# Experiences from using a tool for analyzing the significance of events at nuclear power installations

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**Abstract:** The NRC's significance determination process: "The 'Significance Determination Process' (SDP) is an organized, planned process to evaluate the risk or safety significance of conditions, events or findings at nuclear power reactors." The process is described in detail in the publicly available document, NRC Inspection Manual, Manual Chapter 0609.
This process is not only used by the NRC, but indeed used by nuclear operators and regulators World-Wide to determine the significance of events as well as providing an engineering understanding of their risk and safety significance.
This paper outlines the findings developing and implementing a tool that supports the SDP.

## 1. INTRODUCTION AND BACKGROUND

The Significance Determination Process (SDP) is a risk-informed process for determining the safety or security significance of events or issues at nuclear power plants. It can be part of the determination of performance indicators following assessment of the seven cornerstones of the Reactor Oversight Framework. The Reactor Oversight Framework is a risk-informed, tiered approach developed by the U.S Nuclear Regulatory Commission to ensure plant safety, see figure 1.

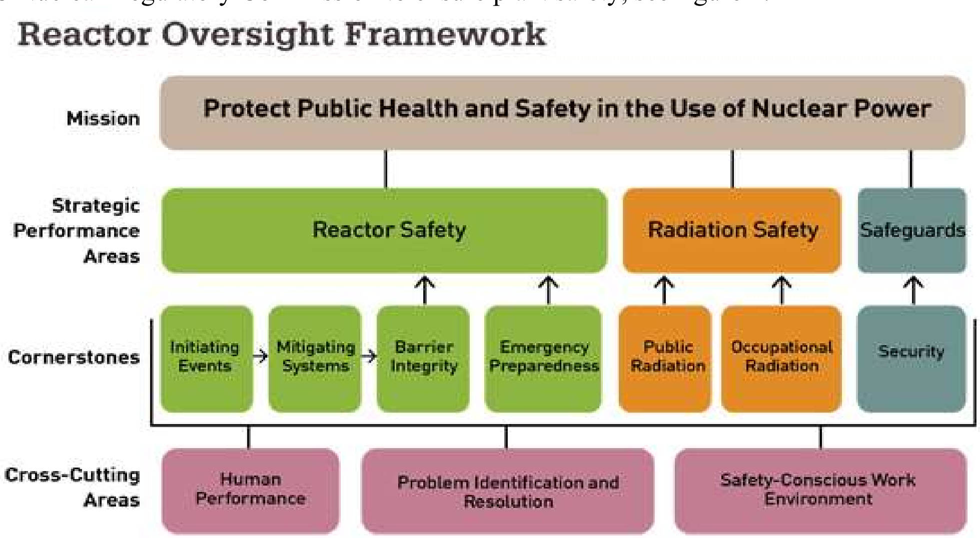



*Figure 1. The reactor oversight process as defined by the US NRC, [1].*

Given a functional degradation over a period of time, the SDP can be used to determine the increase in risk (Core Damage Frequency or Large Early Release Frequency) for postulated initiating events.

## 2. THE SIGNIFICANCE DETERMINATION PROCESS

The SDP is a straightforward process with the purpose of ranking an event that has occurred at a nuclear power plant by significance to safety and security. The purpose is to identify and analyse the significant events and the impact they may have had on safety and security.
A phased approach is used in the reactor safety SDP which lends itself very well to managing it in a software. RiskSpectrum SDP includes a database that facilitates, in a structured way, documentation

and analyses of events or issues reported by a nuclear power plant. RiskSpectrum SDP employs a guided approach with user-defined questions and decision logic.

It should be noted that the process followed in the U.S. places responsibility for the SDP on the regulator, using, as applicable, the SPAR (Standardized Plant Analysis Risk) models that are maintained by the NRC and its contractors at the Idaho National Lab (INL). Utilities are encouraged to perform parallel analyses, particularly for Phase 3, with plant-specific, utility-owned PSA models and in most cases to work with the regulator in ensuring the analyses are adequately representative.

### 2.1. Reactor Safety SDP Phase 1

In Phase 1, a generic worksheet is typically used to describe the observations related to the issue or the event. In the RiskSpectrum SDP software, a guide with predefined questions is presented to the user. Depending on the answers, the user-defined decision logic is used to determine if the event can be characterized as an SDP event or screened out as a low-significance event (green). If deemed an SDP event, it is further processed in Phase 2; if green, the information about the event is stored in the software database for documentation purposes and without any further analysis needed.

