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Identification of Mothballed and Retired Units of Reliability-Based Steam Power Generation Systems

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Abstract

A stteam power generation system is a power generation system that uses steam power. The generating system itself has two types of unit statuses, namely active and inactive, which in this case are subdivided into Mothballed and Retired Unit statuses. The status of the unit provides a statement or decides whether the generating system is still suitable for use or has to be replaced (inactive). Determination of the status of the unit in the steam power generation system is carried out by calculating the work reliability of the generating unit. This is done to get the maximum decision. If you set the unit status incorrectly, the production costs incurred will be greater and not proportional to the number of products produced. This study focuses on two power generation units that have been used for a long time and experienced a decrease in performance. Therefore, identification of the status of the Mothballed and Retired Units of the steam power generation system was carried out by using a reliability test so as to produce a decision in determining the status of a more reliable unit. The method used to determine the status of the unit is to use the Reliability Block Diagram (RBD) and the Generating Availability Data System (GADS), the results of which state that unit one is in Mothballed status, which means the unit is no longer active but can still be used or reactivated within a period of several months. with a reliability level of 4.92% if it operates for 800 hours or a month. Meanwhile, unit two is declared to have the status of Retired Unit or can no longer be used again.

Keywords:
Power generation, Unit status, Reliability

1 Introduction

The generating system is a scientific discipline that studies the method of energy conversion or energy generation which is generally electrical energy. This science is widely used because the power generation system industry is always developing. This can happen due to the increasing demand for electrical energy and the development of the power generation system caused by several factors such as economic, technological, environmental, and government regulations[1].

Currently, the steam power generation system is one of the most frequently used methods of energy conversion or energy generation into electrical energy [2][3][4]. This power plant can produce electrical energy by producing steam in a steam generator using a boiler and distributing it through a turbine so that steam power can be converted into electrical energy[5].

This research was conducted by reviewing two power plant units that are more than 25 years old and are still being used in PLTU. The two power generating units studied are units used in PLTU, where the service life of the two units has been more than 25 years so many repairs are needed if they are to be reused (increased maintenance costs). In general, this steam power plant can ideally operate for 25 years so it can be stated that the power plant that exceeds the ideal time is no longer productive or is no longer productive. However, there is still the possibility that the power plant can be used optimally even though it has exceeded its productive age by carrying out regular repairs and maintenance [6].

For this reason, an analysis is carried out to determine whether the steam power plant can still be operated or not. This problem can be solved by finding the reliability of the power plant and determining the status of the power plant used [7][8]. Based on the IEEE 762 standard, the status of the generating unit is divided into two, namely active status and inactive status. We can determine the status of the generating unit by comparing the percentage between the EAF (Availability) and EFOR (Unavailability) values.

There have been several studies conducted by researchers on the reliability of the work of power generating units to determine whether the generating system is still suitable for use or has to be replaced so as to obtain the maximum decision [7][9][10]. The purpose of this study is to identify the status of the Mothballed and Retired Units of the steam power generation system by using a reliability test so that it can produce decisions in determining the status of a more reliable unit.

Mothballed status is the status for power generation units that are no longer in operation but can still be used or reactivated for several months after repairs have been made. Meanwhile, the Retired Unit status is the status for power generating units that cannot operate again. These two statuses correspond to the 2 generating units studied because these units have been used for more than 25 years.

2 Research Methods

A steam power plant is a generator consisting of several machines such as boilers, turbines, condensers, and pumps. Each machine certainly has a different level of reliability, but overall a steam power plant can operate for a maximum of 25 years. However, after that time the power plant can still be used but it is stated that the power plant is no longer productive due to increased maintenance costs.

Therefore, in this article, the researcher will identify the status of the steam power plant unit by finding and analyzing the reliability value of the power plant based on the data obtained from the steam power plant unit. Meanwhile, according to the IEEE 762 standard, the status of the power generation unit is divided into two, namely as follows.

1. Active Status

Active status is where the power generation unit is still declared to be able to operate optimally, that is, it can provide or produce maximum output. When the power generation unit is still declared active, the power generation unit has not experienced a decrease in producing output or a decrease in productivity. In this case, the active status is further divided into two groups which are explained as follows.

2. Available

The unit is declared available or available when the power plant can still produce output and is still functioning properly.

