Coping Duration Assessment Using RG 1.155 Methodology on Shin-kori 5&6

Geehyu Park

KEPCO International Nuclear Graduate School

KINGS
한국전력국제원자력대학원대학교
KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL

Contents

KINGS
한국전력국제원자력대학원대학교
KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL

Introduction

① **WASH-1400** **(1975)** : SBO can cause severe damage to NPP

② **Unresolved Safety Issue** **(A-44, 1980)**

③ **SBO rule**
(10 CFR 50.63, 1988)

→ **Station Black Out** **(RG 1.155, 1988)**

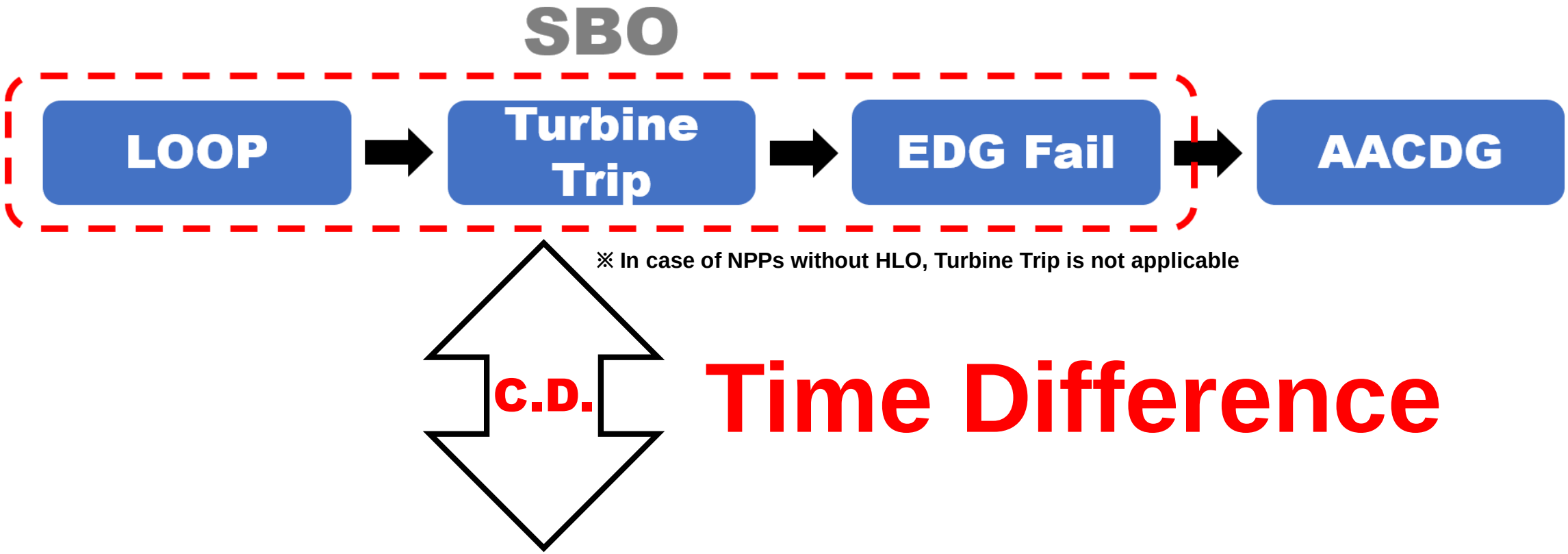
: Every light-water-cooled NPP should be able to maintain and recover from a SBO accident

→ **NUMARC-8700**

: Calculate coping duration for 75 plants in U.S.

Introduction

◆ What is Coping Duration ?



Introduction

◆ What are we going to study?

