Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Development of Outage Risk Indicator of NPPs for New Optimized Power Reactors

Eden Kim[a*], Su Won Lee[a], Young Wook Chung[a], Hyun Gyo Lee[b]
[a]*Future & Challenge Technology Co., Ltd., Heungdeok IT Valley Bldg, 32F, Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 446-908, Korea*
[b]*Korea Hydro & Nuclear Power Co., Ltd., 1312 Yuseongdaero, Yuseong-Gu, Daejeon, Korea*
[*]*Corresponding author: eden@fnctech.com*

1. Introduction

Nuclear power plants in Korea have developed a comprehensive safety management system with real-time evaluation of the possible incidents during operation.

In full power operating condition, the risk of plant is monitored by the assessment of the indirect risk index by PSA (Probabilistic Safety Assessment). But in shutdown and low-power conditions including an outage, the qualitative risk assessment would be applied because the level and temperature of reactor coolant system (RCS), containment integrity, and refueling status are varied in each plant operating status of outage.

To achieve optimal outage, ORION (Outage Risk Indicator of NPPs) is developed for the risk assessment of the nuclear power plant during refueling outage. It also suggests plans to minimize the risk of plants through qualitative risk assessment.

In this study, ORION model which can evaluate the process risk in terms of the outage has been developed. The model will be applied to the case of the Shin-Kori unit 1, the New Optimized Power Reactors of KHNP. As a result of this study, the optimized outage management solution for Shin- Kori unit 1 will be derived with ORION model.

2. Model Development & Assessment

2.1 model development

Plant Operating States (POS) which can be applied to the risk assessment model during the outage of Shin-Kori unit 1 is developed and the filter variables and characteristics of POS are presented in the ORION model. The POS are reflected the differences in RCS level, RCS temperature, containment integrity and refueling status during the outage. Therefore, it is very important to identify the specific characteristics of each POS in the development of ORION models (see Fig.1).

Six of the major safety functions in terms of each POS are selected for the risk assessment of refueling outage of Shin-Kori unit 1. Fig. 2 shows a safety function assessment tree (SFAT) for the safety function of decay heat removal. The SFATs are used to support efficient scheduling and ensure that the safety functions are complied with the requirement of each POS. To check the requirement for technical specification, TSF (Technical Specification Front-line system) and TSS (Technical Specification Support system) are distinguished. And the fault trees based on the each POS and safety function are developed to evaluate risk of Shin-Kori unit 1 (see Fig.3).

Most of variables are needed for evaluating the risk and the environment settings are developed as a storage, plant configuration databases (PCDB).

POS	Filter Variable					
	SK1_ MODE	SK1_ STATE	SK1_ RCS_TEMP	SK1_ RCS_LEV	SK1_ RCS_STATE	SK1_ REFUEL
10-3	3	HSB	>146	RCS_FL	INTACT	NOMOVE
9-4	4	HSD	>146	RCS_FL	INTACT	NOMOVE
8-4	4	HSD	146	RCS_FL	INTACT	NOMOVE
7-5	5	CSD	99	PZR_FL	INTACT	NOMOVE
6-5	5	CSD	60	PZR_70	LGVENT	NOMOVE
4-5	5	CSD	60	REDUCED	LGVENT	NOMOVE
5-5	5	CSD	60	MIDLOOP	LGVENT	NOMOVE
5-6	6	RFL	60	MIDLOOP	LGVENT	NOMOVE
4-6	6	RFL	60	REDUCED	LGVENT	NOMOVE
2-6	6	RFL	60	CAV_FL	LGVENT	NOMOVE
3-6	6	RFL	60	CAV_FL	LGVENT	COREALT
1-0	0	DFL	60	CAV_EMPTY	LGVENT	DEFUELED

Fig. 1. Definitions of POS

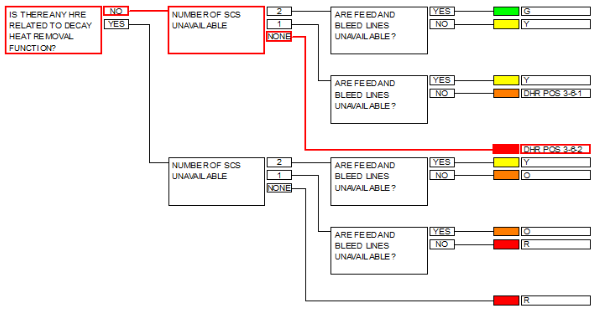


Fig. 2. Development of SFAT

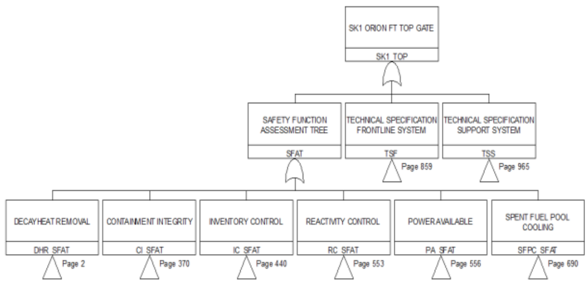


Fig. 3. Development of Fault Tree

Risk assessment according to the logic of the evaluation tree is presented as color codes of GREEN, YELLOW, ORANGE and RED. Orange color is represented for the minimum requirement to achieve each safety functions. Red color is represented for higher risk than orange. Yellow represents a slightly lower risk level than orange. Green represents a very high or maximum level to achieve the safety function and the lowest risk level. Thus, the color codes are used to provide a visual indication of the status of each safety function. Table 1 shows these risk metrics [1].

