Evaluation of Preventive Maintenance Strategy to Increase Diesel Engine Avaibility at Pt Pln Nusantara Power Ulpltd Pulo Pisang

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Abstract

The availability of diesel engines is one of the important indicators in maintaining the reliability of power plant operations. Disruptions that occur in diesel engine components can cause increased downtime to reduce the availability level of the power plant. Therefore, an effective preventive maintenance strategy is needed to minimize disruption and increase the reliability of diesel engine operations. This study aims to evaluate the effectiveness of preventive maintenance strategies in Deutz Unit 5 Diesel Engines at PT PLN Nusantara Power ULPLTD Pulo Pisang based on the parameters of Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and Availability. The research method used is descriptive quantitative by utilizing operation data, fault data, downtime data, and maintenance data for the 2023–2025 period. The results of the study show that the number of disturbances increased from 1 disturbance in 2023 and 2024 to 5 disturbances in 2025. The MTBF value decreased from 357.9 hours in 2023 and 449.4 hours in 2024 to 21.82 hours in 2025, while the MTTR value increased to 10 hours in 2025. The results of the availability calculation showed a value of 97.81% in 2023, 99.45% in 2024, and decreased to 68.57% in 2025. Critical component analysis shows that the Cooling Water Tank is the largest cause of downtime with a contribution of 32 hours or 52.89% of the total downtime. Based on the results of the evaluation, the recommended preventive maintenance strategy is to increase inspection and maintenance of the cooling system, fuel system, starting system, and governor system based on the critical level of components. The implementation of this strategy is expected to reduce downtime and increase the availability and reliability of diesel engines at ULPLTD Pulo Pisang

Keywords: *Preventive Maintenance, Availability, MTBF, MTTR, Downtime, Mesin Diesel*

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Introduction

The availability of power generation units is one of the main indicators used to assess the reliability of power plant operations. High availability values indicate that a power plant unit has the ability to operate according to its planned function within a certain period of time, while low availability indicates disruption or downtime that can reduce the readiness of the unit to support the needs of the electric power system. In an electricity system that increasingly demands high reliability, each power plant unit is required to be able to maintain its optimal operating performance so that the continuity of electrical energy supply is maintained [8], [9].

One of the factors that greatly affects the availability of the power plant unit is the condition of the main equipment of the plant. In Diesel Power Plants (PLTD), diesel engines are critical equipment that functions as the main driver of the generator in the energy conversion process. Diesel engines operate under conditions of high load and operating hours so they are prone to performance degradation, component wear, and technical problems that can cause operation failure. Disturbances that occur in the fuel system, lubrication system, cooling system, and other mechanical components can result in unit downtime and have a direct impact on the decrease in plant availability [16], [17].

To maintain equipment reliability and minimize potential disruptions, power generation companies generally implement preventive maintenance programs as the main maintenance strategy. Preventive maintenance is a maintenance activity that is carried out in a planned and periodic manner before damage occurs with the aim of preventing equipment failure, extending asset life, and maintaining plant operation performance. The effective implementation of preventive maintenance is expected to reduce the frequency of disturbances, reduce repair time, and increase the availability of power generation units [10], [14], [15].

Although preventive maintenance has been widely applied in the generation industry, various studies have shown that the implementation of preventive maintenance that is only oriented to a routine schedule does not necessarily result in optimal levels of reliability. In some cases, equipment failures still occur even though maintenance activities have been carried out according to the set schedule. These conditions indicate that the effectiveness of preventive maintenance strategies needs to be evaluated periodically to ensure that the maintenance program implemented is truly able to reduce equipment failures and increase the availability of generating units [14], [15], [16].

Previous studies on plant maintenance generally focused on measuring reliability indicators such as Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Reliability, and Availability to determine the performance level of an equipment. However, most studies are still limited to analyzing reliability values without providing specific recommendations for preventive maintenance strategies based on the results of the evaluations obtained. In fact, the results of reliability evaluations should be used as a basis for determining maintenance priorities, identifying critical components, and developing more effective and targeted maintenance strategies [10], [14], [16]. Therefore, research is still needed that not only evaluates the performance of preventive maintenance, but also produces recommendations for improving maintenance strategies that are oriented towards increasing the availability of plant units.

