Reliability Analysis of Steam Condenser Instrumentation Using Failure Mode and Effect Analysis (FMEA)

M.Padol Padilla
Teknik Elektro
Universitas Islam Negeri
Sultan Syarif Kasim
Riau, Indonesia
12050513169@students.uinsuska.ac.id

Jufrizel
Teknik Elektro
Universitas Islam Negeri
Sultan Syarif Kasim
Riau, Indonesia
jufrizel@uin-suska.ac.id

Putut Son Maria
Teknik Elektro
Universitas Islam Negeri
Sultan Syarif Kasim
Riau, Indonesia
putut.son@uin-suska.ac.id

Ahmad Faizal
Teknik Elektro
Universitas Islam Negeri
Sultan Syarif Kasim
Riau, Indonesia
ahmad.faizal@uin-suska.ac.id

Abstract— In the realm of steam power generation, the reliability of equipment such as steam condensers plays a critical role in ensuring efficient electricity production. PT. PLN Nusantara Power UP Tenayan, a steam-powered thermal power plant in Central Sumatra with a capacity of 2 x 110 MW, serves as a pivotal component in the regional electrical grid. However, operational challenges, particularly relating to steam condenser failures, periodically disrupt production processes. This research employs the Failure Mode and Effect Analysis (FMEA) method to systematically identify failure types, root causes, failure effects, and to determine Risk Priority Numbers (RPNs). Data collection encompassed literature reviews, interviews, field observations, data analysis, FMEA analysis, findings, discussions, and conclusions. The calculated RPN values for instrumentation components of the steam condenser all fall below the critical threshold of 200, indicating reliability within acceptable limits. Despite the highest RPN observed in temperature indicators, they are deemed reliable and do not necessitate immediate maintenance actions. Identified failure modes include inaccurate readings, sticky switch conditions, unclear or blurred displays, and discrepancies between Distributed Control System (DCS) and local area data. Recommended actions for the condenser instrumentation components include intensified maintenance every three months, specification upgrades for switches to match pressure measurements, relocation of sensors to safer, sheltered areas, and zero calibration every six months for precise operation. This study underscores the importance of proactive maintenance strategies to uphold the operational efficiency and reliability of steam condenser instrumentation in power plant e.

Keywords—Steam condenser, FMEA, RPN, Failure, instrumentation

I. INTRODUCTION

In the current era of globalization, electrical energy plays a crucial role in driving national development progress. Every development effort, whether in infrastructure, industry, or other sectors, heavily relies on the availability of electrical energy. Without adequate electrical energy sources, the development process faces significant obstacles [1]. Indonesia has been developing various types of power plants, one of which is steam power plants. PT. PLN Nusantara Power UP Tenayan operates as a steam power plant (PLTU) with a capacity of 2 x 110 MW, serving as a support for the electrical system in Central Sumatra. Its presence is expected to greatly enhance the reliability of the electrical system and support the provision of affordable and efficient electricity [2].

Operation in this company run 24 hours every day, supported by a variety of production machines essential for its production processes, which are lengthy and multifunctional [3]. During production, however, not everything runs smoothly due to various issues, particularly with the diverse machines. This can impact the power plant's production stages. One of the production machines that frequently experiences failures and disrupts production stages is the steam condenser.

The steam condenser functions to condense or cool down steam that has been used to drive turbines, thereby converting the steam back into water for reuse in the next cycle [4]. The steam condenser includes instrumentation components such as pressure

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

indicators, switches, transmitters for pressure, level indicators, level transmitters, temperature indicators, and flow transmitters, ensuring the steam condenser operates as intended.

Interviews and direct observations with instrumentation and control personnel at PT. PLN Nusantara Power UP Tenayan revealed that failures in the instrumentation components of the steam condenser lead to damage in other components. Therefore, ensuring these instruments function properly requires maintenance to identify failure modes caused by each component within a system, its consequences, and the Risk Priority Number (RPN) resulting from these failures. One effective maintenance method for identifying failures is Failure Mode and Effects Analysis (FMEA) [5]. FMEA is a systematic approach used to identify and evaluate potential failures in a design, process, or system. This method helps recognize potential failure modes, analyze their causes and effects, and determine risk levels using a metric called Risk Priority Number (RPN) [6].

