Critical Maintenance of Thermal Power Plant Using the Combination of Failure Mode Effect Analysis and AHP Approches

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Abstract
The electricity power generation plays the important role of every business or industrial, since it must be supplied to cove with the full consumption on demand sites. To keep with constant operating point of electric power generation of thermal process, the maintenance is the most crucial technique for preserving the deterioration or damage of equipments. In this research the thermal power plant of Electric Generation Authority of Thailand (EGAT) is selected to develop the maintenance system. Historical maintenance data of each unit of thermal plant must be retrieved. The data are classified and identified in four levels such as units, systems, equipments, and component. The data is characterized to database manner by using SQLserver and Visual C# 2005 is used for implementing the user program interfacing. The criteria level applies the combination of Failure Mode Effect Analysis (FMEA) and AHP approaches to find the critical ranking priority of failure mode relating to three criteria such as maintenance cost, man per hour working, line priority. In summary of this research, we analyze and develop the software for maintenance priority and management for thermal power plant. The developed software can help the maintenance team for making decision in spare part management and it is friendly-user to pursuit the maintenance policy focused on critical maintaining equipments in overall systems.

Keywords*: Critical Maintenance, FMEA, AHP, Thermal Power Plant*

1 Introduction

Maintenance is the crucial issue for the plant with highly complexity and a variety of machines such as thermal power plant, cement plant, oil refining plant and so on. The main of maintenance propose is to suppress the risky of plant suddenly shutdown with uncontrollable system. A thousand of equipments at each plant unit must be take care depending on maintenance policy such time based maintenance, break down maintenance etc. All equipments are mostly importance to be maintained in order to keep them working stability supposed with ill-conditioning operation. AHP approach is in the review article in decision system. The review paper of AHP for applications is described by [5]. Paper [1] is applied the AHP for project subcontractor evaluation. Finally they can justify that the best choice of subcontractor has been shown. Also [2] applied the priority of critical analysis derived from eigenvalue method by using AHP. [3] applied the MAHP as tool for decision adding, since MAHP is supported for a wide rank of rating and priority in decision system. [4] also applied the AHP for predictive maintenance policy applied to petrochemical process and food industry. [6] studied the comparison of tool support between CBRank and AHP methods. From the result, the accuracy of AHP is better than CBRank method. [7] employed the AHP in practical methodology of implementation. [8] is the ISO 14224:2006 for Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment. It can applied to be as a standard of design the code of maintenance system.

2 Classification of hierarchy level

2.1 *Four levels and identification code*

Plant is classified into four level of each thermal power plant line. The hierarchy level of each line is depicted in Figure 1, ordering as UNIT, SYSTEM, EQUIPMENT, and COMPONENT respectively.

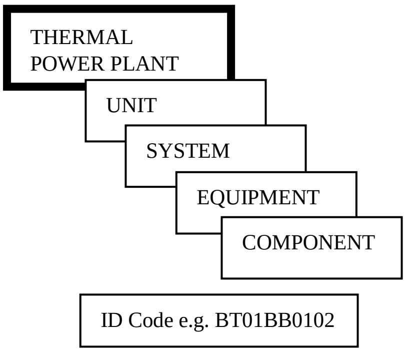


Figure 1: Four levels and identification code

3 FMEA principle

3.1 *FMEA approach*

Principle of Failure Mode and Effect Analysis (FMEA) is based on the derivative of damage analysis. Using this technique, the most importance maintenance choices of equipment are chosen with the proper intensity of damage level. As shown in Figure 2.

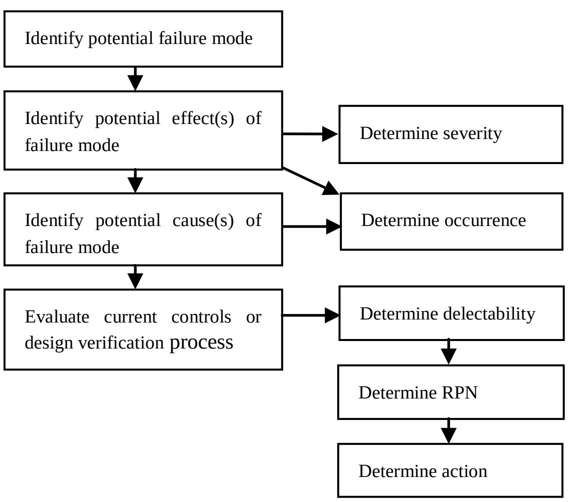


Figure 2: Conventional FMEA

3.2 *Ranking priority*

Comparison of three main considerations of maintenance policy cost, man per hour working, line priority are identifiable, since it reflects to the priority of maintaining system. The backward form of gaining the priority is affected from the lower hierarchy level to the highest level as component, equipment, system and unit respectively. Table 1 shows an example of ranking priority.

