Implementation of Reliability Centered Maintenance Technique on Boiler and Accessories in a Thermal Power Plant: A Case Study

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Abstract

There has been a significant change in the maintenance techniques used in industrial and power sectors due to the new complex designs, advanced technology and a huge increase in the number and variety of physical assets (plant, equipment and buildings). In face of this avalanche of change, modern maintenance managers seek the most appropriate maintenance technique to deal with each type of failure process. Reliability Centered Maintenance (RCM) is the maintenance technique that maximizes reliability at lowest possible cost. It does this by identifying real-time incipient equipment problems, thereby averting potentially catastrophic failures and by providing decision support through recommendations that will aid in identifying and scheduling preventative maintenance. This paper presents the applications of RCM to thermal generating unit and proposes a prototype RCM system for its maintenance. The prototype here is limited to boiler and its accessories.

Keywords: RCM, Pareto, Maintenance, Thermal power plant, Failure, Tripping.

I. Introduction

In order to avoid major upheavals like false starts and dead ends and contribute to advances in utility industry, there is a need for more reliable power supply, better customer service, and fewer emergencies and problems [1]. The need is to provide a tool to effectively manage resources based on reliability and costs. One such “Strategic Framework” or the “Appropriate Technique” required for maintenance is Reliability Centered Maintenance (RCM). RCM is a technique that is used to develop maintenance plans and criteria so the operational capability of equipment is achieved, restored, or maintained [2]. The objective of the RCM process is to focus attention on system equipment in a manner that leads to the formulation of an optimal maintenance plan. The main aim of RCM is to establish an acceptable reliability level and perform maintenance to maintain that reliability level. Realizing this goal opens the possibility of examining increased or decreased reliability criteria in light of costs [3]-[6].

RCM was developed in the airline industry to improve services and reduce costs by developing maintenance plans that maximize reliability at the lowest possible cost [7]. After that many maintenance engineers and researchers have worked on application of RCM in different fields.

A. *Background*

- With the arrival of the Boeing 747, a wide-body aircraft, U.S. airlines realized that their maintenance activity would require considerable change due to a large increase in scheduled maintenance costs. In 1968, airline operators jointly organized a study group to develop methodology for resolving the problem. The group was called Maintenance Steering Group No. 1 (MSG1). The resulting documents, MSG1, MSG2, and MSG3, appeared in 1968, 1970, and 1980, respectively [8].

- The term “Reliability Centered Maintenance” appeared for the first time as the title of a report on the processes used by the civil aviation industry to prepare maintenance programs for aircraft. The report, prepared by United Airlines, was commissioned by the U.S. Department of Defence in 1974.
- By the 1960's and 1970's downtime, which always affected the physical assets by reducing output, was already a major concern in all the manufacturing and processing sectors.
- In recent times, the growth of mechanization and automation has meant that reliability and availability have now also become key issues in these sectors [9], [10].

