International Conference
Nuclear Energy for New Europe 2005
Bled, Slovenia, September 5-8, 2005

Evaluation of Test Interval Strategies with a Risk Monitor

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ABSTRACT

The Swedish nuclear power utility Oskarshamn Power Group (OKG), is investigating how the use of a risk monitor can facilitate and improve risk-informed decision-making at their nuclear power plants. The intent is to evaluate if risk-informed decision-making can be accepted.

A pilot project was initiated and carried out in 2004. The project included investigating if a risk monitor can be used for optimising test intervals for diesel- and gas turbine generators with regard to risk level.

The Oskarhamn 2 (O2), PSA Level 1 model was converted into a risk monitor using RiskSpectrum RiskWatcher (RSRW) software. The converted PSA model included the complete PSA model for the power operation mode. RSRW then performs a complete requantification for every analysis. Time dependent reliability data are taken into account, i.e. a shorter test interval will increases the components availability (possibility to e.g. start on demand).

The converted O2 model was then used to investigate whether it would be possible to balance longer test intervals for diesel generators, gas turbine generators and high pressure injection system with shorter test intervals for the low pressure injection system, while maintaining a low risk level at the plant.

The results show that a new mixture of test intervals can be implemented with only marginally changes in the risk calculated with the risk monitor model. The results indicate that the total number of test activities for the systems included in the pilot study could be reduced by 20% with a maintained level of risk.

A risk monitor taking into account the impact from test intervals in availability calculations for components is well suited for evaluation of test interval strategies. It also enables the analyst to evaluate the risk level over a period of time including the impact the actual status of the plant may have on the risk level.

1 INTRODUCTION

The Swedish nuclear power utility Oskarshamn Power Group (OKG), is investigating how the use of a risk monitor can facilitate and improve risk-informed decision-making at their nuclear power plants. The intent is to evaluate if risk-informed decision-making can be accepted. Several small pilot projects were defined and carried out during the period 2003 – 2004 as part of this investigation. This paper refers to the results and conclusions from one of these projects.

The specific project investigated the use of a risk monitor for optimising test intervals for diesel- and gas turbine generators using risk level results in the decision making process. Specifically it was investigated whether it would be possible to balance longer test intervals for the diesel generators, the gas turbine generators and the high pressure injection system with shorter test intervals for the low pressure injection system, while maintaining the plant's original risk level.

The PSA for Oskarshamn unit 2 (O2) was used in the project. O2 is a 630 MW, ABB Atom, BWR type nuclear reactor that has been in commercial operation since 1974.

2 METHOD

The PSA Level 1 (fault tree and event tree model) for O2 was during 2001converted to a RiskSpectrum RiskWatcher (RSRW) risk monitor model. The converted PSA model includes the complete PSA model for power operation. Minimal cutsets are regenerated and requantified for every RSRW analysis. Time dependent reliability data are included in RSRW, which means that test intervals effects on system and component availability is included in the analyses, i.e. a shorter test interval increases the components availability (e.g. probability for start on demand) for reasonably long test intervals.

With the use of this model, tests were carried out with the purpose to investigate whether it would be possible to balance longer test intervals for diesel generators, gas turbine generators and high pressure injection system with shortened test intervals for the low pressure injection system, the aim being maintaining a low risk level at the plant.

Test activities were logged in the RSRW Event Log and Planning Event Log directly in the RSRW user interface. The Event Log included the current test intervals as described in the operating instructions for periodic tests [1] for the O2 nuclear power plant. In the Planning Event Log, test activities based on proposed new test intervals were inserted. MCS analyses were run for each scheduled test time point as defined by the data in both Event Logs.

Results from the analyses were displayed in both tables and graphs in RSRW. In addition, results from both Event Logs and Planning Event Logs were studied by using a combined graph allowing easy identification of differences.

