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PSA Comparison between OPR100 and VVER1200 Designs

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1. Introduction

A probabilistic safety assessment (PSA) comparison for nuclear power plants (NPP) with similar designs has brought great benefits in improving PSA quality and usefulness of regulatory reviews and assessments of NPP designs. However, a PSA comparison between differing designs has yet to be conducted. It is therefore of considerable interest to compare level 1 PSA results of the South Korean OPR1000 design (OPR1000) with the Russian VVER1200/AES-2006/V491 design (VVER1200).

OPR1000 is a pressurized water reactor (PWR), generation II, developed by Korea Hydro & Nuclear Power and the Korea Electric Power Corporation. The calculated level 1 PSA results for OPR1000 satisfies the Korean requirements for core damage frequency of less than 10^{-4} reactor/year. VVER1200 is also a PWR, but is generation III+, developed by Atomenergoproekt St. Petersburg. One of the requirements during the reactor plant and process system design elaboration was not to reach an estimated severe core damage value of 1.0×10^{-6} reactor/year. The main engineering solution for VVER1200 has been corroborated by VVER operation experience of over 1400 reactor years, including more than 500 reactor years of VVER1000 reactor plant operation. These are important data sources for conducting a PSA for the VVER1200 design. In contrast, there are no specific failure experience data when the PSA is conducted for OPR1000 Ulchin nuclear units 3 and 4. The data used in Ulchin PSA are based on generic failure rates. There are therefore many differences that may be derived from this comparison. The outcome from this comparison can allow identification of beneficial plant modifications and their effects on expected risk profiles.

The purpose of this paper is to provide a comparison of level 1 PSA results for these two designs. The objective of this comparison is to identify differences in the PSA results of OPR1000 and VVER1200 and assess the rationale for these differences.

2. Methods

This section presents a direct comparison of OPR1000 and VVER1200 PSA results. The primary objective is to identify differences and to explain the results by examining data, safety systems, and assumptions. It is made by reading two level 1 PSA documentations.

2.1 Global comparison

The first step consists of a global comparison of the internal event PSA results of OPR1000 and VVER1200 designs for power operation. Here, the task is limited to a comparison of the main contributors to core damage frequencies (CDFs).

2.2 Detailed comparison

The second step is to select the initiating events (IEs) that were the largest contributors to the total CDF in OPR1000 for a detailed comparison. The scope is therefore limited to the two initiating events: small loss of coolant accident and steam generator tube ruptures.

3. Results

3.1. Safety system design differences

A comparison of the safety systems and their functions for OPR1000 with VVER1200 that may be affected by the risk shows typical differences in:

- Presence of passive safety systems: VVER1200 has more passive systems than OPR1000, as follows:
  a. Emergency core cooling system, passive part
  b. Passive heat removal system from containment for beyond design basis accident management
  c. Passive heat removal system through steam generators for beyond design basis accident management
  d. Double-envelope containment and core catcher to retain radioactive substances and ionizing radiation within the limits envisaged in the design
- The strategy of coping with the beyond design basis accidents (BDBA): VVER1200 is based on using passive safety systems while OPR1000 is based on active systems (safety depressurization systems and high pressure safety injection systems) to cope with BDBA.

3.2. Main level 1 PSA results

The total CDFs of these two designs are different. The VVER1200 CDF result of 1.29 x 10^{-7}/year is around 10 times lower than the OPR1000 CDF of 8.25 x 10^{-6}/year. This may be due to differences in plant-specific, applied reliability data, and most important basic events between the two designs.

For the OPR1000 design, the major initiating events contributing to total CDF are small loss of coolant accident, steam generator tube rupture, and loss of feedwater. The most dominant contributors are failures of high pressure safety injection, auxiliary feedwater system, safety depressurization system, and containment spray system.

For the VVER1200 design, the dominant initiating events and system failures making a major contribution to CDF, as presented in Figures 1 and 2, respectively.

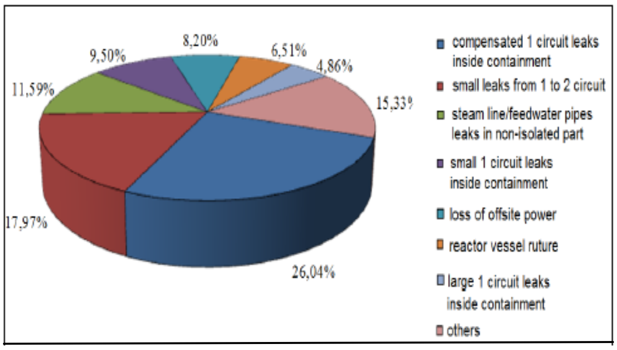

Figure 1: Major initiating events contribution at total CDF for on-power states

According to Figures 1 and 2, the largest contributors to the total CDF are compensated 1 circuit leaks inside containment, small leaks from 1 to 2 circuits, failures of emergency heat removal system (EHRS) and makeup systems of the first circuit (CWI).

The applied data used in the VVER1200 PSA is more plant-specific (based on operating experience) in comparison with the generic data used for the OPR1000 PSA. The chosen data source for examination shows that there are differences in:

- Equipment reliability data source: VVER1200 uses data on malfunctions of equipment at Novovoronezh, Kalinin and the Balakovo nuclear power plants from 1986 to 2010, while OPR1000 has no availability of failure data, which has some impact on reliability of the CDF results.
- Initiating event frequencies: differences in selecting IE groups and IE frequencies are identified.

3.3. Detailed comparison

The main selection criterion for detailed comparison is selecting initiating events that contribute significantly to CDF for OPR1000. Therefore, small loss of coolant accident and steam generator tube rupture events are chosen for detailed comparison. The main difference may be due to the differences in assumed initiating event frequencies, system success criteria, and reliability data.

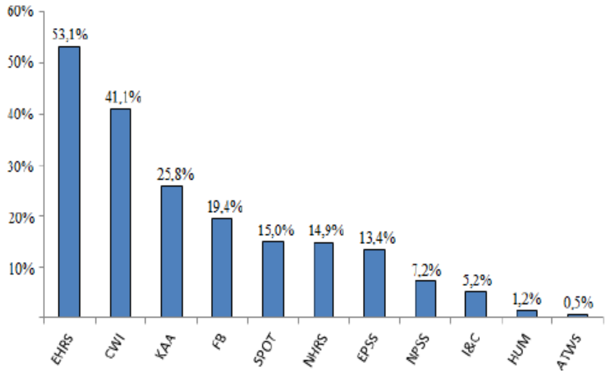

Figure 2: Major system failures contribution at total core damage frequency

4. Conclusions

The comparison of probabilistic safety assessment results of OPR1000 and VVER1200 demonstrates that internal initiating events definition and frequencies, design specifics, system success criteria and component failure data have an impact on PSA results. This comparison therefore allows identification of potential PSA improvements and beneficial plant modifications. In addition, regular updates of data used in PSA are recommended.

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