Analysis on Fault Failure of Automatic Meter Reading System on Hardware Devices

Adam Hidayatullah, Hana Mutialif Maulidiah

Department of Electrical Engineering, Manufacturing Electronics Engineering Study Program,
Politeknik Negeri Batam, Batam, Indonesia

*Email: adam.hidayatullah103@gmail.com

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The Automatic Meter Reading (AMR) system is an indirect measurement system used by PT PLN (Persero) to facilitate the monitoring of customer electricity usage. Electricity usage measurements determine the revenue of electricity providers. Manual data reading errors and device malfunctions are the main complaints customers have against electricity providers. The AMR system has been implemented for many customers, and its presence can reduce irregularities. Irregularities that occur in AMR can generally be divided into two types, namely irregularities due to serial communication failures that need to be repaired, and technical irregularities where energy is not measured optimally. The use of the FMEA analysis method is expected to identify, determine, reduce, and eliminate failures and potential failures from the process before these failures reach customers. Based on the FMEA analysis results, corrective actions in the form of hardware replacement on components with the highest Risk Priority Number (RPN) proved effective in reducing the RPN value after the repairs were made, thereby increasing the reliability of the AMR system and minimizing the potential for electricity reading disruptions.

Keywords: AMR (Automatic Meter Reading), Communication Systems, FMEA, Hardware Devices.

I. INTRODUCTION

PT PLN (Persero), especially in the Batam area as a national electricity provider company, is required to always make improvements in electrical energy services. One of the innovations made by PT PLN Batam is the use of AMR (Automatic Meter Reading) system. Automatic Meter Reading is a digital-based electric power meter that is equipped with electronic controllers, and information exchange. Electronic controllers can process data from current and voltage sensors into digital data, regarding information on the value of electric current, electric voltage, and others. The digital data can then be sent through a communication system. AMR was developed as part of the development of electronic meters (digital meters) that replaced analog meters. The AMR system is a data collection system in the form of energy data, max demand, and load profile periodically read from each meter and collected at the AMR master for billing purposes and to analyze customer profile data. Low voltage (TR) customers, namely business customers (B2) which usually consist of shops or offices using Automatic Meter Reading (AMR) which functions to monitor customer kWh meters at any time from the PLN office more

accurate results with the help of computer applications so that reading errors made by officers will not occur [2]. PT PLN Batam has one of the many problems that occur in Automatic Meter Raiding (AMR). Especially in the design process in the installation and damage to hardware devices, The use of AMR, especially in the Batam area, is only installed on customers with power ranging from 41,500 VA and above, In the implementation of Automatic Meter Reading (AMR), although this technology offers many benefits, there are several problems related to hardware that need attention. Addressing hardware issues in AMR requires a competent approach, starting from proper installation of devices, selection of durable devices, to effective management and maintenance. Awareness of these challenges and issues is critical in ensuring that AMR implementations can run smoothly and deliver optimal benefits to service providers and consumers [2]. In accordance with the background that has been described, therefore the author raises the title “Analysis on Fault Failure of Automatic Meter Reading System on Hardware Devices” with the research location at PT PLN Batam UP3 Tiban.

II. METHOD

To analyze a process that occurs in a system, a flowchart is needed to support the workflow to be carried out, and help in understanding, designing, and communicating work procedures properly and correctly.

A. Procees Flow

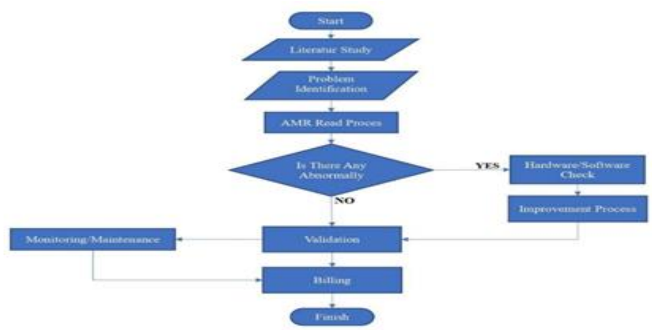


Figure 1. AMR System Flowchart.

The flowchart in the figure illustrates the workflow of the Automatic Meter Reading (AMR) system from start to finish. The process begins with conducting a literature study to understand the basic theories and concepts related to the AMR system. Next, problems are identified to find obstacles or disruptions that may occur in the data reading process. After that, the system automatically runs the AMR data reading process. At this stage, checks are carried out to ensure that there are no discrepancies or mismatches in the data. If discrepancies are found, hardware and software checks are carried out, followed by a repair process to return the system to normal conditions. However, if no problems are found, the data read will go through a validation stage to ensure its accuracy before being used in the billing process. After the billing process is complete, the system is routinely monitored and maintained to ensure the performance and reliability of the AMR system. The process then ends after all stages are completed successfully.

B. *Methode FMEA*

Based on observations made at PT PLN Batam UP3 Tiban, several Hardware components in the AMR system were found to be damaged, resulting in losses in the form of AMR reading failures. Therefore, a new preventive maintenance plan is needed to avoid damage and maximize monitoring of electricity distribution. FMEA (Failure Mode and Effects Analysis) is a systematic method used to identify and analyze potential failures in a system, product, or process, and their impact. In the context of Automatic Meter Reading (AMR), an automated system used to collect consumption data from electricity meter measuring instruments. The goal is to minimize downtime, ensure data accuracy, and improve overall system reliability.
Based on the table above, data about each criterion can be processed into RPN (Risk Priority Number) data. The RPN processing formula is: S x O x D = RPN

The explanation of S,O,D and RPN is as follows:

1. (S) as a symbol for severity level. Determining the severity level (S) of the impact of each failure mode at this stage aims to assess the severity level of the impact caused by the failure that occurs based on the S parameter criteria compiled in the table below.

