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MAINTENANCE STRATEGY SELECTION FOR STEAM POWER PLANT IN RANGE OF CAPACITY 300 - 625 MW IN INDONESIA

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ABSTRACT

The government of Indonesia has rolled out the acceleration program for the construction of power plants to increase the rate of electrification in Indonesia. Coal fired steam power plant is the most widely constructed to support this program and it's became the largest of total installed capacity in Indonesia. This research aims to obtain alternative of maintenance strategy in accordance with existing conditions in Indonesia. Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) used by obtaining criteria, sub criteria and alternative options acquired from the judgement and opinion from 10 experts in power plant. Experts are asked to do a pair wise comparison process to determine which criteria according to experts is more important than the other. The result of the pair wise comparison process is then used as input of the AHP process to determining the weight of each criterion which is used to determine the normalized matrix to be used in the process of the TOPSIS method. This research obtains an approach maintenance strategy to be applied for the steam power plant in range of capacity 300 -625 MW in Indonesia.

Keywords: maintenance strategy selection, power plant, steam generating power plant, AHP, TOPSIS.

1. INTRODUCTION

Regarding data from the Ministry of Energy and Mineral Resources in 2015, the Indonesian government is only able to meet the electrification ratio of 88.30%, with the average increase from 2011 to 2015 is 3.84% (ESDM, 2016).

As an effort to ensure the availability of electricity for the community and efforts to meet the electrification ratio, since 2006 the Indonesian government rolled out a nationwide power plant development program known as "Fast Track Program" to accelerate energy diversification for fuel oil power plants into non-fuel oil power plants, and its program widely constructed coal fired steam power plant in all over Indonesia. Regarding data published by Ministry of Energy and Mineral Resources in 2015 the steam power plant became the largest power capacity in Indonesia with 27.230 MW or 49% from 55.528 MW of total power capacity in Indonesia (ESDM, 2015).

As the largest installed capacity in Indonesia, the performance of steam power plants until 2015 is still below the expectation. Data published by PT PLN (persero) in 2015 shows that the average Equivalent Availability Factor (EAF) of steam power plant ex-FTP1 is only 64% and EAF of the entire steam power plant in 2014 is only 77.4%. As an addition information, there are 20% or 7,540 MW of existing plants age are already > 25 years old.

Poor of availability can be caused by poor maintenance, and proper maintenance requires technical skills, techniques, and methods to be able to maximize availability of assets as well as in power plants (Velmurugan and Dhingra, 2015).

Many studies indicated that most of the facilities whether owned by the private sector or the government, did not prepare the resources needed to perform equipment maintenance to keep availability of production (Sullivan *et al*., 2010)

The occurrence of breakdowns can lead to significant impacts on cost components of the firm as in power generation industries where production losses will have significant cost impacts resulting from cessation of production processes (Tam & Price, 2008). Substantial productivity improvements can be achieved by developing maintenance strategies to reduce downtime due to corrective maintenance activities (Salonen, 2011).

The study of maintenance strategy has been done in many countries with various industrial fields such as in the process plant (Vishnu & Regikumar, 2016), power plants (Ignat, 2013, Carazas and Souza, 2010), paper mills (Braglia *et al*., 2013) newspaper companies (Zaim, Turkyılmaz, Acar, Al-Turki, & Demirel, 2012), manufacturing companies (Lazim & Ramayah, 2010), buildings (Lind & Muyingo, 2012), ship maintenance (Goossens & Basten, 2015), and food production (Jasiulewicz-Kaczmarek, 2016). The objective of this research is to get a model that can be used to select maintenance strategy that suitable with economic condition, technical consideration, social and environmental policy for steam power plant in Indonesia.

2. LITERATURE REVIEW

2.1 Previous Research

In previous research, maintenance strategies have been discussed on various industries in several countries. Maintenance strategy selection has been done to be implemented in several industrial sectors.

Velmurugan & Dhingra (2015) determines the main category of maintenance management in the form of maintenance strategy by explaining in detail about how to formulate, make appropriate selection, and how to implement maintenance strategy.

Khazraei, Khashayar, & Deuse (2011) conducted a study related to the taxonomy of maintenance, which stated that there are two major taxonomy strategies in the

maintenance of machinery activities, namely reactive maintenance and preventive maintenance.