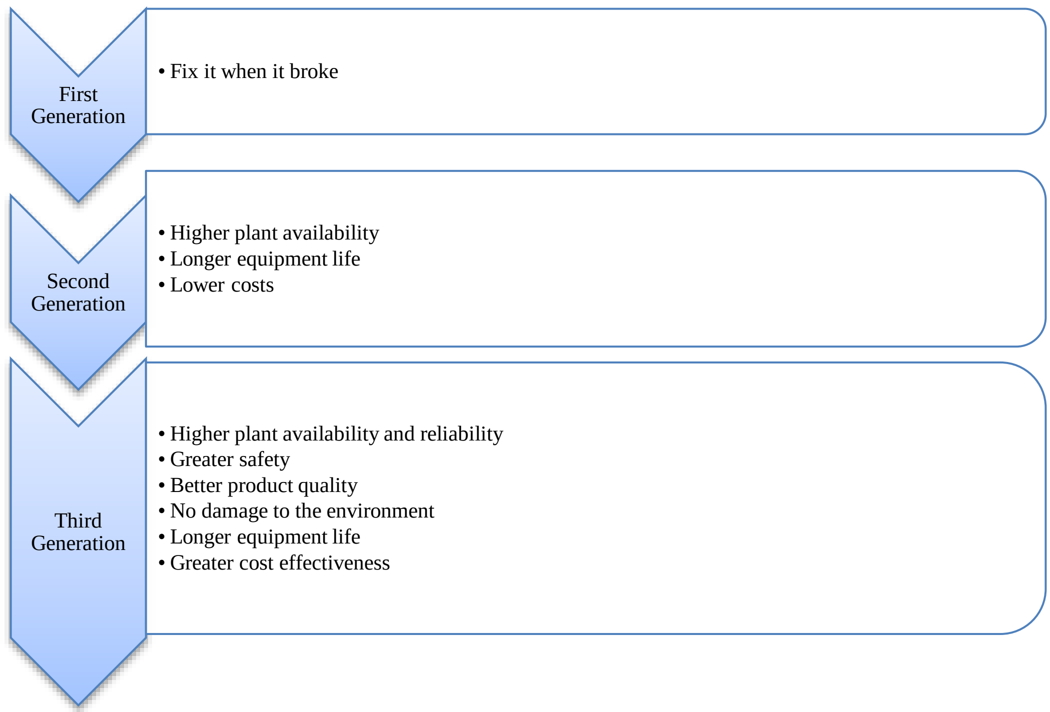

Fig.1 Changing trends of maintenance

Figure 1 gives the changing trends of maintenance from 1st to 3rd generation over the past 30 years.

B. *Electric Utilities and RCM*

The reliability of an electric power system refers to the ability of the electric system to provide consumers with continuous electric service of satisfactory power quality. The electric utility industry maintains a high level of system reliability because when the electric supply to consumers is disrupted, even for a short period of time, the results can range from minor inconvenience to major economic loss. Different reliability levels are experienced by the generation, transmission, and distribution systems. A proper level of electric utility system reliability is that which meets customer load demands and energy at the lowest possible cost while maintaining acceptable levels of service quality. Provisions for higher degrees of service reliability involve higher expenditures for both additional facilities and increased maintenance [11], [12].

Today there is a tendency among electric generation utilities to defer expenditures for expansion and improvement as long as possible. This tendency results in equipment experiencing more severe operating conditions. RCM technique can be the answer to identify and evaluate maintenance related problems in generation plants [13].

C. *RCM Process*

1) As a discipline RCM enables machinery stakeholders to monitor, assess, predict and generally understand the working of their physical assets. This is embodied in the initial part of the RCM process which is to identify the operating context of the machinery, and write a Failure Mode and Effects Analysis (FMEA) [14].

2) The second part of the analysis is to apply the "RCM logic", which helps determine the appropriate maintenance tasks for the identified failure modes in the FMEA. Once the logic is complete for all elements in the FMEA, the resulting list of maintenance is "packaged", so that the periodicities of the tasks are rationalised to be called up in work packages; it is important not to destroy the applicability of maintenance in this phase [15], [16].

3) Lastly, RCM is kept live throughout the "in-service" life of machinery, where the effectiveness of the maintenance is kept under constant review and adjusted in light of the experience gained [17].

According to the SAE JA1011 standard, which describes the minimum criteria that a process must comply with to be called “RCM,” a Reliability Centred Maintenance Process, answers the seven questions as given in Figure 2.

