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Probabilistic Safety Assessment (PSA)-based Seismic Margin Assessment (SMA) for JRTR

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1. Introduction

The purpose of the Probabilistic Safety Assessment (PSA)-based Seismic Margin Assessment (SMA) is to identify potential vulnerabilities and to demonstrate that the seismic margin is greater than 1.67 times the design basis safe shutdown earthquake (SSE). The PSA-based SMA shall be conducted in accordance with Korea Institute of Nuclear Safety (KINS) - Regulatory Guide (RG) No. 4.29 [1] and the recommendation of SECY-93-087 [2] approved by NRC for a seismic risk evaluation.

The operating basis earthquake (OBE), 0.1g for the Jordan Research and Training Reactor (JRTR) is defined as one-thirds (1/3) of the SSE, 0.3g. If the High Confidence of Low Probability of Failure (HCLPF) value from PSA-based SMA is greater than 1.67 times the design basis SSE, the OBE can be eliminated in the seismic analysis and the design of JRTR.

This paper describes the work and the results of the PSA-based SMA for the JRTR that is operating by Jordan Atomic Energy Commission (JAEC).

2. Seismic Equipment Selection

The seismic equipment list (SEL) provides a documented list of the plant structures, systems, and components (SSCs) that could be used for reacting to an earthquake or mitigating potential reactor plant damage initiated by a seismic event. The SEL is identified from the internal events PSA model [3]. Also, passive components such as piping and structures related to a safety function, which are not addressed in the internal events PSA model, are included in the seismic equipment list.

For the SMA, the initial list of equipment is identified firstly based on the internal events PSA and further by reviewing the system P&IDs and electrical diagrams to provide reasonable assurance that all necessary components are on the SEL.

3. Seismic Capability Walkdown

The seismic capability walkdown was conducted for the JRTR safety-related structures and components in accordance with the walkdown procedures described in the EPRI NP-6041 [4]. The screening of elements is not conducted for the SMA of the JRTR since the HCLPF values of the all structures and components are required to be evaluated.

4. Seismic Fragility Analysis

The Reference Earthquake (RE) for PSA-based SMA is selected as the NUREG/CR-0098 median response spectrum [5] anchored to 0.3g. The comparison of the JRTR Design Ground Response Spectrum (DGRS) and RE response spectrum is shown in Fig. 1.

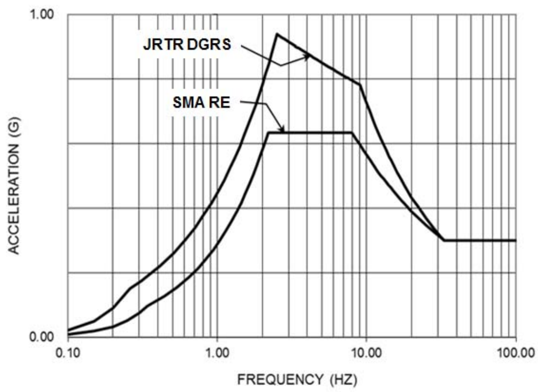

Fig. 1. JRTR DGRS and SMA RE Response Spectrum (Anchored to 0.3g, 5% Damping).

The seismic fragilities are evaluated for the structures, systems and components (SSCs) developed from the SEL. A fragility analysis is performed to obtain the seismic margin of SSCs that could have an effect on safe shutdown of the plant following a seismic event. In this analysis, the seismic margin values of SSCs modeled in the accident sequences are obtained.

5. Seismic Accident Sequence Analysis

5.1 Identification of Initiating Events

Seismically-induced initiating events are identified from the internal events PSA. However, there are differences between seismic events and internal events in order to identify the initiating event because seismic events may damage structures and passive components that are not explicitly modeled in the internal events PSA. A series of event trees is developed to model accident sequences. Modeling all accident sequences begins with the hierarchy event tree as shown in Fig. 2.

Then the event trees are entered by a transfer from sequences on this hierarchy event tree. Each top event of the hierarchy event tree is described in the followings.

