Collection de notes internes de la Direction des Etudes et Recherches

Production d'énergie (hydraulique, thermique et nucléaire)

L'OPTIMISATION DE LA MAINTENANCE PAR LA FIABILITE, UN OUTIL D'OPTIMISATION POUR LES CENTRALES ELECTRIQUES

RELIABILITY CENTERED MAINTENANCE AS AN OPTIMIZATION TOOL FOR ELECTRICAL POWER PLANTS

98NB00010

EDF
Electricité de France

DIRECTION DES ÉTUDES ET RECHERCHES

SERVICE ENSEMBLES DE PRODUCTION
DÉPARTEMENT SURVEILLANCE DIAGNOSTIC MAINTENANCE

EDF
Electricité de France

Août 1997

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Pages : 10 98NB00010

30 - 02

Diffusion : J.-M. Lecœuvre
EDF-DER
Service IPN. Département PROVAL
1, avenue du Général-de-Gaulle
92141 Clamart Cedex

ISSN 1161-0611

SYNTHÈSE :

Il y a sept ans, Electricité de France a lancé un projet pilote d'Optimisation de la Maintenance par la Fiabilité (OMF) en vue d'optimiser la maintenance préventive de ses centrales nucléaires. Après une étude de faisabilité, la méthode OMF a été formalisée. Elle est aujourd'hui mise en oeuvre à grande échelle dans 50 tranches nucléaires d'EDF. Une station de travail OMF basée sur cette méthode a été mise au point ; elle est maintenant utilisée dans chaque centrale. L'étape suivante consiste à inclure dans cette démarche OMF les concepts "Risk-Based Inspection" en vue d'optimiser la maintenance des composants passifs tels que les tuyauteries et les supports.

Compte tenu des avantages potentiels de ces techniques d'optimisation, un processus spécial a également été développé pour la maintenance des centrales futures, (turbines à combustion ou centrales nucléaires).

Cette note présente un aperçu de ces méthodes et outils.

EXECUTIVE SUMMARY :

Seven years ago, Electricité de France launched a Reliability Centered Maintenance (RCM) pilot project to optimize preventive maintenance for its nuclear power plants. After a feasability study, a Reliability Centered Maintenance (RCM) method was standardized. It is now applied on a large scale to the 50 EDF nuclear units. A RCM workstation based on this standardized method has been developed and is now used in each plant. In the next step, ~~we consider~~ whether a Risk based Approach can be included in this RCM process in order to analyze critical passive components such as pipes and supports.

Considering the potential advantages of these optimization techniques, a dedicated process has been also developed for maintenance of future plants, gas turbines, or nuclear units.

~~This paper will present~~ a survey of these different developments of methods and tools.

RELIABILITY CENTERED MAINTENANCE AS AN OPTIMIZATION TOOL FOR ELECTRICAL POWER PLANTS

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II. INTRODUCTION

Maintenance costs in EDF nuclear power plants account for a significant proportion of the cost price per kilowatt-hour. For each plant, annual maintenance expenditure is on the order of 2.5% of initial investment. In 1993, the cost of maintenance for the entire French nuclear capacity stood at $1.5 billion (Mercier, 1992). If maintenance operations are conducted on such a large scale, it is to preserve good operating conditions, maintain plant availability and guarantee the desired level of safety.

Reliability Centered Maintenance was first introduced in aeronautic industry in the late Seventies, with the objective of controlling the costs of aircraft maintenance. More recently, in the United States, the Electric Power Research Institute (EPRI) launched a research program to transpose the methodology to nuclear power plant maintenance. Today, many American utilities are opting for RCM methods.

In 1990, EDF launched an R&D project on maintenance in its nuclear plants, with several focuses: honing of methods of analysis, application of these methods to pilot studies, and research on computerized tools. In light of the favorable conclusions from the project, EDF decided in 1994 to generalize the method on a large scale.

Reliability Centered Maintenance constitutes a general framework enabling the logical definition of a policy of preventive maintenance on an industrial installation. It is also a traceable method which allows for periodic updating of analyses. This general framework can be completed to take into account passive structures such as pipes, supports and vessels.

This paper describes the main principles of the classical RCM process by way of a simple example. It presents the different R&D studies started in Electricité de France, with the constant objective of obtaining a powerful tool to globally optimize the maintenance of both existing plants and future plants under design or construction (gas turbine, future PWR reactors).

