KINGS KEPCO INTERNATIONAL NUCLEAR GRADUATE SCHOOL

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A conceptual comparative study of FLEX strategies to cope with extended SBO

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Contents

Introduction

- The Fukushima NPP accident in 2011 showed that SBO lasted for several days, the so-called extended SBO, and finally resulted in core damage.
- Since that accident, nuclear industries developed onsite and offsite equipment concept that provides an additional layer of defense in depth, called diverse and flexible mitigation strategies (FLEX).
- The implementation difficulty and effectiveness of various strategies developed for extended SBO may not be same. In this study, two strategies for recovery of electric power using mobile generators are examined.

In Korea, KHNP introduced multi-barrier accident coping strategy (MACST). “FLEX” in this presentation means “MACST.”

Introduction

This presentation will give overview on

1

Accident Sequence

- To cope with APR1400 extended SBO using small / large mobile gas turbine generator (GTG) and primary FLEX pump.

2

Human Reliability Analysis

- To calculate HEPs for small mobile GTG and large mobile GTG using Cause-Based Decision Tree (CBDT) and Technique for Human Error Rate Prediction (THERP) methods.

3

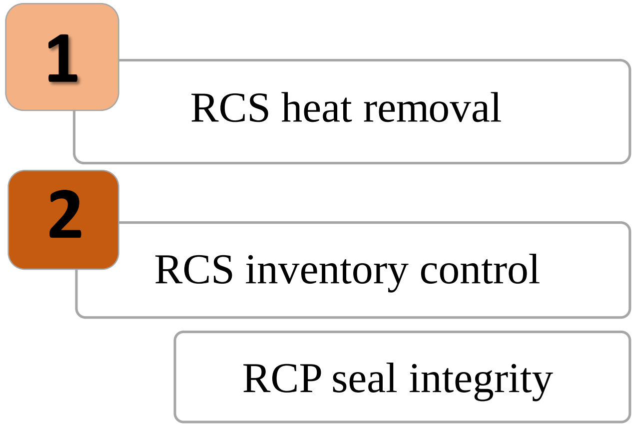
Comparison of HEPs and CDFs

- Comparative study of FLEX strategies with small mobile GTG and large mobile GTG for APR1400 extended SBO, based on core damage frequency.

Extended SBO

- In the APR1400, extended SBO involves complete loss of ac electric power to the Class 1E and non-Class 1E switchgear buses as well as the failure of a non-Class 1E AAC source.
- Under the extended SBO condition, the only dc battery is available for the turbine driven auxiliary feedwater pump (TDAFWP) which supply water to the steam generator (SG).
- The capacity of dc battery is 8 hours and within this period plant safety needs to be recovered.

Challenges under extended SBO



Crediting FLEX

- A small mobile GTG could be connected to class 1E 480V ac bus to recover dc power for maintaining secondary heat removal when TDAFWP are unavailable after battery depletion.

- A large mobile GTG could be connected to one division of the 4.16 kV class 1E buses and the purpose is to recover ac power to maintain the secondary heat removal, feed and bleed operation and containment heat removal.

- One primary FLEX pump could be connected to direct vessel injection (DVI) via the safety injection (SI pump) line to inject borated water into the core to maintain RCS seal integrity.