The maintenance function acts as a support for the production department, and in order to achieve the success of the maintenance objective, the maintenance team should involve the operator in daily maintenance (Lazim and Ramayah, 2010).

Maintenance strategies on leased equipment more likely to reduce losses due machines in not operating condition by reducing amount of preventive maintenance, this action can only perform on most reliable equipment. Preventive maintenance takes a longer time to machine to be not operate, so it is advisable to do optimization in doing preventive maintenance activities (Mabrouk *et al*., 2016).

Maintenance organization should be able to assist the management in achieving its operational performance objectives. Lack of skills and knowledge of technicians, will result in high costs in maintenance management and will affect the performance of the organization. In order to support this organization to work properly, technicians with the necessary skills and knowledge are required to meet the maintenance organizations needs (Au-yong *et al*., 2014).

AHP is used to select validated RCM strategies from maintenance historical data and resulted that higher asset criticality required more preventive maintenance strategies than scheduled maintenance and maintenance breakdowns. The cost of implementing preventive maintenance could be better when compared to breakdown maintenance strategy because it includes losses caused by unproductive machine while breakdown (Velmurugan & Dhingra, 2015).

Carazas & Souza (2010) conducted research on power plants in Brazil by conducting risk assessments combined with the concept of reliability centered maintenance (RCM) and stated that risk-based methodologies can be used to address uncertainties caused by failure. However, this method required a structured database to store "time to failure" information of the equipment and costs associated with the repair of the equipment.

A concept of the RCM method combined with integers linear programming performed by Braglia *et al*. (2013) resulted a combination of several maintenance strategies that provide a choice of decision that leads to more quantitative assessment, and this model is suited to companies with limited maintenance budgets.

Zaim *et al*. (2012) used AHP and ANP methods to get the suitable maintenance strategy for the newspaper company in Turkey by using the consideration of criterion from added value, maintenance cost, safety, and implementation. The result of his research found that the most appropriate strategy for newspaper companies from the both of methods is predictive maintenance.

Chemweno *et al*., (2016) explored data for root cause analysis by performing the following steps: (1) Data selection and standardization. (2) Combining multivariate framework and clustering. (3) Clause mapping. (4) Selection of maintenance strategy. (5) Comparing with ishikawa diagram and 5-why analysis. His research found that the combination between failure based maintenance and design out maintenance is considered the most usable strategy to optimize the resources of maintenance to be more effectively.

SWOT analysis was conducted to determine what is the follow-up needed to implement a planned maintenance strategy in food processing company (Jasiulewicz-Kaczmarek, 2016).

Overall equipment effectiveness (OEE) of maintenance performance performed on 98 plants in Sweden produces an explanation that the handling of production interruptions in the manufacturing industry has not been effective, and maintenance work is still largely a job to handle corrective action and not for prevention activities, his research suggesting to pay special attention to improve system performance on maintenance by enlarging scope and responsibility, and integration between other functions (Ylipää, Skoogh, & Bokrantz ,2017).

Some of companies optimize their maintenance by using the ratio between preventive maintenance and corrective maintenance as key performance indicators. Some of them increased the number of PMs without considering of their activity have a desired effect or not (Salonen and Deleryd, 2011).

2.2 Maintenance

Maintenance is defined as an activity consisting of technical, administrative and managerial activities carried out over the equipment life time and to maintain the asset value. The activities include planning, coordination, finance, and operations to obtained values of reliability, availability, productivity and market value. (Al-Turki, Umar for Ayar *et al*., 2014).

Maintenance is an attempt to keep an equipment or component from damage and performance degradation caused by the operation. And to keep the equipment working properly in accordance with its function (Sullivan *et al*., 2010).

Maintenance can be categorized into two main types, there are corrective maintenance (CM) for a work performed after the damage or failure is clearly found, and preventive maintenance (PM) which aimed to reducing the likelihood of failure and degradation of the function (Al-Turki, Umar for Ayar *et al*., 2014).