In this study [7], historical data on the types of defects occurring in the Induction Quenching Tempering (IQT) process were used. FMEA was employed to identify sources and root causes of these quality issues. The FMEA table creation involved determining failure modes, their effects, causes, controls, and mitigation efforts. Severity, Occurrence, and Detection values were derived from brainstorming sessions with the Production Manager and Inspection Manager. Subsequently, Risk Priority Numbers (RPNs) were calculated by multiplying Severity, Occurrence, and Detection values.

Based on this research [8], it was found that the devices within the Central Mechanical Electrical Unit are reliable and dependable. This was confirmed through FMEA analysis, where despite instances of damage in generator set devices with relatively high RPN values, they still remained categorized as reliable.

Research [9], titled "Analysis of Failure Causes in Woven Bag Products Using Failure Mode and Effect Analysis (FMEA)", aimed to address quality control issues in the company. This was evident from the failure percentages recorded from July to September 2010, each being 2.80%, 2.79%, and 2.94%, respectively, exceeding the company's maximum failure percentage of 2%. The method used in this study was Failure Mode and Effect Analysis, useful for identifying and analyzing failures by determining and multiplying severity, occurrence, and detection levels to obtain Risk Priority Numbers (RPN). The highest RPN failure mode at PT Indomaju Textindo Kudus was a damaged shuttle with an RPN of 196, occurring during the weaving process in circular loom machines.

Based on the background and previous research, the author is interested in conducting research to analyze the reliability of steam condenser instrumentation at PT. PLN Nusantara Power UP Tenayan. This analysis will utilize Failure Mode and Effect Analysis (FMEA) to identify potential failure modes, their causes, and effects on steam condenser instrumentation. The results of this analysis will provide recommendations for necessary improvements to enhance reliability and extend the lifespan of these instrumentation components.

II. RESEARCH METHODS

This research is conducted at PT. PLN Nusantara Power UP Tenayan. The focus of this research is the instrumentation system of the steam condenser. To facilitate the research process, a research flowchart has been created to clearly explain each step to be taken. This research is summarized in the following flowchart:

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

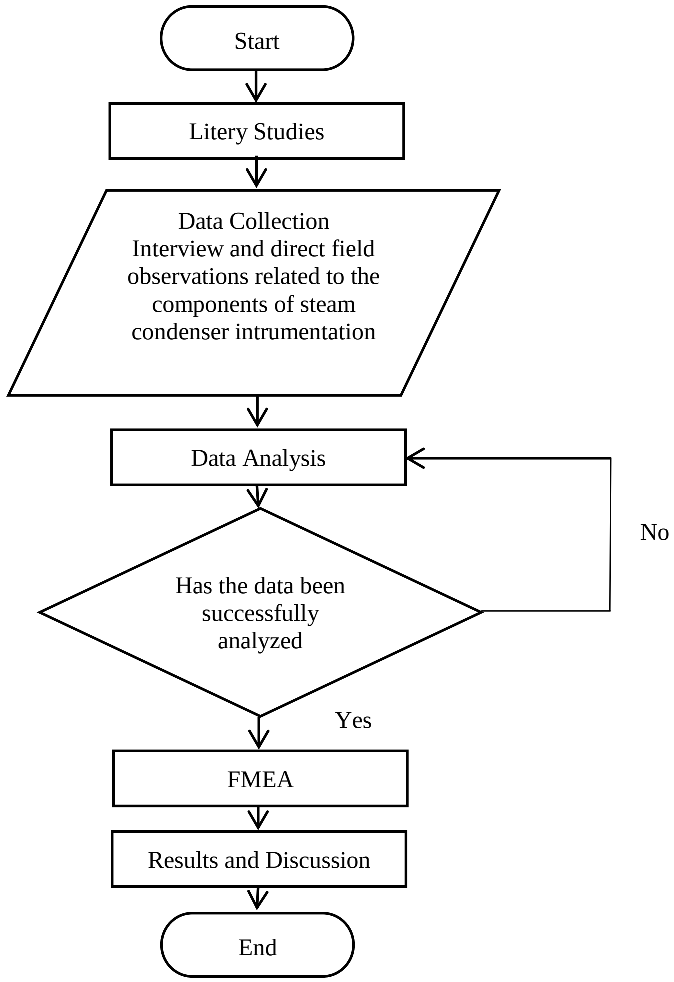

Figure 1. Flowchart of a research

The initial step taken in the data collection process of this research is to conduct an initial review through written sources such as scientific journals, articles, and similar literature. This preliminary review activity assists researchers in obtaining references related to methods and theories relevant to the topic under study. Additionally, researchers gather data after conducting interviews and field observations. Data collection of the steam condenser instrumentation is then carried out to identify the causes of failures and damages in the steam condenser instrumentation. Here are the instrumentation data on the steam condenser:

1. Pressure Transmitter: This component measures pressure and transmits the resulting fundamental quantity to the DCS so that it can be controlled remotely. The type of failure that occurs is a blurred display, making it difficult to monitor, which is caused by frequent water ingress into the display.
2. Pressure Indicator: This component is used to observe and control pressure in the local area. The type of failure that occurs is inaccurate indication, which prevents operators from monitoring parameters or measurements in the local area. This is caused by a weak indicator needle and blocked pressure flow, and can be seen in the difference between local readings and those on the DCS.
3. Pressure Switch: This component serves as a pressure limiting device whose operation can be adjusted according to operational needs. The type of failure

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

that typically occurs is a sticky switch, causing the controlled equipment to not work optimally. This is caused by weak switch terminals or springs, and can be observed on the DCS monitor where the reading appears red or shows an error.

4. Level Indicator: This component measures the level in the condenser tank. The type of failure that occurs is inaccurate measurement, making it impossible to compare measurements correctly. This is caused by leakage in the sensor flow, resulting in trapped air or water, and can be observed through abnormal readings in the local area.
5. Level Transmitter: This component measures level parameters and transmits the measurement results to the DCS. The type of failure that occurs is a discrepancy or difference between the reading and the actual condition of the tank being measured, making it impossible to operate equipment normally. This is caused by the sensor being in an abnormal state for its indication, and can be observed as an error on the DCS screen display.
6. Temperature Indicator: This component reads the temperature in the local area where it is located. The type of failure that occurs is a reading that is too low, preventing the measured equipment from being properly monitored. This is caused by a sticky needle on the Temperature Indicator, and can be observed through visual inspection in the local area.
7. Flow Transmitter: This component reads incoming and outgoing flow. The type of failure that occurs is a blurred display, making it difficult to monitor. This is caused by corroded terminals, and can be observed through visual inspection in the local area.

III. RESULT AND DISCUSSION

A. Analysis of Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a qualitative approach that uses a mapping method to greatly assist researchers in analyzing failure data. This approach serves as a basis for taking preventive actions before problems occur, cataloging failed equipment, and assessing its reliability [10]. In the FMEA method, the Risk Priority Number (RPN) is calculated to determine the risk level of failures by multiplying the severity (Severity), occurrence (Occurrence), and detection (Detection) values [11]. The RPN value indicates the level of risk used to determine countermeasures for failures. The higher the RPN value for a component, the lower the reliability of that component [12]. The RPN formula is shown in Equation (1) below:

$$\text{RPN} = \textit{Severity x Occurance x Detection} \qquad (1)$$

Notes :
RPN : Risk Priority Number Severity
Severity (Sev) : Level of severity Occurrence
Occurance (Occ) : Frequency of failure Detection
Detection (Det) : Action to detect the cause of failure

Severity (SEV) assesses the level of impact caused by a failure mode on the overall system. It is rated on a scale from 1 to 10, where 1 represents the best condition and 10 the worst. Severity rating correlates with the severity of the effects caused by the failure mode. Higher values indicate a greater severity of impact.

