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Optimization of Gas Turbine Component Maintenance to Improve Reliability of Power Plant Industries

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Abstract—**The thermal power plant unit in Java is PLTGU Z with 3 blocks consisting of 9 gas turbines, and 3 steam turbines with a total installed capacity of 1578.78 MW. One of the problems faced is a high component failure rate, decreased system reliability, and an impact on rising maintenance costs. The method to be implemented in order to maintain the achievement of power plant performance and reliability of generating units is to optimize equipment reliability. Periodic component replacement is one way to maintain the reliability of the unit, where current conditions do not yet exist as a standard that is specifically used as a basis for the component replacement activities. For this reason, optimization of component replacement is required by considering the value of reliability, equipment downtime, frequency of replacement time, and costs required. It is intended that the reliability of the equipment is achieved at the optimum cost. The first stage is to identify the reliability value based on the failure data using Weibull ++ 6 software, then adjusted to the system reliability target in accordance with company standards. The second stage performs calculations to determine the minimum time of downtime and minimum preventive maintenance costs in a period of time. The third stage is determining the optimization of equipment reliability and the consequence of the required cost increase according to the system reliability target. After optimizing the reliability of the system with a target value of R(G) = 0.7 the optimization results obtained with the longest preventive maintenance intervals on gas nozzle equipment every 8000 hours, and the shortest maintenance time intervals are found on the fuel gas system equipment that is 40 hours.**

Keywords— **Gas Turbine, Reliability, Preventive Maintenance, Corrective Maintenance.**

I. INTRODUCTION

DATA at the time of power plant commissioning show the gas steam power plant (PLTGU) has the greatest installed power when compared to the steam and gas power plant especially for the local area in Gresik. The PLTGU operating system at PT Z consists of three (3) blocks, where each block consists of three gas turbine generators (GT) and one steam turbine generator (ST). For one gas turbine generator (GT) the installed power is 112.45 MW, while for one steam turbine the installed power is 188.91 MW. So that each block has an installed power capacity of 526.26 MW and a total installed power capacity of 3 PLTGU blocks in PT XYZ Power Plant that is 1578.78 MW.

Over time this PLTGU Z has several top issues, including: Changes in the operating pattern of the PLTGU Z power plant, which initially operated with a base load pattern into a start-stop pattern (peaker), this caused many problems, especially in generating equipment that was designed for the pattern of continuous running operations. The age of the power plant, which is more than 25 years old, causes a decline in the performance and efficiency of the plant so special attention is needed regarding asset management / maintenance methods. Equipment that is difficult to obstruct and enters the wear out phase, component failure rates are getting higher, and has an impact on increasing equipment maintenance costs annually.

Based on database, some equipment areas show that there is a high percentage of failures for gas turbine equipment. This Condition has a large enough portion of this data to be used for research. Past research by Djatmiko (2018) conducted a study to find out the optimal value of the reliability of an equipment by evaluating the reliability of the turbine gas system. System reliability allocation and optimization is used as a basic philosophy to meet the reliability targets to be achieved at the equipment and system level.

It is very important to maintain the reliability of equipment to serve the electricity needs of the community in the electricity generation system. This is done to increase the availability of complex and expensive technology power generation systems. Many industries such as manufacturing, oil and gas production, aerospace, transportation, telecommunications and information technology, and other industries are very dependent on effective equipment reliability management. A good maintenance strategy will reduce the frequency of repairs and also automatically reduce maintenance costs.

In accordance with the directives of shareholders (stakeholders) that is optimizing existing resources and preparing a roadmap to increase capacity and capability for electricity generation units especially those in the area of Java Island, PT Z initiated the initiatives listed in RJPP (Company Long Term Plan) in 2017- 2021. One of the targets to be achieved is to increase reliability. To support the achievement of the roadmap's vision as stipulated in the RJPP and realize the reliability of the generation unit in accordance with the specified targets, PT Z must develop a strategy, plan, and execute properly

II. METHOD

This reliability management study show how reliability in a system defined, calculated, and optimized. The first step is the work order data is processed into component failure

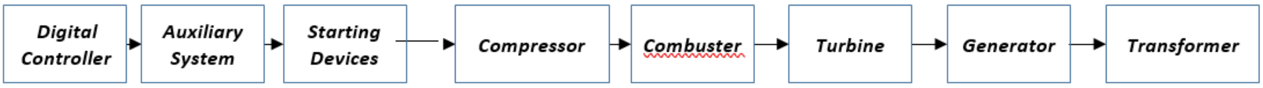


Figure 1. Boundary Condition Research of Gas Turbine sub Equipemnt.