PT PLN Nusantara Power ULPLTD Pulo Pisang is one of the generating units that plays a role in supporting the reliability of the electricity system in the Aceh region. As a generation asset that operates continuously, diesel engines at ULPLTD Pulo Pisang require an effective maintenance program to be able to maintain a high level of operational readiness. Although preventive maintenance has been carried out periodically in accordance with applicable maintenance procedures, the potential for disruption and downtime in diesel engines can still occur due to technical and operational factors. This condition raises the need to evaluate the effectiveness of the preventive maintenance strategy implemented so that it can be known to what extent the maintenance program contributes to increasing diesel engine availability [8], [12], [13].

Based on these problems, this study was conducted to evaluate the preventive maintenance strategy in diesel engines at PT PLN Nusantara Power ULPLTD Pulo Pisang through the analysis of reliability indicators which include Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and Availability. In addition to evaluating the effectiveness of the ongoing maintenance program, this study also offers a strategy to improve preventive maintenance through the identification of critical components that cause downtime and the preparation of maintenance priorities based on the level of their contribution to reducing unit availability. The results of the study are expected to be the basis for more effective maintenance decision-making, increasing diesel engine availability, reducing the frequency of disturbances, and supporting the improvement of the reliability of plant operations in a sustainable manner. [8], [10], [14]

Literature Review

2.1. Maintenance

Maintenance is all activities carried out to maintain or restore the condition of equipment so that it can operate as expected. According to industry standards, maintenance aims to maintain equipment reliability, extend asset operating life, reduce the risk of disruption, and improve operational efficiency [15], [16]. In power generation systems, maintenance activities play an important role because equipment failure can lead to a decrease in the ability of the plant to meet the needs of the electric power system. The main objectives of maintenance are:

a. Ensure the continuity of equipment operation.
b. Reduces the frequency of damage.
c. Improve reliability and availability.
d. Reduce repair costs due to sudden damage.
e. Extending the technical life of the equipment

2.2. Types of Maintenance

2.2.1. Corrective Maintenance

Corrective Maintenance is a maintenance activity that is carried out after damage to equipment [15], [16]. Characteristics:

a. Reactive
b. It was carried out after a disturbance.
c. Generally leads to higher downtime

Disadvantages:

a. The cost of repairs is huge.
b. The risk of losing production increases.
c. Lowering unit availability

2.2.2. Preventive Maintenance

Preventive Maintenance is a maintenance activity that is carried out periodically before damage occurs with the aim of preventing equipment failure [10], [14], [15]. Preventive Maintenance activities include:

a. Periodic checks
b. Replacement of components based on service life.
c. Cleaning of equipment.
d. Lubrication.
e. Equipment function testing

Advantages of Preventive Maintenance:

a. Reduces the risk of sudden damage
b. Lower downtime.
c. Improves system reliability.
d. Extend the life of the equipment.
e. Increase plant availability

2.3. Strategi Preventive Maintenance

Preventive maintenance strategies are the approaches used to determine the type, frequency, and priority of maintenance activities [10], [14]. An effective strategy should consider:

a. Operating hours of the machine.
b. A history of disorders.
c. Critical level of components.
d. Repair time.
e. Impact of disruption on plant operations

In this study, the evaluation of preventive maintenance strategies was carried out using the following indicators:

a. MTBF
b. MTTR
c. Availability

to find out the effectiveness of the maintenance program that has been implemented

2.4. Diesel Engine Generator

Diesel engines are the main drivers of generators in PLTD which function to convert the chemical energy of fuel into mechanical energy and subsequently into electrical energy [13]. The main components of diesel engines include:

a. Fuel System

Functions to supply fuel to the combustion chamber. Components:

1) Fuel Pump
2) Fuel Filter
3) Injector

b. Lubrication System

Functions to reduce friction between components. Components:

1) Oil Pump
2) Oil Filter
3) Lubricating Oil

c. Cooling System

Functions to maintain the working temperature of the machine. Components:

1) Radiator
2) Water Pump
3) Thermostat

d. Inlet Air System

Functions provide combustion air. Components:

1) Turbocharger
2) Air Filter

A malfunction in one of these systems may cause a decrease in unit availability

2.5. Keandalan (Reliability)

Reliability is the probability that an equipment can operate according to its specified function for a certain period of time without experiencing failure [9], [16]. The higher the reliability of an equipment, the less likely it is to cause operational failures. Mathematically reliability is stated:

$$R(t) = e^{-\lambda t} \quad (1)$$

Where:

R(t) = Reliability
L = Failure Rate
t = Operating time (hours)

2.6. Failure Rate

Failure Rate is the failure rate of an equipment in a certain period **[16].** With the equation:

$$\lambda = \frac{n}{T} \quad (2)$$

Where:
λ = Failure Rate
n = Number of distractions
T = Total operating time (hours)
Unit: failure/hour. The smaller the failure rate, the better the reliability of the equipment

2.7. Mean Time Between Failure (MTBF)

MTBF is the average operating time of the equipment between two consecutive faults **[16], [17]**. MTBF is used to determine the level of reliability of a diesel engine. With the formula:

$$MTBF = \frac{Total\ Operating\ Time}{Jumlah\ Failure}\ Atau\ MTBF = \frac{T}{N} \quad (3)$$

Where:
MTBF = Mean Time Between Failure (jam)
T = Total operating time (hours)
N = Number of distractions
Interpretasi:

High MTBF → more reliable machine
Low MTBF → disturbances are more common.

2.8. Mean Time To Repair (MTTR)

MTTR is the average time it takes to repair equipment after a malfunction [16], [17]. With the formula:

$$MTTR = \frac{Total\ Downtime}{Jumlah\ Failure}\ Atau\ MTTR = \frac{D}{N} \quad (4)$$

Where:
MTTR = Mean Time To Repair (jam)
D = Total downtime (hours)
N = Number of distractions
Interpretasi:
Low MTTR indicates a faster repair process.
High MTTR indicates longer repair time

2.9. Availability

Availability is the probability that an equipment is in a state of readiness for operation at the time of need [8], [9], [16]. Availability is the main parameter in this study. The relationship between MTBF and MTTR can be expressed as:

$$Availability = \frac{MTBF}{MTBF + MTTR} X100\% \qquad (5)$$

Where:

Availability = Availability rate (%)

MTBF = Mean Time Between Failure (jam)

MTTR = Mean Time To Repair (jam)

Tabel 2.1 Kriteria availability

Availability (%)	Category
> 95	Excellent
90 – 95	Good
80 – 90	Enough
< 80	Less

Downtime

Downtime is a period when the machine cannot operate due to a fault or maintenance activity [16]. With the formula:

$$Downtime = T_{repair} + T_{waiting} \qquad (6)$$

Where:

Trepair = Repair time

Twaiting = Spare parts or technician waiting time

High downtime will reduce plant availability

Evaluation of Preventive Maintenance Strategy

Evaluation of preventive maintenance strategies [10], [14], [15]. It was done by comparing:

a. Frequency of engine malfunctions
b. MTBF value.
c. MTTR value.
d. Availability unit.
e. Components causing the biggest downtime

Evaluation stages:

a. Collecting diesel engine operation data
b. Collect interference data.
c. Calculating MTBF.
d. Calculating MTTR.
e. Calculating Availability.
f. Identify critical components.
g. Developing recommendations for preventive maintenance strategies

Proposed improvement strategies include:

a. Adjustment of preventive maintenance intervals
b. Priority maintenance of critical components.
c. Increased periodic inspections.
d. Better parts management.

e. Maintenance based on history of disruption

Research Methodology

This study uses a descriptive quantitative method that aims to evaluate the effectiveness of *preventive maintenance* strategies in increasing *the availability* of diesel engines at PT PLN Nusantara Power ULPLTD Pulo Pisang. The research was carried out at PT PLN Nusantara Power ULPLTD Pulo Pisang, Pidie Regency, Aceh Province, with the object of research in the form of a Deutz Unit 5 type BV8M628 Diesel Engine which has an installed power of 1,224 kW, a capable power of 700 kW, began operating in 1987, and consists of one engine unit. The research data uses historical data on operations and maintenance during the period January 2023 to December 2025 consisting of primary data and secondary data.

