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# Reliability, Availability, and Maintainability Analysis of Steam Drum Power Plant- PT YTL, East Java

Ali Musyafa[a,*], Queenawa Jannah Hartono[a], Muhammad Khamim Asy'ari[a], Muhammad Bahruddin Majid[a], Dwi Nur Fitriyanah[a,b] , Mia Dwi Susanti[a], Tajuddin Ahmad Rafi[a]

[a]Department of Engineering Physics, Faculty of Industrial Technology and System Engineering, Institut Teknologi Sepuluh Nopember, ITS Sukolilo Campus, 60111, Surabaya, Indonesia
[b]Department of Instrumentation Engineering, Faculty of Vocational Studies, Institut Teknologi Sepuluh Nopember, ITS Sukolilo Campus, 60111, Surabaya, Indonesia
musyafa@ep.its.ac.id

PT Jawa Power is one of Indonesia's largest independent power producers with a 30-year agreement with the State Electricity Company managed by YTL Power International Berhad, and it operates a 1,220-MW coal-fired power plant in Paiton, East Java. This steam power plant relies on a steam drum, which is a critical component of the boiler, to produce dry steam for the turbine. In this study, the RAM (Reliability, Availability, and Maintainability) of the Steam drum system was evaluated using maintenance data from 2019 to 2024 to optimize the performance and maintenance strategies. The RAM analysis begins by calculating TTF (Time to Failure), TTR (Time to Repair), determining the distribution, and calculating the RAM for each component based on the failure history. The control-level steam drum (50HAD10CL501) has the lowest reliability, reaching 60% after 350 hours of operation, while the Temperature Transmitter Economizer (50HAC53CT201) requires the longest repair time of 13 hours. Preventive maintenance analysis with failure rate was also conducted, and 1 component data was obtained that was recommended for maintenance, namely the Safety valve Steam drum component (50HAD10AA192/AA193/AA194/AA195/AA196) at a reliability level of 60% with a time interval of 9000 hours. This RAM study supports more effective and efficient maintenance planning to improve Steam Power Plant performance and can be implemented in other Steam Power Plant tool systems.

## 1. Introduction

PT. Jawa Power is one of the largest independent power producers in Indonesia, and it has a 30-year power purchase agreement with the State Electricity Company. The power plant supplies electricity to the 500 kV Java-Bali grid, which is owned and operated by the State Electricity Company. YTL Corporation operates its utility activities through its subsidiary YTL Power International Berhad (YTLPI), which is the Operation and Maintenance operator for PT Jawa Power. YTLPI owns 20% of PT Jawa Power, which has a 1,220-MW coal-fired power plant located at the Paiton Power Plant Complex in East Java, Indonesia (YTL Corporation Berhad, 2025). Several important components of steam power plants include boilers, turbines, generators, and condensers. The steam drum is a component of the boiler that separates steam and water and produces steam (Nurcahyo et al., 2023; Sagharidooz et al., 2024; Singh et al., 2025). The steam drum is separated from the water and steam by a bulkhead. Steam is used to drive the turbine to meet the electricity supply needed by the company. The steam produced by the Steam drum is dry. If the steam produced is still in the form of wet steam, it can damage the turbine's operation (Musyafa & Adiyagsa, 2012; Sulanjari, 2016). The role of the Steam drum is quite important because if the level of wet steam in the Steam drum is lacking, there will be a failure of water circulation, and if the Steam drum level exceeds a certain range, there will be a failure of the separation of water vapor and water.Therefore, parameters are required to maintain system function and determine the right maintenance steps to avoid downtime or failure. RAM (Reliability, Availability, and Maintainability) is a tool to evaluate the performance of a system at different stages in the planning process (Corvaro et al., 2017; Faulin

