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Regulation Experience and Analysis Result for LOOP of Nuclear Power Plant in KOREA

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***Abstract*—Caused Analysis for LOOP (Loss of Offsite Power) in NPP shall be review and inspection, before performing evaluation, for trip signal was caused T/G or reactor trip. LOOP event has affected for safety class in NPP. This paper was show that experience and result for LOOP, and presently compared and comment for proposal to reduce it.**

Index Terms*— *LOOP, reliability, deregulation and frequency

I. INTRODUCTION

Treferred power supply (PPS), which power supply from the transmission system to the Class 1E distribution system that is preferred to furnish electric power under accident and post-accident conditions. LOOP means completely loss for offsite ac source of PPS and EDG shall be automatically started by under-voltage signal at Class 1E bus. [4]

LOOP sorted 4 categories by 2009 from KR #1 to UJ #6 in Korea by NUREG/CR-6890 comments, and LOOP frequency related to situation of every country by electric-power restructured policy. [6]

NRC should requires to FERC and NERC for reflect reliability concept at power system and for performance evaluation and corrective activity about interface facility, and LOOP evaluated that is influenced directly or indirectly to CDF (core damage frequency) by systems failure and LOOP event are steadily increased by interface equipment of NPP and Grid. [5][6][13][14]

This paper compared and analyzed for cause and frequency of LOOP event by 2009 in Korea that noticed regulation position and experience.

II. REGULATION EXPERIENCE AND ANALYSIS RESULTS

A. Nuclear position

1) Korea

2009, nuclear energy focus on stable electric power source at 35% in total power generation with table Ⅰ, and more is increasing construction sites by green growth policy and global warming effect. [3]

Table Ⅰ Power generation condition for 5 years (GWh, %)

Year	nuclear	Coal	LNG	oil	hydro	recycle	total
2005	140,367 (41.42)	129,231 (38.13)	48,281 (14.25)	16,704 (4.93)	1,503 (0.44)	2,774 (0.82)	338,861 (100)
2006	142,114 (40.05)	134,480 (37.89)	57,074 (16.08)	15,482 (4.36)	1,741 (0.49)	3,976 (1.12)	354,869 (100)
2007	136,599 (36.49)	149,113 (39.83)	65,666 (17.54)	16,556 (4.42)	1,398 (0.37)	5,051 (1.35)	374,384 (100)
2008	144,254 (36.77)	166,728 (42.50)	65,155 (16.61)	8,965 (2.29)	2,480 (0.63)	4,740 (1.21)	392,322 (100)
2009	141.123 (34.79)	186,137 (45.88)	57,555 (14.19)	12,689 (3.17)	2,814 (0.69)	5,193 (1.28)	405,692 (100)

2) America and Canada

2005, nuclear energy has of base or preliminary power source by 20% in electric power, and construction of the latest new nuclear reactor is planned more than 20 reactors. And NRC assisted and FERC approved NERC NUC-001-1 at 2007, including probability reliability evaluation for electric power since North America blackout. 2005, Canada Nuclear Regulatory Commission (CNSC) approved regulation guideline S-98. [8] [9]

B. Frequency Model [16]

General frequency model use Poisson distribution and binomial distribution by trip events

1) Poisson distribution

A. The frequency event occurred in any specified short exposure time period is approximately proportional to reactor operation of time period
B. Approximately simultaneous events do not occur.
C. Occurrences of events in disjoint exposure time period are statistically independent.
D. As a minimum, the total number of events and the corresponding time period are observed.
E. The above assumptions, number of occurrences X in some Fixed time t is a Poisson distributed random variable with mean $\mu = \lambda t$, $\Pr(X = x) = e^{-\mu}\mu^{x}/x!$

2) Binomial distribution

A. On each demand, the outcome is a failure with some probability ρ, and a success with probability 1- ρ. This probability ρ is the same for all demands.
B. Occurrences of failures for different demands are statistically independent.

C. As a minimum, the total number of failures and number of demands are observed.

D. The above assumptions, the random number is failure X, in some fixed number of demands n, $\Pr(X = x) = \binom{n}{x} p^x (1-p)^{n-x},\ x = 0, \dots n,$ where

$$\binom{n}{x} = \frac{n!}{x!\,(n-x)!}$$

C. LOOP regulation experience and result

1) America

System accident of Grid and interface equipment faults had increased due to avoiding maintenance investment for power system since electric power market deregulation, 1996. According to Table Ⅱ and Table Ⅲ, classifies LOOP Event total 135 events by electric-power restructured, but the US reduces owing to force on corrective activity and reliability evaluation for PPS on utilities, interface facility, since 2003 North America blackout, and recently it is in declining tendency that LOOP event only happens one event for 104 reactors from 2007 to 2009 after NUREG 6890 report. [6][10][11] [12]