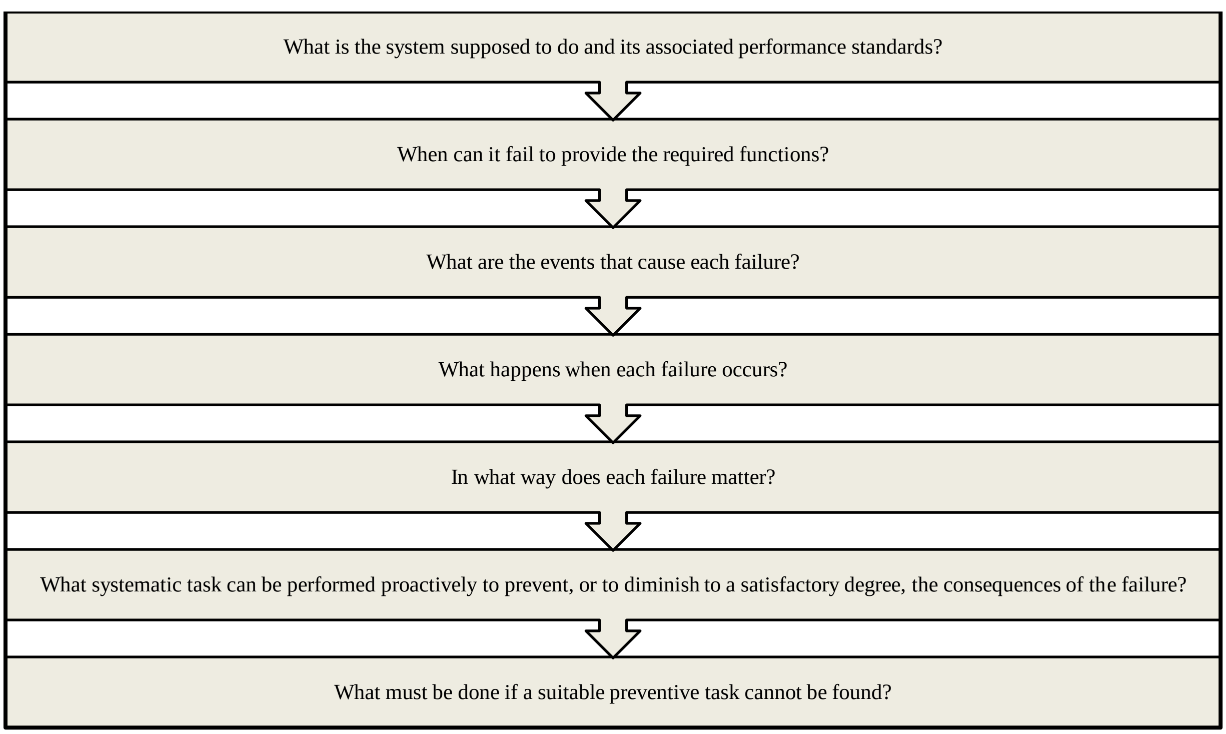

Fig.2 Seven question format of RCM

II. APPLICATION OF RCM

A thermal power plant, in state of Punjab, has been taken as prototype for RCM implementation. The following are the feasible areas of concern where RCM will be helpful:

-To supply reliable power at the least cost;

-To provide better customer service and fewer emergencies and problems;

-To manage resources wisely to reduce operating costs; and

-To answer questions related to improving maintenance [11], [16].

The details of forced outages of the opted thermal power plant for the previous two years i.e. 2014-15 and 2015-16 have been collected and analysed [8], [18]. In this work, the various problems leading to forced outages for the year 2015-16 have been mentioned in Table I.

TABLE I TRIPPING ANALYSIS FOR THE YEAR 2015-16

Sr. No.	Reason for Tripping	No. of Hours
1.	Water Wall Tube Leakage	495.90
2.	Fire at UAT and Gen. Transformer	362.20
3.	Platen SH Leakage	286.17
4.	Leakage at LTSH	169.25
5.	Leakage from Final SH	134.00
6.	Economizer Leakage	90.85
7.	Grid Failure	35.00
8.	Condenser Tube Leakage	30.22
9.	Tripped on -ve Furnace Draft	23.42
10.	Sparking at Carbon Brushes	19.70
11.	Hot Phase Bushing of Generator Transformer	18.05
12.	132 KV Bus Bar Differential Protection	12.60
13.	Loss of Excitation	12.50
14.	Leakage at Axial Bearing Rear	11.11
15.	Distance Protection and Reverse Power Relay	9.00
16.	To Change Gen. Exciter Brushes	7.48
17.	Loss of Fuel Due to Trip of ID Fan	6.34
18.	Tripped on +ve Furnace Draft	5.65
19.	False Operation of MFT	5.43
20.	UAT Buchholz Relay Trip	3.53
21.	Tripping of CW Pumps	3.28
22.	Loss of Secondary Oil Pressure	3.00
23.	Instrument Air Pressure Low	2.50
24.	BFP Failure/Leakage	1.50
25.	Tripping of Scanner Fan AC	1.30
26.	False Operation of EMUL Fire Protection	1.16
27.	Oil Leakage at Generator Transformer	10.65
28.	FD Fan Problem	1.00
29.	Turbine Lubricating Oil Pressure Low	0.55
	TOTAL	1763.34

