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Coping Duration Assessment Using R.G. 1.155 Methodology on Shin-kori 5&6

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1. Introduction

According to the SBO rule (10 CFR 50.63) announced by U.S. NRC in August 1988, every light-water-cooled nuclear power plant should be able to maintain and recover the plant from SBO accident in certain duration. Coping duration is the time between the moment of Station Black Out (SBO) and restoration of off-site AC power which supplies power to safety class switchgear BUS. Coping duration is an important factor for preparing against SBO in nuclear power plant design and operation. In this study, we calculate coping duration on Shin-kori 5&6 using methodology provided in Regulatory Guide 1.155 [1] considering latest weather and design information in Saewool site. After calculation, two assumptions will be suggested to improve coping duration and take margin against SBO accident.

2. Methods and Results

In NUMARC-8700 [2], Nuclear Management and Resource Council provide actual calculation result of total 75 plants in United States using SBO rule. Shin-kori 5&6 coping duration is calculated refer to the result provided in NUMARC-8700 [2]. Coping duration calculation consists of 5 steps. Step 1 : Off-site power design determination, Step 2 : EAC power supply system configuration, Step 3 : EDG reliability, Step 4 : EDG target reliability determination, Step 5 : Coping duration determination

2.1 Off-site power design determination

In R.G. 1.155 [1], off-site power design is classified in 3 groups (Table 1). To determine off-site power design, 5 different analysis is required.

Part 1 is determining site susceptibility to grid-related loss of off-site power events. Since 1978, there was 1 case of LOOP accident caused by equipment failure in Kori unit 2 at 1998. Total operation year of NPPs in Kori/Saewool site is 168 year [4]. Part 1 requires to compare LOOP occurrence rate of target NPP and U.S. industry average which is 20e-3/yr. If target NPP has bigger LOOP occurrence rate than U.S. industry average, off-site power design belongs to group P3. LOOP occurrence rate in Kori/Saewool site is 1/168 yr = 5.6e-3/yr which is lower than U.S. industry average.

Part 2 is calculation of estimated LOOP frequency due to extremely severe weather (ESW). In R.G. 1.155, term extremely severe weather is defined as typhoon with wind velocity greater or equal to 125mph (55.9m/s). Since 1937 to 2020 in Korea peninsula, 4 typhoon recorded to have maximum instantaneous wind velocity more than 55.9m/s [3]. Maemi (2003, 60m/s), Prapiroon (2000, 58.3m/s), Rusa (2002, 56.7m/s), Chaba (2016, 56.5m/s). However, every 4 typhoon had lower wind velocity when it reached near Saewool site and location of maximum wind velocity detected is Jeju, Huksando, Gosan. Therfore, annual wind speed expectation with more than 55.9m/s in Saewool site is 0 which belongs to ESW group 1.

Part 3 is calculation of estimated LOOP frequency due to severe weather (SW). Formula provided in R.G.1.155 is

$$= (1.3\times 10^{-4})\times h1 + b\times h2 + (1.2\times 10^{-2})\times h3 + c\times h4$$

h1 : Annual snow fall around the site in inch, h2 : Annual expected severe tornado at the site, h3 : Annual expected storms at the site with wind velocity between 75 and 124 mph (33.3m/s ~ 55.4m/s), h4 : Annual expected storms with significant salt spray for the site.

According to the 2nd Busan climate change adaptation plan [4], annual average snow fall for last 50 years (1966 ~ 2015) in Busan area was **4.3cm (1.69inch)**.

From the historical record, there was **none** of tornado creation was founded around Saewool site and other places in South Korea. Most of the research also insist it will be hard to see tornado in Korea peninsula because of geographical feature which is formed in mountain with more than 70%.

In Korea Meteorological Administration (KMA), we can search every typhoon pass through certain area since 1977. In this study, we made two options to classify every typhoon that came near the Saewool site.

