18th International Conference on Structural mechanics in reactor technology (SMiRT 18)
Beijing, China, August 7-12, 2005
SMiRT18-O01-7

MAINTENANCE RISK MANAGEMENT IN DAYABAY NUCLEAR POWER PLANT

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ABSTRACT: The importance of proper maintenance to safe and reliable nuclear plant operation has long been recognized by the nuclear utility and regulatory body. This paper presents a process of maintenance risk management developed for a Chinese Nuclear Power Plant (NPP). The process includes three phases: (I) long term maintenance plan risk management, (II) monthly maintenance plan risk management, and (III) detailed risk management for high risk configuration. A risk matrix is developed for phase I whose purpose is to provide a rough guide for risk management in the making of the annual maintenance plan. For Phase II and Phase III, a software tool named Maintenance- Risk-Monitor is developed based on the internal initiating event, level 1 PSA model. The results of Phase II are the risk information of the all plant configurations caused by the unavailability of the components included the monthly maintenance plan. When the increase of core damage frequency (CDF) or the incremental core damage probability (ICDP) of a configuration is higher than the corresponding thresholds, Phase III is needed for this high risk configuration to get the useful information such as risk-importance components, human actions and initial events, from which appropriate preventive measurements could be derived. It is hoped that the provided process of maintenance risk management, together with the developed software tool, could facilitate the maintenance activities in the NPPs of China.

KeyWords: Maintenance, Risk Management, Risk Monitor

1. INTRODUCTION

The importance of proper maintenance to safe and reliable nuclear plant operation has long been recognized by the nuclear utility and regulatory body. Because of its importance in improving overall plant performance, the US industry has placed increased emphasis on improving maintenance, including improved maintenance facilities, enhanced training of maintenance personnel, increased emphasis on good maintenance work practices and use of procedures, better technical guidance, and tracking of equipment performance. The improved effective maintenance has helped many U.S. plants reach world-class performance (NEI, 1996).

The NRC published 10CFR 50.65 Maintenance Rule entitled, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."(NRC,1991), which became effective since July 10, 1996. In 1999, the NRC published the revised Maintenance Rule, in which is add a new section a (4)—"Before performing maintenance activities (including but not limited to surveillance, post- maintenance testing, and corrective and preventive maintenance), the licensee shall assess and manage the increase in risk that may result from the proposed maintenance activities. The scope of the assessment may be limited to structures, systems, and components that a risk-informed evaluation process has shown to be significant to public health and safety. "

There are two different ways to assess and manage the risk caused by the maintenance activities, one is the traditional deterministic approach and another is probabilistic approach. The traditional deterministic approach has been used widely since the emergency of the NPPs and played an essential role in the maintenance of the plant safety. The scope of the traditional deterministic approach includes the engineering analysis and judgment, plant experience, the evaluation of the defense-in-depth attributes and safety margins, etc. The probabilistic approach, using the plant PSA model, could derive some useful information that could be used in the plant risk management. In recent years, the probabilistic approach has been successfully applied as an effective supplement measure in the plant risk-informed management in some countries especially in USA(NRC, 2004).

In some situations where the deterministic approach may be too conservative or difficult to be used, PSA has its special advantages. With the plant PSA model, the risk of the plant could be expressed with some intuitional, easy access numeric risk metrics such as CDF or LERF. Any change of the plant configuration could be easily reflected in these risk metrics, thus the risk increase caused by the equipment unavailability of the maintenance activities could be quantified.

In 1995, the NRC issued a Policy Statement on the use of probabilistic risk analysis (PRA), encouraging its use in all regulatory matters. The Policy Statement states that "... the use of PRA technology should be increased to the extent supported by the state of the art in PRA methods and data and in a manner that complements the NRC's deterministic approach." (NRC, 1995). Since that time, many uses have been implemented or undertaken, including maintenance risk management.