Table Ⅱ Power system restructure (before and after) frequency

Items	Category	1986-1996			1997-2004		
		event	Op/year	frequency	event	Op/year	frequency
Operation	Plant	11	877.2	3.31E-02	1	724.3	2.07E-03
	SWYD	23	877.2	2.68E-02	7	724.3	1.04E-02
	Grid	1	877.2	1.71E-03	13	724.3	1.86E-02
	Weather	3	877.2	3.99E-03	3	724.3	4.83E-03
	total	38	-	4.56E-02	24	-	3.59E-02
Stop/ maintenance	Plant	14	278.5	5.21E-02	5	104.7	5.25E-02
	SWYD	31	278.5	1.13E-01	7	104.7	7.16E-02
	Grid	1	278.5	5.39E-03	2	104.7	2.39E-02
	Weather	9	278.5	3.41E-02	4	104.7	4.30E-02
	total	55	-	2.05E-01	18	-	1.91E-01

Table Ⅲ Event count LOOP cause

Category	External	Hardware	Human error		Power system	Weather worst	total	Percent
			Operation	Stop O/H				
Plant	-	11	8	12	-	3	34	23
SWYD	-	42	3	21	1	8	75	51
Grid	-	3	1	-	14	-	18	12
Weather	6	-	-	-	-	15	21	14
total	6	56	12	33	15	26	148	100
Percent	4	38	8	22	10	18	100	

2) Korea

Since KR #1 commerce at 1978, LOOP event analyzed for actuality occurrence signal, for 31 years operation, total 20 nuclear reactors to 2009 presently. Trip number for Initial operation periods was decreased by repair and design change of power system at prefer time under government control for PPS and interface facility, but difficulty is started after possession and administration control were divided since electric-power industry restructured. Here, Small LOOP excluded in Table Ⅳ. LOOP events are total 13, power plant related (5:38%), weather related (4:31%) are mostly occupy on LOOP caused, and 2 of 6 LOOP happened during O/H by a human errors. Therefore, security minds usually consistently shall be emphasis on to workers. [15]

Table Ⅳ LOOP Event in Korea (*source: Http://opis.kins.re.kr)

No	Plant	Occ Time	Occurrence Causes	RTN Time
1	W1	1985.04.19	#1, #2 T/L trip by CB trip delay	1985.04.25
2	K4	1986.08.28	LA destroy, M.Tr 87 By BERA	1986.09.04
3	K2	1987.04.21	T/L grounding and short	1987.04.22
4	K1	1987.07.15	T/L short by storm and cascading	1987.07.15
5	K4	1993.01.17	PCB trip at SWYD pro' relay (HE)	1993.01.17
6	U2	1997.01.01	T/L short and grounding by storm	1997.01.01
7	U1	2001.01.30	M.Tr B HV overheating	2001.02.02
8	Y5	2002.11.03	TBN H vibration and T/L grounding	2002.11.05
9	Y6	2002.11.03	#1T/L trip On Pre-operation	2002.11.05
10	W2	2004.06.19	ES close during O/H in SWYD (HE)	2004.06.23
11	Y5	2006.11.29	M.Tr SPR mis-operation during O/H	2006.11.30
12	K1	2008.08.08	T/L 2lines was lighting at same time	2008.08.11
13	W2	2009.09.03	Gen 32r injection for O/H (HE)	2009.09.03

LOOP trip signal show below Table Ⅴ, and LOOP Event classified by Plant, Weather, Grid, SWYD. Fig Ⅰ shows analyzed that SKR 1, 2 LOOP calculation value (operation years (1978 ~ 1998) are 95.8 reactors/year, and LOOP event are 3 from PSAR (preliminary safety analysis report), presently total operation years are 320.63 reactors/year by 2009, LOOP event are 6 by 1998. [7] [17]

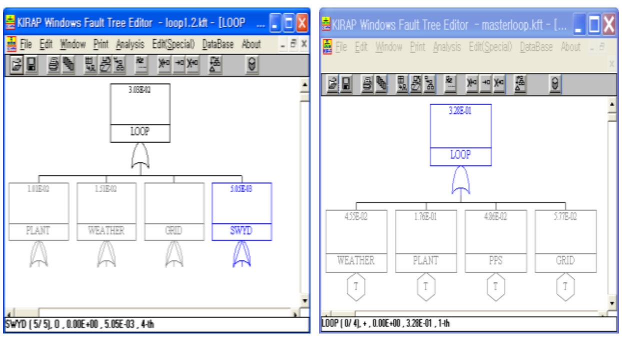

Fig Ⅰ LOOP frequency compare by fault tree

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Table Ⅴ LOOP Electrical Trip Signal

Items	Trip source
switchyard	7(8)x51, 7(8)x00,x 7(8)x22
GCB	phase discrepancy, over-current, reverse-power etc.
Frequency	57.3(0.99s), 57.7(10s), 58.1(1m), 58.5(10m)
Pro' PNL	21, 50BF, 50/51, 59G, 60(voltage balance), 87, 96B, 96D, 96P

D. Deregulation experience and analysis results

Source dada obtained by http://opis.kins.re.kr. LOOP frequency has contracted at YK and UJ site for before and after electric-power restructured by below Tablet Ⅵ, and 61% was occupied at fall season (3/4 quarter), and Fig Ⅱ shows LOOP frequency that before and after deregulation.

