# Evaluating the uncertainty bound of the multiple scenario CDF by the distribution sampling of the basic events.

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**Abstract:** Probabilistic Risk Assessment (PRA) developed in order to investigate the factors that cause threat to nuclear power plants and improve the safety of nuclear power plants. (eg seismic, flooding, multiple components failure, human error). As a result, in addition to the Core Damage Frequency (CDF) obtained by probabilistic analysis, the main reason leading to the core meltdown and their importance can also be known. In some possible hazards (such as floods, fires, etc.), multiple scenarios may be used to develop and analyze the safety assessment of the nuclear power plant, and then the CDFs calculated from multiple scenarios will be summed up as the CDF of the power plant in these scenarios. However, this value is only a point estimate with unknowing uncertainty bound. In order to obtain more statistically significant analysis results, this paper uses the method of randomly sampling basic event values to quantify multi-scenario events, in order to obtain the CDF with statistically significant information.

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## 1. INTRODUCTION

As the ASME internal flood standard has updated various technical requirements, High Level Requirement (HLR) and Supporting Requirement (SR), the internal flood PRA analysis technology and data need to be compared with the ASME internal flood PRA analysis requirements. Basing on with the rich experience in the past, a set of fast, effective and feasible PRA analysis methods for internal flood disasters can be developed from simple to depth and can refer to the results of PRA analysis of internal fires. And further according to the PRA analysis method of the flood disaster in the plant, update the basic model of the PRA for the flood event of the nuclear power plant. The scope of internal flood analysis is to solve the CDF and LERF of internal flood events.
According to the division of the waterproof area and the flood source, the frequency of flood initiation events under various scenarios is identified, and the CDF of all the waterproof areas is added up to obtain the CDF of the entire plant. Due to the limited software, the uncertainty interval was not considered in the calculation of this CDF in the past, it is only an estimated value, so it is impossible to have statistical analysis and insight. This paper uses random sampling method to simulate and calculate a large number of CDF values of the whole plant, and generates a statistically significant uncertainty interval according to its distribution.

## 2. Waterproof Area division

The division of the waterproof zone in the PRA analysis of the flood disaster in the plant is explained as follows:
(1) The division of the waterproof zone and its flood database:
According to the division of each fire zone of a nuclear power plant as the division of its waterproof zone, in order to fully grasp the information of the waterproof zone, the naming principle of the original fire zone/fire zone is also adopted. Confirm the type (including a large amount of liquid (such as oil) or water vapor) and quantity (the length of the pipeline or the number of expansion joints) and the SSC (also known as the target SSC) that may be damaged by the flood in the waterproof area through on-site investigation.), possible flood spread routes, flood protection measures and related information, and establish a flood disaster database for waterproof areas.
(2) Characteristics of waterproof zone:

From the aforementioned flood disaster database, further establish the flood characteristics of each waterproof zone, such as possible local flood phenomena, and the type and frequency of flood initiating events; flood diffusion phenomena caused by possible diffusion routes, and flood initiating events Type and frequency; flood protection measures, etc., to reduce the frequency of flood initiation, the frequency of flood spread, and the sequence consequences of flood accidents, etc., as a flood analysis at each stage (preliminary screening, qualitative screening, quantitative screening, or detailed quantitative analysis) basis.

(3) Confirmation of water sources for floods in the factory:

Corresponding to the general data (Generic Data) of various flood events, confirm the possible flood water sources of nuclear power plants and their types of flood disasters (spraying, flooding), and then inundation is divided into general floods and major floods according to the flood flow. The flood flow rate of spraying is defined as < 100 gpm, the flood flow rate of general flood disaster is defined as 100 gpm ~ 2,000 gpm, the flood disaster flow rate of major flood is defined as > 2,000 gpm (excluding CWS expansion joints), and the major flood disasters of CWS expansion joints It is further divided into two levels: flood flows from 2,000 gpm to 10,000 gpm, and > 10,000 gpm.

(4) Analysis of the onset frequency of unit floods for each type of flood:

Based on the established flood disaster database for the waterproof zone, and then based on the collected data on the critical time of each unit of the nuclear power plant and various flood events over the years, establish Plant Specific Data, and then combine with the general data to calculate with Bayesian analysis Flood types of possible flood sources in the waterproof zone of each nuclear power plant and the onset frequency of floods per unit.

(5) Collection of PRA analysis results of internal fires:

In order to quickly and effectively refer to the results of PRA analysis of fire in the factory, such as the division of fire zones as the division of waterproof zones, the results of qualitative screening analysis of fire zones as the reference starting point for qualitative screening analysis of waterproof zones, and their fire The types of initiating events and their Conditional Core Damage Probability (CCDP) results are used as references for the types of initiating events and their consequences corresponding to the flood analysis.

