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Implementation of Risk Management for Coal Switching in Coal Fired Steam Power Plant

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***Abstract*—Steam Power Plant is the backbone of electricity sector in Indonesia. Steam Power Plants supply 27.5 GW to the grid, in which 90% of them is coal fired. Today, several Coal Fired Steam Power Plants face a supply problem; consequently, they must procure lower quality of coal. One of them is XYZ Coal Fired Steam Power Plant. Even if there are four candidates of provider to supply coal for a minimum 10 years, it is necessary to make assessment about the effects of coal switching on equipment. The risk assessment focuses on effects of each coal sample on equipment in plant site, especially the equipment closely related to firing process, i.e., boiler, electrostatic precipitator (ESP), and Seawater Flue Gas Desulfurization (SWFGD). Risk Breakdown Structure (RBS) is employed to map problem and problem root in equipment. Risk analysis and evaluation use House of Risk (HOR), meanwhile Net Present Value (NPV) is used to evaluate financial traits. HOR analysis shows one environmental factor, i.e., emission, becomes the highest risk as each coal has high ash content; hence it is necessary to improve emission control. Three of four candidates show high NPV values suitable for the company to maximize profitability.**

***Keywords*—Risk Assessment, Risk Breakdown Structure, House Of Risk, Net Present Value.**

I. INTRODUCTION

ELECTRICAL energy today becomes vital necessity in Indonesia, both for household and industry. Electricity is generated by various forms of power plants; one of them is Steam Power Plant. Steam Power Plant is the backbone of electricity in Indonesia, Supplying 27.5 GW To 65 GW Of National Grid. From This 27.5 GW Capacity, More Than 90% Of Steam Power Plants are coal fired.

Coal reserves in Indonesia reach 39.89 billion metric tons [1]; it is adequate to supply Indonesia for 76 years. In 2018, coal mining production reached 577.8 metric ton per year, 64% of them is exported. Exported coal consists of coal with medium quality (5100 to 6100 kcal/kg) and coal with lower quality (below 5100 kcal/kg).

XYZ Coal Fired Steam Power Plant has been operating for 20 years. Now, it faces coal supply problem as the contract to supply coal will expire in 2021. The company tries to procure coal for 10 years supply after 2021. There are four samples of adequately good coal to supply the company for 10 years. But the available coals from those four companies present several problems for the company.

First, the coals offered have lower caloric values than the caloric value designed for the power plant. Second, continuously changing coal chemical properties may damage equipment, especially boiler and emission control equipment such as electrostatic precipitator (ESP) and Seawater Flue Gas Desulfurization (SWFGD). Third, it is the tightening government regulation on power plant emission. Government Regulation Year 2019 stipulates that new emission limits are 100 mg/Nm3 (down from 150 mg/Nm3) for particles, 550 mg/Nm3 (down from 750 mg/Nm3) for SOx, and 550 Nm3 (down from 850 mg/Nm3) for NOx.

It is necessary to make risk assessments on power plant equipment, consisting of risk identification, risk analysis, and risk evaluation. Such assessment must mitigate the risk of coal switching. Based on literature study, there is not any available coal switching risk assessment performed on all equipment. Previous research only focus on how the use of lower quality of coal and coal blending may affect boiler work, ESP, and SWFGD.

This research employs House of Risk (HOR) method to analyze equipment failures because of coal switching. HOR is a combination of Failure Mode Effect Analysis (FMEA) and Quality Function Deployment (QFD), commonly known as House of Quality (HOQ). HOR method initially analyzes risks in supply chain [2]. HOR method is often employed to analyze other risks such as project analysis or preventive maintenance process analysis [3][4]. This research focuses on equipment of power plant closely related to firing process, i.e., boiler [5][6][7][8][9], ESP and SWFGD [10][11]. In final phase, this research employs Net Present Value (NPV) to draw financial analysis for the company to consider.

II. METHOD

This research studies problem faced by XYZ Coal Fired Steam power plant, i.e., coal supply. There is a supply contract to expire in 2021, but the power plant must continue to operate for 10 years after 2021 as designed in its economical operation. The problem is, the presently fired coal to be switched with lower quality of coal containing less caloric value; hence the company needs to understand how such switching may influence power plant state and operation.