Occurrence (OCC) measures how frequently a failure or damage occurs. It is rated on a scale from 1 to 10, where 1 means the issue rarely occurs or is well-controlled, and 10 means the issue occurs very frequently. Occurrence assessment indicates the level or rank of mechanical causes of damage that occur in the machine. From the occurrence rating, it can be determined how likely damage is and how often it occurs in the machine.

Detection (DET) refers to the ability to recognize or detect potential failures or issues. The assessment system uses a scale from 1 to 10, where 1 means failures are definitely detected or can be quickly identified, and 10 means failures are not detected or there are no control tools to recognize such damage. Assessment of detection level is crucial for identifying potential causes of damage and determining necessary corrective actions.[13]. After calculating the RPN values for each instrumentation component, the RPN values are then listed in Table 1 below as follows:

Table 1. FMEA Worksheet for Steam Condenser Instrumentation at PT. PLN Nusantara Power UP Tenayan

Component Instrument	**Function**	**Potensial Failure Mode**	**Potensial Effect Failure**	**SEV**	**Potensial Of Failure**	**OCC**	**Current Control**	**DET**	**RPN**
Pressure Indicator	Measuring pressure in a local area	Inaccurate indication	The operator cannot monitor measurent parameter locally	7	The needle on the indicator is weak	6	There is a discrepancy between the local area reading and DCS reading	3	126
Pressure Switch	As a pressure limiting device whose operation can be adjusted to meet operational needs	The switch is sticky	The controlled equipment is not functioning properly	6	The switch terminals and spring are experiencing weakness	5	The reading appears as red or error on the monitor	4	120
Pressure Transmitter	Measures pressure and transmits the primary value to the DCS	The display is blurry	Difficult to monitor	4	Frequent water entry into the sensor	7	Visual inspection of the local area	4	112
Level Indicator	Measuring the level in the condenser tank	Inaccurate Measure ment	Unable to Compare Measureme nts	8	Leakage in the Sensor Flow	4	Local Reading in the Area is Abnormal	4	128
Level Transmitter	Measure the Level Parameter and Send the Measurement Results to the DCS	The Reading Differs from the Actual Condition of the Tank	Unable to Operate the Equipment Normally	7	The Sensor is in an Abnormal State and Difficult to Read	5	DCS Screen Display Error	3	105
Temperature Indicator	Read the Temperature in the Local Area	The Reading is Too Low	The Measured Equipment Cannot Be Properly Monitored	7	The Needle on the Indicator Transmitter Is Sticky	6	Local Area Reading Is Low	4	168
Flow Transmitter	Reading the flow	There is a blurry display	Difficult to monitor	4	Frequent water ingress into the sensor	7	Visual inspection in the local area	4	112

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

Based on the instrumentation component data for the steam condenser using the Failure Mode and Effect Analysis (FMEA) method, there are 7 instrumentation components with a total RPN of 871. The RPN values for the steam condenser instrumentation components are as follows: Pressure Indicator at 126, Pressure Switch at 120, Pressure Transmitter at 112, Level Indicator at 128, Level Transmitter at 105, Temperature Indicator at 168, and Flow Transmitter at 112. The highest RPN is found in the Temperature Indicator with a value of 168, while the lowest RPN is in the Level Transmitter with a value of 105. Based on the Risk Priority Number (RPN) analysis using the Failure Mode and Effects Analysis (FMEA) method, it can be concluded that the steam condenser instrumentation components at PT. PLN Nusantara Power UP Tenayan have very good performance. This is because the RPN values of each component in the steam condenser are below the standard RPN value threshold of 200. According to the literature, a higher RPN value indicates a more urgent need for maintenance of the instrumentation component, while a low RPN value, below the 200 threshold, indicates that the instrumentation component is still in good condition and does not require immediate maintenance actions [14].

