



Reliability Analysis as A Maintenance Optimization Strategy at PT PLN Indonesia Power Unit PLTP Gunung Salak

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Abstract

The Gunung Salak Geothermal Power Plant (GPP), which has been operating for 30 years until now, has experienced several failures that tend to increase from time to time. Failure of power plant equipment and the length of repair time will result in the loss of production. Based on equipment failure data from GPP, there is an indication of ineffectiveness in the implementation of maintenance activities that have been carried out. Maintenance strategies can be determined from reliability analysis and failure prediction. Reliability analysis is expected to maintain power plant equipment from the risk of failure which causes force outage. This study applies a statistical model based on the Weibull-2 Distribution Parameter Method to determine the reliability of the model and failure prediction in power plant equipment. From the equipment failure data obtained, the Mean Time Between Failure (MTBF) value will then be determined. The results of the calculations that have been carried out, the Mean Time Between Failure (MTBF) values obtained for each piece of equipment are as follows: Turbine 20,156 hours; Cooling Tower 23,781 hours; Condenser 17,685 hours. The interval maintenance outage calculated by reliability analysis showed that turbine equipment, cooling tower, and condenser suggested to be overhaul every 2 years to reduce possibilities of failure.

Keywords: *Reliability, Weibull distribution, MTBF*

1 Introduction

Geothermal energy is one of the alternative solutions to reduce the impact of global warming and society dependent on fossil fuels[1]. Since it was commercially operated in 1994, Gunung salak Geothermal Power Plant (GPP) has its installed capacity of 3x60 MW and operated as base load system[2]. It means that the plant should be operated continuously through the year except in term of scheduled outage (periodic or corrective).

In line with the development of demand electricity needs, the Gunung Salak geothermal power plant's electrical system is required to have good reliability and availability. Often due to network needs, the planned power plant maintenance schedule often changes. Based on equipment failure data from Gunung Salak GPP, there are several disturbances that affect the performance of the generating unit. Maintenance of power plant equipment is an asset management challenge, where the failure of equipment will greatly affect the operation, production and at the same time the safety factor of the plant. A maintenance pattern is needed to accommodate and maintain the reliability of power plant system. The ability to maximize the capabilities and reliability of power plant is an important asset to improve the power plant performance and profitability. Operation and maintenance strategies can be determined by knowing the reliability model and evaluating the current equipment conditions. Statistical model based on the Weibull-2 Parameter distribution method will be used in this study to determine the reliability of the model and failure predictions in power plant equipment. This study aims to evaluate Mean Time Between Failure (MTBF) to determine the right inspection of time interval power plant equipment. Thus, if the right inspection time interval value has been determined, it is expected that maintenance activities can prevent equipment failures that will occur.

2 Method

Maintenance activities that have been carried out at the Gunung salak Geothermal Power Plant (GPP) include preventive maintenance, corrective maintenance, and emergency maintenance. Routine maintenance carried out every day by the maintenance department or commonly called Preventive Maintenance is determined in advance by looking at data on the failure defense task that has been translated into a maintenance strategy. Corrective maintenance is carried out when there is a failure of function of an equipment. Ideally, corrective maintenance should be less than preventive maintenance. In addition, Gunung salak geothermal Power Plant (GPP) also carries out inspection / overhaul activities periodically.

From the maintenance activity data obtained in 2024, it shows that the most maintenance carried out is preventive maintenance. This maintenance method is used to minimize or eliminate the possibility of disruption from generating equipment. However, based on the history of disruptions, it shows a high incidence of equipment failure from year to year. This is a major problem for the reliability of a power plant system.

