

# Analysis of Technical Anomalies in Power Supply AMR Using FMEA at PT. PLN Batam

Ikhsan Perdana<sup>1</sup>, Vivin Octowinandi<sup>1\*</sup>, and Nugroho Adi Prabowo<sup>2</sup>

<sup>1</sup>Jurusan Teknik Elektro, Prodi Teknik Elektronika Manufaktur, Politeknik Negeri Batam, Batam, Indonesia

\*Email: ikhsanperdana032@gmail.com

**Abstract**— The Automatic Meter Reading (AMR) system plays a crucial role in the efficient collection of electricity consumption data at PT. PLN Batam. However, the reliability of this system is frequently disrupted by recurring damage to the AMR device's power supply, leading to failures in accurate and real-time data transmission. This study aims to identify the primary failure modes, analyze their root causes, and formulate mitigation strategies to enhance the reliability of the AMR power supply. Through a combination of fishbone analysis, Failure Mode and Effect Analysis (FMEA), visual inspection, and component measurements, it was found that the two most significant failure modes are the continuous operation (24 hours) of the power supply and exposure to high ambient temperatures. The FMEA results showed Risk Priority Numbers (RPN) of 175 for frequency of use and 245 for temperature, highlighting the urgency of addressing both factors. Specifically, visual inspection and capacitance measurements confirmed that the 220uF electrolytic capacitor is the most vulnerable component, exhibiting significant capacitance degradation due to high temperatures and non-stop operation, which leads to unstable output voltage and frequent modem restarts. Based on these findings, the study recommends power supply PCBA rework, specifically replacing the faulty capacitors, as a cost-effective repair solution. Furthermore, as a preventive measure, the implementation of an active cooling system within the PLN APP box and the use of an external timer to regulate the operational cycle of the power supply and modem are proposed. Although the preventive recommendations have not yet been implemented due to cost and time constraints, this research provides a deep understanding of the root causes of AMR power supply issues and offers practical solutions to improve system performance and customer satisfaction at PT. PLN Batam.

**Keyword:** AMR, Power Supply, FMEA, Failure Analysis, Electrolytic Capacitor, Reliability, PT. PLN Batam.

## I. INTRODUCTION

Automatic Meter Reading (AMR) systems have become an important pillar in the modernization of electrical energy metering systems, replacing conventional methods. Its implementation enables periodic and automatic reading of

energy data, maximum usage, and load profiles, which is essential for accurate billing and rapid customer profile analysis [1]. The system consists of cellular modems, DC 15 V power supplies, and antennas. The cellular modems are used to transmit measurement data from digital meters to a server. Meanwhile, the DC 15 V power supplies are used to power up the modems. Data is sent and received from and to different locations via radio waves emitted by the antennas at specific frequencies[2].

In an effort to improve the efficiency and reliability of the electricity system, PT PLN Batam has implemented the AMR system for all customers with power ranging from 41,500 VA and above. However, the implementation of AMR system in the field faces challenges, especially the high rate of hardware failure.

One of the devices that most often experience damage is the power supply. Power supply or power supply is a device that distributes electrical power to the load after processing it to suit the needs of the load [3]. Figure 1 below is the power supply used in the AMR system:



Fig. 1. Power Supply AMR

The electrical specification from this power supply is :

1. Input Voltage: 90 VAC - 240 VAC
2. Frequency: 50 Hz
3. Output Voltage : 14 VDC [4].

Damage to the electronic components of such power supplies, especially in environments with diverse conditions and high voltage fluctuations, often disrupts the data collection process. In fact, even if the power supply remains on, the cellular modem as a load cannot connect to the network due to the unstable output voltage of the power supply when the

modem requires more current. This causes the modem to constantly reset/restart before successfully connecting to the network, resulting in repeated connectivity failures, the cause of which is damage to the power supply device. This is a technical oddity that technicians face in the field. Thus, the benefits that should have been realized through the use of the AMR system could no longer be obtained effectively. Some of the advantages of using an AMR system are as follows:

1. More accurate and efficient recording of electrical energy consumption.
2. More efficient use of time
3. Monitoring of energy used can be done at any time from the control room.
4. Historical energy data can be stored in a database, and can be integrated with management data.
5. Load profile, stand meter and other data can be displayed based on the time interval as desired.
6. It is easy to identify the time of the problem and the amount of energy lost, if there is a disturbance in the meter, either intentionally or unintentionally [5].

This study aims to identify the cause of damage to the AMR power supply using the fishbone analysis method and FMEA and determine what components are damaged. To determine the components that are damaged, this research will conduct inspections using visual inspection and component measurement methods. By understanding the types of electronic component damage that often occur in AMR modem power supplies, it is hoped that effective prevention and control methods can be formulated.

## II. METHOD

To determine the cause of AMR power supply damage, several structured analysis methods are applied. The methods used are Fishbone Analysis, FMEA (Failure Mode and Effect Analysis), Visual Inspection and Component Measurement.