Primary data was obtained through field observations, interviews with operators and maintenance technicians, and observations of the implementation *of preventive maintenance,* while secondary data was obtained from company documents which included diesel engine *running hour* data, failure data, *downtime* data, *preventive maintenance* data, *corrective maintenance* data, and *dataunit availability*, forced *outage data*, fault data per component, *downtime* data per component, and *preventive maintenance* schedule. The research variables consisted of *preventive maintenance strategies* measured through indicators of maintenance frequency, suitability of maintenance schedules, implementation of inspections, and replacement of components, and diesel engine availability analyzed based on *the parameters of Mean Time Between Failure* (MTBF), *Mean Time To Repair* (MTTR), and *Availability*. The research procedure begins with problem identification and literature study, followed by the collection of *running hour* data, disruption data, *downtime* data, *preventive maintenance* (PM) data, and *corrective maintenance* (CM) data, then data processing and analysis are carried out through MTBF, MTTR, and Availability calculations, as well as interference and *downtime* analysis by component to identify the components that have the greatest contribution to the disruption.

The results of the *next Availability* calculation are compared to *PT PLN Nusantara Power's target availability of 98% to determine the level of engine performance achievement, while a higher MTBF value indicates a longer engine operating interval, a lower MTTR value indicates a shorter repair time, and* a low *forced outage* indicates better operational conditions. Based on the results of the evaluation, recommendations for strategies for improving *preventive maintenance were further prepared* in the form of determining maintenance priorities for the components with *the greatest downtime*, increasing inspections of the cooling *water system*, increasing inspections of the fuel system, periodic checks of the starting system, and adjusting *preventive maintenance intervals* based on the history of the disturbance. The strategy is expected to reduce the frequency of disturbances, reduce *downtime*, increase engine reliability, and increase *the availability* of Deutz Unit 5 Diesel Engines at PT PLN Nusantara Power ULPLTD Pulo Pisang [8], [12], [14], [16].

Results

4.1. Overview of Research Objects

This research was conducted on the Deutz Diesel Engine Unit 5 located at PT PLN Nusantara Power ULPLTD Pulo Pisang, Pidie Regency, Aceh Province. This unit functions as one of the generating units that supports the reliability of the electrical system in the company's operational area. The specifications of the diesel engine used as the object of the research are shown in the table below:

Table 4.1 Specification of Diesel Engine Unit 5

Parameter	Value
Brand Engine	Deutz Unit 5
Machine Type	BV8M628

Installed Power	1,224 kW
Affordability	700 kW
Year of Operation	1987
Number of Units	1 Unit

The data shows that Unit 5 is a diesel engine that has been operating for a long time so it requires an effective maintenance strategy to maintain its availability and reliability.

Data Running Hour Mesin Diesel

Running hour data was used to determine the utilization rate of diesel engines during the study period.

Table 4.2 Running Hour of Diesel Engines

Year	Running Hour (Jam)
2023	357,9
2024	449,4
2025	109,1

Based on this data, it can be seen that Unit 5's operating hours will increase in 2024 and decrease in 2025. This shows a change in the unit's operating pattern which can be influenced by the needs of the system and the plant's operating strategy.

Diesel Engine Fault Analysis

Disturbances that occurred during the study period were used to determine the level of reliability of diesel engines

Table 4.3 Running Hour of Diesel Engines

Year	Number of Distractions
2023	1
2024	1
2025	5

It can be seen that the number of disruptions will increase significantly in 2025 compared to the previous two years. This condition shows a decrease in the performance of several diesel engine components which has the potential to reduce unit availability.

Diesel Engine Downtime Analysis

Downtime indicates the length of time the unit has been inoperative due to a malfunction:

Table 4.4 Downtime Recapitulation

Year	Downtime (Jam)
2023	8
2024	2,5
2025	50

There will be a very significant increase in downtime in 2025. The total downtime of 50 hours indicates that the disruptions that occur not only increase in number, but also require longer repair times

MTBF calculation

The calculation of the Mean Time Between Failure (MTBF) is done using Equation (3):

Year 2023

$$MTBF = \frac{357{,}9}{1}$$

$$MTBF = 357{,}9\ Jam$$

Year 2014

$$MTBF = \frac{449{,}4}{1}$$

$$MTBF = 449{,}4\ Jam$$

Year 2015

$$MTBF = \frac{109{,}1}{5}$$

$$MTBF = 21{,}82\ Jam$$

Table 4.5 MTBF Calculation Results

Year	MTBF (Hours)
2023	357,9
2024	449,4
2025	21,82

There will be a huge decrease in MTBF in 2025 which indicates that the frequency of disruptions is becoming more frequent.