TABLE 1
FMEA SEVERITY INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
1	not significant	No impact on production systems or services, products, or service outcomes.
2	minor	Very minor impact on product performance or service results – there are still complaints from certain users
3	low	Minor impact on product performance or service results – there are still complaints from users.
4	moderate	Product performance or service results have declined but do not require improvement.
5	significant	Product performance or service results have declined but can still be improved.
6	high	Product performance has declined because certain functions are not operating.
7	very high	Slightly disrupts the smooth running of the AMR process.
8	hazardous	Disrupting the smooth operation of the AMR system or product services cannot be operated.
9	very hazardous	Not in accordance with government regulations Produces reading results that are detrimental to consumers.
10	extreme	Not in compliance with government regulations. Discontinue operation of the AMR system.

2. (O) as a symbol for Occurrence. Determine the probability of failure (O) for each failure mode. At this stage, use the O parameter criteria to assess how often the failure is likely to occur. The figure below explains the O parameters that will be used.

TABLE 2
FMEA OCCURANCES INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
10	1 of 2	Extremely high and extreme; failure is almost inevitable.
9	1 of 3	Very high failure is related to a previous failed process.
8	1 of 8	High failure rates continue to recur
7	1 of 20	Relatively high
6	1 of 8	Currently trending high
5	1 of 400	Currently
4	1 of 2000	Relatively low
3	1 of 15000	Low
2	1 of 150000	Very low
1	1 of 1500000	Failure is almost impossible.

3. (D) as a symbol for Detection. At this stage, use the D parameter criteria to assess or measure the ability to control failure modes by considering all control aspects and other indicators inherent in the analyzed process. If control or detection indicators are absent or low, then the detection capability is also low. Below is a table of indicators (D) that will be used.

TABLE 3
FMEA DETECTION INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
10	Almost impossible	No controls to detect potential failures
9	Very small	There is very little control to detect potential failures.
8	Small	There is little control to detect potential failures.
7	Very low	There is control, but its ability to detect potential failures is very low.
6	Low	There are controls, but their ability to detect potential failures is low.
5	Currently	There are controls that have moderate/sufficient capabilities to detect potential failures.
4	Somewhat tall	There are controls with moderate to

		high capability to detect potential failures.
3	Height	There are controls that have a high ability to detect potential failures.
2	Very high	Very low There are controls that have a very high ability to detect potential failures.
1	Almost certainly	Controls can almost certainly detect potential failures.

4. RPN ((Risk Priority Number). The values of S, O, D are on a scale of 1-10. The calculation results of FRPN for each analyzed machine component, which has the highest value indicates that the component has the highest risk level (10).[9] For example for parameters S, O and D with a rating scale of 1 - 10, the highest RPN value is 10 x 10 x 10 = 1000 and the lowest value is 1 x 1 x 1 = 1. FMEA/FMECA centers on identifying failure modes in the process which are then assessed using predefined parameters through technical ranking, followed by the calculation of the Risk Priority Score or RPN. Through these stages, it can determine the level of criticality for each failure mode, then can determine the handling or control action for critical failure modes. Like the philosophy of applying FMEA/FMECA, which is "prevent before it happens", you can also prevent failures in processes or procedures by applying it.

III. RESULT AND DISCUSSION

A. Data Analysis FMEA Result

1. Severity Result

TABLE 4
SEVERITY RESULT

Process	Potential Failure Mode	Potential Failure Mode	value
installation of AMR devices	The AMR modem is not turning on.	data not sent to the server	8
operation of AMR devices	power supply is not workin	AMR system is completely dead	9
Monitoring data	KWH data cannot be read/read manually	inaccurate customer billing	8
device maintenance	hardware devices damaged due to non-compliance with industry standards	long-distance communication interference	7
data transmission from the modem	GSM failed to send data	data cannot be read automatically	7

The table above explains the severity level of the failure is in the range of 7–9, indicating that most potential failures have a high impact on the main functions of the system. This means that if such a failure occurs, the AMR system will not function properly or even shut down completely. The most critical failure occurs in the power supply with a Severity value of 9, as it causes the AMR system to shut down completely and be unable to read and transmit data.Other processes such as AMR device installation, KWH data reading, and GSM data transmission also have serious impacts (values of 7–8) as they cause data transmission disruptions and inaccuracies in customer readings.Overall, the AMR system has a high severity risk in almost all stages of the hardware process. Therefore,

the following are required:
1. Increased hardware testing prior to installation,
2. Power stability monitoring, and
3. Routine maintenance of communication modules and data connections.

2. Occurances Result

TABLE 5
FMEA OCCURANCES RESULT

Potential Cause	Value
installation errors and hardware model errors	7
Components damaged due to temperature pressure because they did not meet standards	6
The central server is experiencing issues and has not been updated with the new modem model.	5
hardware is not resistant to environmental conditions	6
GSM card has excess storage	6

The table above explains the parameters of the Occurrence Rate. The Occurrence Rate (O) indicates that failures in the AMR system occur at a moderate to high frequency (5–7). The highest value (7) appears in the causes of installation errors and hardware model errors, indicating that the installation process and device type incompatibility are still the main sources of problems in the AMR system.

To reduce the Occurrence rate, the following measures need to be taken:

- Standardization of the installation process,
- Selection of components that are resistant to temperature and humidity
- Regular maintenance and updating of the server system and GSM module.

3. Result Detection

TABLE 5
FMEA DETECTION RESULT

Current Control	Value
initial installation inspection	4
calibration or testing during commissioning	5
daily data monitoring	5
routine visual inspection	6

collaborate with GSM card operators to disable messaging services	6

Based on the table above, the detection control system in this process is functioning well, but improvements are still needed, especially in the routine inspection and external collaboration stages, in order to increase effectiveness in detecting potential failures.