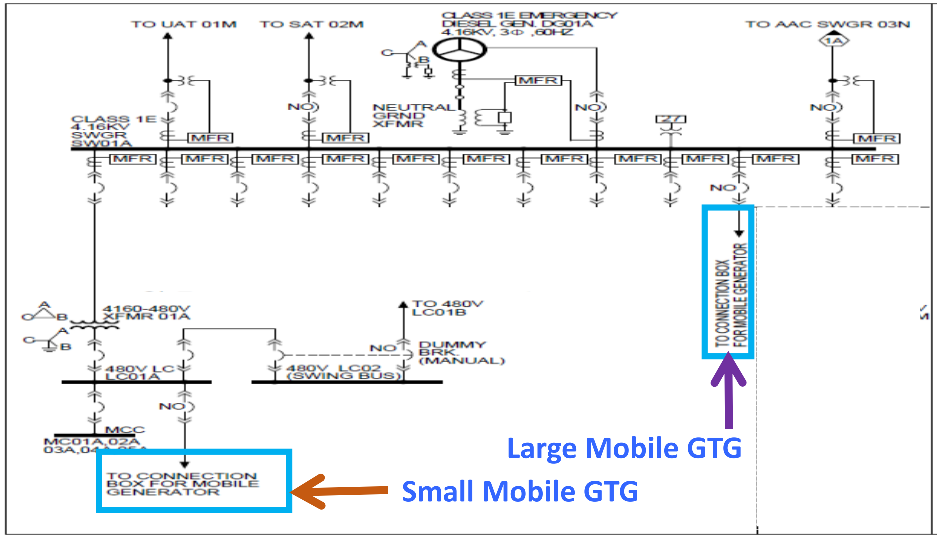


Figure: Connection point of Mobile Generators

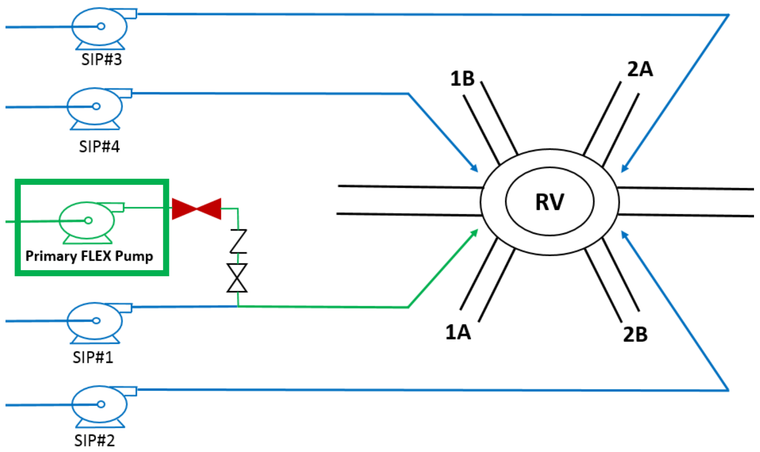
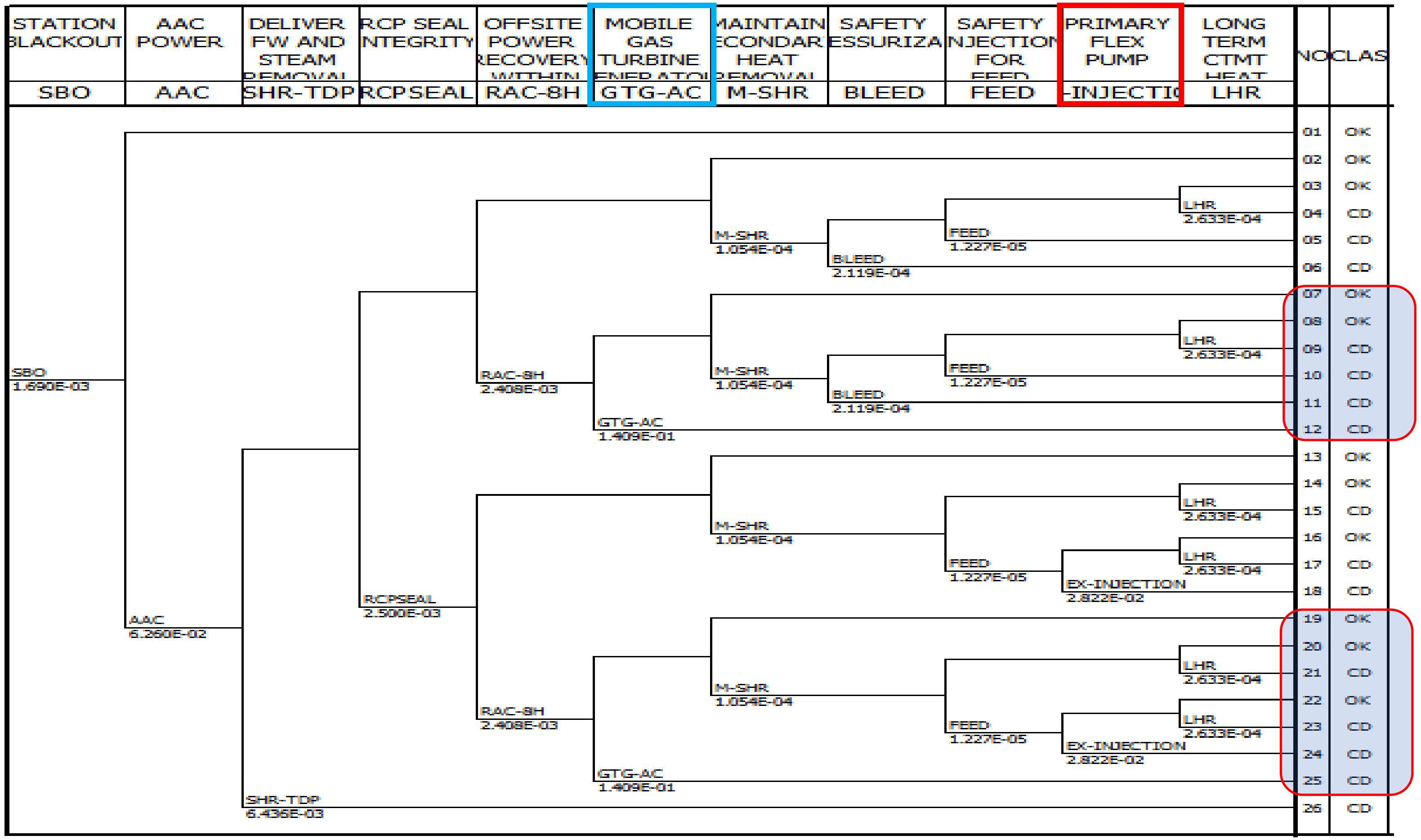


Figure : Connection Line of Primary FLEX Pump

Event Tree: Large GTG

- **Accident Sequence**
- Human Reliability Analysis
- Comparison
- Discussion
- Conclusion