The total outage time is calculated which is 1763 hours (approx.) per annum. Due to this outage time, the reduction in annual generation comes out to be a huge amount and in-a-way this is the total outage cost or the financial loss in the plant per annum [8].

As per the RCM format, the next step i.e. to sort out most important reasons of failure, has been applied on the data. This has been done using Pareto analysis [18], [19], which states that 80% of the problems come from 20% causes.

The Pareto analysis separates the vital few reasons of trippings with their respective outage time from the total, neglecting the least important.

It has been found that for this particular year the vital reasons of tripping are due to problem of leakage in boiler and its accessories i.e. superheaters and economizer as shown in Figure 3.

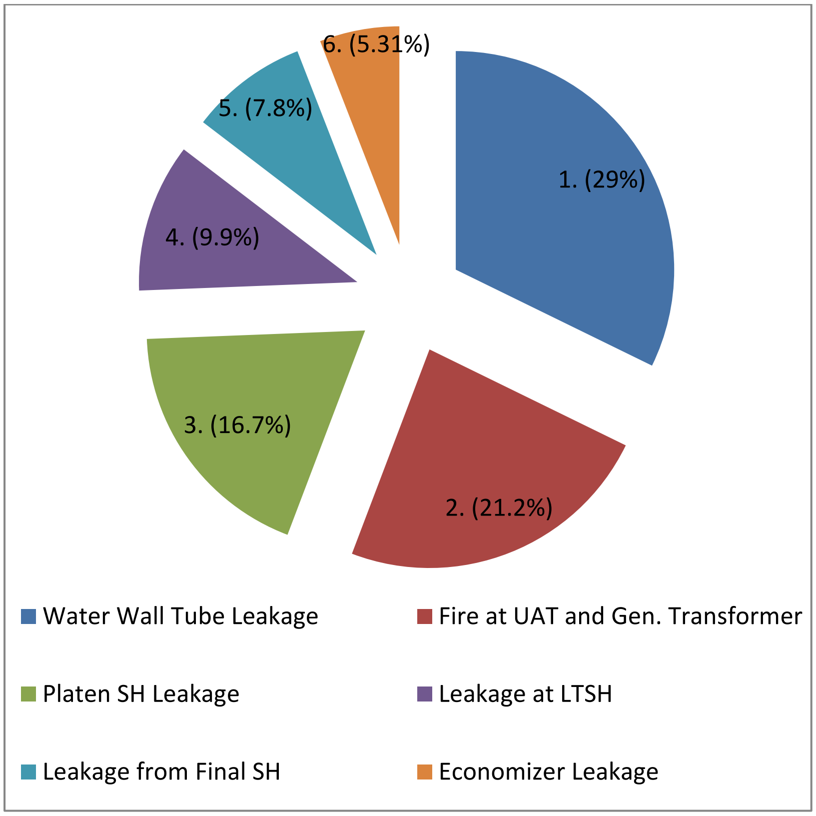

Fig.3 Vital reasons of tripping

The first two issues of identifying the system i.e. collecting data and segregating the major reasons responsible for faults, have been addressed. The next step is to identify the failure modes which are responsibly likely to cause each functional failure and to ascertain the failure effects associated with each failure mode. This is done by performing a failure mode and effect analysis (FMEA) for each functional failure [20], [21]. RCM information worksheet presents the said analysis. Here two separate RCM information worksheets, one for boiler and second for superheaters, are presented.