Per IMC 0308 [2]:
Phase 1, for any risk-informed SDP tool, should aim to expeditiously screen findings for which there is high confidence that the significance is Green. All such findings must still be corrected by the licensee. The [U.S. NRC] staff bears the burden of an appropriate justification for all SDP results determined as greater than Green.

### 2.2. Reactor Safety SDP Phase 2

The SDP events left from Phase 1 are further analysed by following a guide with questions in Phase 2. The guide requests the user to select and, if relevant, adjust the initiating event frequencies, systems/functions that are affected, and the time the plant has been exposed to the event/issue. Based on responses to the predefined questions, the increase in CDF/LERF is calculated using the plant's base-line PSA/PRA model. A colour code is assigned to each SDP event following the process´s recommendations:

Green:
Very low safety significance [Delta]CDF < 1E-6 or [Delta]LERF < 1E-7
Qualitatively, a Green significance indicates that licensee performance is acceptable and cornerstone objectives (mitigation capabilities, emergency preparedness, etc.) are fully met with nominal risk and deviation.

White:
Low to moderate safety significance 1E-6 < [Delta]CDF < 1E-5 or 1E-7 < [Delta]LERF < 1E-6
Qualitatively, a White significance indicates an acceptable level of performance by the licensee, but outside the nominal risk range. Cornerstone objectives are met with minimal reduction in safety margin.

Yellow:
Substantial safety significance 1E-5 < [Delta]CDF < 1E-4 or 1E-6 < [Delta]LERF < 1E-5
Qualitatively, a Yellow significance indicates a decline in licensee performance that is still acceptable with cornerstone objectives met, but with significant reduction in safety margin.

Red:
High safety significance 1E-4 < [Delta]CDF or 1E-5 < [Delta]LERF
Qualitatively, a Red significance indicates a decline in licensee performance that is associated with an unacceptable loss of safety margin. Sufficient safety margin still exists to prevent undue risk to public health and safety.

Per IMC 0308 [2]:
Phase 2 for any risk-informed SDP should, as much as possible, provide a simplified risk-informed process that can be implemented by inspectors and be used as a risk communication tool. The public basis for an SDP result does not have to be more extensive or resource intensive than Phase 2 if this basis reflects the [U.S. NRC] staff's basic understanding of the significance, which may be checked by professional risk-analysts using more detailed computer-based risk models.

### 2.3. Reactor Safety SDP Phase 3

SDP Phase 3 is used for analysing the events in more detail if deemed necessary. PSA/PRA experts are engaged to reach consensus regarding the findings. (Note, again, that in the U.S., the ultimate responsibility lies solely with the regulator.)

Per IMC 0308:
Phase 3 was defined to address the expected need to depart from the Phase 2 guidance when the Phase 2 modelling assumptions are known to be inaccurate or incomplete and requires professional risk analysts to be involved in all such cases.

The process is illustrated in its entirety in the flow chart in Figure 2, below.

