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Plant Configuration Risk Assessment Methodology Development for Periodic Maintenance

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Abstract

As the operation experiences of nuclear power plants in Korea have been accumulated and the safety functions of nuclear power plants are getting enhanced, the role of stable and optimal operation of plant within the acceptable safety criteria becomes important nowadays. To accomplish such goal, maintenance and its related activities should be regarded as the most concerned issue. In terms of the risk concept including core damage frequency and unavailability, the cause that might impact plant safety during normal maintenance activities, can be identified and evaluated effectively. The plant configuration assessment methodology was developed to reflect the field experiences into risk calculation exactly within the limit of probabilistic methods. The plant configuration risk assessment methodology developed in this study consists of six steps and this method was applied to the reference plant. The operational risk was evaluated using maintenance records and the results were presented.

1. Introduction

As the operation experiences of nuclear power plants in Korea have been accumulated and the safety functions of nuclear plants are getting enhanced, the role of stable and optimal operation of plant within the acceptable safety criteria becomes important nowadays. To accomplish the goal of safe and optimal operation, maintenance and its related activities should be regarded as the most concerned issue.

The methodologies for maintenance improvement and optimization have been studied and such studies focused on rather system performance than the hardware itself. From this point of view, the probabilistic methods are one of the most useful for this purpose. In terms of the risk concept including core damage frequency and unavailability, the cause that might impact plant safety during normal maintenance activities, can be identified and evaluated effectively. The results from these probabilistic analyses can provide insightful information for the reallocation of risk contributing maintenance activity. This information can be utilized in a way that separates the significant risk contributing maintenance activities with each other unless they are timely related.

In Korea, the risk monitoring program for operating nuclear power plants is under developing, and will be implemented in 2003. To accomplish the objectives of risk monitoring program, suitable risk evaluation methods should be developed before the implementation of risk monitoring program. The plant configuration assessment methodology was developed for these reasons, and this method is to reflect the field experiences into risk calculation exactly within the limit of probabilistic methods.

2. Methodology Steps

During normal plant operation, the plant operational risk changes frequently depending upon the status of plant system and component arrangement. Specific plant systems or components are typically removed from service due to random equipment failure, planned preventive/predictive maintenance, corrective maintenance, surveillance testing and operational bypass activities, and such events usually impact the plant risk level. Such an arrangement change of the plant equipment and system at a given time period can be represented as the plant configuration.

The plant configuration risk assessment methodology developed during this study consists of six steps and these step are as following.

1. Step 1 - Identification of plant configuration. In this step, various events occurred in plant should be identified through the review of plant operation records such as the periodic maintenance and inspection schedules, maintenance or repair request logs, trouble reports, and other operational activity related documents.
2. Step 2 – Evaluation of PRA model and computer codes. For the effective evaluation of plant risk during normal operation, appropriate plant risk model should be used and the capability of computer codes should be evaluated. There might be numerous events, which require the maintenance activity during normal operation. To handle these events during the risk calculation, it is needed that the optimized plant PRA model and the risk analysis tool of fast calculation capacity.
3. Step 3 – Development of baseline risk model and evaluation of baseline risk. The baseline risk model is the similar risk model used for level 1 PRA but that the maintenance related events are excluded. In this methodology, the relative risk change caused by the usual plant events, were focused. For this purpose, the baseline risk that will be the reference of risk variation, should be evaluation reasonably as possible.
4. Step 4 - Analysis of components and systems. For the detailed risk analysis, it is useful to perform the importance analysis for the target components or systems before calculating the plant risks. In virtue of system unavailability analysis and importance analysis, it could be derived that the information of specific components and systems for which the detailed risk analysis should be performed,
5. Step 5 – Evaluation of configuration risks and sensitivity analysis. By the configuration and the system information from the above steps, the plant configuration risks should be calculated and plotted along with issued time period of analysis. The effects of human

factors, common cause failures, and the truncation levels of calculation on the results, the sensitivity study can be performed.