Table 1.
Gas Turbine Reliability Index

No	System	Sub-System	R(t)
1	*Digital Controller*	*Govenor System*	0.7473
		Lube Oil System	0.3536
2	*Auxiliary System*	*Piping Fuel System*	0.37
		Rotor Cooling System	0.3685
		Air Barrier System	0.6733
3	*Starting Devices*	*Pony Motor*	0.4908
		Starting Motor	0.3396
4	*Compressor*	*Inlet Guide Vane*	0.6388
		Intake Air Filter	0.7468
5	*Combustor*	*Gas Nozzle*	0.4264
		Igniter	0.4356
6	*Turbine*	*Turbine*	0.3674
7	*Generator*	*Exciter Set*	0.55
8	*Transformer*	*Transformer*	0.8241

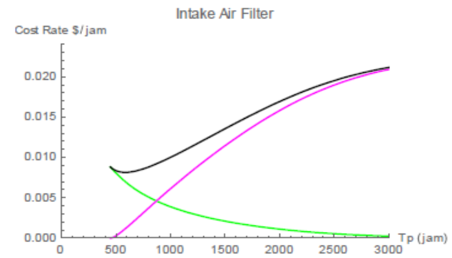
Table 2.
Value of Gas Turbine Reliability and Meanlife After Optimization

Symbol	Sub - System	Mean Life	Optimized R(t)
R1	Govenor System	521.0008	0.9802161
R2	Lube Oil System	545.7597	0.9757341
R3	Piping Fuel System	27.1684	0.9735844
R4	Rotor Cooling Air System	40.399	0.9675425
R5	Air Barrier System	482.9461	0.9790558
R6	Pony Motor	366.1206	0.9788983
R7	Starting Motor	289.7452	0.9774271
R8	Inlet Guide Vane	504.1384	0.9772953
R9	Intake Air Filter	546.3734	0.9783224
R10	Gas Nozzle	931.7584	0.9719937
R11	Igniter	273.565	0.972216
R12	Turbine	154.071	0.9699595
R13	Exciter	351.1169	0.9699323
R14	Transformer	214.6844	0.975759

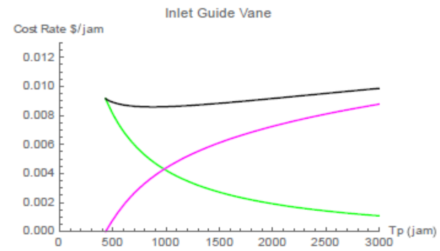
distance data (distance between the first relationship with the second failure distance etc.), then from that data the type of failure distribution that is most suitable for using Weibull ++ 6 software, then reliability analysis is performed. Wolfram Mathematica 9 software is used to get the minimum time of equipment downtime and get the frequency trend of preventive and corrective maintenance costs starting from the highest frequency to the lowest frequency with a cut off at a certain period, from the trend then the frequency of replacement parts is obtained or spare parts with the most minimal cost. The results of preventive maintenance simulations are then adjusted to the equipment reliability target, whether it meets the equipment reliability target criteria according to best practice / company standards or not. For detailed data processing steps can be described as follows: (1) Processing Work Order data at the equipment / component level, then validating the equipment down time due to maintenance activities. Data is taken from Ellipse SIT then this data is converted to failure rate and time interval between component failures (MTBF). (2) Transferring MTBF data into Weibull ++ 6 software to determine the type of distribution that is the closest / most appropriate of the time interval data between failures. This software input is set with the criteria for Goodness of Fit, Plot Fit, and Like Life Function Value. After testing in accordance with the above criteria, a recommendation is obtained for the type of failure distribution that is the closest based on the highest rank for the time data between the intended equipment / component failures. (3) Determine the most appropriate type of distribution of the results of processing by Weibull ++ 6 software, take the output data of the software simulation results, namely the parameters β, η, and ɤ. (4) Determine the opportunity-dense function for failure, failure rate, equipment reliability and the opportunity-dense function for equipment for a certain operating period. (5) Determine the minimum downtime t (min) on the equipment and the minimum cost D (tp) required for the maintenance process of replacing components for each equipment / component by simulations using mathematical software using following equation:

$$D(t_p) = \frac{T_p[1-R(t_p)]}{(t_p+T_p)R(t_p)+\left[\int_{\gamma}^{tp} t*\frac{\beta}{\eta}\left(\frac{t-\eta}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} dt\right]+T_f[1-R(t_p)]}$$

