Unavailability Analysis of the Reactor Core Protection System using Reliability Block Diagram

Hyun Kook Shin, Sung Ho Kim, Woong Suk Choi, Jae Hack Kim
Korea Power Engineering Company Inc. (KOPEC), 150 Dukjin-Dong, Yuseong-Gu, Daejeon, Korea
hkshin@kopec.co.kr, shkim9@kopec.co.kr, cwkjc@kopec.co.kr, ghost@kopec.co.kr

1. Introduction

The reactor core of nuclear power plants needs to be monitored for the early detection of core abnormal conditions to protect plants from a severe accident. The core protection calculator system (CPCS) has been provided to calculate the departure from nucleate boiling ratio (DNBR) and the local power density (LPD) based on measured parameters of reactor and coolant system.

The original CPCS for OPR 1000 has been designed and implemented based on the concurrent 3205 computer system whose components are obsolete. The CPCS based on Westinghouse Common-Q system has recently been implemented for the Shin-Kori Nuclear Power Plant, Units 1 and 2(SKN 1&2).

An R&D project has been launched to develop new core protection system called as RCOPS (Reactor Core Protection System) with the partnership of KOPEC and Doosan Heavy Industries and Construction Co. RCOPS is implemented on the HFC-6000 safety class programmable logic controller (PLC). [1]

In this paper, the reliability of RCOPS is analyzed using the reliability block diagram (RBD) method. The calculated results are compared with that of the CPCS for SKN 1&2.

2. System Reliability Evaluation

2.1 System analysis

RCOPS is a safety system consisting of 4 identical channels whose input signals should be independent from one another as presented in Fig.1. Each channel of RCOPS consists of four racks and shares the penalty factor with the other three channels. Based on this design, the number of processors per channel has been reduced to four, whereas those of SKN 1&2 CPCS is six.

The channel communication processor(CCP) receives CEA(control element assembly) position signals and sends them to the CEA processor(CEAP) and the core protection processor (COPP). The COPP calculates LPD and DNBR. The CEAP examines CEA position deviations. If a deviation is higher than a preestablished value, the CEAP sends a penalty factor to the COPP.

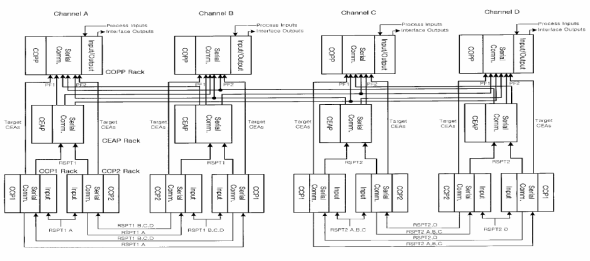

Figure 1. The system configuration of RCOPS

2.2 The generation of RBD

RBD is one of the reliability calculation methods, which gives the engineering insight of the total system structure by defining the logical failure relation using serial/parallel-connected blocks. From the signal flow analysis of RCOPS, simplified RBD is generated as shown in Fig.2. Isograph reliability software tool was used for RBD reliability analysis. [2]

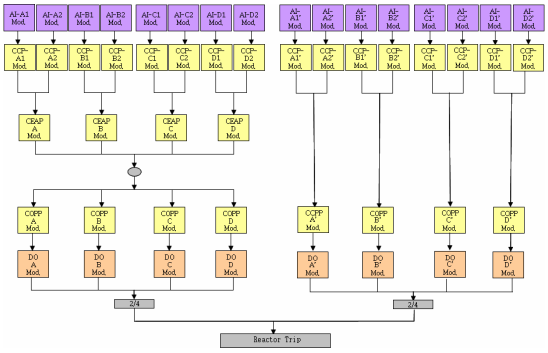

Figure 2. Simplified RBD of RCOPS

2.3 Assumptions for the Calculation

The assumptions for the calculation are as belows:

a. CCF (common cause failure) can be checked by periodic tests. Periodic test interval is one month.
b. CCF consideration used a standard Beta factor Model and the Beta factor is 0.05
c. Failure rate of a communication module is not counted as input data for the calculation of RBD.
d. All of the software in RCOPS are considered to have no errors by good software development practice and the strict software verification and validation processes.

2.4 Calculation Results

The system unavailability of RCOPS is calculated as 1.80×10^{-5} F/D, while that of SKN1&2 CPCS is as 1.33×10^{-4} F/D. This means that the reliability of RCOPS is about ten times better than that of SKN1&2 CPCS. The CCF of a digital output (DO) module in minimal cutsets is a dominant contributor reducing the system reliability. To find out the effect of CCF in the DO module, sensitivity analysis has been performed by varying the periodic test interval on the DO module. The result of sensitivity indicates that reducing the period of test interval increases the reliability of the system.

3. Conclusion

The reliability of RCOPS has been evaluated using the RBD method. The results of unavailability calculations show that the reliability of RCOPS is about ten times better than that of SKN1&2 CPCS. It is concluded that the system reliability of RCOPS is good enough to improve the safety of nuclear power plants.

REFERENCES

[1] HF Controls Corporation, "HFC - 6000 Nuclear Safety System Technical Description", 2005

[2] Isograph Reliability Software, "Reliability Workbench for Windows Ver.9.0 Reference Manual", 2001