- Typhoon Haishen and Maysak caused huge concerns to public about SBO accident
- In this study, using methodology provided in RG 1.155 (Station Blackout), we will calculate coping duration of Shin-kori 5&6 using latest weather and design condition
- Compare the result with current design basis (8 hours)
- Suggest 2 improvement points which can reduce coping duration

Past and Present of SBO

After Fukushima Daiichi Accident (SBO)

- **Risk Reduction**
- **Need for plant safety evaluation considering SBO**
- **Multi-unit SBO at the same time**
- **Coping method for long term SBO**
- **Trust from Government/Public to NPP**

→

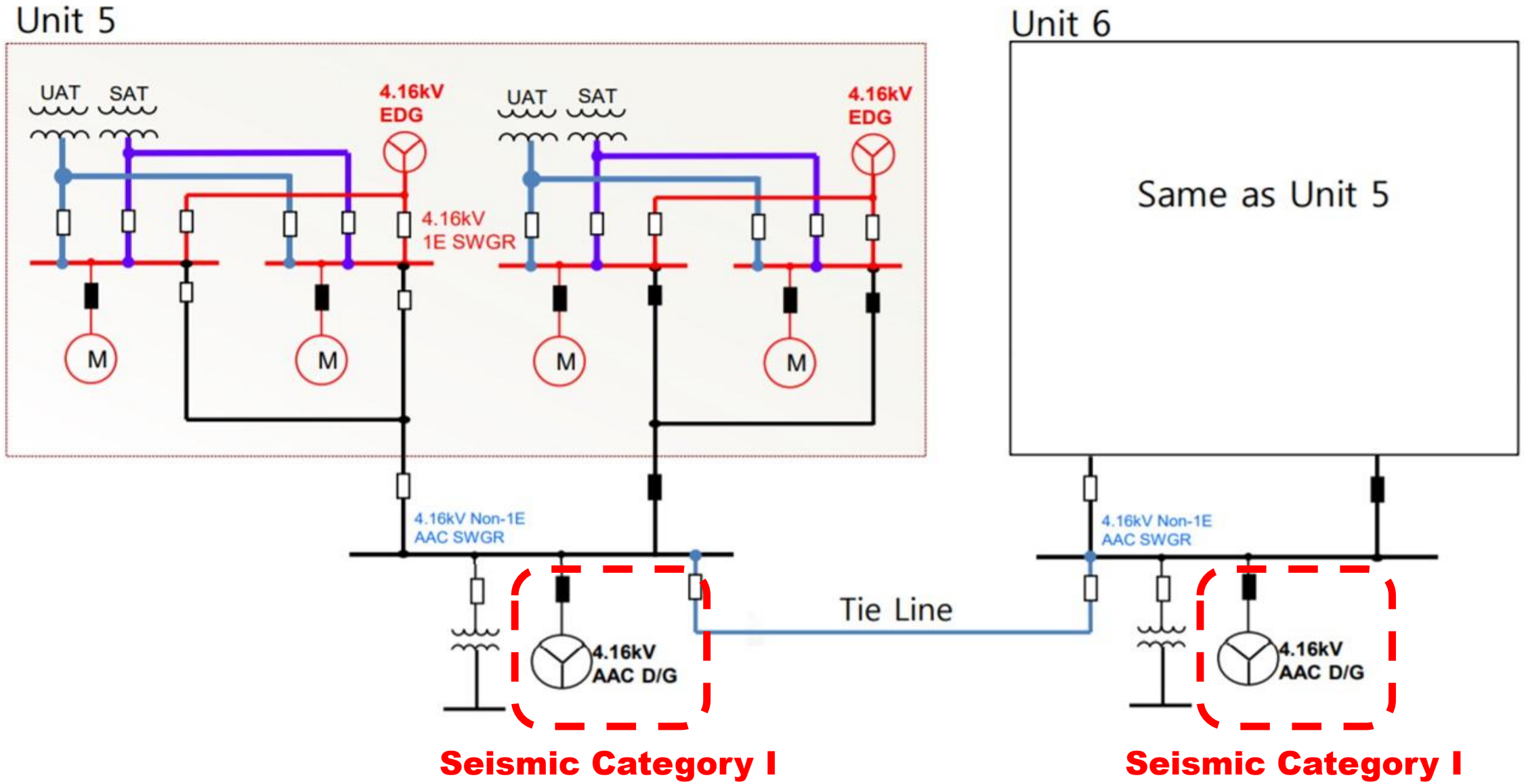
- **Mobile DG**
- **Increasing Quality of AACDG**

