Study on COLSS In-Service Operation at ICI Processing Channel Failure

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1. Introduction

OPR1000 has 45 fixed ICI (In-Core Instrumentation) strings which have five neutron detectors axially per string. COLSS (Core Operating Limit Supervisory System) requires minimum 75% available ICIs to generate core power distribution.[1] ICI signals are grouped into four channels and processed in this channel-wise manner. When a power fails or a processing card fails in a channel, COLSS becomes out-of-service due to the less amount of available ICIs than 75%.

A study was done to recover COLSS in-service operation in this situation. Basically, this exceptional operation is limited to maximum 7 days to follow the surveillance requirement in the Technical Specification.[2] COLSS uncertainty analysis and an assessment of Limiting Condition for Operation (LCO) were performed according to ICI failure rate. COLSS monitoring of power distribution with the higher failure rate was justified by comparison with the CPC (Core Protection Calculator) monitoring. Effects of this exceptional operation were analyzed to give a proper guideline for plant application.

2. Methodology and Anaylses

2.1 Justification of COLSS Monitoring with Higher ICI Failure Rate than Current Limit

When the COLSS is out-of-service, CPC is used for core monitoring. If COLSS generates more accurate results than CPC even at higher ICI failure rate, COLSS monitoring can be justified. A comparison was made based on plant data. First, reference power distribution is generated with plant ICI signals using CECOR code, which is used for power distribution surveillance in off-line manner. Second, CPC power distributions are generated with the plant snapshot data using CEFAST code. Lastly, COLSS power distribution is generated with the ICI signals using off-line COLSS code. Several cases of COLSS power distribution are made assuming no ICI failure, channel failure, and random failure with different failure rate. To exclude faulty evaluation, several comparisons were made with different plant data depending on core burnup. Figure 1 is a result of the comparison with Ulchin Unit 6 Cycle 1 EOC data. COLSS2, COLSS3, and COLSS4 are off-line COLSS results depending on ICI failure rates, which are no failure, channel A fail, and 50% failure rate with channel A and random fail, respectively. Results show that COLSS axial power distribution is not so sensitive to the ICI failure rate; COLSS power distribution with higher failure rate is still accurate than the CPC power distribution. Other comparison results also show similar results and the COLSS monitoring at the higher ICI failure rate is justified.

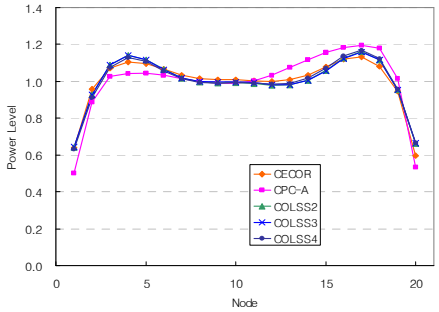
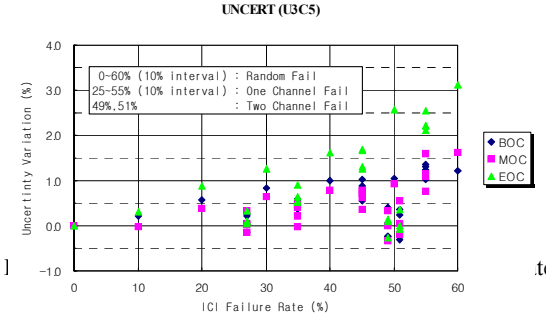


Figure 1. Comparison of CPC and COLSS Power Distribution

2.2 Uncertainty Analysis Depending on ICI Failure Rate

During design stage, COLSS uncertainty analysis is performed with 25% ICI failure rate. It is expected that higher failure rate causes higher uncertainty. COLSS uncertainty Analysis on LHR, DNBR, and ASI were performed depending on the failure rate. All kinds of fuel loading and burnup conditions were considered to get universal uncertainties. Failure type, random or channel fails, was also considered. Figure 2 and Figure 3 show LHR and DNBR uncertainty changes depending on the failure rate, respectively.