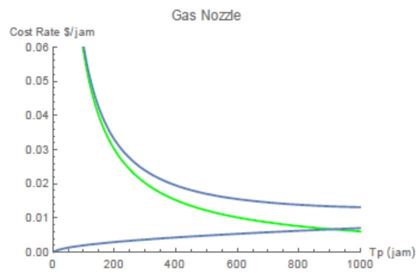
(6) Determine the feasibility index for equipment / component replacement maintenance, with the following criteria: (a) Reference to the reliability target of the equipment required by the company. (b) Minimum time for equipment downtime for component maintenance / replacement activities. (c) Number of frequency of maintenance of component replacement within a certain period of time (d) Costs required for preventive component replacement activities in a certain period of time (7) Optimization of the value of system reliability according to the target company reliability standard (8) Determine the equipment replacement



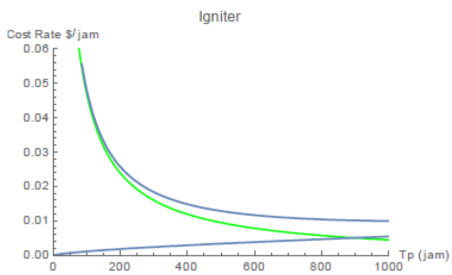
Intake Air Filter			
Maintenance Interval	1556	887	546
R(t)	0.4244	0.741	0.978
Pm cost ($/jam)	$ 0.00220	$ 0.00420	$ 0.00130
Cr Cost ($/jam)	$ 0.01250	$ 0.00470	$ 0.00820
Total Cost ($/jam)	$ 0.01470	$ 0.00890	$ 0.00950



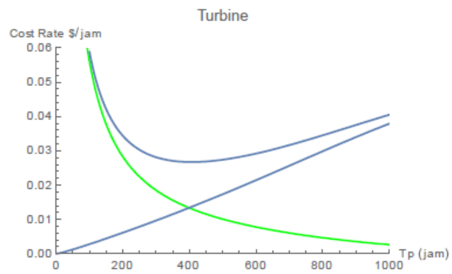
Inlet Guide Vane			
Maintenance Interval	2869	1250	504
R(t)	0.3679	0.636	0.977
Pm cost ($/jam)	$ 0.00150	$ 0.00570	$ 0.00050
Cr Cost ($/jam)	$ 0.00950	$ 0.00580	$ 0.01000
Total Cost ($/jam)	$ 0.01100	$ 0.01150	$ 0.01050



Gas Nozzle			
Maintenance Interval	8627	1113	932
R(t)	0,4264	0,952	0,972
Pm cost ($/jam)	$ 0.00500	$ 0.00827	$ 0.00877
Cr Cost ($/jam)	$ 0.12425	$ 0.00834	$ 0.00911
Total Cost ($/jam)	$ 0.12925	$ 0.01661	$ 0.01788



Igniter			
Maintenance Interval	2118	978	274
R(t)	0.4356	0.857	0.972
Pm cost ($/jam)	$ 0.00433	$ 0.00456	$ 0.00487
Cr Cost ($/jam)	$ 0.07865	$ 0.00511	$ 0.00524
Total Cost ($/jam)	$ 0.08298	$ 0.00967	$ 0.01011



Turbine			
Maintenance Interval	723	403	154
R(t)	0,4604	0,793	0,970
Pm cost ($/jam)	$ 0.00644	$ 0.01273	$ 0.00466
Cr Cost ($/jam)	$ 0.08250	$ 0.01273	$ 0.03278
Total Cost ($/jam)	$ 0.08894	$ 0.02546	$ 0.03744

Figure 2. Graph of the effect of maintenance intervals on preventive and corrective maintenance costs on reliability value.

maintenance strategy / components based on minimum time criteria for downtime, frequency of component replacement, and reliability optimization.

III. RESULT AND DISCUSSION

A. Gas Turbine sub Equipment Configuration

As seen in the system modeling according to Figure 1, it can be seen that there are 8 main equipment act as the main drive of gas turbine system. For example, the pony motor act to deliver continued rotation through the torque converter equipment. The other devices are arranged in serial order, there is no redundancy for each equipment if the equipment fails during operation

B. Equipment Reliability Analysis

According to the input time data between equipment failures, then running / simulating using Weibull ++ 6 software, the following test results are obtained as described in Table 1.