Past and Present of SBO

Plant	Safety System	EDG/unit	AACDG
Hannul 3&4 (OPR1000)	Mech. 2 division Elec. 2 division	2	1/4 unit (Diesel)
Shin-kori 3&4 (APR1400)	Mech. 4 division Elec. 2 division	2	1/2 unit (Diesel)
Shin-kori 5&6 (APR1400)	Mech. 4 division Elec. 2 division	2	1/1 unit (Diesel)
EU-APR 1400 (APR+)	Mech. 4 division Elec. 4 division	4	1/1 unit (Gas Turbine)

IMPROVING

Design Review of SKN 5&6



Design Review of SKN 5&6

Coping Duration Calculation

◆ Coping Duration (5 steps)

① Off-site Power Determination

- Site susceptibility to grid-related loss of off-site power
- Estimated frequency of loss of off-site power due to Extremely Severe Weather (ESW)
- Estimated frequency of loss of off-site power due to Severe Weather (SW)
- Independence of off-site power system (I group)

② EAC power supply system configuration classification

③ EDG reliability

④ EDG target reliability determination

⑤ Coping Duration Determination

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

Group	Contents
P1	Sites characterized by redundant and independent power sources that are considered less susceptible to loss as a result of plant-centered and 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.

※ To determine off-site power design characteristic group, 4 steps needs to be analyzed.

① Site susceptibility to grid-related loss of off-site power

② Estimated frequency of loss of off-site power due to Extremely Severe Weather (ESW)

③ Estimated frequency of loss of off-site power due to Severe Weather (SW)

④ Independence of off-site power system (I group)

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

: Site susceptibility to grid-related loss of off-site power (Sub step 1)

- Analyze frequency of LOOP event caused by transmission and distribution system due to insufficient generating capacity, dynamic instability or excessive loads. (Grid failure caused by other reasons such as severe weather or brush fires are not considered)

- If loss of off-site power frequency caused by transmission and distribution system is higher than U.S. industry average (20e-3/yr) off-site power design characteristic group belongs to P3

Coping Duration Calculation

LOOP accident in Korea since 1978

Unit	Date	Initial event	Recovery Time
Kori 3/4	1986.08.28	Typhoon	7 hours 45 minutes
Kori 1/2/3/4	1987.07.16	Typhoon	8 hours
Hanul 1/2	1997.01.01	Heavy snow	28 minutes
Kori 2	1998.09.27	Equipment failure	30 minutes
Wolsong 2	2004.06.19	Human error	3 hours 53 minutes
Hanbit 5	2006.11.29	Equipment failure	26 minutes
Wolsong 2	2009.09.03	Human error	1 hour 23 minutes
Hanbit 5	2010.12.29	Human error	21 minutes
Kori 3	2011.04.19	Human error	50 minutes
Kori 1	2012.02.09	Human error	12 minutes
Kori 3/4 Shin-kori 1/2	2020.09.03	Typhoon	N/A*

Operating year of NPPs in Kori/Saewool Site

Unit	Commercial Operation Start	Operation Year
Kori 1	1978.04.29	40
Kori 2	1983.07.25	37
Kori 3	1985.09.30	35
Kori 4	1986.04.29	34
Shin-kori 1	2011.02.28	9
Shin-kori 2	2012.07.20	8
Shin-kori 3	2016.12.20	4
Shin-kori 4	2019.08.29	1
Total		168

- Kori/Saewool site experienced 1 time since 1978
- Total operating year of NPPs in Kori/Saewool site is 168 year
- 1/168 = 5.6e-3/yr which is lower than U.S. industry average 20e-3/yr

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

: Estimated frequency of loss of off-site power due to Extremely Severe Weather (Sub step 2)

- Extremely Severe Weather is defined as typhoon or tornado with wind velocity greater or equal to 125mph (201.2km/h or 55.9m/s)

- Since off-site power systems are not designed for this severe weather conditions, we would think the occurrence of these weather causes loss of off-site power.

