

Study on Identifying Risk-Significant Configuration in Risk-Informed Technical Specifications Optimization in Nuclear Power Plant

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Abstract. Risk-informed Technique, combining Deterministic analysis with Probabilistic Risk analysis, could evaluate the whole risk of Nuclear Power Plant, which is more and more deeply used in different areas in NPP, such as Technical Specifications, In-service inspection, GQA and so on. In Risk-informed Technical Specifications Optimization, a three-tiered approach for licensees to evaluate risk associated with proposed TS changes: Probabilistic Risk Assessment Capability and insights, Avoidance of Risk-Significant Plant Configuration, and Risk-Informed Configuration risk management. The Avoidance of Risk-Significant Plant Configuration is one of the essential links, which is also the chief content of Risk-informed Technical Specifications Optimization, so identifying the risk-signification configurations is particularly important for evaluating risk impact. This paper takes one proposed Spray isolation valve TS item change of Containment Spray System in some NPP as an example, to illustrate the method and process of Identifying Risk-significant Configuration from importance analysis result, and gives management suggestions based on the Risk-significant Configuration result, which gives a special way to analysis avoidance of risk-significant configuration, and a well practical lesson for Risk-informed application.

1. Introduction

Risk-informed Technique, combining Deterministic analysis with Probabilistic Risk analysis, could evaluate the whole risk of Nuclear Power Plant(NPP), which is more and more deeply used in different areas in NPP, such as Technical Specifications, In-service inspection, GQA and so on. Generally, the risk informed applications are carried out based on RG1.174 and RG1.177. In Risk-informed Technical Specifications Optimization, a three-tiered approach for licensees to evaluate risk associated with proposed TS changes: Probabilistic Risk Assessment Capability and insights, Avoidance of Risk-Significant Plant Configuration, and Risk-Informed Configuration risk management. The Avoidance of Risk-Significant Plant Configuration is one of the essential links, which is also the chief content of Risk-informed Technical Specifications Optimization, so identifying the risk-signification configurations is particularly important for evaluating risk impact.

This paper takes one proposed Spray isolation valve TS item change of Containment Spray System in some NPP as an example, to illustrate the method and process of Identifying Risk-significant Configuration from importance analysis result, and gives management suggestions based on the Risk-



significant Configuration result, which gives a special way to analysis avoidance of risk-significant configuration, and a well practical lesson for Risk-informed application.

2. Risk-informed Method and Principles

Risk-informed technique has begun to be developed firstly and been deeply used in USA. With accumulated experience on its application, NRC released a series of guidelines to guide the industry to make better application about risk-informed technique, among which the two guidelines is important to decision making and optimization on TS: RG1.174< An approach for using probabilistic risk assessment in risk-informed decisions on plant specific changes to the licensing basis > and RG1.177 <An approach for plant-specific, risk-informed decision making: technical specifications>.

In 2010, NNSA release the policy of enhancing the application of PSA, and the translation version of the risk-informed guidelines, so that the PSA can be step by step actively used in lager range and deeper level, among which the NNSA-0147 and NNSA-0148 are the translation of the corresponding RG1.174 and RG1.177, to concretely guide the risk-informed applications.

The guideline RG 1.174 gives five rules and 4 steps to be complies with when carrying out risk decision making. The five rules are that as below: (1) The proposed change meets the current regulations; (2) The proposed change is consistent with a defense-in-depth philosophy; (3) The proposed change maintains sufficient safety margins; (4) When proposed changes result in an increase in CDF or risk, the increases should be small and consistent with the intent of the Commission's Safety Goal Policy Statement; (5) The impact of the proposed change should be monitored using performance measurement strategies. Based on the above five rules, the NRC expert has defined a four-step method to evaluate the proposed changes in design, operation, and some other actives of NPPs which need to be approved by NRC. The four steps are as below: (1) Define the Proposed Change; (2) Perform Engineering Analysis; (3) Define Implementation and Monitoring Program; (4) Submit Proposed Change.

In RG1.174 and RG1.177, the risk criteria are defined, for example, ICDP<1E-6 and ILERP <1E-7. Furthermore, a three-tiered evaluation process on risk assessment, which includes: Probabilistic Risk Assessment Capability and insights, Avoidance of Risk-Significant Plant Configuration, and Risk-Informed Configuration risk management.

