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Reliability Analysis of Steam Turbine Instrumentation Using the Failure Mode and Effect Analysis (FMEA) Method at PT. PLN Nusantara Power UP Tenayan

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ABSTRACT

PT. PLN Nusantara Power Unit Generation Tenayan is a company operating in the Steam Power Plant sector in Pekanbaru, Indonesia. One of the main components of a steam power plant (PLTU) is a steam turbine. A steam turbine is a machine that functions to convert kinetic energy into electrical current. Operational failures are often caused by less than optimal instrumentation in the steam turbine. This research uses the failure mode and effect analysis (FMEA) method with the aim of identifying the type of failure, the cause of the failure, the effect of the failure, and determining the RPN value. The analysis results from this research show that the turbine instrumentation components still meet performance standards because the risk priority number (RPN) value is less than 200. The conclusion from this research is that errors in steam turbine instrumentation are inaccurate sensor readings, switches cannot deactivate the equipment, and readings control room does not match local readings, the instrumentation component with the highest risk priority number (RPN) is the solenoid valve with a value of 140, and the instrumentation component with the lowest risk priority number (RPN) is the pressure indicator with a value of 30. The component given top priority in action The recommendation is for the solenoid valve component, namely to carry out maintenance every 6 months and add an overspeed protection system.

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1. INTRODUCTION

The type of secondary energy most commonly used by humans is electrical energy, electrical energy is produced from the conversion of primary energy sources such as water, wind, petroleum, coal, sunlight, gas, and others [1] . Electrical energy can be easily converted into various forms of energy and easily transferred from one form to another [2] . Therefore, electrical energy is mandatory for the production process to take place, both for large and small industries [3] .

The need for electrical energy in Indonesia is increasing every year, one of which is Riau province. From data from the Central Statistics Agency, Riau province has an area of 87,023.66 km2 with a population in 2016 of 6,500,971 people, in 2017 of 6,657,911 people, in 2018 of 6,814,909 people, and in 2019 of 6,971,745 soul. This increasing population growth causes a very large need for

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electrical energy [4] . Therefore, PT. PLN Nusantara Power UP Tenayan built PLTU Tenayan Raya to overcome the electrical energy crisis that occurred in Riau (Fadilla et al., 2023). Steam power plants (PLTU) are plants that rely on kinetic energy from steam to produce electrical energy [1] . PLTU Tenayan has a capacity of 2 × 110 Mega Watt [5] .

In carrying out the process, the Tenayan Steam Power Plant (PLTU) involves a series of complex stages, supported by various kinds of equipment and machines. However, the production process of Steam Power Plants (PLTU) is often hampered. This is caused by a failure in the instrumentation components on the machine used, which results in disruption of the electrical energy production process. One machine that often fails is the steam turbine.

One of the main components in a steam power plant is a turbine [6] . A steam turbine is a machine that functions to convert kinetic energy into electrical current [7] . A simple steam turbine has one moving part called a rotor. When fluid flows into the turbine, the blades rotate, producing the energy needed to move the rotor [8] . In a steam turbine there are several instrumentation components such as temperature indicators, vibration sensors, resistance temperature detection, pressure indicators, temperature indicator switches, solenoid valves, limit switches, pressure transmitters.

From the results of interviews and observations carried out directly with the instrumentation and control team leader at PT. PLN Nusantara Power UP Tenayan, it is known that failures that occur in steam turbine instrumentation components can cause damage to other components, and result in the performance of the steam turbine not being optimal. In order to ensure that the components in the steam turbine run well, it is necessary to prevent failure to identify potential causes of failure that will occur. One maintenance method that is able to identify failures is the Failure Mode and Effect Analysis (FMEA) method [9] . In the FMEA analysis process, there are three variables used to determine the problem, including severity, frequency and detection level [10] .

In research [11] discussed the damage that occurred on the Al Pin 350 lathe machine, and succeeded in proving that the machine was still in the reliable category and was proven by calculating the risk priority number (RPN) value using the failure mode effect and analysis (FMEA) method, even though the machine there is damage with the highest RPN but it is still in the reliable category. Research [12] Analysis that was carried out using the Failure Mode and Effect Analysis (FMEA) method succeeded in obtaining important components in lubricant system failures that require high priority for maintenance activities in the lubrication system on ships.

In research conducted by [13] using the failure mode and effect analysis (FMEA) method, it succeeded in identifying the failure mode and the failure effects resulting from the failure, and was able to provide recommendations for actions that the company should take to reduce the effects of failure. It was discovered that failures had an RPN value. The highest is still in the low category, but the frequency of damage occurs frequently and cannot be ignored.

