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Reliability centered maintenance optimization for power distribution systems

B. Yssaad [a,*], M. Khiat [b], A. Chaker [b]

[a] University Center of Relizane, 48000 bourmadia Relizane, Algeria
[b] Laboratory of Simulation, Control, Analysis and Maintenance of Electrical Network, National Polytechnic School of Oran NPSO, BP 1523 El M'Naouer, Algeria

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ABSTRACT

Today's electricity distribution systems operate in a liberalized market. These systems should therefore be able to provide electricity to customers with a high degree of reliability and be cost-effective for suppliers. RCM (Reliability Centred Maintenance) was invented by the aircraft industry in the 1960s, to organize the increasing need for maintenance for reducing costs without reducing b safety. Today RCM-methods invented by ALADON [1] are seen as very complex and are not fully accepted by the Algerian power industry. The extensive need of human and capital resources in the introduction phase is also a negative factor that could be one of the reasons of why RCM methods are not used in our branch. This article provides a discussion of the two primary objectives of RCM: to ensure safety through preventive maintenance actions, and, when safety is not a concern, preserve functionality in the most economical manner. For the power distribution systems facilities, the mission should be considered at the same level as safety.

1. Introduction

Reliability centered maintenance (RCM) is a systematic process used to determine what has to be accomplished to ensure that any physical facility is able to meet continuously its designed functions in its current operating context [2]. RCM leads to a maintenance program that focuses preventive maintenance (PM) on specific failure modes likely to occur. Any organization can benefit from RCM if its breakdowns account for more than 20–25% of the total maintenance workload [3].

This paper proposes a practical procedure to develop a cost effective maintenance program for electric power distribution systems. The procedure is mainly based on the reliability centered maintenance (RCM) method that prioritizes maintenance requirement of failure modes, and selects the effective maintenance activity for the critical failure modes. Reliability centered maintenance (RCM) is a decision making process in the selection of a cost-effective maintenance program to improve the reliability, based on determined criticality of failure modes. It prioritizes the maintenance requirement of all failure modes, and selects the effective maintenance activity for the critical failure modes [4,5]. In this paper, the RCM based maintenance program is developed using the proposed procedure for an electric utility in ALGERIA.

2. Reliability centered maintenance (RCM)

RCM is a systematic method to keep a balance between preventive and corrective maintenance. This method chooses the right preventive maintenance activities for the right component at the right time to reach the most cost-efficient solution [6].

The first description came in 1978 by Nowlan. It was introduced in nuclear power in 1980 and in hydro power in 1990 [7]. RCM is characterized by maintaining system function, identifying failure modes, prioritizing functions, and choosing efficient maintenance.

RCM is a technique that is used to develop cost effective maintenance plans and criteria so the operational capability of equipment is achieved, restored, or maintained. The main objective of RCM is to reduce the maintenance cost by focusing on the most important functions of the system. There are several different formulations of RCM processes in the literature. According to [8] an RCM analysis basically provides answers to the following questions

1. What are the functions and associated performance standards of the equipment in its present operating context?
2. In what ways can it fail to full fill its functions?
3. What is the cause of each functional failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to prevent each failure?

* Corresponding author. Tel.: +213 773906245.
E-mail address: benyssaad_y@yahoo.fr (B. Yssaad).

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7. What should be done if a suitable preventive task cannot be found?

The RCM analysis may be carried out as a sequence of activities or steps. In IEC standards for RCM analysis [9] following basic steps in an RCM analysis are listed, Fig. 1 shows a detailed logic diagram of the RCM method.

- Defining the system and/or subsystems and boundaries.
- Defining the functions of each system or subsystem identifying functionally significant item (FSI).
- Identifying the pertinent FSI functional failure causes.
- Predicting the effects and probability of these failures.
- Using a decision logic tree to categorize the effects of the FSI failures.
- Identifying applicable and effective maintenance tasks which comprise the initial maintenance program.
- Redesign of the equipment or process, if no applicable tasks can be identified.
- Establishing a dynamic maintenance program, which results from a routine and systematic update of the initial maintenance program and its revision assisted by the monitoring, collection and analysis of in-service data?

