architecture

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5.3.4. Scanning ASP Module - Main Loop

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Figure 26 ASP Main Loop Software Architecture

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5.4. APRM / LPRM Gain Adjustment

An LPRM detector signal is a current produced by a fission ion chamber. This current signal is assumed to be proportional to the neutron flux in the vicinity of the LPRM detector. However, to represent a calibrated flux value for the LPRM signal, gain factors must be applied to the measured detector current. [[ ]]

Individual LPRM detector signals are calibrated relative to the set of LPRM detectors using a traveling in-core probe (TIP). [[

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APRM / LPRM Gain - LPRM / APRM Instrument

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LPRM / APRM Gain Adjustment Architecture

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Figure 27 LPRM / APRM Gain Adjustment Architecture

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5.5. Control Room (HICR) / NUMAC Chassis Display Interface

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Figure 28. NUMAC Chassis Interface and APRM / LPRM Front Panel Display & Keypad

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Figure 29 APRM / LPRM Operator Display Hardware Architecture

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5.5.1. APRM / LPRM Operator Display Interface Software Architecture

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Figure 30 APRM / LPRM Operator Display and Keypad Interface Partial Software Architecture

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5.5.2. NUMAC Chassis – Front Panel Display & Keypad Interface

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Figure 31 APRM / LPRM Front Panel Display & Keypad

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5.5.3. PRNM System (HICR) Control Room Operator Display

The Operator Display Assembly ODA is designed to provide the operator with Local Power Range Monitor (LPRM) detector signals, average neutron flux, upscale and downscale trip and alarm setpoints, recirculation flow, equipment status, and OPRM stability data, in a remote location from the APRM instruments.

The ODA in the PRNM HICR console located in the control room is depicted in Figure 32.

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Figure 32 Operator Display Assembly - Control Room PRNM System HICR Console

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6. Two Out of Four Logic Module

The 2-Out-Of-4 Logic module provides the interface for the PRNM system to the RPS divisions. The 2-Out-Of-4 Logic functions are shown in Figure 33. [[

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Figure 33 2-Out-Of-4 Logic Functions

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Figure 34 2-Out-Of-4 Logic Module

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