Risk Analysis due to the Extension of STI for CANDU Diesel Generators

Moonhak Jee[a], Kwanghee Choi[a], Hyunjong Jung[a], Seongsoo Choi[b], Jaewon Lim[b], Jinbae Song[c]
a. 103-16, Munji-dong, Yusung-gu, Daejeon, Korea electric Power Research Institute
b. 1688-5, Sinil-dong, Daedeok-gu, Daejeon, Atomic Creative Technology Co., Ltd.
c. 260, Naa-ri, Yangnam-myeon, Kyungju-si, Kyungbuk, Wolsong Unit #1 NPP

1. Introduction

The purpose of this study is to provide technical rationale for the extension of the Surveillance Test Interval (STI) of the Standby Diesel Generator (SDG) and the Emergency Power Supply Diesel Generator (EPS-DG) of CANDU plants in Korea in a reliability aspect. The current STI of 2 weeks aims to be extended to 4 weeks through this study.

2. Analysis Methods and Results

This study is comprised of major four analyses. The first is the reliability data analysis for the SDG and the EPS-DG, and the second is system unavailability analysis for four special safety systems. The third is the analysis of Core Damage Frequency (CDF) and Large Early Release Frequency (LERF) and the last is related with the sensitivity analysis with DG unavailability analysis.

2.1 Reliability Data Analysis for DG

The reliability data corresponding to the starting failure of a DG were analyzed using the various data sources. The primary reliability data related to the starting failure were derived from the AECL Analysis Report for Wolsong Units 2,3,4. The operating experience data of the SDG and EPS-DG of Wolsong Units were also reviewed for the starting failure history. In addition, the starting failure data for the SDG and the EPS-DG of Point Lepreau generating station in Canada [1,2] and the DG reliability data for the nuclear power plants in America [3] were analyzed.

The starting failure probability of the SDG and the EPS-DG is set to 5.00E-2/d in the AECL Analysis Report on the basis of Point Lepreau's 1991 quarterly data.

The Wolsong site historical starting failure probability of the SDG is 1.79E-2/d. The starting failure probability of the SDG in Point Lepreau generating station, where the DG STI is 2 weeks, was 2.16E-2 in 1993 and 1.68E-2 in 2002 using lifetime data. In CANDU plants, the failure probability of the EPS-DG is less than that of the SDG.

In case of America, the starting failure probability is in a range from 3.00E-3/d to 5.42E-2/d in case the DG STI is 4 weeks, and the reliability data of EPRI-URD for DG starting failure is 1.40E-2/d.

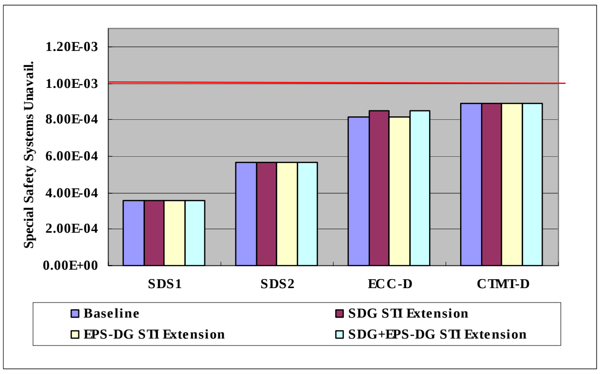
Through the reliability data analysis, the starting failure probability of the SDG and the EPS-DG in the AECL Analysis Report seems to be too conservative. In the risk analysis, the starting failure probability of the SDG and the EPS-DG is set to 6.00E-2/d conservative realistically to reflect the STI extension to 4 weeks.

2.2 System Unavailability Analysis

There are four special safety systems in CANDU plants, which are safety shutdown system #1 and #2 (hereafter SDS #1 and SDS #2), Emergency Core Cooling System (ECCS), and Containment System. Their system unavailability was analyzed in this study by reflecting the changed starting failure probability and test/maintenance unavailability due to the DG STI extension.

In case of SDS #1 and #2, there was no effect to the unavailability due to the STI extension at all. This is because the shutdown system does not depend on Class III electrical power. For the ECCS, the unavailability has increased to be 8.52E-4 about 1.05 times above the baseline value (= 8.12E-4). The dormant unavailability of the containment system was evaluated to be no change with the value of 8.88E-04 and its long-term reliability analysis showed the unavailability of 1.91E-2 with the 1.02 times increase compared to the baseline unavailability (= 1.88E-02).

The analysis results in Figure 1 shows that the system unavailability for the special safety systems meets target unavailability of 1.00E-3 [4-6] though the DG STI is extended to 4 weeks.