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et al., 2010). The RAM is used to predict the system performance indexes and analyse the influence of external factors, such as logistics, spare parts, redundancy configuration, and the effect of preventive maintenance, on the system performance (Calixto, 2016; Dono, 2017). RAM analysis can address operational and security issues to identify system elements for which corrective action can be taken (Charles E. Ebeling, 2003; Jakkula et al., 2022; Karaani et al., 2024). The key performance metrics generated from this RAM analysis are availability, MTTF (Mean Time to Failure), and MTTR (Mean Time to Repair) (Sabzebin, 2022; Sayed & Elshahed, 2019; Tsarouhas, 2020). The mean time to failure is the average time between the damage events in the system. The mean time to repair is the average time required to repair a system that experiences a breakdown or damage. Availability is the probability that a system operates according to its function when it is to be used (Hatala et al., 2023; Saraswat & Dubey, 2024; Zhang et al., 2013)
Considering that the steam drum is an important unit in the process, in this study, we analysed the reliability using the RAM method to determine the reliability of a system or component to minimize failure. In addition, it can be used as a consideration for companies in the process of maintaining units so as not to hamper the production process.

## 2. Material and Method

Field reviews were conducted to identify failures that often occur in plants. The data taken were maintenance data for the last 5 years, namely from 2019 to 2024. Company data collection includes maintenance data, P&ID (Piping & Instrumentation Diagram), PFD (Process Flow Diagram), and component specifications.

### 2.1 Reliability

The data used to determine TTF are maintenance data for 5 years, namely, 2019 to 2024, at PT YTL East Java. The 5-year observation period is considered adequate because the number of failure events covered more than six MTTF cycles, thus fulfilling the data sufficiency criteria in the statistical reliability analysis. The possibility of damage occurring during a certain period can be determined by identifying the TTF distribution, where the pattern of damage data analysis influences the choice of distribution. The suitability of the distribution type for each steam drum component can be determined using Reliasoft Weibull++ version 6 software (K et al., 2019). This software enables matching data characteristics with the most appropriate statistical model. This ensures that the distribution identification used in the reliability calculation is based on accurate statistical justification, thereby maintaining the data processing results' validity and accountability. The distribution of each steam drum component was determined from the Reliasoft Weibull data processing results, and the reliability value was calculated using the following equation (Charles E. Ebeling, 2003):

1. Weibull 2 Parameter Distribution, The reliability function of the 2-parameter Weibull distribution is:
$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \quad (1)$$
2. Weibull 3 Parameter Distribution, The reliability function of the 3-parameter Weibull distribution is:
$$R(t) = e^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}} \quad (2)$$
3. Lognormal Distribution, The reliability function of the lognormal distribution is expressed as follows:
$$R(t) = \int_{\ln(t)}^{\infty} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx \quad (3)$$
4. Normal Distribution, The reliability function of the normal distribution is:
$$R(t) = \int_{t}^{\infty} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2} dx \quad (4)$$
5. Exponential Distribution, The reliability function of the exponential distribution is:
$$R(t) = e^{-\lambda(t-\lambda)} \quad (5)$$

where,
R(t) : Reliability function ; t: operating hours (hour); $\eta$: scale parameter (hour); $\beta$: shape parameter; $\gamma$ : location parameter (hour); $\mu$: mean time to failure (hour); $\sigma$: standard deviation (hour); $\lambda$ : failure rate (1/hour)
The reliability, maintainability, and failure rate were analyzed using the Weibull method based on Equations (1-5). Determination of TTR value is determined from the time repair data for each component. The data is taken from the maintenance data of PT. YTL East Java for the last 5 years. After obtaining the TTR value, the type of distribution appropriate for each component was determined using the Reliasoft Weibull++ Version 6 software.

### 2.2 Maintainability Evaluation

From determining the type of distribution in the TTR data, we can continue to find the Maintainability value of each component using an equation that corresponds to the type of distribution (Charles E. Ebeling, 2003).

Maintainability of the 2-Parameter Weibull Distribution; Maintainability of the 3-Parameter Weibull Distribution, Maintainability of The Lognormal Distribution; Maintainability of Normal Distribution and Maintainability of Exponential Distribution.