2.1 Current Test Interval

Information about which weeks and week days the different components are tested was taken from the operating instructions for periodic tests [1] for O2. Test activities for the diesel generators, the gas turbine generators, the high pressure injection system and the low pressure injection system are compiled in Table 1, below.

Table 1: Test plan for a selected set of systems from the Opertaing Instructions for Periodic Tests at O2 nuclear power plant.

System	**Test**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
323 sub 1	Operation		1					6					11
	Back feed of filter												
	Start and capacity												
323 sub 2	Operation			2					7				
	Back feed of filter												
	Start and capacity												
327 sub 1	Start			2					7				
327 sub 2	Start		1					6					11
649-G13 Gas turbine	Start		1		3		5		7		9		11
649-G23 Gas turbine	Start	0		2		4		6		8		10	
661/714-DG211/P1 Diesel Generator	Start and load		1		3		5		7		9		11
661/714-DG212/P2 Diesel Generator	Start and load	0		2		4		6		8		10	

The test plan activities were added to the Event Log in the O2 PSA model in RSRW beginning week no. 30, 2003 (week 0 in Table 1, above) and until week no. 14, 2004. The total number of tests during the period 23 July 2003 to 31 March 2004 is 104.

2.2 Proposed New Test Intervals

New test intervals were deduced making iterative calculations with the goal to increase the test intervals for the diesel generators, the gas turbine generators and the high pressure injection system and allowing shorter test intervals for the low pressure injection system without increasing the risk level at the plant.

The test activities for the diesel generators, the gas turbine generators, the high pressure injection system and the low pressure injection system are compiled in Table 2, below.

Table 2: Test plan of the proposed new test intervals for a selected set of systems at O2 nuclear power plant

System	Test	0	1	2	3	4	5	6	7	8	9	10	11
323 sub 1	Operation		1			4			7			10	
	Back feed of filter												
	Start and capacity												
323 sub 2	Operation			2			5			8			11
	Back feed of filter												
	Start and capacity												
327 sub 1	Start			2						8			
327 sub 2	Start		1						7				
649-G13 Gas turbine	Start		1				5				9		
649-G23 Gas turbine	Start	0				4				8			
661/714-DG211/P1 Diesel Generator	Start and load		1			4			7			10	
661/714-DG212/P2 Diesel Generator	Start and load	0			3			6			9		

The test activities were added to a Planned Event Log in the O2 PSA model, beginning week no. 30, 2003 (week 0 in Table 1, above) and until week no. 14, 2004. The total number of tests during the period 23 July 2003 to 31 March 2004 is 82.

2.2.1 Calculation Method

A separate tool, the RiskSpectrum Test Interval Analyser (RSTIA) was used for making the iterative calculations. The tool is designed to calculate alternative test intervals for a set of specified test interval parameters used in a specific PSA model. The specified test interval parameter values are varied in an iterative calculation method with the aim at finding the least number of tests required maintaining a specified target consequence value, e.g. Core Damage Frequency (CDF).

In the tool you can specify a consequence and a target value for it and which test interval parameters that you allow the program to change for an analysis case in a specific RiskSpectrum model. When running an analysis, the application will find new test intervals for the listed parameters that render the least number of tests required for reaching the specified target value consequence. With no target consequence value indicated the software will use the original value from the PSA analysis in RiskSpectrum PSA Professional.

Figure 1, below, depicts an example of test interval optimisation based on an example project (EXPSA.RSD).