6. Step 6 – Development of configuration risk profile. The developed risk profiles along with the time axis for the selected time period could provide the insightful information on the plant operation performance and the risk effectiveness of maintenance activities. From this analysis, the specific risk patterns of plant performance by the basis of operation such as technical specifications and the limiting conditions of operations, might be derived and that information can be utilized during the activities for the improvement of plant operation.

3. Configuration Risk Profiles

During the application of this developed methods to the Korean nuclear power plant, Younggwang nuclear unit 3, the schedules of periodic surveillance and maintenance, and the trouble reports issued between Jan. 2000 and Oct. 2000 were reviewed. Through the review of these plant operation records, the configurations occurred during that period was derived, and the technical specifications and the in-service test procedures were considered. The development of risk profile is now under performing.

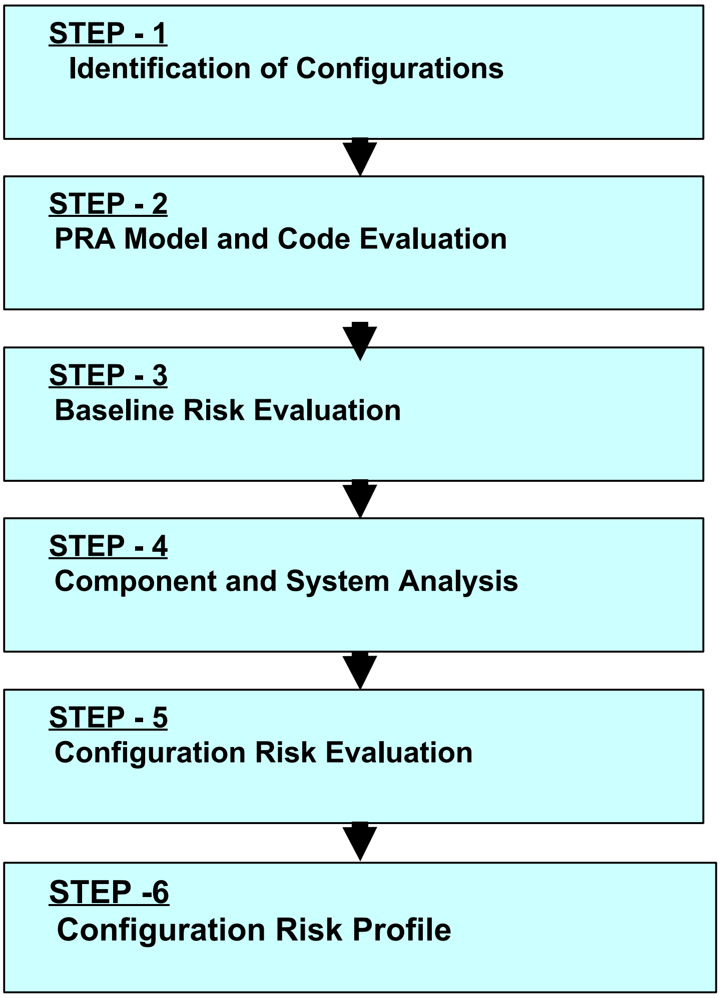

Figure 1. Configuration Risk Profile Methodology Steps

The plant PRA model used in this study was developed by KAERI for the purpose of risk monitoring. This plant model was constructed in the way of integrating fault trees and event trees, and it is called as one-top model. It is convenient to calculate core damage frequency by using this risk monitoring model. The configuration risk profile estimation needs a lot of calculation of CDF by solving many logical trees and needs lots of computation time. The utilization of risk monitoring plant model in this estimation procedure can save time and efforts

The configurations according to the periodic test and maintenance schedule were identified and the configuration risks were evaluated. For conservative evaluation, the test and maintenance related components or systems were downed during the test and maintenance. Therefore the unavailability of related basic events were set as one during the risk evaluation. Through figure 2 and 7, the operational risk profile was depicted. Figure 2 shows the risk profile of whole analysis period and others represent the risk profile for shorter period for the detailed analysis.

