Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2015

Development of an Evaluation Methodology for Loss of Large Area induced from extreme events

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1. Introduction

After September 11 event in 2001 and Fukushima nuclear disaster in 2011, the landscape of nuclear safety paradigm has been changed drastically. Before September 11 event, malevolent man-made hazards have rarely taken into consideration for safety design of nuclear installations. And Fukushima catastrophic disaster gave us a wakeup call for re-consideration of robustness of current accident management framework against the event of loss of large area induced from beyond design basis extreme external events (BDBEEE). USNRC announced several regulatory requirements and guidance documents regarding the event of loss of large area including 10CFR 50.54(hh)[1], Regulatory Guide 1.214[2] and SRP 19.4[3]. In Korea, consideration of loss of large area has been limitedly taken into account for newly constructing NPPs as voluntary based. In general, it is hardly possible to find available information on methodology and key assumptions for the assessment of LOLA due to "need to know based approach". Urgent needs exists for developing country specific regulatory requirements, guidance and evaluation methodology by themselves with the consideration of their own geographical and nuclear safety and security environments. Currently, Korea Hydro and Nuclear Power Company (KHNP) has developed an Extended Damage Mitigation Guideline (EDMG) for APR1400 under contract with foreign consulting company. However, accident management during the event of loss of large area at multi-unit site requires cross-cutting and interdisciplinary coordination and cooperating among in-house organizations or inter-organizations. The submittal guidance NEI 06-12[4] related to B.5.b Phase 2&3 focused on unit-wise mitigation strategy instead of site level mitigation or response strategy. Phase 1 mitigating strategy and guideline for LOLA (Loss of Large Area) provides emphasis on site level arrangement including cooperative networking outside organizations and agile command and control system. Korea Institute of Nuclear Safety has carried out a pilot in-house research project to develop the methodology and guideline for evaluation of LOLA since 2014. This paper introduces the summary of major results and outcomes of the aforementioned research project [5].

2. Methodology

The main purposes of LOLA evaluation are to delineate potential mitigation measures through identifying vulnerability and anticipated offsite consequences leading from the chosen hazards or threats. Figure 1 provides an outlook of LOLA assessment, methodology.

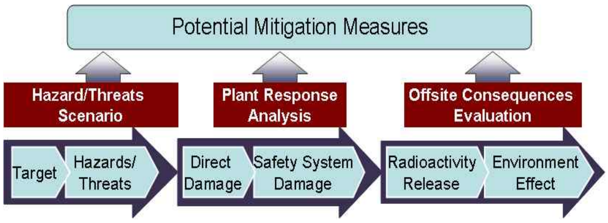

Fig. 1. The framework of LOLA assessment

In case of LOLA events induced from fire and explosion malicious origin, most of countries have dealt the selection of target scenarios and major analysis assumptions as "need to know" basis or safeguard information approach. The detailed information on the aforementioned should be dealt as sensitive information in terms of nuclear security due to the possibility of misuse to identify vulnerability of being targeted facilities for malicious acts such as radiological sabotage.

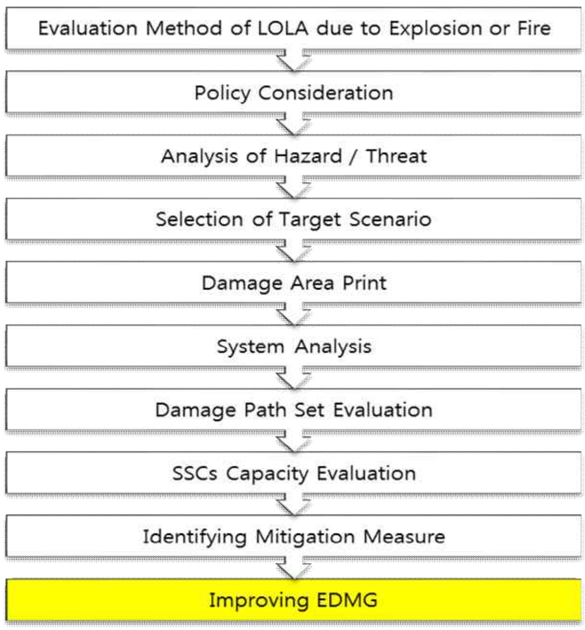

Fig. 2. A methodology for LOLA Assessment

Figure 2 provides an evaluation methodology for the event of LOLA induced from explosion or fire with malicious origin. The approach of need-to-know requires policy consideration step to select the target scenarios and assumptions for the analysis reflecting following aspects:

