Evaluation of Frequency and Restoration time for Loss of Offsite Power events based on domestic operation experience

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1. Introduction

It is recognized that the availability of AC power to nuclear power plants is essential for safe operation and shutdown and accident recovery of commercial nuclear power plants (NPPs). Unavailability of AC power can be a important adverse impact on a plant's ability to recover accident sequences and maintain safe shutdown. The probabilistic safety assessment (PSA or PRA) performed for Korea NPPs also indicated that a loss of offsite power (LOOP) event and a station blackout (SBO) event can be a important contributors to total risk at nuclear power plant, contributing from 30% to 70% of the total risk at some NPPs in Korea. But, up to now, the LOOP and subsequent restoration time are important inputs to plant probabilistic risk assessment have relied upon foreign data. Therefore, in this paper, the actual LOOP events that have occurred from 1978 to 2004 at commercial nuclear power plants in Korea are collected. A statistical analysis for LOOP frequency and restoration time are performed to apply NPPs's specific and realistic risk model in Korea. Additionally, an engineering analysis is also performed to obtain the insights about the LOOP events.

2. Data

For this study, the operating experience data are reviewed from the plant trip analysis Data base program[1]. The unplanned plant transient data has been gathered from all the commercial nuclear power plants in Korea during April 1978 in which the first nuclear power plant(Kori 1 Unit) started its commercial operation through the end of 2004. During this duration, about 515 plant transient events were gathered from 19 commercial operating nuclear power plants(4 units in Kori, 4 unit in Wolsong, 5 units in Ulchin and 6 units in Youngkwang) and the cumulative operating experience has been about 197.2 reactor operating years and 32.5 shutdown operation years. In this data base, all of the plant trip events have stored and classified based on EPRI PWR transients category. To extracted the LOOP events data, 49 experience data were reviewed in detail involving some electrical failure such as partial or complete losses of offsite power. The LOOP definitions used on reviewing progress are a simultaneous loss of electrical power to all safety buses requiring the emergency power generators to start and supply power to safety buses and a total loss of power at transmission line. A total 14 events are identified as a LOOP event.

3. Analysis

In this study, the Korean NPPs's LOOP events were grouped into several categories to analyze effectively as described in foreign LOOP analysis report [2, 3 , 4] . The analysis results are as follows and summarized table 1 & 2. To compare with the U.S. recent data, the quantitative results of the U.S. recent data are summarized also in table 3 & 4.

The first LOOP categorization is LOOP occurring period. A LOOP events could occur at power operation and during shutdown operation. The impacts of a LOOP depend upon whether the plant is at power operation or during shutdown operation. If the plant is at power operation when a LOOP occurs, then a reactor trip generally occurs, challenging various safety systems designed to bring the plant to a safe shutdown. Total 12 out of 14 events have occurred at power operation and the other 2 events have occurred during shutdown operation. The second LOOP categorization scheme is based on a restoration time. The LOOP Events restored to at least one safety bus within less than two minutes are defined momentary LOOP events. And the events did not restored to at least one safety bus within less than two minutes are defined sustained LOOP events.

The LOOP events were grouped into several categories based on root cause also. A LOOP events could be classified several cause as the foreign precedent results[2, 3, 4]. But in this study three classification scheme was applied such as plant centered, grid related and severe weather related and summarized in table 1 & 2.

The engineering insight from LOOP events in Korea nuclear power plant as follows. The major contributor of LOOP cause is external causes(two typhoon, heavy snow and forest fire). Especially the units at Kori site located on the southeastern coast of Korea have only experienced LOOP events more frequently than other units in other site because the typhoon usually strike the southeastern coast of Korea. The restoration time of typhoon induced LOOP events is longer than that of other types LOOP events and a typhoon has induced all unit in a site at the same time. It would be a important adverse impact on a plant's ability to recover accident sequences and maintain safe shutdown. External cause like a severe weather induced LOOP events accounted for the majority of the LOOP.

In this study, only the sustained LOOP events were using for a statistical analysis because the momentary events were caused by switching error or delayed transfer result from failing to transfer from a faulted prefered power

source to a live back-up power source and actual restoration time is less than 2 minutes. Therefore the momentary LOOP events are excluded from LOOP parameter estimation such as frequency or restoration time to apply RIR & RIA. A LOOP frequency estimation and the restoration time analysis(the probability of exceedance versus duration) are performed for only one case not for each category because of lack of number of each category such as plant centered, grid related and severe weather related LOOP also. The frequency estimation result summarized in table 5 and restoration time analysis presented in figure 1

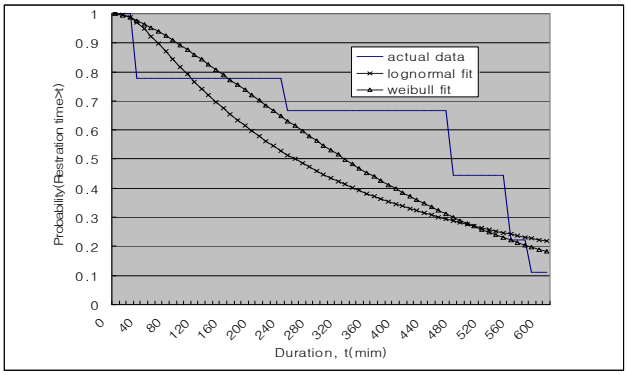

Figure 1. Probability of exceedance versus duration for LOOP

3. Conclusion

It is recognized that the availability of AC power to nuclear power plants is essential for safe operation and shutdown. To utilize PSA & Risk informed application, and get a engineering insight, a total of 14 LOOP events are collected and analyzed. The major contributor of LOOP cause is external causes(two typhoon, heavy snow and forest fire). Almost of sustained LOOP Events that are based on to estimate the LOOP frequency and its restoration time were caused by typhoon. A statistical analysis for LOOP frequency and restoration time are performed to apply NPPs's specific and realistic risk model in Korea.

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Table 1. Summary on LOOP events at power operation in Korea(12 events with 197.2 critical years)

	Plant Centered	Grid-Related	Severe weather related
# of momentary events & frequency	1, 0.005/cy	4, 0.02/cy	
# of sustained events & frequency			7, 0.035/cy
total # of events & frequency, by unit	1, 0.005/cy	4, 0.02/cy	7, 0.035/cy

Table2. Summary on LOOP events at shutdown in Korea(2 events with 32.5 shutdown years)

	Plant Centered	Grid-Related	Severe weather related
# of momentary events & frequency			
# of sustained events & frequency	1, 0.03/sy		1, 0.03/sy
total # of events & frequency	1, 0.03/sy		1, 0.03/sy

Table 3. Summary on plant centered events in U.S.(116 Unit with 1188.8 critical years and 455.5 shutdown years)[3]

	at power operation	at shutdown operation
# of momentary events & frequency	4. 0.003/cy	11, 0.02/sy
# of sustained events & frequency	46, 0.04/cy	69, 0.16/sy
total # of events & frequency	50, 0.043/sy	89, 0.18/sy

Table 4. Summary on grid and severe weather related events in U.S.(74 site with 1065.2 site calendar years)[3]

	Grid-Related	Severe weather related
# of momentary events & frequency	1, 0.001/scy	7, 0.002/scy
# of sustained events & frequency	3, 0.003/scy	10, 0.009/scy
total # of events & frequency	4, 0.004/sy	17, 0.011/sy

Table 5. LOOP Frequency

	5%	median	mean	95%
Critical operation	1.82E-03	2.46E-02	3.55E-02	1.06E-01
Shutdown operation	3.15E-03	4.26E-02	6.14E-02	1.84E-01