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Post-Fukushima Probabilistic Safety Enhancements of Industry

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1. Introduction

After the Fukushima accidents, several measures were taken and still upgrades are undergoing for the safety improvements by nuclear industries.

Nuclear concerned society as well as regulatory agency of Korea also asked several safety measures be included to the existing safety principles. These measures include the post-Fukushima near action items, several mid-long term obligations for severe accidents and rare external hazards which were disregarded due to unlikely event probabilities.

This paper illustrates some activities being done or planned in view of probabilistic assessment boundaries; 1) Items currently performed by industry, 2) Regulatory measures which will impact to the industry activities, 3) Activities planned by mid-long bases.

2. On-Going Activities & Insights from LPSD PSA

2.1 Activities in Severe Accidents and PSA

Rightly after the accidents in 2011, each country has specific rules against severe accidents. For example, US regulatory imposed safety upgrade on extended loss of powers, whereas European Union asked stress test. Especially, the Japan regulatory commissioned the industries with complete new safety requirements such as implementation on full spectrum of safety from external hazards to severe accidents.

The Korean Regulatory Agency with expert group focused on any possible design vulnerabilities and improvements in case of loss of ultimate heat sinks and power sources considering external hazards such as seismic, flood or complex initiated events. One of measures is to develop SSAMG(Shutdown Severe Accident Management Guidelines) during LPSD(Low Power & ShutDown) operation to the existing SAMG for full power operation.

At first, KHNP decided to develop the LPSD PSA models to upgrade the quality of SSAMG. To get a technical adequacy, KHNP decided to revise the full spectrum of PSA model which was developed by severe accident mitigation strategy of 2002. It includes full power, low power, external, and level 2 models incorporating up-to-date plant design information, methodologies, and reliability data. (Fig.1)

Through living PSA and configuration risk management process, many issues related to standardization were raised for the application and management of PSA models. So, we, in this PSA updating projects, needed to standardize and manage the technical elements of PSA by consistent guideline and methodology.

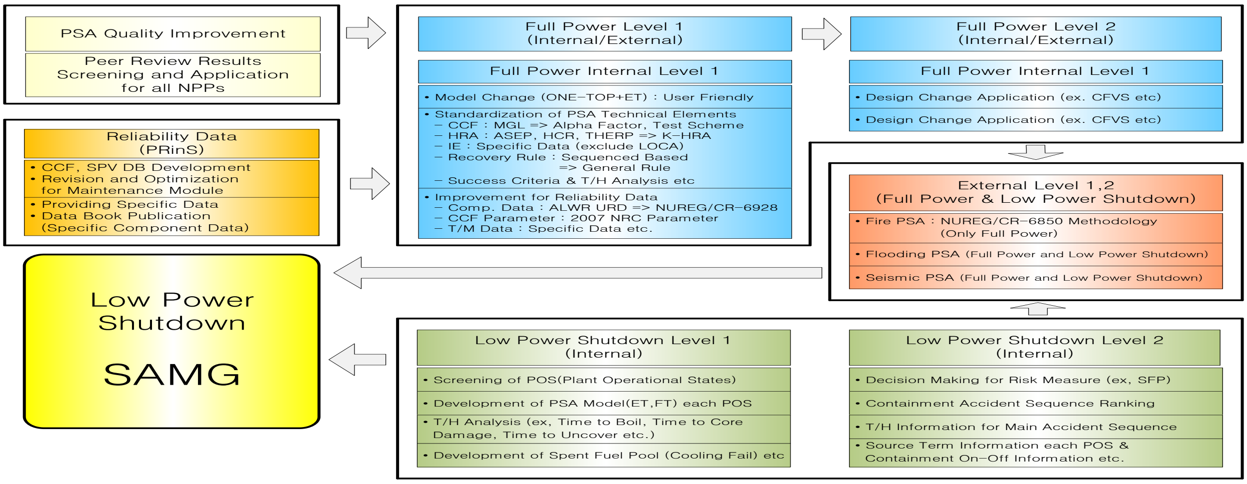

Fig. 1 Implementation Strategy of Full Spectrum Risk Analysis

KHNP evaluated mid-loop operation of LPSD PSA for two pilot plants in early 2000 and continued full LPSD models for newly construction plants. We will develop or revise internal and external LPSD Level 1 PSA model for all plants by 2015. In addition we have plans to analyze the fuel damage frequency due to loss of cooling at spent fuel pool and to start LPSD Level 2 PSA for the first time.

And, we updated component reliability data(Fig. 2) by using the latest operating experiences and NUREG/CR-6928[1]. The database has following major differences as compared to the conventional ALWR URD[2] data; 1) Provides normal running, normal standby data for 9 major components 2) Provides fail to load and run data for normal standby system 3) Beta distribution for demand failure and gamma for running failure data, each.