B. Recommended Action

Recommended Action refers to the improvement or corrective measures suggested to reduce the impact, likelihood of occurrence, or to enhance the detection of specific failure modes that have been analyzed in the FMEA process. The goal of these recommended actions is to minimize the risks that could affect the system, process, or product being analyzed[15].

Recommended action is typically determined based on the evaluation of three key factors in FMEA: severity (the degree of impact), occurrence (the likelihood of the failure occurring), and detection (the ability to detect the failure). The higher the Risk Priority Number (RPN) derived from the combination of these factors, the more critical the failure mode is and the more urgent the need for appropriate corrective actions[16]. To view the recommended actions for the steam condenser instrumentation components, see Table 2 below:

Table 2.
Recommended Actions for the Steam Condenser

Component Instrument	Recommended Action
Pressure Indicator	Perform more intensive maintenance every 3 months
Pressure Switch	Upgrade the switch specifications according to the pressure range to be measured
Pressure Transmitter	Move the pressure transmitter to a safer area protected from water exposure
Level Indicator	Perform regular inspections or maintenance every 3 months and record level parameter data periodically
Level Transmitter	Perform zero calibration on the level transmitter every six months
Temperature Indicator	Replace the sensor regularly
Flow Transmitter	Move the flow transmitter to a safer area

Table 2 above aims to improve the reliability and extend the service life of the steam condenser instrumentation, ensuring optimal operation and preventing failures that could cause problems in the system. The recommended implementation period is adjusted according to the criticality level and failure potential of each component.

IV. CONCLUSION

The ranking of instrumentation component values for the steam condenser, from highest to lowest, is as follows: Temperature Indicator 168, Level Indicator 128, Pressure Indicator 126, Pressure Switch 120, Pressure Transmitter 112, Flow Transmitter 112,

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

Level Transmitter 105. Based on the RPN calculation results, none of the instrumentation components exceed the RPN standard limit of 200, indicating that they are still considered reliable. From the analysis conducted, several types of failures that can occur in the steam condenser instrumentation have been identified. These include issues such as inaccuracies in reading values, switches experiencing sticky or malfunctioning conditions, risks of display failure causing unclear or blurred images, and potential discrepancies between data displayed on the DCS and the local area. And from the analysis conducted, several recommended actions for the steam condenser instrumentation components are as follows: conduct more intensive maintenance every three months, enhance the specifications of switches according to the pressure measurements to be taken, relocate sensors to a safer area protected from water exposure, and perform zero calibration on the steam condenser instrumentation components every six months.

REFERENCES

[1] U. Situmeang, B. Mulyanto, dan M. Putra Halilintar, "Transformator Daya 125 Mva Menggunakan Indeks Polarisasi Tangen Delta Dan Breakdown Voltage Di Pltu Tenayan Raya 2 X 110 Mw", Jurnal Teknik Elektro Uniba, Vol. 2, no 5,8-14. April. 2022.

[2] A. Lestari, "Ruang Lingkup SCM (Supply Chain Management) dan Hubungannya dengan Penggunaan Aplikasi Maximo dalam Menunjang Kegiatan Operasi Pemeliharaan Pada PT. PJB UBJOM PLTU Tenayan Pekanbaru Riau", Skripsi, Universitas Andalas. 2020.

[3] R. Putra Pratama, "Analisis Keandalan Instrumentasi Batching Plant Menggunakan Metode Reliability Centered Maintenance (RCM) di PT. Kunango Jantan Pekanbaru", Jurnal EL Sains, Vol. 5, no 1, Juni 2023

[4] A. Ramadhan, "Analisa Keandalan Kondensor dengan Menggunakan Debris Filter di PLTU Belawan," Jurnal Surya Teknika , Vol. 5, no. 2, hlm. 18–24. 2017.