Maintenance initially has an intuitive purpose, but the latest concepts introduce the proactive maintenance and corporate organizations that focus on the reliability. Nowadays many companies are focusing on reliability and maintenance organizations that proactively presents the list of goals for maintenance achievement. Reliability and maintenance are no longer just "fix it when it breaks", but further to the reliability of the equipment before the equipment is damaged (Wireman, 2010).

2.3 Corrective Maintenance

Corrective maintenance or known as reactive maintenance is carried out based on the maintenance concept with the principle of "run it till it breaks". No

action or effort are taken to ensure that the equipment life design is achievable (Sullivan *et al.*, 2010)

Corrective maintenance is also known as breakdown, failure based, run-to-failure or unplanned maintenance which is a classic maintenance type where the equipment is used until it breaks / fails by simply performing a job repair and service the component of equipment. Corrective maintenance can be justified when the impact of the failure is tending to small. In corrective maintenance mode, failure can ~~be~~ occur at any time in many ways and sometimes when it happens at an improper time can result in greater costs than expected (Lind & Muyingo, 2012).

2.4 Preventive maintenance
Preventive maintenance (PM) is a type of maintenance that is adapted to the design of the asset, PM used to increase the asset's life time and avoid any unscheduled maintenance activities. The activities of preventive maintenance such as cleaning, adjusting, and lubrication, as well as minor component replacements are conducted to extend the life time of the assets and the age of facility (Al-Turki, 2014).

The approach of preventive maintenance mechanism would be more beneficial to the long-term strategy for the economic life of the equipment, it is because the cost of preventive maintenance activity is smaller than corrective maintenance activity in the same period during the life cycle asset, or the whole lifecycle of the equipment. Therefore, many papers have confirmed that the preventive maintenance approach as better maintenance strategies (Velmurugan & Dhingra, 2015).

Preventive maintenance can be defined as a maintenance action based on timeliness or based on engine operating schedule. Preventive maintenance is used to detect, prevent or to mitigate degradation of the components or systems in order to extend the life time of equipment by controlling degradation in acceptable levels (Sullivan *et al.*, 2010).

2.5 Predictive maintenance
Predictive maintenance is a measurement action to detect the occurrence of system degradation (low functional state) in order to provide an opportunity to reduce the impact caused of the failure, so that it can be reduced or controlled before significant physical deterioration occurs on the components (U.S Department of Energy, 2010).

Predictive maintenance provides an opportunity to forecast a failure by analyzing the condition of the equipment. Analysis performed generally performed based on the condition of the pattern of parameters such as vibration, temperature and flow (Wireman, 2003).

2.6 Reliability Centered Maintenance (RCM)
The RCM evolved in the aviation industry during the 1960s and 1970s from the original work of F. Stanley Nowlan and Howard F. Heap as its initiator. RCM's is underlying on the three logic questions that are (1) how the failure occurred, (2) what are the consequences for safety or operation and (3) what is the purpose of current prevention effort. RCM is also a process to ensure assets are continuously capable of doing what their owners expect in an operational context (Al-Turki, Umar for Ayar *et al.*, 2014).

RCM is a systematic approach to evaluate the availability of equipment and resources to be integrated and produce a good level of equipment reliability and expected to improve cost-effectiveness. RCM identifies that the entire equipment at a facility have different interests in terms of both the process and of its security facilities. The RCM approach is to manage the maintenance program, where limited financial resources and personnel availability are considered, the use of both must be optimized and determined by priority (Sullivan *et al.*, 2010).

RCM helps to classify hidden or apparent failures related to their impact on safety, the environment, production or leads to maintenance measures. This classification leads practitioners to determine what action that must be taken if predictive maintenance or preventive maintenance is not practicable (Campbell *et al*, 2011).

Ramesh Gulati (2013) states four principles that differentiate RCM from other preventive maintenance planning (1) to maintain the function of the system (2) to identify the failure mode that threatens the function of the system (3) to prioritize the functional requirements of a system (4) provide applicative and effective maintenance task.

2.7 Analytic Hierarchy Process (AHP)
The AHP method consists of data collection process for pairwise comparisons, determination of global and local values, and consistency calculations of comparative matrices. The AHP method allows the analyst to evaluate the correctness and consistency of pairwise comparison provided by calculating the consistency ratio(Shafiee, 2015).

four steps of action in decision making on AHP are: (1) determine the problem and alternative solution, (2) create hierarchical structure, (3) determine the criteria and alternative decisions by doing a comparison of each element at the same level and at the level below, (4) determine the final priority of alternative by comparing each element on one level to determine the weight (Goossens and Basten, 2015).