To use the risk information derived from a PSA, an important issue is to ensure the technique accuracy of PSA results. Several important reports dealing with this important issue are available. The U.S. nuclear industry has developed a Peer Review process for assessing the technical capability and adequacy of a PRA to support risk-informed regulatory licensing applications (NEI, 2000). ASME published a standard for PRA for NPP applications (ASME, 2001). And in Feb. 2004, US NRC issued Regulatory Guide 1.200 for trial use, providing an approach for determining the technical adequacy of PSA results for risk-informed activities (NRC, 2004).

In china, there are 6 NPPs and 5 of them have finished internal event, level 1 PSAs by the plant personnel or the contractors. The quality of the finished PSA reports is still in review by the regulatory body, in which the review the PSA of Dayabay NPP is close to be finished. Whether the quality of a PSA is adequate or not is out of the content of this paper and will not discussed here.

This paper mainly presents a process of maintenance risk management developed for Dayabay NPP, including the software we developed. The purpose of the maintenance risk management is to manage the plant risk in its maintenance activities, as well as to improve economic benefits on the premise of the plant Technique Specifications. Section 2 lists the whole process and section 3, 4 and 5 respectively correspond with the three phases of the process, and section 6 is the discussion of the paper.

2. THE WHOLE MAINTENANCE RISK MANAGEMENT PROCESS

The whole maintenance risk management process is illustrated as Fig.1. The process mainly includes three phases: (I) long term maintenance plan risk management, (II) monthly maintenance plan risk management, and (III) detailed risk management for high risk configuration. These 3 phases are conducted before the maintenance is conduct at least one month ago. The derived risk information, especially from phase III, will be provided to the control room operators, local operators and related maintenance men in the beginning of the day when the maintenance activities are conducted.

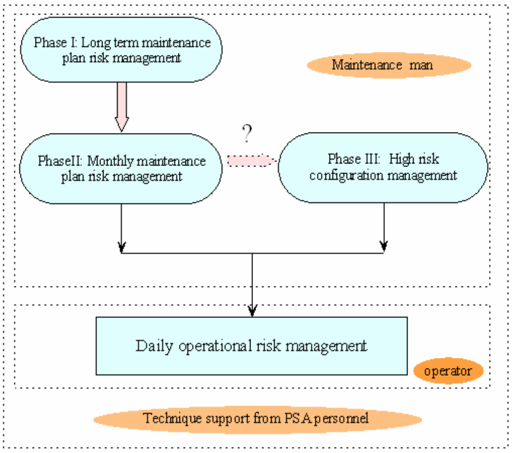

Fig. 1 The whole maintenance risk management process

If some unplanned situations emerge such as the unavailability of a standby pump, daily operational risk management would be conducted to evaluate its impact on the planned or on-going maintenance activities. This daily operational risk management is called as phase IV, for which a separate software tool is developed based on the plant PSA model, whose potential users could be the managers, control room operators, STA, and PSA personnel.

All the 4 phases of the maintenance risk management are based on the plant internal initiating event, level 1 PSA model, developed several years ago and being revised continually. So the accomplished of the maintenance risk management could not realised without the PSA personnel, who developed the plant PSA model and are familiar with the model assumptions, initiating events, system fault trees, event trees of PSA. The users of the 4 phases especially those with no idea of the PSA model will need the help of PSA personnel in their operation of the tools. PSA personnel are also responsible for updating the PSA model to reflect the changes of the plant and maintain the technical capability and adequacy of the model to support risk-informed applications.

The emphases of the paper are about the phase I, II and III, and the detailed information of the phase IV is not included in this paper.

3. LONG TERM MAINTENANCE PLAN RISK MANAGEMENT (Phase I)

The purpose of this phase is to manage and optimize the risk of the long term maintenance plan. Here long term maintenance plan means the whole or half a reactor year maintenance plan whose items are defined by the Technique Specification, plant operation, engineering judgment and other information. Fig. 2 is the process of the Phase I.