Table 1: Example of ranking form

unit	**system**	**equipment**	**component**	**C**	**M-H**	**LP**
Bt01	bb	10	01			
	Air gas mixing	nozzle	Head	400	5	***B***
			seal	300	4	***B***
Bt02	bc	20	05			
	Heat pipe	Valve	Nipple	200	3	***C***
			Elbow	100	2	***C***

Where C represents cost of material. M-H represents man per hour working. LP represents line priority dividing into 3 groups, ***A***, ***B*** and ***C*** respective. ***A*** means the most significant line. ***B*** means the moderate significant line. ***C*** means the least significant line.

The result of FMEA technique displays with the ranking of each unit of plant ranged from maximum to minimum value as indicated at Table 1.

4 AHP approach

4.1 *Design principle of AHP*

Analytical Hierarchy Principle (AHP) is the principle of decision making system. The operation is employed the technique of pair wise comparison of decision between C_i and C_j in $n \times n$ dimensional matrix described by Equation (1)

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \quad (1)$$

Where the a_{ij} is the relative importance of C_i and C_j. The entries a_{ij} are defined by the following rules [9]:

1. If $a_{ij} = \alpha$, then $a_{ji} = \frac{1}{\alpha}$, $\alpha \neq 0$.

2. If C_i is meant to be equal relative intensity of importance as C_j, then $a_{ij} = a_{ji} = 1; a_{ii} = 1$ for all i.

The applied AHP for priority ranking consequently for critical maintenance is designed in hierarchy level as depicted in Figure 3.

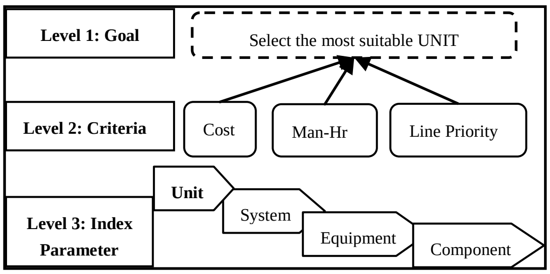


Figure 3: Hierarchy of the system

Table 2 is the judgment score of importance intensity of Unit, system, equipment and component consecutively. This is the weighting technique that creates by the maintenance operator on the site of operation.

Table 2: Importance level of priority

Definition of Verbal Judgment	Intensity of Importance
Equal	1
Moderate	3
Strong	5

Table 3: Pair-wise comparison matrix for Cost

Cost	Unit1	Unit2	Unit3	Unit4	Priority vector SUM/4
Unit 1	1	1/3	3	5	0.288
Unit 2	3	1	1/3	3	0.309
Unit 3	1/3	3	1	1/5	0.211
Unit 4	1/5	1/3	5	1	0.189
SUM	4.53	4.66	9.33	9.2	

In order to determine the pair-wise comparison, matrix is calculated by dividing each element of the matrix by column in total. For the case of Unit 1, the value 1/4.53= 0.22 which is 4.53 is the sum of the column in Table 3. For Unit 2, the value (1/3)/4.66 = 0.071. For Unit 3, the value 3/9.33 = 0.543.

The priority vector in Table 3. can be obtained by finding the row averages. For example, the priority of Unit 1 with respect to the criterion 'cost' in Table 4 is calculated by dividing the sum of the rows (0.22 + 0.071 + 0.321 + 0.543=0.288) by the number of Unit (columns), which is 4, in order to obtain the value 0.288. The similar manner of the value obtained in Table 4, Table 5 and Table 6 is the same procedure as indicated in Table 3.

Table 4: Pair-wise comparison matrix for Man-Hour

Man-Hour	Unit1	Unit2	Unit3	Unit4	Priority vector (SUM/4)
Unit 1	1	3	3	5	0.478
Unit 2	1/3	1	1/3	1/5	0.087
Unit 3	1/3	3	1	5	0.273
Unit 4	1/5	5	1/5	1	0.164
SUM	1.86	12	4.53	11.2	

Table 5: Pair-wise comparison matrix for Line Priority

Line Priority	Unit1	Unit2	Unit3	Unit4	Priority vector SUM/4
Unit 1	1	3	5	1/3	0.337
Unit 2	1/3	1	3	5	0.337
Unit 3	1/5	1/3	1	1/3	0.062
Unit 4	3	1/5	3	1	0.276
SUM	4.53	4.53	12	6.66	

Table 6: Pair-wise comparison matrix for the three criteria

Criteria	Cost	M-H	LP	Priority vector (SUM/3)
Cost	1	3	1/3	0.256
M-H	1/3	1	1/5	0.276
LP	3	5	1	0.63
	4.33	9	1.53	1.162

In pair-wise comparison the matrix is applied to each standard criteria in order to finding the priority of critical maintenance of decision making in management system.

