# Frequency Estimate of Accident Scenario to Support Selection of Design Extension Condition Scenario for OPR1000

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## 1. Introduction

The requirement for safety in nuclear power plant (NPP) is being strengthened in the world since the Chernobyl accident. The target for the nuclear safety is to minimize radioactive releases. The Fukushima accident accelerates this trend for safety in nuclear power plant.

IAEA INSAG-12 [1] states "even those of very low probability, radiological consequences, if any, would be minor; and to ensure that the likelihood of severe accidents with serious radiological consequences is extremely small" and "consideration of multiple failures and severe accidents will be achieved in a more systematic and complete way from the design stage" for NPPs.

IAEA SSR-2/1 [2] states "the design shall be such that design extension conditions that could lead to significant radioactive releases are practically eliminated." It introduced the concept of design extension condition (DEC) so that the nuclear power plant should be designed safe enough against design extension conditions more severe than design basis accident (DBA).

WENRA (Western European Nuclear Regulators Association) [3] evolves the philosophy of IAEA and provides the requirements in more detail. WENRA's requirements are applied to existing reactors as well as new reactors. It can be summarized as follows:

- Enhance the safety to minimize radioactive releases
- Verify that a NPP is safe against DEC, which are not considered in DBA
- Derive representative DEC scenarios, based on a combination of deterministic and probabilistic assessments as well as engineering judgement

The DEC concept is introduced to improve the safety of NPPs as far as reasonably practicable.

WENRA provides a list of events to be considered in DEC A class; such as prolonged station blackout, loss of ultimate heat sink, anticipated transients without scram, total loss of feed water, LOCA with the complete loss of one emergency core cooling function, and so on.

The use of the PSA is required to check if there is additional DEC scenario.

This study is performed to provide insight for selection of DEC scenarios by evaluating the frequency of accident scenarios for OPR1000 nuclear power plant.

This study is limited to accident scenarios regarding to the core damage due to internal events during full power operation. We do not consider accident scenario related to release of radioactive materials, external events, shutdown operation and spent fuel pool, which will be analyzed in future.

## 2. Evaluation of Accident Scenario Frequency

WENRA [3] considers two categories of DEC: one is DEC A for which prevention of severe fuel damage in the core or in the spent fuel storage can be achieved, and the other is DEC B with postulated severe fuel damage. The selection process for DEC A starts by considering all relevant events and combinations of events otherwise a scenario is excluded with a high degree of confidence to be extremely unlikely to occur. STUK [4] considers three categories of DEC. It considers scenario by combining DBA and a system failure (DEC A), combination of failures identified as significant in PSAs (DEC B) and rare external event (DEC C).

Basically, DEC scenario should consider all possible combination of initiating event and system failures. Thus, selection of DEC scenario requires reviewing PSA insights and combining DBA scenario and failure of safety systems.

In this study, we evaluated the frequency of accident scenario as follows:

- scenario given in PSA and
- combination of initiating event and failure of systems

OPR1000 full power internal PSA model is used for this analysis. The base calculation is done using the data and assumption used in the PSA. Sensitivity calculation is done using conservative assumptions if a scenario includes a non-safety system, an operator action not describe in emergency operating procedures, or a key assumption.

The frequencies estimated for example scenarios are shown in Table 1.