### 2.3 Availability

After determining the appropriate distribution type, the availability value for each component is calculated using the following equation (Charles E. Ebeling, 2003):

$$A = \frac{MTBF}{MTBF+MTTR} \tag{6}$$

The Availability value that changes over time is written in the following equation:

$$A(t) = \left[\left(\frac{\mu}{\lambda+\mu}\right) + \left(\left(\frac{\lambda}{\lambda+\mu}\right) e^{(-(\lambda+\mu)t)}\right)\right] \tag{7}$$

where,
A: Availability; MTBF: Mean Time Between Failure (hour); MTTR: Mean Time to Repair (hour); A(t): Availability at time t; $\lambda$: failure rate (1/hour); $\mu$: repair rate (1/hour); t: operating hours (hour)

### 2.4 Determination of Preventive Maintenance with Reliability

Preventive maintenance (PM) is effective for systems with increasing failure rates. In addition, in a system with a decreasing failure rate, preventive maintenance can reduce reliability (Charles E. Ebeling, 2003). The following reliability model assumes that a system is restored to its original condition after preventive maintenance. Reliability under preventive maintenance can be calculated by the following equation (Charles E. Ebeling, 2003):

$$Rm(t) = R(t) \qquad untuk\ 0 \le t \le T \tag{8}$$

$Rm\ (t)$ is the reliability with maintenance, $R(T)$ is the probability of not failing until the first preventive maintenance.

$$Rm(t) = R(T)R(t-T) \quad untuk\ T \le t \le 2T \tag{9}$$

$R\ (t-T)$ is the probability of not failing at time T after the system is restored to its initial state at time T.

$$untuk\ nT \le t < (n+1)T, n = 0,1,2 \tag{10}$$

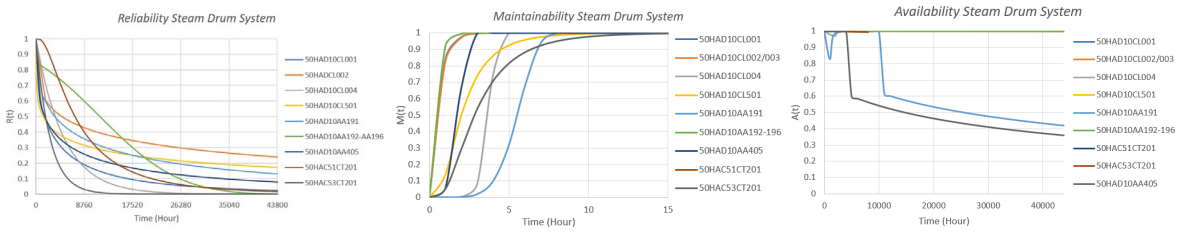
where,
Rm(t): system reliability with maintenance; R(t): system reliability without maintenance; T: preventive maintenance time interval (hours); R(T): probability that the system will not fail until time T, R(t-T): probability that the system will not fail after PM is performed and will run again for (t−T).

### 2.5 Quantitative Evaluation

The data used are maintenance data for the last 5 years at PT YTL East Java, from 2019 to 2024. The data are in the form of damage data and major overhaul data carried out in 2019.
Based on the failure data of 50HAD10CL001, a failure time distribution and repair test were conducted. It was found that the most appropriate failure time distribution was the Weibull 3 distribution with parameters β = 0.512, η = 3226.722, and γ = 260.92. Thus, the MTTF value was obtained = 4692. The most appropriate repair distribution was exponential with parameters λ = 1.839 and γ = 1.8768. Thus, the MTTR value was obtained = 2.375.
Based on the failure data of 50HAD10AA192/AA193/AA194/AA195/AA196, a failure time distribution and repair test were conducted. The most appropriate failure time distribution was found to be the normal distribution with parameters μ = 11608 and σ = 11309. Thus, the MTTF value is 11608. The most appropriate repair distribution is exponential with parameters λ = 2.5196 and γ = 5.8356. Thus, the MTTR value is 6.1667.
Based on the failure data of 50HAD10CL501, a failure time and repair distribution test was conducted. It was found that the most appropriate failure time distribution was the Weibull 3 distribution with parameters β = 0.2603, η = 5056.32, and γ = 426.52. Thus, the MTTF value was obtained = 9396. The most appropriate repair distribution was lognormal with parameters μ = 0.6931 and σ = 0.6404. Thus, the MTTR value was obtained = 2.25.
Based on the failure data of 50HAC53CT201, a failure time and repair distribution test was conducted. The most appropriate failure time distribution was found to be exponential with parameters μ = 0.0004 and σ = 1588.395. Thus, the MTTF value was obtained = 3432. For the most appropriate repair distribution, lognormal with parameters μ = 1.0397 and σ = 0.6364. Thus, the MTTR value was obtained = 3.

