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NRW-FPGA-Based I&C System Qualification Project

Study Report

Title: Setpoint Analysis Report for Safety-Related Oscillation Power Range Monitor (OPRM)

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1 Purpose

The purpose of this report is to document uncertainty calculations for the setpoint of safety related trip signal of the Oscillation Power Range Monitor (OPRM) designed for Advanced Boiling Water Reactor (ABWR) plants. Toshiba developed the OPRM as a Field Programmable Gate Array (FPGA) Based Instrumentation and Control (I&C) System. The information provided in this report is typically used by nuclear industry users for establishing safety related setpoints.

2 Acronyms

ABA	Amplitude Based Detection Algorithm
ABWR	Advanced Boiling Water Reactor
APRM	Average Power Range Monitor
CSA	Channel Statistical Allowance
EA	Environmental Allowance
EPRI	Electric Power Research Institute
FPGA	Field Programmable Gate Array
GRA	Growth Rate-Based Algorithm
I&C	Instrumentation and Control
LPRM	Local Power Range Monitor
OPRM	Oscillation Power Range Monitor
PBDA	Period Based Detection Algorithm
PEA	Primary Element Accuracy
PMA	Process Measurement Accuracy
RCA	Rack Calibration Accuracy
RD	Rack Drift
RG	Regulatory Guide
RMTE	Rack Measurement & Test Equipment Accuracy
RRA	Rack Reference Accuracy
RTE	Rack Temperature Effects
SCA	Sensor Calibration Accuracy
SD	Sensor Drift
SMTE	Sensor Measurement & Test Equipment Accuracy
SPE	Sensor Pressure Effects
SRA	Sensor Reference Accuracy
SRSS	Square-Root-Sum-of-Square
STE	Sensor Temperature Effects

3 References

(1) RG 1.105

"Setpoints for Safety-Related Instrumentataion", Rev.3, 1999

(2) ISA S67.04 Part I, 1994

"Setpoints for Nuclear Safety-Related Instrumentation."

(3) ANSI/ISA 67.04.01-2006

"Setpoints for Nuclear Safety-Related Instrumentation."

(4) ANSI/ISA 67.04.02-2000

"Methodologies for the Determination of Setpoints for Nuclear Safety Related Instrumentation"

(5) EPRI TR-107330

"Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants," December 1996.

4 Methodology

EPRI TR-107330 (Reference (5)) requires that information be provided to support an application specific setpoint analysis per ISA-RP67.04.02-2000 (Reference (4)). The latest version of Regulatory Guide 1.105 (Revision 3) (Reference (1)) endorses the 1994 version of ISA-S67.04, Part I (Reference (2)). The latest version is of ISA-S67.04, Part I is ANSI/ISA-67.04.01-2006 (Reference (3)). Toshiba has evaluated and determined that the uncertainty calculations in this report consistent with ISA 67.04.01-2006 and ISA-RP67.04.02-2000 are also consistent with Regulatory Guide 1.105 Revision 3.

The methodology used to combine the uncertainty components for a channel is an appropriate combination of those groups which are statistically and functionally independent. Those uncertainties which are not independent are conservatively treated by arithmetic summation and then systematically combined with the independent terms. The basic methodology used is Square-Root-Sum-of-Square (SRSS) method. The generalized relationship between the uncertainty components and calculated uncertainty for a channel is noted in Eq.2.1:

$$CSA = \{(PMA)^2 + (PEA)^2 + (SRA)^2 + (SMTE + SD)^2 + (SMTE + SCA)^2 + (SPE)^2 + (STE)^2 + (RRA)^2 + (RMTE + RD)^2 + (RMTE + RCA)^2 + (RTE)^2\}^{1/2} + EA + BIAS \qquad \text{Eq.2.1}$$

where:

CSA	=	Channel Statistical Allowance
PMA	=	Process Measurement Accuracy

PEA	=	Primary Element Accuracy
SRA	=	Sensor Reference Accuracy
SMTE	=	Sensor Measurement & Test Equipment Accuracy
SD	=	Sensor Drift
SCA	=	Sensor Calibration Accuracy
SPE	=	Sensor Pressure Effects
STE	=	Sensor Temperature Effects
RRA	=	Rack Reference Accuracy
RMTE	=	Rack Measurement & Test Equipment Accuracy
RD	=	Rack Drift
RCA	=	Rack Calibration Accuracy
RTE	=	Rack Temperature Effects
EA	=	Environmental Allowance
BIAS	=	One directional, known magnitude allowance

Eq.2.1 is based on the followings: 1) The sensor and rack measurement and test equipment uncertainties are treated as dependent parameters with their respective drift and calibration accuracy allowances. 2) While the environmental allowances are not considered statistically dependent with all other parameters, the equipment qualification testing generally results in large magnitude, non-random terms that are conservatively treated as limits of error which are added to the statistical summation. Toshiba generally considers a term to be a limit of error if the term is a bias with an unknown sign. The term is added to the SRSS in the direction of conservatism. 3) Bias terms are one directional with known magnitudes (which may result from several sources, e.g., drift or calibration data evaluations) and are also added to the statistical summation. 4) The calibration terms are treated in the same radical with the other terms based on the assumption that general tending, i.e., drift and calibration data are evaluated on a periodic and timely basis. This evaluation should confirm that the distribution function characteristics assumed as part of treatment of the terms are still applicable. This approach results in a net reduction of the CSA magnitude (over that which would be determined if trending was not performed).

These parameters are categorized in following three categories:

- Sensor Allowances: SRA, SCA, SMTE, SD, STE, SPE and EA
- Rack Allowances: RRA, RCA, RMTE, RTE, and RD
- Process Allowances: PMA and PEA

5 Evaluation and Conclusion

The function of the OPRM setpoint is to trip the reactor during a core instability event before the critical power ratio drops below the fuel safety analysis limit anywhere in the core. To determine core instability, the OPRM is comprised of multiple cells which receive input from Local Power

Range Monitor (LPRM)s. Each LPRM signal is processed through a conditioning filter followed by an averaging filter in order to generate a normalized signal to the OPRM cells. Because of the filtering process and generation of the normalized signal, the LPRM sensor and process uncertainties that are used in other Neutron Monitoring functions (e.g. APRM) are indiscernible for the OPRM system. The normalized signal is then sent to three detection algorithms (the Amplitude Based Detection Algorithm (ABA), Growth Rate-Based Algorithm (GRA) and Period Based Detection Algorithm (PBDA)). Of the three detection algorithms used by the OPRM system, only the PBDA is applied in the protection of the safety limit. Since the OPRM PBDA algorithm uses the normalized signal for trip determination and a digital rack contact for the trip, the uncertainties in Eq 2.1 are effectively zero for this trip function. Applying the methodology to the OPRM PBDA value will still result in a same value as a setpoint for the OPRM PDBA trip.