Reevaluation of the PMS alarm set-points in OPR1000

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1. Introduction

In Optimized Power Reactor 1000 (OPR1000), the common alarm of the plant monitoring system (PMS), which is related to the channel-to-channel core protection calculator (CPC), experiences frequent deviations in the departure from nucleate boiling ratio (DNBR) and the local power density (LPD) between the middle of the cycle and the end of the cycle. Because the channel-to-channel CPC causes deviations in the values of the DNBR and LPD, the increase in the CPC input variables exceeds the alarm set-points. The CPC DNBR and LPD are defined as follows:

Deviation = the average of four CPC channels of the LPD and DNBR minus the value of each CPC channel LPD and DNBR.

In this paper, we report on a review by the Korea Hydro & Nuclear Power Co., Ltd. (KHNP) regarding the suitability of the alarm set-points for the channel-to-channel deviations of the CPC DNBR and LPD. The set-points were revaluated in light of operational experience and the case of Palo Verde (which is the reference model of OPR1000). The KHNP consequently revised the relevant procedures, as well as and the PMS alarm set-points, as part of its follow-up action.

2. Review of the PMS alarm set-points

2.1 Background of the PMS alarm set-points

The PMS alarm set-points are determined solely on the basis of the uncertainty of the CPC input variables, which are related to the system hardware. The burn-up and environmental conditions are ignored. Thus, the Palo Verde plants revised the PMS alarm set-points in accordance with the OPR1000 PMS common alarm and similar cases which required an appropriate value for the vendor (WEC).

2.2 The PMS alarm set-points of OPR1000 and Palo-Verde

Point ID	PID Description	Set-points
CUYK057	Min STATIC DNBR	0.083
CUYK042	Compensated LPD	20.600 W/cm

Table1. PMS alarm set-points of OPR1000

Before the PMS alarm set-points were revised, those of Palo-Verde were similar to those of OPR1000.The revised PMS alarm set-points **[1]** are as follows:

Point ID	PID Description	Set-point
CPCK1	Min STATIC DNBR	0.4
CPCK3	Compensated LPD	65.62W/cm

Table2. Revised PMS alarm set-points of Palo Verde

2.3 Comparison between OPR1000 and Palo Verde

The revised alarm set-point for the CPC DNBR deviation at Palo Verde is four times greater than that of OPR1000. Furthermore, the alarm set-points for the CPC LPD deviation at Palo Verde is three times greater than that of OPR1000.

3. Reevaluation of the PMS alarm set-points for the CPC DNBR and LPD

3.1 DNBR revaluation with CPCFORTRAN

The CPCFORTRAN **[2]** program is a tool for verifying whether the functional definition of a CPC algorithm complies with the safety requirements. It is also used to generate reference test data for real-time CPC software.
CPCFORTRAN calculates the DNBR and LPD by using an ex-core detector signal. The input variables are as follows:

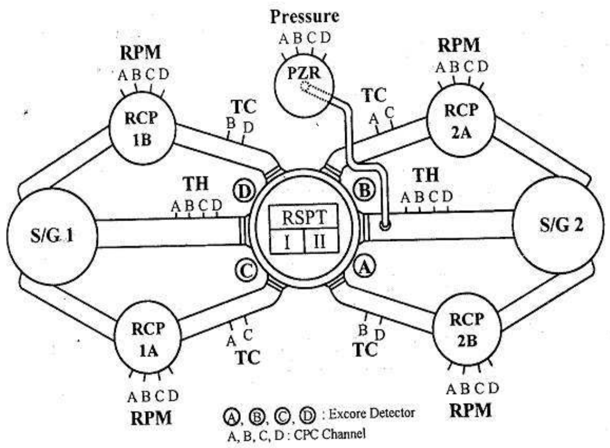

Figure1. Relative locations of the CPC input sensors

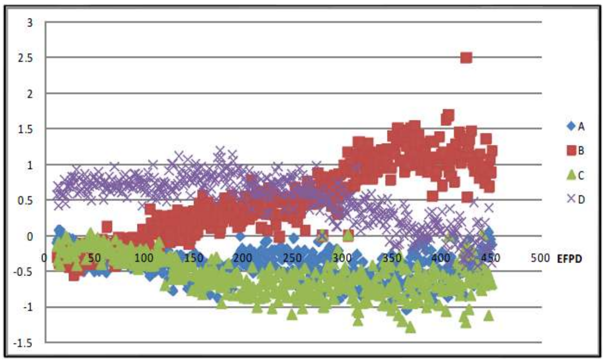

Figure2. Middle ex-core detector deviation trend

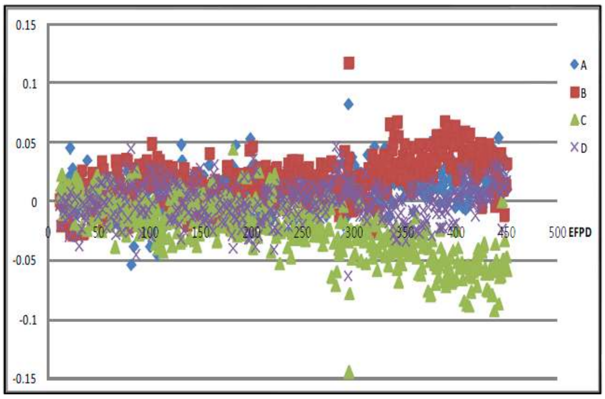

Figure3. DNBR deviation trend

Figure 2 and Figure 3 show how deviations in the input variables affect the DNBR. The DNBR trend is shaped by adjustments to the CPC input variables. The applied input variables are as follows:

CPC input variables	(1) PMS CPC deviation limits	Tech. Spec.	Applied input variables	
			Min	Max
RCP speed	(2) 53 RPM (0.0418 Fraction)	-	1.0000 (fraction)	1.0418 (fraction)
RCS cold leg temp	5 ℃	293.9℃ ≤ Tcold ≤ 298.3℃	295 ℃	296 ℃
RCS hot leg temp	5 ℃	-	319.6 ℃	324.6 ℃
PZR pressure	3.5 kg/cm^2	151.6kg/cm^2 ≤ PP ≤ 161.6kg/cm^2	164.32 kg/cm^2	157.82 kg/cm^2
Upper ex-core detector	10 %	-	97.125 %	107.125 %
Middle ex-core detector	10 %	-	118.06 %	128.06 %
Lower ex-core detector	10 %	-	80.525 %	90.525 %

The applied input variables were conservatively decided on the basis of the Tech. Spec.and the deviation limits of the input variables.

3.2 Reevaluation of the PMS alarm set-points

The results of the CPCFORTRAN simulation with the applied input variables are as follows[i]:

1) DNBR deviation ≥ 0.25
2) LPD deviation ≥ 33 W/cm.

3.3 Follow-up action

The KHNP relied on the reevaluated results for its revision of the PMS alarm set-points. The old LPD of 20.6 W/cm was changed to 33 W/cm, and the old DNBR of 0.083 was changed to 0.25. The KHNP also revised the procedures for checking the core performance variables during operation.

4. Conclusion

A review of the operational experience and the case of Palo Verde showed that the OPR1000 PMS alarm set-points for the CPC DNBR and LPD deviations were too conservative. The KHNP consequently used a CPCFORTRAN simulation to reevaluate the PMS alarm set-points. The simulation results are as follows:

1) DNBR deviation = 0.25
2) LPD deviation = 33 W/cm.

The KHNP revised the PMS alarm set-points as well as the relevant procedures.

REFERENCES

[1] M. J. Reid, R. R. Wenzel, "PMS CPC/CEAC Application Program Deviation Set-points", SA-ALL-NCR-91-012, July 19, 1991.
[2] User's Manual for the CPC/CEAC FORTRAN Simulation Code, Rev.01, Report Number 00000-ICE-3812.

[i] This values are conformed that there is no problem in the point of safety from the Vendor