Figure: Event Tree for Extended SBO Using Large Mobile GTG and Primary FLEX Pump



Mitigations

- ac power recovery
- RCS make up by Primary FLEX Pump

Success Criteria: Large GTG

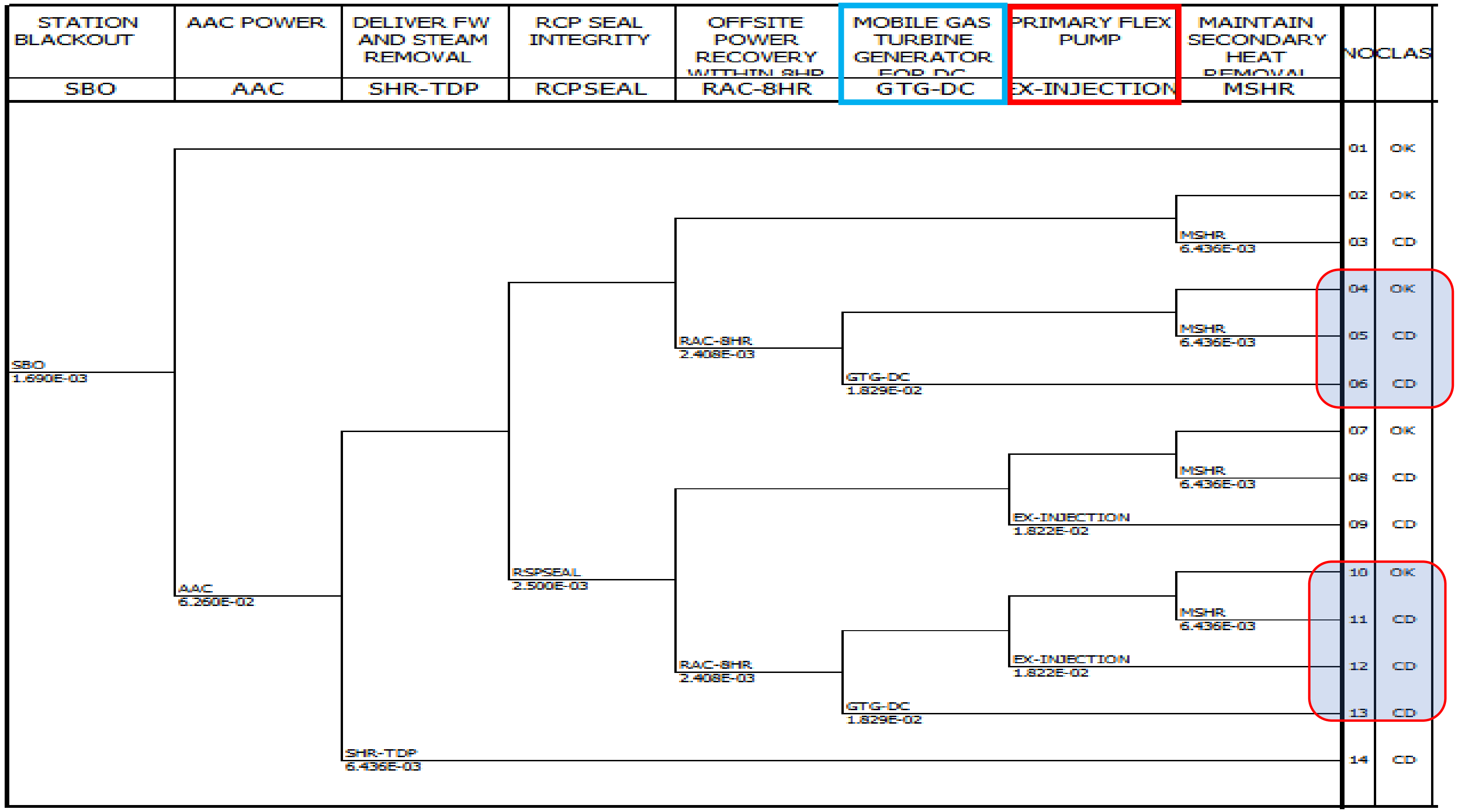
Table : Success criteria for Extended SBO using Large Mobile GTG and Primary FLEX Pump

No	Event Name	Description
1	AAC	AAC power source aligned to one Class 1E 4.16 kV ac bus.
2	SHR-TDP	1 of TDAFPs to associated SG and 1 MSADV or 1 MSSV on associated SG.
3	RCPSEAL	RCP seal remains intact.
4	RAC-8HR	Offsite power restored within 8 hours following an LOOP event.
5	GTG-AC	AC power resorted within 8 hour following battery depletion which is aligned to 4.16 kV safety class 1 AC bus.
6	M-SHR	AFW flow from AFWST after depletion of battery to associated SG and 1 MSADV or 1 MSSV on associated SG.
7	BLEED	2 of 4 POSRVs need to open.
8	FEED	1 of 4 SI pumps provides DVI injection.
9	EX-INJECTION	Primary FLEX pump injects sufficient water to RCS inventory.
10	LHR	1 of CS (containment spray) pumps to associated CS nozzle or 1 of SC (shutdown coo ling) pumps to associated IRWST cooling.