Even so, units that are still available can be temporarily deactivated or become a reserve shutdown status. Reserve shutdown status or also known as economy shutdown status is the status for power generating units that can still be used but are not operating due to several factors such as economy, etc.

3. Unavailable

Units can be declared unavailable or unavailable when the power plant is no longer able to produce output due to damage to some parts. Therefore, units that are already in an unavailable status are checked and maintained regularly to repair damage to parts of the unit.

4. Deactivated Shutdown

The deactivated shutdown is the status of the power generation unit where the unit can no longer operate. This status is divided into three types which are described as follows.

5. Inactive Reserve

The power generation unit can be declared to be in an inactive reserve status when the power plant is unavailable or no longer operating but can still be used or activated for several days after repairs are made.

6. Mothballed

Similar to an inactive reserve, a power generation unit is declared to be in a mothballed state when the power generation unit is no longer operational but can still be used or reactivated for several months after repairs have been made.

7. Retired

The power generation unit can be declared to be in a retired status when the power generation unit is no longer operating and can no longer operate.

In this article, the author will identify the status of Mothballed and Retired steam power plant units that have passed the productive period or have been operating for over 25 years by looking for the reliability of the unit using the Generating Availability Data System (GADS) and Reliability Block Diagram (RBD) methods which are described as following.

3 Reliability Block Diagram (RBD)

Reliability Block Diagram (RBD) is one of the calculations or formulations that can be used to find reliability [11]. The reliability formula used can be seen in formula (1).

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

Notes:
R = reliability value
e = constant real numbers whose value is close to 2.71828
λ = Lambda
t = wanted operation time

To find reliability using the formula above, it is necessary to find the failure rate first by using formula (2) as follows.

$$\lambda = \frac{1}{\text{MTBF}} \quad (2)$$

However, before we can get the failure rate we have to find the mean time between failure using the MTBF (3) formula as follows.

$$\text{MTBF} = \frac{\textit{Operating time}}{\textit{Failure}} \quad (3)$$

Notes:

MTBF (*Mean Time Between Failure*) shows the reliability of the operating engine in producing the products based on the average time of the tools. The machines will function from one damage to another.

Operating Time: engine working time

Failure: Number of failures during operating time.

After getting the reliability value, the authors look for the EAF and EFOR values of the steam power plant unit in order to determine the status of the unit using the Generating Availability Data System (GADS) method as described below.

3.1 Generating Availability Data System (GADS)

Generating Availability Data System (GADS) is a method that compares the availability and unavailability values of a power generating unit to determine the status of the unit. The concept of calculation using the GADS method can be seen as follows.

1. Availability

Availability is the level of readiness of the generating unit which is calculated as the Equivalent Availability Factor (EAF). With formulation (4).

$$\text{EAF} = \frac{\mu}{\lambda + \mu} = \frac{m}{m + r} = \frac{m}{T} = \frac{f}{\lambda} \quad (4)$$

Notes:
λ = *failure rate*
μ = *repair rate*
m = mean time between failure = MTBF = 1/λ
r = mean time to repair = MTTR = 1/μ
m + *r* = mean time between failures = MTBF = 1/*f*
f = frequency
T = periode = 1/*f*

2. Unavailability

Unavailability is the level of unpreparedness of the generating unit which in the calculation is expressed as the Equivalent Forced Outage Rate (EFOR) with formulation (5).

$$\text{EFOR} = \frac{\lambda}{\lambda + \mu} = \frac{r}{m + r} = \frac{r}{T} = \frac{f}{\mu} \quad (5)$$

Notes:
λ = failure rate
μ = repair rate
m = mean time between failure = MTBF = 1/λ
r = mean time to repair = MTTR = 1/μ
m + r = mean time between failures = MTBF = 1/f
f = frequency
T = periode = 1/f

To perform an analysis related to the status of the steam power plant unit, it is necessary to data on the failure and repair of the power generation unit. The failure data used is data where the power generation unit fails to be used or cannot be started to calculate the failure rate in determining the level of availability and level of unavailability of power plants. While the repair data is data when repairs are carried out on the damage that has occurred. Therefore, the authors have observed the steam power plant unit and collected data from the observations (table 1). Pareto Loss Output PLTU Unit 2 is shown in Table 2. Major Disturbance Data Unit PLTU is shown in Table 3

