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Nonlinear Programing in Preventive Maintenance Optimization Control Valve Level Steam Drumcombined Gas and Steam Power Plant Gresik

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Abstract:- Reliability become one of the main things in industrial world. Power plant is one of industry that need pay attention in reliability. One of Power plant in Java Island is Combined Gas and Steam Power Plant Gresik. There is lots of support equipment in Combined Gas and Steam Power Plant, one of them is Control valve Level Steam Drum Heat Recovery Steam Generator (HRSG). This Control Valve is one of tool that use as level regulator Steam Drum HRSG. When there is disturbance to control valve, can interfere with production of steam which will also affect the MW power generated by steam turbine itself. In last 2 years, disturbance in control valve and its supporting component increased, caused the performance of Combined Gas and Steam Power Plant Gresik itself disrupted. Nonlinear programing can be used as one of the method to reduce breakdown and increase reliability with preventive maintenance.

***Keywords**:- Nonlinear Programing, Control Valve, Hazard Rate, Preventive maintenance, Reliability.*

I. INTRODUCTION (*HEADING 1*)

Electricity now has become one of the main things that are needed in human life. Therefore the power plant business is needed to sustain the availability of electricity in Indonesia. One of the power plant that supporting Java Island is Combined Gas and Steam Power Plant that located in Gresik Therefore Power Plant Gresik must maintain reliability of the power plant so can maintain electricity supply in Java Island.

The equipment in Combined Gas and Steam Power Plant Gresik has very old age considering the power plant established since 1995. So Power Plant Gresik must continue to monitor the equipments in the plant so breakdown that cause availability of the power plant can be reduced. One of the main equipment in Combined Gas and Steam Power PlantGresik is Control Valve (CV) Level Steam Drum. Function of this Control Valve is regulating water in steam drum HRSG. When there is disturbance in control valve, steam production for steam turbine will reduced significantly. Because of that this control valve must be monitoring to reduce downtime so steam turbine can work efficiently.

With good preventive maintenance and on schedule, the possibility of damaged components can be prevented before the damage occurs. Equipment reliability can significantly increase with the presence of preventive maintenance. Considering this age and importance of control valve itself, it is necessary to conduct research to analyze the reliability and optimization maintenance interval to maintain reliability and reduced breakdown control valve itself. Nonlinear programing can be used as one of the method to optimize preventive maintenance.

II. LITERATURE REVIEW

A. Non-linear Programing for Reliability Optimization

Consider a system consisting of n components. A goal reliability is sought for this system. The objective is to allocate reliability to all or some of the components of that system, in order to meet that goal with a minimum cost. The problem is formulated as a nonlinear programming problem as follows (Mettas,2000):

$$P : \min C = \sum_{i=1}^{n} c_i (R_i)$$
$$s.t : R_S > R_G$$
$$R_{i,\,min} < R_i < R_{i,\,max}$$

Where:

C	= total system cost
c_i	= cost of subcomponent i
R_i	= reliability of subcomponent i
n	= number of subcomponent in system
$R_{i,\,min}$	= minimum reliability of subcomponent i
$R_{i,\,max}$	= maximum reliability of subcomponent i
R_s	= system reliability
R_G	= system reliability goal

This formulation is designed to achieve a minimum total system cost, subject to R_G, a lower limit on the system reliability. The first step will be to obtain the system's analytical reliability function (in terms of its component's reliability (mettas, 2000).

B. Reliability

Reliability is defined by probability a component can survive or do its function without failures for certain time. When we want to calculate reliability from failures data we must know what distribution from the data. Weibull distribution is most common distribution that we can use in reliability analysis. The equation below gives the pdf for Weibull distribution (lewis,1987):

$$f(t) = \frac{\beta}{\eta}\left[\frac{t-\gamma}{\eta}\right]^{\beta-1} exp\left[-(\frac{t-\gamma}{\eta})^{\beta}\right] \quad (2)$$

Where:

β = *Shape Parameter*, β>0
η = *Scale Parameter*, η>0
γ = location parameter

After we find pdf Weibull distribution, we can find reliability function. The Weibull distribution reliability function is given by:

$$R(t) = exp\left[-(\frac{t-\gamma}{\eta})^{\beta}\right] \quad (3)$$

Next parameter for reliability analysis is mean time before failures. The Weibull distribution MTBF is given by:

$$MTBF = \gamma + \eta\Gamma\,(1/\beta + 1) \quad (4)$$

Last parameter that we need for reliability analysis is failure rate. The Weibull distribution failure rate function is given by

$$\lambda(t) = \frac{\beta}{\eta}\left[\frac{t-\gamma}{\eta}\right]^{\beta-1} \quad (5)$$

C. Maintenance Cost

In maintenance process there is cost that come up from preventive maintenance cost (C_p) and breakdown maintenance cost (C_f). C_p is cost that come up from company scheduled maintenance. C_p can defined by equation below:

$$C_p=(labor\ cost\ x\ MTTR) + component\ cost \quad (6)$$

C_f is cost that come up from equipment failures. Or we can say cost that come up from component breakdown. C_f is defined by equation below:

$$C_f = [(Labor\ Cost\ + revenue\ lost\ from\ breakdown)\ x\ MTTR] + Component\ Cost \quad (7)$$

And we can defined total cost (C) from certain reliability by equation below:

$$C = [\ (1-R_{(t)}\ )\ x\ C_f\ ] + (R_{(t)}\ x\ C_p) \quad (8)$$

III. METHOD

In this research, we used TBF and TTR data of subcomponent control valve to calculate control valve reliability. TBF data will be used to define distribution that fit TBF data and its parameter to calculate reliability. To define distribution that fit TBF data and define distribution parameter, we used help Weibull++ software.

To calculate reliability of control valve Level Steam Drum HRSG, we used equation (2) with distribution parameter that we got from software Weibull++. First we must calculate control valve subcomponent reliability, after that we can calculate reliability control valve by serial model of reliability because if one component fail all system will fail.

Before we defined optimal reliability, we must defined cost that will be used in program nonlinear. In this case we used Preventive maintenance cost (Cp) that follow equation (6).Next step we used program nonlinear that follow equation (1) to find optimal reliability and optimal maintenance scheduled time. Equation (8) is used for compare cost before and after optimization.

IV. RESULT AND DISCUSSION

A. Reliability Analysis

Control Valve Level Steam Drum has 5 subcomponent. That subcomponents is Plug Cage, membrane actuator, regulator, booster relay and positioner. We will calculated each reliability subcomponent so we will know reliability of control valve. First we must know what distribution that fit distribution data. Table 1. below is type distribution data and its parameter from result Weibull++ software:

Subcomponent	Distribution	Β	η	ϒ
Plug Cage	WEIBULL 3	2,0226	14120	0
Membrane Actuator	WEIBULL 2	1,2783	24716	0
Regulator	WEIBULL 2	2,3027	9022,7955	0
Booster Relay	WEIBULL 3	5,1616	23881	0
Positioner	WEIBULL 3	1,0592	7781,8799	0

Table 1. Distribution Type Subcomponents and Its Parameter

After we know distribution type and its parameter we can calculate reliability for each subcomponents. We assume t=8760 hours for this research. Table II below is result reliability analysis:

Subcomponents	t (Hours)	Failure Rate	MTBF	MTTR	R(t)
Plug Cage	8760	0,000088	12511,16	10,4	0,68
Membrane Actuator	8760	0,00004	22906,84	4,50	0,77
Regulator	8760	0,00025	7993,54	5,17	0,39
Booster Relay	8760	0,00014	9660,95	3	0,50
Positioner	8760	0,000137	7607,90	10,63	0,32
System Reliability					0,03

Table 2. Reliability and parameter reliability Subcomponent

System reliability calculated by serial model reliability. Its mean we must multiple all subcomponents reliability to find system reliability.

B. Optimal Interval Maintenance Time

Before we calculate optimal maintenance time, we must calculate maintenance cost. Because cost is one of the parameter that needed for find optimal maintenance time with nonlinear programing. We calculate Cost with data from Power Plant Gresik and we use equation (6) to calculate C_p and equation (7) to calculate C_f. Table 3. is result calculating maintenance cost.

