Application of Reliability Centered Maintenance Concept to Petrochemical Industry

P. Umpawanwong & P. Chutima
Faculty of Engineering/Industrial Engineering
Chulalongkorn University, Wangmai, Patumwan, Bangkok 10330, Thailand

ABSTRACT: Reliability Centered Maintenance (RCM) is a well-known method in several industries. RCM is a structure decision process to cost-effective determines and optimum maintenance requirements. This paper proposes the application of the RCM concept to a petrochemical case study. The results indicate that preventive maintenance plans and available time of maintenance staff are improved significantly.
KEYWORD: Reliability Centered Maintenance (RCM); Preventive Maintenance (PM)

1 INTRODUCTION

The production process in the case study is the oldest olefins production plant in Thailand which has 9,712 equipment in total classified into four groups, i.e. electrical, instrument, machinery and stationary, as shown in Table 1 and Figure 1.

Table 1: Number of equipment in production process

Class	Number of Equipment			
	Electrical	Instrument	Machinery	Stationary
A	109	522	48	373
B	348	2,117	262	790
C	580	3,290	288	985
Sum	1,037	5,929	598	2,148

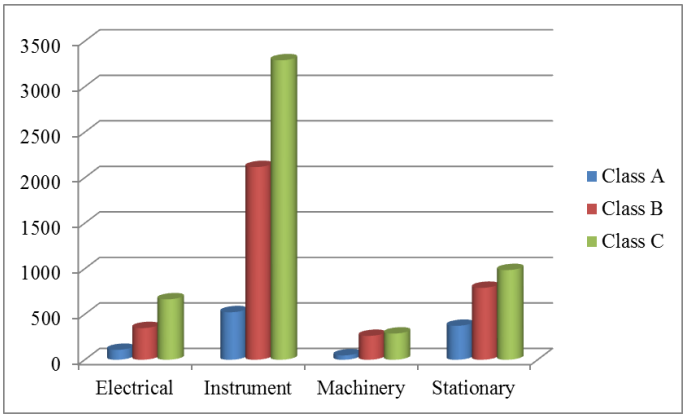

Figure 1: Proportion of equipment class in production process

In addition, if the equipment in class A fails, the production process will be totally shut down within 30 minutes. For class B's equipment, the impact to the production process is still high and the time to total shut down is more than 30 minutes. Whereas, there will be no effect to the process if the equipment in class C fails.

Table 2: Number of preventive maintenance plans in 2013

Class	Preventive Maintenance Plans			
	Electrical	Instrument	Machinery	Stationary
A	256	872	113	275
B	692	1868	353	775
C	1,324	471	173	460
Sum	2,272	3,211	639	1,510

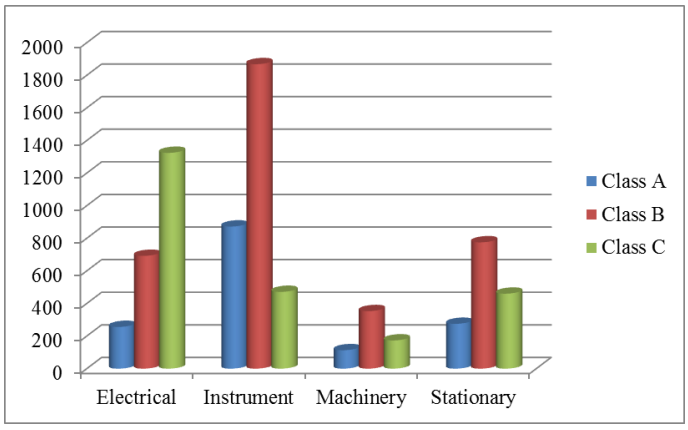

Figure 2: Proportion of preventive maintenance plans in 2013

From the 2013's maintenance report (Table 2 and Figure 2), the proportion of preventive maintenance plans in the electrical group was different from other groups observing from a high proportion of class C which should be normally low resulting in an excessive man-hour is used ineffectively in class C. Therefore, the reliability centered maintenance (RCM) concept is applied to improve this problem.

2 LITERATURE SURVEY

2.1 *Reliability Centered Maintenance (Moubray, 1997)*

Maintenance has been evolved through three generations. The first generation covered the period up to World War II. During the time, industry was not very highly mechanized. Hence, maintenance was simple whereby the machine was fixed only when it failed.

In the second generation (between 1950's and 1970's), machines of all types were more complex. Then downtime came into focus and the concept of preventive maintenance became worldwide. In this period, a scheduled maintenance was planned in advance.