III. THE RCM PROCESS

A. General principles

The principles underlying the RCM approach are based on plain common sense. Failures must be prevented by preventive maintenance operations in all cases when the repercussions for the installation could be serious or critical. In other words, maintenance must be directed to the right place and must call on the most appropriate techniques. More specifically, the method follows a logical sequence.

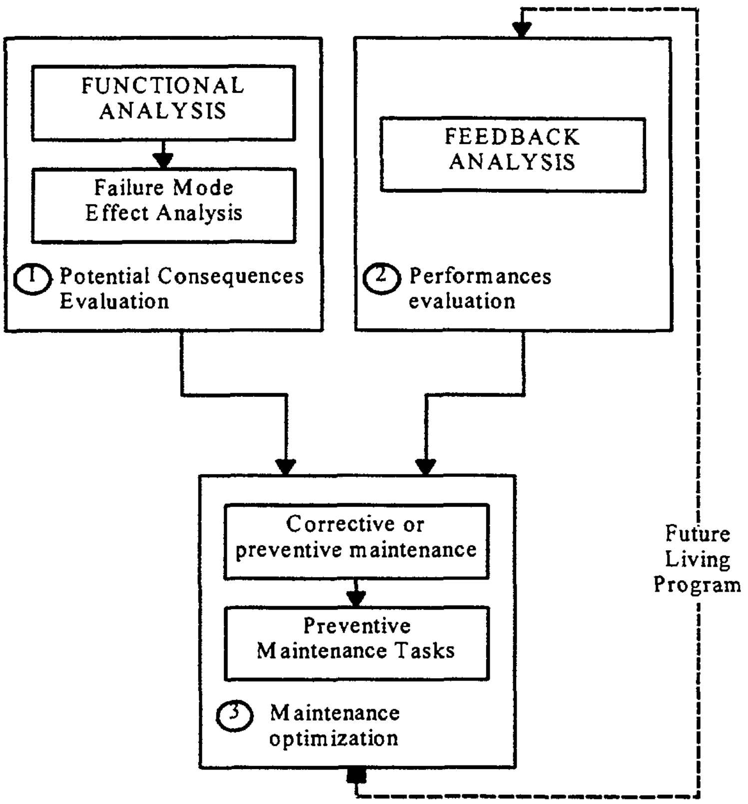

FIGURE 1 : THE RCM METHOD

B. RCM Methods

1. Potential consequences evaluation (Phase 1)

The RCM approach is based on an evaluation of the functional consequences of failures (Despujols, 1994). The first step therefore, consists of a functional analysis of the system or component. For example, to study the emergency diesel sets, we adopted the FAST method (Functional Analysis System Technique), which presents the advantage of being well adapted to existing equipment.

The second step is to analyze failure modes and causes all the way down to the level of detail required for maintenance. The reliability assessment techniques used in this phase are generally Failure Mode and Effect Analysis (FMEA).

2. Performances evaluation (Phase 2)

The analysis of operation experience carried out as the second phase is fundamental to the RCM approach. This provides information on the failures and degradations which have actually occured throughout the system . It is the only mean of showing that an expected failure or degradation has only rarely occurred and that a given preventive maintenance task is therefore not needed, and may even be counter-productive. In the diesel set study, some 2,000 operation experience forms were validated and processed.

3. Maintenance optimization (Phase 3)

The final step in RCM analysis is selection of maintenance tasks, on the basis of the phase 1 results, the FMEA in particular, and of results from operation feedback. Maintenance tasks are selected according to a specific selection logic which views all preventive maintenance operations in ascending order of difficulty: lubrication, inservice monitoring, checks and tests, and scheduled replacement. Today, this final step is essentially based on the judgment of an expert.

C. Results of the RCM study

An analysis of the failure modes with which this information was then associated led to the proposal of suitable maintenance tasks. The RCM recommendations call for a decrease in "complex" tasks (inspections, standard replacement), the shifting over of certain modes to corrective maintenance, a few proposals for change, and a greater emphasis on condition-directed maintenance than on scheduled maintenance. Applying these recommendations should lead to significant financial gains.

Classically, a RCM program proposes a preventive maintenance which is 5 to 10% cheaper than the existing program for two reasons :

a) the number of critical components (such as pumps, valves) selected for applying Preventive Maintenance is generally more limited than those of the existing program (more condition directed tasks, decrease in the task periodicity),

b) the RCM recommended maintenance tasks are globally cheaper than the existing tasks.

