July 2022

PSAM 16

Back together in Hawaii

PSA for Small Modular Reactors

RiskSpectrum has the tools

Next generation tools

Model Based Safety Assessment is the future

RiskSpectrum Magazine

RiskSpectrum

July 2022

Johan Sörman,
Editor-in-Chief

We need to share and learn. We need to improve. And this is best done together

In a world that is becoming more polarised we need to continue to share experiences within the global nuclear domain and safety is a critical component.

Ola Bäckström,
RiskSpectrum Product Manager

The outcome of a risk assessment is something that can affect many people. It can affect the people that are directly involved and are operating the system (for example a nuclear plant), but it can also affect third persons (the general population). In the nuclear domain this is especially true since the risk that needs to be managed (release of nuclear material) does not see space or borders.

A nuclear renaissance could be on the horizon. With countries globally identifying ways in which they can achieve Net Zero 2050 ambitions, nuclear is becoming a more frequently discussed and viable option. Aside from a need for more environmentally sound power generation options, the question around energy independence is not one that is being taken lightly. Many countries are investing in the development of SMR technology, but traditional nuclear power is also expanding.

The need for continuous and improved collaboration across industry will be required to drive forward the nuclear renaissance. We need to share and learn. We need to improve. And this is best done together. The risks that we are analysing are global. We require better solutions, better accuracy, easier ways to model and maintain PSA models. In short, we need evolution.

These themes are precisely what the PSAM 16 event is for. So that we can get together with the right people and discuss how we, as an industry, evolve and progress to ensure the future viability of nuclear assets – and in our case, how RiskSpectrum can improve the operation, maintenance and safety of assets new and old. We are sure that we're in for an incredibly interesting event.

We're looking forward seeing you at the RiskSpectrum booth where our team is on hand to discuss how we can support your business.

Ola Bäckström

RISK SPECTRUM

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PSAM 16 – Back together in Hawaii

It's been two years since the last PSAM conference, which moved online in 2020. What are you most excited about now that you are welcoming people back in-person?

Dr. Smith: It's exciting and scary at the same time. Most events have been online for the last two years, so coming to PSAM16 may be the first trip in two years for many people. While planning a conference during COVID has been a little worrying, welcoming our attendees back is so exciting and we can't wait to see everyone again.

Dr. Paulos: This is us getting the band back together in a sense after Curtis and I chaired PSAM in 2014. I know some of us have not travelled a great deal in recent times so the chance to go out to such a great location and see everyone in person again is so exciting.

LEFT: Dr Curtis Smith, General Chair PSAM 16
RIGHT: Dr Todd Paulos, Technical Chair PSAM 16

What are the key themes and issues that you hope to highlight at PSAM16 this year?

Dr. Smith: I think it's the diversity of speakers and topics we're seeing this year. There are a lot of different applications and new technologies, like AI and machine learning, which we can't wait to hear more about.

Dr. Paulos: There's so much diversity. The goal of PSAM from day one has been not to just focus on nuclear, but to get everybody involved. This year absolutely embodies that.

Are there any speakers or topics that you are particularly excited about at this year's event?

Dr. Smith: We wanted to reflect on that to showcase where we came from as an organization and as a community so we have a special session on a little bit of the PSAM history and some of its key figures.

Dr. Paulos: I'm excited that NASA has stepped up and sponsored us, and we'll have Nancy Lindsay the reliability, maintainability deputy fellow for NASA coming to speak.

There is a huge emphasis on the energy transition and more environmentally sustainable operations, how do you think that risk, reliability and safety can play a role?

Dr. Smith: It's imperative that we all do more to focus on creating environmentally sustainable operations and you're starting to see that come out in terms of topics. I know we're going to have some special sessions on some of the work that we're doing with nuclear power plants and how we can use the excess heat from the power plants to make hydrogen for transportation or other manufacturing uses.

Dr. Paulos: I've been so happy with the way the conference is exploding in terms of the diverse topics and speakers and as Curtis says we're really seeing the energy transition theme come through in some of our topics.

You're hosting the event in Honolulu, Hawaii. Is there any significance in the choice of location?

Dr. Paulos: The Sheraton Waikiki hotel is just a fantastic place to go. When we were here in 2014, we had such a positive experience from start to finish. It's not just a place to have a conference, it's a place to where you would want to travel. The timing of this conference is right around the 4th of July holiday and I know a lot of my colleagues are all going to stay in Honolulu for the festivities… plus everybody likes to send out a Christmas card of them in Hawaii!

Dr. Smith: It's a beautiful city and we're confident of a beautiful PSAM conference there. Safe travels to all our attendees and we can't wait to see you here!

Quick guide to RiskSpectrum papers

Following a challenging few years, we are delighted to be returning to the first post-pandemic PSAM conference. This time the RiskSpectrum team has produced a mix of papers about improved algorithms, new tools and methods to address new technology and the increasing demand for efficiency and effectiveness. In addition to visiting us at the RiskSpectrum stand at PSAM 16, you are most welcome to come and listen to the session where we will be presenting. Below you can find each paper's ID and a short description.

Alex Moga,
RiskSpectrum Software
Sales Representative

Y178: CNNP Trip Monitor

This paper outlines the findings of the implementation and use of RiskSpectrum RiskWatcher trip monitor at the Qinshan nuclear power plant in China *(see also page 5)*.

PA128: Implementation of Conditional Quantification in RiskSpectrum PSA

Conditional quantification of basic events in Probabilistic Safety Assessment (PSA) presents a flexible, simple, and transparent tool to model:

1. dependencies between operator actions,
2. correlations between events in PSA, e.g., incurred by seismic events, and
3. common cause events.

Experiments on industrial-sized models show that our method, compared to the standardly used HRA event replacement in post-processing, can efficiently generate minimal cut sets which would be otherwise missing or discarded.

PA131: Control Logic Encoding using RiskSpectrum ModelBuilder

This paper exemplifies the power of Figaro coding language for Digital I&C for Nuclear Power Plants allowing dependability experts to formalize and codify dependability knowledge for a specific domain or application type. It can then be used by non-experts in the form of a component library to build any model from this domain.

JO179: Software for Significance Determination Process

RiskSpectrum SDP 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.

OL137: Use of PSA for Small Modular Reactors

This paper discusses topics related to PSA quantification typical for SMRs, like the need to manage longer mission times, multi-unit risk and digital control systems.

PA127: Transparency of dynamic calculation approaches

(abstract and presentation – no paper)

Scalable methods for dynamic risk analysis are examined and options for increasing transparency of results and effects of dynamic features in models are explored showing how to gain an equal degree of confidence in dynamic approaches for modelling and analysis as in the static ones.

WE77: RiskWatcher Connector

This paper outlines the findings of a project for developing and implementing a tool for mapping and transferring information from plant logs and planning tools automatically into a risk monitor at Sanmen Nuclear Power plant in China. The tool reads event log data from a data source, converts, and merges it with event logs in the risk monitor database.

Preventing trip at Qinshan Nuclear Power Plant

China National Nuclear Power (CNNP) has installed RiskSpectrum RiskWatcher Trip Monitor at nine nuclear units at Qinshan ll nuclear power plant. This is the first application in China to evaluate the risk of trip using quantitative analysis.

Mr. Yi Zou Senior software developer, RiskSpectrum AB

To date, RiskSpectrum RiskWatcher has been installed at a total of 14 nuclear power plant units in mainland China. RiskWatcher is a risk monitor solution that allows operators to effectively monitor and analysing the risk of nuclear accident at nuclear stations.

In 2017, CNNP was also provided with a new version of RiskWatcher designed to analyse the risk of 'tripping' the reactor. 'Tripping' the reactor is the terminology applied to the risk of an automatic shut-down of the plant. As part of a pilot project, RiskWatcher trip monitor was installed and implemented for trial use at CNNP nuclear units Qinshan phase II, units 1&2.

After the successful implementation of RiskWatcher Trip Monitor at Qinshan phase II, units 1&2, CNNP started a project for the implementation of RiskWatcher Trip Monitor at the remaining 7 units at the Qinshan site. In September 2021, an updated version of RiskWatcher Trip Monitor including additional functionality requested by CNNP was provided. The implementation was completed in December 2021. Beginning 2022, all 9 units at Qinshan phase I, phase ll and lll was equipped with RiskWatcher Trip Monitor.

The trip monitor tool allows operators at nuclear stations to:

- Assess the online risk of reactor or turbine trip (loss of production)
- Assess the offline (planning) risk of reactor or turbine trip (for assessment of maintenance and test activities)
- Identify the critical components, or so-call Single Point Vonerability (SPV), whose single failure will lead to reactor or turbine trip
- Evaluate qualitatively the status of key system/functions

"CNNP Nuclear Power Operations Management Co., Ltd" is a subsidiary of the CNNC group. CNNC (China National Nuclear Cooperation) is the one of the two main nuclear utility companies in China, with 24 nuclear units in operation and 6 under construction. CNNP Nuclear Power Operations Management Co., Ltd is providing operation support services mainly to Qinshan site (9 units in operation) and to other CNNC sites.

Teamwork from start to finish

RiskSpectrum PSA 1.5 brings a major update of the flagship product from the RiskSpectrum suite. Apart from usual fixes of issues mostly related to special use cases, the new version offers several new features improving the existing functionality or providing brand new possibilities for modelling and analysis.

TOP: Dr. Pavel Krčál, RiskSpectrum Methods Research Lead, RiskSpectrum AB

BOTTOM: Helena Troili, RiskSpectrum Development Team Manager, RiskSpectrum AB

Developing a major RiskSpectrum PSA version is always a big project. The team dives with excitement into the product architecture to investigate the best ways of including different features in the product. For the calculation engine – RSAT – this research has often begun long time before we decide to include a feature in the concept for a specific release. When the development sets off, everyone is keen to dig deeper into the different strategies of implementation and architecture and to start coding and testing.

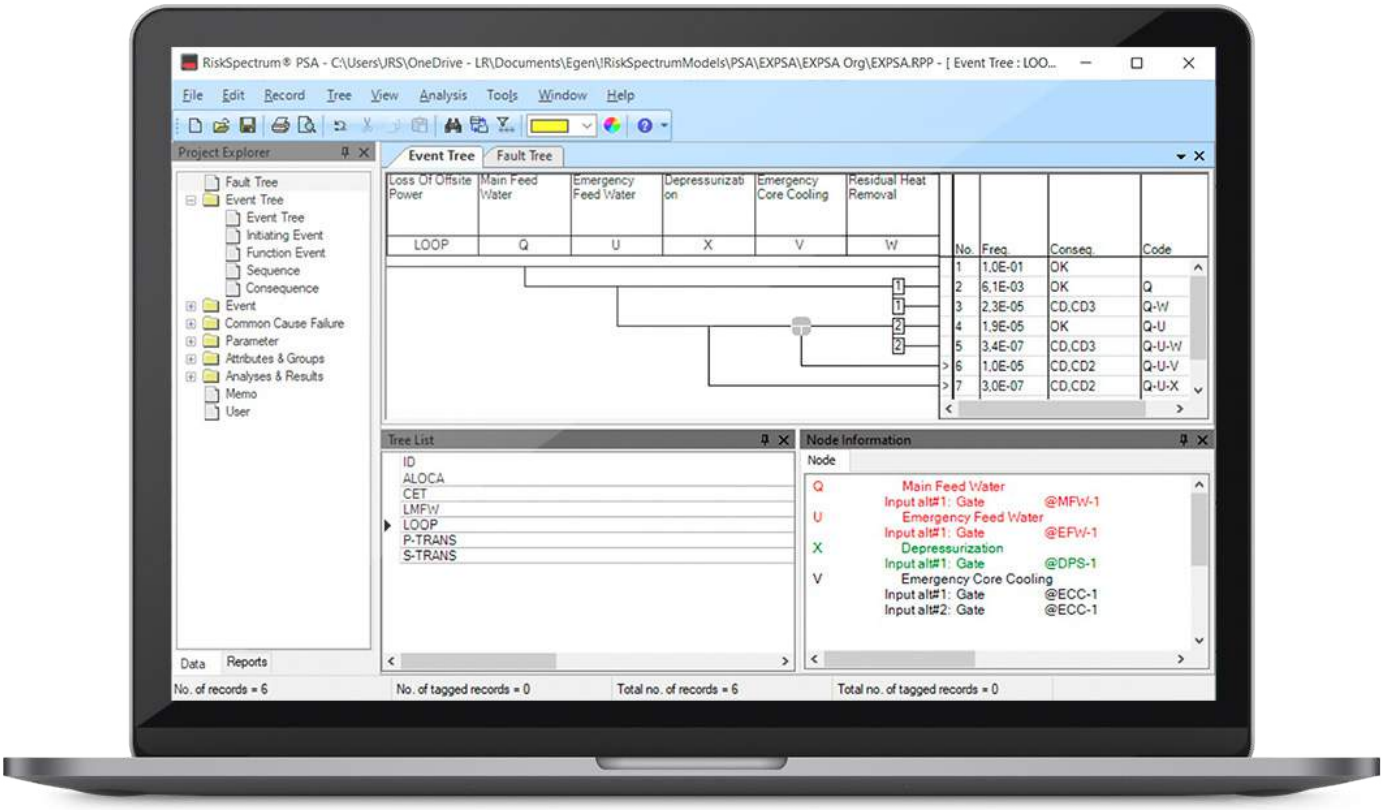
The pandemic brought the team closer together

The project soon had to deal with the pandemic, which brought its own challenges for individual team members. The team adapted quickly to remote work. Suddenly, geographical distances played a much smaller role as most of the discussions moved to the virtual space. This paradoxically strengthened the feeling of being one team, even though distributed to different locations.

Fitting new pieces of the puzzle

Even relatively straightforward changes like extending the length of record IDs to 50 characters require good care, especially in synchronising all plug-ins called from RiskSpectrum PSA. More complex features, such as enabling specification of MCS BDD quantification and parameters per analysis case instead of global settings in the previous version, extending inputs to Initiating Events also to MCS Analysis Case results, or a brand-new possibility to quantify basic events dependent on

The project soon had to deal also with the pandemic situation, which brought its own challenges for individual team members. The team adapted quickly to remote work.



other events in the same minimal cut set, affect both the database, the graphical user interface, and the calculation engine. Subject matter experts discuss with the development team to fine-tune both user experience and correct functionality in all special cases.

Increasing precision

The new version of RSAT released together with RiskSpectrum PSA 1.5 implements all changes relevant for calculations introduced in PSA, but it also improves minimisation of cut sets in presence of success modules. This increases precision of results in large models with linked event trees and the simple quantitative treatment of event tree success. We are sure that minor usability improvements such as more reliable progress bar for large sequence and consequence analysis cases will be appreciated by users.

Growing the team

Not only new versions of products stand in the focus of the development team. We continuously improve the way in which we work and is one aspect of our agile development process makes us especially proud. The growing Quality Assurance (QA) group within our team becomes an integral part of the process from an early stage of the project, bringing the testing perspective to the attention of the whole team even before the implementation has started. This will improve the product quality and development efficiency in coming versions.

Celebrate the release

Final steps of a release are always a bit ceremonial. We check for the last time that everything is at its place, including the installation package, manual updates, documentation, and the appropriate coverage of the performed tests. Then we can sign off the new version and celebrate that all improvements in RiskSpectrum PSA are finally made available to clients.

RiskSpectrum 1.5

All new functionality, changes and bugfixes are listed in the Release History section in the Help file of RiskSpectrum 1.5. Here are the highlights:

- Conditional Quantification
- Long ID support
- MCS BDD Settings per analysis case
- Apply a different quantification to already generated MCS
- Using MCS analysis case results as input to initiating events
- Support CCF events in MCS Post Processing Action rules

All licensees with a valid Maintenance & Support agreement will receive the upgrade to RiskSpectrum PSA 1.5.0 at no cost.

The RiskSpectrum community helps improve RiskWatcher

Those who are familiar with RiskSpectrum RiskWatcher will know that it boasts more than 15 years' heritage and in the last few years it has seen significant additions and updates to include many new features, developed in collaboration with our most advanced and proactive clients.

Dr. Wenjie Xia, Principal Software Developer, RiskSpectrum AB

RiskSpectrum RiskWatcher delivers real-time risk intelligence to inform vital operational decisions. It helps to assess and manage risk at vital assets like nuclear power stations and offshore drilling rigs, and has been optimised to work with probabilistic safety assessment (PSA) models created in RiskSpectrum PSA.

The most recent release of RiskWatcher sees the addition of several great features that have been developed through close cooperation with major energy companies globally.

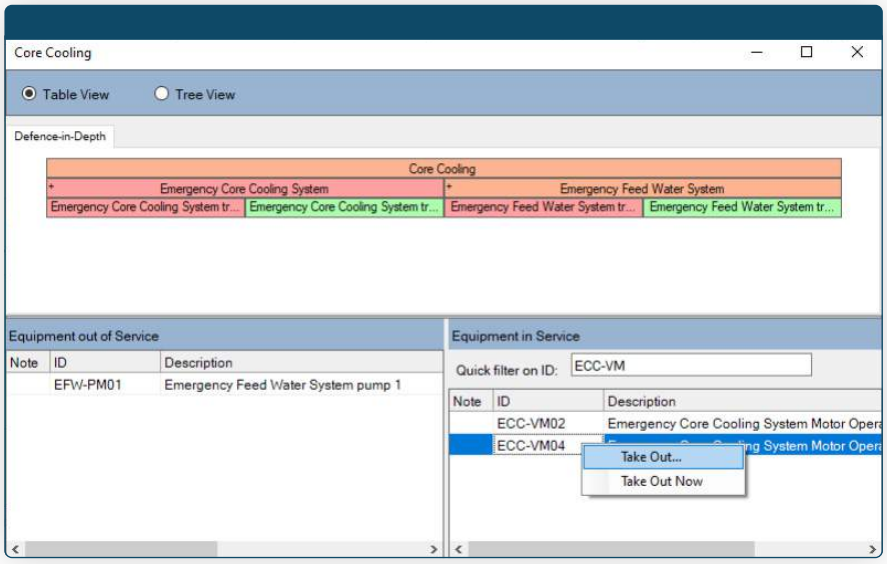


Figure 1. Take equipment out of service with a simple right-mouse-click

Figure 2. Quick access to frequently used commands.

Reducing manual work

One key functionality, to reduce the need for manual work, is facilitating importing data from external data sources (planning, work order, etc.) to RiskWatcher. This has been realised by the development of a separate tool – which seamlessly integrates the two – called RiskWatcher Connector *(see also PSAM 16 paper WE77)*.

RiskWatcher Connector can be configured to read data sources in many different formats, for example from your planning tools, auto log, real time systems, etc. It has a smart interface for matching information to be imported with already logged events in RiskWatcher, validating data and removing events that are in conflict.

Software interface is key

Major improvements have been made to increase the operability of the software, providing a better user interface experience. These improvements in the user interface have been reviewed by human factors experts and new functionality has been developed in cooperation with nuclear power plant staff and include:

- Frequently used commands have been added to the toolbar, including calculation, input event, etc. *(see Figure 2)*
- The background colour of the header banner in the interface can be changed and the reactor name can be added
- The Operations and Planning tabs font size has been increased.
- When in client server mode the visible feedback for calculations running on the server has been enhanced.

- Several improvement have been made to the visualisation of the qualitative risk status, for example use of tabs for better overview, enhanced ways of presenting the tables, inclusion of ways to present impact in addition to colour (colour blindness) and creating links to external tables *(see Figure 4)*
- Ability to take components out of service (and restore) directly from the qualitative risk overview *(see Figure 1)*

Different risk settings for different plant operating states

In Figure 3, the risk graph shows that it is now also possible to specify different thresholds between the colour bands for different plant operating states. Baseline risk, current risk, Allowed Configuration Time (ACT) and cumulative risk are all calculated based on the actual plant operating states and its settings.

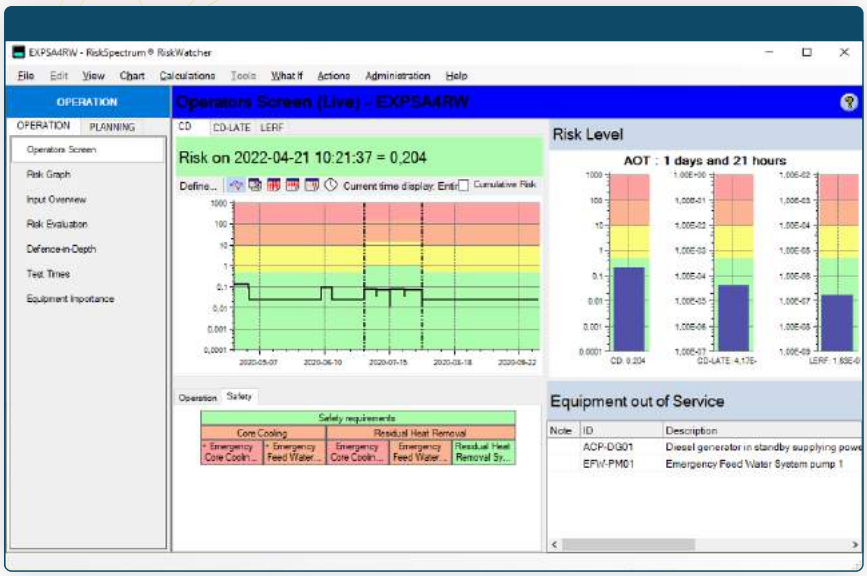


Figure 3. The Operations and Planning tabs size has been increased and you can change the background colour of the header banner.

Qualitative analysis now includes messages (OTS) and guidance documents

The qualitative assessment display includes the possibility to present messages related to the current system availability or compliance with technical specifications. These messages are user defined and connect to the logic structure representing the qualitative assessment. You can also link documents relevant to the current system availability or procedures relating to the technical specifications.

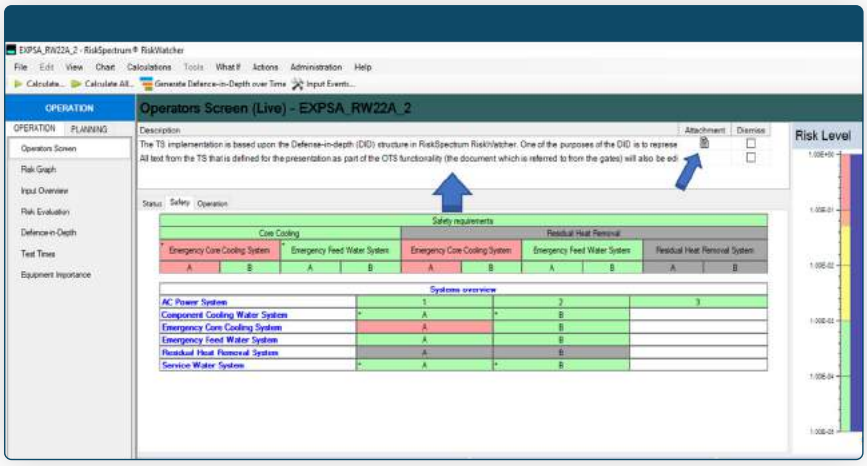


Figure 4. User defined messages and links to documents, relevant to the current configuration, are available in the qualitative display.

The results of the calculation of Allowed Configuration Time (ACT), previously denoted AOT in RiskWatcher, now also includes a graph displaying the time left in the configuration. The operator can monitor the accumulate risk from the start of the component outage or operation exception to its restoration to normal operations *(see Figure 5)*.

The ACT is based on a cumulative risk calculation where the risk is accumulated from the time the component was taken out of service or an operation exception is started to its restoration to normal operations.

These changes have been brought in with the intent of meeting expectations of the requirement from new Chinese technical policy on NPP configuration risk management and to provide ACT guidance in line with RITS 4b as defined by the US NRC but can be used on assets globally.

Consideration of potential common cause failure (CCF)

Component unavailability can be due to maintenance (planned) or corrective action/maintenance (unplanned). In case the unavailability is caused by corrective maintenance, there is a risk that

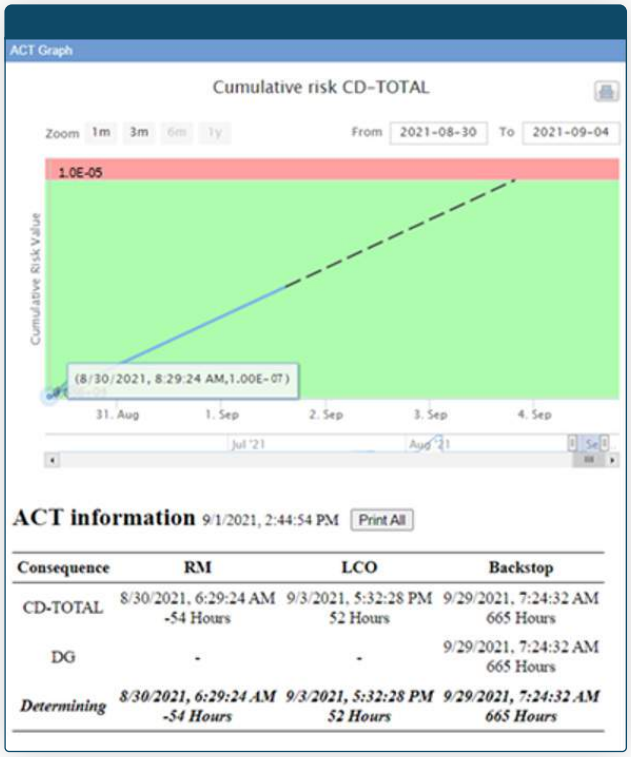


Figure 5. A separate view has been added for the operators to monitor how risk accumulates during an online maintenance activity.

Figure 6. If a component is found to be unavailable and it cannot be ruled out that it is due to a CCF, the user can check the box "CCF related".

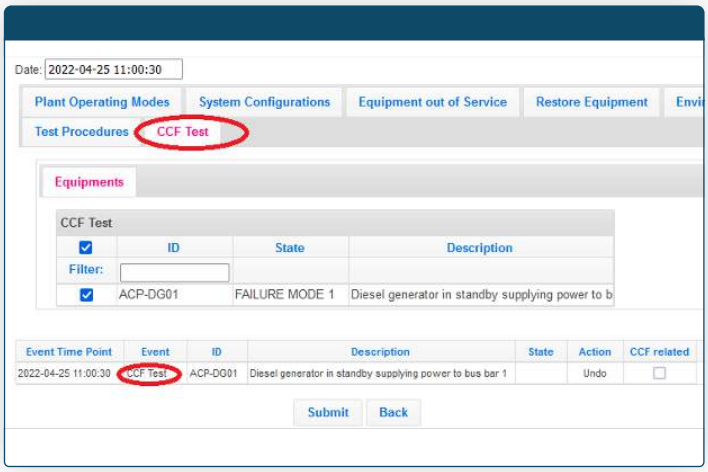


Figure 7. An additional tab for CCF Test has been added to enable the user to ad the test of redundant components

redundant components may be affected by the same failure.

It is common practice to test redundant components in a nuclear station when an important stand-by component is found to be unavailable. If the redundant components are working as intended, it can be assumed that the reason for the unavailability is not due to a common cause failure (CCF).

In RiskWatcher, it is, by default, considered that when a component is taken out of service for maintenance it is a planned action, i.e., not CCF related. However, the user can actively take out a component as CCF related, as shown in Figure 6.

In this case, the unavailability of the redundant components is increased to the conditional probability represented by the CCF factor that the components have been assigned in the CCF group it belongs to.

When the redundant components have been tested and it can be confirmed that there is no CCF causing the unavailability of the component, the unavailability of the redundant components can be reset to their default values.

RiskSpectrum RiskWatcher has seen several advancements and adaptions over the years, and through collaboration with our clients and partners, we're confident that the latest release will enhance user operations and ultimately reduce risk for nuclear operations, worldwide.

The operator can monitor the accumulate risk from the start of the component outage or operation exception to its restoration to normal operations.

Model Based Safety Assessment for effective and efficient risk management

In July 2020, NPP Gösgen-Däniken AG (KKG), Switzerland, launched a project to refurbish and restructure its plants probabilistic safety assessment (PSA) model using RiskSpectrum ModelBuilder. Dusko Kancev of KKG and Gerben Dirksen of Framatome GmbH explain how.

TOP: Dr. Dusko Kancev, PSA Specialist, NPP Gösgen-Däniken, AG

BOTTOM: Dr. Gerben Dirksen, Senior Advisor for Nuclear Safety at Framatome GmbH

The main purpose of the project is to progress the current KKG PSA model into the RiskSpectrum software suite, including its update in terms of consideration of all additional plant modifications, model & documentation review, necessary model & documentation corrections and increasing the level of modelling detail, as well as improving the level of modelling and documentation consistency.

The goal is to achieve a consistent and comprehensive PSA model and documentation, compiled within a state-of-the-art PSA modelling software environment, to perform the relevant PSA applications and fulfil the national regulatory requirements more effectively and in a more time-efficient manner.

Improving traceability and simplifying review

In classical PSA, fault tree (FT) and event tree (ET) modelling is performed in a dedicated probabilistic safety assessment tool, such as RiskSpectrum® PSA. Although such models are well understood by PSA specialists, they have low accessibility for third parties not familiar with the detailed fault tree logic. This makes it difficult to perform independent verification and validation (V&V) reviews of the model, which is often performed based mainly on the results. This low accessibility also makes it difficult to explain and justify the results of the PSA to third parties such as plant management or regulatory bodies.

The application of RiskSpectrum ModelBuilder (RSMB) offers high grade of consistency in PSA studies; the modelling assumptions are systematic and traceable, and a higher grade of homogeneity among the system models is achieved. Also, once the PSA model is built using the RSMB tool, a rapid, efficient, and systematic model update potential is ensured for the future.

Outlining the scope and the methodology

KKG embarked on this large-scale PSA project of migrating the KKG's existing PSA model as a joint project with Framatome GmbH. The first phase of the project encompassed the modelling of internal events, full power, low power and shutdown states for both Level 1 PSA and Level 2 PSA.

A methodology, tailored for this project, was developed by Framatome GmbH regarding the application of the RSMB tool on the system-level PSA modelling and comprises the following steps:

- Creation of KKG plant-specific knowledge base (KB) for the PSA-relevant components
- Visual marking of the designated PSA-relevant system functions in the corresponding piping and instrumentation diagrams (P&ID)
- Failure mode and effect analysis (FMEA)
- Automation of the import process into RSMB

Well-documented and traceable reliability models of plant systems can be created using RSMB to improve the automation, acceleration and standardisation of the risk and reliability modelling process.

- Creation of the RSMB flow diagram models
- Automatic generation of fault trees.

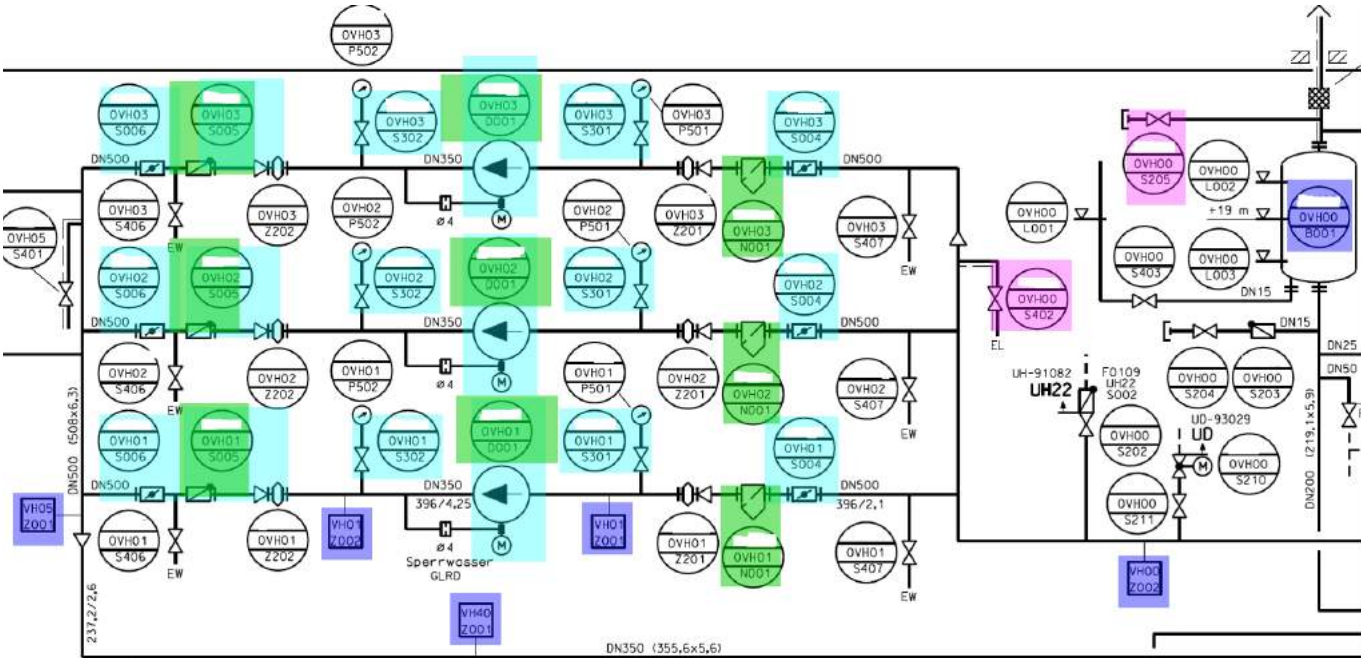
Creating the Knowledge Bases

In RSMB, the inherent logic of systems, structures and components (SSCs) is defined in a knowledge base (KB), written in the probabilistic programming language Figaro. A plant-specific KB encompasses the various SSCs that are to be considered by the system modelling. For the KKG project, Framatome developed two dedicated KB (one for hydraulic systems, one for electrical systems).

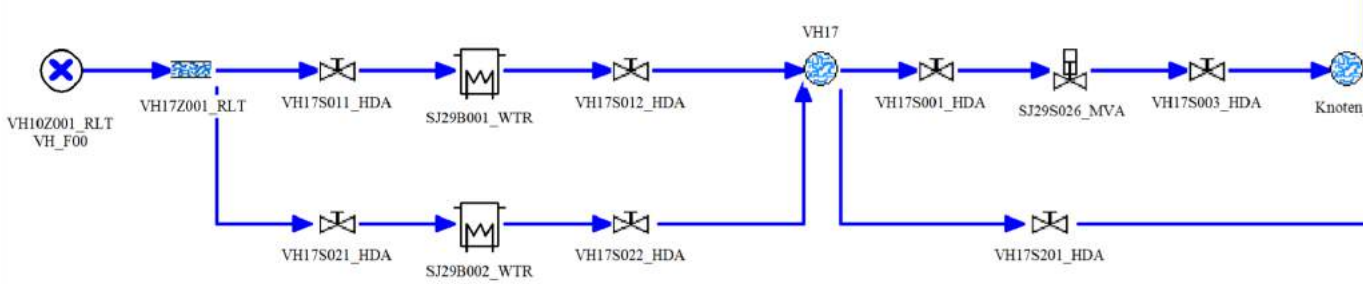
Automating the building of the RSMB model

The next step was the identification and designation of the plant's PSA-relevant systems and system functions. Each system's P&ID is used as an input and the components are marked with different colours according to a pre-agreed convention corresponding to the different components' failure modes.

In parallel, FMEA is also performed for that given system. A FMEA database has been created for each analysed system, which is in alignment with the marked P&ID. Framatome's dedicated software tool, ScanAKZ, enables the automated import of the marked P&ID to the FMEA database



Part of the system flow diagram of the conventional closed cooling water system (VH) – marked P&ID according to colour convention



Part of the RSMB model for the VH system study

and creates validation and verification protocols. The Microsoft Access based FMEA database comprises the following component information: ID, type and description, system affiliation, relevant system functions as well as failure modes for each system, PSA relevance as well as intra- and inter-system dependencies (e.g., power supply, I&C, component cooling and common cause component groups).

Further on, a dedicated RSMB-study was created for each PSA-relevant system. As the number of components to be modelled in the PSA is very large, an automated procedure to import the information from the FMEA into RSMB was developed. By using this automated procedure, all the components marked in the P&ID are imported in the RSMB study including their system tasks for the different system functions, and the relevant interfaces such as power supply and relevant reactor protection signals. Moreover, the components are aligned in the RSMB study similarly to the system P&ID to assist the PSA analyst's work.

Generating the fault trees

After finalising the RSMB model, the undesired event (UE) corresponding to the top event in the fault tree (FT) to be exported is defined. The UE defines the system failures for which one would like to generate a FT. The UE trees are defined using the same FT logic (OR-, AND, K/N-gates) as the FTs within RiskSpectrum® PSA.

After the UEs are defined, the corresponding FTs within the RSMB study can be compiled. The system configuration is defined from a profile (mandatory) and from variants (optional). The user selects the required system profile, possibly applying variants via house events, as a sub-configuration within the same profile, or overloading those variants into the selected profile (i.e., overriding the configuration's setting with the one of the variants). Basically, the RSMB tool allows defining different configurations that eventually can be used in different cases when the FTs are generated.

Naming rules are applied automatically

Once the RSMB study is finalised and the FT is generated within RSMB, they can be exported to the RiskSpectrum® PSA plant-level model. One can choose which RSMB trees are to be exported to the RiskSpectrum® PSA target project and by applying naming rules, consistent naming of basic events, top gates and intermediate gates is ensured.

RiskSpectrum ModelBuilder is a software tool for building and maintaining risk, reliability and availability models. Building on the strength of KB3, originally developed and used by EDF for risk analysis across their critical infrastructure, RSMB accelerates the generation of risk and reliability analysis by automating and standardising the risk modelling process. By using this platform, EDF experienced productivity gains of 40-80%. As such, RSMB was commercialised by RiskSpectrum AB in 2019/2020 and rendered compatible with the RiskSpectrum PSA platform as part of the RiskSpectrum suite.

Three key features of RiskSpectrum ModelBuilder

Well-documented and traceable reliability models of plant systems can be created using RSMB to improve the automation, acceleration and standardisation of the risk and reliability modelling process. Key features include:

1. Intuitive drag-and-drop interface to draw systems and subsystems based on the actual P&IDs.
2. Central knowledge base containing standardised definitions of systems, structures and components (SSCs) as well as their functional properties and constraints.
3. Automatic generation of fault trees and other risk models for each system design, with automatic export into RiskSpectrum PSA ready for further analysis and/or PSA-modelling further on, on the plant level.

The future is the product of what we do today

We continue to invest heavily in the development of the RiskSpectrum products. The team is growing, and so are our ambitions. In this article, RiskSpectrum product manager, Ola Bäckström and Pavel Krčál, RiskSpectrum Methods Research Lead, describe some of the latest introductions and the themes for years to come.

TOP: Ola Bäckström, RiskSpectrum Product Manager

BOTTOM: Dr. Pavel Krčál, RiskSpectrum Methods Research Lead, RiskSpectrum AB

RiskSpectrum PSA 1.5.1 – Staying ahead of the game

RiskSpectrum PSA is our main product and is a leading platform for probabilistic risk assessment. With version 1.5.0 we have introduced some new and improved functionality, including:

- conditional quantification
- MCS BDD settings per analysis case
- quantify cutset results without regenerating the MCS list
- MCS analysis cases as input to initiating events
- support CCF events in MCS post processing actions
- improvements to the success module identification and support for long IDs

Conditional quantification enables better implementation of primarily human reliability analysis (HRA) dependencies but can also be used to implement a different type of Common Cause Failure (CCF) modelling. As part of the PSAM 16, we will be presenting the conditional quantification capabilities during the conference.

As well as changes in the user interface and bug fixes to the platform, we are also making changes behind the scenes. RiskSpectrum PSA 1.5.0 is on the .NET framework 4.6.2 and uses SQL server 2012 (to be able to operate on older Windows OS), but the RiskSpectrum PSA version 1.5.1 has now been updated to the .NET framework 4.8 and use SQL server 2019.

The most significant improvements, though, will affect the calculation engine – RSAT – with an ongoing focus on calculation speed. Recently we have observed a growing number of models with increasingly high complexity, driven by model completeness, accuracy and modes of operation. Paired with the use in risk monitors this puts even more emphasis on calculation speed. A lot of effort has been, and will continue to be, put into accelerating the enhancement of the calculation speed.

RiskSpectrum I&AB for proper inclusion of repair

Special focus has been on improving the accuracy in which we can represent

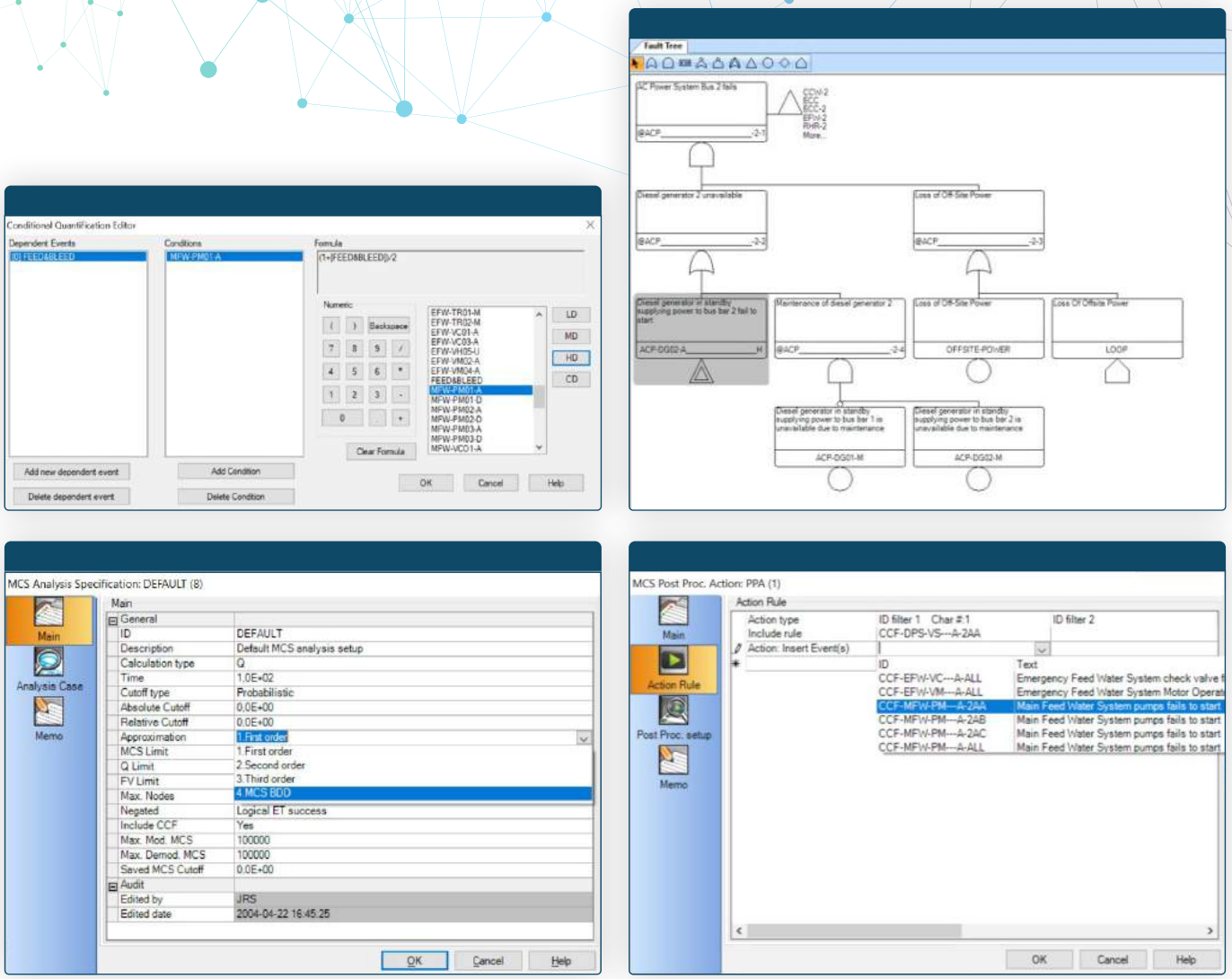


Figure 1. Examples of improvements in PSA version 1.5.0. From top left: Conditional quantification, long ID implementation. From lower left: Specification of quantification approach by analysis case, CCF in post processing actions

the reality. Different approaches where dynamic features can contribute to better representation are being evaluated. This is particularly of interest in situations where longer mission times are studied, and therefore repair and mitigating actions may be considered more extensively. We have taken some initial steps with the possibility to use the Initiators & All Barriers (I&AB) approach in RiskSpectrum PSA. The I&AB approach would be suitable in situations where you have extended mission times – like for fuel pool cases.

To further enhance the dynamic features in the context of large-scale PSA models we are also developing an approach called bounded repairs. The bounded repairs approach will enable the use of triggers in the modelling – which is an excellent tool to represent for example cold spares.

RiskSpectrum I&AB

RiskSpectrum I&AB (Initiators and All Barriers) is an add-on to RiskSpectrum PSA. It includes a special algorithm developed to:

- Calculate safe, stable end states without introducing mission times
- Account for the possibility to repair equipment with calculations
- Credit grace times in your system

Our expectation is that the use of operational risk management systems will continue to grow and support decision-making during operations.

RiskWatcher evolves thru collaboration

While RiskSpectrum PSA allows you to fulfill regulatory requirements, it is part of the larger RiskSpectrum family and can also be used in conjunction with other solutions, especially in the nuclear domain, such as for configuration risk management (CRM). With RiskSpectrum RiskWatcher we continue to develop the functionality needed for operational risk management, both for risk monitoring of safety aspects as well as trip monitor for increased availability of systems needed for operation.

Working in partnership with our clients has allowed us to not only see where efficiencies could be made, but also work directly with them to receive and implement case specific requests that can be built into the base software offering. The most recent release of RiskSpectrum RiskWatcher is an example of this, in which many new features are embedded and some of which have come directly as a result of working with clients to address their needs. RiskWatcher includes improved capabilities and flexibility in the qualitative risk assessment, the addition of the operational technical specification or messages, allowed configuration time view, different filters and last, but not least, the integration of risk monitors with external systems like planning systems, work order systems and plant information systems. Please have a look at the article on page 8 for more details.

Our expectation is that the use of operational risk management systems will continue to grow and support decision-making during operations. The integration of the systems will be a very important factor to facilitate continued growth.

RiskSpectrum SDP for managing your significant events

While risk and trip monitors use the risk model to estimate the impact of a plan or to assess the current risk, we have also added a tool for SDP (Significance Determination Process) to our portfolio. This tool is developed together with our partner CNNO, China and assist event analysts to both assess and manage findings or events from a risk perspective. RiskSpectrum SDP follows the US Nuclear Regulatory Commission's SDP process to estimate the risk significance of a finding or event. It guides you through the process from an initial finding or event, screen out, phase 1 impact assessment, phase 2 evaluation and phase 3 for a detailed analysis. The process assigns a colour code to each finding or event and the evaluation can be both qualitative and quantitative. All findings or events serve as inputs to the system, and it is therefore an excellent management tool for all findings or events identified. As the tool includes the complete process it is also an excellent system for storing and managing the findings or events.

RiskSpectrum ModelBuilder is the future

The introduction of RiskSpectrum ModelBuilder (KB3) has seen changes to the basis of modelling from the ground up. The use of ModelBuilder can have several applications, due to its flexibility. One of which is the automatic generation of fault trees.

The automatic generation of fault trees enhances quality, transparency, will lead to time savings and will make it possible to engage system experts in the model creation. The article on page 11 describes the use of ModelBuilder for Gösgen nuclear power plant in Switzerland.

ModelBuilder can also be used as a workbench to define your specific toolbox to solve different types of problems. With the ability to use the fault tree calculation engine as well as a Monte Carlo algorithm, other type of problems can also be addressed. For example,

availability simulations such as Petri nets or Markov chains. The calculation algorithms discussed previously will also have a very natural place with ModelBuilder, due to the flexibility in how systems and models can be designed.

We are confident that RiskSpectrum ModelBuilder is the way of the future. It is the tool that will bring digitisation to the risk models.

The development of the RiskSpectrum suite of tools is continuing and accelerating at pace. The coming years will be very exciting.

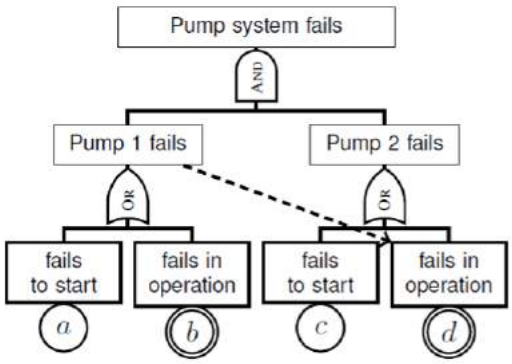


Figure 2. A fault tree with a trigger. Pump 2 is started only when Pump 1 has failed. The OR-gate modelling a failure of Pump 1 is a triggering gate for the basic event d.

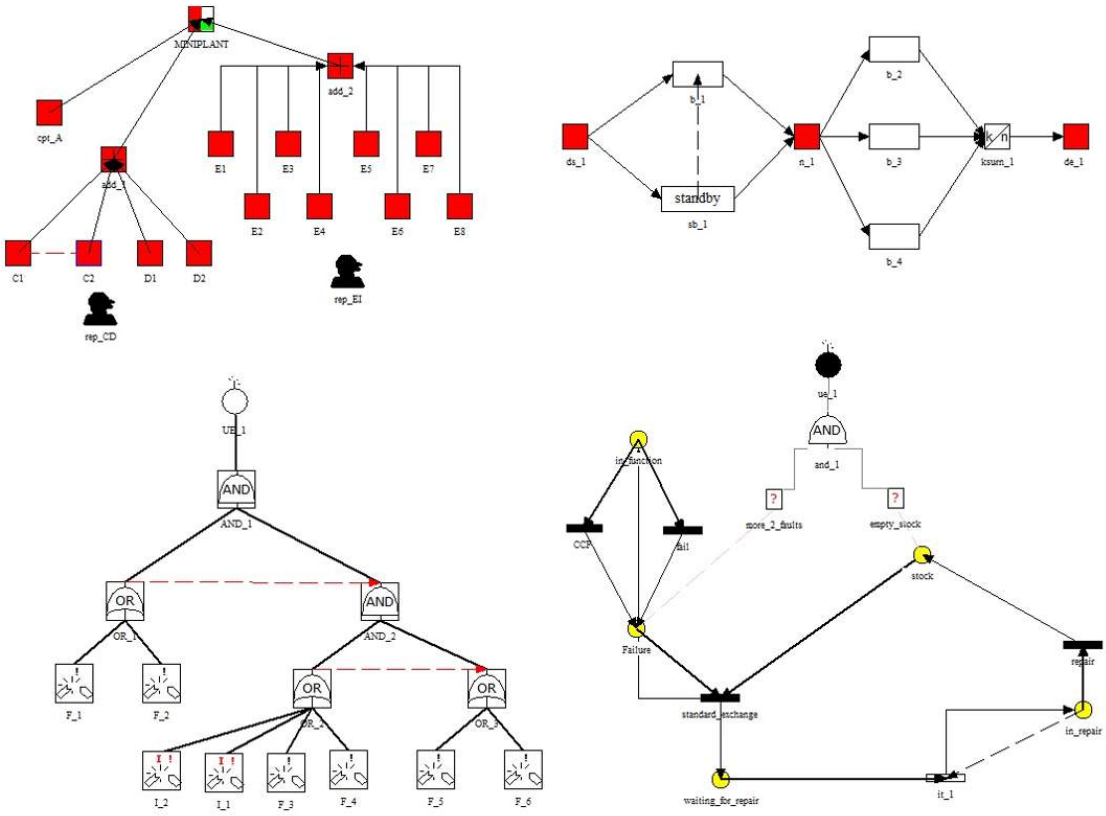


Figure 3. Some examples of calculations that can be processed with RiskSpectrum ModelBuilder (with the use of relevant knowledge base). Availability assessment, Reliability Block Diagram, Boolean Driven Markov Processes (BDMPs) and Petri Nets.

Demonstrating safety for SMRs – what are the challenges?

To move towards zero-carbon energy production and a world where net zero is a reality, nuclear will play a vital role and advancements in technology will be required. Small modular reactors are rapidly trending to be an essential component of energy generation and will be integral part of decarbonising our energy systems. Lemmer Lusse, PSA Analyst at USNC, tells us about the challenges of probabilistic safety assessment for SMRs.

Ultra Safe Nuclear (USNC) is currently engaged in the first step in commercialising the USNC-designed micro modular reactor with the MMR Project (MMRP) at Chalk River Laboratories, Canada. Micro modular reactors (MMRs) will advance decarbonisation opportunities in the off-grid market, such as remote mines and communities that are presently reliant on fossil fuels to produce electricity.

USNC will develop and construct its first reactor at Chalk River Laboratories site, under partnership with Global First Power, which was established with Ontario Power Generation.

Demonstrating safety of a new design is a challenge

SMRs such as USNC's MMR rely extensively on passive safety systems, reducing the need for active safety systems or early operator intervention in response to an initiating event. The designs are simpler than traditional large-scale nuclear power systems and tend to have lower power density, which increases the reactor safety margins. Additionally, the characteristics of the various safety systems may lead to a reduced or even possibly eliminated need for Emergency Planning Zones. Furthermore, SMRs characteristics make below-grade siting possible, providing protection from natural weather events and human hazards.

The main challenge to establish SMRs as the future standard is to demonstrate the safety of the designs to nuclear regulators; most of the existing regulations are based on the vast shared international experience of operating light water reactors (LWRs) around the globe. Some of these regulations and approaches are not directly applicable to SMRs, and presents challenges to the designers, licence applicants and the regulators.

New design requires a new PSA modelling approach

One of the major differences in the PSA model approach is that the traditional Level 1 and Level 2 approach is not appropriate for modelling SMRs. The USNC MMR design makes extensive use of passive structures, systems and components (SSC) in its approach to ensure the safety goals are met for design basis accidents. Therefore, event sequences where active SSC fail, does not seem to exceed that of the safety goals due to the reliance on passive safety features. This presents some challenges in defining success criteria for the active SSC and establishing the failure modes and associated failure likelihood of passive safety features.

Certain categories of initiating events applicable to SMRs are similar to those in LWR designs (such as pipe breaks in the primary and secondary systems or transients in the primary and secondary systems), but there may be a several unique initiating events to specific designs within the scope of SMRs. The magnitude of the consequences for SMRs are expected to be much less severe than for traditional and modern LWR designs.

Even for LWR PSAs, there are several event sequences that can be categorised

Lemmer Lusse

Lemmer started his career as a PSA engineer in 1995 in the Nuclear Safety Analysis department for Eskom (South Africa). After a decade, he joined the PBMR programme in South Africa working on PSA until October 2010 when he took hire at NECSA (South Africa). There he worked as a licensing manager for a planned new dedicated isotope production reactor. When this programme was placed on hold in early 2013, Lemmer performed licensing services for the SAFARI-1 reactor and other facilities at the site. In circa 2018 he got involved in the field of QA as well as compliance assurance and enforcement.

Lemmer is now working since October 2021 at the USNC as a PSA analyst for Micro Modular Reactor (MMR®) design.

USNC MMR®

The USNC MMR® is a high temperature gas reactor which leverages world-wide experience with gas reactor technology. USNC's proprietary Fully Ceramic Micro-encapsulated (FCM®) fuel technology builds on the industry standard TRISO fuel, an industry standard that is already considered to be the safest fuel design. The MMR® is designed to maximise technology maturity to support short-term commercial deployment.

There is an active application for a Licence to Prepare Site from the Canadian Nuclear Safety Commission (CNSC), and the Environmental Assessment work is underway. The Vendor Design Review with the CNSC is in Phase 2 of three phases. The MMRP is the only project in Stage 3 of Canadian Nuclear Laboratories' 4-stage process to site an SMR.

The reactor at Chalk River is planned to be operational by 2026 solidifying USNC's leading position to commercialise in the 2020s. Chalk River will serve as a blueprint for future projects and demonstrate the MMR as a tangible energy solution.

In parallel, USNC is partnering with University of Illinois, Urbana-Champaign to deploy a training, research, and test reactor. The MMR unit will test new technologies to decarbonise energy production, provide practical solutions for microgrid integration, and train a future workforce through hands-on experience with a next-generation advanced reactor. The Illinois reactor will be the first Gen IV reactor deployed at a university, and the first new U.S. university reactor in nearly 30 years. The University of Illinois has submitted a Letter of Intent to the US Nuclear Regulatory Commission (NRC) to apply for a licence to Construct a research and test reactor on the UIUC campus.

as "long term", i.e., the time to terminate in a safe, stable end state is well beyond 24 hours. This is especially the case for postulated events occurring at low power and shutdown states for some LWR event sequences. The mission time for SMRs will therefore also be event sequence specific, but it seems that, with specific reference to the USNC MMR design, the mission time for several events will exceed 24 hours. Though, it should be noted that, since we are at the starting phase of the MMR PSA, we will be in a better position to provide a more definitive response in time.

RiskSpectrum's flexibility works for us

I've used RiskSpectrum in previous companies where I was employed. When USNC went into the market for PSA software, we considered the available options and concluded on RiskSpectrum.

With the confidence of a really good, flexible, versatile and internationally respected software (RiskSpectrum), we have a considerably easier task to demonstrate the integrity of the PSA software to regulating authorities as part of the verification and validation requirements. Over the years in dealing with RiskSpectrum personnel, the quality of responses and advice, as well as the turnaround time, remained consistent and at a very high level of professionalism.

The software itself is easy to use, which allows the analyst focussing on the technical aspects of model construction and analyses, rather than trying to figure out how the software "works". The flexibility of the software permits the construction of a PSA model that do not fit in the classical Level 1 and Level 2 PSA approach. Furthermore, we intend to develop the model such that it allows us to use several risk-informed applications to derive insights in terms of investment protection.

With the experience of the software, the integration of low power/shutdown events as well as external hazards is expected to be seamless. A further positive is that the server option of the installation means that USNC's PSA personnel located in different parts of the world can almost work around the clock in constructing the model and performing risk informed analysis.

The software does offers additional tools, such as ModelBuilder, a unique risk modelling platform that helps designers and operators of safety-critical systems ensure uninterrupted, safe, and reliable operations by transforming the way they conduct risk assessments, to aid with the effort of model construction and maintenance.

SMRs fit the future's energy mix

SMRs provide safe, carbon-free energy, and there will therefore be increased interest in the technology from both governments and industries across the world as we look to transition power generation and grids to more environmentally friendly sources.

SMRs are an exciting area of innovation and offer the potential for hybrid energy systems with renewable wind and solar sources, thereby providing reliable clean baseload power supply for these green energy applications. Given their size and modularity, SMRs are also ideal for providing energy security to island nations, remote communities, and off-grid projects that currently rely on fossil fuels. It is likely that significant interest will be realised by these nations and communities that desire to enable reliable and abundant energy to leverage the benefits of energy security.

In the next 5-10 years, SMR technologies will be demonstrated and generate the confidence needed in areas of cost, safety, and application to enable commercialisation. This commercialisation will not only be for electrical generation, but also for industrial process heat and the production of hydrogen.

As governments and industry shift from fossil fuels to a carbon-free energy future, SMRs will occupy more of the conversation and eventually make up more of the world's power grid supply as a necessary element to achieving global emissions reductions targets.

RiskSpectrum software sheds light on your operations so you can move forward confidently.

Learn more:
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