# APPLICABILITY OF RELIABILITY CENTERED MAINTENANCE APPROACH FOR THERMAL POWER PLANTS IN SRI LANKA

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### *ABSTRACT*

*More than 70% of entire power demand in Sri Lanka mainly caters through thermal power and oil base thermal power plants contributes to cater more than 55% of demand in the country. Even though plant reliability and efficiency should be maintained at higher value to cater this demand, sudden island wide power cuts and Ceylon electricity board (CEB) statistics has been revealed the prevailing plant performance issues of thermal power plants.*

*Reliability Centered Maintenance (RCM) approach has been adopted successfully for wide range of industries including thermal power industry in considerable number of countries to overcome plant performance issues while reducing maintenance cost. Therefore the focus of this research is to study applicability of RCM approach for maintenance planning of thermal power plants in Sri Lanka to overcome current issues relating to maintenance operation. Comprehensive literature review was conducted to explore RCM concept. Through the preliminary survey current maintenance practices, issues that directly related with maintenance practice, currently available resources that necessary for RCM base analysis and attitude of industry practitioner towards RCM implementation were identified. Streamline Reliability Centered Maintenance (SRCM) was identified as ideal type of RCM analysis method for thermal power plants in Sri Lanka through findings of literature review and preliminary survey.*

*Findings of single case study revealed criticality evaluation criteria and applicable maintenance strategies for critical and non-critical components of typical thermal power plants. A comprehensive maintenance plan was developed for fuel pre pressure system using currently available physical and human resources. Considering findings, the research suggests that thermal power industry in Sri Lanka should initiate SRCM base maintenance program to overcome existing performance issues using existing resources.*

***Keywords****: Maintenance Optimisation; Performance Issues; Reliability Centered Maintenance; Thermal Power Plants.*

## 1. INTRODUCTION

Drawing parallels to many emerging economies in the world, Sri Lanka has been grappling to meet the rising demand for power (Illangasekera and Jawfer, 2012). Public Utilities Commission (2013) reveals maximum recorded electricity demand in Sri Lanka was 2146.4MW in year 2012 and in order to cater existing power demand installed capacity of Sri Lankan power plant is 3323 MW. According to Ceylon Electricity Board (CEB, 2012) install capacities of hydro and thermal power plants are 1584 MW and 1638 MW respectively.

Sri Lanka's thermal power system comprises both Ceylon Electricity Board (CEB) and Independent Power Producers (IPP) owned power plants operated with auto diesel or fuel oil (Ratnasiri, 2013). According to Ceylon Electricity Board (2012) 71% of total electricity demand was catered through thermal power plants. Further Oil base thermal power plants and existing coal based thermal power plants have contributed by 59% and 12% respectively to provide entire power demand.

Ministry of Power and Energy (2012) reveals that island wide two hour power cut experience due to a sudden breakdown at the Kerawalapitiya West Coast Thermal Power Plant and the Lakwijaya Power Plant in Puttlam. The CEB had to face a power crisis as they are deprived of 400 MW of power, due to the breakdown. Further CEB (2012) reveals that several CEB own thermal power plants have been operated at

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low thermal efficiency. In order to successfully compete in the electrical generating industry today, plant availability and reliability must be maintained at desired levels while operating costs must be kept as low as reasonably achievable (EPRI, 2001).

The availability of a complex system like thermal power plant is strongly associated with the parts reliability and maintenance policy (Carazas, and Souza, 2010). In general, it is viewed from the perspective of maintenance policies such as Corrective or breakdown Maintenance (CM), Preventive Maintenance (PM), and Predictive Maintenance (PDM). Sometimes, maintenance concepts like Total Productive Maintenance (TPM) or Reliability-Centered Maintenance (RCM) are also included in the above list (Pinjala *et al*., 2006).

Nowlan and Heap (as cited in Fore and Mudavanhu, 2011) RCM is defined as "a structured process for developing or optimising the maintenance requirements of a physical resource in its operating context to realise its inherent reliability by logically incorporating the optimal mix of reactive, preventive, condition-based and proactive maintenance practices". The goal of this approach is to reduce the Life-Cycle Cost (LCC) of a facility to a minimum while continuing to allow the facility to function as intended with required reliability and availability (National Aeronautics and Space Administration [NASA], 2008).