Event Tree: Small GTG

- **Accident Sequence**
- **Human Reliability Analysis**
- **Comparison**
- **Discussion**
- **Conclusion**

Figure: Simplified Event Tree for Extended SBO Using Small Mobile GTG and Primary FLEX Pump



Mitigations

- dc power recovery
- RCS make up by primary FLEX pump

Success Criteria: Small GTG

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Table : Success criteria for Extended SBO Using Small Mobile GTG and Primary FLEX Pump

No	Event Name	Description
1	AAC	AAC DG power source aligned to one Class 1E 4.16 kV ac bus.
2	SHR-TDP	1 of TDAFPs to associated SG and 1 MSADV or 1 MSSV on associated SG.
3	RCP SEAL	RCP Seal remains intact.
4	RAC-8HR	Offsite power restored within 8 hours following an LOOP event.
5	GTG-DC	dc power restored within 8 hrs following battery depletion.
6	EX-INJECTION	Primary FLEX pump injects sufficient water to RCS inventory.
7	M-SHR	AFW flow from AFWST after depletion of battery to associated SG and 1 MSA DV or 1 MSSV on associated SG.

FLEX Procedures

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- Accident Sequence
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Table : Proposed FLEX deployment and installation procedures

Step No.	Description of Actions
Step 01	Diagnose the plant abnormal conditions and perform abnormal procedure guideline.
Step 02	Verify reactor trip occurrence and perform post trip actions.
Step 03	Check LOOP occurrence and perform emergency operating procedures
Step 04	If the operator fails to activate EDG, then declare an SBO
Step 05	Operator check AAC DG availability. If not available extended SBO is declared.
Step 06	Operator load sheds dc bus to preserve battery for vital instrumentation & control
Step 07	STA may instruct the operator to deploy and install FLEX equipment.
Step 08	FLEX equipment deployment route are reviewed.
Step 09	Deployment of mobile GTG in front of the auxiliary building.
Step 10	Operator checks status of the circuit.
Step 11	Connect powerline from mobile GTG to class 1E bus.
Step 11-a	Perform pre-operational check of large GTG.
Step 12	Energize mobile GTG.
Step 13	Check procedure if the vital bus is not restored
Step 14	Deployment and staging of primary FLEX pump.
Step 15	Connect primary FLEX pump to IRWST line
Step 16	Connect primary FLEX pump hose line to SI injection line via DVI.
Step 17	Perform pre-operational check for primary FLEX pump.
Step 18	Start primary FLEX pump.
Step 19	Check procedure if RCS inventory is not recovered.

Timing Analysis

- **Accident Sequence**
- **Human Reliability Analysis**
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After 8 hours from the start of SBO, the mobile GTG is required unless offsite power recovery.

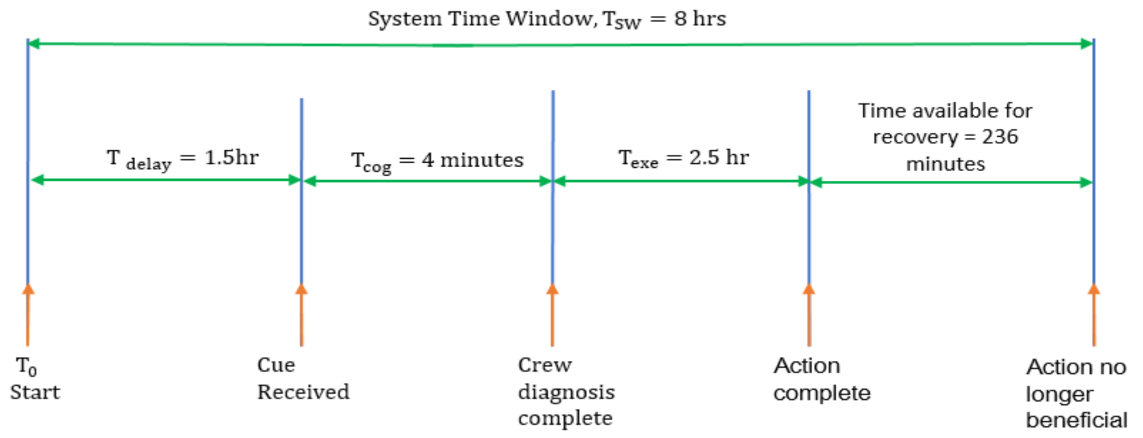

Figure : Timing analysis for extended SBO

T_{delay}= 90 mins. Delay time includes diagnose the situation and begin the deployment of the mitigating strategies equipment, measured from the time of SBO.

T_{cog} = 4 mins. Cognition time includes the time for operators to receive enough indication, evaluate the written instructions, and take any necessary preparatory decision to begin the deployment actions.

T_{exe} = 150 mins. Execution time which includes FLEX equipment transportation, installation, start and re-power the vital buses along with inclement weather.

T_w = 236 mins. Time available for recovery.

HEP Calculation

- Human failure events, namely operator fails to deploy and install a small GTG, a large GTG and primary FLEX pump under APR1400 extended SBO, were considered to calculate human error probabilities, HEPs.
- Cognitive portion of HEPs (P_{cog} & P_{CR}) were calculated using CBDTM.
- Execution portion of HEPs (P_{exe} & P_{ER}) were calculated using THERP.