C. Reliability Optimization

Based on realistic targets in accordance with the performance contract with a reliability value of R (G) 0.7, an

Table 3.
Time and cost interval tables before and after reliability optimization

Sub - System	Before		After	
	Tp	Cost ($)	Tp	Cost ($)
Govenor System	1818.30	$ 18,461	521.00	$ 5,068
Lube Oil System	2959.29	$ 11,089	545.76	$ 3,804
Piping Fuel System	669.20	$ 2,482	27.17	$ 1,000
Rotor Cooling Air System	1206.43	$ 6,216	40.40	$ 2,228
Air Barrier System	3948.78	$ 22,963	482.95	$ 5,836
Pony Motor	2329.68	$ 21,776	366.12	$ 2,668
Starting Motor	3967.86	$ 20,985	289.75	$ 3,558
Inlet Guide Vane	2868.95	$ 29,018	504.14	$ 3,304
Intake Air Filter	1556.09	$ 24,357	546.37	$ 8,786
Gas Nozzle	8627.44	$ 58,944	931.76	$ 14,736
Igniter	2118.40	$ 60,426	273.57	$ 9,643
Turbine	723.07	$ 37,946	154.07	$ 5,357
Exciter	1144.28	$ 298	351.12	$ 56
Transformer	1876.05	$ 86,530	214.68	$ 5,000
Total		**$ 401,490**		**$ 71,043**

optimal reliability allocation will be determined using the equation. According to Mettas (2000) "The reliability of the system is determined by the reliability of each component or sub-system. But in reality historical data about the detailed cost of each component of equipment is very difficult to obtain. According to Mettas (2000), if that happens then by looking at the properties of the cost function, the relationship between costs and the reliability function can be formulated. By using Lingo 17.0 software and the equation below, it can be determined that the optimal reliability allocation value for the gas turbine equipment is as follows Table 2.

D. Sensitivity of Reliability Value to Maintenance Costs

The following tables 3 show the results of determining Tp for each gas turbine sub system / component based on the target reliability of the equipment that has been targeted in accordance with section 2 with details of the reliability target of each equipment in accordance with reference to table number 2. From the reference table, for the smallest total cost of preventive maintenance in accordance with the results of the simulation, not all of them can meet the target system reliability values required by the company namely RG 0.7. For this reason, a tradeoff is needed so that the reliability target can be achieved, the higher the value of reliability that will be achieved, the higher the frequency of preventive maintenance, automatically the higher the maintenance costs needed in a certain period of time. In this case, the reliability value constraint is set as the first priority. Graphs numbers 3 show the effect of the maintenance time interval (Tp) on the rate of maintenance costs

E. Cost and Time Intervals Before and After Reliability Optimization

In accordance with the target value of the reliability of the turbine gas system that is R (s) 0.7, the optimum preventive maintenance time (Tp) time interval and the rate of preventive maintenance costs for each gas turbine sub-system are shown in Table 3.

Table 3 is a recap of maintenance time intervals vs. total costs required (preventive + corrective) before and after reliability optimization. The total cost required for a 4000-hour maintenance cycle before reliability optimization is $ 71,043, whereas after the optimization of reliability the maintenance cost has decreased to $ 71,043. Savings that can be obtained from the optimization of the reliability of this equipment is $330,447.

IV. CONCLUSION

Based on the discussion that has been done in the previous chapters and sub-chapters related to the optimization of the reliability of the turbine gas system based on simulations and calculations for maintenance time intervals and their effects on maintenance costs, it can be concluded: The length of time intervals after optimizing the reliability of the turbine gas system reliability has on average increased, the longest preventive maintenance time interval is found in gas nozzle equipment with an interval of 8627.4385 hours, while the shortest time interval is 669.1965 hours found in the fuel system piping equipment. After optimizing the reliability of the system, preventive maintenance time intervals are obtained for each sub system. The longest time interval is found in gas nozzle equipment which is 931.76 hours, while the shortest preventive maintenance time interval is found in the fuel system piping equipment, which is 27.17 hours. The total maintenance cost after optimized reliability is $ 71,043 for the target system reliability value R (G) = 0.7. Savings obtained after reliability optimization are $ 330,447.

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