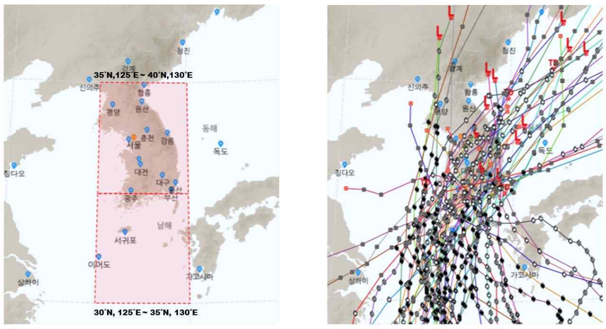

Fig. 1. Typhoon passed through two area 1 (1977~2020)

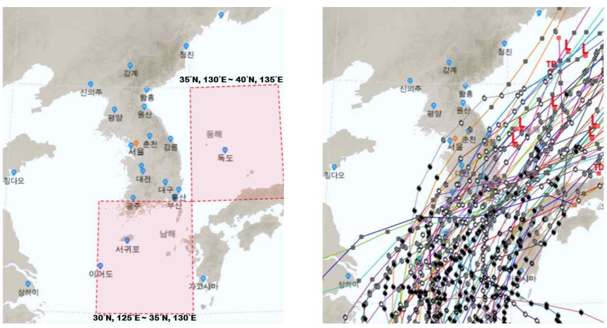

Fig. 2. Typhoon passed through two area 2 (1977~2020)

Total 62 typhoons are detected and 14 typhoons (Haishen, Maysak, Chaba, Goni, Sanba, Shanshan, Songda, Maemi, Rusa, Robyn, Mireille, Caitlin, Dinah, Thelma) had wind velocity more than 33.3m/s when it reached near Saewool site. For 43 years total 14 typhoons with wind velocity more than 33.3m/s came near Saewool site. Final result is **14/43yr = 0.3256/yr**.

As same as other NPPs in Korea, Shin-kori 5&6 is under construction on east sea coast. If typhoon with strong wind strikes near the site, typhoon must bring salt spray and gives an impact. However it is not easy to determine how much strong wind will give an impact to the plant. On September 3, 2020 typhoon Maysak strike near the Saewool site with salt spray and caused reactor trip on Kori 3&4 and Shin-kori 1&2. In this study, we will assume Shin-kori 5&6 is venerable to the salt spray and typhoon with wind velocity more than 40m/s (wind velocity of Haishen) brings critical salt spray to the site. Among 62 typhoons, 6 typhoons (Haishen, Maysak, Songda, Robyn, Mireille, Dinah) had wind velocity with more than 40m/s. So the result is **6/43yr = 0.1395/yr**.

Finalizing total processes we have, h1 = 1.69, h2 = 0, h3 = 0.3256, h4 = 0.1395. According to the NUMARC-8700 [2], if the certain plant determines that it is susceptible to salt spray, annual expectation of typhoon with wind velocity (h3) can be zero because the annual frequency of salt spray already considered the effect of typhoon. Thus, the final result of estimated LOOP frequency due to severe weather is **0.109** which belongs to SW group 5.

$$= (1.3\times 10^{\ 4})\times 1.69 + b\times 0 + (1.2\times 10^{-2})\times 0 + 0.78\times 0.1395$$
$$= 0.109$$

Part 4 is evaluating independence of off-site power system. Plants are classified in two groups. I1/2 or I3. I1/2 group has independence and redundant AC source from off-site and more desirable transfer design. I3 group has less desirable transfer design, simpler and more dependent in switchyard capability. For Shin-kori 5&6, switchyard system has electrically and physically independent 765kV and 154kV system which are connected to the Main Transformer (MTR) and Standby Auxiliary Transformer (SAT) respectively. Thus, Shin-kori 5&6 belongs to **I1/2** group.

Last part in off-site power design group classification is determination stage. With our analysis, Shin-kori 5&6 design has I1/2 off-site power group, ESW group 1, SW group 5. Thus, by the table provided in R.G. 1.155 [1], Shin-kori 5&6 design is classified in **P3 group**.

Table I: Off-site power design group classification

Group	Contents
P1	Sites characterized by redundant and independent power sources that are considered less susceptible to loss as a result of plant-centered weather-initiated events.
P2	Sites whose off-site power sources are less redundant or independent, or that are more susceptible to extended off-site power losses due to weather-initiated events or more frequent losses due to plant-centered events
P3	Sites whose off-site power sources are (1) least redundant or independent combined with moderate severe weather potential, (2) most susceptible to extended off-site power losses due to weather-initiated or grid-related events, or (3) susceptible to grid-related events.

