Pilot Safety Function Assessment Tree Development for KSNP

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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. Especially for low power and shutdown operation, DID evaluation using SFAT is main evaluation method. In this paper, example SFAT development was discussed.

2. SFAT Development

For UCN 3&4, 8 safety functions for LP/SD operation were defined. Among safety functions, SFAT development for decay heat removal safety function was discussed in this paper as example. Also, 16 unique POSs for LP/SD operations were defined. POS C was chosen for SFAT development example. In POS C, operation mode is 4(hot standby) and RCS temperature is below 148°C.

2.1 Systems for Decay Heat Removal in POS C

In POS C, shutdown cooling system is used for decay heat removal. Among 2 SCS trains, 1 train is operating and the other train is in standby. SGs are in wet layup condition and main heat removal method is SCS. There is no large vent in RCS boundary and decay heat removal using natural circulation is possible as if SGs are available. For long term cooling in case of LOCA, containment spray system can remove decay heat through sump recirculation paths. Also, it should be recognized that there are any higher risk evolution(HRE) event related to decay heat removal.

Considering the main and alternative decay heat removal methods for POS C, the questions to determine status of decay heat removal safety function are derived as bellows.

1. HRE related to decay heat removal
2. No. of SCS trains available
3. No. of CS trains available for long-term cooling
4. No. of SGs available

2.2 Color Assignment

With the main questions for logic boxes in SFAT, logical paths which represent the configuration of SSCs related to decay heat removal can be derived. To every end state of SFAT, proper color-GREEN, YELLOW, ORANG and RED- should be assigned. ORANGE status means the status in which there is no DID margin. For decay heat removal safety function in POS C, 1 SCS train is necessary. 1 CS trains should be in standby condition according to tech. spec. In case that active decay heat removal methods-SCS and CS- were unavailable, natural circulation using SGs becomes necessary. Therefore the minimum criteria to maintain decay heat removal safety function in POS C is 1 SCS train, 1CS train and 1 SG. This path in SFAT becomes the criteria. If additional train is available, color can be assigned as YELLOW only if the additional train can provide additional DID method. Based on this approach, or bottom-up approach, colors can be assigned to every end state.

The criteria should be derived from the safety analysis result including FSAR, PSA, and severe accident analysis. For some cases, the confidence on the operation practice can be reflected to color assignment.

2.3 Conservative vs. Practical Criteria

Many plants in US use tech. spec. as color assignment criteria. With the application of RIR, many regulatory elements have been optimized. In some part of tech. spec. are relaxed and some part of tech. spec. are enforced or other supplementary safety and management methods are enforced. With these changes in tech. spec., color assignment criteria based on tech. spec. resulted acceptable color evaluation to both regulatory body and utilities. But there are still arguments on color assignment.

Using the current tech. spec. which is used in Korea as basis, may result conservative color evaluation results in some cases. To give more flexibility in operations, this issue should be discussed between regulatory body and utilities.

2.4 SSC Selection for SFAT Evaluation

After top logic in SFAT is developed, operation and configuration model including each component which is necessary to maintain decay heat removal safety function, should be selected and modeled. SSCs modeled in PSA can be a good start. If there are any component which is decided as critical to maintain the relevant safety function, should be included in the SFAT model.

2.5 Filter Variable Selection

Each SFAT should be linked to each POS according to safety function using filter variables. Filter varables are the physical parameters which can represent the important status of RCS such as modes, RCS temperature, inventory level in RCS, refueling status and etc. With proper combination of filter variables, each POS should be discriminated.

3. Conclusion

Safety function assessment trees are the main defense-in-depth evaluation method for low power and shutdown operation. With clearly defined safety functions and the methods which can evaluate the level of defense-in-depth according to maintenance schedules, low power and shutdown risk in nuclear power plant can be managed more easily and more objective way. Through this defense-in-depth evaluation and shutdown risk management, the overall safety of nuclear power plant can be enhanced.

REFERENCES

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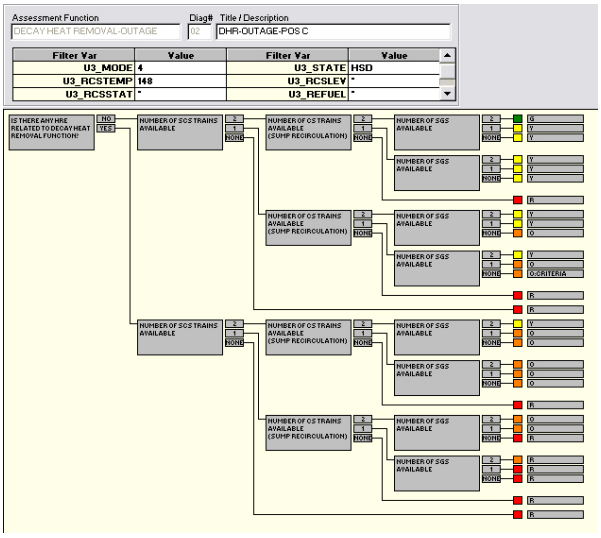

Figure 1. Example Decay Heat Removal SFAT in POS C