### 2.6 Reliability Evaluation

Each component was calculated for the reliability value. The calculation results can then be visualized in the form of a graph, as shown in Figure 1a, which shows the reliability values of all the components in the steam drum. Several components were analysed, such as 50HAD10CL001, which is the Tx level transmitter or signal sender in the Steam drum process section with number 1 on unit 50. The level transmitter is a part of the instrumentation that measures and monitors the height or water level in the Steam drum. After calculating the Reliability using Eq(2), a reliability graph was obtained, as shown in Figure 1a, which shows that the Steam drum level transmitter component has a Reliability value of 0.603 or 60% after 850 hours of operation, so that the component has a chance of failure of 40%.




(a) (b) (c)

*Figure 1: Steam Drum System (a) Reliability, (b) Maintainability, (c) Availability Graph*

### 2.7 Maintainability Evaluation

Figure 1b is a visualization of the maintainability value of each component obtained based on the determination of the distribution type from the Time to Repair (TTR) data. In component 50HAD10CL001, the appropriate distribution type is exponential, so that the Maintainability value can be determined using Eq(10). The Maintainability graph shows that to achieve a probability of 0.99 or 99% on the Steam drum transmitter level component with asset code 50HAD10CL001 requires 3 hours. So, it can be said that the effective time to make repairs to the component is 3 hours. If it is less than 3 hours, the component may be under repair, thus reducing its performance of the component is not as before. In the same way as before, the Maintainability Graph shows that to achieve a probability of 1 or 100% on the Steam drum safety valve component 50HAD10AA192/AA193/AA194/AA195/AA196, it takes 3 hours. Therefore, the effective time to repair the component is 3 hours. If the time is less than 3 hours, the component may be under repair, thereby reducing its performance, whereas it should not be.

### 2.8 Availability Evaluation

The Availability value is obtained using Eq(12) so that the Availability graph results are obtained as in Figure 1c, which shows that the probability of availability on the Steam drum transmitter level component with asset code 50HAD10CL001 has decreased to 99%, so it can be said that the component has a possibility of being used according to its function of 99%. While the other 1% represents a component experiencing downtime that can be caused by failure or during the repair stage.

### 2.9 Determination of Preventive Maintenance with Reliability for Each Steam Drum Component

Preventive maintenance is carried out to prevent damage to equipment or systems by conducting scheduled checks, maintenance, and repairs so that the equipment continues to function optimally and has a longer service life. In determining preventive maintenance, the results of the failure rate data were considered. If the nature of the failure rate is an increase failure rate if PM is carried out, it will be effective, while the constant failure rate and decrease failure rate do not need to be PM, but it does not mean that no action is taken at all on the component but can be replaced such as by checking it periodically.

Based on maintenance data for 5 years, the distribution type for Time to Failure (TTF) for the Steam drum safety valve components with asset codes 50HAD10AA192/AA193/AA194/AA195/AA196 is obtained using Eq(16), the appropriate distribution type is normal, so that the failure rate properties of the components are IFR, which indicates that the components are in the ware out phase and it is recommended to carry out preventive maintenance.

Based on the failure rate data results, there are 3 types of failure rates: increasing, decreasing, and constant failure rates. 4 components are analysed, namely 2 components with DFR, 1 component with IFR, and 2 components with CFR. From the results in Table 1, the nature of the failure rate states that the Steam drum safety valve component with asset code 50HAD10AA192-AA196 needs to be preventive because it has an increased failure rate. The evaluation of preventive maintenance is performed based on the known reliability

value. The evaluation was carried out by comparing the reliability when it was 55%, 60%, and 65%, which had sequentially operated for 10,000, 9,000, and 7,000 h as shown in Figure 2.