During the risk profile development, some configurations which cause risk peaks in the risk profile were identified and the risks resulted from those configurations were compared in figure 8. By the test and maintenance schedule, multiple configuration can occur and the risks from those possible configurations were presented in figure 9. The sensitivity study for the truncation levels during the risk estimation were performed and the results were shown in figure 10. The sensitivity study was performed for two different sensitivity levels of 10E-8 and 10E-10.

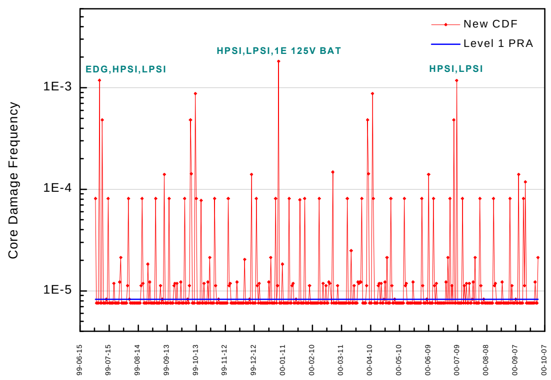

Figure 2. Risk Profile during Jul. 99 and Sep. 00

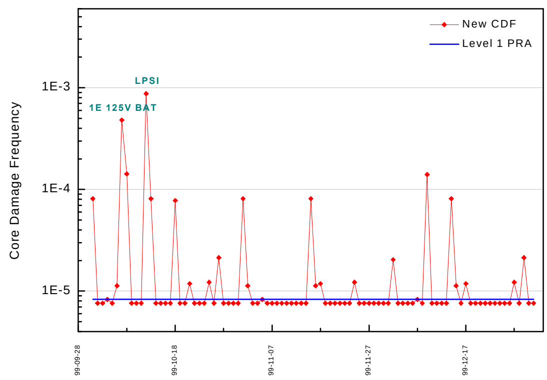

Figure 3. Risk Profile during Jul. 99 and Sep. 99

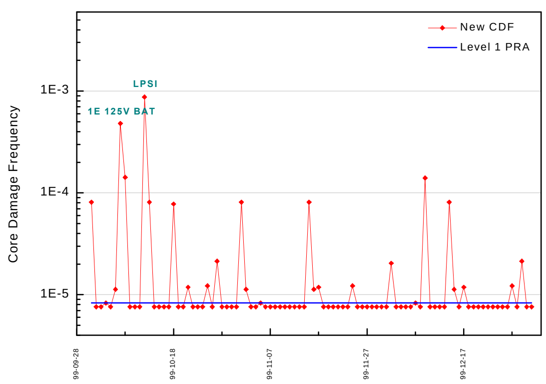

Figure 4. Risk Profile during Oct. 99 and Sep. 99

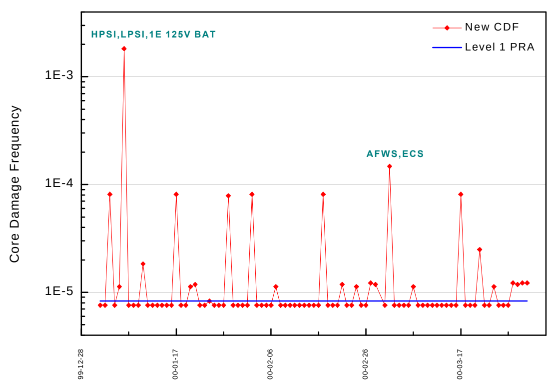

Figure 5. Risk Profile during Jan. 00 and Mar. 00

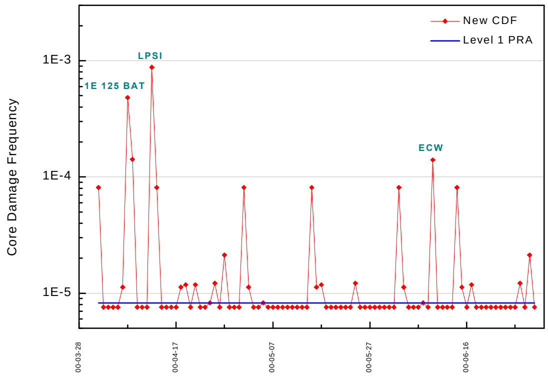

Figure 6. Risk Profile during Apr. 00 and Jun. 00

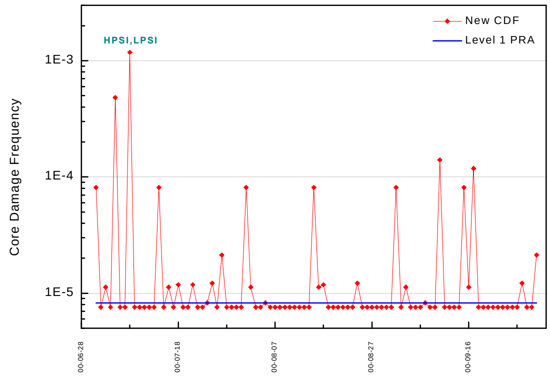

Figure 7. Risk Profile during Jul. 00 and Sep. 00

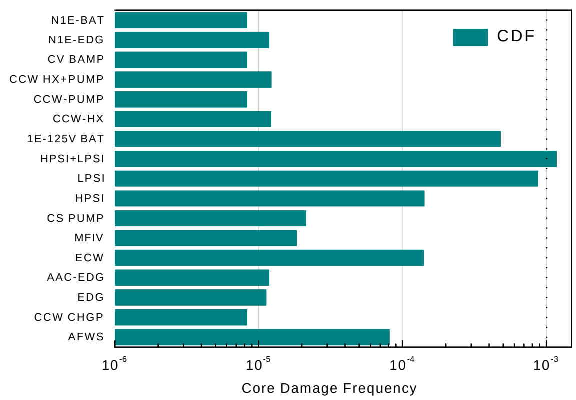

Figure 8. Important Configuration Risk Comparison

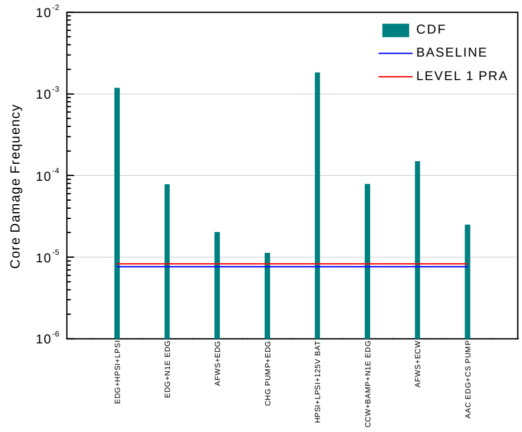

Figure 9. Possible Multiple Configurations