Coping Duration Calculation

Maximum Wind Velocity (1937~2020)

Name	Detected Area	Maximum Instantaneous Wind Velocity (m/s)	Date
MAEMI	JEJU	60	2003.09.12
PRAPIROON	HUKSANDO	58.3	2000.08.31
RUSA	GOSAN	56.7	2002.08.31
CHABA	GOSAN	56.5	2016.10.05
NARI	GOSAN	52	2007.09.16
BOLAVAN	WANDO	51.8	2012.08.28
TED	ULLEUNGDO	51	1992.09.25
VERA	ULJIN	49	1986.08.28
NABI	ULLEUNGDO	47.3	2005.09.07
SARAH	JEJU	46.9	1959.09.17

Extremely Severe Weather Group (ESW)

ESW Group	ANNUAL WINDSPEED EXPECTATION ≥ 125MPH
1	e < 3.3*10-4
2	3.3*10-4 ≤ e < 1*10-3
3	1*10-3 ≤ e < 3.3*10-3
4	3.3*10-3 ≤ e < 1*10-2
5	1*10-2 ≤ e

- Total 4 typhoon recorded instantaneous maximum wind velocity with more than 55.9m/s
- However, detected area is far and wind velocity reduced when it came near the Saewool site

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

: Estimated frequency of loss of off-site power due to Severe Weather (Sub step 3)

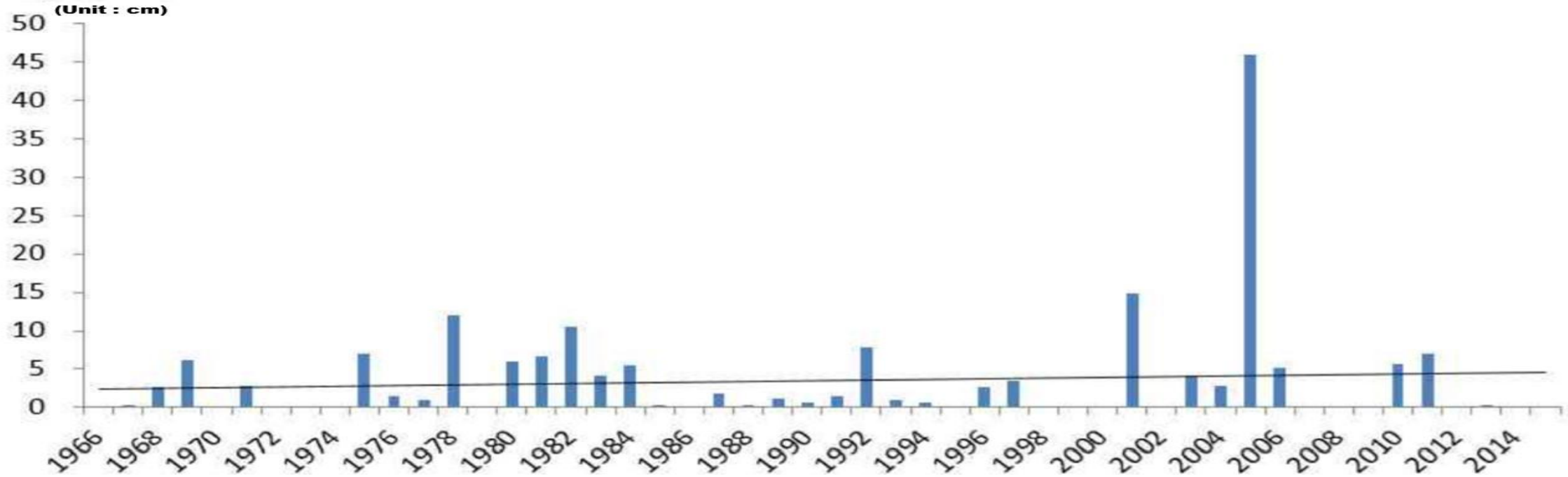
- 4 factors are used to calculate estimate frequency of loss of off-site power due to severe weather
  - ① Annual expected snow fall around the site in inches (h1)
  - ② Annual expected severe tornado at the site (h2)
  - ③ Annual expected storms at the site with wind velocity between 75 and 124 mph (120.7km/h~199.6km/h or 33.33m/s~55.44m/s) (h3)
  - ④ Annual expected storms with significant salt spray for the site (h4)