The aim of this research is to study applicability of RCM approach for maintenance planning of thermal power plants in Sri Lanka. In order to achieve this aim first a thorough literature review has been carried out to identify the current issues of thermal power plants relating to maintenance practices and different maintenance strategies used. Then availability of resources that required for RCM implementation initiative and barriers to implement RCM approach were evaluated. After identifying applicable type of RCM analysis for thermal power plants in Sri Lanka, applicability of selected type of RCM analysis method was evaluated.

## 2. RELIABILITY CENTERED MAINTENANCE

RCM has been widely recognised by maintenance professionals as the most cost effective way to develop world class maintenance strategies by determining what must be done systematically and scientifically to ensure that physical assets' continues operation in order to fulfil user requirements. RCM leads to rapid, sustained and substantial improvements in plant availability and reliability, product quality, safety and environmental integrity (Moubray, 1992).

Literature reveals different types of approaches for RCM implementation. These approaches are called classical, rigorous, intuitive, streamlined, or abbreviated (Pride, 2008). Rigorous RCM requires too many resources to perform an analysis on an average system. Streamlined Reliability Centered Maintenance (SRCM) has been developed to overcome this issue. The SRCM process has been validated against rigorous RCM by applying both methods independently on same plant. According to comparison of the result obtained through both analyses had slid difference (EPRIGN Engineering and Research, 1999).

Only the important functions are evaluated in the critical analysis in the streamlined RCM Process. If the component is determined to be critical, the analyst identifies the appropriate failure causes and recommends the applicable PM tasks to prevent or detect the identified failures. Components that are initially analysed in the Critical Analysis but are identified as non-critical will get evaluated again during the Non-critical analysis to determine if there are cost effective PM tasks that should be performed (EPRI, 1998, 2001). EPRI (1998, 2001) stated that non-critical analysis provides an evaluation using economic criteria for those components that were identified as functionally non-critical in the Critical Analysis.

The next step is to recommend applicable and effective preventive maintenance tasks based on the component's importance. Selecting the type of task to be performed and the frequency of the task can be accomplished considering the analyst selects failure causes associated with failure modes and effects. Another method available to determine the appropriate preventive maintenance tasks for each component is the standard RCM logic tree analysis (EPRI, 1998, 2001). The final step of SRCM analysis is recommendations with the existing PM program for revise the recommendation (EPRI, 1998).

## 3. RESEARCH METHODOLOGY

This paper basically focuses on how RCM approach can be applied for maintenance planning of thermal power plants in Sri Lanka to overcome current issues relating to maintenance operation. A mix approach including survey and case study was used to accomplish aim and objectives of the research.

A preliminary survey was conducted with expert industry practitioners in order to identify current maintenance practices, current issues directly related with maintenance operations, available resources and practices that support to RCM implementation, attitude of practitioners for RCM implementation and barriers of RCM implementation in Sri Lankan thermal power industry. Findings of comprehensive literature review were used to identify types of RCM approaches and criteria to be considered to determine appropriate type of RCM approach. Comparing findings of preliminary survey with circumstances that each type of RCM analysis method applied, SRCM approach was chosen as most appropriate RCM approach for thermal power plants in Sri Lanka. Preliminary survey was limited to seven thermal power plants that represent 71 percent of installed capacity of thermal power sector.

A single case study was conducted using a selected typical case to identify the applicability of RCM based approach for maintenance planning of thermal power plants to overcome current issues relating to maintenance operation. Semi structured interviews were used as the data collection technique for the preliminary study. Further semi structure interviews, documents, archival records, direct observation were used as data collection techniques for the single case study.

Simple statistical parameters such as mean, mode, percentage were used as data analysis techniques for preliminary survey. Further content analysis and SRCM analysis process were used as data analysis techniques for single case study to develop comprehensive maintenance plan for most important system that affect the plant operation. Development of maintenance plan limited to most important one system for plant operation.

