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Sensitivity Analysis via Modelling FLEX/MACST Equipment into a PSA Model

Young A Suh, Jaewhan Kim *, Mee-Jeong Hwang
Risk and Reliability Assessment Research Team, Korea Atomic Energy Research Institute, 111 Daedeok-daero 989, Yuseong-gu, Daejeon, Republic of Korea, 34057
Corresponding author e-mail: jhkim4@kaeri.re.kr

1. Introduction

Implementing diverse and flexible mitigation strategies (FLEX/MACST) for coping with Beyond-Design-Basis External Events (BDBEE) is one of the post-Fukushima actions. The FLEX/MACST equipment is combined into an NPP risk model to confirm its effectiveness [1].
However, standardized modeling practice and data associated with FLEX/MACST strategies and equipment have not been established yet in current probabilistic safety assessment (PSA) approaches. Thus, the objective of this study is to reflect FLEX/MACST equipment into a PSA model on a sensitivity analysis aspect.

2. Considerations for modeling FLEX/MACST equipment

According to the EPRI [2], US NRC [3], INL reports [4-5], the challenges for adequate PSA methodology reflecting FLEX/MACST equipment are 1) data analysis of portable equipment and 2) human reliability analysis (HRA) of actions associated with portable equipment. Therefore, this paper applied the arbitrary data (component failure rate, human error probability) into the PSA model.

The station blackout (SBO) and total loss of component cooling water (TLOCCW) are selected as target scenarios because FLEX/MACST strategies have developed for crediting the case of extended loss of AC power (ELAP) and loss of ultimate heat sink (LUHS). Currently, SBO events are modeled in internal events, but most of the causes of loss of offsite power (LOOP) and SBO events are external events (e.g., typhoons). Therefore, although considered in the internal event tree (ET), the effects of external hazards, such as weather, should be reflected in the transport, deployment, and installation of the MACST equipment. The MACST equipment consists of portable pumps and portable generators. The human error probability and component failure of the MACST equipment consider weather impact.

2.1. Portable generators

Thankfully, according to the recent MACST operation strategy in Korea, portable generators will adopt a pre-deployment or pre-installing cable method, so only carrying out cable connection work if necessary. In this case, we can assume that external events and weather conditions are not significantly affected by the component failure and HRA.

The generator's component failure's default value was assumed as 0.1, which was used in the existing FLEX model [5]. Based on the available time for implementing FLEX/MACST strategies, the default human error probabilities (HEP) were assigned as 0.01 and 0.001 in the case of 1 hour and 9 hours available time.

A portable generator can be modeled in AAC-24HR (AAC), but HRA available time varies case by case, so it is modeled on individual accident sequences.

Depending on the ELAP declaration rule in emergency operating procedures (EOP), the event of ‘recovery AC power’ can be creditable if the ELAP declaration is made early in the event or no creditable if done after 1 hour.

Besides, dependencies between the act of 'AAC’ and the act of portable generator connection' should be considered, and these two actions considered complete dependency (CD).

Fig.1 shows the example of a fault tree for the MACST generator. We only considered the component failure and human error probability. In order to modeling in detail, the basic events of the generator fails to run, common cause failure (CCF), fails to start, fails to load, and run must be all considered as depicted in Fig.2. However, it is not easy to get the portable generator's failure data, so we simplified the fault tree to minimize inaccurate data impact.