Table 1. Pareto Loss Output PLTU Unit 1

No.	Failure Cause	Lost Output (MWh)	Percent (%)	Cumulative Percent (%)
1	Other lube oil system problems	80016.1	45.50	45.5
2	Circulating water pumps	32086.2	18.25	63.7
3	Instrumentair compressors	17860.9	10.16	73.9
4	Vacuum pumps	15080.0	8.58	82.5
5	Waterwall (furnace wall)	11422.7	6.50	89.0
6	Feedwater piping downstream	11042.4	6.28	95.3
7	Debris in circulating water	2795.0	1.59	96.8
8	Closed cooling water pumps	1967.3	1.12	98.0
9	Turbine instrument and control	1183.0	0.67	98.6
10	Fuel oil pumps	914.3	0.52	99.2
11	Circulating water system	514.6	0.29	99.4
12	Forced draft fans	476.7	0.27	99.7
13	Feedwater regulating valve	243.8	0.14	99.9
14	Instrument air dryers	195.0	0.11	100.0
15	Feedwater pump	41.2	0.02	100.0
16	Exhaust hood and spray controls	17.3	0.01	100.0

Table 2. Pareto Loss Output PLTU Unit 2

No.	Failure Cause	Lost Output (MWh)	Percent (%)	Cumulative Percent (%)
1	Shaft seals	95160.0	38.13	38.1
2	Other feedwater valves	41427.8	16.60	54.7
3	Circulating water pumps	38151.8	15.29	70.0
4	Thrust bearings	32532.5	13.03	83.0
5	Turbine governing system	12547.3	5.04	88.1
6	Economizer	10212.6	4.09	92.2
7	Vacuum pumps	7800.0	3.13	95.3
8	Waterwall (furnace wall)	6246.5	2.50	97.8
9	Tuming gear and motor	3061.5	1.23	99.0
10	Air heater (regenerative)	1191.7	0.48	99.5
11	Other boiler instrumentation and control problems	1114.8	0.45	100.0
12	Other oil and gas fuel supply problems (see codes 0360-0410 for bumer problems)	115.9	0.05	100.0

Table 3. Major Disturbance Data Unit PLTU

No	Gangguan	Durasi	kWh
1	Vacuum condenser bad	512.28	14.343.933,3
2	Temperature thrust bearing turbine high	286.72	8.028.066,7
3	Leakage in boiler walltube	264.1	7.394.800

4 Result and Discussion

After observing and collecting data from the two steam power plant units, analysis and calculations to determine the status of the power generating unit can be carried out using the Reliability Block Diagram and Generating Availability Data System (GADS) calculations. The data collected in Tables 1, 2, and 3 in the form of failure cause and loss output are used in calculating the reliability value using the Reliability Block Diagram method and used to determine the status of the unit using the Generating Availability Data System (GADS) method.

4.1 Reliability Block Diagram (RBD)

The calculation of the reliability value using the Reliability Block Diagram (RBD) method is carried out using historical data, namely data on machine components that are damaged. The formulation of this method can be analyzed by calculating the value of Mean Time Between Failure (MTBF), failure rate (λ), and reliability which is calculated based on operating hours. The operating hours used are 50, 100, 150, 200, and 800 hours.

4.1.1 PLTU Unit 1

So, after calculating using the Reliability Block Diagram (RBD) method, the reliability value in unit 1 of a steam power plant based on operating hours can be in Table 4

Table 4. Reliability Value of PLTU Unit 1

Jam Operasi (*Hours*)	$Reliability_{system}$	Persentase (%)
50	0,828426538	82,84
100	0,686290528	68,63
150	0,568541286	56,85
250	0,470994689	47,10
800	0,04921121	4,92

We can see based on the calculation data of the reliability value of the power plant unit 1 that the reliability value and operating hours are inversely proportional. This states that if the unit's operating hours last longer, the reliability of the unit will decrease. The reliability value is inversely proportional to operating hours due to the value of Mean Time Between Failure (MTBF) and failure rate (λ) of large power generating units. This statement is supported by the results of the RBD calculations that have been carried out based on the generator unit failure data which can be seen in tables 1 and 2. (Fig. 1).