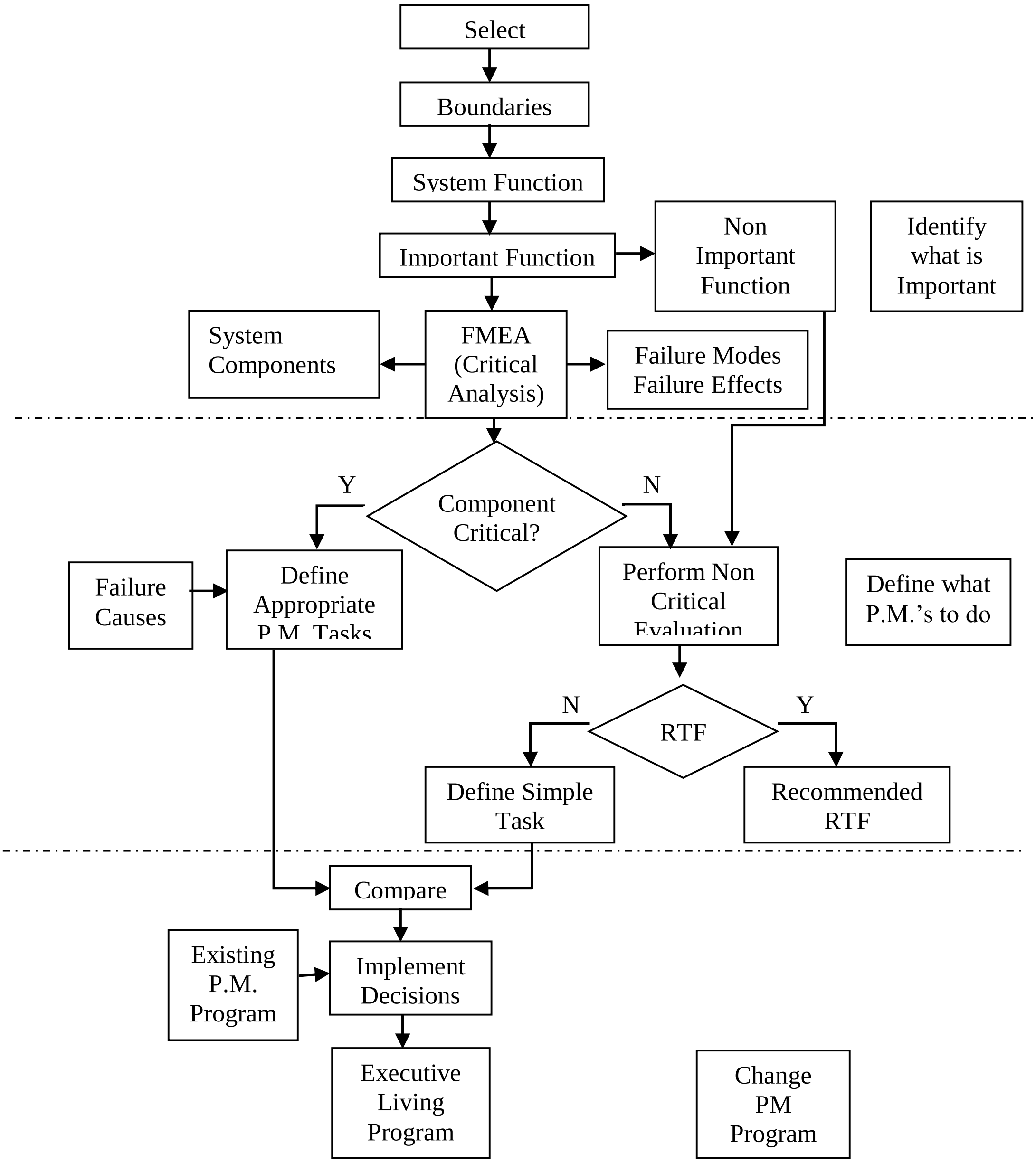


Figure 1: SRCM Analysis Process
Source: EPRIGN

## 4. Research Finding and Analysis

### *4.1. Findings of the Preliminary Survey*

Table1: Plant Capacity

| Plant Code | Capacity (MW) |
|---|---|
| A | 168.5 |
| B | 300 |
| C | 165 |
| D | 215 |
| E | 160 |
| F | 24 |
| G | 100 |