4. RPN Result

TABLE 6
FMEA RPN RESULT

Potential Failure Mode	S	O	D	RPN
The AMR modem is not turning on.	8	7	4	224
power supply is not workin	9	6	5	270
KWH data cannot be read/read manually	8	5	5	200
hardware devices damaged due to non-compliance with industry standards	7	6	6	252
GSM failed to send data	7	6	6	252

based on the FMEA RPN table above, the following are the RPN (Severity × Occurrence × Detection) calculation results for the FMEA table above :

- Row 1: $8 \times 7 \times 4 = (8\times7)=56 \rightarrow 56\times4 = 224$
- Row 2: $9 \times 6 \times 5 = (9\times6)=54 \rightarrow 54\times5 = 270$
- Row 3: $8 \times 5 \times 5 = (8\times5)=40 \rightarrow 40\times5 = 200$
- Row 4: $7 \times 6 \times 6 = (7\times6)=42 \rightarrow 42\times6 = 252$
- Row 5: $7 \times 6 \times 6 = (7\times6)=42 \rightarrow 42\times6 = 252$

Priority (based on RPN)

- Operation of AMR devices: RPN 270 (highest priority)
- Maintenance of devices & Data transmission from modems: RPN 252 (second)
- Installation of AMR devices: RPN 224
- Monitoring of consumption data: RPN 200 (lowest on this list)

Based on the FMEA analysis results, the main priority for improvement is focused on items with the highest RPN value, namely in the operation of AMR devices. The high RPN value of 270 indicates that the potential for failure at this stage has a significant impact on the overall reliability of the system. Therefore, corrective measures are aimed at reducing the Occurrence rate and increasing Detection effectiveness. Efforts that can be made include implementing temperature protection and ventilation systems to reduce the risk of disruption due to excessive ambient temperatures, as well as improving the quality of the power supply to ensure power stability in the device. In addition, adding a monitoring or alarm system to the power supply is important to speed up early detection of power anomalies that can cause system failure.

Furthermore, for two items with an RPN value of 252, corrective actions focused on improving detection capabilities and mitigating environmental influences. Implementing a remote health-check feature on modems and periodically monitoring GSM signals can strengthen detection of potential data communication disruptions. On the other hand, the use of enclosures that are resistant to extreme weather conditions and antennas with more stable performance can minimize interference due to external environmental factors, such as humidity and rain.

In general, for all components analyzed in FMEA, it is recommended to review the effectiveness of detection controls (D value). In many cases, improvements to the detection system have proven to be one of the most efficient ways to reduce the overall RPN value. With improved detection and monitoring mechanisms, potential failures can be identified earlier so that corrective actions can be taken before the disruption impacts the main system.

B. Identification of Disruptions and Handling Strategies in the AMR Work Process

The Automatic Meter Reading (AMR) process begins with the acquisition of usage data through meters installed at customer premises. These devices consist of a main meter, communication module, measurement sensor, and power source that supports system operations. Each hardware component plays an important role in ensuring successful automatic and continuous data reading.

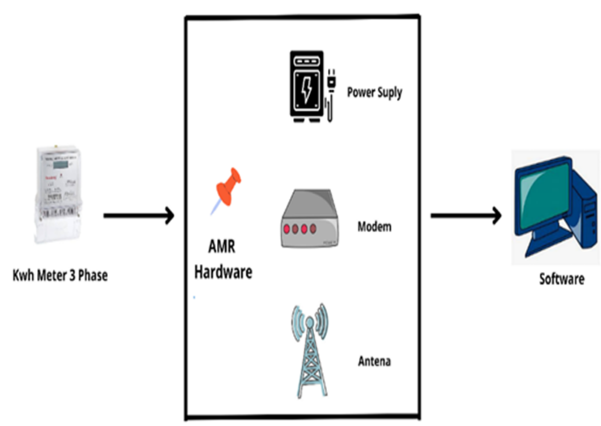


Figure 2. Konfigurasi Automatic Meter Reading

1. Automatic Meter Reading (AMR) Process

The AMR implementation process is a series of systematic activities aimed at obtaining energy usage data automatically, accurately, and continuously. In general, this process consists of the following stages:

1.1 System and Device Preparation

The system and device preparation stage is the first step in implementing Automatic Meter Reading (AMR), which aims to ensure the operational readiness of all hardware. At this stage, the condition of energy meters, including kWh meters and flow meters, is checked to ensure measurement accuracy. In addition, communication modules such as GSM/GPRS, RF, or PLC are checked to ensure data transmission reliability. Inspection of power sources, both power supplies and backup batteries, as well as validation of the initial configuration of AMR devices are also carried out to ensure that system parameters are in line with operational requirements. This stage aims to minimize the risk of technical disruptions before the data reading process begins.

1.1.1 Solutions at the Preparation Stage

Solutions at the preparation stage focus on preventing technical disruptions through regular physical checks of meters and AMR modules. Communication cables and power sources are installed correctly in accordance with applicable technical standards. In addition, the use of AMR devices that meet the recommended technical specifications is an important factor in maintaining system reliability. The implementation of these solutions aims to minimize potential disruptions from the start of AMR system operation.

1.2 Meter data collection process

The meter data collection stage is an automated process in the Automatic Meter Reading (AMR) system that is carried out through sensors and communication ports on energy meters. The measurement data is then sent by the communication module to the central server as part of the centralized data collection process. The acquired data includes kWh readings or energy volume, electrical parameters such as voltage, current, power, and power factor, as well as meter status and device alarm information, which are used as the basis for system monitoring and analysis.

1.2.1 Solutions at the Data Collection and Delivery Stage

Solutions at the data collection and transmission stage focus on the reliability of the communication process by using stable and compatible communication modules. The data reading interval is adjusted to the network capacity to avoid transmission overload. In addition, the communication signal quality is ensured to be at an adequate level so that data can be sent completely and on time to the central server. The implementation of this measure aims to prevent data loss and failure in sending measurement information.

