Appendix to Attachment to PLA-6130

ARTS/MELLLA RBM Calculation

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Instrument Limits Calculation
PPL Susquehanna, LLC
Susquehanna Steam Electric Station
Units 1 & 2

Rod Block Monitor
(NUMAC ARTS-MELLLA)

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

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Contents:

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, Ref. 3.1 Intro. System Purpose, Ref. 3.2 Intro. System Purpose, Ref. 4 Bases Section B 3.3.2.1
Function After Earthquake	☐ Required ☒ Not Required	Ref. 4 Bases Section 3.3.2.1, Comment 9
Setpoint Direction: • Low Power Trip Setpoint (LTSP) Rod Block • 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. 4 Bases Section 3.3.2.1
Single or Multiple Channel	☒ Single ☐ Multiple	Ref. 4 Bases Section 3.3.2.1, Ref. 6.2 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)
LPRM Detector (APRM PEA) (% power)			
$APEA_{Accuracy}$	± 1%; bias 0.49%		Ref. 7.2 Section 2.1.1
$APEA_{PowerSupplyEffect}$	negligible		Ref. 2, Comment 6
DPEA			
• Trip Setpoints	negligible		Ref. 7.2 Sec. 2.1.2
• Power Setpoints	± 0.2% / 7 days); bias 0.33% / 7 days		Ref. 7.2 Section 2.1.1

1. Function: RBM Rod Withdrawal Blocks (cont'd)

Plant Data:	Value	Sigma if not 2	Reference(s)
LPRM Detector (APRM PMA) (% power)			
• Tracking - Trip Setpoints	± 1%	3	Ref. 7.2 Sec. 1.1.2
• Tracking - Power Setpoints	± 1.11%		Ref. 7.4 Sec. 1 b), Ref. 7.2 Sec. 1.1.1
• Noise - Trip Setpoints	± 2%		Ref. 7.4 Sec. 2, Ref. 7.2 Sec. 1.1.1
• Noise - Power Setpoints	n/a		Ref. 7.4 Sec. 1 b)

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 (LTSP) Rod Block

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RBM Ave. Flux)		Ref. 6.2 Sec. 4.8.2.4
Analytical Limit	n/a	118% for TLO/SLO	Ref. 3.1, Ref. 3.2	Ref. 5.3
Tech Spec Allowable Value	n/a		Ref. 3.1, Ref. 3.2	
Nominal Trip Setpoint	n/a		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	Ref. 1, Ref. 2, Comment 3

1.2 RBM Intermediate Power Trip Setpoint (ITSP) Rod Block

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RBM Ave. Flux)		Ref. 6.2 Sec. 4.8.2.4
Analytical Limit	n/a	113% for TLO/SLO	Ref. 3.1, Ref. 3.2	Ref. 5.3
Tech Spec Allowable Value	n/a		Ref. 3.1, Ref. 3.2	
Nominal Trip Setpoint	n/a		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	Ref. 1, Ref. 2, Comment 3

1.3 RBM High Power Trip Setpoint (HTSP) Rod Block and Clamp

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RBM Ave. Flux)		Ref. 6.2 Sec. 4.8.2.4
Analytical Limit TLO SLO	$0.58W_d$ + 58% Clamp: n/a $0.58W_d$ + 53%	108% for TLO/SLO Clamp: n/a	Ref. 3.1, Ref. 3.2	Ref. 5.3
Tech Spec Allowable Value TLO SLO	$0.66W_d$ + 55% $0.58W_d$ + 50%		Ref. 3.1, Ref. 3.2, Ref. 4 Section 3.3.2.1	
Nominal Trip Setpoint TLO SLO	$0.58W_d$ + 52% $0.58W_d$ + 47%		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	Ref. 1, Ref. 2, Comment 3

1.4 RBM Low Power Setpoint (LPSP)

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RTP)		
Analytical Limit	≥ 30%	30% for TLO/SLO	Ref. 4 Section 3.3.2.1	Ref. 7.1, Ref. 5.3
Tech Spec Allowable Value	n/a		Ref. 3.1, Ref. 3.2	
Nominal Trip Setpoint	n/a		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	Ref. 1, Ref. 2, Comment 3

1.5 RBM Intermediate Power Setpoint (IPSP)

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RTP)		
Analytical Limit	n/a	65% for TLO/SLO	Ref. 3.1, Ref. 3.2	Ref. 5.3
Tech Spec Allowable Value	n/a		Ref. 3.1, Ref. 3.2	
Nominal Trip Setpoint	n/a		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	Ref. 1, Ref. 2, Comment 3