To avoid waiting again for several years prior to application to obtain this information, it seems necessary to predict the evolution of equipment reliability and so the consequences of implementing the new program. This step involves the modeling and simulation program, before its application [10]. Fig. 1 shows a detailed logic diagram of the RCM method.

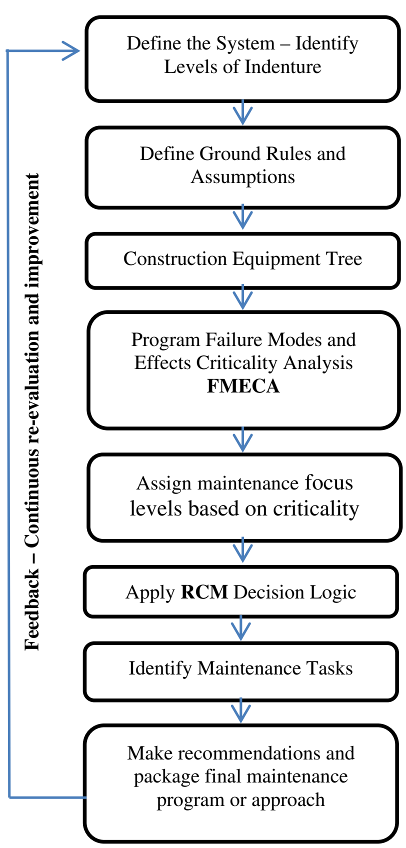

Fig. 1. Performance evaluation of maintenance program: model RCM.

2.1. Practical method of FMECA

FMECA is a useful tool when performing an RCM analysis. FMECA is a way to evaluate potential failure modes and their effects and causes in a systematic and structured manner. Failure modes means the ways in which something could fail. Effects analysis refers to studying the consequences of those failures.

The purpose of the FMECA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. By itself, an FMECA is not a problem solver; it should be used in combination with other problem solving tools. The analysis can be done either in a qualitatively or quantitatively way. Basic steps in performing a FMECA could be [11]:

1. Define the system to be analyzed. Complete system definition includes defining of system boundaries, identification of internal and interface functions, expected performance, and failure definitions.
2. Identify failure modes associated with system failures. For each function, identify all the ways failure could happen. These are potential failure modes.
3. Identify potential effects of failure modes. For each failure mode, identify all the consequences on the system. "What happens when the failure occurs?"
4. Determine and rank how serious each effect is. The most critical pieces of equipment which affected the overall function of the system need to identified and determined.
5. For each failure mode, determine all the potential root causes.
6. For each cause, identify available detection methods.
7. Identify recommended actions for each cause that can reduce the severity of each failure.

Then, a block diagram of the system needs to be created. This diagram gives an overview of the major components or process steps and how they are related. These are called logical relations around which the FMECA can be developed. It is useful to create a coding system to identify the different system elements. The block diagram should always be included with the FMECA. Fig. 2 shows a detailed logic diagram of the FMECA method.

2.2. Analysis FMECA

2.2.1. Evaluation criteria for different parameters of the FMECA

For the evaluation of failure modes, using the usual parameters of the FMEA, the frequency O, which characterizes occurrence failure modes, the severity S characterizes the duration of the outage caused by the failure mode detectability and D, which characterizes the probability of detecting the failure before it starts to take corrective or preventive actions. From the three previous parameters, we define C criticality or risk priority number RPN, which is calculated by the product of three factors O, S and D. It allows analyzing the risk and setting the threshold of acceptability for each failure mode [12].

$$\mathrm{RPN} = S * O * D \quad (1)$$

Quantification and the choice of values for each parameter were obtained from the history of the index of continuity of service (IC) and the number of interruptions over a period of 7 years from the data center operation of distribution (COD) located in the area north west of RELIZANE in ALGERIE de 2007–2010. The rating scale is 1–10 for the three parameters O, S and D.

Tables 1–4 summarizes the evaluation grid for each parameter, O frequency, severity, S, D detectability and criticality C.