Another study [14] also discussed the reliability of thresher machine components using the FMEA method. The researchers succeeded in getting availability values for machine components and knowing which equipment required special maintenance. In another study [15] also analyzed the RPN value of double screw compressor machine components using the FMEA method, and it can be seen that the FMEA method is able to identify failures and analyze the RPN value on double screw compressor machines by getting the highest RPN value and getting the lowest availability of components. double screw compressor machine.

Based on several related studies above, the FMEA method is able to identify failures and reduce the occurrence of failures by providing suggestions for preventive or maintenance actions for machine components that have the highest RPN values. The author is interested in conducting research which aims to determine the RPN value and analyze failures that occur in steam turbine instrumentation at PT. PLN Nusatara Power UP Tenayan using the failure mode and effect analysis (FMEA) method.

2. RESEARCH METHOD

2.1. Research Design

This research is illustrated in a flow diagram which aims to explain the steps in conducting research, the research diagram is shown in Figure 1 Research flowchart.

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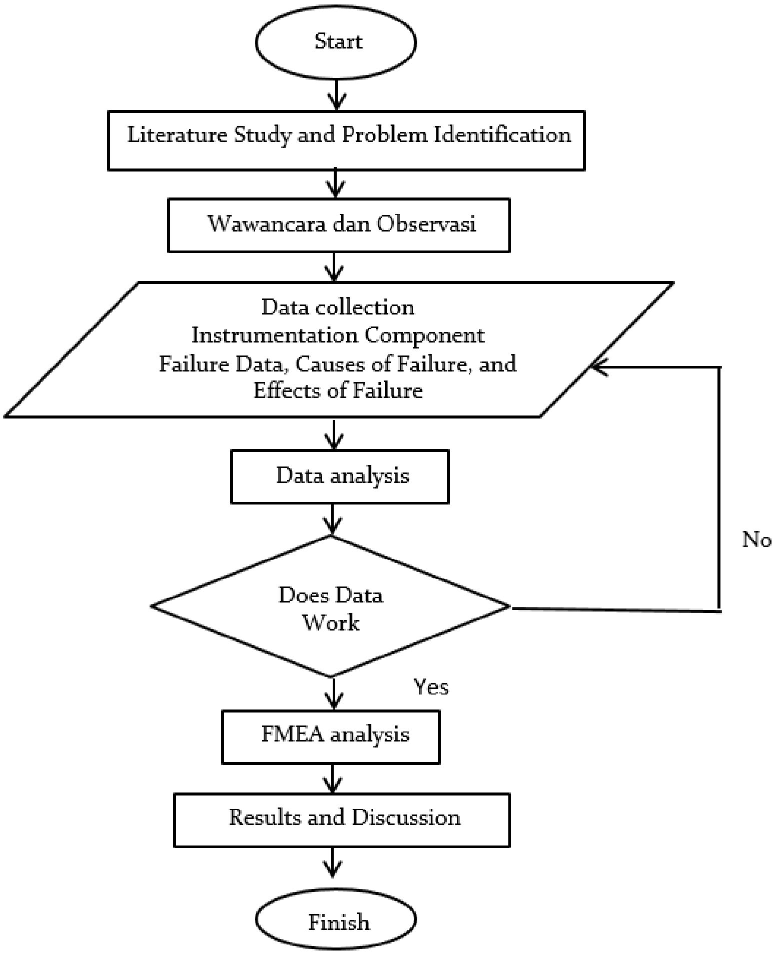

Figure 1. Research Flowchart

2.2. FMEA analysis

Failure Mode and Effect Analysis (FMEA) is a method that can be used to identify and eliminate defects or failures in products during the production process. FMEA can be used to define the consequences of failure at each stage, then create priorities related to prevention and improvement efforts, with the aim that the products produced in the next production process can be in accordance with customer wishes. In the FMEA analysis process, there are three variables used to determine the problem, including severity, frequency and detection level [10] .

In the FMEA method, the risk priority number (RPN) is calculated to determine the highest level of failure risk, by connecting three criteria, namely severity, occurrence and detection. The higher the RPN value, the lower the level of reliability of a system's components [15]. To determine the level of risk of failure, it can be written using the following equation:

$$RPN = Sev \times Occ \times Det \quad (1)$$

Description :
RPN = risk priority number
Sev = severity (level of damage)
Occ = occurrence (frequency)
Det = detection (detection level)

3. RESULTS AND DISCUSSION

3.1. Failure Mode Effect And Analysis

Failure mode effect and analysis is used to see the steam turbine instrumentation components that most often fail during the electricity production process. FMEA worksheet table which functions to

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provide severity, occurrence and detection values based on potential failure effects, causes of failure and control processes carried out, thus producing a risk priority number (RPN) value. The FMEA worksheet can be seen in table 1 below:

Table 1. FMEA Worksheet

No	Component	*function*	*Potential Failure Mode*	*Potential Effect Failure*	SEV	*Potential Of Failure*	OCC	*Current Control*	DET	RPN	*Recommended Action*
1	Pressure transmitters	Measuring pressure and carrying out monitoring	Error sensor reading	Damage to other components	5	The sensor is infected with dirt or dust	4	Readings on DCS do not match local	4	80	Carry out preventive maintenance every 6 months and provide special protection so that it is not easily infected by dirt
2	Temperature indicator	Temperature measurement in steam turbines	Function failure	The performance of the steam turbine is not optimal	4	High temperature	5	The temperature indicator indication is not accurate	3	60	Carry out preventive maintenance every 6 months and add a temperature protection system
3	Temperature indicator switch	Controls the temperature on the turbine	The switch failed to turn off the equipment	Trip units	8	Age of use	2	The equipment remains active at elevated temperatures	7	112	Carry out checks and maintenance every 6 months
4	Vibraton sensor	Measuring vibrations in steam turbines	Sensor readings are inaccurate	Trip units	8	Corrosion sensor connector cable	4	The reading in the control room is unreadable	3	128	Carry out preventative maintenance every 6 months and provide a protection system to prevent excessive vibration
5	Resistance temperature detector	Detect and monitor temperature changes	Overheating or excessive temperature in the turbine	Damage to other devices	5	Improper calibration	5	Readings in the control room are local	4	100	Recalibrate the sensor every 6 months and add a protection system for overheating
6	Solenoid valve	Controls fluid flow automatically	Failure to control fluid flow to the turbine	Fluid entering the turbine is excessive (overspeed)	7	Damaged or disconnected connection cable	5	Computers in the control room	4	140	Carry out maintenance every 6 months and add an overspeed protection system
7	Pressure indicator	Pressure gauge on steam turbine	The reading on the pressure indicator is inaccurate	damage to other related devices	5	Long service life	2	Readings on local indicators are inaccurate	3	30	Carry out preventative maintenance once every 1 year

1. Pressure transmitter

   This instrumentation component functions to measure pressure and carry out monitoring by sending electrical signals to the controller. Failure occurs when the reading from the sensor is inaccurate, causing damage to other components because the sensor is contaminated by dirt or dust. This can be seen from the reading on the DCS not matching the local reading. The instrument and control team leader gave a score of 5 for severity, gave a score of 4 for frequency of occurrence, and gave a score of 4 for level of detection. So the RPN value is 80.

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2. Temperature indicator
   This instrumentation component functions as a temperature measurement in the steam turbine. The failure that occurred was an error in the temperature sensor reading. So it can result in high temperatures and have an effect on non-optimal steam turbine performance. This can be seen from the inaccurate indication of the temperature indicator. The instrument and control team leader gave a score of 4 for severity, gave a score of 5 for frequency of occurrence, and gave a score of 3 for detection level. So the RPN value is 60.
3. Temperature indicator switch
   This instrumentation component functions as a device that automatically activates or deactivates based on the temperature detected in the steam turbine. The failure that occurs in this component is that the switch fails to turn off the equipment when overheating occurs due to the lifetime of the temperature sensor, resulting in the unit tripping. This can be seen from the device remaining active at increasing temperatures. The instrument and control team leader gave a score of 8 for severity, gave a score of 2 for frequency of occurrence, and gave a score of 7 for detection level. So the RPN value is 112.
4. Vibration sensor
   This instrumentation component functions as a vibration measurement in the steam turbine. Failure occurs because the sensor readings are inaccurate, which can result in excessive vibration and the effect of the unit shutting down. This is caused by corrosion of the cable or connector and can be seen from the CCR (central control room) being unreadable. The instrument and control team leader gave a score of 8 for severity, gave a score of 4 for frequency of occurrence, and gave a score of 3 for detection level. So the RPN value is 128.
5. Resistance temperature detector
   This instrumentation component functions to detect changes and monitor temperature changes and can be monitored from the DCS (distributed control system) room. Failure is overheating or excessive temperature in the turbine which occurs because the readings on the DCS do not match the local readings. This can result in damage to the related equipment and it not being able to work properly, which is caused by improper cable calibration and can be seen from the readings in the control room. The instrument and control team leader gave a score of 5 for severity, gave a score of 5 for frequency of occurrence, and gave a score of 4 for detection level. So the RPN value is 100.
6. Solenoid valve
   This instrumentation component functions to control fluid flow automatically. The failure that occurs is the inability to control the fluid flow due to damaged or disconnected cables or connections, causing the fluid entering the turbine to be uncontrolled, in other words, it can cause overspeed. This can be seen from the computer in the control room where the rotation of the turbine increases due to uncontrolled fluid flow entering the turbine. The instrument and control team leader gave a score of 7 for severity, gave a score of 5 for frequency of occurrence, and gave a score of 4 for level of detection. So the RPN value is 140.
7. Pressure indicator
   This instrumentation component functions as a pressure gauge in the steam turbine. The failure that occurs is that the pressure reading on the pressure indicator is inaccurate due to the age of the sensor, this can cause damage to other devices because the pressure exceeds the safe limit. This can be seen from the indication on the pressure indicator which is not actual.sentence. The instrument and control team leader gave a score of 5 for severity, gave a score of 2 for frequency of occurrence, and gave a score of 3 for detection level. So the RPN value is 30.

