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Development of RCM Framework for Implementation on Safety Systems of Nuclear Power Plant

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ABSTRACT

This paper presents a Reliability Centered Maintenance (RCM) framework for implementation on safety system of nuclear power plant (NPP). RCM is a systematic methodology to optimize the surveillance and maintenance tasks for critical components which provides efficiently and effectively reliability of system and safety of plant. Maintenance of the safety systems is essential for its safe and reliable operation. Reliability Centered Maintenance at NPP is the program which assure that plant system remains within original design criteria and that is not adversely affected during the plant life time.

Aim of this paper is to provide the RCM framework to implement it on safety systems. RCM framework is described in four major steps.

1. Introduction

The large, complex, high technology systems such as those used in nuclear and aircraft, require much high performance and reliability. They must be reliable and maintainable in order to render their operation both safe and cost-effective and they must be supported by an efficient, responsive maintenance program.

Reliability Centered Maintenance (RCM) methodology was originally developed by the commercial airlines industry in the year of 1960 for identifying applicable and effective preventive maintenance tasks. Safety systems are usually standby systems that should be periodically checked to reveal and repair failures that may have occurred since the previous activation or inspection.

RCM is a systematic methodology to optimize the surveillance and maintenance tasks for critical components which provides efficiently and effectively reliability of system and safety of plant.

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RCM pursues the identification of applicable and efficient preventive maintenance tasks to prevent these components from developing their dominant failure causes, and in turn towards achieving proper levels of components availability with low cost.
Aim of this paper is to provide the RCM framework to implement it on safety systems. Objective of the RCM is described in section 2. RCM framework is described in four major steps, which is described in section 3. Section 4 presents the implementation of RCM. And section 5 presents the conclusion and comments.

2. Objective of RCM

The major objective of RCM is to improve the performance of the system. RCM is intended to improve or maintain high levels of system reliability and plant availability. Since the reliability of safety systems will be improved, then naturally there will be a corresponding improvements in plant safety. It means that reliability and availability of safety systems will also be improved.
Another goal of RCM is to optimize the maintenance and testing tasks that are performed such that the overall level of resources required to accomplish essential tasks is kept to minimum. RCM also strives to eliminate unnecessary corrective maintenance and to select the simplest yet most cost-effective approach to maintenance, testing and inspection for system components.
A well-maintained system will experience breakdown less frequently. Less frequent breakdown equals increased reliability and improved plant availability. Breakdowns are not only measure of reliability. Frequently taking a system out of service for preventive maintenance makes it no more reliable than one experiencing frequent failures. RCM can correct the frequent breakdowns by setting up maintenance that decreases the incidence of component failure thereby increasing the reliability. In the latter case, RCM can reduce maintenance induced unavailability by eliminating unnecessary preventive maintenance and inspections. Also, RCM increases equipment availability because of the emphasis on the use of performance monitoring and diagnostic techniques in place of more intrusive maintenance methods.

3. Framework of RCM

For safety systems, performance means reliability that is, systems have to work correctly as required. Four steps is used for framework of RCM, which has been given below.

(1) System Functional Analysis

When the system under analysis is complex or performs numerous functions, a partitioning into subsystems is recommended to enable the RCM analyst to concentrate on a particular part of the system in order to avoid confusion with other system functions. This partitioning into subsystems requires a documented identification of its functions and its boundaries. Every subsystem consists of components. Each component has individual properties and failure rate. Some of them are more important for subsystem. Following information is needed for selection of subsystem:

- Failure and maintenance history records
- Operating procedure and technical specifications as specified by manufacturer
- System design report and probabilistic safety analysis (PSA) report

(2) Selection of Critical Components

Critical components are identified in each subsystem on the basis of failure record and maintenance history, whose failures will cause the functional failures of subsystem. Generally, components are declared as critical if their effects on system and plant are significant and have high probability or there is no redundancy or backup equipment. Figure 1 shows logical diagram for critical component selection.

