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The Evaluation of the Adequacy of PRA Results for Risk-informed Decision Makings With Respect to Incompleteness

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1. Introduction

PRA(Probabilistic Risk Assessment), as a quantitative tool, has many strengths as well as weaknesses. There are several limitations on the use of PRA techniques for risk modeling and analysis. First, the true values of most model inputs are unknown. Ideally, probability distribution models are well developed and assigned to the unknown input parameters to reflect the analyst's state of knowledge of the values of this input parameter. The problem of overconfidence and lack of confidence in the values of certain model input parameters can lead to inaccurate PRA results. Secondly, the analyst's lack of knowledge of a system's practical application as opposed to its theoretical operation can lead to modeling errors.

The quality of PRAs has been addressed by a number of regulatory and industry organizations Some have argued that a good PRA should be a complete, full scope, three level PRA, while others have claimed that the quality of a PRA should be measured with respect to the application and decision supported. we show by way of an example that the adequacy of a PRA results is important to risk-informed decision making process and should be measured with respect to the application and decision supported.

2. Methods and Results

The significance of an event within a PRA is defined as the impact of its exclusion from the analysis on the final outcome of the PRA. When the baseline risk is the final outcome of interest, we define the significance of an event as risk significance (RS), measured in terms of the resulting percentage change in the baseline risk. When there is a change in plant design or activities and risk change is the final PRA outcome of interest, we define the significance of an event as risk change significance (RCS). These two significance measures can therefore be useful in identifying basic events and initiating events that are important to the accuracy of the baseline risk and risk change.

2.1 A Proposed Measure of Risk Significance

We define our proposed measure of risk significance of an initiating event or a basic event in the PRA in terms of the percentage change in the baseline risk due to the omission of the event from the logic model. By letting $R_{,0}$ be the baseline risk after taking event *i* into consideration, and $R_{w/o,i}$ be the risk evaluated when event *i* is omitted from the analysis, our proposed measure of risk significance of event *i* with respect to the baseline risk can be written as:

$$RS_i = \frac{R_{w/o,i} - R_0}{R_0} \quad (1)$$

The measure of RS of an event measures the degree of sensitivity of the accuracy of the baseline risk to the exclusion of the event from the analysis. Therefore, RS is useful to decision makers who are concerned with improving the accuracy of the baseline risk.

2.2 A Proposed Measure of Risk Change Significance

In many instances, risk-informed decision making processes also require an assessment of the resulting change in risk, such as change in the CDF and LERF that could result from proposed changes in plant design and operation or maintenance activities. The comparison results of the baseline risk and risk changes with regulatory acceptance guidelines, along with insights derived from deterministic analyses, are then used to determine the acceptability of a risk level or an activity. By analogy with our proposed new measure of risk significance, RS, the proposed measure of risk change significance of an event is defined to be the resulting percentage change in risk change that could result from the omission of the event. Mathematically, the risk change significance of event i with respect to the nominal baseline risk and risk change can be represented as:

$$RCS_i = \frac{\Delta R_{w/o,i} - \Delta R_0}{R_0} \quad (2)$$

Where

ΔR_0 : the nominal risk change
R_0 : the nominal risk
$\Delta R_{w/o,i}$ *:* risk change evaluated when event *i* is omitted from the analysis

2.3 CCW Case Study

In this section, we compare our proposed measure of risk significance and risk change significance with several other importance measures widely used in practice using an example. The differences are then

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illustrated by presenting the importance measures of each component in the example system. The Component Cooling Water (CCW) system of a pressurized water nuclear reactor is selected to illustrate the application of the framework developed in this paper.

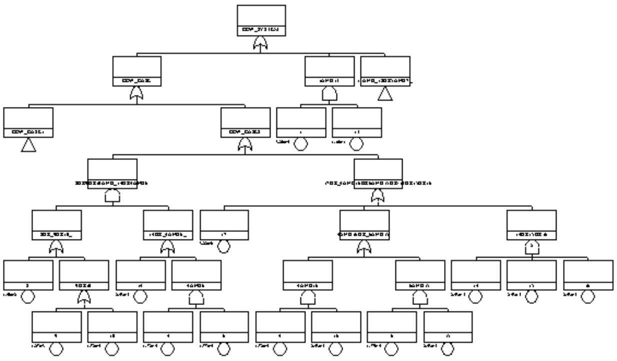

Fig 1. Component Cooling Water (CCW) system of a pressurized water nuclear reactor

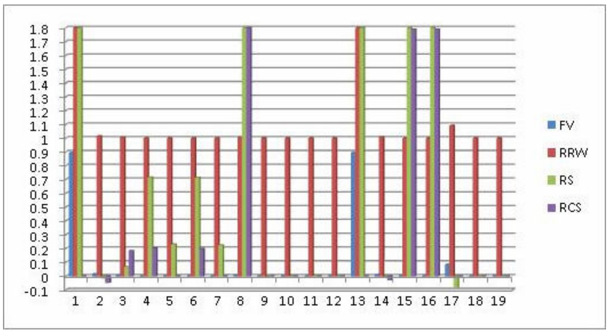

Fig 2. The FV, RRW, RS, RCS of the components in the CCW system

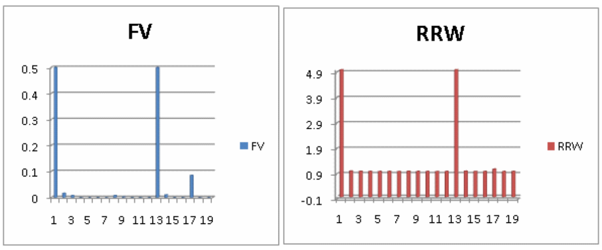

Fig 3. The FV, RRW of the components in the CCW system

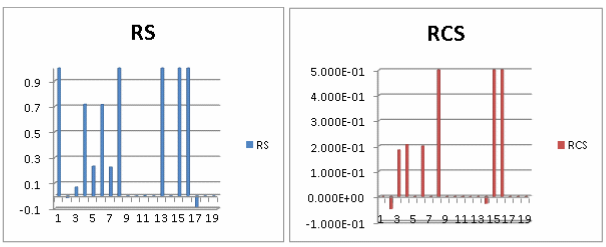

Fig 4. The RS, RCS of the components in the CCW system

The results of our case study of the component cooling water (CCW) system in a pressurized water nuclear reactor show that the rank orders of the events in the PRA obtained using FV, RAW, RS, and RCS generally do not overlap. The omission of an event with low FV and RAW may have extreme large effects (i.e. two orders of magnitude or more) on the expected risk and risk change. In such cases, the PRA which does not take these events into account can seriously underestimate or overestimate the expected plant risk level. The results also show the values of RS and RCS change significantly after epistemic uncertainty on input parameters were taken into consideration.

3. Conclusion

1. The development of the RS and RCS measures which rank events in a PRA in terms of their importance to the accuracy of risk and risk change.
2. The investigation of the use of RS and RCS to identify events that are important to achieving the desired accuracy of risk and risk change for risk-informed activities.

When an event is omitted from a PRA, the RS of that event is defined to be the resulting percentage change in the baseline risk. This measure identifies which events are important to achieving an accurate estimate of the baseline risk. By analogy, when risk change is the final outcome of a PRA, we defined RCS of an event to be the resulting percentage change in risk change due to the exclusion of the event from the analysis. This measure tells us which events are important to achieve an accurate estimate of risk change. RS and RCS are therefore useful to decision makers who are concerned with obtaining accurate and meaningful information and insights to assess the acceptability of proposed changes in plant design or activities.

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