PHWR Characteristics for Defense-In-Depth Evaluation Model

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1. Introduction

Defense-in-depth(DID) evaluation using Safety Function Assessment Trees(SFAT) and Plant Transient Assessment Trees(PTAT) becomes general method for risk management in nuclear power plants. Based on the defined safety functions, configurations of key elements needed for maintain the DID should be tracked, evaluated and adjusted through the risk profile according to the maintenance schedules. Because DID evaluation concepts and methods were developed for light water reactors in US originally, the new approach and modification is necessary for PHWR defense-in-depth evaluation. The characteristics which should be considered and reflected during the development of DID evaluation model were discussed, and the status of development for PHWRs in Korea was introduced in this paper.

2. DID Model Development for PHWR

CANDU type PHWR has many unique safety features and its own safety concept. Generally, safety functions are not defined explicitly in EOP of CANDU and there are special safety systems such as SDS1&2, ECCS and containment spray system. The operation and maintenance principle and practice shows difference from those in PWRs. Therefore, the unique features of PHWR should be recognized clearly and should be reflected to DID evaluation model development framework.

2.1 Safety Functions

For PWR, safety functions are clearly defined in EOP and the safety features and actions are described. In PHWR EOP used in Korea, action statements are not based on symptom or safety functions but accident scenario. To define the safety functions for PHWR, the general safety functions for PWRs such as reactivity control, core cooling, secondary side heat removal, containment integrity, essential power, and cooling waters are considered as draft set of PHWR safety functions. Through the review by plant personnel who has expertise in operation and maintenance, PHWR safety function were defined as bellows.

1. Reactivity Control
2. Core Cooling
3. Secondary Side Heat Removal
4. PHT Pressure and Inventory Control
5. Reactor Building Integrity
6. Essential Power AC
7. Essential Power DC
8. Cooling Water

This safety function definition can be applied to both at-power and shutdown operations.

2.2 Safety Features

PHWR has unique safety concept of separated safety system group and special safety systems. This means that PHWR has much diversity and independency compared with PWR and this can be reflected to color assignment criteria in SFAT and PTAT. For example, emergency water supply system can be used to makeup the PHT inventory using MP ECCS injection path and it can supply feedwater to SGs. This shows the flexibility of operation in PHWR. Considering the flexibility and diversity of safety features in PHWR, proper key elements in SFAT should be selected.

For WS 3&4, the systems to maintain the safety functions were classified and reviewed by plant personnel. It is important to reflect the real operational practice those are not described in procedures explicitly. During the development, interview and consultation with plant personnel were performed and the results were reflected into model development.

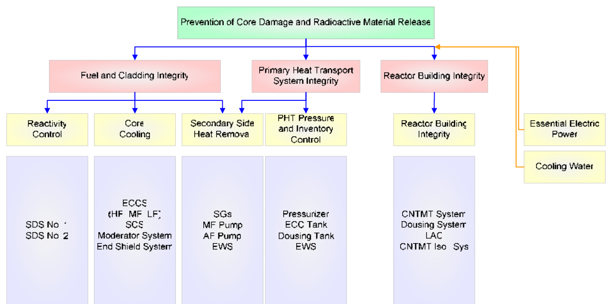

Figure 1. PHWR Safety Functions and System for Safety Functions

2.3 Plant Operating State and Mode

Plant Operating State(POS) means the period of operation in which the safety characteristic can be regarded as same. The physical status of operation is a criteria for the POS determination. Generally, decay heat level after shutdown, inventory in RCS or PHTS, alignment of safety system, existence of large vent and etc. are important to determine the POSs. Operational modes are another critical parameter for POS determination because the technical specifications concern the operational modes and the action statements are specified along with mode changes.

For the case of PHWR, operational modes were defined in technical specifications but modes and tech. spec. are modified to PHWR based on PWR. There are a lot flexibility in PHWR startup and shutdown operations compared with PWR but defined operational modes can not reflect such flexibility in operations of PHWR. For this reasons, operational modes of PHWR were not selected major parameter for PHWR POS determination. 7 major POSs from A to H were defined as draft regarding PHT temperature, PHT inventory level and PHT status including large vent. These POS definition is under revision to consider the review result by plant personnel.

2.4 Deterministic Safety Analysis

To develop SFAT logic and color assignment rule, the deterministic safety analysis including severe accident analysis results should be referred. Generally, the safety status which is determined as marginal, or there is not margin in DID, is decided as “ORANGE” status. For this determination, safety analysis results in FSAR, PSA and other severe accident analysis reports should be basis. Additionally, the operation practice and the opinion of plant personnel can be reflected into color assignment. For PHWR in Korea, information from the deterministic safety analysis is rather insufficient compared with PWR. Therefore, additional thermal-hydauric analysis should be performed.

3. Conclusion

Defense-in-depth evaluation model for PHWRs in Korea is under development. During the development, many lessons for the DID evaluation model development which can reflect the operational practices were derived. These lessons will be utilized in the rest period of development and will contribute to the enhancement of risk management for PHWRs in Korea.

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