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

Coping Duration Calculation

◆ **h1 calculation : Annual expected snow fall around the site in inches**

Annual average snow fall in Busan area (1966~2015)



- According to the 2nd Busan climate change adaptation plan reported by Busan Metropolitan City, annual average snow fall in Busan area is 4.3cm (1.69inch), h1 = 1.69

Coping Duration Calculation

◆ h2 calculation : Annual expected severe tornado at the site

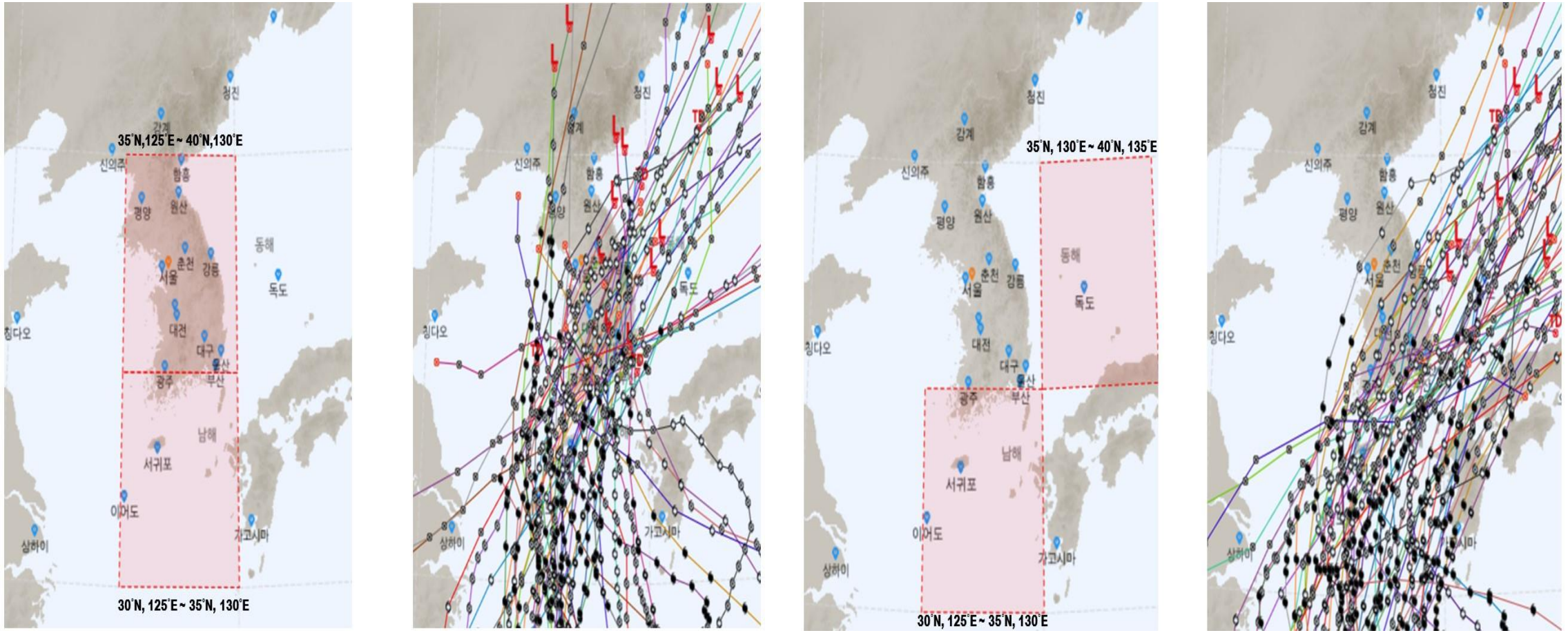
- Tornado is a type of powerful wind with that occurs in the ground or sea which is a high-speed vortex
- Tornado vary in shape and size but are usually funnel-shaped, average 150~600m in diameter, and travel at a speed of 40~80km/h
- From the historical record, there are none of tornado creation is founded near the Saewool site
- For the conclusion, h2 = 0

Coping Duration Calculation

◆ **h3 calculation : Annual expected storms at the site with wind velocity between 75 and 124 mph**