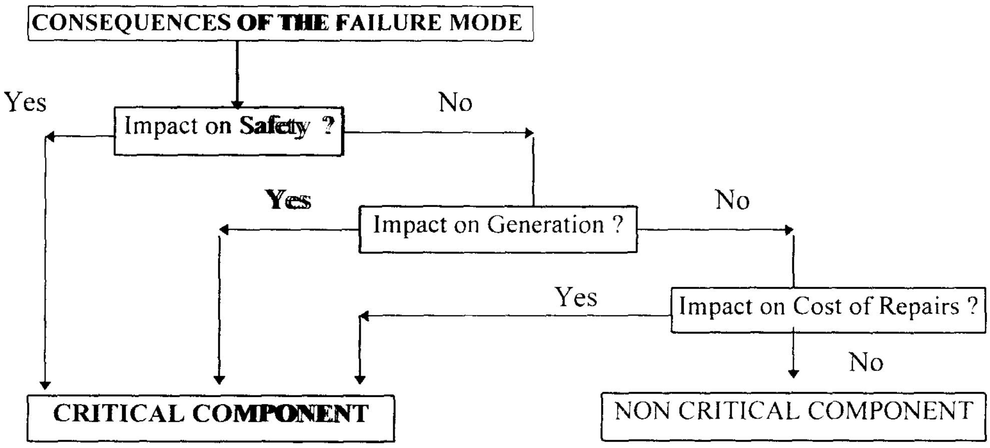

Figure 1: Logical Diagram for Critical Component Selection

(3) Failure Mode Analysis

Failure modes of each component are identified using appropriate risk measure. The most common criteria used to rank the criticality of a component functional failure are related to their impacts on safety, availability and maintenance costs. Past operating experience are also useful to take decision of failure mode of component.

Failure modes and effects analysis (FMEA) is used to analyze system to determine what the effects of individual components might be on the entire assembly or system. At first, major assemblies of the system are listed, after which each assembly is broken down into its component elements. Each component is then studied to see how it could fail, what could cause each type of failure, and the effect of this failure on other components, subassemblies, and the entire product. FMEA is a tool to systematically analyze all contributing component failure modes and identify the resulting effects on the system that shows component is critical or not critical. Effect of any failure mode on component is classified as follows:

Criticality	**Effect**
I. Safe	Negligible: No effect on component
II. Marginal	Failure will degrade the component to some extent but will not damage to the component or system or injury to personnel.
III. Critical	Failure will degrade component performance and/or cause personnel injury, and if immediate action is not taken, serious injuries or deaths to personnel and/or loss of component/ system functions will occur.

The final step in the FMEA is to classify the component failure mode as critical or non critical. A critical component failure mode causes the loss of function, it affects on plant safety or operation. If the effects do not call for a critical classification, other factors to consider include a high probability of failure and a large amount of corrective maintenance. These factors, by themselves, do not make a failure mode critical.

The worksheet for FMEA is shown in Table 1. Which is very useful to decide the maintenance policies for each failure mode of component. If any new failure occurs during operation, surveillance test and maintenance period it should be entered into worksheet of FMEA and how to detect this failure is to be mentioned.

Table 1: Worksheet for FMEA.

Component	Failure Mode	Class of Failure Mode	Failure Cause	Effect on other compo. or system	How to detect	Failure Prob.	Remark
Air compressor	1. Oil 2. Bearing	II II		Yes No			Change in 1 Yr. Change in 6 months

(4) Recommendation of Maintenance Task

Select the maintenance policies for each failure mode of component on the basis of failure records and history. Concept should be very clear to take the decision of preventive or predictive maintenance for component. New maintenance technology should be considered, for instance such new condition monitoring or inspection technologies as vibration monitoring for moving components, infrared thermography for circuit breakers, MOVAT or VOTES technology for motor-operated isolation valves have been developed. Finally new technologies can be recommended if they provide better reliability with marginal costs during plant life time. There should be an appropriate cost benefit guidelines between safety and cost. RAW (Risk achievement Worth) and RRW (Risk Reduction Worth) concept in PSA can be used for safety and cost measure. It is also important to discuss with site persons, when you are going to implement the maintenance policies. After discussion with site person you can make a final decision.