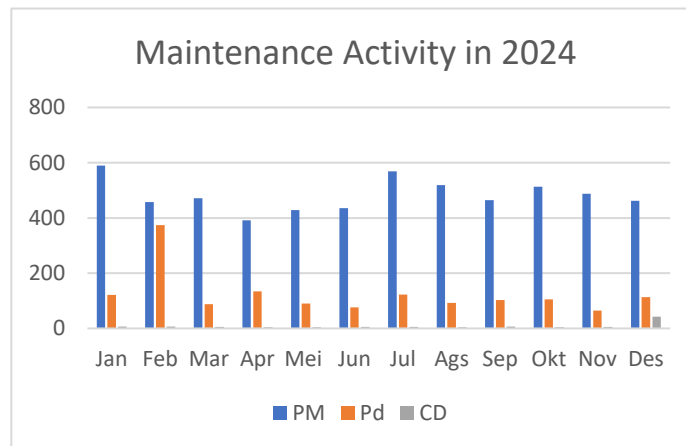


Figure 1 Total Maintenance Activity in 2024

Reliability is defined as the probability that component or system will perform the required function for a given period of time when use understate operating condition (Ebeling, 1997)[3]. The lifespan of an item can generally be divided into 3 different phases: the phase during installation (burn-in), the phase during operation (useful life) and the phase when damage occurs (wear-out). The failure rate function has three forms as illustrated in the figure below, the failure rate function may decrease in the burn-in phase, approach constant in the useful life phase, and increase in the wear-out phase.

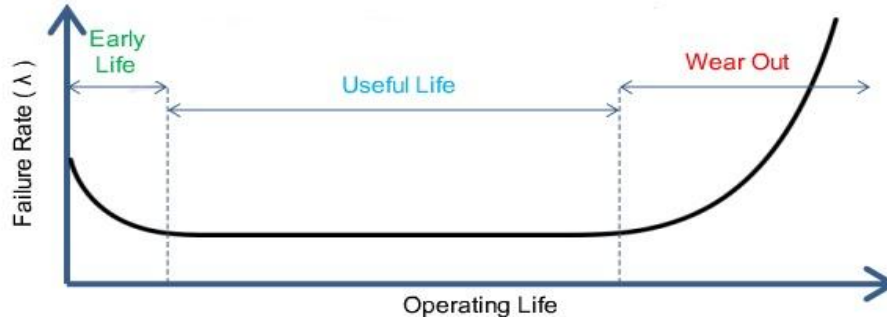


Figure 2 Bath-up Curve

By conducting a reliability assessment, the reliability characteristics of the equipment will be obtained. This can then be the basis for determining strategic steps in order to increase reliability to obtain optimal production results. A statistic model based on Weibull Distribution-2 Parameters Method is proposed in order to determine reliability model and failure prediction the component of Gunung salak Geothermal power plant.

Purnomo in [5], Anggraeni in [6], Taufiq in [7], Islam in [8], Vaishali in [9], using a several document such as failure and maintenance equipment data to analysis reliability. In this study, Maintenance and operational data were collected from 2014-2024 and used to consider a mathematical model which allows for the equipment failure data to be fitted and could be used for generating the maintenance scheduling. Weibull-2 Parameter distribution method is such a general model for representing the failure pattern. It is particularly convenient for representing the failure data because of the many different shapes this distribution may assume.

Cumulative distribution function, probability density, reliability, and failure rate of the standard Weibull distribution with 2 parameters (Weibull, 1951)[4] can be calculated using the equations below:

Cumulative distribution function:

$$F(t) = 1 - \exp \left[- \left(\frac{t}{\alpha} \right)^\beta \right], \text{ for } t \geq 0, \alpha > 0, \text{ dan } \beta > 0 \quad (1)$$

Probability density function:

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

Reliability function:

$$R(t) = 1 - F(t) = \exp \left[- \left(\frac{t}{\alpha} \right)^\beta \right] \quad (3)$$

Failure Rate function:

$$\lambda(t) = \frac{f(t)}{R(t)} = \left(\frac{\beta}{\alpha} \right) \left(\frac{t}{\alpha} \right)^{\beta-1} \quad (4)$$

Mean Time Between Failure function:

$$t_R = \alpha (-\ln R)^{1/\beta} \quad (5)$$

Where e , α , β , t is base of the natural logarithms, characteristic life, shape parameter and time to failure.

The representation of the Weibull distribution depends on the value of the shape parameter (β):

- a. For $0 < \beta < 1$, the failure rate decreases with time.
- b. For $\beta = 1$, the failure rate is constant.
- c. For $\beta > 1$, the failure rate increases with time.