- Factor h3 is expected frequency of typhoon with wind velocity between 75mph and 124mph (33.33m/s~55.44m/s)
- In this study, we used statistical data which is provided in Korea Meteorological Administration (KMA) website
- Maximum three 5˚x 5˚area is selected and system search every typhoon pass through those area

Coping Duration Calculation



Typhoon passed through two area I (1977~2020) **Typhoon passed through two area II (1977~2020)**

- Unfortunately, target area (Saewool site) is located in boundary line. So we had to search in two options

Coping Duration Calculation

- Total 62 typhoon passed by these area since 1977
- 14 typhoon had wind velocity more than 33.3m/s near Saewool site
- HAESHEN (2020), MAYSAK(2020), CHABA(2016), GONI(2015), SANBA(2012), SHANSHAN(2006), SONGDA(2004), MAEMI(2003), RUSA(2002), ROBYN(1993), MIREILLE(1991), CAITLIN(1991), DINAH(1987), THELMA(1987)
- 14/43yr = 0.3256/yr, ∴ h3 = 0.3256

Coping Duration Calculation

◆ **h4 calculation : Annual expected storms with significant salt spray for the site**

- If typhoon with strong wind comes near the plant, salt spray must be affected to the off-site and uncovered on-site facilities
- We experienced impact of salt spray with typhoon MAYSAK(2020), HAISEHN(2020) and THELMA(1987)
- So, we made assumption that if typhoon with wind velocity more than 39m/s(Lowest among three typhoons) gives an impact of salt spray to Shin-kori 5&6

Coping Duration Calculation

- Total 7 typhoon record more than 39m/s of wind velocity when it reached near Saewool site since 1977
- HAISHEN(40m/s, 2020), MAYSAK(43m/s, 2020), SONGDA(41m/s, 2004), ROBYN(41m/s, 1993), MIRELLIE(46m/s, 1991), DINAH(44m/s, 1987), THELMA(39m/s, 1987)
- 7/43yr = 0.1627/yr, ∴ h4 = 0.1627/yr

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

: Estimated frequency of loss of off-site power due to Severe Weather (Sub step 3)

- For the conclusion, h1=1.69, h2=0, h3=0.3256, h4=0.1627

$$f=(1.3\times 10^{-4})\times 1.69+b\times 0+(1.2\times 10^{-2})\times 0+0.78\times 0.1627=0.1272$$

※ According to NUMARC-8700, if certain plant determines it is susceptible to salt spray, h3 can be 0 because the impact of typhoon is considered in h4 calculation (which is way higher value)

SW Group	ESTIMATED FREQUENCY OF LOSS OF OFFSITE POWER
1	$f < 0.0033$
2	$0.0033 \leq f < 0.01$
3	$0.01 \leq f < 0.033$
4	$0.033 \leq f < 0.1$
5	$0.1 \leq f$

Coping Duration Calculation

◆ Off-site power design characteristic group determination

: Evaluate independence of off-site power system (Sub step 4)

- Classified in two groups, I1/2 and I3
- I1/2 group has independent 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 capabilities
- Shin-kori 5&6 has electrically and physically independent 765kV and 154kV system. Thus, Shin-kori 5&6 off-site power design belongs to I1/2 group

Coping Duration Calculation

◆ Off-site power design characteristic group determination (Step 1)

- Shin-kori 5&6 off-site AC power design belong to P3 group according to the chart provided in R.G.1.155

Off-site power design characteristic group matrix (I1/2)

		ESW Group				
		1	2	3	4	5
SW Group	1	P1	P1	P1	P2	P3
	2	P1	P1	P2	P2	P3
	3	P2	P2	P2	P3	P3
	4	P3	P3	P3	P3	P3
	5	P3	P3	P3	P3	P3

Coping Duration Calculation

◆ Emergency AC Power Configuration determination (Step 2)

EAC Group	Shared and dedicated supplies 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 shared

- Shin-kori 5&6 design has 2 EDGs and 1 AACDG per each unit
- Only 1 EDG requires to energize safety class BUS for safe shutdown
- Shin-kori 5&6 belongs to group C in EAC group