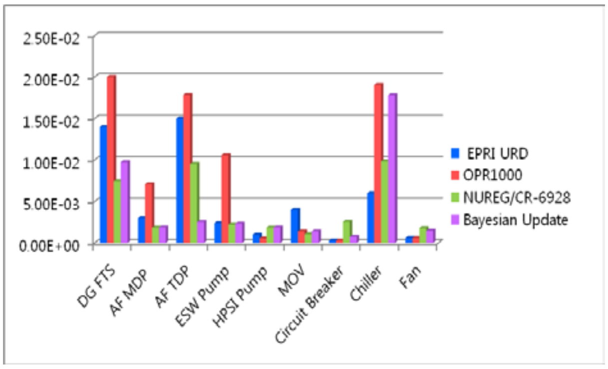

Fig. 2 Korean Specific Component Reliability Data

2.2 Insights from PSA

As a result from performing PSA for the operating NPPs in Korea, we could identify the following risk insights based on reactor types. As for westinghouse type reactors, LOCCW (Loss of Component Cooling Water) is the major initiating event to CDF (Core Damage Frequency). For one of the reactors, CDF of LOCCW were estimated over 50% of the total CDF, and the most important factor was identified as the RCP seal integrity. According to the latest technical report of WOG-2000[3], the endurance time without seal cooling is changed from 30 minutes to 13 minutes. Therefore, the accident scenarios related to RCP seal integrity were estimated higher than the previous results. RCP seal change to shutdown seal(SHIELDⓇ, GenIII) was reviewed as the effective safety improvement of Westinghouse type reactors.

As for OPR1000, MLOCA(Medium Loss of Coolant Accident) was estimated higher than the result of previous PSA. It is because of the change of initiating event data based on latest data source of NUREG/CR-6928. And, the functional loss of HVAC (Heating, Venting and Air Conditioner) system for a switchgear room was identified as the important factor to the safety. Therefore, we performed the room heat up calculation in detail, and prepared improvements of the related procedure and training for recovery action.

3. Future Plans

In addition to the on-going activities, some mid-long term safety options planned at this time are as follows;

- PSA for operating plants as a way of ten year Periodic Safety Review(PSR) implementation
- PSA for construction plants in Chapter 19 of Safety Assessment Report(SAR)
- Extreme external hazards and severe accidents in view of Design Extension Conditions(DEC)

Before the accidents, IAEA already requested member states to include PSA as one of 14 periodic safety review elements and it was formally introduced at plants from 2014. Even if KHNP performed PSA for severe accidents and had living PSA plans, the scope and quality for PSA need to be enlarged and upgraded for PSR requirements.

The way PSA being actively involved is at design stages, which reports the results separately from SAR. Because PSA is widely used for the verification of safety and design robustness, US NRC introduced the PSA into SAR chapter 19. It is not yet formalized the contents, but, KHNP submitted preliminary report for the Construction Permit(CP) review of new plant. There are some technical issues, and in-depth discussions will be followed for the contents and application.

Design Basis Accidents(DBA) widely applied to the safety and design of nuclear plants needed more enlarged concepts covering the risks of beyond DBA or severe accidents. This added safety concepts include the identification of initiating events from common cause failure, multiple failure, severe external events and etc. Probabilistic methods will be used for the selection and screening of events, confirmation of increased safety measures.

4. Conclusions

After the Fukushima accident, the significance of severe accidents and PSA came to the public as well as the industry itself. Among fifty safety-related plans, in this paper, we showed the implementation strategies and interim insights from LPSD PSA.

The plans or activities now underway are further enhancing the safety for operating by introducing PSR and construction plants by inclusion of PSA insights into SAR. The main focus for safety improvement is targeted by not only the hardware improvement, but also systematic structure and effective operational improvement.

The results of LPSD PSA implementation strategy will contribute to conforming of regulatory requirement and legislation of PSA which requests the application of extended scope of analysis, new methodology, PSA quality, living PSA through technically sound and application- specific PSA models.

REFERENCES

[1] USNRC, Industry-Average Performance for Components and Initiating Events at U.S Commercial Nuclear Power Plants, NUREG/CR-6928, 2007

[2] EPRI, Advanced Light Water Reactor Utility Requirement Document, Volume II, ALWR Evolutionary Plant Ch1, Appendix A Rev 7, 1995.

[3] WCAP-15603 Rev.1-A, WOG 2000 Reactor Coolant Pump Seal Leakage Model for Westinghouse PWRs, 2003