3 Reliability Analysis

The number of equipment failure and operating hours are required to perform calculations. According to asset register criteria, the equipment should be mapped first into system and sub system classification to get the appropriate failure data. Failures data concerns the one that may affects equipment degradation and production decrement. The failure data samples was taken from 2014 until 2024.

Table 1. Power Plant Equipment Failure Data

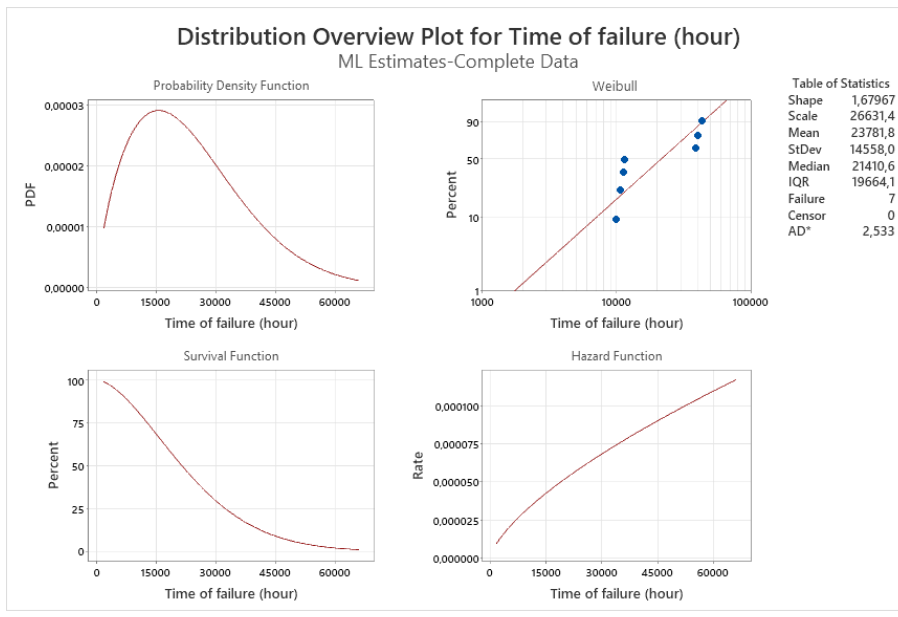
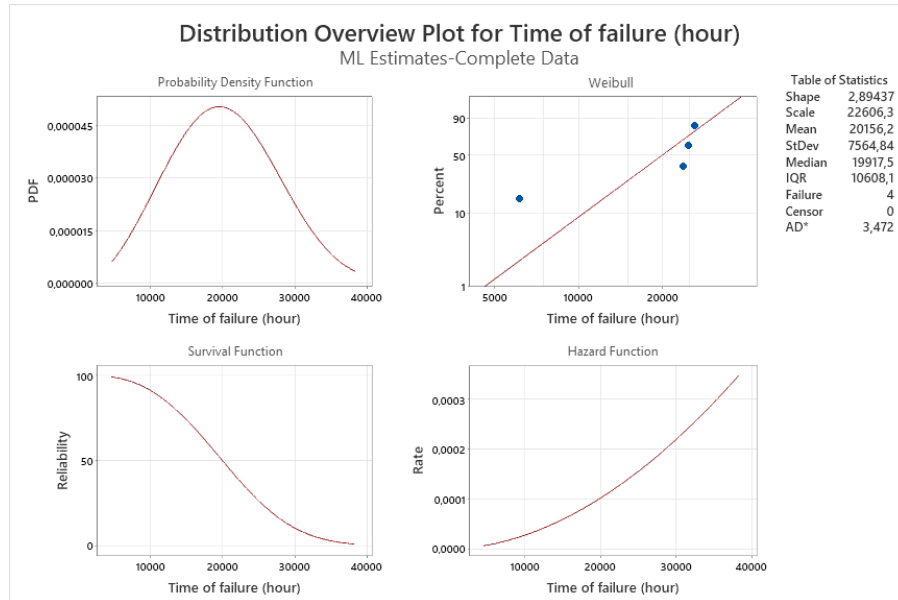
No	Date	Main Equipment	Failure Cause
1	31/07/2015	Turbine	Vibration Turbine Trip
2	28/09/2017		Vibration Turbine Bearing
3	29/11/2017		Recovery Turbine Trip
4	23/01/2018		turbine Trip Vibration
5	02/01/2016	Cooling Tower	Gearbox FCT No. 1 Fail
6	05/02/2016		FCT no.4 Trip High Vibration
7	29/02/2016		Fan Cooling tower No. 1 Failure
8	04/03/2016		Fan Cooling Tower No 1 damage
9	22/04/2019		Fan Cooling tower No. 1 Failure
10	28/06/2019		Gearbox FCT No. 1 Broken
11	31/10/2019	Breaker FCT No.4 Broken	
12	30/11/2015	Condenser	Vacuum breaker broken
13	10/11/2017		Level condenser B Failure