KINGS
한국전력국제원자력대학원대학교
KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL

Coping Duration Calculation

◆ EDG Reliability determination (Step 3 & 4)

- Average the number of failures in individual EDGs for the last 20, 50 and 100 demands
- If average is over 0.9 in 20 demands and 0.94 in 50 demands, the unit might select target reliability either 0.95 or 0.975
- If latest 20 demand do not meet 0.9 criteria, 0.95 reliability shall be selected
- For EDGs in Shin-kori 5&6 there is no start or failure record yet
- We will use EDG operation demand record from Shin-kori 1&2 (OPR 1000) and Shin-kori 3&4 (APR 1400) for last 5 years

KINGS
한국전력국제원자력대학원대학교
KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL

Coping Duration Calculation

Plant	EDG	Demand	Sucess	Fail (Date)	Reliability
Shin-kori U1	A	88	87	1 (18.01.10)	0.989
	B	83	81	2 (20.07.14) (17.02.07)	0.976
Shin-kori U2	A	96	94	2 (18.03.28) (17.09.19)	0.979
	B	96	94	2 (15.03.11) (15.06.15)	0.979
Shin-kori U3	A	96	95	1 (15.11.11)	0.99
	B	95	94	1 (18.11.13)	0.989
Shin-kori U4	A	49	49	0	1
	B	45	45	0	1

- Every EDGs in Shin-kori unit 1/2/3/4 has reliability more than 0.975
- Since Shin-kori 5&6 has new design with new EDGs, we will assume target reliability of Shin-kori 5&6 EDG in 0.975

Coping Duration Calculation

◆ Coping Duration Determination (Step 5)

Emergency AC Power Configuration Group							
Off-site Power Design Characteristic 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	5	4
P2	4	4	4	4	4	8	8
P3	4	8	4	8	**8**	16	8

- Off-site power design characteristic group was P3
- Emergency AC power configuration group was C
- Target EDG reliability is 0.975
- For the conclusion, coping duration for Shin-kori 5&6 is 8 hours
  (Current design applied 8 hours)

Improvement

◆ Protecting for salt spray

- If Shin-kori 5&6 design is protected from salt spray, h4 will be zero
- Off-site power loss frequency due to severe weather calculation will change

  $f=(1.3\times 10^{-4})\times 1.69+b\times 0+(1.2\times 10^{-2})\times 0.3256+0\times 0.1395=0.004125$
- SW group will be in group 2 and off-site power loss frequency characteristic group will be in P1

		ESW Group				
		1	2	3	4	5
SW Group	1	P1	P1	P1	P2	P3
	2	P1	P1	P2	P2	P3
	3	P2	P2	P2	P3	P3
	4	P3	P3	P3	P3	P3
	5	P3	P3	P3	P3	P3

Improvement

◆ Protecting for salt spray

Emergency AC Power Configuration Group							
Off-site Power Design Characteristic 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**	5	4
P2	4	4	4	4	4	8	8
P3	4	8	4	8	8	16	8

- If Shin-kori 5&6 design is protected from salt spray, coping duration will reduce to 4 hours and secure 4 hours of margin against SBO in current design

Improvement

◆ Including AACDG in EAC group

- AACDG in Shin-kori 5&6 has improved safety criteria and design than previous design
- If we include AACDG in EAC group, AACDG in each unit can be considered as Alternate AC power source to each other(By tie line)
- Then, Shin-kori 5&6 can be considered to have 3 EAC system with 1 requiring for safe shutdown

EAC Group	Shared and dedicated supplies 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 shared

Improvement

◆ Including AACDG in EAC group

Emergency AC Power Configuration Group							
Off-site Power Design Characteristic 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	5	4
P2	4	4	4	4	4	8	8
P3	4	8	4	8	8	16	8

- If we consider AACDG to be included in EAC group, coping duration of Shin-kori 5&6 will be 4 hours and secure 4 hours of margin against SBO in current design

Conclusion

- SKN 5&6 is designed based on coping duration 8 hours and calculated in 4 hours (PSAR)
- In this report, coping duration of SKN 5&6 is calculated in 8 hours
- Main difference between current design document (PSAR) and this study is applying effectiveness of salt spray