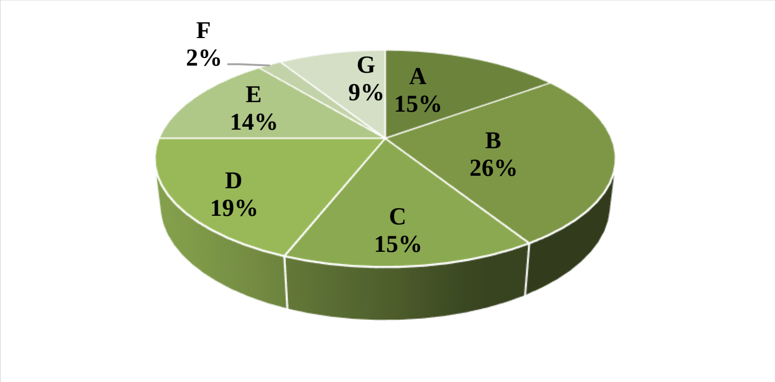


Figure 2: Capacity Profile

Overall capacity of selected thermal power plants for this preliminary survey is 1132.5 MW. Therefore these selected power plants represent 71.31 % of total thermal power sector in Sri Lanka. Further according to responses obtained through preliminary survey, preventive maintenance is the most widely adopted maintenance strategy for thermal power plants in Sri Lanka.

According to Table 2, the main factor affecting to the current maintenance related decisions is manufacture recommendation. The next important factor according to the priority is ensuring power generation reliability.

Table 2: Factors Affecting to Current Mix of Maintenance Strategy

| Factors Affecting for Current Mix of Maintenance | Percentage of Power Plant the Factor has been Affected | Priority Order |
|---|---|---|
| Traditional practice | 14% | 6 |
| Manufacturer recommendation | 100% | 1 |
| Legal requirement | 29% | 5 |
| Maintenance budget | 14% | 6 |
| Safety and environment issues | 57% | 3 |
| Energy efficiency | 43% | 4 |
| Ensuring power generation reliability | 86% | 2 |

According to findings, 71.43% of power plants used for preliminary survey have been confronting reliability and plant availability issues. The next most commonly faced issue according to priority order is plant efficiency related issues, which affected to 57.14 %of power plants used for this study. 42.86% of the power plants have faced safety issues and environment related issues according to opinion of the respondents.

Fortytwo percent (42%) of professionals are aware regarding RCM concept and 57 % of professionals are not aware regarding RCM concept. Further, all the seven number of expert professionals contributed to preliminary study accepted the necessity of using analysis method for rational decision making regarding power plant maintenance.

## 5. APPLICATION OF STREAMLINE RELIABILITY CENTERED MAINTENANCE FOR THE SELECTED CASE

The thermal power plant labelled as G in the preliminary survey was selected for in detail single case study regarding applicability of SRCM approach. This selected power plant has been categorised as Internal Combustion (IC) engine base power plant. The main fuel type used for operation is Heavy Fuel Oil (HFO). At the moment all the maintenance operations are conducted by in house maintenance staff. Maintenance tasks and respective frequencies have been decided mainly depending on manufacture recommendation and past experience of failures.

According findings, prevailing main issues affecting the plant operation are plant reliability related issues and plant efficiency related issues. Budgetary issues, safety related issues, environmental Issues and contractual issues are not critical for plant operation.

According to literature, basic required resources that should be available in facility in order to successful implementation of SRCM approach are as follows.

- System descriptions and system drawings
- Component list
- Component corrective maintenance history for 3- 5 years
- Existing preventive maintenance plan
- Plant professional with expert knowledge to analyse the systems

According to findings it can be concluded that there are sufficient basic resources within the selected case in order to initiate SRCM based maintenance practices.

Through semi structured interviews all the steps associate with SRCM analysis process were identified as feasible steps in selected power plant. Those feasible steps are as follows.

- Ability to failure mood determination of component
- Ability to failure effect determination of component
- Ability to determine component criticality under criticality evaluation criteria
- Ability of failure cause determination of components
- Ability of optimum maintenance tasks selection for critical component
- Ability of maintenance task selection for non-critical components

Main fuel system was identified as most important system according to results obtained through evaluation of importance of main system of power plant facility. There were fourteen identical generator units with 7.1 MW power generation capacities to provide 100MW total capacity of power plant. Each generator unit has separate auxiliary systems. However fourteen number of generator units depends on common starting compressors and main fuel supply system. Therefore, main fuel supply system was selected as the most important system of power plant considering importance on entire power generation process and expert views of maintenance professionals.