1.3 Data Transmission to the Server

The data transmission stage to the server is a follow-up process in the Automatic Meter Reading (AMR) system, where the reading data is automatically sent through a communication network to the AMR server, Head End System (HES), and central database. The success of this process is highly dependent on network stability and communication device reliability, as disruptions in these aspects can directly impact data transmission delays or failures.

1.3.1 Fault Monitoring and Detection Solutions

The monitoring and fault detection solution is implemented through routine monitoring of the operational status of AMR devices to ensure optimal system performance. Devices with high read failure rates are identified as evaluation priorities. Furthermore, faults are classified based on the type of hardware damage to facilitate analysis and determination of corrective actions. The implementation of this solution aims to accelerate the process of identifying the source of problems and improve the reliability of the AMR system.

1.4 Data Monitoring and Evaluation

Usage data stored in the system is then analyzed to assess the success rate of readings and detect indications of hardware malfunctions. The evaluation process is carried out by identifying data irregularities, such as missing data, zero consumption values, and abnormal data spikes. The results of this analysis form the basis for determining the need for repairs or device replacement.

1.4.1 Hardware Troubleshooting Solutions

If the disruption cannot be resolved through configuration adjustments or minor repairs, hardware replacement will be carried out based on the results of technical analysis. Replacement includes AMR communication modules, energy meters that have experienced performance degradation, and power supplies or backup batteries that no longer meet operational standards. The selection of replacement devices is made by considering more reliable technical specifications that are compatible with the AMR system used, accompanied by official recommendations to superiors or relevant management

Based on the above explanation, old devices that were declared unfit for operation were replaced with the latest AMR model devices that have better reliability and stability. After the installation process, a reading verification was carried out to ensure that the new devices functioned according to standards. The implementation of this solution aims to restore the AMR system's performance to its optimal level and reduce the risk of reading failures in the future.

The implementation of a systematic monitoring and evaluation process, supported by hardware replacement decisions based on technical analysis and appropriate recommendations, has proven to improve AMR reading success rates and minimize the risk of reading failures on an ongoing basis.

C. Data Processing Technique Analysis

The defect data table serves as the main tool for documenting, analyzing, and evaluating the causes and handling of the failed reading process in the Automatic Meter Reading (AMR) system on a monthly basis. The AMR system, which plays an important role in automatic meter data collection, requires a high level of accuracy and reliability. When a read failure occurs, corrective measures must be carried out systematically, and this table provides guidance to identify areas that require further attention.

Table 7. AMR failed read repair data in September.

NO	Customer ID/Address	Type of Damage	Affected Components	Main Causes	Improvement Plan	Status
1	152001579628	Server Update	kWh Meter	New kWh	kWh will be updated	Done
2	152002110742	Server Update	kWh Meter	New kWh	kWh will be updated	Done
3	152001353976	Physical Damage	Modem	Voltage Demage	Replace and Upgrade	Done
4	152001933292	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
5	152000012045	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
6	152000202723	Server Damage	GSM	long range	Amr cannot be repaired.	Bad Signal
7	152001391608	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
8	152001987852	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
9	155000002656	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
10	152001386242	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
11	152002153417	Server Update	kWh Meter	New kWh	kWh will be updated	Done
12	155000000039	Server Damage	N/A	N/A	N/A	empty
13	152001832682	Physical Damage	Modem	Voltage Demage	Replace and Upgrade	Done
14	152001701186	Physical Damage	kWh Meter	Short Circuit	kWh Replace and Upgrade	Done
15	152002042314	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done
16	152001693715	Physical Damage	Power Supply	Overheating	Replace and Upgrade	Done

Based on the September table data, most of the damage to AMR devices was caused by physical damage, with the most frequently affected components being the power supply and kWh meter. The main cause of damage identified was weather, which affected the stability and reliability of the devices in the field. The most common repair action was replacement and upgrade, especially for the power supply, as well as kWh updates for meters that could still be repaired. However, there were several cases that could not be repaired, such as AMRs with weak GSM signals and permanently damaged kWh meters. Overall, the completion status shows that most cases have been "Done" or repaired, with a few other cases still in progress or unable to be fully repaired.

Table 8. AMR failed read repair data in October.

NO	Customer ID/Address	Type of Damage	Affected Components	Main Causes	Improvement Plan	Status
1	152000202723	Server Damage	GSM	long range	Amr cannot be repaired.	Bad Signal
2	155000000039	Physical Damage	N/A	N/A	N/A	empty
3	152001987852	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
4	152001693715	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
5	152001933292	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
6	152001832682	Physical Damage	Modem	Voltage Demage	Replace and Upgrade	Done
7	152002174077	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
8	152000133329	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
9	152001579628	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
10	152001701186	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
11	152001476837	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
12	152000058085	Server Update	kWh Meter	New kWh	kWh will be updated	Done
13	152002176724	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
14	152001296387	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
15	152002173821	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
16	152002153417	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
17	152001777198	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
18	152002178409	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
19	152002178864	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
20	152002051090	Physical Damage	GSM	Broken Network	Reset GSM	Done
21	152001406986	Physical Damage	Modem	Voltage Demage	Replace and Upgrade	Done

The table above shows device damage data with two color categories that have different meanings. Red indicates devices that have suffered severe damage and cannot be repaired. In the table, **red** damage occurred on devices with Customer IDs *152000202723* and *155000000039*. The type of damage is Physical Damage affecting the GSM component, with the main cause being "long range" or excessive signal distance. The final status is "Bad Signal" and "Empty," indicating that the device cannot be restored to functionality even after repair.