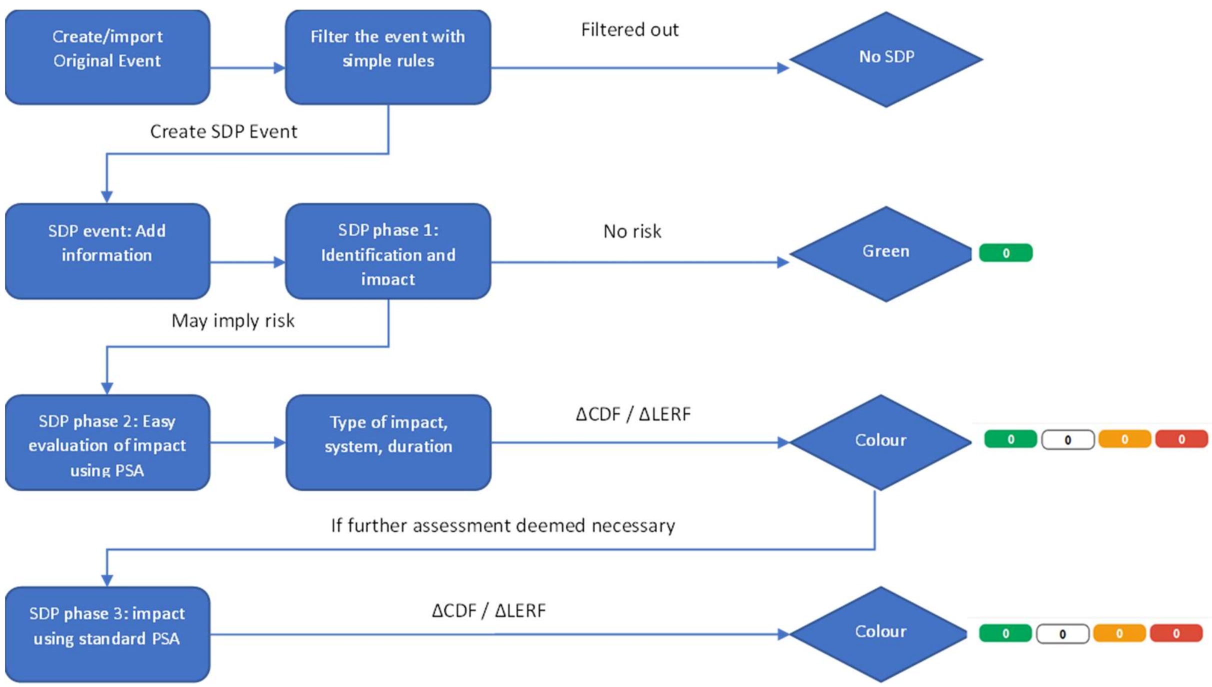



*Figure 2. The SDP process*

## 3. RISKSPECTRUM SDP

RiskSpectrum SDP provides assistance for the steps in the SDP. Events that are found to be of low significance are screened out but stored in the database for documentation purposes. Other events, that are determined to be of significance are further analysed following the SDP. All details of the events are documented in the tool and based on this information, the impact on risk is quantified using the PSA model. The results are categorized according to the significance colour coding system as outlined in 2.2.

The software is designed to offer a customisable step-by-step guide that asks questions relevant to the status of the plant at the time of the event. It focuses on the three cornerstones: Initiating Event, Mitigation System and Barrier Integrity.

The baseline PSA model is used and, depending on the answers provided in the step-by-step guide, the baseline PSA model is adjusted to reflect the plant's configuration and system status at the time of the event.

## 4. IMPLEMENTATIONS AT NUCLEAR POWER PLANTS

In China, Hainan and Fuqing NPPs are using the RiskSpectrum SDP tool since 2020. At Sanmen, a pilot application of the SDP tool started in January 2022.

Below is an example of an SDP for an event analysis in Sanmen. The event is "diesel generator 02A fails to run". The software includes several questions organised in a guide that the user follows.

The first is about filtering the original event. The user answers the following predefined question unique to Sanmen:
"Is the finding associated with the operability, availability, reliability or function of a mitigation system?", see figure 3, below.

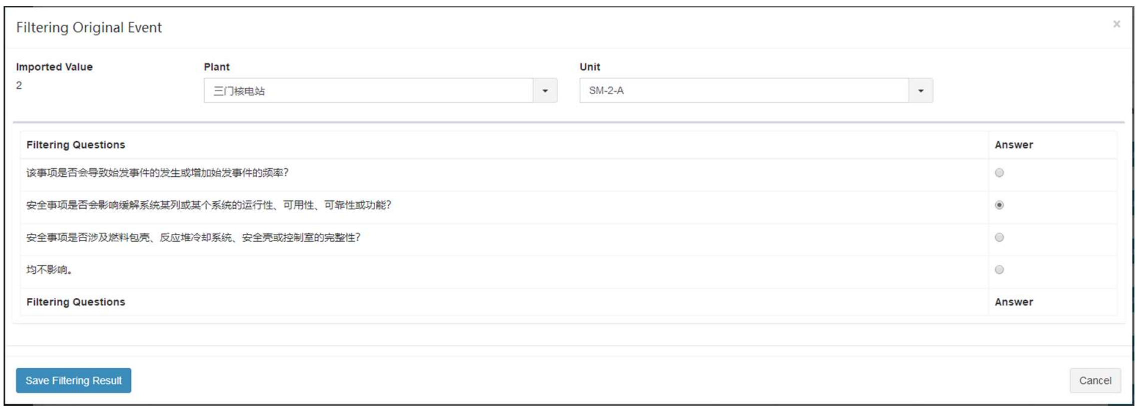



*Figure 3. Dialog window for filtering of the original event*


*Figure 4. The SDP event details window*

Next is the SDP Phase 1: Identification and impact, see Figure 5, below.