Main fuel supply system consists with main HFO unloading tanks, HFO separators, HFO service tanks, diesel tanks and fuel pre pressure unit. There are three number of fuel separators and two separators are sufficient to provide required fuel amount for full load operation of power plant. One pre pressure unit is sufficient only for providing required fuel amount for any seven number of generator units for their full load operation. Therefore, operation of both units is very important to operate entire plant with fourteen generator unit at full load capacity. Thus, reliability of power generation process totally depends on reliability of two identical pre pressure units. Considering this importance one pre pressure unit of two identical units is considered to develop optimum maintenance plan using SRCM approach.

One pre pressure unit basically consists with diesel supply pump arrangement, HFO supply pump arrangements and auto filter. Diesel supply pump arrangement consists mainly with a strainer, a motor driven pump, non-return valves, a pressure valve and Globe valves. HFO supply pump arrangement consist two identical arrangements consisting of a strainer, a motor driven pump and non-return valves. There is a pressure valve to regulate the pressure in HFO system. Further pressure release safety valve has been integrated with HFO supply arrangement that consisting heated up HFO to ensure the safety of the system. An auto filter has been integrated next to the pre pressure pump arrangement to improve quality of HFO through filtration process.

HFO supply pipe line and diesel supply pipe line has been interconnected before pre pressure pump arrangement through three way valve to convert HFO supply pump arrangement in to diesel before maintenance operation of HFO supply pump arrangement as a cleaning method. Further this arrangement is very important to convert HFO supply system into Diesel prior to long-term shutdown of plant.

### 5.1. *FUNCTION/ FUNCTIONAL FAILURE ANALYSIS (FFA)*

Table 3: Function/ Functional Failure Analysis
System: Fuel Pre Pressure System

| ID | Function | Functional Failure |
|---|---|---|
| 01 | Supplying required Fuel amount for Generator Facility. | Fails to provide required fuel amount for Generator Facility |
| 02 | Maintain the quality of Heavy Fuel Oil (HFO) with filtration process. | Unable to maintain required quality of HFO |

### 5.2. *FAILURE MOOD EFFECT AND CRITICALITY ANALYSIS*

Table 4: Criticality Analysis Report

| Component ID | Failure Modes | Failure Effect | Critical? | Criticality Evaluation Criteria | Failure Causes |
|---|---|---|---|---|---|
| DV 0008/ 0010/ 0011/0012 - Diesel pre pressure unit Globe Valve | Fails to close<br>Fails to open<br>Oil leaks | Difficulties for maintenance Operation<br>Operator action required | No | Component is important to support maintenance or operation activities | Corrosion<br>Valve Gland failure |
| DP 0002 – Diesel Oil pre pressure pump | Fails to start<br>Fails to run (Include degraded operation) | Loss of redundancy<br>Unable to provide required Fuel requirement for Generators | Yes | Result in reduction of significant power generation capacity of plant | Electrical failures<br>Bearing damage<br>Damage of coupling<br>Mechanical oil seal damage |

### 5.3. *MAINTENANCE TASK SELECTION*

Table 5: Maintenance Task Selection for Critical and Non Critical Components

| Component ID | Component Type | Recommended Task | Interval | Resp. Discipline | Recommended Base | Critical? |
|---|---|---|---|---|---|---|
| DV 0008/ 0010/ 0011/ 0012 - Diesel pre pressure unit Globe valve | GV - Glob Valve | Check for the operation and oil leaks<br>Clean and Lubricate the valve | 1M | MTC | This decision has been made based on Staff interview | No |
| DF 0002 – Diesel oil pre pressure pump Strainer | STR – Strainer | Check the suction and discharge pressure of pre pressure pump and Clean the strainer | 2W | MTC | This decision has been made based on Staff interview | YES |

### *5.4. COMPARISON OF EXISTING AND RECOMMENDED MAINTENANCE TASKS*

Table 6: Comparison of Existing and Recommended Maintenance Tasks

| Component ID | Existing Task | Interval | Recommended Task | Interval |
|---|---|---|---|---|
| DV 0008/ 0010/ 0011/ 0012 - Diesel pre pressure unit Globe valve | Run to fail | | Check for the operation and oil leaks<br>Clean and Lubricate the valve | 1M<br>1M |
| DP 0002 – Diesel Oil pre pressure pump | Replace oil seal<br>Bearing Replace | 1Y<br>2Y | Replace oil seal<br>Bearing Replace<br>Perform Vibration Analysis<br>Perform Motor Current analysis | 1Y<br>2Y<br>6M<br>6M |