Meanwhile, **blue** indicates devices that were repaired in the previous month but experienced damage again this month. This case occurred with Customer IDs *152001987852*, *152001693715*, *152001933292*, and *152001832682*. All of them had Physical Damage with affected components such as Power Supply and Modem. Although repair measures in the form of Replacement and Upgrade have been carried out and the status is "Done," the recurrence of damage indicates that there are recurring external factors that need further evaluation, such as device protection against weather or the quality of replacement components.Overall, the data shows two main conditions: devices that can no longer be repaired **(red)** and devices that can still be repaired but have the potential for recurring damage **(blue).**

Table 9. AMR failed read repair data in November.

NO	Customer ID/Address	Type of Damage	Affected Components	Main Causes	Improvement Plan	Status
1	152000202723	Server Damage	GSM	long range	Amr cannot be repaired.	Bad Signal
2	155000000039	Physical Damage	N/A	N/A	N/A	empty
3	152000058085	Server Update	kWh Meter	New kWh	kWh will be updated	Done
4	152002174077	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
5	152000133329	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
6	152001579628	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
7	152001701186	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
8	155000002656	Server Damage	GSM	Broken Network	Reset GSM	Done
9	152001386242	Server Damage	GSM	Broken Network	Reset GSM	Done
10	152000056335	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
11	152001155112	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
12	152001150791	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
13	152000133317	Physical Damage	Power Supply	overheating	Replace and Upgrade	Done
14	152000133329	Server Damage	GSM	Broken Network	Reset GSM	Done
15	152001777198	Server Damage	GSM	Broken Network	Reset GSM	Done
16	152002173821	Physical Damage	kWh Meter	kWh Broken	kWh cannot be repaired or replaced.	Broken
17	152002176724	Physical Damage	kWh Meter	kWh Broken	kWh cannot be repaired or replaced.	Broken
18	152002176724	Physical Damage	Modem	Voltage Demage	Replace and Upgrade	Done

The table above shows device damage data consisting of several color categories with different meanings. The blue color in the table indicates devices that have experienced damage in the previous month and have been repaired, but have experienced damage again this month. This recurring damage occurred to several customers. The type of damage that occurred was generally physical damage that affected components such as kWh meters, power supplies, and GSM. The main causes were weather and broken networks. Repair efforts included replacement and upgrades as well as GSM resets, all of which were recorded as completed.

However, the fact that repaired devices continue to break down indicates that temporary repairs are not effective enough. Based on the results of the RPN (Risk Priority Number) analysis using the FMEA (Failure Mode and Effect Analysis) method, the risk value for the same component remains high because the Occurrence (likelihood of recurrence) and Severity (level of severity) factors have not decreased significantly.
Therefore, it can be concluded that to prevent recurring damage, it is necessary to replace the hardware with better quality and standard-compliant hardware. This step is expected to:

- Reduce the frequency of damage due to weather factors or network disruptions
- Improve the overall reliability of the system
- Reduce the RPN value in the FMEA analysis in the next period.

Therefore, replacing standard hardware is the primary solution to ensure device reliability and prevent recurring damage in the coming months.

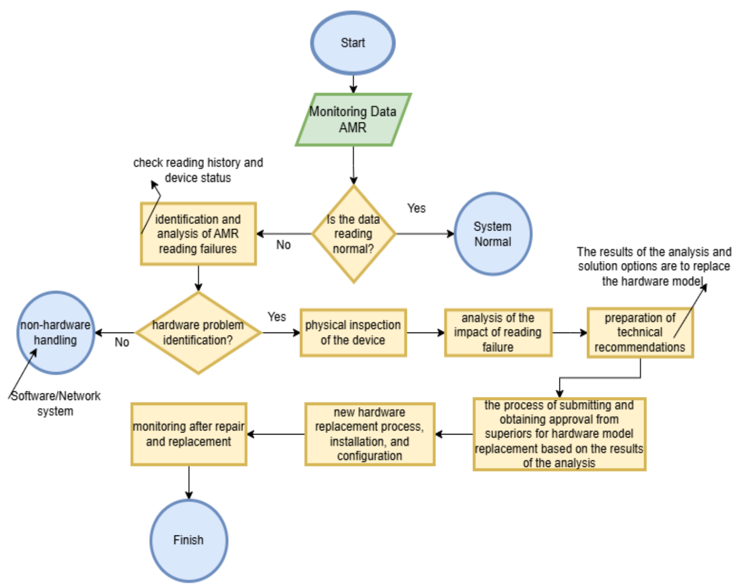


Figure 3. Recommendation process flowchart

Based on the flowchart above, the process begins with monitoring AMR data to evaluate the reading history and device status. If the reading data is normal, the system is declared to be operating properly. However, if the data is found to be abnormal, the cause of the AMR reading failure is identified and analyzed. Next, it is determined whether the disruption is caused by a hardware problem.

If the disruption does not originate from the hardware, then it is handled through repairs to the software or network system. Conversely, if the disruption is identified as a hardware problem, a physical inspection of the device and an analysis of the impact of the reading failure are carried out. The results of this analysis form the basis for the preparation of technical recommendations and the submission of approval requests to the relevant parties for hardware replacement. After the approval process, the replacement, installation, and configuration of the new device are carried out, followed by post-repair monitoring to ensure that the AMR system is back to normal operation.

Table 10. New Model Model AMR

Photo results	Short Description
OLD MODEM (Edmi TM87) 	The AMR EDMI modem uses an 8-pin Micro-Fit connector and SMA Female, but does not have a USB port, status indicator, or environmental protection. Its configuration is manual and impractical for maintenance.
NEW MODEM (Hexing HXM 300) 	Hexing AMR modem complies with PLN standards with 2G/3G/4G support, USB port, LED status indicator, easily accessible SIM slot, and strong antenna connector for stable connection..