From the analysis carried out on the steam turbine instrumentation components at PT. PLN Nusantara Power Up Tenayan using the failure mode and effect analysis (FMEA) method has produced a risk priority number (RPN) value for the steam turbine instrumentation, and it can be seen from the FMEA worksheet table above, it can be summarized from highest to lowest as follows in table 2 below. The results of identifying the RPN value on steam turbine instrumentation show that all components of the steam turbine instrumentation have an RPN value below 200. Based on the

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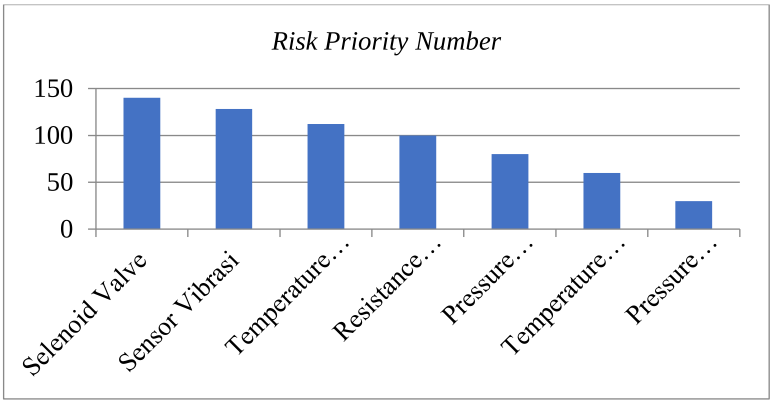
literature, an RPN value that has a value range of less than 200 means that the risk of this condition is considered low, and the instrumentation can be categorized as reliable [16] .

Table 2. Risk Priority Number Steam Turbine

NO	Component	Risk Priority Number (RPN)
1	Pressure transmitters	80
2	Temperature indicator	60
3	Temperature Indicator Switch	112
4	Vibration sensor	128
5	Resistance temperature detector	100
6	Solenoid valve	140
7	Pressure Indicator	30

Based on the results of reliability analysis carried out using the qualitative FMEA method. So it is found that the instrumentation components have risk priority number (RPN) values from highest to lowest, namely solenoid valve 140, vibration sensor 128, temperature indicator switch 112, resistance temperature detector 100, pressure transmitter 80, temperature indicator 60, and pressure indicator 30. The following is a form of Pareto diagram that makes it easier for readers to briefly identify the components that have the highest RPN values and the components that have the lowest RPN values.



Figures 2. Steam Turbine Pareto Diagram

From the Pareto diagram above, it shows that the largest RPN value lies in the solenoid valve component which is useful for controlling fluid flow automatically. This component is very influential in the continuity of electricity production with an RPN value of 140, which means that this component often experiences failures such as failure to control fluid flow to the turbine. Meanwhile, the pressure indicator component is an instrumentation tool that is useful for measuring pressure in steam turbines, which is the component that experiences the least damage with an RPN of 30. All of these components depend on other components, because if one component is damaged then the system cannot run or can be said to trip until the damaged component can return to normal operation.

4. CONCLUSION

Based on the results of the reliability analysis of the instrumentation system on the PT steam turbine. PLN Nusantara Power UP Tenayan Pekanbaru, using the faiure mode and effect analysis (FMEA) method, it can be concluded that.

1. After analyzing the instrumentation system on the steam turbine using the failure mode and effect analysis (FMEA) method, it can be seen that the instrumentation component on the steam turbine that has the highest RPN value is the solenoid valve with a value of 140, even though the solenoid valve component has the highest value but still in the reliable category.
2. The results of identifying the type of failure that occurred in the steam turbine were that the readings from the sensors were inaccurate, the switch failed to turn off the equipment, and the readings in the control room did not match local conditions.

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3. The causes of failure are sensors contaminated by dirt, age, improper calibration, and corroded or disconnected connection cables.
4. The effects of failure caused by failure of instrumentation components are damage to other related components, the performance of the steam turbine is not optimal, excessive speed occurs and the unit shuts down.

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