From the failure data, a reliability analysis is then carried out to determine the Mean Time Between Failure (MTBF) of the main equipment power plant. By using the Weibull-2 distribution method, the shape parameter (β), scale parameter (α), reliability, and failure rate values will be obtained. The calculation results obtained are as follows:

Table 2. Weibull-2 Parameter

Main Equipment	Weibull-2 Parameter Distribution Method		
	Shape Parameter	Scale Parameter	Mean
Turbine	2,89	22.606	20.156
Cooling Tower	1,67	26.631	23.781
Condenser	2,27	19.965	17.685

By using Minitab, the results of the Weibull distribution calculations along with reliability models and failure rates were also obtained.



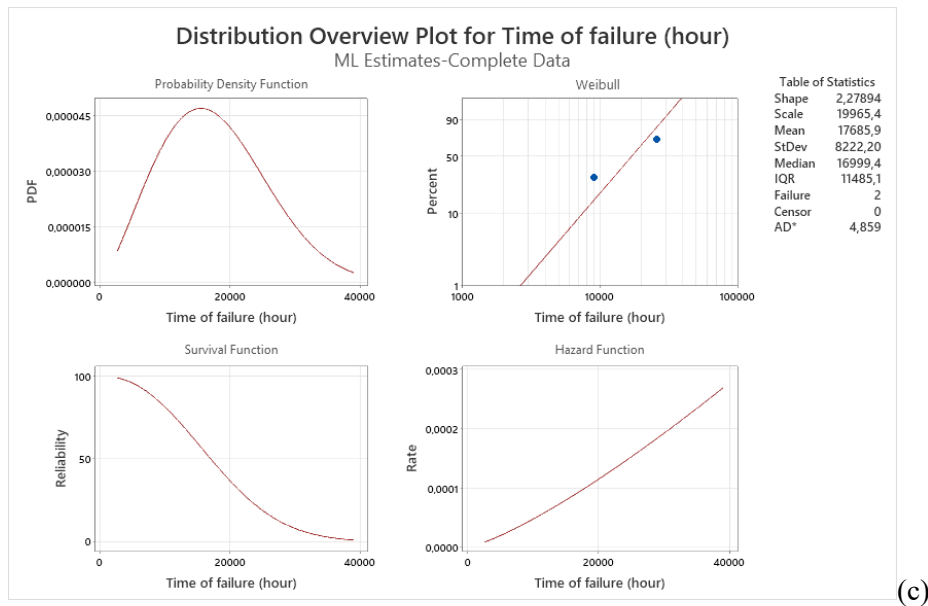


Figure 3 Reliability model and failure rate of each main equipment (a) turbine (b) cooling tower (c) condenser

From the results of statistical parameter calculations, the reliability cycle calculation for each failure component is then obtained

Table 3. Reliability Model of Gunung Salak Power Plant Equipment

Main Equipment	Reliability (hours)				
	0,2	0,4	0,6	0,8	0,99
Turbine	26.750	22.000	18.000	13.500	5000
Cooling Tower	35.500	25.250	18.000	11.000	2000
Condenser	24.500	19.250	14.750	10.250	3000

4 Results and Discussion

From the Mean Time Between failure (MTBF) value of turbine equipment, it is recommended to conduct inspection / maintenance within a period of 20.156 hours to prevent failure / damage to turbine equipment. By implementing a maintenance implementation strategy within a period of 20.000 hours, it will increase the reliability value of turbine equipment.