In the third generation (after 1970's), a big change in maintenance was noticed. The maintenance was expected not only to increase machine availability but also with minimum maintenance cost. As a result, the concept of RCM, which is a process to determine the maintenance requirements of physical equipment, was developed. Seven steps of the RCM process are shown in Figure 3.

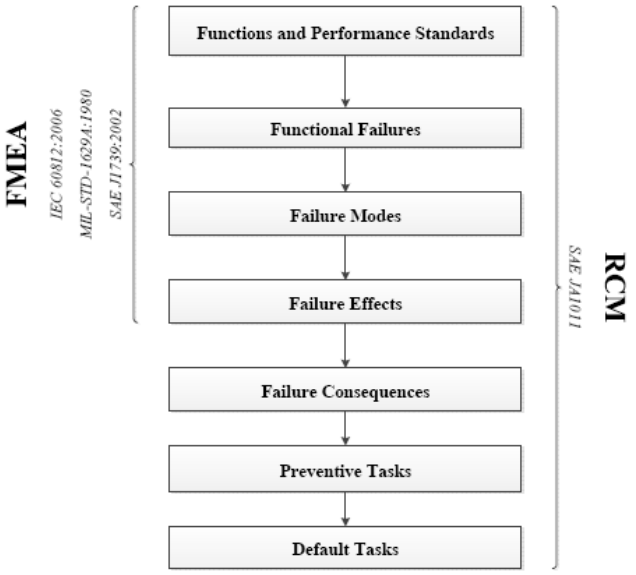

Figure 3: Seven steps of the RCM process

Step 1: Functions and performance standards: define the functions and performance standards of equipment.

Step 2: Functional failure: define the performance expectations of equipment.

Step 3: Failure modes: define the failure modes of equipment.

Step 4: Failure effects: define the failure effects of equipment at each failure mode.

Step 5: Failure consequences: define the failure consequences to the production process when the equipment cannot be in service at the expected level.

Step 6: Preventive tasks: choose the suitable maintenance strategy for all failure modes.

Step 7: Default tasks: update the new maintenance list and schedule in the computerized maintenance management system (CMMS)

2.2 *Literature Review*

Penrose (2005) proposed maintenance strategies which are suitable for motor management by using RCM techniques on electric motor. This paper describes about effective maintenance strategies such as condition-based monitoring (CBM) and assists maintenance staff for selecting the optimum in performing the right maintenance on the right equipment at the right time for the right reasons.

Yu & Zhao (2005) proposed maintenance plan based on RCM, which considered the condition of electrical equipment and its importance in the power system network. The actual condition of electrical equipment can be identified based on various criteria. They suggested identifying the criticality equipment which must be maintained first.

Ozdemir & Kuldasli (2010) proposed an RCM program for Turkish national power transmission system. This paper described steps of applying the RCM methodology and decision tree diagram for selecting right maintenance strategy to achieve the target to improve the reliability of the system by minimize the failure with applying appropriate maintenance procedure.

3 RESEARCH METHODOGY

The first step of RCM is data collection. Motor and switchgear which are the main equipment of class C are chosen in this study (Table 3). Normally the equipment with fully redundant has two units (one is on duty and the other is standby), whereas the equipment with not-fully redundant has only one.

Table 3: Motor and Switchgear data

Type	Class	Fully Redundant	Not Fully Redundant	Total
Motor	C	144	76	220
Switchgear	C	250	81	331

Appropriate maintenance strategies have been developed specifically for fully and not-fully redundant equipment. The functional failures, failure modes and failure consequences for each equipment group are shown in Tables 4 and 5.

Table 4: Motor RCM information form

Equipment: Motor			
Function (F)	*Functional Failure* (FF)	*Failure Mode* (FM)	*Failure Consequence* (FC)
Pump Driver	Stator Winding Insulation Failure	Over Current	Pump Cannot Run
		Moisture	
	Bearing Failure	Lack of Lubrication	
		Grease is Dirty	
	Cooling Fan Failure	Ambient Temp	

Table 5: Switchgear RCM information form

Equipment: Switchgear			
Function (F)	*Functional Failure* (FF)	*Failure Mode* (FM)	*Failure Consequence* (FC)
Power Supply	Arc Flash	High Contac Resistance	outage
	Nuisance Trip	Protection Relay Malfunction	

Decision tree is developed for selecting the right maintenance strategy to achieve the target, which can be explained as follows (Figure 4). Firstly, we have to know that whether the functional failure can be managed effectively or not. If it is not, the fix-after-fail strategy is used. If yes, we have to check whether the equipment is fully redundant or not. If the equipment is fully redundant, the run-to-fail strategy is used; otherwise, we have to further check whether the failure is age related or random. If it is an age-related failure, the time-based maintenance is used; otherwise, we have to use the condition based maintenance instead.