2.2 Determine the Emergency AC Power Configuration

Shin-kori 5&6 has 2 EDGs and 1 AACDG per each unit. And only one EDG requires to safely shutdown the plant. As quality of AACDG is improving time to time, its resonable to think about including AACDG in EAC group but still AACDG is not a quality class equipment and the purpose of system is backup of 2 EDGs. Thus we will deterimne Shin-kori 5&6 has 2 EAC supplies with 1 necessary for safe shutdown which belongs to **group C**.

Table 2: EAC Power configuration group

Group	Shared and dedicated supplies necessary for safe shutdown	Supplies available
A	1	3 dedicated
A	1	4
B	2	5
B	2	4
C	1	2 dedicated
C	1	3 shared
D	3	4
D	3	5
D	2	3
D	1	2

dedicated - EAC emergency power supplies without haring with other units, shraed - EAC emergency power supplies sharing with more than one unit at a site.

2.3 Determine the EDG Reliability

As we reviewed from KHNP EDG reliability program, most of the plant had EDG reliability more than 0.975 in last 5 years. Shin-kori 5&6 will have newest design with improved engine quality of EDG system, so we will assume EDG reliability in Shin-kori 5&6 is 0.975.

2.4 Determining coping duration

For the final step to decide coping duration, Table 3 is provided in R.G.1.155 [1]. As we review off-site power design, weather condition, EAC design, EDG reliability, Shin-kori 5&6 requires to prepare for 8 hours of coping duration according to the table. Since current design of Shin-kori 5&6 is installing based on 8 hours of coping duration, there is no safety issue but still some of the improvement factors can be suggested which can reduce coping duration to 4 hours.

Table 3: Coping duration capability (hours)

	Emergency AC Power Configuration Group						
	A		B		C		D
	Unit "Average" EDG						
	0.975	0.95	0.975	0.95	0.975	0.95	0.975
P1	2	2	4	4	4	4	4
P2	4	4	4	4	4	8	8
P3	4	8	4	8	**8**	16	8

3. Assumption

In this section, we will assume two things and calculate how much coping duration it can be reduced.

First is assuming Shin-kori 5&6 is prepared and protected from salt spray. Venerability of salt spray was used in calculation of severe weather group determination. If h4 becomes 0 and apply other factors as same as previous result, estimated LOOP frequency due to severe weather becomes 0.004127.

$$= (1.3\times10^{4})\times1.69+b\times0+(1.2\times10^{-2})\times0.3256+0.78\times0$$
$$= 0.004127$$

If SW group changes and apply with ESW group 5, off-site power design characteristic group become P1. According to Table 3, coping duration capability table, P1, EAC group C and 0.975 EDG reliability belongs to 4 hours coping duration group.

Second is assuming AACDG in EAC group. If AACDG belongs to EAC group, that means Shin-kori 5&6 has 3 EAC system per unit. 3 EAC system with one supplies necessary for safe shutdown belongs to EAC group A in Table 2. EAC group A and off-site power design characteristic group P3 belongs to 4 hours of coping duration.

4. Conclusions

In this study, we calculate coping duration of Shin-kori 5&6 and concluded in 8 hours which is same duration as current design criteria. However, weather and design approach we made in our calculation was very conservative and harsh. Also, coping duration methodology provided in R.G.1.155 seems not sufficiently considered the domestic situation. Such as giving a credit about AACDG in Shin-kori 5&6 design. Nevertheless we used coping duration calculation methodology in R.G. 1.155 because still this document is considered and used in regulation and licensing in Korean type NPPs. Further research and investigation seems necessary to develop coping duration calculation for domestic NPPs. Also as suggested in section 3, if Shin-kori 5&6 design is not vulnerable to salt spray and includes AACDG in EAC group will reduce coping duration to 4 hours and gives 4 hours of margin against SBO.

REFERENCES

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[3] Korea Meterological Administration (KMA), Typhoon record
[4] 2nd Busan Climate Change Adaptation Plan [2017 ~2021], Busan Metropolitan City, 2016.