The problem is defined based on such information to assess potential risks because of coal switching. Subsequently, measures are to be taken to mitigate or eliminate such risks. Finally, this research draws financial analysis related to coal switching for the company to consider. Such analysis helps the company to invest in power plant equipment, reducing risks, and assuring power plant continuous operation.

Table 1.
Coal Specification

		A Coal	B Coal	C Coal	D Coal
Gross Calorific Value	kcal/kg	5.212	5.100	5.000	4.700	4.700
Total Moisture	% wt	24	24	28.14	30	29
Ash Content	% wt	1,5	5,88	5,21	5	4
Sulphur Content	% wt	0,2	0,45	0,41	0,3	0,3
HGI	N/A	47	46	59	55	55
Ash Fusion Temperature						
Initial Deformation	°C	1.074	1.170	1.572	1.230	1.200
Spherical	°C	1.142	1.190	1.572	1.255	1.210
Hemisphere	°C	1.162	1.220	1.573	1.295	1.230
Fluid	°C	1,.182	1.280	1.574	1.320	1.250
Coal Consumption and Price						
Coal Consumption	Million ton per year	2,48	2,53	2,58	2,75	2,75
Coal Price	US $ per year	49,42	45,77	43,23	40,57	41,46

Table 2.
House of Risk 1 (HOR1) Matrix

Risk events	**Risk agents (Aj)**							**Severity of Risk events**
(E_i)	**A_1**	**A_2**	**A_3**	**…**	**…**	**…**	**A_j**	**(S_i)**
E_1	R_{11}	R_{12}	R_{13}					S_1
E_2	R_{21}	R_{22}						S_2
E_3	R_{31}							S_3
…								
…								
E_i							R_{ij}	S_i
Occurrence of Agent j	O_1	O_2	O_3	…	…	…	O_j	
Aggregate Risk Potential j	ARP_1	ARP_2	ARP_3	…	…	…	ARP_j	
Priority Rank of Agent j	R_1	R_2	R_3	…	…	…	Rk	

A. Data Collection

Data collection is gathered in various ways, i.e., literature study, discussion, interview, dan internet research. Gathered data are primary and secondary data.

1) Secondary Data

This research gathers secondary data by requesting information from XYZ Coal Fired Steam Power Plant, and also by studying literatures from journals, textbooks, libraries, and personal notes/collections, including internet research. Gathered data contains coal data, equipment specifications, maintenance history, equipment study journal from similar steam power plant, journal of study method, textbook on power plant, research method and engineering economics, regulation on emission, coal price and exchange rate reference, and Bank of Indonesia (BI) rate.

2) Primary Data

Discussion and interview collect primary data in two stages:

a. The researcher discusses designs and blueprints of boiler, ESP, and SWFGD with three expert engineers with more than 10 years' experience. The discussion is focused on coal analysis and analysis about how those four coal samples may affect power plant equipment. Other than to define Risk agents and Risk events in identification process, these engineering inputs are to be considered in the process of House of Risk by Focus Group Discussion.
b. Two Operation and Maintenance (O&M) Supervisors in mechanical and electrical fields are interviewed to uncover history of damages. Such history is important to define Risk agents and Risk events.

B. Data Processing

1) Risk Identification

Risk identification begins by defining potentials and origins of risk threatening equipment, i.e. boiler, ESP, and SWFGD. The identification is based on gathered primary and secondary data. The risk are indentified based on design and substitute coals as shown in Table 1, meanwhile the performance of Power Plant based on output 610 MW with 91% efficiency, total heat input is 6426,5 MBTU per hour and emission limits are 100 mg/Nm3 particles and 550 mg/Nm3 for SOx.