In the process, the avoidance of risk-significant plant configuration is very important with the proposed TS change occurring. And the first step of avoiding risk-significant plant configuration is to discriminate the high risk configuration. An appropriate way of carrying out this step of assessment is evaluate equipment risk contribution on the condition that the equipment of proposed TS change is out of service. Consequently the evaluation of identifying the risk-significant equipment is based on the tier 1 risk result which the ICDP and ILERP acceptance criteria are complied with.

3. Illustration on Proposed Change and Risk Assessment Result

In this paper a proposed TS change is taken as an example to illustrate the assessment of avoidance of risk-significant, of which the content is to add one condition of "one containment spray isolation valve inoperable" to the TS.

3.1. The Technical Adequacy of PSA

The latest PSA model (Mode Power Operation Internal Event Level 1) is used during the evaluation, which data is the special data of the NPP. The model uses the large fault tree/small event tree, also known as the linked fault tree, methodology. Basic failure events are modeled down to the component level. The model began to be established in 1980s when the internal general data was used. The Model has been reviewed by Peer Review Group like IAEA and Chinese Nuclear Industry, and received the general recognition. The continuous quality improvement of the PSA model is always carried out, and the updating data, the PSA application, and the review questions during daily application are considered so that the model reflects the real condition of the NPP.

Based on the qualitative analysis, the influence of the internal fire and the internal flood are similar with the internal event, and other external hazard is considered little contribution, of which the influence can be negligible. So the result of the evaluation reflects adequately the real risk of the NPP.

3.2. The Result of Risk Assessment on Proposed Change

In this part, the risk of the proposed change condition is evaluated and the assessment result is also given. The evaluation is only about the added condition corresponding equipment inoperable, which is about “One containment spray isolation valve inoperable”. There some instructions about the evaluation, as follows:

- i. Power Mode evaluation is taken into account because the condition proposed is in power mode;
- ii. The evaluation is based the latest Level 1 internal events PSA module of the selected NPP;
- iii. Three types of indexes are used: the Δ CDF/ Δ LERF, the ICDP/ILERP, and the RIAOT;
- iv. Select 5E-7 as the acceptable risk guideline according to the general practice, because the evaluation is only based on the internal events module, the internal fire module, internal water logging module, and the external events module are not included.

Based on the PSA module of the NPP, and the acceptable risk guideline, the risk assessment of the condition is performed.

Because the proposed change is to hence the safety assessment with not being managed before, the unavailability of the containment spray isolation valve is decrease, and the Δ CDF and the Δ LERF of the condition will not increase, which meet the demand of the guide line RG1.174.

The quantitative evaluation is carried out based on the zero-maintenance PSA module, and the ICDP and the ILERP also meet the demand of the guide line RG 1.177, and the results of the condition are showed in the tables as below.

Table 1. The risk assessment result of proposed change (ICDP)

Condition content	CDF1(per reactor year)	CDF0(per reactor year)	Δ CDF(per reactor year)	AOT (day)	ICDP
One containment spray isolation valve inoperable	1.27E-05	7.70E-06	4.96E-06	30	4.43E-07

Table 2. The risk assessment result of proposed change (ILERP)

Condition content	LERF1(per reactor year)	LERF0(per reactor year)	Δ LERF(per reactor year)	AOT (day)	ILERP
One containment spray isolation valve inoperable	2.62E-06	2.40E-06	2.30E-07	30	2.10E-08

4. Identifying the risk-significant

4.1. Definition of Risk Achievement worth (RAW)

To identify the risk-significant configurations, measures of risk importance need to be cleared which is performed in risk evaluation. The RAW measure is useful in charactering risk properties and in decision making, which is to measure the worth of a feature in achieving the present risk, is a logic approach is to remove the feature and the determine how much the risk has increased. Depending on how the increase in risk is measured, the risk achievement worth can either be defined as a ratio or an interval. Let

R_i =the increased risk level without feature i or with feature i assumed failed,

And

R_0 =the present risk level

Where the risk can be any measure such as core melt frequency, expected dose, etc. Then on a ratio scale the risk achievement worth A_i of feature I is defined as:

$$A_i = R_i / R_0$$

4.2. Content and Method of Identifying the Risk-Significant

The purpose of the tier 2 risk assessment is to identify the risk-significant plant configuration when the equipment of the proposed change is out of service, and take appropriate measures to avoid risk-significant configuration. A method of using RAW importance to identify the risk-significant plant configuration is proposed based on the risk-informed technical specifications optimization and the practice of operation experiences, because there is no detailed process in U.S.NRC Guide. And the detailed process is given in the section 4.3.