The impact is identified in the guide under "Mitigation System":

- Degradation of core residual heat removal performance
  - Primary circuit
    - Normal residual heat removal system
    - Passive residual heat removal heat exchanger
  - Secondary circuit
    - Start-up feedwater system

- Protect the water capacity of the primary circuit
    - Chemical and volume control system

Under "The selection of safe elements" questions about safe elements are asked:

1. "Is the safety issue attributable to a design or qualification defect, but it can be confirmed to not lead to loss of operability or functionality?" -> NO
2. "Does the safety element indicate that a system has lost its safety function?"-> YES

Based on the answers applied in a user defined algorithm, see figure 6, the outcome is for this event to go to Phase 2.

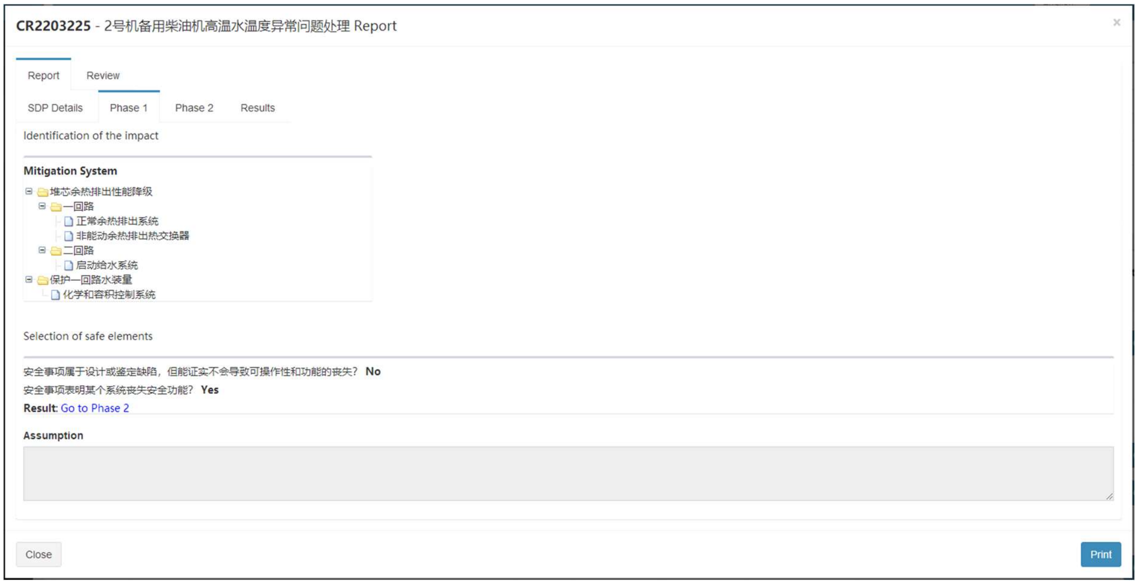



*Figure 5. Phase 1, Identification, and impact*

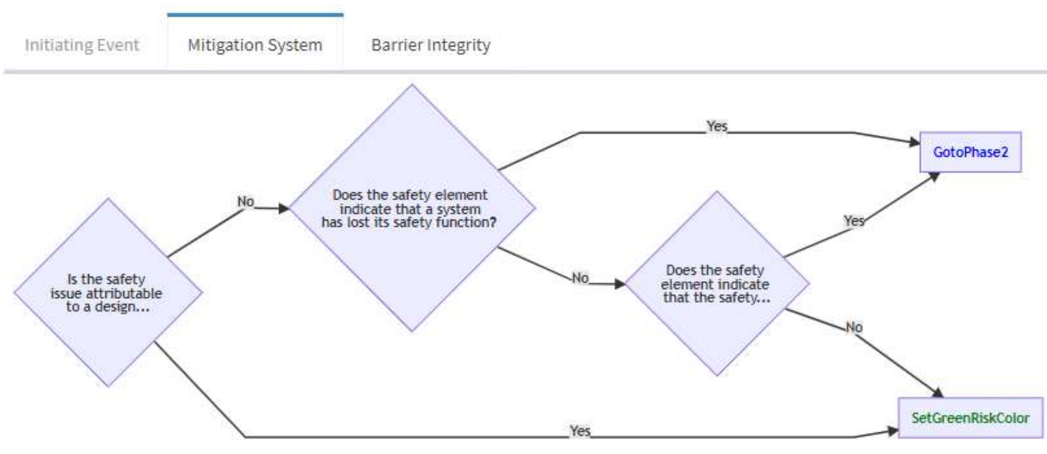



*Figure 6. User defined algorithm on how to process answers regarding Mitigating Systems and Selection of safe elements.*

In SDP Phase 2, Evaluation of impact using PSA, the user is requested to indicate the type of impact, duration and failure mode. See figure 7, below.