2) Risk Analysis

Risk analysis is based on identified risk events and risk agents. Risk analysis uses House of risk method in stage 1 (HOR 1), in which correlation matrix is used between risk events and risk agents with each risk is weighted. Weighting comes from Focus Group Discussion (FGD) involving five expert engineers with more than 10 years' experience in power plant operation and maintenance. They are Service Managers and Engineers with expertise in mechanical and electrical fields; servicing boiler, ESP, and SWFGD. In risk events, weighting is in 1 to 9 scales to see the effect and severity caused by each risk events. A high scale value show more severe effect if an incident in risk events truly occurs, and vice versa. A similar way is also conducted to uncover the probability of such risk to occur through each risk agents. The correlation between risk agents and risk events is shown in correlation matrix in the range of 0, 1, 3, and 9. The zero value shows that there is no correlation between them;

Table 3.
House of Risk 2 (HOR2) Matrix

To be treated risk agents (Aj)	**Preventive Action (Pak**							**Aggregate Risk Potential (ARPj)**
	PA1	**PA2**	**PA3**	**…**	**…**	**…**	**PAk**	
A1	E11	E12	E13					**ARP1**
A2	E21	E22						**ARP2**
A3	E31							**ARP2 ARP3**
…....								
…....								
Aj							Eij	**ARPj**
Total Effectiveness (TEk)	TE1	TE2	TE3	…	…	…	TEk	
Difficulty Level (Dk)	D1	D2	D3	…	…	…	Dk	
Ratio of effectiveness to difficulty level (ETDk)	ETD1	ETD2	ETD3	…	…	…	ETDk	
Rank of Priority (Rk)	R1	R2	R3	…	…	…	Rk	

Table 4.
Severity of Risk events

Code	**Risk event**	Coal			
		A	B	C	D
E1	Low Primary Air Temp.	7	9	9	9
E2	Low coal output	9	9	7	7
E3	High coal rejection	3	3	3	3
E4	Hight Slagging Index	7	7	5	5
E5	High Fouling Index	7	7	5	5
E6	E6 Water wall tube leak	7	7	7	7
E7	E7 Bottom Slope tube leak	7	7	5	5
E8	E8 Economizer tube leak	5	5	5	5
E9	E9 SH & RH tube leak	5	5	5	5
E10	E10 Low Steam Outlet Temp.	5	5	5	5
E11	E11 High Slagging & fouling	7	7	7	7
E12	E12 Limited sootblower covering	7	7	7	7
E13	E13 Low Force Draft Air Temp.	5	5	5	5
E14	E14 Low Combustion Air Temp.	5	5	5	5
E15	E15 Element air heater corroded	5	5	5	5
E16	E16 Low Force Draft Fan	3	3	3	3
E17	Low Primary Draft Fan	3	3	3	3
E18	Low Induced Draft Fan	3	3	3	3
E19	Wear of coal tips	5	5	5	5
E20	Exhaust emission rises	9	9	9	9
E21	High Electricity consumption	7	7	7	7
E22	Low ampere	7	7	7	7
E23	Rapping system damage	3	3	3	3
E24	collecting electrode damage	3	3	3	3
E25	emitting electrode damage	3	3	3	3
E26	Uneven flue gas flow	7	7	7	7
E27	Ash accumulation in hopper	7	7	7	7
E28	Hight Sulphur emission	9	9	9	9
E29	SWFGD System failure	7	7	7	7
E30	Blocking in ash line	9	9	9	9
E31	slow ash distribution system	7	7	7	7

meanwhile 1, 3, and 9 show low, medium, and high correlation respectively. Based on the values of occurrence of risk agents (O_j), severity of risk events (S_i), and correlation of risk events and risk agents (R_{ij}); it is possible to calculate Aggregate Risk Potential (ARP) using Equation (1).

$$ARP_j = O_j \sum_i S_i R_{ij} \quad (1)$$

After ARP values of each risk agents are known; it is possible to sort priorities of risk agents to define risk response based on ARP. This risk analysis is shown in matrix in Table 2.