Subcomponent	C_f	C_p
Plug Cage	IDR 292.133.507	IDR 6.736.000
Membrane Actuator	IDR 125.846.736	IDR 2.355.000
Regulator	IDR 146.608.142	IDR 4.732.650
Booster Relay	IDR 84.961.204	IDR 2.635.000
Positioner	IDR 297.103.283	IDR 5.394.100

Table 3. Maintenance Cost Subcomponents

Next step we find optimal reliability for each subcomponent with nonlinear programing. We used C_p in this research as maintenance cost for nonlinear programing with system reliability target is 50%, 60%, 70% and 80%. We define this target from discussion with Power Plant Gresik management team. The nonlinear programing model will be like this:

P : min C = 4.732.650 (R_1) + 2.635.000(R_2) + 5.394.100 (R_3) + 2.355.000 (R_4) + 6.736.000 (R_5)

$R_1 \times R_2 \times R_3 \times R_4 \times R_5 \geq R_G$
$R_{1\,min} \leq R_1 \leq R_{1\,max}$
$R_{2\,min} \leq R_2 \leq R_{2\,max}$
$R_{3\,min} \leq R_3 \leq R_{3\,max}$
$R_{4\,min} \leq R_4 \leq R4_{max}$
$R_{5\,min} \leq R_5 \leq R_{5\,max}$

Where :
R_1 = Regulator Reliability
R_2 = Booster Relay Reliability
R_3 = Positioner Reliability
R_4 = Membrane Aktuator Reliability
R_5 = Plug+Cage Reliability
R_G = Reliability Target (50%,60%,70% and 80%)

Table 4. below is result from nonlinear programing for optimal reliability:

Reliability Target	Optimal Reliability Subcomponents				
	Plug Cage (R_1)	Membrane (R_2)	Regulator (R_3)	Booster (R_4)	Positioner (R_5)
0,50	0,71	0,97	0,93	0,94	0,84
0,60	0,75	0,97	0,94	0,95	0,93
0,70	0,83	0,98	0,95	0,96	0,94
0,80	0,91	0,99	0,96	0,97	0,95

Table 4. Optimal Reliability subcomponents

Now we know optimal reliability for each subcomponents control valve, next step we must calculate maintenance time for each subcomponents. We used equation (2) to calculate t as maintenance time and used optimal reliability that we find before to define $R_{(t)}$ in equation. Table 5. below is result maintenance time calculation:

Reliability Target	Interval Maintenance Time(Hours)				
	Plug Cage (R_1)	Membrane (R_2)	Regulator (R_3)	Booster (R_4)	Positioner (R_5)
0,50	8313,02	1762,98	2878,16	2266,83	1495,93
0,60	7644,50	1513,75	2680,09	2049,42	684,80
0,70	6137,29	1011,75	2470,03	1816,35	530,30
0,80	4393,84	676,25	2249,52	1572,57	452,98

Table 5. Optimal Interval Maintenance Time

C. Comparison Cost Before And After Optimization

A Company target to do preventive maintenance is to gain more profit. After we calculate optimal maintenance time, we must compare maintenance cost before and after optimization to find out it can gain more profit for company. We used equation (7) to calculate total maintenance cost and we assume C_p before optimization equal to 0 because Power Plant Gresik never do preventive maintenance for this control valve before. Table 6. below is comparison cost before and after optimization:

Before Optimization		After Optimization		Saving
R(t)	*Total Cost*	*R(t)*	*Total Cost*	
0,03	IDR 454.778.687	0,50	IDR 170.636.175	IDR 284.142.512
		0,60	IDR 131.247.301	IDR 323.531.386
		0,70	IDR 99.364.193	IDR 355.414.494
		0,80	IDR 71.331.921	IDR 383.446.766

Table 6. Comparison Cost Before and After Optimization

V. CONCLUSION

Reliability analysis allow us to know which subcomponent of control valve that need more attention. In this research that subcomponent is Positioner because it has lowest reliability and it will affect whole system reliability. To reduce maintenance cost, nonlinear programing can be used to help us to find optimal reliability allocation for each subcomponent. Subcomponent that has higher maintenance cost will has lowest reliability allocation in optimization. In this case that subcomponent is Plug Cage. And at last with applied preventive maintenance based on optimization interval maintenance time from nonlinear programing, we can reduce maintenance cost and gain more profit for company.

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