[5] W. O. Widyarto,G. A. Dwiputra, Y. Kristiantoro, "Penerapan Konsep *Failure Mode and Effect Analysis* (FMEA) Dalam Pengendalian Kualitas Produk Dengan Menggunakan Metode *Sig Sigma*", Jurnal REKAVASI, Vol.3,54-60. 2015

[6] A. Surya, S. Agung, and P. Charles, "Penerapan Metode FMEA (*Failure Mode And Effect Analysis*) Untuk Kualifikasi Dan Pencegahan Resiko Akibat Terjadinya Lean Waste," Jurnal Poros Tek. Mesin, Vol. 6, no. 1, pp. 45–57. 2017.

[7] Nurlailah Badariah, dkk. "Penerapan *Metode Failure Mode And Effect Analysis*(FMEA) Dan *Expert System* (Sistem Pakar) ". Jurusan Teknik Industri Fakultas Teknologi Industri Universitas Trisakti. Jakarta. 2016.

[8] Ahmad Faizal, Samsul Arifin. "Analisis Keandalan Instrumentasi Pada *Unit Central Mechanical Electrical* Menggunakan Metode *Failure Mode And Effect Analysis* (FMEA) (Studi Kasus PT. Telkom Area Network Riau Daratan Pekanbaru)". Jurusan Teknik Elektro UIN Suska Riau.2017.

[9] Nadia Rahmadhani. "Analisa Penyebab Kegagalan Produk *Woven Bag* Dengan Menggunakan Metode *Failure Mode And Effects Analysis* (Fmea) (Studi Kasus Di Pt Indomaju Textindo Kudus)". Prosiding Seminar Nasional Sains dan Teknologi, Vol. 1, No. 1, 2011.

[10] F. A. Basanta, J. Ahilman, and A. Musnansyah, "Perancangan Aplikasi RCM (Reliablity Centered Maintance) Dan RCS (Reliablity Centered Spares) Dalam Menentukan Kebijakan Maintenance Dan Persediaan Spare part", E-Proceeding Of Enginerring, vol.4. 2867-2874. Agustus. 2017

[11] A. Rahman, F. Fahma. "Penggunaan Metode FMECA (Failure Modes Effects Criticality Analysis) Dalam Identifikasi Titik Kritis Di Industri Kemasan" Jurnal Teknologi Industri Pertanian, hlm. 110–119, April. 2021.

©Asosiasi Prakarsa Indonesia Cerdas (APIC)

[12] M. Rinoza dan F. Ahmad Kurniawan, "Analisa Rpn (Risk Priority Number) Terhadap Keandalan Komponen Mesin Kompresordouble Screw Menggunakan Metode Fmea Di Pabrik Semen PT. XYZ" Jurnal Buletin Utama Teknik, Vol. 17, No. 1. September. 2017

[13] N. Y. H. Noor Ahmadi, 2017, Analisis Pemeliharaan Mesin *Blowmould* Dengan Metode RCM Di PT. CCAI," J. Optimasi Sist. Ind., vol. 16, no. 2, pp. 167–176. Oktober. 2017.

[14] T. J. Wibowo, T. S. Hidayatullah, and A. Nalhadi, "Analisa Perawatan pada Mesin Bubut dengan Pendekatan Reliability Centered Maintenance (RCM)," Jurnal Rekayasa Ind, Vol. 3, No. 2, 2021.

[15] A. Alijoyo, Q. B. Wijaya, dan I. Jacob, "Failure Mode Effect Analysis Analisis Modus Kegagalan dan Dampak RISK EVALUATION RISK ANALYSIS: Consequences Probability Level of Risk." [Daring]. Tersedia pada: www.lspmks.co.id

[16] K. R. Ririh, A. S. Sundari, dan D. P. Wulandari, "Analisis Risiko Pada Area Finishing Menggunakan Metode Failure Mode Effect And Analysis (FMEA) Di Pt. Indokarlo Perkasa". Jurnal Semrestek, Vol. 99, No. 4. Agustus. 2018

©Asosiasi Prakarsa Indonesia Cerdas (APIC)