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Application of a PSA tool for Accident Sequence Precursor Evaluation

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1. Introduction

Since 2002, KINS has developed a regulatory PSA model named MPAS (Multi-purpose Probabilistic Analysis of Safety). Six cases for typical reactor types in Korea, i.e., Westinghouse 600, Westinghouse 900, Framatome, CANDU, OPR-1000, and APR-1400, have been developed for the MPAS model, which has a primary objective to provide a standardized regulatory tool and technique. KINS staff should use it to achieve more consistent regulatory decision making when performing risk assessments of operational events and licensee performance issues.

However, in case of on-site/on-line risk assessments of operational events and licensee performance issues by the staffs, KINS was willing to use more user-friendly PSA tools utilizing the MPAS model.

Moreover, the government notice No.2018-03 for reporting rule of operational events revised last year, which adopted a new requirement for the quantification of event significance utilizing like an accident sequence precursor (ASP) program.

In this paper, we would like to introduce new KINS tool for implementing ASP and significance determination process (SDP) programs, so-called RYAN, and to give an example evaluation result for application to an actual nuclear event in Korea.

2. Development of RYAN for ASP Evaluation

The development of RYAN was ended in late 2018, and it was fully supported by KAERI PSA group [1].

2.1. Overall proposed Scheme of Risk-informed Application in KINS

Even many chances were given to PSA basics and methodology since the emerging movement of risk-informed regulation initiated by USNRC, most of the regulatory staffs in KINS are not familiar with PSA tools. Therefore, for easy uses of PSA tools by KINS staff to the actual regulation like inspection and investigation of events, i.e., similar concept of the risk-informed application, we have proposed 3 steps' approach, as shown in Figure 1.

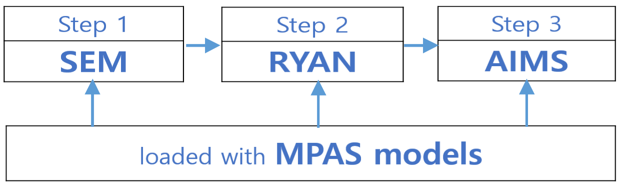

Figure 1. Steps of Risk-informed application in KINS (Currently proposed)

The SEM used in Step 1, which stands for a significance evaluation management system, has developed with a Web-based tool for the purpose of easy screening calculation of risk measures everywhere by any KINS staff. If someone wants to do an exact evaluation of a given problem after quantification by the SEM, the second step using the RYAN tool will be provided. The risk measures used in SEM and RYAN are following as;

- ΔCDF (change of core damage frequency [/yr])
- CCDP (conditional core damage probability) or ΔCDP (change of core damage probability).

The AIMS, addressed in Step 3, has been developed in KAERI and is a more comprehensive analytical tool performed by PSA experts.

2.2. Evaluation Module of the RYAN

The RYAN stands for "risk analysis for ASP and/or SDP of nuclear power plants." Figure 2 shows the first monitor screen of RYAN, where four frames of a window are given after the baseline risk evaluation.

As shown in Figure 2, the first window figure of RYAN after opening any desired project is provided with five calculation options, depending on problem cases either initiating events or SSC failures. Among these options, most practical one for ASP evaluation may be third one, IE+SSC(Inclusive) [2], which can deal a deficiency problem with concurrent SSC failures given one of the various potential initiating events. In the RYAN, IE+SSC(Inclusive) has the following formula;

$$\text{Combined CCDP } (\Delta CDP) = \text{Max } \{ \text{IE CCDP, SSC } \Delta CDP \}$$

and SSC ΔCDP = {CDFnew - CDFbase} × Δt

where Δt is exposure time of affected SSCs.

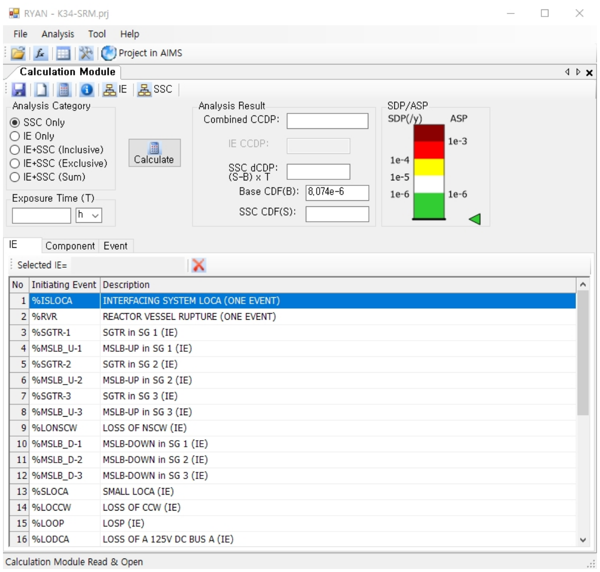

Figure 2. Base presentation of RYAN tool

The right side of the RYAN window shows a bar graph with five colors. We have divided bar colors corresponding to multipliers for ASP and SDP, respectively.