Based on the table above, it explains the differences between the old and new devices used by PT PLN according to the analysis results. The AMR EDMI modem is an older generation device used in the Automatic Meter Reading (AMR) system, which functions to send meter data to a central location via a cellular communication network. Although it still works well for some applications, this modem has several weaknesses that affect its efficiency and reliability in the field.

- Does not have a USB port
  The EDMI modem only has an 8-pin Micro-Fit data connector, without support for a standard USB port. This means that manual data retrieval or device configuration must be done using a special cable and adapter. For field technicians, this makes troubleshooting difficult because it cannot be directly connected to a computer or laptop.
- Not Equipped with LED Indicator
  This modem does not have status indicator lights to show conditions such as power, signal, or data activity. As a result, technicians cannot immediately tell whether the modem is functioning normally, connected to the network, or experiencing interference without the aid of additional measuring instruments.
- Antenna Connectors Prone to Loosening
  The SMA Female antenna connector on EDMI modems can easily become loose if frequently disconnected and reconnected. This condition can cause unstable signals, or even signal loss, especially in areas with high vibration or exposure to the outside environment. In the long term, this has the potential to reduce the quality of AMR data communication.

Overall, the AMR EDMI modem has a basic design that is still functional, but it is outdated in terms of technology and ease of operation. Limitations on the USB port, the absence of LED indicators, impractical special connectors, and no power stability make this device less efficient for PLN's modern AMR needs.

The Hexing AMR Modem is a communication device designed for Automatic Meter Reading (AMR) systems with modern features and specifications that meet PLN industry standards. This modem functions to automatically send electricity meter reading data to a central server via a cellular network.

- Equipped with USB Port for Data Access
  Unlike older models, this modem has a USB port that allows technicians to manually retrieve data, update firmware, or configure devices more quickly and easily. This port is also compatible with standard computer devices without requiring special cables.
- Has LED Status Indicator
  There are three LED indicators (Power, Signal, and Data) that provide visual information about the modem's operating status. This feature facilitates monitoring and diagnosis in the field, as technicians can immediately determine the connection status or any disruptions that may occur.
- In accordance with PLN industry communication standards
  This modem has undergone testing and certification in accordance with PLN AMR standard specifications, in terms of software compatibility, data communication, and integration with Hexing and EDMI meters. This ensures the interoperability and security of the customer data communication system.

Overall, the Hexing AMR modem offers significant improvements over previous models in terms of ease of configuration, communication stability, and maintenance efficiency. Features such as 4G network support, USB ports, LED indicators, and ergonomic design make this modem more reliable, practical, and compliant with PLN operational standards for automatic meter reading systems.

Table 11. New Model Power Supply.

Photo results	Short Description
Old Power Supply 	The power supply does not meet industrial installation standards there is no clear grounding, surge protection and ventilation are inadequate, and certification indicators are not visible.
NEW Power Supply 	The power supply has advantages in terms of voltage stability, energy efficiency, and internal protection, making it compliant with PLN and industry standards.

Based on the comparison table, the table shows an improvement in quality and reliability after replacing the power supply. In the old model, the installation did not meet standards—there was no clear grounding, limited surge protection, inadequate ventilation, and no certification to ensure safety. In contrast, the new power supply model is equipped with better voltage stability, higher energy efficiency, and more comprehensive internal protection. These features make the new device much more compliant with PLN and industry standards, while also improving the overall safety and reliability of the system.

- In accordance with PLN and Industry Standards
  This power supply meets the industrial electrical standards commonly used by PLN, with stable output voltage quality that is safe for data communication devices such as AMR modems. Its design and housing material are more robust, with overcurrent protection and overvoltage protection, ensuring the safety and longevity of the device.
- High Voltage Stability
  This power supply provides a constant DC voltage without significant fluctuations, even when there are changes in load or interference from the AC input side. This is important so that the AMR modem can operate continuously without restarting, freezing, or meter reading failures, especially when automatic data collection is in progress.
- Supporting the Sustainability of the AMR System
  With stable output and internal protection, this power supply helps keep the AMR system online 24 hours a day, enabling automatic and accurate meter data readings. As a result, the energy data distribution system becomes more efficient, minimizes manual intervention, and meets PLN's operational targets.

The latest power supply used in this AMR system is of much better quality than the previous version. This unit meets industry standards and PLN specifications, with stable output voltage, high efficiency, and protection against current and voltage surges. Its design is also more robust, safe, and resistant to conditions outside the panel. With these improvements, the latest power supply is able to increase the reliability and smoothness of the AMR data reading process, reduce the risk of power interruptions, and keep the modem functioning optimally in the long term.

Table 12. AMR failed read repair data in December after analysis FMEA

NO	Customer ID/Address	Type of Damage	Affected Components	Main Causes	Improvement Plan	Status
1	152000202723	Server Damage	GSM	long range	Amr cannot be repaired.	Bad Signal
2	155000000039	-	N/A	N/A	N/A	empty
3	152002176724	Physical Damage	kWh Meter	Short Circuit	kWh cannot be repaired or replaced.	Broken
4	152002173821	Physical Damage	kWh Meter	Short Circuit	kWh cannot be repaired or replaced.	Broken
5	152002043357	Server Damage	GSM	Broken Network	Reset GSM	Done
6	152000057573	Server Damage	GSM	Broken Network	Reset GSM	Done
7	152000027582	Server Update	kWh Meter	New kWh	kWh will be updated	Done
8	152000207815	Server Update	kWh Meter	New kWh	kWh will be updated	Done

Based on the results of FMEA (Failure Mode and Effect Analysis), several potential failures in the Automatic Meter Reading (AMR) system that affect reading failures were identified. The Risk Priority Number (RPN) value was used as the basis for prioritizing corrective actions. Components or processes with the highest RPN value became the main focus in efforts to improve system reliability. After making improvements and replacing hardware as recommended by the RPN results, there was a noticeable decrease in the rate of reading failures on AMR devices. Several corrective actions were taken, including:

- Replacement of major hardware components that are prone to damage, such as communication modules, power supplies, and reader sensors, with versions that have better specifications and durability in accordance with industry standards.
- Improvement of the detection system by adding a new feature to the modem in the form of a data storage system that can be accessed using a USB cable connected directly to the server and monitoring to facilitate early identification of potential

disturbances, so that damage can be prevented before it has a widespread impact.