The method of identifying the risk-significant configuration is as bellows: identifying the risk-significant according to the risk contribution of the other equipment when the proposed change equipment is inoperable. Specially, the equipment at higher RAW level is chose based on the equipment importance analysis, which is the risk-significant when it is out of service at the same time with the proposed change equipment. The judgment criterion of the risk-significant is based on the acceptance criterion in the tier1 assessment, the ICCDP and the ILERP.

Based on the identified risk-significant, the measures will be chose by engineering analysis and interview on operators. There are many compensation measures, such as checking the availability of the redundant train, limiting the coinstantaneous test and maintenance of the redundancy and the variety system, improving the operation procedure and the operator training to decrease the influence of human error, improving the procedure of testing and maintenance, and so on. The importance of the tier 2 assessment is to give the plant plan reference on avoiding the risk-significance configuration.

4.3. Process of Identifying the Risk-Significance Equipment

In this part the detailed process of identifying is given. There are four steps as bellows:

Step1: The CDF1 of “one containment spray isolation valve inoperable” is calculated as $1.27E-5$, based on the zero-maintenance PSA module, in which the containment spray isolation valve is inoperable, and the RAW equipment list is got;

Step2: Based on the formula of $(RAW \times CDF1 - CDF0) \times \Delta T < ICCDP$, and choosing $5E-7$ as the limit ICCDP value, and 30 days as the AOT of the valve inoperable, and finally find that the $RAW > 1.05$, which shows that in the RAW equipment list, the equipment, of which the $RAW > 1.05$ is inoperable at the same time with the isolation valve, is the risk-significant;

Step3: Based on equipment list get on step 2, calculating the corresponding RIAOT, which being shown in the table 3;

Step4: for the planers in NPP, when it comes to the condition “one containment spray isolation valve inoperable”, if the planning time, for example the test, is more than the corresponding RIAOT, this is the risk-significance configuration, and the planning should be changed to avoid the plant in high risk level.

According to comparing the NPP production plans, including the time of preventability, the AOT in TS, and the corresponding RIAOT, it's found that there is no risk-significance configuration when it comes to this condition.

Table 3. The list of equipment in high RAW importance degree scope

<i>NO.</i>	<i>Risk-significance configuration</i>	<i>RAW</i>	<i>RIAOT(h)</i>
1	the first loop MHSI inoperable	35.05	9.2
2	the second loop MHSI inoperable	35.05	9.2
3	the third loop MHSI inoperable	35.05	9.2
4	the first turbine bypass inoperable	10.92	30.9
5	the second turbine bypass inoperable	10.92	30.9
6	the third turbine bypass inoperable	10.92	30.9
7	Train A of CS inoperable	3.77	100.9
8	Train B of CS inoperable	3.77	100.9
9	Train A of LHSI inoperable	2.83	143.3
10	Train B of LHSI inoperable	2.80	145.1
11	The turbine-driven pump inoperable	2.49	169.1
12	Auxiliary power inoperable	2.06	218.8
13	Nuclear Auxiliary Building Ventilation inoperable	1.93	241.7
14	The moter-driven pump 01 inoperable	1.88	249.6
15	The moter-driven pump 02 inoperable	1.88	249.6
16	SI 011PO inoperable	1.84	258.5
17	Diesel Generator A inoperable	1.46	376.0
18	Diesel Generator B inoperable	1.17	570.8
19	Train A HHSI inoperable	1.15	587.7

5. Conclusion

Taking a simplified proposed change as an example in this paper, a new thought, the RAW importance analysis, is performed to identify risk-significant, and combined well with the result of Probabilistic Risk Assessment result and the acceptance criteria, which gives an use for reference for risk-informed applications. And the identified risk-significance configuration can give good support to the safety management in NPPs.

Acknowledgments

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References

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