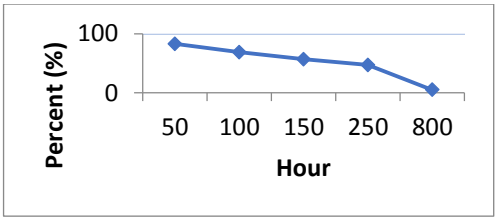

Fig. 1. Reliability Value of Unit 1

From the picture above, we can see the relationship between the percentage of unit reliability and the unit's operating hours. The relationship between these two things is inversely proportional, where the longer the unit operates, the lower the level of reliability and vice versa. The greater the percentage level of reliability of a unit, the greater the output that the unit can produce.

4.1.2 PLTU Unit 2

After calculating using the Reliability Block Diagram (RBD) method, the reliability value of unit 2 steam power plant based on operating hours can be seen as follows. (Table 5)

Table 5. Reliability Value of PLTU Unit 2

Jam Operasi (*Hours*)	$Reliability_{system}$	Persentase (%)
50	0,933843677	93,38
100	0,872064014	87,21
150	0,814371466	81,44
250	0,760495644	76,05
800	0,334492916	33,45

We can see based on the calculation data of the reliability value of the power plant unit 2 that the reliability value and operating hours are inversely proportional. This states that if the unit's operating hours last longer, the reliability of the unit will decrease. The reliability value is inversely proportional to operating hours due to the value of Mean Time Between Failure (MTBF) and failure rate (λ) of large power generating units. This statement is supported by the results of the RBD calculations that have been carried out based on the generator unit failure data which can be seen in tables 1 and 2 (Fig. 2).

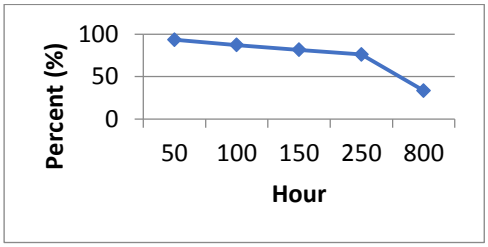

Fig. 2. Reliability Value of Unit 2

From the picture above, we can see the relationship between the percentage of unit reliability and the unit's operating hours. The relationship between these two things is inversely proportional, where the longer the unit operates, the lower the level of reliability and vice versa. The greater the percentage level of reliability of a unit, the greater the output that the unit can produce.

5 Generating Availability Data System (GADS)

Determining the status of the power generation unit can be done using the Generating Availability Data System (GADS) method which uses the concept of a comparison between Availability and Unavailability. To perform Availability and Unavailability calculations, it is necessary to have failure data on the engine components of the power generation unit which we can see in Table 1 and Table 2. The results of these calculations are explained in Table 6.

Table 6. *Availability* and *Unavailability* Value of PLTU Unit

No.	Parameter	PLTU 1	PLTU 2
1	EAF	51,17%	44,04%
2	EFOR	52,73%	66,06%

The results of the calculation of the Equivalent Availability Factor (EAF) and the Equivalent Forced Outage Rate (EFOR) can be seen in the table above. We can see that in unit 1 of the steam power plant the EFOR (unavailability) value is greater than the EAF (availability) value with a difference of 1.56% so it can be stated that the status of unit 1 steam power plant is Mothballed due to the difference in EFOR and EAF values. still below 10% to be declared as Retired Unit.

Meanwhile, the EFOR (unavailability) value in unit 2 power plant is greater than the EAF value (availability) with a difference of 22.02% so it can be stated that the status of unit 2 steam power plant is Retired Unit because the difference between EFOR and EAF is already greater than 10%.

From the EFOR and EAF values, we can determine the status of the power generation unit because this value is the availability and unavailability value of a generating unit. If the availability value is greater than the unavailability value then the power generating unit can still be used, but if the unavailability value is greater then the power generating unit cannot be used again with the provision that it is not greater than or greater than 10% (the provision is taken based on the permanent procedure document declaration generator condition and power plant performance index of PT PLN).

6 Conclusion

Based on the results of the analysis of the status of the steam power plant unit based on reliability using the Reliability Block Diagram (RBD) and Generating Availability Data System (GADS) methods which are calculated based on the observation data of units 1 and 2 power plants, it can be stated that unit 1 has the status of Mothballed which the unit is no longer active but can still be used or reactivated within a period of several months with a reliability level of 4.92% if it operates for 800 hours or a month. Meanwhile, unit 2 can be declared as Retired Unit status or can no longer be used again were based on the calculation results of the Generating Availability Data System method, the unit's unavailability value is greater than its availability value.

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