Risk Assessment of Emergency Diesel Generator(EDG) Allowed Outage Time Extension

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1. Introduction

Allowed outage time(AOT) was defined as the time for which a safety component can remain inoperable before an plant state is changed and AOT was determined based on deterministic analysis or engineering judgments. Recently, the result of probabilistic safety assessment (PSA) and the operating experiences of nuclear power plants (NPP) show that the AOT can be optimized. From the point of NPP utilities, AOT extension is desired for the avoiding unnecessary shutdown of NPPs and the flexibility of the NPP operation.

In order to provide the necessary operation flexibility during the power operation, the extension of existing AOT is needed. The extension of AOT affects the plant safety. So, overall analysis and evaluation due to the risk changes should be performed. The validity of changed technical specification (TS) requirements should be proved by the assessments. In this paper, we examined the State of the EDG AOT extension, present established AOT methodology, also evaluated the extension of emergency diesel generator(EDG) AOT for a single inoperable EDG from 72 hrs to 7 days, 10days and 14days.

2. State of the EDG AOT extension

Since the mid-80', utilities in the United States have been applying the risk-informed operation & maintenance based on PSA technology to the NPPs. They successfully operated the NPPs through extensions of AOTs and surveillance test intervals (STI) for safety systems.

The nuclear regulatory commission recommended utilities in the U.S. to reasonably improve T.S. requirements based on the plant risk by NUREG-1366 "Improvements to Technical Specifications Surveillance Requirements" issued in December 1992. In 1998, the staff published the guidance of TS in RG 1.174 "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis" and 1.177 "An Approach for Plant-Specific, Risk Informed Decision making : Technical Specification". According to these guidance, westinghouse owner's group(WOG) and CE owner's group(CEOG) have performed several studies of AOTs and STIs optimization.

Many NPPs have extended AOTs of safety injection tank (SIT), low pressure safety injection (LPSI), containment spray system(CSS) and EDG. Lately, risk-managed T.S. studies for high pressure safety injection (HPSI) system to extend the AOT until 30days are been lead by utilities. Table 1 illustrates the EDGs AOT extension in U.S. NPPs [1]

Table 1. EDGs AOT extension state of the U.S. NPPs

Description	D.C Cook		Beaver Valley		Calvert Cliffs		Millstone
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2	Unit 2
Owner	I&M		FENOC		CCNPP		DNC
NSSS Provider	WH	WH	WH	WH	CE	CE	CE
Application date	SEP. 21,2004		May 26, 2004		MAY 12, 2003		MAY 31, 2001
Issuance date	SEP. 30,2005		SEP. 29, 2005		APR. 13, 2004		JAN. 04, 2002
Extension of AOT (days)	3→14	3→14	3→14	3→14	3→14	3→14	3→14

3. Methodology of the Risk Assessments

The evaluation of the "at power" risk increment result from the extended EDG AOT was evaluated in a plant specific basis using the most current individual plant PSAs for their respective baselines. Plant specific evaluations were performed by each participating utility. Results of these evaluations were them compared using the following risk measures [1]

- *Average Core Damage Frequency (CDF)*

The average CDF represents the frequency of core-damage occurring. In a PSA, the CDF is obtained using mean unavailabilities for all standby-system components.

- *Core Damage Probability (CDP)*

The CDP represents the probability of core-damage occurring. Core-damage probability is approximated by multiplying core-damage frequency by a time period

- *Conditional Core Damage Frequency (CCDF)*

The conditional CDF is the Core Damage Frequency (CDF) conditional upon some event, such as the outage of equipment. It is calculated by re-quantifying the cutsets after adjusting the unavailabilities of those basic events associated with the inoperable equipment

- *Increase in Core Damage Frequency (△CDF)*

The increase in CDF represents the difference between the CCDF evaluated for on train of equipment unavailable minus the CCDF evaluated for one train of equipment always available. For the EDGs :

$\triangle CDF$ = Conditional $CDF_{(1\ EDG\ unavailable)}$-Conditional $CDF_{(1EDG\ perfect)}$

Where CDF = Core Damage Frequency (per year)

4. Emergency Diesel Generator AOT Assessment

The assessment of the plant specific PSA was performed to investigate the impact of the emergency diesel generator AOT on the plant risk. The analysis of PSA indicated that initial events frequencies, event/ fault tree logics, system success criteria and component failure rates were unaffected.