1.6 RBM High Power Setpoint (HPSP)

Current Function Limits:	Value/Equation		Reference(s)	
	Present Susq1 & Susq2 Calculation (% RTP)	**ARTS-MELLLA Condition** (% RTP)		
Analytical Limit	n/a	85% for TLO/SLO	Ref. 3.1, Ref. 3.2	Ref. 5.3
Tech Spec Allowable Value	n/a		Ref. 3.1, Ref. 3.2	
Nominal Trip Setpoint	n/a		Ref. 3.1, Ref. 3.2	
Operational Limit	n/a	n/a	Ref. 3.1, Ref. 3.2	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.	Not provided	Comment 2
Instrument vendor	GE / Reuter-Stokes	Ref. 5.3
Model ID No. (including Range Code)	LPRMs: NA300	Ref. 5.3
Plant Location(s)	Control Structure - Lower Relay Room	Ref. 5.1, Ref. 5.2, Ref. 5.3
Process Element	Neutron detector	Ref. 6.2 Sections 1.5 & 3.2, Ref. 7.3

Inputs:

Vendor Specifications	Value / Equation	Sigma if not 2	Reference(s)
Top of Scale	FS = 125%		Ref. 6.2 Sections 4.3.2 & 4.7.2
Bottom of Scale	0%		Ref. 6.2 Sections 4.3.2 & 4.7.2
Upper Range Limit	n/a		Ref. 6.2 Sections 4.3.2 & 4.7.2
Accuracy • LPRM Detector • LPRM Electronics	 See APRM PEA (Section 1) ± 0.943% (% local power)		$A_{LPRM\ Detector}$ = APRM PEA per Ref. 1 & Ref. 2 Ref. 7.3 Section 5.1.1.1.1
Temperature Effect	included in accuracy		Ref. 7.3 Section 5.1.1.1.1
Seismic Effect	negligible		Ref. 6.7 Section 4.1.1, Comment 4
Radiation Effect	negligible		Ref. 7.3 Section 5.1.1.1.1
Humidity Effect	included in accuracy		Ref. 7.3 Section 5.1.1.1.1
Power Supply Effect (Detector)	See APRM PEA		
RFI/EMI Effect	negligible		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	Sigma if not 2	Reference(s)
Calib Temperature Range	60 to 80 degF		Ref. 5.3
Normal Temperature Range	60 to 80 degF		Ref. 5.3
Trip Temperature range	60 to 80 degF		Ref. 5.3
Plant seismic value	1.95g		Ref. 5.3
Plant Radiation value	1.8×10^2 RAD TID		Ref. 5.3
Plant Humidity value	10 to 60% RH		Ref. 5.3
Power Supply Variation value	Not provided		Comment 4
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. 4 Table 3.3.1.1-1
Desired Calib. Interval	7 days	☐Includes extra 25%		Ref. 4 Table 3.3.1.1-1
Drift Source	☒Vendor Trip Setpts	☒Calculated Power Setpts		Ref. 1, Ref. 2
Drift Value (Trip Setpoints)	± 0.3% FS / 4 hours (% RBM power)			Ref. 6.2 Section 4.7.2.9, Comment 8
Drift Value (Power Setpoints) (% power)	± 0.5% FS / 700 hours	± 0.5% SP / 8.75 days		Ref. 6.4 Section 4.3.3.3

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

Calibration:	Value / equation	Sigma if not 3	Reference(s)
	Included in APRM calibration		Ref. 5.3
As Left Tolerance	Trip setpoints: 0 Power setpoints: AGAF		Ref. 7.3 Sections 5.1.1.1.1 & 5.2.2.1, Comment 7
As Found Tolerance	Trip setpoints: = ALT Power setpoints: = ALT		Ref. 5.3, 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. 6.6 Sections 4.3.3.3 & 4.3.4.5
Minimum no. of LPRMs per APRM Channel (Power Setpoints)	20 of 43		Ref. 6.1 Section 4.1.5
APRM Gain Adjustment Factor (Power Setpoints)	± 2% RTP	3	Ref. 4.1 Table 3.3.1.1-1, Ref. 5.3

3. Summary Results:

Calculated Values

Setpoint Function	Analytic Limit (from Section 1) (% ARTS-MELLLA RTP)	Allowable Value (% ARTS-MELLLA RTP) τ	Nominal Trip Setpoint (% ARTS-MELLLA RTP) τ	Meets LER Avoid-ance Criteria	Meets Spurious Trip Avoid-ance Criteria
Low Power Setpoint (LPSP)	30%	28.0%	26.0%	Y	n/a
Intermediate Power Setpoint (IPSP)	65%	63.0%	61.0%	Y	n/a
High Power Setpoint (HPSP)	85%	83.0%	81.0%	Y	n/a
Setpoint Function	**Analytic Limit (from Section 1)** (% ARTS-MELLLA RBM Average Flux)	**Allowable Value** (% ARTS-MELLLA RBM Average Flux)τ	**Nominal Trip Setpoint** (% ARTS-MELLLA RBM Average Flux)τ	**Meets LER Avoid-ance Criteria**	**Meets Spurious Trip Avoid-ance Criteria**
Low Power Trip Setpoint (LTSP)	118%	115.6%	115.2%	Y	n/a
Intermediate Power Trip Setpoint (ITSP)	113%	110.6%	110.2%	Y	n/a
High Power Trip Setpoint (HTSP)	108%	105.6%	105.2%	Y	n/a

τ See Comment 12.