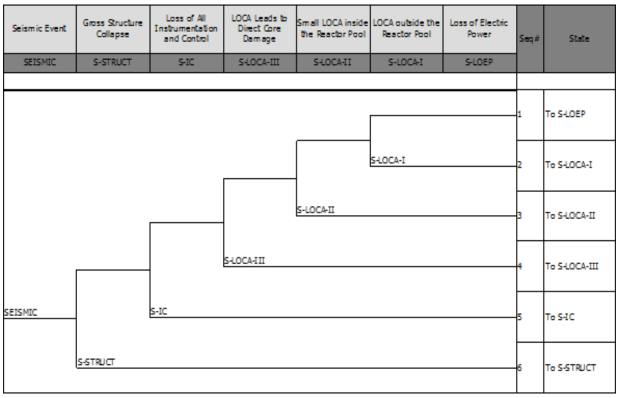

Fig. 2. Seismic Initiating Event Hierarchy Tree

This top event, S-STRUCT represents failure of the reactor or the service building. S-IC represents failure of RPS cabinets or all 120V DC/AC power sources. S-LOCA-III (large LOCA inside the pool and LOCA by beam tube rupture), S-LOCA-II (small LOCA inside the reactor pool), S-LOCA-I (LOCA outside the reactor pool), S-LOEP(loss of normal electric power), etc.

5.2 Seismic Event Tree and Seismic Capacity Evaluation

The PSA-based SMA does not consider seismic hazard curves. Therefore, initiating event frequencies are not calculated for each seismically induced initiating event. Although seismically generated initiating event frequencies are not calculated, it is important to evaluate the seismic vulnerability of the components and systems that contribute to the initiating event categories. This is done by estimating a HCLPF for each seismic initiating event category. For this, the seismic event trees for each category have been developed to represent the accident progression and equipment failures that can be expected following a seismic event. Seismic capacity for accident sequences was evaluated.

The success paths used for the SMA were taken conservatively in many cases. All SMA sequences were evaluated with the loss of offsite power and with no credit for operator action. So, the results were valid without operator intervention. The plant design was shown to be robust against seismic event sequences. The JRTR design provided some aspects that make the plant more robust against the reference earthquakes.

Namely, pressure boundary components are sufficiently rugged, therefore pool water inventory can be maintained for cooling of the core in case of a seismic event. Flap valves and the siphon break valves can be opened and enable the natural cooling of the core in case of a seismic event.

6. Conclusions

The PSA-based SMA was conducted for the JRTR in accordance with EPRI NP-6041. As a result, it quantitatively revealed the most vulnerable structures, systems and components (SSCs), and probable accident scenario extended to the direct core damage under a seismic event. Also, it demonstrated that the HCLPF magnitudes of SSCs required for safe shutdown and the accident scenarios leading to the core damage were greater than 0.5g as shown in Table 1. This indicated that the seismic margin of the JRTR was greater than 1.67 times the design basis SSE. Consequently, the JRTR plant could meet or exceed the requirement to withstand a reference earthquake of 0.3g, and an explicit seismic analysis or design for the SSCs subjected to OBE load was not needed in terms of KINS-RG No.4.29.

Table 1: Sequence-Level HCLPF Values

Seismic Induced Initiating Event	Sequence	Sequence-Level HCLPF Values
S-STRUCT	Direct Core Damage	0.66g
S-IC	Direct Core Damage	0.71g
S-LOCA-III	Direct Core Damage	0.96g
S-LOCA-II	S-LOCA-II (0.96g) & Flap Valve Failure (2.81g) & Siphon Valve Failure (1.11g)	2.81g
	S-LOCA-II (0.96g) & Reactor Trip Failure (0.70g)	0.96g
S-LOCA-I	S-LOCA-I (0.61g) & Pool Isolation Failure by Siphon Valve (1.11g)	1.11g
	S-LOCA-I (0.61g) & Flap Valve Failure (2.81g)	2.81g
	S-LOCA-I (0.61g) & Reactor Trip Failure (0.70g)	0.70g
S-LOEP	S-LOEP (<0.5g) & Flap Valve Failure (2.81g) & Siphon Valve Failure (1.11g)	2.81g
	S-LOEP (<0.5g) & Reactor Trip Failure (0.70g)	0.70g

REFERENCES

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