## 3. Method and Result

After the waterproof zone is divided, the quantitative method of detailed analysis is in principle based on the flood onset frequency of each phenomenon (including local and diffusion) in each waterproof zone and the magnitude of its safety impact (that is, by all the damages caused by floods). device-derived flood initiating event category), which is also known as the flood initiating event category for this flood phenomenon. The mathematical calculation formula of the furnace core melting loss frequency (CDFi) of the sub-phenomenon of local floods is shown:

CDFi = IEi × FRi × CCDPi

CDFi: Flood in Waterproof Zones CDF

IEi: Flood initiation frequency in waterproof zone

FRi: Correction factor for flood onset frequency in waterproof zone

CCDPi: The probability of melting damage of furnace core under flood conditions in waterproof zone

Therefore, the CDF of the whole plant is:

CDF=ΣCDFi

This paper firstly sorts N flood scenarios according to the size of CDF, and finds the top 5 important risk scenarios. The initiating event frequency of the flood scenario is discretized and distributed by the initiating event types corresponding to each flood scenario, thereby obtaining the discrete flood initiating event frequency under each flood scenario with statistical distribution information.

Then, the basic events related to all the components in the data bed files of the input mode are distributed and sampled, and a total of 1000 sets of input data bed files are generated. WinNUPRA is used to calculate the CCDP point estimates of 1000 groups of flood scenarios. Multiplying the frequency distribution of initiating events under individual flood scenarios by the CCDP value of one sampling of the corresponding scenario generates the CDF value distribution of the scenario, and then summing the CDF distributions of all scenarios to obtain the flood CDF distribution of the sampling. Finally, the flood CDF distribution of a total of 1000 samples is sorted, and the flood CDF with statistical distribution information can be obtained. Taking the CDF of the flood disaster in a PWR nuclear power plant as an example, the CDF calculated by using the mean value of the components when using WinNUPRA quantification is 5.42E-07/ry. Within the 54.57% confidence level of the CDF uncertainty interval calculated using random sampling as shown in table 1.

**Table 1: CDF distribution of floods in the plant**

| Confidence | frequency (1/ry) | Confidence | frequency (1/ry) |
|---|---|---|---|
| 5.00% | 4.0480E-08 | 50.00% | 4.5674E-07 |
| 10.00% | 6.1463E-08 | 55.00% | 5.4951E-07 |
| 15.00% | 8.7081E-08 | 60.00% | 6.6361E-07 |
| 20.00% | 1.1557E-07 | 65.00% | 7.9507E-07 |
| 25.00% | 1.4860E-07 | 70.00% | 9.6857E-07 |
| 30.00% | 1.9038E-07 | 75.00% | 1.2115E-06 |
| 35.00% | 2.4142E-07 | 80.00% | 1.5394E-06 |
| 40.00% | 3.0351E-07 | 85.00% | 2.0069E-06 |
| 45.00% | 3.7657E-07 | 90.00% | 2.7097E-06 |
| 50.00% | 4.5674E-07 | 95.00% | 3.9693E-06 |
| 55.00% | 5.4951E-07 | 100.00% | 2.5462E-05 |

## 4. CONCLUSION

Qualitatively, the CDF uncertainty mainly comes from the relevant assumptions set in the process of flood analysis in the plant, and is classified according to the analysis steps. It is divided into: the definition of the waterproof zone of the power plant division, the determination and characteristics of the water source of the flood, and the beginning of the flood situation. Quantification of events, flood scenarios, and flood-induced accident sequences, respectively, that these assumptions may create uncertainties about parameters, model, or analytical integrity. In order to ensure that the analysis results tend to be conservative, most of the analysis assumptions are set with a more or less conservative degree. There are only a few uncertain sources that cause the CDF/LERF of internal floods to be un-conservative. Therefore, the overall CDF/LERF of internal floods is still Conservative.

In quantitative analysis, based on the division of waterproof areas and the water sources of flood disasters, the frequency of flood initiation events in various scenarios is identified, and the CDFs of all waterproof areas are summed up as the flood disaster CDF of the entire plant. Due to the limited software, the uncertainty interval was not considered in the calculation of this CDF in the past, it is only an estimated value, so it is impossible to have statistical analysis and insight. This paper uses random sampling method to simulate and calculate a large number of CDF values of the whole plant, and generates a statistically significant uncertainty interval according to its distribution.

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