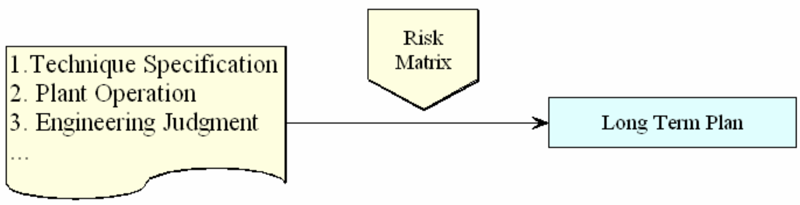

Fig. 2 Phase I process

A risk matrix is developed for phase I whose purpose is to provide a rough guide for risk management in the making of the long term maintenance plan. Table 1 is the prototype of the risk matrix. The systems constituting the table are the front systems and support systems that included in the period maintenance and prevention maintenance. The number of the trains depends on the design of the plant system. Here only two trains, i.e. train A and train B are listed for each system for illustration. Three colors are used to show the risk level of the plant for the unavailability of the 2 trains in the corresponding systems. Red indicates the high risk level of the plant which means these two trains can not be maintained at the same time. Yellow and green indicate the relative low risk level of the plant which means the two trains can be maintained at the same time. The allowed outage time (AOT) of these two trains is defined by the Technique Specification. If the AOT is not provided in the TS, then the AOT could be derived with the risk insight got from the plant specific PSA model with the method provided in the RG1.177(NRC, 1998).

Table 1 The prototype of the risk matrix

		Front System 1		Front System 2		...		Support		Support		...	
		A	B	A	B	A	B	A	B	A	B	A	B
Front System	A		X	10d	10d			3d	3d	30d	30d		
	B	X		30d	30d			3d	3d	30d	30d		
Front System	A	10d	30d		X			10d	10d	30d	30d		
	B	10d	30d	X				10d	10d	30d	30d		
...	A												
	B												
Support System	A	3d	3d	10d	10d				X	15d	15d		
	B	3d	3d	10d	10d			X		15d	15d		
Support System	A	30d	30d	30d	30d			15d	15d		X		
	B	30d	30d	30d	30d			15d	15d	X			
...	A												
	B												

4. MONTHLY MAINTENANCE PLAN RISK MANAGEMENT (PHASE II)

The purpose of this phase is to evaluate and manage the risk of the monthly maintenance plan. The input of the monthly plan is the long term maintenance plan adjusted by the plant implementation situations. The results of Phase II are the risk information of the all plant configurations caused by the unavailability of the components included the monthly maintenance plan.

Figure 3 is the main interface of the Maintenance-Risk-Monitor for Phase II. A maintenance planner used the developed software Maintenance-Risk–Monitor to evaluate the risk increase caused by the equipment outages of the draft monthly plan. Maintenance-Risk–Monitor can easily modify the values of basic events, gates, and house events to reflect the influences of the maintenance activities.