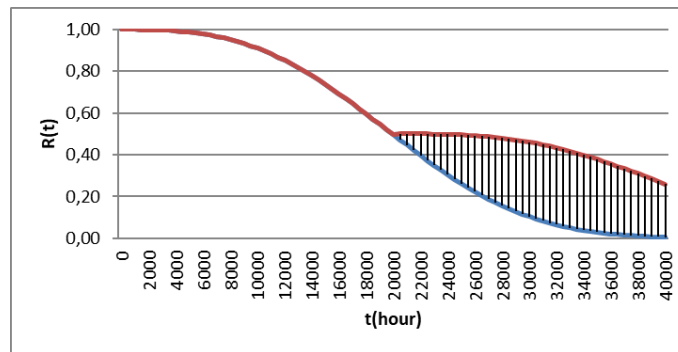


Figure 4 Reliability of turbine

From the Mean Time Between failure (MTBF) value of cooling tower equipment, it is recommended to conduct inspection / maintenance within a period of 23.000 hours to prevent failure / damage to cooling tower equipment. By implementing a maintenance implementation strategy within a period of 23.000 hours, it will increase the reliability value of cooling tower equipment.

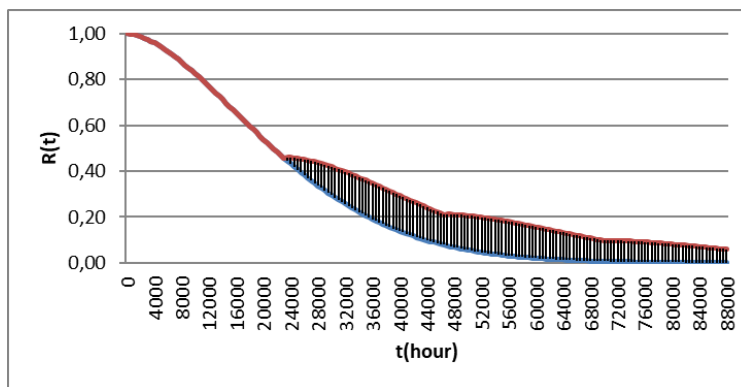


Figure 5 Reliability of cooling tower

From the Mean Time Between failure (MTBF) value, it is recommended to conduct inspection / maintenance within a period of 17.685 hours to prevent failure / damage to condenser equipment. By implementing a maintenance implementation strategy within a period of 17.685 hours, it will increase the reliability value of condenser equipment.

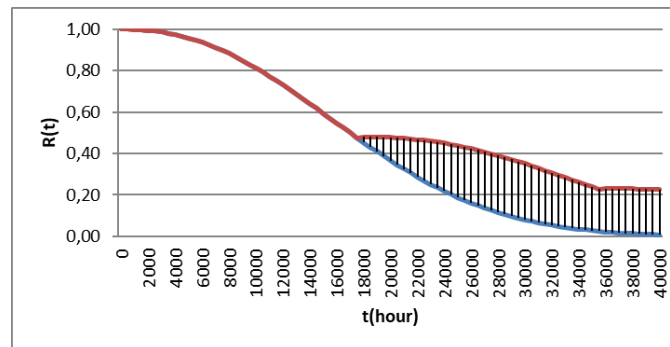


Figure 6 Reliability of condenser

5 Conclusion

1. With reliability analysis, the Mean Time Between Failure (MTBF) value for each equipment is obtained as follows: Turbine 20,156 hours; Cooling Tower 23,781 hours; Condenser 17,685 hours.
2. The shape parameter value (β) on all equipment is more than 1. This provides information that the equipment at the Gunung Salak Geothermal Power Plant is entering the Increasing Failure Rate (IFR) phase so that inspections or scheduled maintenance intervals are required in order to maintain the condition of the subunit effectively and efficiently.
3. The reliability value is 63.2% of failures, occurring on equipment within a period of 2 years. The study recommends to do a simple inspection (overhaul) of power plant equipment to prevent equipment failures that will occur.

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