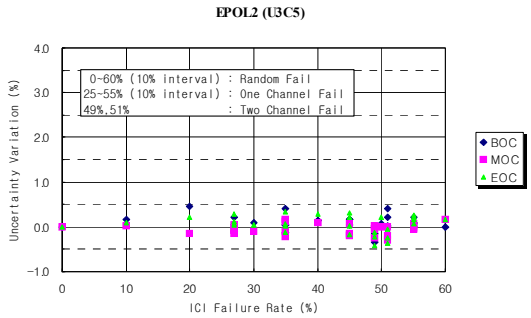


Figure 3. DNBR Uncertainty Depending on ICI Failure Rate

The Results shows that LHR uncertainty increases as the ICI failure rate is increasing, but DNBR uncertainty change is not large. After reviewing of all tested cases, it was concluded that increase in LHR uncertainty from 25% failure rate was limited within 2% up to 50% failure rate, and increase in DNBR uncertainty was conservatively limited within 1%. ASI uncertainty analysis showed that uncertainty up to 40% failure rate was within current ASI uncertainty assumption.

2.3 Assessment of LCO Depending on ICI Failure Rate

Tech. Spec. LCO and COLSS require minimum of 6 available tilt groups and minimum of 3 levels out of 5 for tilt estimate. There are 45 tilt groups, 9 groups per each level. One tilt group is formed by 4 symmetric ICIs. When an ICI fails, tilt group owning the ICI becomes inoperable. As the failure rate increases, probability of violation of the LCO and COLSS requirement also increases. Assessments were carried out on both random and channel failure modes. Figure 4 and Figure 5 are number of available tilt groups and levels depending on failure rate, respectively. Numbers of 2000 tries were applied to get statistical reasonable data. Less than half of the trial survived at 50% failure rate with respect to available tilt group. The probability of COLSS out-of-service is still large more than 40% failure rate

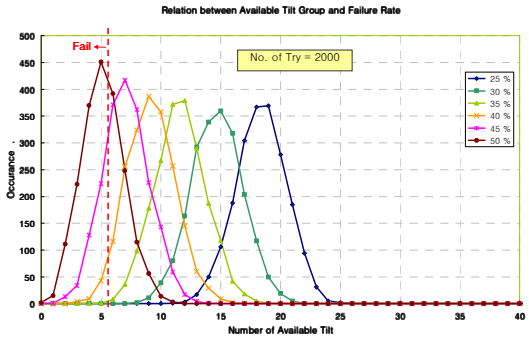


Figure 4. Available Tilt Groups Depending on Failure Rate

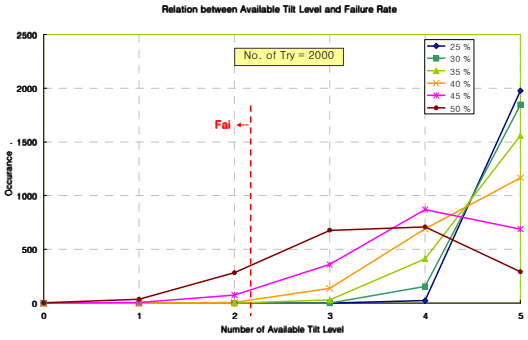


Figure 5. Available Tilt Levels Depending on Failure Rate

2.4 Effect of Operation in Failed ICI Channel

ICI signal conversion to neutron flux power is a function of accumulated charge. However, charge is not accumulated automatically for failed ICI. Un-accumulation effect was analyzed depending on operational days in failed condition. Figure 6 shows that radial effect is greater than axial effect but is not large. However, a manual update of accumulated charge is recommended to minimize the difference when operation with failed condition exceeds 4 days.

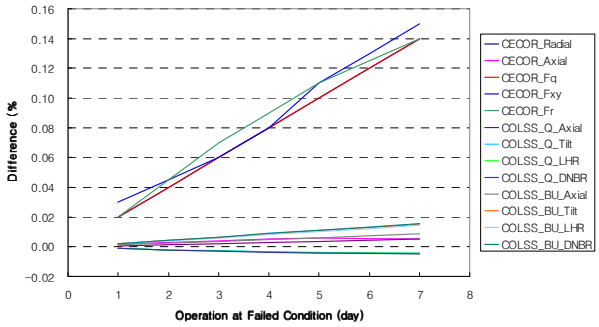


Figure 6. Effect of Un-Accumulation of ICI Charge

3. Conclusion

If one of the ICIs processing channel fails out of four, COLSS becomes out-of-service due to the violation of minimum operable ICI requirement. The Study shows that COLSS in-service operation is feasible up to 40% ICI failure rate with increasing LHR and DNBR uncertainties by 2% and 1%, respectively. This study is applied to Ulchin Units 3 and 4.

REFERENCES

[1] KNFC, " Functional Design Requirements for a COLSS for KSNP," KNF- KSNGEN-02014, Rev. 02, March 2005.
[2] 울진 3,4 호기 운영기술지침서