Criticality analysis report presents criticality analysis results regarding each and every component of pre pressure unit under their operating context. Through this analysis each and every component identified consist of pre pressure system has been evaluated according to their operating context. Analysis reveals that same component under different operating context and different systems, has different level of criticality for entire plant operation. As an example the normally closed glob valve holding component ID HV0027 is a critical component for plant operation under its operating context even though other most of the globe valves in system are not critical. Therefore each and every component at the system should be evaluated to identify whether the component is critical under criticality evaluation criteria prior to assign maintenance task. Failure mood and failure effect identification helps to evaluate the criticality of component under criticality evaluation criteria. Further identified causes for each failure mood which is important to maintenance task selection also has been presented in criticality evaluation report.

Critical and non-critical task selection summary report has been presented recommended maintenance task for each and every component of the pre pressure unit assigned under critical task selection process or non-critical evaluation process. Maintenance task selection was done under critical task selection process for components decided as critical under criticality analysis. Further maintenance task selection was done under non critical evaluation process for component decided as non-critical through criticality analysis process. Required condition monitoring or condition based maintenance task, time based preventive maintenance task and surveillance task have been assigned for critical components according to requirement under critical task selection. Only time based preventive maintenance task and surveillance tasks have been assigned under non critical evaluation process according to requirements. Any non-critical components that any maintenance task has not been assigned and allowed to run to fail have not been compatible with non-critical evaluation criteria.

Recommended maintenance task and their intervals were compared with existing maintenance program through task comparison table. Through this process modification for recommendation can be done prior to implement. According to this analysis it is obvious that additional maintenance tasks were added with compared to existing maintenance practice considering the criticality of components as mentioned in the comparison report. Further through this analysis several neglected component have been identified as critical components. As an example, annul operation test has been recommended for pressure release safety valve of HFO system. This comparison report further reveals that applicability of currently available predictive testing techniques with power plant such as thermography, vibration analysis for critical component to improve the reliability and safety. The examples are inspection of HFO line for fuel leaks with thermography, application of vibration analysis and motor current analysis for fuel pumps.

## 6. CONCLUSIONS

The preliminary survey disclosed current maintenance practices, existing issues, available resources and practices that support the RCM implementation, attitude of practitioners for RCM implementation and barriers of RCM implementation considering the profile of power plants used for preliminary survey in Sri Lankan thermal power industry. Single case study findings have been presented including existing issues of selected case, evaluation of applicability of SRCM process for selected case, applicability of each step of SRCM process together with applicable evaluation criteria and applicable type of maintenance strategies. Further developed SRCM based maintenance plan for selected case has been presented.

### *6.1. RECOMMENDATIONS FOR INDUSTRY PRACTITIONERS*

The prime objective of application of RCM base approached for various industries is to minimise the cost associated with maintenance operation while reliability of plant and equipment is increased. According to research finding more than 50% of practitioners of thermal power industry which is reliability is concerned are not aware about the RCM concept. Therefore knowledge regarding new maintenance concepts of industry practitioners should be improved through training programs and continual professional development program. According to findings of this research there are sufficient resources to initiate SRCM base maintenance program. Therefore following recommendations are suggested for industry practitioners.

- Try to implement SRCM base maintenance program as pilot study for a problematic history and evaluate the success as initiation to RCM base maintenance program in Sri Lankan context.
- Use corrective maintenance records to determine optimum maintenance interval of components.
- Get consultancy services to obtain expert knowledge to establish RCM base maintenance program.
- Always try to obtain information regarding expected lifetime of component to determine preventive maintenance interval

### *6.2. RECOMMENDATION FOR ACADEMIC RESEARCHERS*

This research study only limited to identify the applicability of RCM approach for maintenance optimisation of thermal power plants in Sri Lanka. Therefore the following recommendations are offered to the academic researches to carry out further research.

- Conduct in depth study regarding applicability of SRCM approach for other facilities such as healthcare facilities, data centers, manufacturing facilities for maintenance decision making
- Study the relationship between per unit cost of electricity generation and current maintenance practice
- Conduct in depth study regarding the scientific techniques of optimum maintenance interval determination for maintenance decision making
- Explore the available software application developed for RCM base maintenance planning and implementation together with applicability of such software packages for Sri Lankan facilities

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