3) Risk Evaluation

Risk evaluation over handled risk agents focuses on preventive action to reduce or eliminate risk agent's occurrence using House of Risk in stage 2 (HOR 2). The correlation between preventive action and risk agents is weighted to show how much preventive actions reduce or eliminate risk agents after identification. Weighting is based on the result of Focus Group Discussion (FGD) involving five expert engineers with more than 10 years' experience in steam power plant engineering and commercial operation. The multiplication correlation between preventive actions and risk agents (E_{jk}) and ARP value of each risk agents related is total effectiveness (TE_k) as shown in Equation (2).

$$ARP_k = \sum_j ARP_j * E_{jk} \quad (2)$$

Table 5.
Occurrence of Risk agents

Code	Risk event	Coal			
		A	B	C	D
A1	Air damper leakage	5	5	5	5
A2	Air Duct Insulation leakage	5	5	5	5
A3	Vane wheel leakage	3	3	3	3
A4	Instruments error	3	3	3	3
A5	Decrease grinding ability	9	7	3	3
A6	High Moisture of Coal	7	7	7	7
A7	Low Ash Fusion Temperature	7	7	5	5
A8	High Based/Acid Ratio	7	5	5	5
A9	High total alkali	5	5	5	5
A10	High Iron content	5	5	5	5
A11	High ash loading	9	9	9	9
A12	High calcium content	5	5	5	5
A13	Decrease heating surface	7	7	7	7
A14	Overheating	3	3	3	3
A15	Ash abrasion	3	3	3	3
A16	Ash Erosion	3	3	3	3
A17	Corrosion	3	3	3	3
A18	Material fatigue 3	3	3	3	3
A19	Weld failure	3	3	3	3
A20	Sootblower process failure	3	3	3	3
A21	Limited sootblower quantity	7	7	7	7
A22	Incorrect sootblower location	5	5	5	5
A23	No sootblower opening	7	7	7	7
A24	Dirty air heater element	5	5	5	5
A25	seal air heater leakage	5	5	5	5
A26	High acid and sulfur content	3	3	3	3
A27	Equipment derating	3	3	3	3
A28	Coal Abrasion	3	3	3	3
A29	Use conventional transformer	7	7	7	7
A30	Controller under performance	7	7	7	7
A31	rapping system wear parts	3	3	3	3
A32	Electrode under performance	3	3	3	3
A33	GD Screen is misdirected	7	7	7	7
A34	High Sulphur coal	9	9	9	9
A35	Limited FGD capacity	7	7	7	7
A36	Limited FGD capacity	3	3	3	3
A37	Limited ash handling capacity	9	9	9	9

The HOR 2 eventually defines level of difficulty to implement each preventive action as defined. The difficulty level is scaled based on current limitation of resources, especially financial and human resources. The difficulty level (D_k) of each preventive action is defined in certain scale. Assigning scale on difficulty level during evaluation of preventive action is realistic, considering owned internal resources. Hence, the ratio of effectiveness to difficulty level (ETD_k) of each preventive action is reflected in Equation (3). House of risk 2 (HOR2) Matrix can bee see Table 3.

$$ETD_k = \frac{TE_k}{D_k} \quad (3)$$

4) Financial Analysis

Net Present Value (NPV) is chosen to calculate the present value of project investment operating in certain period [12]. These steps are taken to analyze Net Present Value:

1. Estimating initial investment value (A) to upgrade/retrofit equipment.
2. Estimating cash in coming from each coal sample, i.e., how much money saved from purchasing cheaper and lower caloric value of coal.
3. Estimating cash out, i.e., regular expenses because of coal switching using each coal samples, such as consumable chemicals and spare parts.
4. Estimating cash flow (Q_i), i.e., difference between cash in and cash out annually.
5. Estimating discount rate (r) to find present value.
6. Estimating Net Present Value using formula:

$$NPV = -A + \sum_{i} \frac{Q_i}{(1+r)^i} \quad (4)$$

Results and recommendation of this research consider priorities of preventive actions coming from risk evaluation; hence, priorities to handle risk are known. The recommendation to select coal from four samples is based on calculation of Net Present Value (NPV) related to chosen PA. It considers how much risk to occurs from each coal sample, especially on power plant equipment modification investment and coal cost saving. It recommends decisions based on NPV estimation of each coal sample. Considering cost, coal with the highest NPV is concluded to offer maximum profitability.