- Improvements to network installations and connections to reduce data transmission disruptions, which are one of the main causes of read failures.

The impact of these measures showed positive results. Based on the following month's monitoring data, the read failure rate decreased significantly, indicating that the replacements and repairs carried out were successful in reducing the risk and impact of failures on the AMR system. Thus, it can be concluded that the implementation of recommendations based on RPN results not only repaired existing damage but also improved the overall reliability of the system, while reducing the potential for read failures in AMR in the future.

After the required data is collected, the next step is to describe the data, combining the repair data for five months and the application of FMEA. resulting in data processing in the form of calculations as follows :

- Calculate the number of Malfunctions resulting in AMR read failure that can be corrected in 4 months.
- Ensure the AMR system is operating optimally to support accurate and reliable data collection.
- Maintenance and repair measures can be directed at areas that require the most attention.
- Prove its effectiveness in reducing the risk of read failures on AMR systems within 4 months.

Table 13. Processing of total repair data for 4 months

Month	Total failure to read AMR	Hardware Repair result				Status		Percentage of Improvement (%)	Description
		Power Supply	Modem	KWH	GSM	Repaired Successfully	not repairable		
September	16	8	2	4	1	13	2	100%	Long Range & N/A Data
Oktober	21	15	2	1	2	19	2	100%	Long Range & N/A Data
November	18	7	1	3	6	14	4	100%	Long Range , N/A Data & kWh Broken
Desember	8	0	0	4	3	4	4	100%	Long Range , N/A Data & kWh Broken

The table Processing of total repair data for 4 months summarizes the repair data for AMR reading failures during the four months from September to December. In September, there were 16 cases of failed readings, with damage spread across the power supply, modem, KWH, and GSM module components. Of these cases, 13 units were successfully repaired while 2 units were declared irreparable, indicating that there are still devices experiencing severe damage. Entering October, the number of incidents increased to 21 cases, but all problematic devices were successfully resolved by the technical team. This condition continued in November with 18 cases, and December with 8 cases, where all units that experienced incidents were successfully repaired without any devices being categorized as irreparable. This shows an increase in the effectiveness of incident handling from month to month.

The table shows data on malfunctions and repairs of AMR devices over four consecutive months. At the beginning of the period, specifically in September, there were still devices that could not be repaired, namely 2 units out of a total of 16 cases. The malfunctions included power supply, modem, KWH module, and GSM. However, after that month, the effectiveness of repairs improved significantly. In October, all 21 problematic units were successfully repaired. This positive trend continued in November with 18 cases and December with 8 cases, all of which were restored without any devices being classified as permanently damaged. The types of malfunctions that occurred were relatively consistent, such as long range errors, unreadable data (N/A), and problematic KWH readings, but all of these malfunctions were handled well by the technical team.

Tabble 14. FMEA RPN RESULT (AFTER IMPROVEMENT)

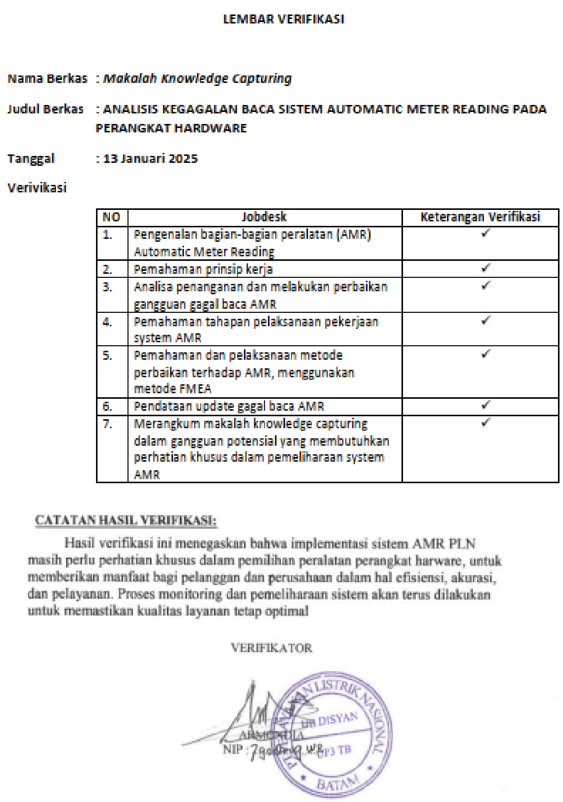
Potential Failure Mode	S	O	D	RPN December	Decrease in RPN
The AMR modem is not turning on.	8	3	3	72	↓ 152
power supply is not workin	9	2	3	54	↓ 216
KWH data cannot be read/read manually	8	3	4	96	↓ 104
hardware devices damaged due to non-compliance with industry standards	7	3	4	84	↓ 168
GSM failed to send data	7	3	4	84	↓ 168

Based on the table above, the severity value in the FMEA analysis remains high even though corrective actions have been taken. This is because severity represents the level of impact of failure on the system, not the frequency of occurrence. If the failure recurs, the impact on AMR reading failure remains significant. The occurrence and detection values were determined by converting the actual number of disturbances per month to an FMEA scale of 1–10 and considering the disturbance detection mechanism before and after the implementation of improvements. The decrease in the occurrence and detection values in December shows the effectiveness of the initial FMEA recommendations.