In this example, the following selections are made.

- Type 2: "Degradation over a time period", and the failure impact duration is 3 days
- No initiating events are impacted
- Failure mode (basic event) ZOS-MG-02A-FTA is selected

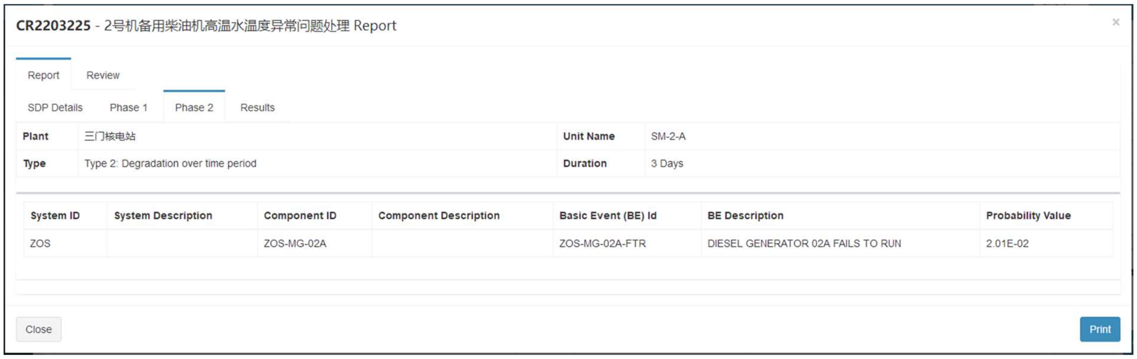
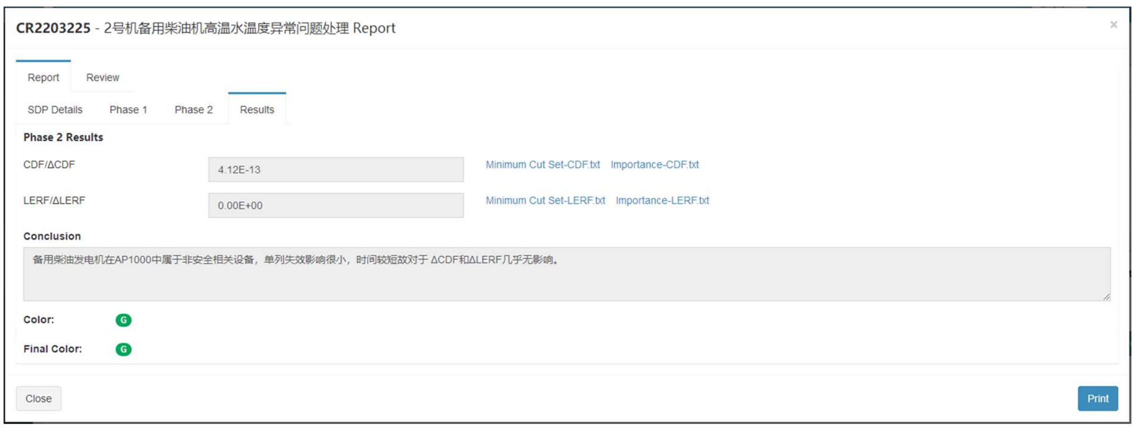


*Figure 7. Impact evaluation settings for the PSA model*

Finally, results using the PSA model can be produced and displayed in the final tab of the guide. The quantitative results and significance colour code are generated and displayed. Minimal Cut Set list and importance results are accessible from the RiskSpectrum SDP interface.




The colour code obtained when all the steps have been done are based on user defined settings. These are defined in a separate dialog window in RiskSpectrum SDP, see figure 8, below.
The baseline risk for each consequence and the significance rating thresholds are added here.

Sanmen in their initial validation tests found that the CDF/LERF and the increase in CDF/LERF for analysed significant events prove to be very low, indicating a calibration error in the customisation of the tool. For this reason, their settings have been changed accordingly.