III. RESULTS AND DISCUSSION

The research gathers data through various ways and sources, i.e., literature study, discussion, interview, and other data collection activities in internet. The data consists of primary and secondary data. They become a starting point in data processing in subsequent phases. Data processing has four stages. These stages are risk identification using Risk Breakdown Structure (RBS) based on primary and secondary data, risk analysis using House of Risk 1 (HOR 1), risk

Table 6.
Aggregate Risk Potential (ARP) Value

Code	Risk agents	A Coal	B Coal	C Coal	D Coal
A_{1}	Air damper leakage	150	180	170	170
A_{2}	Air Duct Insulation leakage	150	180	170	170
A_{3}	Vane wheel leakage	75	81	75	75
A_{4}	Instruments error	48	54	48	48
A_{5}	Decrease grinding ability	1.296	1.134	432	432
A_{6}	High Moisture of Coal	1.106	1.232	1.092	1.092
A_{7}	Low Ash Fusion Temperature	294	294	180	180
A_{8}	High Based/Acid Ratio	294	210	180	180
A_{9}	High total alkali	315	315	255	255
A_{10}	High Iron content	210	210	180	180
A_{11}	High ash loading	3.051	3.051	2.835	2.835
A_{12}	High calcium content	105	105	75	75
A_{13}	Decrease heating surface	973	973	973	973
A_{14}	Overheating	72	72	66	66
A_{15}	Ash abrasion	72	72	66	66
A_{16}	Ash Erosion	72	72	66	66
A_{17}	Corrosion	114	114	108	108
A_{18}	Material fatigue	72	72	66	66
A_{19}	Weld failure	72	72	66	66
A_{20}	Sootblower process failure	147	147	129	129
A_{21}	Limited sootblower quantity	1.323	1.323	1.197	1.197
A_{22}	Incorrect sootblower location	315	315	285	285
A_{23}	No sootblower opening	441	441	399	399
A_{24}	Dirty air heater element	130	160	160	160
A_{25}	seal air heater leakage	130	160	160	160
A_{26}	High acid and sulfur content	66	72	72	72
A_{27}	Equipment derating	69	69	69	69
A_{28}	Coal Abrasion	45	45	45	45
A_{29}	Use conventional transformer	1.155	1.155	1.155	1.155
A_{30}	Controller under performance	385	385	385	385
A_{31}	rapping system wear parts	9	9	9	9
A_{32}	Electrode under performance	18	18	18	18
A_{33}	GD Screen is misdirected	588	588	588	588
A_{34}	High Sulphur coal	1.296	1.296	1.296	1.296
A_{35}	Limited FGD capacity	63	63	49	49
A_{36}	Limited FGD capacity	48	48	48	48
A_{37}	Limited ash distribution system capacity	1.296	1.296	1.296	1.296

Table 7.
Risk agents Rank Based on Pareto

Code	Risk agents	A oal		B oal		C oal		D oal	
		C ARP	Rank	C ARP	Rank	C ARP	Rank	C ARP	Rank
A_{11}	High ash loading	3.051	1	3.051	1	2.835	1	2.835	1
A_{21}	Limited sootblower quantity	1.323	2	1.323	2	1.197	4	1.197	4
A_{5}	Decrease grinding ability	1.296	3	1.134	7				
A_{34}	High Sulphur coal	1.296	4	1.296	3	1.296	2	1.296	2
A_{37}	Limited ash distribution system capacity	1.296	5	1.296	4	1.296	3	1.296	3
A_{29}	Use conventional transformer	1.155	6	1.155	6	1.155	5	1.155	5
A_{6}	High Moisture of Coal	1.106	7	1.232	5	1.092	6	1.092	6
A_{13}	Decrease heating surface	973	8	973	8	973	7	973	7
A_{33}	GD Screen is misdirected					588	8	588	8

evaluation using House of Risk 2 (HOR 2), and financial analysis using Net Present Value (NPV).

A. Risk Identification

The gathered data are arranged using Risk Breakdown Structure (RBS) [13][14]. Risks are grouped based on equipment and sub-equipment. In the end of RBS, this research finds 31 risk events and 37 risk agents. House of Risk (HOR) 1 is employed to analyze them.