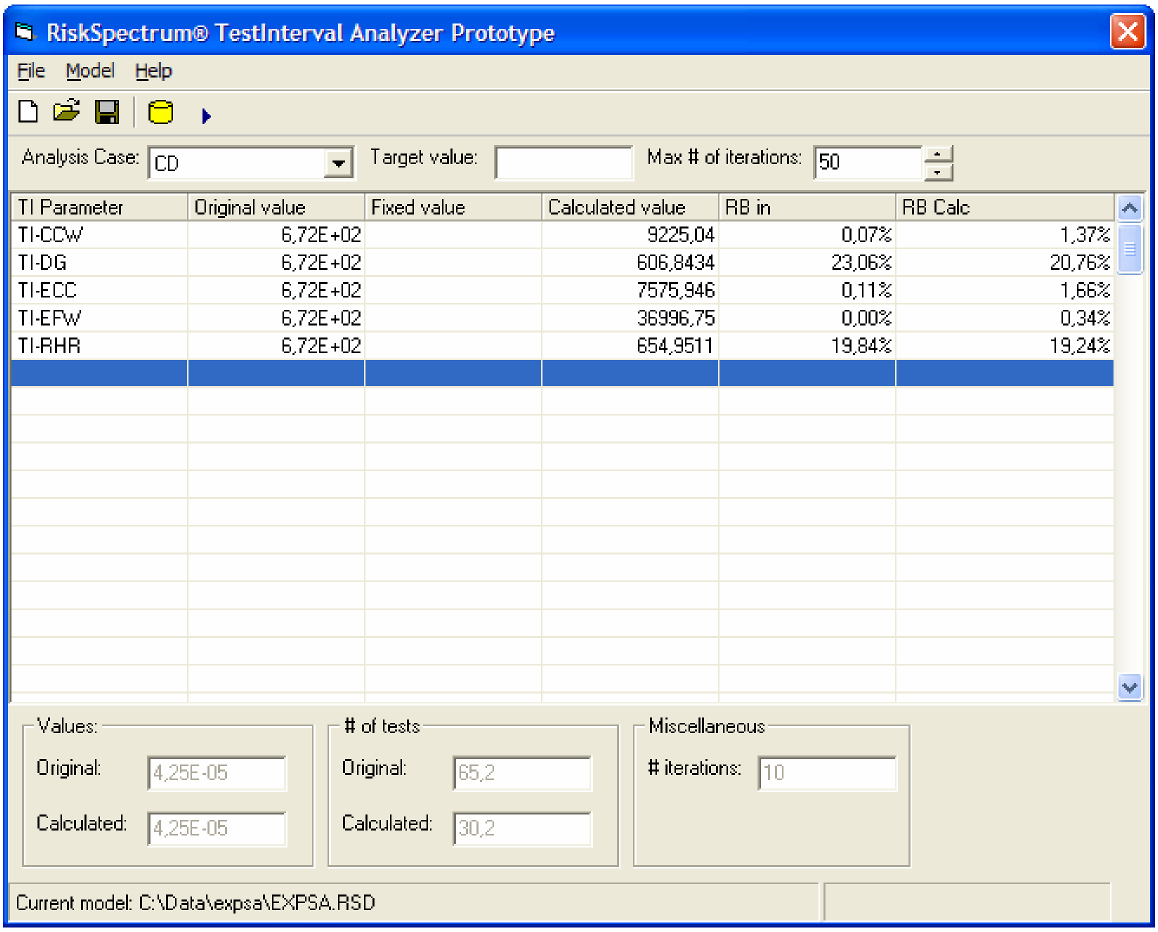

Figure 1. The RiskSpectrum Test Interval Analyser (RSTIA) user interface.

3 RESULTS

The number of tests for the systems and components included in this study, during the period 23 July 2003 to 31 March 2004, could be reduced from 104 to 82 tests in total, without any significant change in risk.

The analysis indicates that the risk level changed only little over a 12 week period when test interval for diesel generators was increased from 2 to 3 weeks, the test interval for gas turbine generators from 2 to 4 weeks and the test interval for the high pressure injection system from 5 to 6 weeks. The test interval for the low pressure injection system was decreased from 5 to 3 weeks.

The results indicate that the total number of test activities for the systems included in this pilot study could be reduced by 20% while maintaining the same risk level, see figures 1 and 2.