Table Ⅶ showed for events numbers by plant, weather, grid-SWYD orders. Table Ⅷ, Ⅸ, and Ⅹ show for trip events and frequency in NPPs, respectively.

Table Ⅵ Power system restructure (before and after) frequency

plant	1978.5-2001.4			2001.5-2009.12		
	count	Op-year	frequency	count	Op-year	frequency
KR	4	70.26	5.69E-02	1	33.60	2.97E-02
YK	0	39.20	-	3	47.98	6.25E-02
WS	1	25.37	3.94E-02	2	33.60	5.95E-02
UJ	2	27.36	7.30E-02	0	43.26	-
Total	7	162.19	4.31E-02	6	158.44	1.39E-01

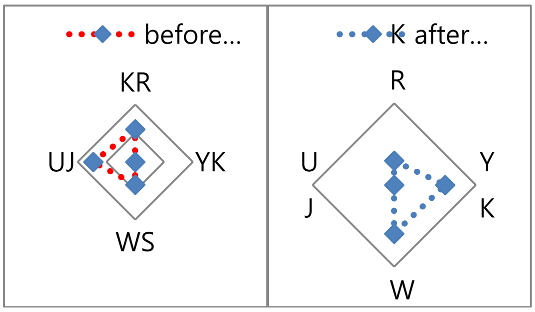

Fig Ⅱ LOOP frequency compare

Table Ⅶ LOOP cause classification

Category	KR	YK	WS	UJ	Total
Plant	0	3	1	1	5
Grid	1	0	1		2
Weather	3	0	0	1	4
SWYD	1	0	1		2
total	5	3	3	2	13

Table Ⅷ LOOP number of item by site divergence

Plant	1978.5-2009.12		Plant	1978.5-2009.12	
	Quarter	Count		Quarter	Count
KR	1	1	WS	1	0
	2	1		2	2
	3	3		3	1
	4	0		4	0
YK	1	0	UJ	1	2
	2	0		2	0
	3	0		3	0
	4	3		4	0

Table Ⅸ Trip Count and frequency by YK N/P, UJ N/P

WK		1978.5-2009.12				UJ		1978.5-2009.12			
		count	Op-year	%	frequency			count	Op-year	%	frequency
#1	G	-	22.81	-	-	#1	G	-	20.78	-	-
	P	-		-	-		P	1		100	4.81E-02
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
#2	G	-	21.94	-	-	#2	G	-	19.75	-	-
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	1		100	5.06E-02
#3	G	-	14.45	-	-	#3	G	-	10.83	-	-
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
#4	G	-	13.60	-	-	#4	G	-	9.60	-	-
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
#5	G	1	7.37	50	1.36E-01	#5	G	-	5.25	-	-
	P	1		50	1.36E-01		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
#6	G	1	7.01	100	1.43E-01	#6	G	-	4.41	-	-
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
TTL		3	87.18	-	3.44E-02	TTL		2	70.62	-	2.83E-02

Table Ⅹ Trip Count and frequency by KR N/P, WS N/P

KR		1978.5-2009.12				WS		1978.5-2009.12			
		count	Op-year	%	frequency			count	Op-year	%	frequency
#1	G	-	31.41	-	-	#1	G	1	26.42	100	3.78E-02
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	2		100	6.37E-02		W	-		-	-
#2	G	1	25.86	100	3.39E-02	#2	G	-	11.94	-	-
	P	-		-	-		P	1		50	8.38E-02
	S	-		-	-		S	1		50	8.38E-02
	W	-		-	-		W	-		-	-
#3	G	-	23.75	-	-	#3	G	-	10.90	-	-
	P	-		-	-		P	-		-	-
	S	-		-	-		S	-		-	-
	W	-		-	-		W	-		-	-
#4	G	-	22.84	-	-	#4	G	-	9.75	-	-
	P	-		-	-		P	-		-	-
	S	1		50	4.39E-02		S	-		-	-
	W	1		50	4.39E-02		W	-		-	-
TTL		5	103.86	-	4.81E-02	TTL		3	59.01	-	5.08E-02

E. Future study directions

Risk control includes electrical problem, as EDG failures, and recently offsite power problems is affected at safety class of plants by transient phenomenon, power quality as voltage sag and swell in grid or plant.

Nuclear is a hazard and important energy, and as possibly probability concept will be apply all electrical system in plants, and do develop regulation guideline in detail aspect.

Recently LOOP is repeated and increased from human error, and need that review to safety culture, policy decision and regulation direction establishment. These may be troubled to costs, additional responsive and times on utilities or regulators during short-terms, but judge that fairly strength at safety side, and risk or failure events can be decrease by ours actions. [1][2]

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