B. Analysis of House of Risk 1 (HOR1)

This research uses HOR 1 to find values of Aggregate Risk Potential (ARP) of risk agents. These values define risk agents prioritized in treatment. FGD defines weighting as members of Focus Group Discussion are expert engineers in Operation and Maintenance of Steam Power Plant; hence they are considered to give objective opinions based on real experiences facing steam power plant equipment failures. The first step in HOR 1 is weighting severities of risk events in Table 4 and also occurrence of risk agents in Table 5.

To understand the correlation between risk events and risk agents, this research weights identified risk events and risk agents. A certain risk events occurs because of influences of several risk agents, and vice versa. ARP values are known after inputting values severities of risk events, occurrences of risk agents, and correlations of risk agents and risk events. ARP values come from multiplication of severities of risk events and occurrences of risk agents, gathered from each coal sample as shown in the Table 6.

The analysis uses Pareto diagram. Thus, it helps decision making to see risk agents with the highest potential triggering risk events to occur. Pareto Diagram is named after an Italian

Table 8.
Result of House of Risk 2

Code	Preventive Action	A Coal		B Coal		C Coal		D Coal	
		ETD	Rank	ETD	Rank	ETD	Rank	ETD	Rank
PA1	Additional Sootblower	8.947	3	8.947	3	8.332	3	8.332	3
PA2	Additional Dynamic Classifier	5.405	5	5.324	5	819	8	819	8
PA3	SWFGD modification	3.202	7	3.170	7	2.900	5	2.900	5
PA4	Ash Handling System modification	10.112	2	10.112	2	9.594	2	9.594	2
PA5	ESP Modification	10.118	1	10.118	1	10.042	1	10.042	1
PA6	Increase air temperature entering pulverizer	3.704	6	3.866	6	2.700	6	2.700	6
PA7	Pressure Parts modification	6.771	4	6.813	4	6.550	4	6.550	4
PA8	Preventive Maintenance Improvement	2.707	8	2.653	8	2.357	7	2.357	7

Table 9.
Net Present Value Calculation (in Billion Rupiah)

Year	0	1	2	3	4	5	6	7	8	9	10
A COAL											
Cash In	-	92	92	92	92	92	92	92	92	92	92
Cash Out	297	21	21	21	21	21	21	21	21	21	21
Cash Flow	-297	-226	-156	-85	-14	57	128	198	269	340	411
NPV	-297	-226	-156	-85	-14	57	128	198	269	340	411
Total NPV	**624**										
B COAL											
Cash In	-	151	151	151	151	151	151	151	151	151	151
Cash Out	297	20	20	20	20	20	20	20	20	20	20
Cash Flow	-297	-166	-35	96	227	358	489	620	751	882	1.013
NPV	-297	-166	-35	96	227	358	489	620	751	882	1.013
Total NPV	**3.939**										
C COAL											
Cash In	-	154	154	154	154	154	154	154	154	154	154
Cash Out	241	26	26	26	26	26	26	26	26	26	26
Cash Flow	-241	-113	15	142	270	398	526	654	782	909	1.037
NPV	-241	-113	15	142	270	398	526	654	782	909	1.037
Total NPV	**4.379**										
D COAL											
Cash In	-	120	120	120	120	120	120	120	120	120	120
Cash Out	230	25	25	25	25	25	25	25	25	25	25
Cash Flow	-230	-135	-40	55	149	244	339	434	529	623	718
NPV	-230	-135	-40	55	149	244	339	434	529	623	718
Total NPV	**2.686**										

economist, Vilvredo Pareto. He proved that the majority of problem could be solved using less solution. Statistically, around 20% work may affect up to 80% in solution.

In FGD stage 1, ARP values of each coal sample are known. Subsequently, it is the process to decide certain risk agents/s to handle. From the discussion, it is decided to select 20% of risk agents to define preventive actions related. Based on Pareto Diagram, these 20% of risk agents contribute 71 to 72% of potential risks in total ARP. These 20% of risk agents are selected to make treatment more focused. It succeeds to lower potential or risk agents caused by each coal sample. Concluding to select only 20%, it means that it is necessary to choose 8 of 37 risk agents to evaluate preventive actions taken later. There is also a probability that it needs more money to spend even if preventive actions are taken. The list of risk agents in priority based of Pareto a shown in the Table 7.