*Table 1: Recommendations for Steam Drum Preventive Maintenance*

| Component | Asset Code | Failure Rate Properties | Maintenance Recommendations | Recommended Actions |
|---|---|---|---|---|
| Steam Drum (SD) LT | 50HAD10CL001 | DFR | PM is not carried out | Recalibration |
| SD safety valve | 50HAD10AA192/AA193-196 | IFR | PM needs to be carried out | Re-lapping the seat |
| SD Level Control | 50HAD10CL501 | DFR | PM e is not carried out | Periodic checks and cleaning |
| TT Economizer | 50HAD53CT201 | CFR | PM is not carried out | Recalibration: |

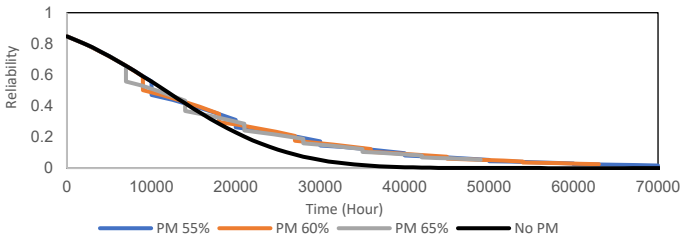



*Figure 2: Reliability 50HAD10AA192/AA193/AA194/AA195/AA196 with Preventive Maintenance*

The black graph is the Reliability graph of the Steam drum safety valve when not in PM. The blue, orange, and grey graphs show the reliability of the Steam drum safety valve with PM 55%, 60%, and 65% operating for 7000, 9000, and 10,000 hours, respectively. The results of the graph show that the Reliability levels of the three are not too different. So it can be chosen that PM 55% can be achieved but needs to be reconsidered because at the Reliability level of 50%, it means having a 50% chance of failure.
The company does not want to speculate with a 50% chance of failure. As another consideration, PM is recommended to be 60% because it has a failure rate of 40%. PM that can be performed on the Safety valve Steam drum 50HAD10AA192/AA193/AA194/AA195/AA196, such as by providing redundant or by re-lapping/reconditioning the seat to ensure a perfect seal between the valve and its seat. When the reliability value of a component has reached ≤ 60%, the component is prone to failure. Therefore, periodic inspections are required every 8 h to minimize the risk of downtime and ensure that the component continues to function according to operational standards.

### 2.10 RAM Analysis of All Components

The analysis was conducted on several main components: a level transmitter (50HAD10CL001-004, 50HAD10CL501), safety valve (50HAD10AA191-196), pressure gauge isolation valve (50HAD10AA405), and temperature transmitter (50HAC51CT201, 50HAC53CT201). The maintenance data for 5 years shows that most components have DFR (Decreasing Failure Rate) characteristics, which indicate that the components are in the burn-in phase, except for component 50HAD10AA192-196, which has IFR (Increasing Failure Rate) characteristics, which indicate that the components are in the wear-out phase.In terms of Reliability, most components achieved a Reliability value of 60% with varying operating times ranging from 350 to 8700 hours. For Availability, almost all components have a high availability value of approximately 99%, except for components 50HAD10AA191 and 50HAD10AA405, which have lower Availability of 41% and 35% due to high downtime. The maintainability or effective component repair time was varied between 3 and 13 hours to achieve a repair probability of 99-100%.This shows that although the components in the steam drum system have fairly good Reliability or are quite reliable, some components require special attention, especially the steam drum safety valve, because it has an increased failure rate. This indicates the need for improved maintenance strategies to minimize downtime and maintain the overall system performance.

## 3. Conclusions

The lowest reliability value in 1 year for the steam drum component is in the Steam drum control level component with asset code 50HAD10CL501, namely, at 350 hours or 14 days the reliability value has reached 60%, and the highest reliability value is in the 50HAD10AA192 / AA193 / AA194 / AA195 / AA196 components with a

reliability value reaching 60% at 8760 hours or 1 year. The longest repair time was in the temperature transmitter economizer component with asset code 50HAC53CT201, which was 13 hours, and the lowest availability value was in the safety valve steam drum component with asset code 50HAD10AA191 and the safety pressure gauge valve steam drum with asset code 50HAD10AA405, namely 41% and 35%, respectively. Based on the failure rate, failure rate, of the 9 components that have been analysed, there is 1 component that has an increased failure rate, so PM is needed, namely on the Steam drum safety valve with asset code 50HAD10AA192/AA193/AA194/AA195/AA196. By comparing the Reliability of 55%, 60%, and 65%, PM is recommended after 9000 hours of operation.

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