We have to keep in mind that the global level of safety and availability must not be affected.

In light of the favorable conclusions from the pilot projects (CVCS System, Emergency Diesel generator of a nuclear plant), EDF decided in 1994 to generalize the method on a large scale. The RCM process is now considered as a reference method. Today, each French nuclear plant has analyzed at least one or two systems. The results of each system RCM study is validated at the EDF corporate level and is subsequently applicable by each similarly designed nuclear plant in France.

IV. THE RCM WORKSTATION

A. Objectives:

During the different RCM projects, the volume of information to be handled and the need to assist the specialists in their analyses pointed to the need for a suitable workstation. The development of a RCM workstation was decided in order to prepare the maintenance program as well as to update this program, thus setting up a "living program". The objectives set for the workstation are as follows :

- to handle the great amount of RCM analysis data and provide study efficiency,
- to describe systems using a generic functional breakdown of components,
- to aid the user by providing him with a standard list of failure causes or failure modes...,
- to automate certain tasks (building of tables...),
- to facilitate any modification of RCM analysis.

The RCM workstation garantees the coherency of the current analysis with the EDF standard RCM methodology.

B. Principles

The RCM workstation is a PC based tool. This software is essentially composed of an ORACLE database associated with various modules corresponding to RCM process steps such as :

- functional analysis,
- Failure Modes Effects and Criticality Analysis (FMECA) based on a generic description of the main components of a plant.
- maintenance task selection

In addition to its function as a technical support for analysis, the workstation has capabilities for administration and project management.

C. State of development

The RCM workstation was developed in 1995 and validated by three nuclear plants. It is now adopted on 22 EDF nuclear power sites. The next version of the RCM software will be included in the nuclear plant information system and connected to the maintenance management system.

V. MAINTENANCE OF PASSIVE COMPONENTS

A. Objectives:

Up to now, the structural components such as pipes, supports, vessels have not been taken into account in the process, for three main reasons :

- The lack of structural failures reported in the operating experience precludes from knowing the corresponding failure rates and their time dependence.
- The consequences of individual structural failures are often not taken into account by existing PSA,
- The optimization of non-critical structural component inspections was only performed at the component level (i.e.: reliability-based rather than risk-based).

To overcome these limitations, an optimization process is developed by EDF. The Auxiliary Feedwater System of a 900 MW French nuclear plant has been studied as representative in order to lay the fundations of the method. A generalization should be proposed by the end of 1997.

This pilot-study points out that the extension of the RCM process to the structural components involves two kinds of specific developments :

- Qualitative models and quantitative component reliability models must be available in order to select some structural elements and predict their time-dependent failure rate.
- An adaptation of the existing PSA results must be done to evaluate the contribution of structural failures to core damage frequency.

A first « RCM-Structures » process has then been proposed. Its principles lead to include some « Risk-Based Inspection » concepts into the standard RCM method.

B. The « RCM - structures » processs

Three main phases are identified :

1. Potential consequences evaluation

◊ The system is decomposed into structural segments and a functional analysis of each segment is performed,

◊ A FMEA of each structural segment is driven. It leads to select a first set of « severe segments » whose failure has significant effects on the safety or availability of the unit. For safety-related consequences, the results of existing PSA are completed in order to assess the contribution of individual structural failures to core damage frequency.

2. Performances evaluation

◊ Severe segments are decomposed into structural elements. A qualitative analysis is then performed in order to select the « sensitive elements » where degradation mechanisms may be active. For that purpose, qualitative models have been developed : they are based on the available operating experience on degradations and failures, simplified physical models and expert judgements.

◊ A quantitative FMECA is performed on the sensitive elements. Failure probabilities are assessed by using structural reliability or expert judgment models. Therefore, risk is evaluated for each sensitive element and « risk-significant elements » are finally selected.

3. Maintenance optimization

is being developed. For risk-significant elements, qualitative and quantitative processes should be performed in order to select candidate programmes and to improve maintenance decisions by taking risks and costs into account.

VI. MAINTENANCE OF FUTURE POWER PLANTS

A. Maintenance and design of systems

The RCM process was first developed in the nuclear industry to optimize the preventive maintenance of existing plants. This approach is derived from practices developed in the aeronautical industry which uses it in the design phase of systems.