C. Analysis of House of Risk 2 (HOR2)

Analysis of House of Risk 2 (HOR2) is necessary to evaluate risk agents triggering risk events. Here, risk agents are analyzed using Pareto diagram to find dominant risk agents; thus it is possible to define preventive actions to avoid occurrences of risk events. Subsequently, it is necessary to evaluate preventive actions (PA) to find suitable ones. To find proposed PA and objectivity, weighting is given through Focus Group Discussion Stage 2. Here, such discussion involves engineers handling plant equipment and commercial team, to give inputs related to cost.

1. Preventive Action 1: Improving capacity to remove ash, slagging, and fouling by adding sootblower
2. Preventive Action 2: Improving capacity of pulverizer by adding dynamic classifier
3. Preventive Action 3: Improving capacity and capability of SWFGD to reduce sulfur emission
4. Preventive Action 4: Improving capacity of distribution of Ash Handling System
5. Preventive Action 5: Improving capacity dan performance of WSP to catch ash
6. Preventive Action 6: Adding equipment to increase air

temperature entering pulverizer
7. Preventive Action 7: Modifying Superheater and Reheater areas
8. Preventive Action 8: Increasing frequency of preventive maintenance activity to check equipment condition.

After preventive actions are defined, it is necessary to calculate Total Effectiveness (TEk) and Ratio of Total Effectiveness to Difficulty (ETDk) of each preventive action, performed on each coal sample using HOR 2 Matrix. From such calculation it is possible to rank preventive actions priorities. Calculation results are shown in the Table 8.

Based on ETDk values, it is concluded that emission control must be the main priority, as there is a high risk of ash loading coming from each coal samples. On the other hand, it is also necessary to maintain reliability and effectiveness of equipment to make power plant operates well using new coal.

D. Analysis of Net Present Value (NPV)

This research aims to give input to the company to choose new coal fuel, by considering the lowest risk based on preventive actions and profitability. Net Present Value Method is employed to calculate present value of cost and cost saving from coal switching. To calculate NPV, it is important to know cash flow from the difference of cash in and cash out.

1. Investment period is 10 (ten) years. Assumed that economical operation of power plant is 30 years, today the plant has been operating for 20 years.
2. The Steam Power Plant total capacity is 610 MW
3. The Steam Power Plant Efficiency is 91%.
4. Total heat input is 6426.5 MBTU per hour.
5. Exchange rate IDR to 1 United State Dollar is 14,014 rupiah, based on Jakarta Reference Rate.
6. Discount rate (r) based on BI rate from Bank of Indonesia in May 19th, 2020, is 4.5%.

Investment feasibility is evaluated simply using NPV. A positive NPV value shows that such investment is profitable. But if it is negative, it is not feasible to invest. Based on NPV analysis over each coal sample as shown in the Table 9, all four of them give positive values. Thus, it is concluded that it is feasible to do coal switching. The selected coal should not be mutually exclusive, as the company may not only choose one coal supplier to ensure reliability of reserves in coal yard. Based on NPV values, C coal has the highest NPV value, followed by B and D coals. A coal becomes the last option as it has the lowest NPV value.

IV. CONCLUSION

Conclusion among others; (a)The assessment of equipment condition is based on technical calculation only, thus it is necessary to do comprehensive assessment over steam power plant equipment (boiler, ESP, and SWFGD). Such comprehensive assessment is able to give more insights about equipment condition and maintenance needed before intensifying its work; (b)To reduce emission, the first priority is improving performances of ESP, ash handling system, and SWFGD. Adding sootblower and preventive maintenance increases boiler reliability. On the other hand, it is important to modify pulverizer and pressurized parts. Such modification improves subsequent efficiency and flexibility of coal firing; (c)All coal samples have positive NPV values. C coal is the best choice as its NPV value is the highest. NPV value of A coal is the lowest and it becomes the last option to choose; (d)It is necessary to have two or three coal suppliers to ensure availability of adequate reserves in coal yard. Thus, if one supplier is unable to supply coal, the plant is still able to continue to operate normally.

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