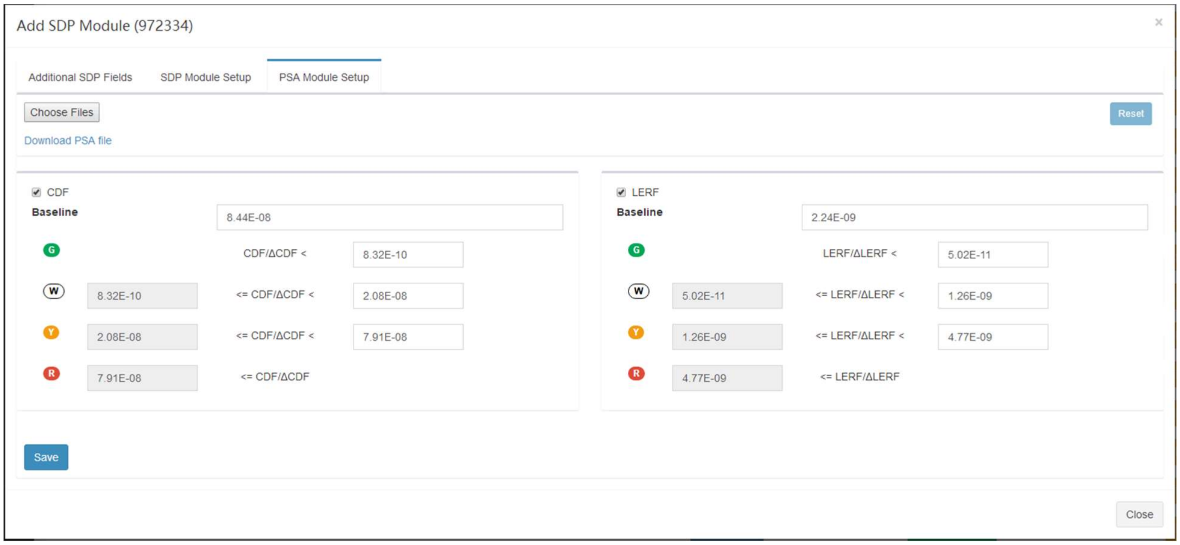



*Figure 8. The Significance Rating Settings window*

## 5. DIFFERENCE BETWEEN A RISK MONITOR AND A TOOL FOR SDP

A risk monitor based on a PSA/PRA model is used for calculating CDF/LERF and changes in risk, and, outside the U.S., to verify compliance with technical specifications detailing the deterministically determined conditions for operations at nuclear power plants. The purpose is typically to manage plant operational safety, support scheduling activities, achieve greater flexibility in plant operations and to provide justifications for carrying out maintenance on-line.

The SDP is designed to analyse and determine the significance of events that have occurred or inspection findings. For this purpose, the baseline PSA/PRA model is used when escalated beyond a screening analysis, and calculations of the change in CDF/LERF are used for determining the significance of the events or issues that are analysed. Detailed plant configuration is incorporated as needed and the event-specific timeline can be considered.

## 6. CONCLUSION

RiskSpectrum SDP provides assistance for the steps in the SDP. Events that are found to be of low significance are screened out but stored in the database for documentation purposes. Other events, that are determined to be of significance, are further analysed following the SDP. All details of the events are documented in the tool and based on this information, the impact on risk is quantified using the PSA model.

RiskSpectrum SDP uses a baseline PSA model to rank events that have occurred at a nuclear power plant by significance to safety. The software is designed to offer a customisable step-by-step guide that asks questions relevant to the status of the plant at the time of the discovered event. It focuses on the three cornerstones: Initiating Event, Mitigation System and Barrier Integrity. The baseline PSA model is used and depending on the answers provided in the step-by-step guide, the baseline PSA model is automatically adjusted to reflect the plants configuration and system status at the time of the event.

The purpose is to identify and analyse the significant events and the impact they may have had on safety.

**Acknowledgements**

Sanmen nuclear power plant has been very supportive in producing this paper and have provided information and results from their initial use of the RiskSpectrum SDP software. The evaluation of their pilot project implementation of RiskSpectrum SDP is, at the time of writing this paper, still ongoing.

**References**

[1] US NRC Website: https://www.nrc.gov/reactors/operating/oversight/rop-description.html
[2] US NRC Inspection Manual Chapter 0308, Reactor oversight process basis document 09/04/14.