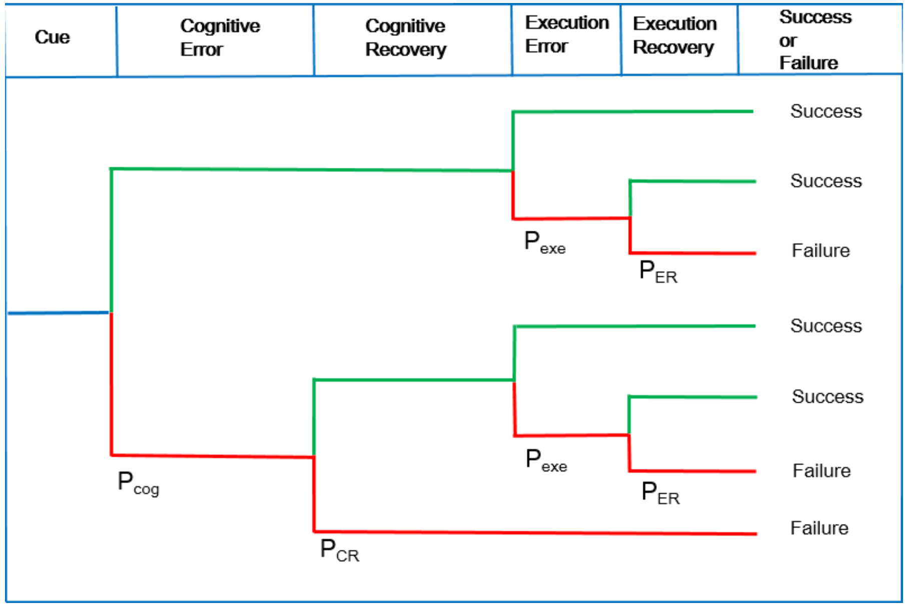

Figure : HFEs Probability Assessment

P_{cog} : Cognition HEP, P_{exe} : Execution HEP, P_{CR} : Cognitive Recovered HEP and P_{ER} : Execution Recovered HEP

Cognition Error Probability

Table: Cognitive HEP without recovery, P_{cog}

CBDTM Failure Mechanism	Branch	HEP
p_ca : Availability of information	**a**	**0.0**
Notes: Operator can access to all information and required indication to operate a plant in the main control room (MCR).		
p_cb : Failure of attention	**m**	**1.5×10^{-2}**
Notes: In general, within 2 hours from SBO initiation, the workload is assumed to be high. It may be necessary to monitor parameters and indicators continuously rather than one time check under SBO. It's is assumed that the indicator to be checked is always displayed on the front panel of the MCR because all of the controls in the modern control room are expected to be located in the front of the room. It is also predicted that operators concentrate on emergency operating guideline (EOG) and performs EOG-driven actions after the reactor trip. Thus, operators cannot wait for alarms to respond until the related parameter are mentioned in the EOG step.		
p_cc : Misread/ miscommunicate data	**a**	**0.0**
Notes: It is assumed that required indicator on the control board such as layout, demarcation, labelling, and others is always located easily. With the advanced digital I&C interface in the MCR, the indication is assumed to be "good". It also is predicted that formal communications will always be used when the specified value is transferred between operators.		
p_cd : Information misleading	**b**	**3.0×10^{-3}**
Notes: All cues are not as stated for these HFEs and the EOG may provide contingency actions which are instructions on how to proceed.		
p_ce : Skip a step in procedure	**g**	**6.0×10^{-3}**
Notes: It's assumed that it's always transparent for operators to proceed with the relevant instruction or stand-alone numbered step on the EOGs. The operator is required to use an additional procedure in addition to the EOG, so "multiple" branch is selected for these HFEs. For this operator action, related procedure step is "not graphically distinct".		
p_cf : Misinterpret Instruction	**a**	**0.0**
Notes: It is generally assumed that the wording of the procedures will be standard, clear. The step presents all information required to identify the actions directed and their objects.		
p_cg : Misinterpret decision logic	**a**	**1.6×10^{-2}**
Notes: It is assumed that the operators are trained and practiced about specified scenario to perform.		
p_ch : Deliberate Violation	**a**	**0.0**
Notes: The operators are always assumed to believe in the adequacy of instruction presented.		
Initial P_{cog} (without recovery)		**4.0×10^{-2}**

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Recovery of Cognition Error

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- Shift Technical Adviser (STA) review is possible to recover failure of attention (p_cb), information misleading (p_cd) and misinterpret decision logic (p_cg). In addition, the extra crew can review the steps in the procedures (p_ce).
- For an initial estimate, a value of 0.1 was used.
- For complete independence, the factor is the HEP itself (p_c e case).