Overall priority of Unit 1
= (0.256)0.289+(0.276)0.478 + (0.63)0.337
= 0.418

Overall priority of Unit 2
= (0.256) 0.309+(0.276) 0.087 + (0.63) 0.337
= 0.315

Overall priority of Unit 3
= (0.256) 0.211+(0.276) 0.273 + (0.63) 0.062
= 0.168

Overall priority of Unit 4
= (0.256) 0.189 + (0.276) 0.164 + (0.63) 0.276
= 0. 267

Table 6: Priority matrix for the selecting Unit

Criteria	Cost(0.256)	M-H(0.276)	LP(0.63)	Overall Priority vector
Unit 1	0.289	0.478	0.337	0.418
Unit 2	0.309	0.087	0.337	0.315
Unit 3	0.211	0.273	0.062	0.168
Unit 4	0.189	0.164	0.276	0.267

Table 7: Output from applied AHP for decision making

Alternate	***Ranging critical value***		
	Cost	M-H	LP
Unit 1	△	☆	☆
Unit 2	☆	○	☆
Unit 3	△	△	○
Unit 4	○	△	△

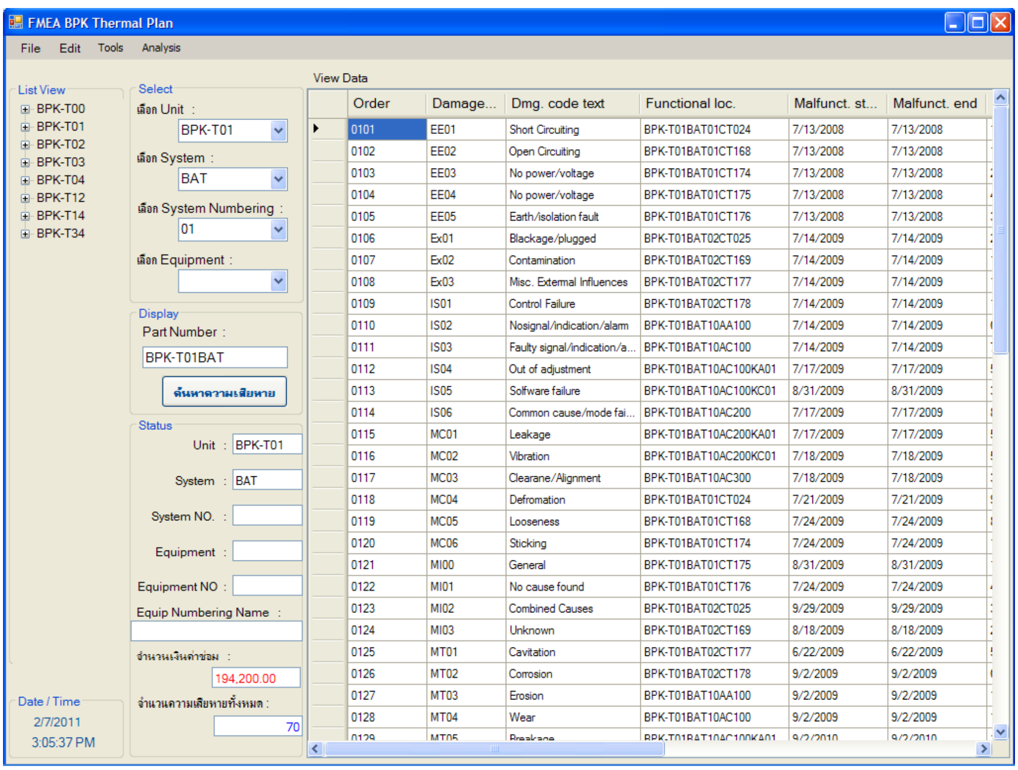
☆ High critical
△ Medium critical
○ Low critical

Table 7 describes in case of each criteria effected to each Unit. For example in cost aspect of maintenance system, the high critical line of thermal power plant process is indicated by Unit 2, but in consideration of Man-Hour aspect of maintenance is shown by Unit 1.

5 Results

5.1 *Ranking of priority*

Figure 4 shows the window from development of maintenance system for EGAT of Thailand. Data retrieval and displaying are selecting the icon with hierarchy level of maintenance system for Thermal plant of electricity generation at Pangprakong site. Failure mode and ranking priority are used for analysis overall components of each unit line, ranging selection by Unit 1 to Unit 4.



(a)

(b)

Figure 4: Result of software development; (a) selected hierarchical system and (b) frequency damage output

The result from calculate data by using AHP approach is shown by Table 6. Unit 1 is the first priority of maintenance system according with all criteria composition. The lower level of priority is ranging to Unit 2, Unit 4, and finally Unit 3 respectively. On the similarity, Table 7 displays the ranging critical relating to each criteria. From the example result in cost criteria, Unit 2 is the most critical maintenance. Unit 1 and 3 are the medium critical maintenance. Finally Unit 4 is the low critical maintenance.

6 Conclusions

Critical maintenance and management is self-developed by software specially applied for thermal plant for electricity generation unit. Data of historical maintenance is retrieved and rearranged to database program. Hierarchy level of system is obtained and classification into four levels of each unit such as unit, system, equipment and component. The FMEA is designed to find and to collect the system failure mode. Ranking is provided into three categories such cost, man per hour working, line critical. The proposed AHP criteria are applied of this project in order to decision the critical maintenance as proposed. The result of our development is satisfied for management operator and applied into the real maintenance operator of EGAT, Bangpakong thermal plant.

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