TABLE III RCM INFORMATION WORKSHEET I

RCM Information Worksheet	**System: Boiler** **Sub-System: Water walls**		
Function	**Functional Failure**	**Failure Mode**	**Failure Effects**
Water heating for converting it to steam	Unable to seize water and steam	Tube rupture or cracks in the tube	1. Severe water leakage 2.Degraded performance 3.Tripping of the plant

The second major reason of tripping according to the data is fire at unit auxiliary transformer and generator transformer. This is a mere miss-happening which has occurred once in this particular year. No record of such incident has been found in previous data collected. So this reason does not come under scanner of RCM process and can be neglected here.

TABLE IIII RCM INFORMATION WORKSHEET II

RCM Information Worksheet	**System: Superheaters** **Sub-System: Platen SH, LTSH and Final SH**		
Function	**Functional Failure**	**Failure Mode**	**Failure Effects**
To convert wet steam into dry steam i.e. superheating	Unable to superheat	A. Wear out of tubes B. Cracks in superheating tubes	1.Steam leakage 2. Poor efficiency 3. Tripping of the plant

The last reason to be discussed is leakage in the economizer. The RCM worksheet for this has been presented in Table IV.

TABLE IV RCM INFORMATION WORKSHEET III

RCM Information Worksheet	**System: Economizer** **Sub-System: Economizer tubes and bends**		
Function	**Functional Failure**	**Failure Mode**	**Failure Effects**
Heat exchange i.e. heating feed water entering boiler's steam drum	Unable to restrain water and exchange heat properly	Cracks in tubes	1. Water leakage 2. Reduced water volume for boiler drum 3. Tripping

III. CAUSES OF FAILURES

1. Water wall leakage is due to
   (i) Contamination of boiler water at condenser due to which it becomes acidic with low pH value. The interaction of low pH value water with parent tube surface leads to generation of nascent hydrogen. In high heat region hydrogen penetrates into the steel tube. This hydrogen combines with carbon in metal structure and forms methane. Methane molecules being too large to diffuse through steel, cause tube rupturing [22].
   (ii) Sticking of mineral contents to water walls due to fusion of coal ash which is formed by heating poor quality of coal i.e. clinker formation.
2. The leakage at superheaters is due to
   (i) Erosion due to continuous exposure to flue gases.
   (ii) Lack of careful maintenance.
   (iii) Ageing [18].
3. Economizer leakage is due to
   (i) Low temperature corrosion.
   (ii) Gas side deposits.
   (iii) Accumulation of soot with severe acid attack [18].

IV. REMEDIAL MEASURES

The following is the list of remedial measures to be taken to curtail the above mentioned faults:

1. Water wall leakage:
   - Regular check up of tubes for cracks.
   - Ultrasonic probe testing can be done.
   - Testing for cracks using acoustic instruments.
   - Regular poking of hopper for clinker removal.
   - Check up for condenser tube leakage as this is the weak links where boiler water is contaminated.
2. Superheater leakage:
   - Use of pure water.
   - Careful preventive maintenance.
   - Periodic inspection i.e. replacement of superheating tubes when and where required.
3. Economizer leakage:
   - General cleanliness.
   - Inspection of tubes and bends to prevent such failure.

V. CONCLUSIONS

The most vital faults in boiler and sub-systems have been segregated by analysing the previous tripping data. RCM information worksheets give failure mode and effect analysis for these repetitive and frequently occurring faults which are responsible for most of the downtimes of the plant. The causes of failures and respective remedial measures have also been mentioned in this paper which can be helpful for the maintenance department to perform RCM based maintenance policies for preventive maintenance. This will enhance the availability of the plant and more revenue can be earned.

As far as future scope is concerned, the work can be extended to further sub-system level. Instead of analysing total plant's tripping data, each unit can be analysed separately. The payback period can be calculated due to enhanced availability. Also for repetitive faults, RCM information worksheets and decision logics can be prepared using reliability software like Reliosoft.

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