Table: Cognitive recovered, P_{CR}

	Branch	Initial HEP	Self-Review	Extra Crew	STA Review	Shift Change	ERF Review	DF	Multiply By	Final Value
p_ca	a	0.0	NC	0.5	NC	X	X		1.0	0.0
p_cb	m	1.5×10^{-2}	0.1	NC	0.1	X	X	MD	0.16	2.4×10^{-3}
p_cc	a	0.0	NC	NC	0.1	X	X		1.0	0.0
p_cd	b	3.0×10^{-3}	NC	0.5	0.1	X	X	MD	0.15	4.5×10^{-4}
p_ce	g	6.0×10^{-3}	0.1	0.5	NC	X	X		0.5	3.0×10^{-3}
p_cf	a	0.0	NC	0.5	0.1	X	X		1.0	0.0
p_cg	a	1.6×10^{-2}	NC	0.5	0.1	X	X	MD	0.16	2.6×10^{-3}
p_ch	a	0.0	NC	0.1	0.1	X	X		1.0	0.0
Sum of recovered p_ca through p_ch = Total of cognitive recovered P_{CR}										8.45×10^{-3}

- For p_c a, p_c c, p_c f, & p_c h, we multiplied the initial HEPs by 1 as no recovery factors are identified.
- The dependency factor (DF) was increased from zero dependence (ZD) to moderate dependence (MD). This is because MD is usually assessed between the shift technical advisor (STA) and the operators for tasks in which the STA is expected to interact with them.
- For p_cb, p_cd and p_cg decision trees, the conditional HEPs values for MD were calculated using failure equation $Pr[F_{"N"}|F_{"N-1"}] = (1+6N)/7$ which represent probabilities of failure on Task "N" given failure on the immediately preceding task, "N-1".

THERP

Table : THERP Execution performance shaping factors

Environment	Lighting	Portable
	Heat/humidity	Hot/Humid
	Radiation	Green
	Atmosphere	Normal
Special Requirements	Tools	Required
	Parts	Required
	Clothing	Available
Complexity of response	Execution	Complex
Equipment Accessibility (Cognitive)	Main control room	Accessible
Equipment Accessibility (Execution)	Auxiliary Building	Accessible

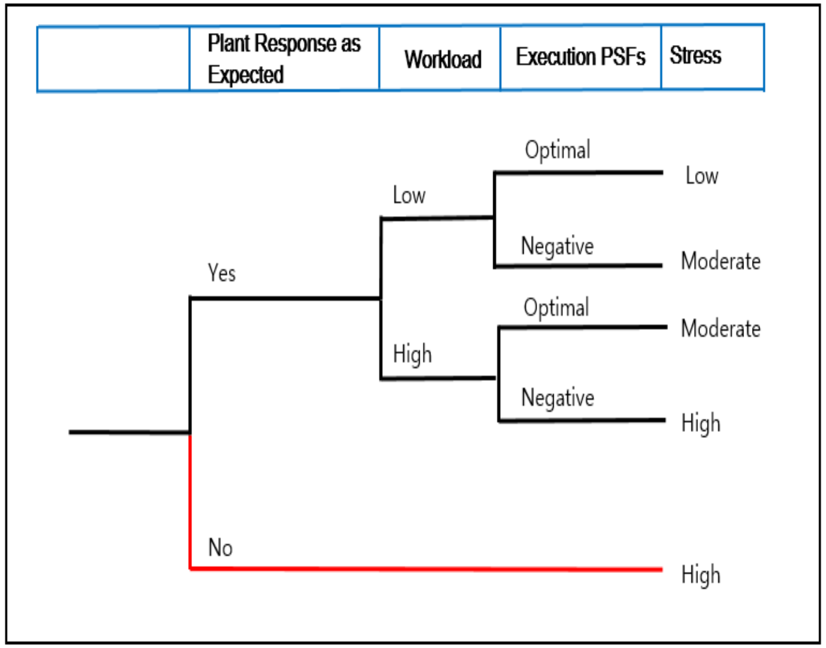

Figure : THERP stress decision tree

The execution stress level was considered high and modifier 5 value was used.

Execution Error Probability

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Table : P_{exe} without recovery for small mobile GTG

Procedure		Error type	THERP		HEP	Stress factor	Total Step HEP
Step No.	Action		Table	Item			
09	Deployment of small GTG in front of auxiliary building.	EOM	20-7b	1	4.17×10^{-4}	High	8.59×10^{-3}
		EOC	20-13	1	1.3×10^{-3}	High	
10	Operator checks status of circuit.	EOM	20-7	2	3.75×10^{-3}	High	2.53×10^{-2}
		EOC	20-10	6	1.3×10^{-3}	High	
11	Connect powerline to 480V for small GTG.	EOM	20-7b	2	1.25×10^{-3}	High	7.13×10^{-2}
		EOC	20-12	13	1.30×10^{-2}	High	
12	Energize mobile small GTG.	EOM	20-7b	2	1.25×10^{-3}	High	3.78×10^{-2}
		EOC	20-12	11	6.3×10^{-3}	High	
13	Check procedure if vital bus is not restored	EOM	20-7b	2	1.25×10^{-3}	High	1.28×10^{-2}
		EOC	20-11	2	1.3×10^{-3}	High	

Table : Execution recovered, P_{ER} for small mobile GTG

Critical Step No.	Recovery Step No.	Action	HEP (Critical)	HEP (Rec)	DF.	Cond. HEP (Recovery)	Total for Step
09		Deployment of small GTG in front of auxiliary building.	8.59×10^{-3}				1.68×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
10		Operator checks status of circuit.	2.53×10^{-2}				4.95×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
11		Connect powerline to 480V for small GTG.	7.13×10^{-2}				1.40×10^{-4}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
12		Energize mobile small GTG.	3.78×10^{-2}				7.40×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
Total Unrecovered, P_{exe}			**1.43×10^{-1}**	**Total Recovered, P_{ER}**			**2.80×10^{-4}**

The calculated P_{exe} without recovery and execution recovered, P_{ER} for small mobile GTG values are 1.43×10^{-1} and 2.8×10^{-4} respectively.