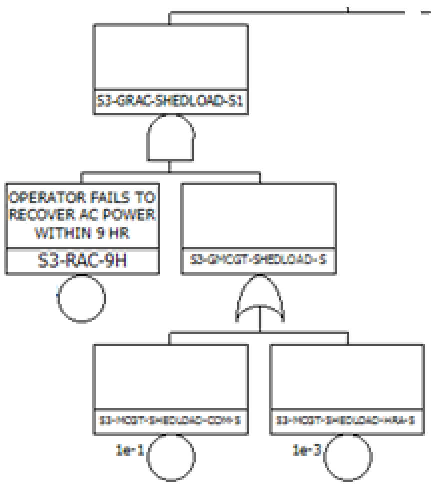

Fig.1. The example of a fault tree for MACST generator

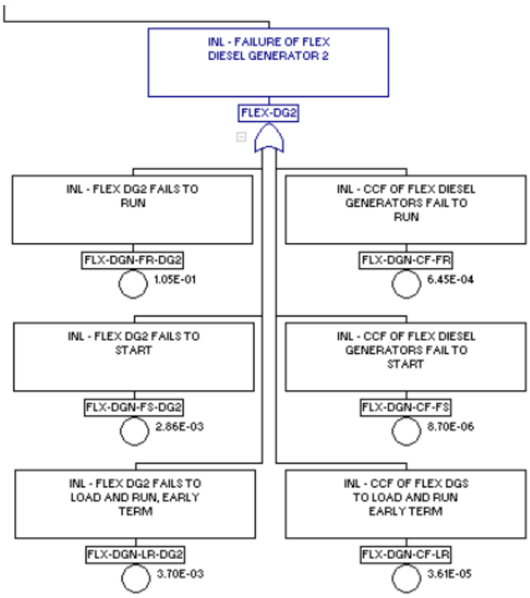

Fig.2. The example of a fault tree for FLEX generator from NEI 16-06 [1]

2.2. Portable pumps

This paper assumed all SG water loss situations when modeling TLOCCW and SBO accident sequences. Unlike the generator, a portable pump requires transport, connection, and starting and operation actions, so the pump requires sufficient time available with more than 4 hours of available time (assumption). The portable pump was credited during turbine-driven pump (TDP)/ motor-driven pump (MDP) Fail to Run (FTR) events and MSHR (Long-term Water Source Replacement), but no credit for TDP/MDP Fail to Start (FTS) Events.

In addition, the implementation of MACST pump strategies may be sensitive to external events and weather effects. Thus, the component reliability and human reliability values can be applied 0.1, 0.5, and 1.0 according to external events/weather strength ranges.

- 0.1: Area expected to show confidence within the normal range
- 0.5: Area where the probability of success is expected to be moderate
- 1.0: Unable to guarantee (human and component) reliability if a certain value is exceeded

3. Sensitivity Analysis

Fig.3 showed the core damage frequency (CDF) results when reflecting MACST equipment depending on TLOCCW and SBO scenarios. In the case of TLOCCW, the CDF decreased by 74% when implementing MACST strategies in normal weather conditions. However, when the weather condition is terrible, the CDF only decreased by 1%. In the case of SBO, regardless of weather conditions, the CDF decreased by almost 98%. Thus, portable MACST equipment can significantly impact the baseline risk profile at the plant.

Fig.3. CDF changes with MACST strategies

4. Conclusion

This paper aims to verify FLEX/MACST strategies' effectiveness with modeling the portable equipment into an existing PSA model. This study revealed that the MACST equipment could reduce plants' CDF values to satisfy the plants' safety goals.

Unanswered issues remained, such as lack of data for portable hardware reliability and lack of human error probabilities for key operator actions needed to use portable MACST equipment. These problems will be solved in future studies.

ACKNOWLEDGEMENT

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REFERENCES

[1] NRC, Assessment of the Nuclear Energy Institute 16-06, "Crediting Mitigating Strategies in Risk-Informed Decision Making," Guidance for Risk-Informed Changes to Plants Licensing Basis, Washington DC, 2017.
[2] EPRI, Human Reliability Analysis (HRA) for Diverse and Flexible Mitigation Strategies (FLEX) and Use of Portable Equipment, 3002013018, 2018.
[3] US NRC, RIC 2019, 2020
[4] Z. MA et al., “Plant-Level Scenario-Based Risk Analysis for Enhanced Resilient Plant? ATF, FLEX, and Passive Cooling,” INL/EXT-19-53556, Idaho National Laboratory, 2019.
[5] Yadav, Vaibhav, & Biersdorf, John M. Utilizing FLEX Equipment for O&M Cost Reduction in Nuclear Power Plants. INL/EXT-19-55445, Idaho National Laboratory, 2019.