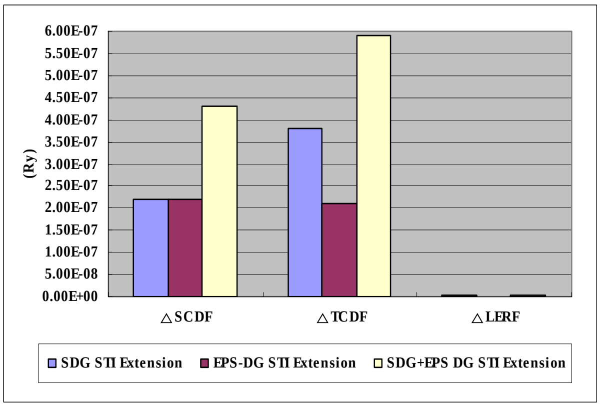


[Figure 1. Unavailability for the Special Safety Systems]

2.3 CDF and LERF Analysis

In this step, the changes in CDF and LERF were quantified to verify the risk increase due to the STI extension.

Figure 2 shows the changes of Severe Core Damage Frequency (SCDF), Total Core Damage Frequency (TCDF), and LERF.

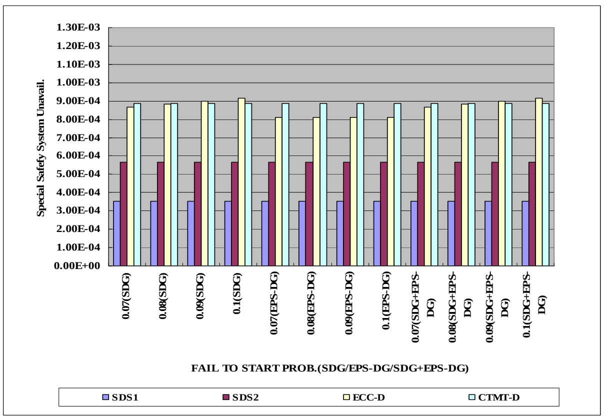


[Figure 2. Analysis results for ΔSCDF, ΔTCDF, ΔLERF]

It showed that the changed values of CDF and LERF were within the region Ⅲ of the acceptance criteria proposed in the regulatory guide 1.174 [7]. Because the risk increase in CDF and LERF is very small, the DG STI extension can be acceptable in view of risk-informed decision making.

2.4 Sensitivity Analysis

Sensitivity analysis was performed for the variation of starting failure probability from the bottom line of 7.00E-2/d up to 1.00E-01/d. For the overall sensitivity analysis range, the unavailability of the special safety systems was verified to be less than the regulatory target, that is, unavailability of 1.00E-3 as shown Figure 3.



[Figure 3. Sensitivity Analysis Results]

In case of CDF and LERF, the risk incremental values are within the region Ⅱ or Ⅲ, which are acceptable regions.

3. Conclusion

The purpose of this study is to provide technical rationale for the extension of the STI of the SDG and the EPS-DG of CANDU plants in Korea in a reliability aspect.

To achieve the purpose, reliability data analysis for DG was carried out and the special safety system unavailability was analyzed to find out whether the changed unavailability impinges the regulatory target. In addition, the risk increases in CDF and LERF were quantified on the basis of risk-informed regulatory approach and the sensitivity analysis was performed with variation of starting failure probability.

When considered the integrated evaluation approaches with both the existing regulation and the newly developed risk-informed risk analysis, this sort of technical study can be applicable to wide range of the plant-specific regulatory changes as well as the extension of DG STI.

References

[1] "Point Lepreau Generating Station Quarterly Technical Report: Fourth Quarter 1993", PLGS-QTS-4-93, New Brunswick Power Corp., 1993

[2] "Point Lepreau Generating Station Annual Reliability Report: 2002", PLGS-ARR-2002, New Brunswick Power Corp., 2003

[3] R.E Battle and D.J Campbell, "Reliability of Emergency AC Power System at Nuclear Power Plants", NUREG/CR-2989, US NRC, June 1983

[4] "Requirements for Shutdown Systems for CANDU Nuclear Power Plants", R-8, AECB, 1991.

[5] "Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants", R-9, AECB. 1991.

[6] "Requirements for Containment Systems for CANDU Nuclear Power Plants", R-7, AECB, 1991.

[7] "An Approach for Using PRA in Risk-Informed Decision on Plant Specific Changes to the Licensing Basis", Reg. Guide 1.174, NRC, 1998.