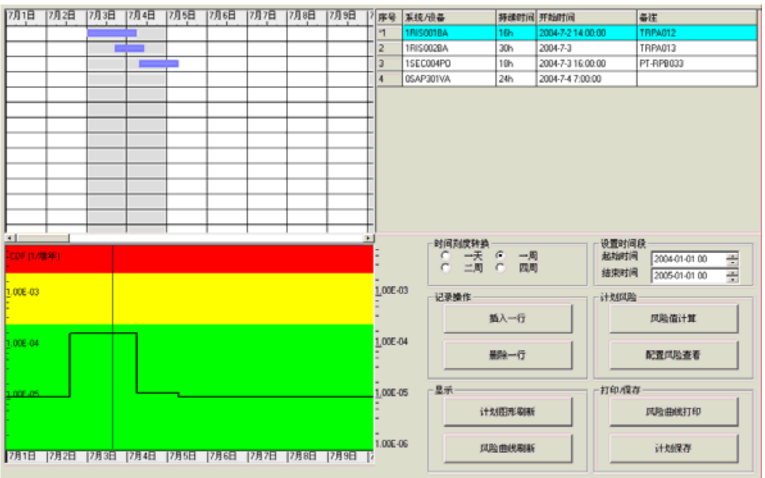

Fig. 3 Main interface of the Maintenance-Risk-Monitor for Phase II

For example, if one maintenance activity causes the unavailability of a pump, the basic event of the pump failure to start or other identical basic event could be assigned as “true” in the PSA model and the instant plant risk level would be derived. Two measures are used to control the risk: the amount accrued by any given plant configuration, and the level of instantaneous risk. If the calculated instantaneous risk (CDF) or the accrued risk (the incremental conditional core damage probability, ICCDP) for the generated configurations is unacceptable (i.e. in the Caution range), then equipment outages are arranged and adjusted until the risk is sufficiently low.

The acceptance guideline of the ICCDP is 5.OE-7, recommended by the RG1.177, from which the allowed duration of this configuration (ACT) could be derived as ACT= ICCDP/CDF. For the instantaneous risk CDF, two thresholds are provided as 3E-4 and 1E-3. If instantaneous CDF is large than 1E-3, plant state will be assigned with red which means unacceptable high risk and not allowed to enter. If instantaneous CDF is large than 3E-4 but small than 1E-3, plant state will be assigned with yellow which means relatively high risk and it should be careful to enter. If instantaneous CDF is small than 3E-4, plant state will be assigned with green which means the risk is acceptable and normal control is only needed.

It is noted that these threshold values are not static and could be changed for different plants with different baseline risk values or different applications. For the interested high risk configurations, Phase III will be entered to get more detailed risk information.

5. HIGH RISK CONFIGURATION MANAGEMENT (Phase III)

The purpose of Phase III is to get the useful risk insights for the interested high risk configurations identified in Phase II, such as risk-importance components, human actions, initial events and accident sequences, from which appropriate preventive or recovery measurements could be derived. Fig. 4 is the process of the Phase III.

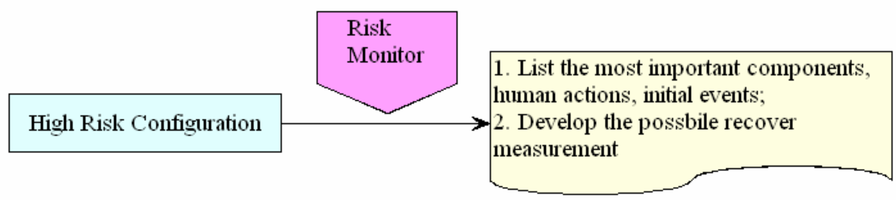

Fig. 4 The process of the Phase III

Two widely used important measures, i.e. Fussel-Vessell (FV) and risk achievement worth (RAW), are used to get the risk important components. Only FV measure is used to get the risk important human actions, initiating events and accident sequences. Additional control measures could be applied based on the above findings, such as: risk acquaintance and administration control, shorten the out of service times of the equipments, some important equipment protections, and additional people set in important spots, etc.

6. CONCLUSIONS

Risk-informed management, using both a PSA component and a deterministic component, has been successfully applied in many nuclear power plants in USA in all regulatory matters including in the maintenance to support for the implementation of the Maintenance Rule.

With the new regulatory rules issued in April 2004 in China, PSA is expected to play more and more roles in the management issues of the plants. Most of the NPPs in China have developed their PSA model and are active in improving the PSA quality.

The provided maintenance risk management process is aimed to facilitate the risk management of the maintenance activities in the NPPs of China. A Risk matrix and a software tool Maintenance-Risk-Monitor is developed for the application of the process. With the plant PSA model available, Maintenance-Risk- Monitor could be easily used by the terminal users other than the PSA personnel to change the PSA model and get the wanted risk information of the maintenance activities.

Unlike the situation of USA, the experience of PSA application is limited for NPPs in China. The provided process and developed software tool should be continually improved in their practical applications.

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