Consistency assessment checks are performed using Consistency Ratio (CR). A 10% or less consistency ratio value is accepted as a good consistency measure. If the value exceeds 10%, it means that justification may be random and should be revised (Goossens & Basten, 2015; Shafiee, 2015; Hanine *et al*, 2016).

2.8 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
The TOPSIS method selects the closest alternative to a positive ideal solution and has the furthest appraisal of a negative ideal solution. This method is considered as the most realistic form of modeling

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compared to methods without compensators (Hanine *et al*., 2016).

TOPSIS is used to select the alternative that simultaneously has the shortest distance from the positive ideal solution and has the furthest distance from the negative ideal solution. Positive ideal solutions will maximize the value of the criteria that provide benefits and minimize cost-related criteria, whereas the ideal negative solution provides on the criteria that will maximize costs and reduce profits (Behzadian, Otaghsara, Yazdani, & Ignatius, 2012).

The steps in performing the process in TOPSIS method are as follows (Behzadian *et al*., 2012; Hanine *et al*., 2016; Kumar, pravin; singh, 2012):

a) Determine the decision matrix to be used
b) Normalize the decision matrix
c) Determine the rating of each matrix normalized by assigning weights.
d) Identify positive ideal solutions and ideal negative solutions.
e) Calculate the distance from the ideal solution alternative positive and negative ideal solution.
f) Calculate the proximity index relative to the ideal solution, then made in the order of the largest to the smallest where the largest value as the optimum solution.

3. RESEARCH METHODOLOGY

3.1 Determination of criteria, sub criteria & alternatives

The selection of related criteria and sub-criteria is done by involving 10 experts and practitioners of power plants in Indonesia with working experience in the field of steam power plants at least 11 years to determine the most appropriate and influential criteria to determining the maintenance strategy for the steam power plant in Indonesia.

The selection process is carried out against the criteria, sub-criteria and alternatives that will be used in this study to reduce the number of criteria and sub-criteria so that the pair wise comparison process is not too much and difficult.

Company policy related to economic, technical considerations, social conditions and environmental policies will be different in each country as well as the type of ownership of the company that manages the steam power plant so that the selection process is carried out to determine criteria that are considered to be the most part of consideration in selection of maintenance strategy.

The criteria, sub-criteria and alternative maintenance strategies that have been selected and used in this study as described in the hierarchical structure according to Figure-1.
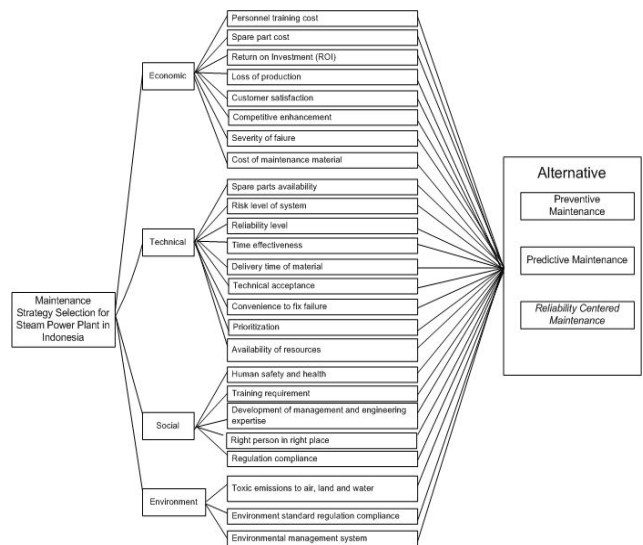

Figure-1. AHP hierarchy structure for the selection of maintenance strategies in Indonesian power plants.

3.2 Determination of weights on the AHP method

To get a value on the comparison between criteria, sub-criteria and comparison between alternatives to all sub-criteria. The data retrieval process is done by involving 8 experts in the field of steam power plants to conduct a pair wise comparison process so we get the weight value on each criterion as table 1 below.