Consequently, the RCM method developed in EDF is now adapted for the design phase of future plants such as gas turbines or nuclear power plants. For this purpose, the RCM process is adapted in two ways:

- the analysis is functionally oriented ; it is a more global process, considering components such as an electric pump or a valve where the "classical" RCM process adresses a rotor, a stator, a gear...,
- the analysis takes into account design alternatives more systematically in order to maximize availability of the system and reduce maintenance costs.

B. Integrated logistic support concept in the design of nuclear plants

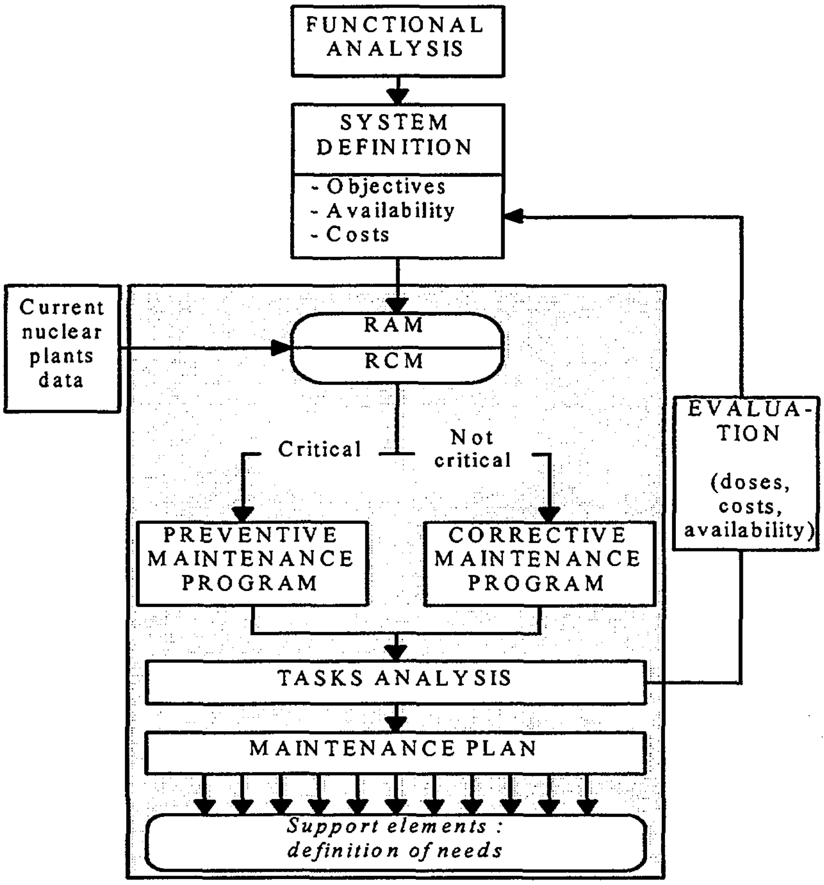

FIGURE 3 : THE ILS PROCESS

1. Logistic support analysis

The RCM process considers a preventive maintenance task as a simple activity: a vibration measurement, a systematic replacement. However the performances and cost of maintenance are actually related to the logistic support system.

The integrated logistic support (ILS) initiative was developed by the US Department of Defense for military system acquisition. The purpose of this initiative was for the DOD to provide the best balance between cost, schedule, performance and supportability.

2. Define an ILS methodology

For its future nuclear project, Electricité de France has decided to utilize an approach based on an ILS concept. It will be based on methods and standards drawn up on US DOD initiative. These methods and standards would be adapted to the nuclear plant design.

The purpose of the preliminary study is to show, through a demonstration example, how the military ILS concept can be used for nuclear power plant application and which methodology to use or to adapt. The main support elements are: maintenance plan, tools and test equipment, personnel and training, facilities, spare parts.

The basic principle of this ILS methodology is to deduce the logistic components from the Reliability Availability Maintenability (RAM) and RCM analysis, and consequently to globally evaluate the performances of the system (Meuwisse, 1996).

VII. CONCLUSIONS

The RCM approach is now widely recognized as an effective tool which enables updating preventive maintenance programs. Its traceability and exhaustiveness are particularly beneficial to a living maintenance program.

The RCM process is extended to include passive components such as pipes, vessels with the objective of defining an unique and global optimization process which includes active and passive components.

The RCM approach is a good base for defining a global optimizing process including Safety, Availability and Costs. This approach will probably be applied to plants under design. Considering the importance of maintenance in the overall cost of electricity, EDF will continue to develop simulation models, and decision making tools,

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