- Type and size of aircraft being crashed
- Hitting point and angle
- Terminal velocity to crash
- Amount of residual fuel

Target scenarios and analysis assumptions affect significantly to characterize the scope of analysis and potential mitigation strategies and measures.

The characterization of target scenarios and major assumptions based on the policy consideration is followed by specifying damage area print as shown in Figure 2. Damage area footprint provides visualization of damaged area and list of affected rooms and structures, system and components (SSCs). Figure 3 gives an example of visualization of affected area. Magnitude of damage area varies with hitting point and size of fireball generated by fire and explosion. The size of fireball specifies the number of SSCs to be considered for the assessment. Identification of damage area can be made by computational fluid dynamics, fire analysis and empirical correlation of damage functions considering following aspects:

- Fireball overpressure
- Cable fragility
- Fire propagation effect
- Available firefighting assets
- Fire-induced failure of SSCs
- Burning liquid fuel spread in multi-level structures

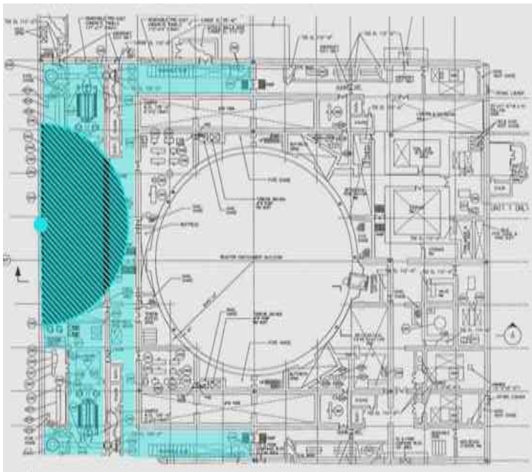

Fig. 3. Example of damage footprint

We can utilize various mechanistic models as a function of amount of fuel and duration time of fireball for calculate maximum diameter of fireball [6][7].

Identified damage area footprint and list of affected SSCs make possible to specify the path sets to core damage using PSA (Probabilistic Safety Assessment) models and existing PSA result. For the conservative approach, an assumption that entire SSCs included in fireball diameter are fail can be made. Through the site walk-down and detailed evaluation of survivability of SSCs, unnecessarily pessimistic sequences of events or SSCs can be screened out from the list of target analysis. Based on finalized path sets to core damage and listed SSCs, consequence analysis should be made by utilization of existing severe accident analysis codes such as MELCOR or MAAP.

However, when we utilize existing PSA and severe accident analysis results, careful attention should be given due to the possible ailien machnism of containment failure, which is screened out existing PSA framework .

Final outcomes of LOLA evaluation is to identify candidate strategies for EDMG (Extended Damage Mitigation Guides). Through this pilot reserch, we posposed a draft EDMG guideline for domestic nuclear power plants with emphasis on following aspects at the strategical point of view:

- Fire fighting response strategy
- Response strategies for mitigating core damage
- Response strategies for mitigating fuel damage at spent fuel pool

3. Conclusions and remarks

After Fukushima Dai-Ichi accident, the awareness on countering the event of loss of large area induced from extreme man-made hazards or extreme beyond design basis external event. Urgent need exists to develop regulatory guidance for coping with this undesirable situation, which has been out of consideration at existing nuclear safety regulatory framework due to the expectation of rare possibility of occurrence. This paper proposed a methodology and consideration to be given for evaluating the event of loss of large area at nuclear power plant in regard with preparing extended damage mitigation guide (EDMG). The refining of the proposed methodology and its demonstration of the feasibility will be continued through consecutive research work.

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