3. Application of RYAN to an Actual Event

We selected an actual event occurred in a domestic nuclear power plant in 2016. In this case, performance deficiency(PD) problem, which occurred in the expansion joint of the condenser, caused an initiating event with subsequent reactor trip. In addition, following another PDs also caused unavailability of corresponding SSCs that were required as a mitigating function, even though those are mutually exclusive of the initiating event.

- Running failure of a Turbine-driven AFW pump, and
- Loss of a Non 1E 4.16 kV bus.

Plant-specific features of any kind of plants are not considered in the evaluation because the MPAS models were only developed for 6 typical reactor types. However, we believe that any plant-specific features of a plant among the same type' reactors may not significantly affect the overall risk results.

It is assumed that the exposure time of above failures is one year (limited maximum value) conservatively [2] because the occurrence of two unavailable SSCs would exist at any time, so unavailable condition of these SSCs could be fixed during full power operation. This assumption is based on the corrective actions written in the LER by the utility and the investigation report by KINS.

Figure 3 shows an example reporting window given to an RYAN user with a saved file to provide insights during a case-by-case calculation with different assumptions.

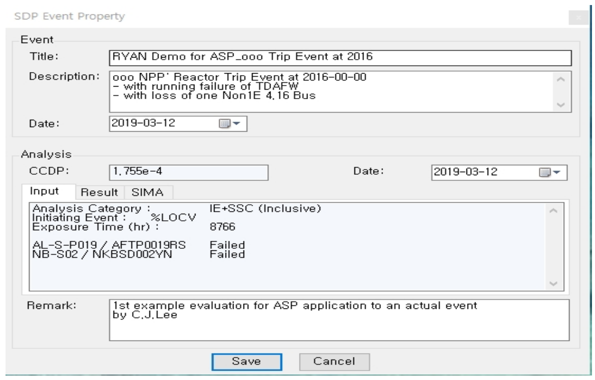

Figure 3. A reporting window of RYAN (Example)

The final CCDP of this example application is shown in Figure 4. You can see the bar color after the calculation is going up to "red" state, which means this event case has a potential risk level between a precursor (> 1.0E-6) and a significant precursor (> 1.0E-3) as defined in the USNRC.

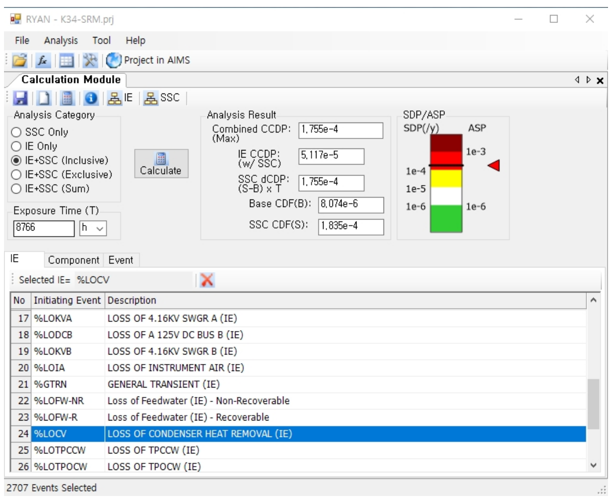

Figure 4. CCDP presentation of an Example Application

It is noted that the evaluations for the purpose of SDP-like regulatory activity are also possible using the RYAN tool. The analysis category of "SSC only," as shown in Figure 2 or Figure 4, is chosen for the case. Some actual events, which occurred with a PD problem without an initiating event, were selected and calculated for this application [1]. In this case, we believe that exposure time, sometimes we had to assume the value, is the most sensitive input giving the risk insights.

4. Conclusions

This study has introduced a risk-informed application example currently proposed in KINS. Especially, in case of application of ASP tool, it seems that we can get many practical benefits for confirming actual safety and reducing residual risk of domestic nuclear facilities.

It is noted that proposed systematic steps for risk-informed application in KINS, as shown in Figure 1, should be broadened out to get more reliable decision making in the off-line and on-line regulatory activities.

REFERENCES

[1] KINS/GR-628, Development of Regulatory PSA Model Utilization Framework, KINS, Aug. 2018.

[2] RASP Handbook – Vol.1 Internal Events, Rev.2.02, USNRC, Dec. 2017.