COLOR	METRIC	STATUS OF SAFETY FUNCTION
GREEN	ACCEPTABLE	Very high or maximum level of DID. Lowest risk level. Configurations with this DID do not require additional actions to manage risk (i.e. normal work controls are sufficient).
YELLOW	REDUCED	Adequate DID. Slightly elevated risk level, but still relatively low risk. Configurations with this DID may take actions to minimize the duration of exposure and/or implement compensatory actions to reduce risk.
ORANGE	MINIMAL	Reduced DID. Elevated risk, but tolerable for short durations. Configurations with this DID require detailed planning for the configuration including compensatory actions to minimize exposure time, and contingency planning to restore and/or protect alternate means of supporting the safety function. Typically represents the case where a single failure will result in loss of DID for the safety function.
RED	UNACCEPTABLE	Unacceptable DID characterized by the inability to support the safety function. Risk is unacceptably high and not tolerable for any duration. Typically represents a state that will not be planned for or entered voluntarily.

Table Ⅰ: Risk Metrics

2.2 risk assessment

Orders for the maintenance of nuclear power plant are collected to assess the risk in the second outage of Shin-Kori unit 1 with ORION. All of 2225 orders are issued for the maintenance of Shin-Kori unit 1 and only 455 of orders are selected for the assessment. The pre-evaluation result shows that each color code of safety function is red. Therefore, the orders should be modified to satisfy the requirement of each safety function in reference to each POS and main process drawing to maintain the required safety function. If the maintenance period for EDG A and the period of EDG B are overlapped, for example, the order for the maintenance period for EDG B should be modified in accordance with the requirement of Technical Specification, since the outage process should be derived to minimize the risk caused by the overlapping.

3. Result

Figure 4 presents a result of the risk assessment for Shin-Kori unit 1 second outage using ORION model. Figure 4 (a) shows that most of color codes of each safety function are red and it is very hard to meet the minimum requirement. However, in the post-evaluation using the modified orders in terms of POS and main process drawing are applied, most of color codes are presented as a green (see Figure 4 (b)).

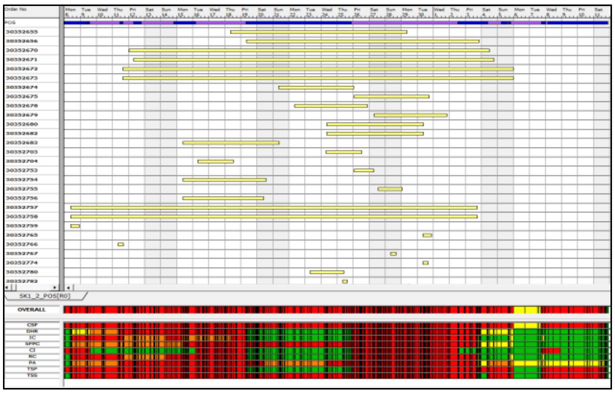
The result of analyzing the assessment includes the following:

1. In terms of each POS, the required numbers of the system and equipment are different even in the same system. Therefore, for the planning of the outage maintenance process, the POS should be considered.

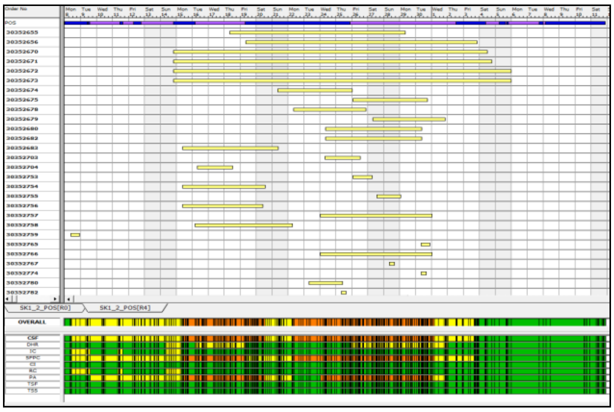
2. For the risk assessment of the plants outage with ORION, the maintenance process should be planned according to the actual date of the process.

3. The orders cannot cause the unavailability of the equipment in the actual process should not be considered in the risk assessment with ORION.

If optimal outage process is created to ensure the plant safety, therefore, it seems to be able to minimize the risk by evaluating the risk of outage process.



(a) Assessment of the original order



(b) Assessment after the adjustment of order

Fig. 4. Assessment by adjustment the order

4. Conclusions

In this study, ORION model has been developed and the risk of the outage of Shin-Kori unit 1 are evaluated to improve a nuclear power plant safety. The ORION model provides optimal outage planner and scheduler to meet the requirement of safety functions.

The ORION model for Shin-Kori unit 1 can be used to ensure adequate evaluation of safety functions during the outage.

REFERENCES

[1] EPRI 1016231, Development of a Shutdown Qualitative Risk Assessment Standard, pp.16, 2007.