The search of the maximum extension of the EDG AOT was performed by increasing the EDG outage time assumption in the base model from 3 days (base case) to 7, 10, and 14 days, and calculating the incremental changes of the CDF and LERF. As shown in Table 3, the CDF and LERF were increased as the EDG AOT increased. The LERF in Table 3, however, did not exceed 1.0E-6/yr with △LERF less than 1.0E-7/yr, when the AOT was set to be 14 days. [2]

Table 2. Base Case of PSA results

Description	Base model (3days)
CDF(/yr)	4.83E-06
LERF(/yr)	6.60E-07

Table 3. △CDF and △LERF Sensitivity analysis results due to the changes of the EDG Allowed Outage Time

System	Items	Results (/yr)		
		7days	10days	14days
EDG	EGDGZ001MA EGDGZ002MB EGDGZ003MZ	1.92E-02	2.74E-02	3.84E-02
	Proposed CDF	5.14E-06	5.29E-06	5.49E-06
	Delta CDF	3.13E-07	4.61E-07	6.59E-07
	Proposed LERF	6.71E-07	6.76E-07	6.84E-07
	Delta LERF	1.14E-08	1.69E-08	2.43E-08

Table 4. ICCDP Sensitivity analysis results on EDG AOT extension change

Systems	ICCDP		
	7days	10days	14days
EDG	2.45E-07	2.96E-07	3.63E-07

Table 5. ICLERFP Sensitivity analysis results on EDG AOT extension change

Systems	ICLERP		
	7days	10days	14days
EDG	8.06E-09	9.80E-09	1.21E-08

Table 4,5 showed the results of ICCDP (Incremental Conditional Core Damage Probability) and ICLERP (Incremental Conditional Large Early Release Probability). The ICCDP and ICLERP represent the changes of probabilities of the core damage and large early release due to the out-of-service of a particular equipment/system.

According to the RG 1.177, the acceptance criteria for the equipment/system out-of-service are to be ICCDP < 5.0E-6, and ICLERP < 5.0E-7. Also, the acceptance domain for the change of CDF and LERF due to the increase of the out-of-service duration is represented in Figure 1. Through Table 3, it was concluded that the △CDF and △LERF due to the EDG AOT extension up to 14 days were in the acceptance domain (Region III). Also, the ICCDP and ICLERP were found to meet the RG 1.177 acceptance criteria. [3,4]

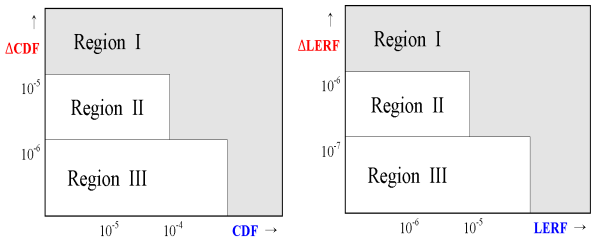

Figure 1. Acceptance Guidelines for △CDF and △LERF

5. Conclusions

The unavailability of one EDG was found to not significantly impact the three cases events of the EDG outage time increasing from 3days to 7, 10, and 14 days AOT extension in the risk analyses. The possibility of the EDG AOT extension was performed by analyzing the changes of CDF, LERF, ICCDP, and ICLERP. Through the base case, the extension of the EDG AOT was found acceptable, meeting the criteria of RG 1.174 and RG1.177.

Consequently, the AOT extension contributes the NPP performances through decreasing the unexpected plant trips, reinforcing maintenance and avoiding risks due to unnecessary operation mode changes when the NPP is under the surveillance tests or maintenance.

REFERENCES

[1] CEOG, Emergency Diesel Generators AOT Extension, May, 1995
[2] KHNP, Optimization of Allowed Outage Times for Kori Units 3&4 and Yonggwang Units 1&2, Oct. 2007
[3] USNRC, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, Regulatory Guide 1.174, 1998.
[4] USNRC, An Approach for Plant-Specific, Risk-Informed Decision-making : Technical Specifications, Regulatory Guide 1.177, 1998.