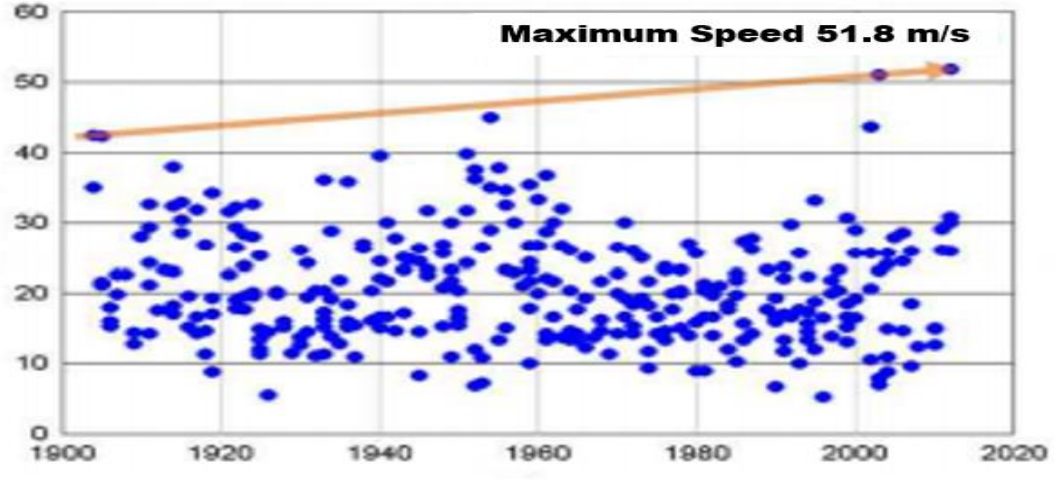
Conclusion

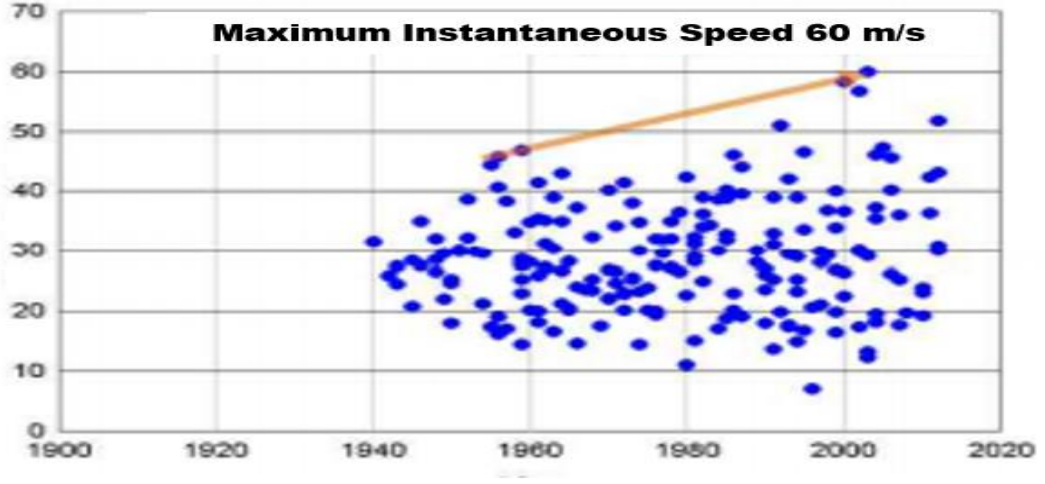
- And weather and design approach we applied in this study was very conservative and harsh
- Coping duration methodology provided in RG 1.155 is not sufficiently considered for domestic NPPs
- Further research and investigation is necessary to develop coping duration calculation for domestic NPPs

Conclusion

- Due to the global warming, maximum wind speed and maximum instantaneous wind speed increased rapidly
- Also, speed and size of typhoon is predicted to increase in Korea peninsula
- For the future safety against SBO, <u>developing facilities against salt spray</u> and <u>improving quality of AACDG</u> seems necessary

Maximum Wind Speed change (1904~2012)





Thank you

KINGS
한국전력국제원자력대학원대학교
KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL