

# Application of Web-based Risk Monitor in Tianwan Nuclear Power Plant

Hao Zheng<sup>a\*</sup>, Wei Wang<sup>b</sup>, Xiaohui Gu<sup>c</sup>, Yong Qu<sup>c</sup>, Zhenli Bao<sup>c</sup>, Xuhong He<sup>b</sup>

<sup>a</sup>Lloyd's Register Consulting, Beijing, China

<sup>b</sup>Lloyd's Register Consulting, Stockholm, Sweden

<sup>c</sup>Jiangsu Nuclear Power Co., Lianyungang, China

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**Abstract:** As one of the specific applications of Living PSA, Risk Monitor, which is a real-time analysis tool used to determine the instantaneous risk based on actual plant configuration, has been widely used in risk-informed decision-making process during plant operation. A web-based Risk Monitor application for Tianwan nuclear power plant (NPP) is currently being used onsite to improve the PSA applications, popularize the concept of risk-informed management, and then enhance the whole risk management level in Tianwan NPP. Compared with the traditional windows based tools, this web-based Risk Monitor application is a natural multi-user program with great advantages. It has good interface with plant's existing information system and can automatically update the risk information upon changes of component status/configurations.

This paper presents the overview of the Risk Monitor application used in Tianwan NPP, including challenges and experience of implementing Web-based Risk Monitor, and major feature improvements which facilitate the application of Risk Monitor. Example PSA applications implemented in Tianwan NPP will also be presented together with future plan and challenges.

**Keywords:** PSA Application, Risk Monitor, Tianwan Nuclear Power Plant.

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## 1. INTRODUCTION

Since the beginning of 1990s risk monitors based on PSA models have been used at more and more Nuclear Power Plants (NPP) for operation risk management. Benefits of risk monitor application on following aspects have been demonstrated by many successful cases during the past twenty years:

- To increase plant safety via an enhanced ability to improve risk awareness, and assess and manage risk
- To increase operational flexibility resulting from support of risk-informed regulation to achieve more economic operation

China National Nuclear Safety Administration (NNSA) published the technical policy "Application of PSA in nuclear safety" for guidance of PSA applications in February 2010 and initiated several PSA application pilot projects in August 2012. As a part of PSA application project, Tianwan nuclear power plant started the application of the web-based risk monitor tool via agreements with Lloyd's Register Consulting and China Nuclear Power Engineering Co. (CNPE) in 2012.

Tianwan NPP has two operating units of VVER-1000/V320 type reactor with some advanced safety features including the double containment, N+3 redundant safety systems, a core catcher, fully digital control system (DCS) etc. The risk monitor tool currently being used in Tianwan NPP is the Web-based RiskSpectrum<sup>®</sup> RiskWatcher (RWWeb) developed by Lloyd's Register Consulting. It has distinct advantages in comparison with the traditional desktop based tools, when it comes to PSA application in nuclear power plants.

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\* email address: hao.zheng@lr.org

improvements which facilitate the application of Risk Monitor. Some PSA applications implemented in Tianwan NPP based on the Risk Monitor will also be presented together with future plan and challenges.

## **2. RISK MONITOR OVERVIEW**

The Tianwan Risk Monitor RWWeb is designed to be used by both PSA knowledgeable and non-PSA knowledgeable personnel. Most of the Risk Monitor users are assumed to not be familiar with PSA model or PSA jargon. The application therefore uses the normal plant equipment IDs and descriptions and a minimum level of PSA related terms.

RWWeb enables plant operators and schedulers to evaluate the plant risks associated with scheduling and approving online and outage maintenance activities, and will help plant personnel better understand the risks in any plant configuration.

The RWWeb supports the following primary functions:

- Managing plant operational safety
- Logging historical records of actual plant configurations
- Online maintenance planning
- Long term scheduling
- Defence-in-depth analysis
- Providing information on the risk importance of the components that are in service as well as out of service

One of the key features in the Tianwan RWWeb is that all model related data is edited in the baseline PSA model and no changes need to be introduced "afterwards" in the separate risk monitor model. The information about changes in plant configuration are stored separate from the PSA model data and then dynamically combined into the PSA model as boundary conditions when doing model re-quantification. This principle simplifies the process of going from a living PSA baseline model to a functional risk monitor model and will greatly simplify continuous update work - i.e. maintaining a true living PSA model.

The Tianwan RWWeb supports the blended approach of risk-informed decision making by providing qualitative and quantitative evaluations. The instantaneous risk can be quantified according to the changes of plant configuration. Following risk information can be presented in Tianwan RWWeb:

- A risk profile showing the risk level over time
- Comparison of different risk curves
- Cumulative risk during any user defined period of time
- Indication of current risk level at a given time point in the form of a number (relative or absolute risk), and in the form of colour indication e.g. green, yellow, orange and red
- Qualitative "defence-in-depth" status, which shows whether safety functions, systems, sub-systems and components are available, degraded or unavailable e.g. green, yellow, orange and red
- Importance measures showing how important components, systems are in terms of contributing to current risk, or in terms of possible reduction of current risk

## **3. ADVANCED FEATURES**

The Tianwan RWWeb is designed to be an advanced risk assessment and management platform to facilitate the risk-informed decision-making process, and it has great advantages compared to other traditional desktop-based risk monitor tools. Several important features are introduced during the

development to facilitate its application on site, some are the characteristics of the web application, and others are due to the new innovative design.

### **3.1. Web-based Application**

The Tianwan RWWeb is a web-based application. In comparison with traditional desktop-based applications, the web application has some distinct advantages:

- Easy to deploy
- Easy to maintain and update
- More accessible
- More traceable
- Platform independent, better adaptability and compatibility

The web applications avoid the burden in deploying on each client machine. No installation is required for the users, since all the deployment and maintenance work will be concentrated on the server side, and the users only need the standard web browser to access to the application. These characteristics have made it ideal for the Risk Monitor application. The web-based Risk Monitor is easier to use, and has the possibility to be more widely used, which is of great significance for the promotion of Risk Monitor application, and thereby be very helpful to the plant safety management.

Web applications are more traceable since all data are centralized on server side and users may only be able to make changes via pre-designed operation interfaces. It is easy to observe the log information and user browsing patterns as every request is sent to the server and can be logged. This makes the web-based Risk Monitor well consistent with the quality assurance requirements of nuclear power plants.

Risk Monitor runs the PSA model, reads, interprets and displays the results of the quantification, and stores them for future retrieval and review. The users may specify how to display the results, as well as other specific information from the quantification. A Risk Monitor should be designed for different personnel in nuclear power plant. It is preferred if Risk Monitor can provide interface and capabilities for users without PSA experience while providing functions and features that are useful for PSA practitioners. The RWWeb is customized to fulfil these requirements.

The high customization and extensibility of web application also makes it a plant-specific application. The function modules are properly designed to be independent along with clear boundaries. So it can be easily customized to fully support specific needs in functionalities and interfaces.

### **3.2. Multi-user Operation**

The RWWeb is a natural multi-user application, and it is easy to provide collaboration between multiple users, as all data are centralized. Multiple users are able to access the same model data and plant configuration information at the same time. Multiple users can simultaneously perform many standard functions on the same model dataset without affecting other users or their data. These standard functions include but are not limited to, viewing risk profile, tracing operation log, performing individual What-if analysis, printing reports, etc. In the Tianwan RWWeb, logic check has been introduced before editing operation event log to prevent timing errors due to event log edited by more than one user at the same time.

However, risk quantification in Tianwan Risk Monitor is performed asynchronously as the model calculation is not instantaneous. As a result it is possible that quantification might have been expired before it is accomplished due to that the base data of the calculation (plant configuration) have been superseded. The result of these quantifications will be tagged to tell users that they are no longer valid and that there are new results available.

### **3.3 Integrated Model Management**

The PSA model used by the risk monitor is based on, and is consistent with, the Living PSA for the facility, and should be updated with the same frequency as the Living PSA.

The Tianwan RWWeb adopts an integrated model management strategy, which greatly improves traceability of the model and plant configuration. When the Living PSA model has changed, the Risk Monitor model should be updated accordingly, and then it will be asked whether it is a model upgrade indicating the real changes in the actual plant or whether it is a PSA model correction to fix a known error. For model upgrading, the new model will be applied continuously. For model correction, the new model will replace the previous one. Different versions of the model are preserved and seamlessly integrated, the model changes are well kept and easily tracked, therefore activities at any particular time point can be linked to the true real-time plant model.

### **3.4 Calculation Scheduling**

Calculation speed is one of the key issues for a real-time Risk Monitor application system. It becomes even more important for a web-based Risk Monitor since there might be many concurrent calculation requests. In the Tianwan RWWeb, a series of measures have been taken to improve the performance of quantifications.

- Perform calculation asynchronously, risk profile can be refreshed when calculation is finished
- Use distributed calculation architecture, and the calculation capability can be extended with increasing of calculation cores and servers
- Intelligent scheduling algorithm has been adopted to manage the calculation resources more efficiently. Calculation priority is considered in the scheduling algorithm, for instance the online quantification should always be given higher priority than planning
- Avoid duplicate calculation, if the same plant configuration has been quantified, the results can be re-used directly. a new quantification is only started when the current plant configuration has been changed and the new configuration has never been analysed before

Generally, quantification algorithms can be developed based on either fault tree logic or pre-solved minimum cut sets with different accuracy. Quantification based on fault tree logic from PSA model solved for each new plant configuration is applied for Tianwan RWWeb due to requirements of accuracy.

### **3.5 Automatic Operation Log Import**

Tianwan RWWeb has good interfaces with the plant's existing information system. A standalone tool was developed and embedded in RWWeb which can automatically download all relevant status signals of equipments from information system, convert to equipment status based on mapping rules and update in RWWeb upon the changes of status/configuration. Calculation will be automatically initiated after configuration change and the risk profile will be refreshed after calculation completed.

In theory no operator intervention is required during the whole process of operation risk updating by using this function. It can reduce the workload of using risk monitor for operational risk monitoring, and increase the accuracy and real-time characteristics of risk monitor. Feedback from Tianwan NPP indicate that there is almost no time delay caused by automatic input of plant configuration change. The major time delay for on-line operational risk monitoring is the PSA calculation time. For quality assurance of the automatic updating of the plant configurations, the users should review all the imported logs.

## **4. APPLICATIONS IN TIANWAN NPP**

Since December 2013, Tianwan NPP had started the trial use of the RWWeb on site. The scope of PSA applied in risk monitor for Tianwan NPP is Level 1 PSA of internal events for both full power and low power/shutdown modes. Four colour risk bands (Green, Yellow, Orange and Red) have been used for representing risk levels from low to unacceptable. Management measures related to each risk level has been established and integrated into overall risk-informed management system.

#### 4.1 Risk Awareness

It was found safety concept and safety culture change are the most challenging things in the beginning of using risk monitor in Tianwan NPP. Currently most safety management activities in the NPPs are derived from either requirements in regulations/rules or results from deterministic safety analysis. Those prescriptive requirements are familiarized and well accepted by plant staff, and implemented in their daily work as well. One goal of risk monitor application is to increase risk awareness of each working staff and introduce risk insights from PSA point of view into existing safety/risk management framework.

During the period of risk monitor trial use, several external and internal training courses on PSA, risk monitor and risk-informed management were carried out for plant staff to increase knowledge of the whole concept and functionality of the tools. The deployment and configuration of the Tianwan RWWeb makes it accessible for everyone in plant to view risk profile and carry out risk analysis by using "What-if" module. It increases the involvement of each staff on risk management and perceptual experience of risk concept.

Good communication is ensured during the whole process. Questions or suggestions raised in use of risk monitor can be emailed to dedicated PSA engineer onsite for discussion and problem solving.

#### 4.2 Online Risk Monitoring

Online risk monitoring is considered as one of the major applications at the current stage in Tianwan NPP. One dedicated computer is deployed in the main control room for risk monitoring and a dedicated account is assigned to be used in main control room with permission for online module. With automatic operation log import function, this system can continuously and steadily monitor risk status of NPP unit, update and refresh risk profile without operator's intervention. ()

Both quantitative risk measure (CDF) and qualitative risk measures (defence-in-depth status) are monitored and treated separately in the system. The qualitative risk measures provide risk insights at the safety function/system level/sub-system level in addition to the quantitative risk insights including CDF and risk importance measures.

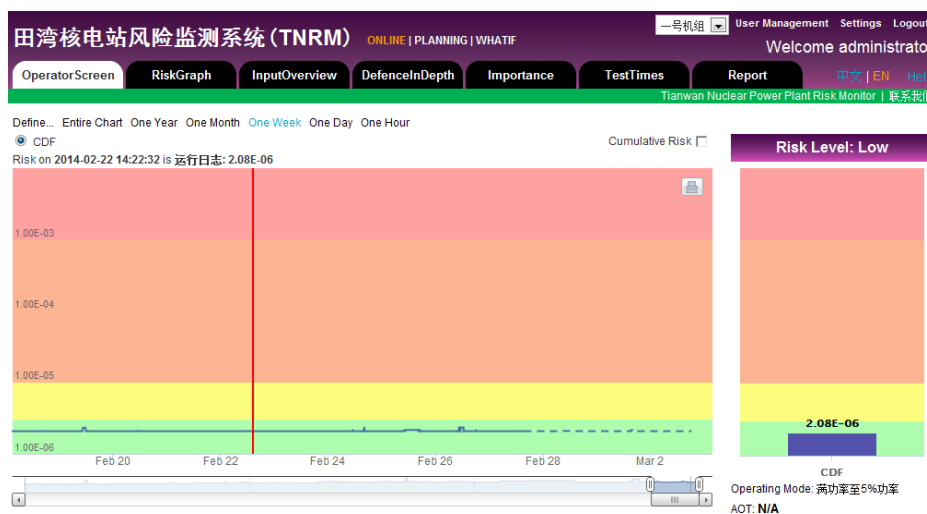


Figure 1 - Online Risk Monitoring with Risk Curves in Upcoming Days

### **4.3 Risk of Maintenance Planning**

Planning module in RWWeb can be used for both day-to-day maintenance and maintenance scheduling purpose. The planning module is mainly used for day-to-day maintenance risk management in Tianwan NPP so far.

As a part of the planning work process every day, draft daily plan (three-day rolling plan) will be imported into risk monitor for risk calculation. A risk report for daily plan will be generated and used by planning staff as input for further adjustment. The finalized daily plan with its risk insights will be published in the risk monitor as part of online risk profile. In other words, operation staff can easily get risk insights of the upcoming activities in addition to current risk level by using RWWeb.

### **4.4 Safety Supervision**

Dedicated PSA engineers onsite use risk monitor for plant routine risk supervision. Risk report for each unit will be prepared each week together with traditional STA safety report. Based on the plant management procedure, detailed risk evaluation report will be published if there is a significant risk increase (e.g. reach the risk level of Orange) and suggestions on risk reduction and control will be prepared based on integrated consideration which includes the risk insights from the RWWeb.

### **4.5 Future Plans**

The RWWeb was put into trial use since the last December and only several applications have been implemented in Tianwan NPP. Tianwan NPP has a long term plan for promoting PSA application and establishing risk-informed management system. Following aspects are considered in the future plan for application of risk monitor.

Enhancement of current practice on application of risk monitor including online risk monitoring, day-to-day maintenance risk management etc. is to be carried out in 2014. Risk management activity based on risk monitor is to be integrated into operation management procedures in a better way. Improvements on RWWeb are also planned to facilitate application. One example is to have alarm in main control room when there is significant change of risk (e.g. risk increase from Green to Yellow) in order to alert operator for attention.

Risk monitor is planned to be used as a support tool for plant engineering and technology modification. A professional local team will be established to implement application of risk monitor with support from external experts.

More applications based on risk monitor for more economic operation is to be planned in Tianwan NPP. It can be found that current applications of the RWWeb in Tianwan NPP are all related to risk monitoring and risk awareness to enhance safety. Operation flexibility has not been changed by the current practices. It is partly because there is no guidance available on specific risk-informed applications in current Chinese regulation system. On the other hand, the scope and quality of PSA model also limit the scope of risk monitor applications. Some pilot projects for PSA application on operation flexibility will be planned in Tianwan NPP. The experience and lesson learned from these pilot projects can also be used as input in developing guidance.

## **5. CONCLUSION**

Application of the risk monitor in a nuclear power plant without previous experiences of the risk-informed application may encounter several challenges like safety culture change from prescriptive framework to risk-informed framework, incomprehension due to lack of knowledge, uncooperative staff due to additional workload, no requirements in regulation etc. A transition process with proper

educational sessions and good communication is significant for success of risk monitor application. A well designed and customized web-based risk monitor tool can facilitate the whole process.

The RWWeb developed for Tianwan NPP fulfills the general requirements for risk monitor. In addition to that, the web-based framework brings lots of inherent advantages including the flexibility to deploy and manage the application, better adaptability and compatibility, more accessible, etc. Improvements on calculation scheduling make speed of fault tree solution within an acceptable level. Automatic operation log import significantly reduces the workload of operator in using risk monitor and increases the precision of configuration input.

However, there are some limitations of current risk monitor used in Tianwan.

- Uncertainty is not addressed. Only point value of CDF is provided in current risk monitor. As the RWWeb is to re-quantify the PSA model each time, it is possible to have uncertainty results for each plant configuration. However, the uncertainty results are not required either from Tianwan NPP or authority.
- Unable to apply different risk bands for different operation modes. One risk band definition will be used for all operation modes. This may result in that the baseline risk in some shutdown modes is at Yellow band.
- Effect of different failure modes for one component is not considered. All failure modes for one component are mapped together to the component in current version of risk monitor. This inaccuracy treatment may cause the result more conservative and the risk monitor model does not reflect the plant in a exact way.

Those limitations will be further investigated in further development.

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