Execution Error Probability

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Table : P_{exe} without recovery for large mobile GTG

Procedure		Error type	THERP		HEP	Stress factor	Total Step HEP
Step No.	Action		Table	Item			
09	Deployment of large GTG in front of auxiliary building	EOM	20-7b	1	4.17×10^{-4}	High	8.59×10^{-3}
		EOC	20-13	1	1.3×10^{-3}	High	
10	Operator checks status of circuit.	EOM	20-7	2	3.75×10^{-3}	High	2.53×10^{-2}
		EOC	20-10	6	1.3×10^{-3}	High	
11	Connect powerline to class 1E 4.16kV for large GTG.	EOM	20-7b	2	1.25×10^{-3}	High	7.13×10^{-2}
		EOC	20-12	13	1.30×10^{-2}	High	
11-a	Perform pre-operational checking of large GTG.	EOM	20-7b	1	4.17×10^{-4}	High	3.36×10^{-2}
		EOC	20-12	11	6.30×10^{-3}	High	
12	Energize mobile large GTG.	EOM	20-7b	2	1.25×10^{-3}	High	3.78×10^{-2}
		EOC	20-12	11	6.3×10^{-3}	High	
13	Check procedure if vital bus is not restored	EOM	20-7b	2	1.25×10^{-3}	High	1.28×10^{-2}
		EOC	20-11	2	1.3×10^{-3}	High	

Table : Execution recovered, P_{ER} for large mobile GTG

Critical Step No.	Recovery Step No.	Action	HEP (Critical)	HEP (Rec)	DF	Cond. HEP (Recovery)	Total For Step
09		Deployment of large GTG in front of auxiliary building	8.59×10^{-3}				1.68×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
10		Operator checks status of circuit.	2.53×10^{-2}				4.95×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
11		Connect powerline to class 1E 4.16kV for large GTG.	7.13×10^{-2}				1.40×10^{-4}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
11-a		Perform pre-operational checking of large GTG.	3.36×10^{-2}				6.59×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
12		Energize mobile large GTG.	3.78×10^{-2}				7.40×10^{-5}
	13	Check procedure if vital bus is not restored		1.28×10^{-2}	MD	1.96×10^{-3}	
Total Unrecovered, P_{exe}			**1.76×10^{-1}**	**Total Recovered, P_{ER}**			**3.46×10^{-4}**

The calculated P_{exe} without recovery and execution recovered, P_{ER} for large mobile GTG values are 1.76×10^{-1} and 3.46×10^{-4} respectively.

Comparison of HEPs

Table : Comparison of HEP Results

HEP Results Summary				
		P_{cog}	P_{exe}	Total HEP
Small Mobile GTG	Without Recovery	4.0×10^{-2}	1.43×10^{-1}	8.73×10^{-3}
	With Recovery	8.45×10^{-3}	2.80×10^{-4}	
Large Mobile GTG	Without Recovery	4.0×10^{-2}	1.76×10^{-1}	8.80×10^{-3}
	With Recovery	8.45×10^{-3}	3.46×10^{-4}	
NEI 16-06 Guide HEP Results Summary				
FLEX Generator	Without Recovery	2.0×10^{-3}	1.18×10^{-1}	5.35×10^{-3}
	With Recovery	2.9×10^{-4}	5.06×10^{-3}	

(Assumed) BE Data

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- There is no failure data available for portable equipment while there are sources of generic failure rates for permanently-installed equipment at NPPs.
- In this study, failure probability of diesel generator and combustion turbine generator are used as failure probability of a small mobile GTG and a large mobile GTG, respectively.