Based on the results of the Failure Mode and Effects Analysis (FMEA), it can be concluded that the implementation of improvement recommendations in the form of replacing the AMR hardware model with more efficient and reliable specifications has a significant impact on reducing the Risk Priority Number (RPN) value. This decrease in RPN is mainly influenced by a reduction in the frequency of occurrences and an increase in the system's ability to detect faults.

The determination of Occurrence (O) and Detection (D) values in FMEA analysis is based on actual AMR device failure data and failure detection mechanisms before and after the implementation of corrective actions. In the power supply failure mode, during the period from September to November, there were 30 recorded incidents with an average of about 10 incidents per month, so the occurrence value before the repair was set at 6. After replacing the hardware model with a more efficient one, no malfunctions were found in December, so the occurrence value was conservatively lowered to 2. In terms of detection, before the improvement, malfunctions were generally only discovered after a read failure occurred and required field inspection, so the detection value was set at 5. After the improvement, increased stability and system monitoring caused the detection value to decrease to 3. In the AMR modem failure mode, the average number of incidents before repair was around two per month, so the occurrence value was set at 4 and decreased to 2–3 in December. The detection value also improved from 4 to 3 as the connection status became clearer. Meanwhile, in GSM failure mode, disruptions before repair are generally identified after data is marked as N/A, so the detection value is set at 6 and decreases to 4 after repair. The GSM occurrence value also decreases from 6 to 3, indicating a reduction in the frequency of disruptions in December.

The results of the evaluation in December show that the implementation of a more efficient hardware model replacement has greatly helped to significantly reduce the AMR read failure rate, even though the severity value remains high because the impact of failure on system operations is still critical. Overall, the corrective actions taken have proven to be effective in improving the reliability of the AMR system and supporting the success of continuous reading.



LEMBAR VERIFIKASI

Nama Berkas : *Makalah Knowledge Capturing*

Judul Berkas : ANALISIS KEGAGALAN BACA SISTEM AUTOMATIC METER READING PADA PERANGKAT HARDWARE

Tanggal : 13 Januari 2025

Verivikasi

NO	Jobdesk	Keterangan Verifikasi
1.	Pengenalan bagian-bagian peralatan (AMR) Automatic Meter Reading	✓
2.	Pemahaman prinsip kerja	✓
3.	Analisa penanganan dan melakukan perbaikan gangguan gagal baca AMR	✓
4.	Pemahaman tahapan pelaksanaan pekerjaan system AMR	✓
5.	Pemahaman dan pelaksanaan metode perbaikan terhadap AMR, menggunakan metode FMEA	✓
6.	Pendataan update gagal baca AMR	✓
7.	Merangkum makalah knowledge capturing dalam gangguan potensial yang membutuhkan perhatian khusus dalam pemeliharaan system AMR	✓

CATATAN HASIL VERIFIKASI:

Hasil verifikasi ini menegaskan bahwa implementasi sistem AMR PLN masih perlu perhatian khusus dalam pemilihan peralatan perangkat harware, untuk memberikan manfaat bagi pelanggan dan perusahaan dalam hal efisiensi, akurasi, dan pelayanan. Proses monitoring dan pemeliharaan sistem akan terus dilakukan untuk memastikan kualitas layanan tetap optimal

VERIFIKATOR

NIP :

Figure 4. Verivikator Data

Based on the image above, the paper "Analysis of Automatic Meter Reading System Failures in Hardware Devices" underwent a verification process on January 13, 2025. Based on the assessment results, the verification team stated that this paper has met almost all aspects of the evaluation standards. The content of the paper successfully explains in detail the main components of the AMR system, the working principles of the device, and the stages of implementation in the field. In addition, the analysis of reading failure disturbances in AMR devices is also clearly presented, including handling steps in accordance with technical procedures.

The verification team also certified that the FMEA method used in the paper had been reviewed and deemed valid. This is evidenced by the verification mark on the point that assesses the understanding and application of the FMEA method to analyze potential failures of AMR devices. In addition, the analysis and supporting data used in risk identification and prioritization of improvements are also assessed in accordance with applicable standards, ensuring that the methodology presented meets the correct technical rules.

Although there is one point that has not been fulfilled, namely the latest data on failed readings, overall the paper is considered to be quite comprehensive. Through verification notes, the team also emphasized that the implementation of AMR in the field still requires attention to hardware maintenance and periodic monitoring so that reading performance remains optimal. Thus, this paper is deemed suitable and has been verified as a knowledge capturing document that can be used to support the improvement of AMR system maintenance effectiveness in the future.

IV. CONCLUSION

This analysis has thoroughly investigated common hardware failures in Automatic Meter Reading (AMR) systems. The FMEA analysis results identified two main causes of AMR PSU failure, namely continuous use (24 hours) which causes component wear and tear, and high ambient temperatures which accelerate component degradation. Communication module failure and sensor inaccuracy are the most frequent and significant points of failure. These hardware failures not only cause significant data loss and billing discrepancies, but also require costly manual intervention and undermine the inherent efficiency benefits of AMR technology. Our findings highlight the critical need for robust hardware design, rigorous testing protocols, and proactive maintenance strategies to improve the reliability and operational integrity of AMR implementations. Future research should explore the development of self-diagnostic hardware components and predictive maintenance algorithms to address the identified vulnerabilities.

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Curriculum Vitae

Name	: Adam Hidayatullah
TTL	: Batam, 07 Oktober 2004
Religion	: Islam
Address	: Tembesi, Citra Laguna B1A No 5
E-mail	: adam.hidayatullah103@gmail.com
Educational background	
Elementary School	: SDN 014 Sagulung
Junior High School	: SMPN 37 Batam
Senior High School	: SMKN 1 Batam