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. 6.2 Section 4.7.9.1.2 and Section 4.8.2.4, Comment 10
Calculated AL to AV Margin and AL to NTSP Margins	**AL to AV (Minimum Required Margin)***	**AL to Selected AV**	**AL to NTSP1 (Minimum Required Margin)***	**AL to Selected NTSP**
LPSP	1.939174	2.0	2.358089	4.0
IPSP	1.939174	2.0	2.358089	4.0
HPSP	1.939174	2.0	2.358089	4.0
LTSP	2.313792	2.4	2.339689	2.8
ITSP	2.313792	2.4	2.339689	2.8
HTSP	2.313792	2.4	2.339689	2.8

* Per Reference 1 and Reference 2.

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 SSES setpoint calculation(s) and is considered unnecessary because the impact of this information is included within the instrument accuracy values.

3. STA evaluations are not performed for rod blocks or permissives per GE 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. The variation of the LPRM ion chamber output current with ± 1 percent change of the ion chamber voltage in the saturated range is negligibly small. (Reference 2 Section 4.5.3)

7. The APRM subsystem is calibrated on-line weekly (Reference 4) 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. This is equivalent to a standard calibration of the APRM electronics sub-loop (consisting of the LPRM and APRM signal conditioning electronics), where the P/C is the calibration tool and standard. It is assumed that the P/C and heat balance error is already accounted for in transient analyses. 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 Blocks limit 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. (Reference 5.3)

   Therefore, the Seismic Effect for the RBM does not need to be considered.

10. As described in the Technical Specifications (Reference 4 Section 3.3.2.1), the LPSP is considered as an automatic "enable" feature when 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 (and the Reference 4 Bases) treat the LPSP as an automatic "bypass" feature (Reference 6.2) 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.

4. Comments and Recommendations (cont'd):

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 94 is recommended, but it can be lowered if operational problems are encountered. (Reference 7.1)

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. Transfer functions used in this calculation:

RBM Power Electronics:	Output is proportional to the average of the inputs, and multiplied by a gain to increase the output to match the APRM reference.
APRM Power Electronics:	Output is proportional to the average of the inputs.

5. References:

1. NEDC-32889P, Rev. 3, General Electric Methodology for Instrumentation Technical Specification and Setpoint Analysis, November 2002

2. NEDC-31336P-A, General Electric Instrument Setpoint Methodology, September 1996

3. Current applicable Susquehanna setpoint calculations:

   3.1. CALC EC-078-0509, Rev. 4, Unit 1 RBM A and B Flow Biased Setpoint Change, July 21, 1999

   3.2. CALC EC-078-0503, Rev. 4, Unit 2 RBM A and B Flow Biased Setpoint Change, July 22, 1999

4. Susquehanna Technical Specifications and Bases, as revised through Amendment 219 for Unit 1 and Amendment 190 for Unit 2.

5. Current applicable Susquehanna procedures/documents:

   5.1. Procedure SI-178-325A, Rev. 2, 24 Month Channel Calibration of Rod Block Monitor (RBM) Channel A, August 7, 2001

   5.2. Procedure SI-178-325B, Rev. 2, 24 Month Channel Calibration of Rod Block Monitor (RBM) Channel A, August 7, 2001

   5.3. PPL Susquehanna, LLC, Extended Power Uprate Project, ARTS/MELLLA: Completed Design Input Request T0506, EPUL-0188, (Rev. 2), transmittal letter dated July 28, 2005, from Michael S. Gorski (PPL) to Larry W. King (GE)

6. Vendor Specifications:

   6.1. GE 24A5221WJ, Rev. 0, PRNM Requirements Specification, Data Sheet, Susquehanna 1 & 2

   6.2. GE 24A5221, Rev. 11, NUMAC Power Range Neutron Monitor (PRNM), Requirements Specification, March 23, 2005

   6.3. (not used)

   6.4. GE 25A5916, Rev. 5, NUMAC Average Power Range Monitor (APRM), Performance Specification, February 28, 2005

   6.5. (not used)

   6.6. GE 25A5917, Rev. 3, NUMAC Rod Block Monitor (RBM), Performance Specification, November 14, 2003

   6.7. GE 23A5082, Rev. 1, NUMAC Requirements Specification, Design Spec, August 9, 1995

7. GE Letters / Reports:

   7.1. GE Project Task Report, PPL Susquehanna LLC, Susquehanna Steam Electric Station Units 1&2, ARTS/MELLLA, Task T0500, GE-NE-0000-0026-6330-R0, Rev. 0, Class III, March 2005

5. References (cont'd):

7.2. Bases for PMA & PEA Values for NMS setpoints, BasesNMSPMAPEA2.doc, DRF C51-00217, Y. Dayal, 3/15/99 [internal GE document; not releasable]

7.3. GE CD-4608 Volume XI DCD; Rev. B, Design Calculation for NUMAC Power Range Neutron Monitoring System (PRNM), DRF C51-00136 (4.42), October 9, 1998 [not releasable]

7.4. GE document, "Closure of CAR 6912 for RBM and APRM Setpoint Calculations, file CAR6912Closure Basis.doc, DRF A74-00011-00, 3/19/2002 [internal GE document; not releasable]