Table : Basic Event Data Considered for FLEX Strategies

Basic Event	Description	Probability	Data Source
EIEPL-S-PP01	Portable pump fails to load run	9.80×10^{-4}	Component Reliability Data Sheets 2015 Update (Table 2-10)
EIEPM-S-PP01	Portable pump unavailable due to maintenance	7.51×10^{-3}	NUREG/CR- 6928 (Table 6-1)
EIEPR-S-PP01	Portable pump fails to run	1.98×10^{-3}	Component Reliability Data Sheets 2015 Update (Table 2-10)
EIEPS-S-PP01	Portable pump fails to start	2.17×10^{-3}	Component Reliability Data Sheets 2015 Update (Table 2-10)
EIMP-PP01--HOSE	Failure to Portable pump hose	5.89×10^{-6}	SAND 2006-7723
GTTGL-L-GTG	Large GTG fail to run for 1hr	5.79×10^{-3}	Component Reliability Data Sheets 2015 Update (Table 3.-8)
GTTGM-L-GTG	Large GTG unavailable due to maintenance	5.00×10^{-2}	NUREG/CR-6928 (Table 6-1)
GTTGR-L-GTG	Large GTG fail to run	8.49×10^{-3}	Component Reliability Data Sheets 2015 Update (Table 3-8)
GTTGS-L-GTG	Large GTG fail to start	5.12×10^{-2}	Component Reliability Data Sheets 2015 Update (Table 3-8)
GTBSY-S-SW01	AC bus faults switchgear of GTG	9.55×10^{-7}	Component Reliability Data Sheets 2015 Update (Table 5-19)
GTBSY-P-SW01	DC bus faults switchgear of GTG	2.17×10^{-7}	Component Reliability Data Sheets 2015 Update (Table 5-19)
GT-GTG- REEL	Failure of large GTG reel cable	1.20×10^{-6}	NUREG/CR-3263
GTOPH-S-GTG	Operators fails to provide 1E class DC bus	5.35×10^{-3}	NEI-16-06
GTTGL-S-GTG	Small GTG fails to run for 1 hr	3.72×10^{-3}	NUREG/CR- 6928
GTTGS-S-GTG	Small GTG fails to start	2.88×10^{-3}	NUREG/CR- 6928
GTTGM-S-GTG	Small GTG unavailable due to maintenance	1.34×10^{-3}	NUREG/CR- 6928
GTTGR-S-GTG	Small GTG fails to run	1.52×10^{-3}	NUREG/CR- 6928
GT-SGTG-REEL	Failure of Small GTG cable reel	4.00×10^{-8}	NUREG/CR- 3263

Comparison of CDFs

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Table : CDF Contribution using large mobile GTG

Sequence Number	Sequence	CDF Contribution (events/year)
ESBO-05	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal intact)(success of recovery offsite power within 8 hours)(failure to maintain secondary heat removal)(Safety dep. For bleed OK)(safety injection for feed fails)	6.48×10^{-14}
ESBO-06	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal intact)(success of recovery offsite power within 8 hours) (success of mobile GTG for ac power recovery)(failure to maintain secondary heat removal)(Safety dep. For bleed fails)	1.03×10^{-10}
ESBO-11	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal intact)(failure of recovery offsite power within 8 hours)(failure to maintain secondary heat removal)(Safety dep. For bleed fails)	1.49×10^{-13}
ESBO-12	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal intact)(failure of recovery offsite power within 8 hours)(failure of mobile GTG for ac power recovery)	3.72×10^{-8}
ESBO-25	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(failure of RCP Seal)(failure of recovery offsite power within 8 hours)(failure of mobile GTG for ac power recovery)	9.29×10^{-11}
ESBO-26	(SBO)(failure of AAC)(failure to delivery of feedwater using turbine driven pumps)	6.93×10^{-7}
Total		**7.30×10^{-7}**

Table : CDF Contribution using small mobile GTG

Sequence Number	Sequence	CDF Contribution (events/year)
ESBO-06	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal intact)(failure of recovery offsite power within 8 hours)(failure of mobile GTG for dc power recovery)	7.00×10^{-9}
ESBO-09	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal leakage)(success of recovery offsite power within 8 hours)(failure of primary injection of RCS inventory by primary FLEX pump)	7.52×10^{-9}
ESBO-12	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal leakage)(failure of recovery offsite power within 8 hours)(success of mobile GTG for dc power recovery)(failure of primary injection of RCS inventory by primary FLEX pump)	1.11×10^{-11}
ESBO-13	(SBO)(failure of AAC)(successful delivery of feedwater using turbine driven pumps)(RCP Seal leakage)(failure of recovery offsite power within 8 hours)(failure of mobile GTG for dc power recovery)	1.74×10^{-11}
ESBO-14	(SBO)(failure of AAC)(failure of delivery of feedwater using turbine driven pumps	6.93×10^{-7}
Total		**7.08×10^{-7}**

- Based on these comparative study results, the CDF of an extended SBO with a small mobile GTG, 7.08×10^{-7}/year is almost same as the CDF of an extended SBO with a large mobile GTG, 7.30×10^{-7}/year .
- The frequency sequences of ESBO-12 of large GTG is 5 times higher than frequency sequences of ESBO-06 of small GTG.

Discussions

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- Accident Sequence
- Human Reliability Analysis
- Comparison
- Discussion
- Conclusion

- At the present time, there are deficient data and procedures of FLEX that may affect the HEP calculation.
- **Due to lack of information as well as experience on FLEX equipment, only** step 11-a for large GTG is considered differently from small GTG case. It makes small difference between HEPs as well as CDFs. **It could not be realistic to suggest now which portable GTG is more useful.**
- **However, the error probabilities of step 9 to 13 for large GTG and small GTG would be different because the difficulties of deployment and operation of mobile GTGs are not same.**
- It is obligatory to develop precise procedures if we want to get more accurate HEP results.

Conclusion

- Even though there is no PRA, the decrease of CDF when FLEX strategy is implemented should be obvious.
- Because of lack of information of FLEX strategy, currently, it is not effective to perform PRA of NPP with FLEX strategy, for showing how much decrease of CDF could be achieved after FLEX strategy implementation.
- To develop optimized FLEX strategy implementation, such as optimization the use of portable equipment under beyond design basis accidents, the detailed information and experiences related to FLEX strategy are required.
- On the other side, there may also require to address any inadvertent consequences due to the implementation of FLEX equipment like impact to the existing plant design bases, physical & cyber security, etc.

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