Table-1. The weight of comparison between criteria.

Criterion	Weight
Economic	0.349
Technical	0.365
Social	0.131
Environment	0.156

The result of pair wise comparison between sub-criteria and alternative will get the weight value of each alternative based on sub-criteria value as shown in Table-2 below:

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Table-2. Weighting results on each sub-criteria and alternatives to criteria.

	L	G	PM		PdM		RCM	
			L	G	L	G	L	G
ECONOMIC								
Personnel training cost	0.035	0.012	0.129	0.005	0.212	0.007	0.659	0.023
Spare part cost	0.064	0.022	0.207	0.013	0.165	0.011	0.628	0.040
Return on Investment	0.172	0.060	0.115	0.020	0.237	0.041	0.648	0.111
Loss of production	0.184	0.064	0.158	0.029	0.214	0.039	0.628	0.115
Customer satisfaction	0.104	0.036	0.180	0.019	0.267	0.028	0.553	0.058
Competitive enhancement	0.133	0.046	0.134	0.018	0.196	0.026	0.670	0.089
Severity of failure	0.235	0.082	0.146	0.034	0.269	0.063	0.585	0.137
Cost of maintenance material	0.074	0.026	0.104	0.008	0.267	0.020	0.629	0.046
TECHNICAL								
Spare parts availability	0.075	0.027	0.156	0.012	0.303	0.023	0.541	0.040
Risk level of system	0.148	0.054	0.173	0.026	0.251	0.037	0.576	0.085
Reliability level	0.197	0.072	0.209	0.041	0.248	0.049	0.543	0.107
Time effectiveness	0.069	0.025	0.090	0.006	0.196	0.014	0.714	0.050
Delivery time of material	0.064	0.023	0.129	0.008	0.246	0.016	0.625	0.040
Technical acceptance	0.114	0.041	0.129	0.015	0.268	0.030	0.603	0.069
Convenience to fix failure	0.094	0.034	0.207	0.020	0.241	0.023	0.552	0.052
Prioritization	0.139	0.051	0.131	0.018	0.233	0.032	0.637	0.089
Availability of resources	0.099	0.036	0.113	0.011	0.178	0.018	0.709	0.070
SOCIAL								
Human safety and health	0.485	0.063	0.260	0.126	0.328	0.159	0.412	0.200
Training requirement	0.072	0.009	0.139	0.010	0.248	0.018	0.612	0.044
Development of management and engineering expertise	0.077	0.010	0.144	0.011	0.205	0.016	0.650	0.050
Right person in a right place	0.122	0.016	0.121	0.015	0.294	0.036	0.586	0.072
Regulation compliance	0.244	0.032	0.259	0.063	0.237	0.058	0.504	0.123
ENVIRONMENT								
Toxic emission to air, land and water	0.281	0.044	0.349	0.098	0.210	0.059	0.280	0.079
Environment standard regulation compliance	0.335	0.052	0.415	0.139	0.503	0.168	0.418	0.140
Environmental management system	0.384	0.060	0.236	0.091	0.287	0.110	0.302	0.116

3.3 TOPSIS modeling

The results of the assessment of the modeling process with AHP then further processed by TOPSIS method to obtain the most appropriate alternative to the ideal solution of the ideal and ideal solution. TOPSIS method can be used to determine the rank order of several alternatives, wherein the global weight of each sub-criteria generated from the AHP calculation can be used as input the TOPSIS method (Hanine *et al*., 2016; Perçin, 2009).

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From the results, we have obtained at the time of data processing using AHP in Table-1, then to obtain a normalized matrix used the value of the global weight of each sub-criterion generated from the previous AHP calculation, multiplied by the value of local weight generated on an alternative to sub these criteria. Normalized matrix produced in accordance with Table-3 below.

Table-3. Normalized matrix and ideal solution number.