MTTR calculation

The calculation of Mean Time To Repair (MTTR) is carried out using the equation (4)

Year 2023

$$MTTR = \frac{8}{1}$$

$$MTTR = 8\ Jam$$

Year 2024

$$MTTR = \frac{2{,}5}{1}$$

$$MTTR = 2{,}5\ Jam$$

Tahunn 2025

$$MTTR = \frac{50}{5}$$

$$MTTR = 10\ Jam$$

Table 4.6 MTTR Calculation Results

Year	MTTR (Jam)
2023	8
2024	2,5
2025	10

The highest MTTR value occurred in 2025 which indicates that the repair process takes longer than in previous years.

Perhitungan Availability

Availability calculation is done using equation (5):

Year 2023

$$Availability = \frac{357{,}9}{357{,}9 + 8} x100$$

$$Availability = 97{,}81\%$$

Year 2024

$$Availability = \frac{449{,}4}{449{,}4 + 2{,}5} x100$$

$$Availability = 99{,}45\%$$

Year 2025

$$Availability = \frac{21{,}82}{21{,}82 + 10} x100$$

$$Availability = 68{,}57\%$$

Table 4.7 Availability Calculation Results

Year	Availability (%)
2023	97,81

2024	99,45
2025	68,57

These results show that availability in 2025 will experience a significant decrease due to the increasing number of disruptions and downtime

Critical Component Analysis

Based on the downtime data per component, the following results were obtained:

Table 4.8 Downtime Per Component

Components	Downtime (Jam)
Tangki Cooling Water	32
Starting Valve	8
Fuel Rack	8
Elektrik Governor	4
Clearance Valve	4
Filter HSD	2,5
Disc Coupling	2

Total downtime: 60.5 hours

Water Cooling Tank Contribution: $\frac{32}{60,5}x100 = 52,89\%$

Thus, the Cooling Water Tank is the most critical component as it accounts for around 52.89% of the total diesel engine downtime.

Based on PM data that has been carried out at Unit 5 Deutz, preventive maintenance activities have been carried out through the P1, P2, and P3 programs on a regular basis. However, there are still several disturbances related to:

a. Cooling Water System
b. Fuel System
c. Sistem starting
d. Sistem governor

This shows that the preventive maintenance strategy implemented still needs to be improved, especially in the components that have the largest downtime contribution

Proposed Preventive Maintenance Strategy

Based on the results of the evaluation, the proposed strategies are:

a. Refrigeration System Priority
   Conduct more intensive inspection and testing of cooling water tank leaks because it accounts for the largest downtime
b. Fuel System Priorities
   Increase inspection frequency: HSD filter, Fuel Rack, Injection Pump
c. System Starting Priorities
   Perform cleaning and testing of the starting valve on each PM P2 and P3 activity
d. Monitoring Governor
   Perform periodic testing of the governor system to reduce the risk of engine start failure
e. Preventive Maintenance Based on Fault History

Preparation of maintenance schedules based on component failure history so that PM activities focus more on components that have the highest level of risk

Conclusion

Based on the results of the evaluation of the preventive maintenance strategy on the Deutz Unit 5 Diesel Engine at PT PLN Nusantara Power ULPLTD Pulo Pisang for the 2023–2025 period, it can be concluded as follows:

a. The results of the analysis show that the number of diesel engine disturbances will increase in 2025 with a total of 5 disturbances compared to 2023 and 2024, which are only 1 disturbance each. The increase in the number of disturbances will cause an increase in downtime to reach 50 hours in 2025

b. The Mean Time Between Failure (MTBF) value decreased from 357.9 hours in 2023 and 449.4 hours in 2024 to 21.82 hours in 2025. Meanwhile, the Mean Time To Repair (MTTR) value increased to 10 hours in 2025, indicating a decrease in the reliability level of diesel engines as well as an increase in repair time due to the disruption that occurred.
c. Based on the analysis of downtime per component, the cooling system, especially the Cooling Water Tank component, is the most critical component with a downtime contribution of 32 hours or around 52.89% of the total downtime that occurred during the study period
d. The proposed preventive maintenance strategy to increase diesel engine availability is to prioritize maintenance on the cooling system, fuel system, starting system, and governor system based on the history of interference and downtime contribution of each component so that potential interference can be minimized and unit reliability can be improved

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