HCLPF Assessment of an OPR 1000 Nuclear Power Plant for a High Wind-Induced Loss of Offsite Power Event

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1. Introduction

Climate change is projected to increase the intensity of high winds [1]. High winds can damage the structures, systems, and components (SSCs) of a nuclear power plant and thereby affect plant safety [2]. Damage to the SSCs of the offsite power system has been reported in a number of cases [3], and such damage can lead to a loss of offsite power (LOOP) and subsequently to a station blackout (SBO).

The IAEA requires that the safety margin be confirmed for external hazards exceeding the design basis [4]. Confirming the safety margin requires a quantitative evaluation of the safety capacity of the plant, which can be expressed as the high confidence of low probability of failure (HCLPF), the load at which the core damage frequency (CDF) reaches 1% [4]. In this study, the HCLPF for a high wind-induced LOOP was derived using the accident scenario model of an OPR 1000 nuclear power plant.

2. HCLPF Assessment for Wind-Induced Loss of Offsite Power

To assess the HCLPF for a wind-induced LOOP, the SSCs susceptible to high winds were first selected and their wind fragilities were derived. An Accident scenario model for high winds was then constructed, and the CDF was quantified as a function of wind speed to determine the HCLPF for the LOOP event.

2.1. Wind Fragility of SSCs

High winds can affect a nuclear power plant through the collapse or failure of SSCs caused by wind pressure, and through the penetration, perforation, and spalling of SSCs caused by missile impact. Accordingly, the SSCs susceptible to wind pressure and missile impact were selected, and their fragilities were derived for each load. The fragilities were derived following the method presented in the EPRI high wind risk assessment guidelines [5]. Fig. 1 shows an example of the missile impact fragility derived for the condensate storage tank (CST). Perforation of the CST shell by a missile can cause the stored water to leak, thereby affecting the supply of cooling water required for accident mitigation.

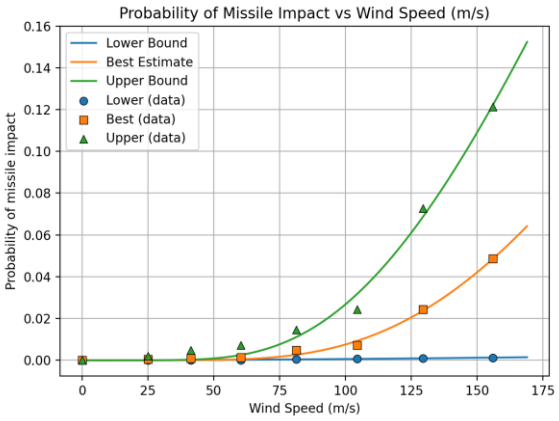

Fig. 1. Missile impact fragility curve of the CST

2.2. Accident Sequence Model for High Winds

An accident sequence model for high winds was constructed based on the internal event scenario model of the OPR 1000. The damage of the SSCs caused by high winds was introduced as basic events, while the logic and the basic event probabilities of the existing model were left unchanged. Fig. 2 shows an example of a fault tree in which the wind-induced damage basic events have been added.

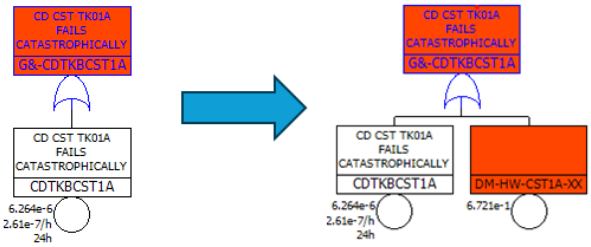

Fig. 2. Fault tree with wind-induced damage basic events

2.3. Derivation of the HCLPF for the LOOP Event

The frequency at which a high wind-induced LOOP leads to core damage was quantified as a function of wind speed. The quantification was performed using

Monte Carlo simulation. The wind speed at which the resulting CDF (Core Damage Frequency) reaches 1% was determined as the HCLPF for the LOOP event. The CDF and the HCLPF as functions of wind speed are presented in Fig. 3.

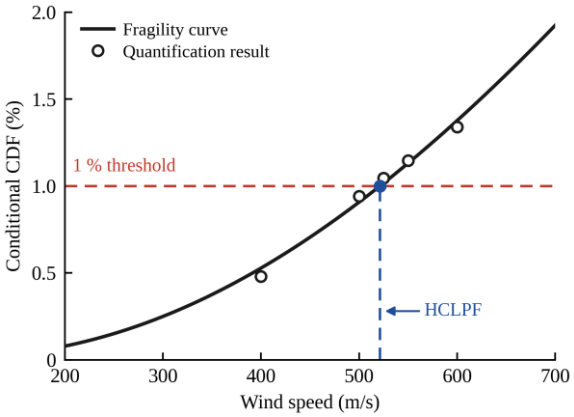

Fig. 3. Fragility Curve and HCLPF for the wind-induced LOOP

3. Conclusions

The HCLPF for a high wind-induced LOOP was derived using an accident scenario model. The fragilities of the SSCs susceptible to high winds were derived from wind pressure and missile impact, and an accident sequence model for high winds was constructed. The CDF was then quantified as a function of wind speed, and the wind speed at which the CDF reaches 1% was determined as the HCLPF. The results of this study can be used to evaluate the safety capacity and the safety margin of a nuclear power plant against high winds and can be extended to other external hazards by changing the input load.

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