Sub Criteria	PM	PdM	RCM	Ideal Solusion	
	Normalized Matrix			A+	A-
Personnel training cost	0.0016	0.0026	0.0081	0.0016	0.0081
Spare part cost	0.0046	0.0037	0.0141	0.0037	0.0141
Return on Investment	0.0069	0.0142	0.0389	0.0389	0.0069
Loss of production	0.0101	0.0138	0.0403	0.0101	0.0403
Customer satisfaction	0.0065	0.0097	0.0201	0.0201	0.0065
Competitive enhancement	0.0062	0.0091	0.0311	0.0311	0.0062
Severity of failure	0.0120	0.0221	0.0480	0.0120	0.0480
Cost of maintenance material	0.0027	0.0069	0.0162	0.0027	0.0162
Spare parts availability	0.0042	0.0018	0.0035	0.0042	0.0018
Risk level of system	0.0093	0.0044	0.0064	0.0044	0.0093
Reliability level	0.0150	0.0086	0.0102	0.0150	0.0086
Time effectiveness	0.0023	0.0006	0.0012	0.0023	0.0006
Delivery time of material	0.0030	0.0011	0.0020	0.0030	0.0011
Technical acceptance	0.0053	0.0019	0.0039	0.0053	0.0019
Convenience to fix failure	0.0071	0.0040	0.0047	0.0071	0.0040
Prioritization	0.0066	0.0024	0.0042	0.0066	0.0024
Availability of resources	0.0041	0.0013	0.0020	0.0041	0.0013
Human safety and health	0.0165	0.0327	0.0413	0.0413	0.0165
Training requirement	0.0013	0.0014	0.0025	0.0013	0.0025
Development of management and engineering expertise	0.0014	0.0016	0.0023	0.0023	0.0014
Right person in a right place	0.0019	0.0018	0.0043	0.0043	0.0018
Regulation compliance	0.0083	0.0164	0.0150	0.0164	0.0083
Toxic emission to air, land and water	0.0153	0.0342	0.0206	0.0153	0.0342
Environment standard regulation compliance	0.0217	0.0576	0.0698	0.0698	0.0217
Environmental management system	0.0142	0.0214	0.0260	0.0260	0.0142

To determine the value of the positive ideal solution can be determined based on the elements used in each sub-criterion, where to determine the value of the positive ideal solution (A+) can be done by classifying the attributes used, are the criteria give a profit, or a criterion associated with the cost or resulted in a loss. In sub-criteria related to the gain, A+ is the largest value in the weights of alternative, and A- is the opposite value. Whereas in sub-criteria related cost and loss values A+ use smallest value on alternative weight and A- use the largest value on alternative weight

Relative Euclidean range can be calculated between positive (A+) and negative (A-) ideal solution against each alternative of maintenance strategy. The result from its calculation are shown in Table-4.

Table-4. Euclidean range for each alternative.

Si+			Si-		
PM	PdM	RCM	PM	PdM	RCM
0.0707	0.0452	0.0512	0.0546	0.0581	0.0719

Relative closeness index is calculated by combining the range of positive and negative ideal solution on each alternative and its result obtained number

of relative closeness index to ideal solution on each alternative as shown in Table-5.

Table-5. Result of relative closeness index to ideal solution.

Ci*		
PM	**PdM**	**RCM**
0.436	0.563	0.584
Ranking Sequences		
3	2	1

As the end result of the AHP - TOPSIS modeling, Reliability Centered Maintenance is the first priority to be selected as the maintenance strategy for steam power plant in range of capacity of 300-625 MW in Indonesia.

4. RESULT AND DISCUSSIONS

4.1 Sensitivity analysis

Sensitivity analysis is performed to measure the effect of the criteria weight on the results of each alternative by swapping the global weight between two criteria while the other criterion values are constant (Chiu & Hsieh, 2016; Hanine et al., 2016; Perçin, 2009; Singh & Kumar, 2013). Sensitivity analysis will change the results of the modeling to see the effect of each criterion and used to determine the final conclusions of this model.

The sensitivity analyses in this research are conduct in two conditions, first condition is sensitivity analysis on sub-criteria level and second condition is sensitivity analysis on criteria level. For the result of sensitivity analysis on sub criteria level as shown in Figure-2.
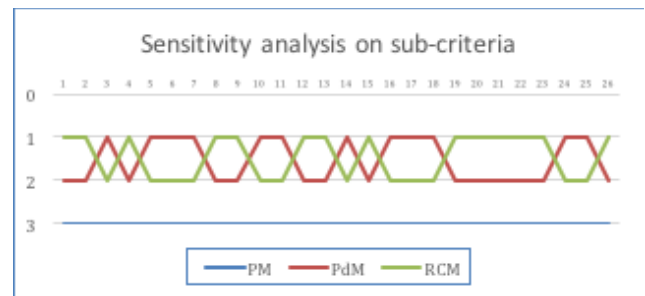

Figure-2. Sensitivity analysis on sub-criteria.