Table 1. Frequency estimate for accident scenarios

| Scenario | Frequency | Remark |
|---|---|---|
| Large LOCA | >1e-6(1) | |
| Medium LOCA | >1e-4 | |
| +(2) HP SIS | >1e-7 | CD(3) |
| + CS recirculation | >1e-7 | CD |
| Small LOCA | >1e-4 | |
| + AFWS | >1e-9 | |
| + HP SIS | >1e-7 | CD |
| + CS recirculation | >1e-7 | CD |
| SGTR | >1e-3 | |
| + HP SIS | >1e-6 | |
| + AFWS | >1e-6 | |
| + SG isolation | >1e-3 | |
| + HP SIS, LP SIS | >1e-7 | CD |
| + RCS pressure control, RWST refill | >1e-8 | CD |
| Interfacing systems LOCA | >1e-8 | CD |
| General transients | >1e-1 | |
| + MFW, AFWS, Feed & Bleed | >1e-8 | CD |
| Loss of main feed water | >1e-2 | |
| + AFWS | >1e-7 | |
| + AFWS, Feed & Bleed | >1e-9 | CD |
| Loss of condenser vacuum | >1e-2 | |
| + AFWS | >1e-7 | |
| + AFWS, Feed & Bleed | >1e-8 | CD |
| Loss of total CCW/ESW | >1e-4 | |
| + AFWS (TDP) | >1e-7 | CD |
| + RCP seal failure | >1e-8 | CD |
| + RCP seal failure assumed | | PCD(4) |
| + Portable equipment is not credited | | PCD |
| Loss of a 125V DC bus | >1e-3 | |
| + AFWS | >1e-7 | |
| + AFWS, Feed & Bleed | >1e-7 | CD |
| + failure of another 125V DC bus assumed | | PCD |
| Loss of a 4.16KV bus | >1e-3 | |
| + MFW, AFWS, Feed & Bleed | >1e-8 | CD |
| + RCP seal failure, HP SIS | >1e-8 | CD |
| Station blackout | >1e-5 | |
| + AAC | >1e-6 | |
| + AAC, offsite power | >1e-7 | CD |
| ATWS | >1e-6 | |
| + unfavorable moderator temperature coefficient | >1e-8 | CD |
| + CVCS | >1e-8 | CD |

1) frequency per year. ">1e-6" represents the frequency is between 1e-6 and 1e-5/yr.
2) + means additional failure to an initiating event
3) CD : Core damage scenario
4) PCD : Core damage scenarios with conservative assumption

We can get the following insights from the result of frequency evaluation for accident scenarios:

- In most cases, the frequency of an accident scenario is evaluated below 1e-6/yr if the scenario consists of an initiating event and a system failure.
- There are several core damage scenarios whose frequency are larger than 1e-8/yr.
- A large break loss of coolant accident is classified as DBA in a safety analysis report. It can be considered as DEC from the viewpoint of frequency.
- The frequency for total loss of CCW/ESW (component cooling water/essential service water) is above 1e-4/yr. It is reasonable to be considered as DBA. There are two problems in case of total loss of CCW/ESW. One is that an operator action using portable equipment is required to protect ESF switchgear and inverter from the loss of room cooling. The other is a possibility of RCP seal leak which results in loss of coolant accident. If anyone occurs, it may result in core damage.
- The frequency for loss of a 125V DC bus is above 1e-3/yr. It is reasonable to be considered as DBA. If a remaining train of 125V DC bus is assumed to fail, which is the typical assumption made in single failure criterion, it may result in core damage.
- The frequencies of station blackout or anticipated transients without scram are above 1e-6/yr, which may be considered in DEC.

## 3. Conclusions

PSA should be used to support the selection of DEC scenario. In this study, the frequency is evaluated for various scenarios which can occur due to internal events.

The results for OPR1000 show that there are a few additional scenarios which should be added to the DEC list given in WENRA [3]. Total loss of CCW/ESW and loss of a DC bus are corresponding to DBA events from the viewpoint of frequency. Those events could result in core damage if a system failure is assumed or a conservative assumption is made. These events should be carefully considered in DEC analysis.

The introduction of DEC concept is to prevent core melt or large release by improving safety of nuclear power plants against possible core damage scenarios. It is difficult to determine how low enough is in core damage frequency. The frequency evaluation for various scenarios can give insights when to select DEC scenarios.

In future study, level-2 PSA or external event PSA will be also reviewed to support the selection of DEC scenarios.

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**REFERENCES**

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