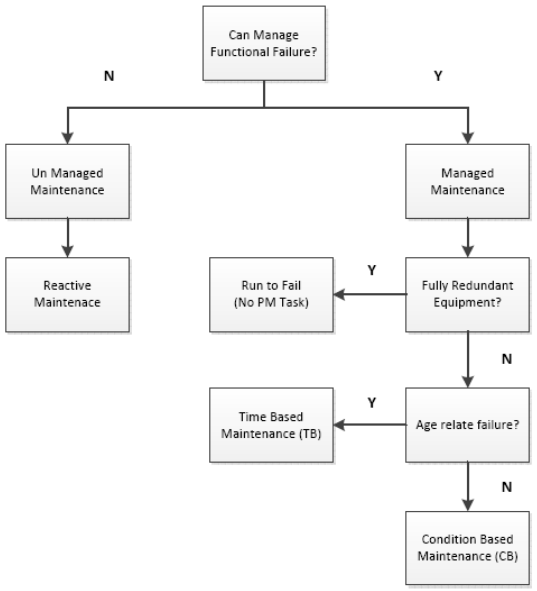

Figure 4: Decision tree for maintenance strategy

Following the guideline given in the decision tree, the maintenance strategies for motor and switchgear are shown in Tables 6 and 7, respectively.

Table 6: RCM Decision table for motor

Equipment: Motor			
Functional Failure (FF)	*Failure Mode* (FM)	*Type of Failure*	*PM Task*
Stator Winding Insulation Failure	Over Current	Random Failure	CB
	Moisture	Random Failure	CB
Bearing Failure	Lack of Lubrication	Age Relate	TB
	Grease is Dirty	Random Failure	CB
Cooling Fan Failure	Ambient Temp	Age Relate	TB

Table 7: RCM Decision table for switchgear

Equipment: Switchgear			
Functional Failure (FF)	*Failure Mode* (FM)	*Failure Consequence* (FC)	*PM Task*
Arc Flash	High Contact Resistance	Age Relate	TB
Nuisance Trip	Protection Relay Malfunction	Random Failure	CB

4 RESULTS

The number of new total PM plans and the proportion of PM plans are improved significantly, as a result of improving PM plans by applying the RCM concept as shown in Table 8 and Figure 5.

Table 8: Comparison between existing and new PM plans

Class	Electrical PM Plans	
	Before Improve	After Improve
A	256	256
B	692	692
C	1,324	443

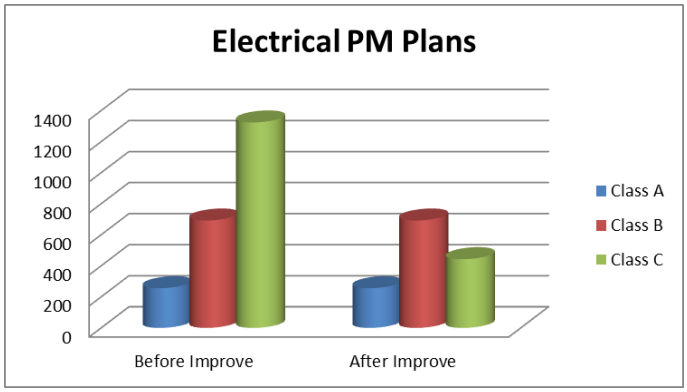

Figure 5: Comparison between existing and new PM plans

In addition, it is noticed that the maintenance cost is reduced and the available man-hour of maintenance staff is increased substantially as shown in Table 9.

Table 9: Maintenance cost saving

Electrical PM Plans	Man Hour/Year (Hrs.)	Maintenance Cost/Year (USD)
Before Improve	7,944	47,664
After Improve	2,658	15,948
Total Saving	5,286	31,716

5 CONCLUSION

Normally the concept of RCM is applied for class A's equipment to improve the mean time between failure. However, this study shows that this concept is also applicable to class C's as well. The goal is to reduce maintenance cost and increase the available man-hour of maintenance staff. The results from this study indicate that the concept of RCM can also apply to class's C and it could result in significant improvement in terms of cost and man-power requirement.

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