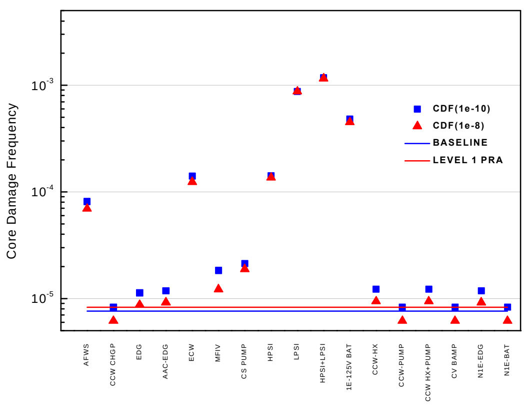

Figure 10. Sensitivity Study for Truncation Level

4. Summary and Conclusion

Six-step configuration risk assessment methodology was developed and by this method the plant configuration risk for various configurations occurred by testing and maintenance schedules can be evaluated. The result of application to the reference plant was presented also. The result of application showed that some risk-significant configurations can occur and such configuration can be identified by this methodology. Such identification and operational activity to avoid the identified risk contributing configuration can be a help to the safe and optimal plant operation in terms of risk.

This plant configuration risk assessment methodology can be utilized in the fields of technical specification improvement, risk-informed in-service inspection and test, and the optimization of surveillance requirements such as surveillance test intervals and allowed outage times by providing the risk insights for the normal plant operation. This methodology also can provide the supplementary information of the online risk monitoring and performance monitoring for the maintenance rule implementation.

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