The result of sensitivity analysis on sub criteria level as shown in Figure-1 explained that RCM obtained highest rank in 14 conditions from total 26 conditions tested and its result ensured that RCM became the majority of optimum solution for maintenance strategy for steam power plant.

Sensitivity analysis on criteria level is conduct by change the weight value of criteria as shown in Table-6.

Table-6. Sensitivity analysis on criteria level.

No	E	T	S	E	PM	PdM	RCM	PM	PdM	RCM
1	0.349	0.365	0.131	0.156	0.436	0.5625	0.5840	3	2	1
2	0.365	0.349	0.131	0.156	0.441	0.5616	0.5778	3	2	1
3	0.131	0.365	0.349	0.156	0.377	0.5601	0.7114	3	2	1
4	0.156	0.365	0.131	0.349	0.391	0.4826	0.6306	3	2	1
5	0.625	0.125	0.125	0.125	0.486	0.5497	0.5212	3	1	2
6	0.125	0.625	0.125	0.125	0.369	0.5608	0.6918	3	2	1
7	0.125	0.125	0.625	0.125	0.513	0.4265	0.5451	2	3	1
8	0.125	0.125	0.125	0.625	0.488	0.4194	0.5728	2	3	1
9	000	0.333	0.333	0.333	0.387	0.3327	0.7586	2	3	1
10	0.333	0.000	0.333	0.333	0.500	0.4992	0.5132	2	3	1
11	0.333	0.333	0.000	0.333	0.193	0.6188	0.8765	3	2	1
12	0.333	0.333	0.333	0.000	0.416	0.5820	0.6203	3	2	1
13	0.500	0.500	0.000	0.000	0.433	0.5819	0.5837	3	2	1
14	0.000	0.500	0.500	0.000	0.410	0.5382	0.6727	3	2	1
15	0.000	0.000	0.500	0.500	0.585	0.2867	0.5067	3	2	1
16	0.500	0.000	0.000	0.500	0.484	0.5386	0.5244	3	1	2
17	0.000	0.500	0.000	0.500	0.373	0.5295	0.6940	3	2	1
18	0.500	0.000	0.500	0.000	0.473	0.5405	0.5515	3	2	1

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The result of sensitivity analysis on criteria level as shown in Figure-3, where the result shown that RCM became the majority of optimum solution for maintenance strategy for steam power plant by obtaining highest rank in 16 conditions of 18 conditions tested.
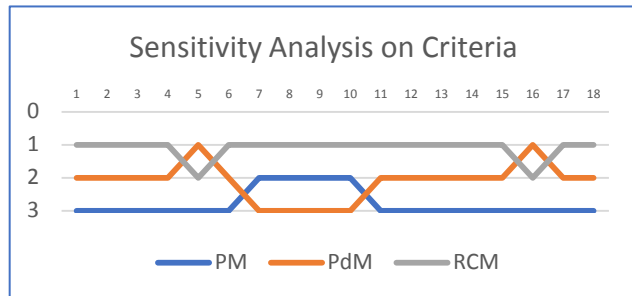

Figure-3. Sensitivity analysis on criteria.

5. CONCLUSIONS

This research has formulated criteria and sub-criteria that accommodate the importance of economic aspect, technical aspect, social aspect and environmental aspect in Indonesia. Criteria selection method and pair wise comparison between each criterion is done by involving experts who have long been engaged as practitioners in the field of power plants in Indonesia.

Based on the result of this research, for the selection of maintenance strategy in steam power plant with range of capacity 300-625 MW in Indonesia where the process of determining criteria and determining the weight in this modeling process is done by the power plant experts in Indonesia using AHP and TOPSIS method, maintenance closest to the relative ideal solution of reliability centered maintenance (RCM) to be implemented in PLTU with range of capacity 300-625 MW in Indonesia.

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