System Functional Failure Analysis

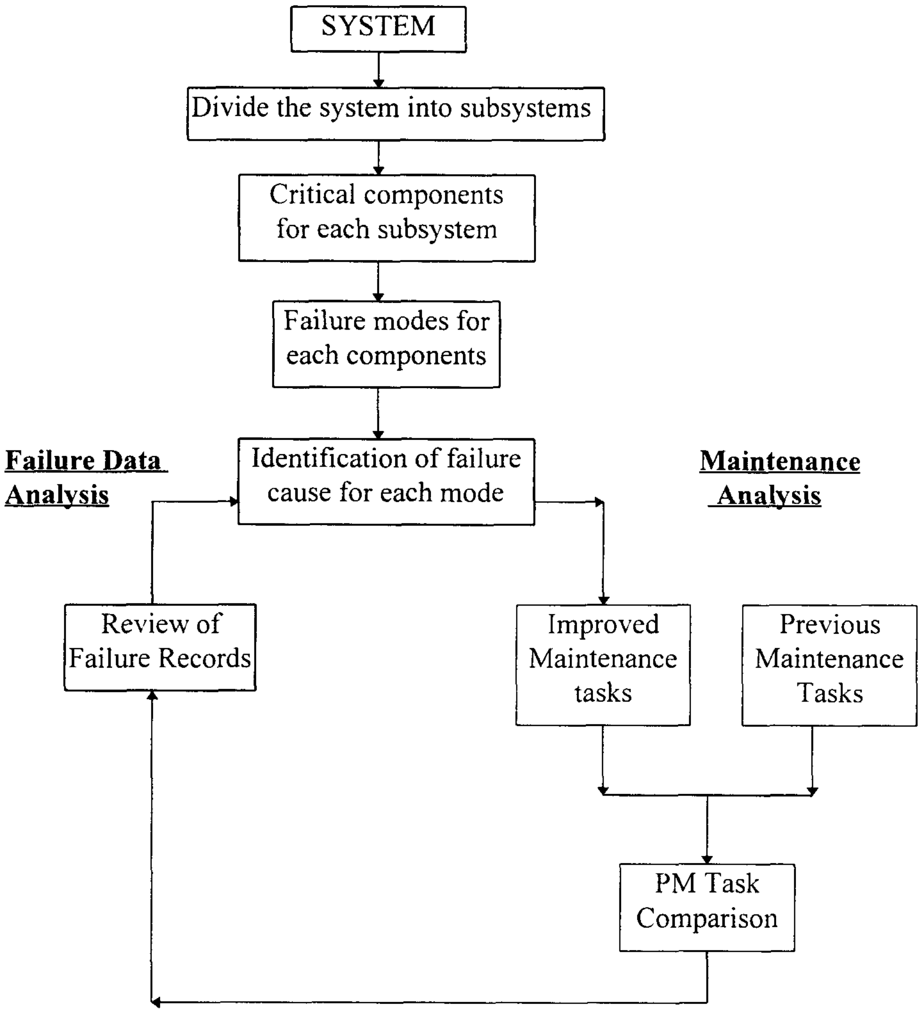

Figure 2: Implementation of RCM

4. Implementation of RCM

Implementation of RCM is divided into three phases. In first phase, maintenance history records of a system is to be reviewed. In second phase, functional failure analysis is required and in third phase selection of maintenance policies after discussion with site persons. Figure 2 shows the implementation of RCM.

5. Conclusion & Comments

RCM of safety systems is intended to improve or maintain high levels of system reliability and plant safety. Since the reliability of safety systems will be improved, then naturally availability of safety systems will also be improved, it means that there will be a corresponding improvements in plant safety.

RCM also strives to eliminate unnecessary corrective maintenance and to select yet most cost-effective approach to maintenance, testing and inspection for system components.

Plant interviews are one of the important step for implementation of RCM, because system engineering personnel have an overview of the system and may be the best source for identifying design problems or the cause of recurring failures. Maintenance personnel have good knowledge of maintenance because they have already faced some problems during the maintenance. His experience can be utilized for implementation of RCM.

Based on this concept we have written guidelines for implementation of RCM on safety systems. This technical report is under publication. We have also written a technical report for FMEA of Diesel Generator based on failure and maintenance records of foreign and domestic NPPs. This report is also under process.

6. References

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