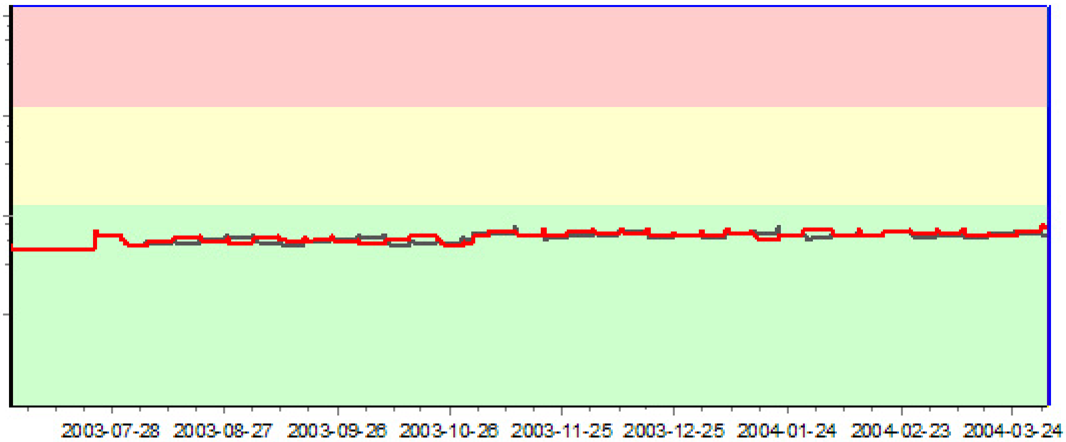

Figure 2: The graph shows the core damage frequency (CDF) per hour for the studied time period for CDF calculated with current test intervals (for colour readings: black curve), and CDF calculated with proposed new test intervals (for colour readings: red curve).

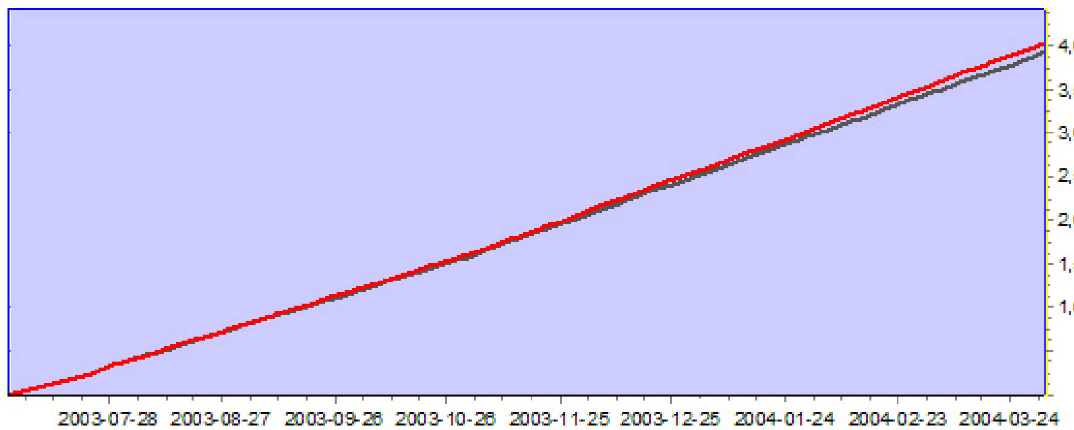

Figure 3: The graph shows the cumulative core damage frequency for the studied time period for CDF calculated with current test intervals (for colour readings: black curve), and CDF calculated with proposed new test intervals (for colour readings: red curve).

4 CONCLUSIONS

A risk monitor with capability for taking into account the component test interval impact on availability calculations is well suited for evaluation of test interval strategies. It also enables the analyst to evaluate the risk level over a period of time including the impact the actual status of the plant may have on the risk level.

ACKNOWLEDGMENTS

RELCON thanks the Oskarshamn Power Group for allowing publication of the results presented in this paper.

REFERENCES

[1] OKG Operating Instructions 2-D2.5.1 Edition 11, “Block 2 Periodiska prov”.