Fishbone analysis will map potential failure modes that may be the cause of power supply damage. Then FMEA analysis will assess what potential failure causes and potential failure effects are caused and provide an RPN assessment. Furthermore, visual inspection and component measurement methods will be applied to quantitatively validate the results of the fmea analysis and prove whether the damage really occurred in the suspected part.

### A. Fishbone Analysis

A fishbone diagram is a visual tool to identify, explore, and graphically depict in detail all the causes associated with a problem. The categories of causes that are often used as a starting point include materials, machines and equipment, manpower, methods, Mother Nature/environment, and measurement [6]. In this problem, Fishbone analysis is used to map potential failure modes that may occur. Mapping is done from various sources of failure, starting from man, method, machine, material and environment which may be the cause of the power supply failure. Figure 2 below shows the fishbone diagram used.

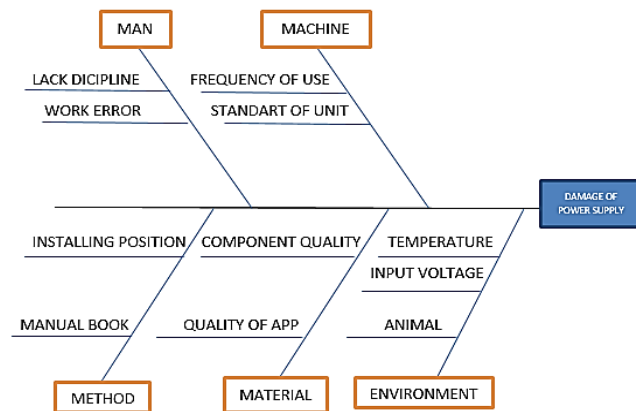


Fig. 2. Fishbone diagram

### B. FMEA ( Failure Mode and Effect Analysis)

FMEA (Failure Mode and Effect Analysis), was introduced by an aircraft industry company in the 1960s as an analytical method with a framework designed to identify, analyze, and address potential failures in a process or product. At that time the aviation industry was very aware of the importance of safety and quality in aircraft production so FMEA became a very useful tool[7].

FMEA analysis is used to assess whether failures in a process or product can be analyzed or quantified, so that preventive measures can be taken to reduce the failure rate and its negative impact on other factors and the end result of the process. The FMEA method allows the determination of the relative value of the most important problems using three criteria: Severity, Occurrence, and Likelihood of Detection. These three criteria are combined to produce a Risk Priority Number (RPN), which is calculated by the formula :

$$S \times O \times D = RPN \quad (1)$$

The higher the RPN value, the greater the impact of the problem on product or process quality, so corrective action must be taken immediately. So the benefits of conducting Process FMEA are identifying variables that should be the focus, developing a ranked list of potential Failure Modes, thus forming a prioritized system for prevention/correction considerations[8].

Table 1 until 3 below is a reference to defining the rating scale from 1-10 in the FMEA analysis used.

TABLE 1  
FMEA SEVERITY INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
1	not significant	no disruption.
2	minor	slight inconvenience.
3	low	noticeable performance decrease.
4	moderate	significant performance decrease.
5	significant	loss of some functions.
6	high	loss of primary function (quick recovery).
7	very high	loss of primary function (long) / safety impact.
8	hazardous	potential injury/serious damage (sudden).
9	very hazardous	potential severe injury/damage (with indication).
10	extreme	life-threatening / catastrophic system

damage.

TABLE 2  
FMEA OCCURRENCES INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
1	remote	very unlikely.
2	occasional	possible a few times in lifespan.
3	infrequent	a few times per year.
4	moderately frequent	every few months.
5	frequent	every month.
6	very frequent	several times per month.
7	repeated occurrences	every week.
8	very repeated occurrences	several times per week.
9	almost certain	every day.
10	certain	continuous / very often.

TABLE 3  
FMEA DETECTION INDIKATOR

Value	Description Severity Level	Detailed Explanation Impact
1	almost certainly detected	automatic / continuous monitoring
2	likely to be detected	routine inspection / clear indicators.
3	moderately easy to detect	periodic checks / reports.
4	possible to be detected	requires specific testing.
5	Difficult but Possible to Detect	by chance / analysis after issue.
6	very difficult to detect	highly specific & in-depth testing.
7	very remote chance	unlikely before problem occurs.
8	almost impossible	no effective method.
9	not detected	only known after impact.
10	no detection control	no detection efforts.

TABLE 4  
RPN INDIKATOR

Value	Description RPN Level	Risk
1-199	low	Represents a minimal risk.
200-399	moderate	Points to a moderate risk.
400-599	high	Signifies a significant risk
600-799	very high	Denotes a high risk with the potential to cause significant impact on system function or performance,
800-1000	critical	Indicates an extremely severe risk that threatens the system's primary function, occurs very frequently, and/or is extremely difficult to detect.

### C. Visual Inspection

Visual Inspection is an inspection method that is done visually to find and assess the physical condition of a product. Visual inspection is commonly use in both manufacturing tasks and nonproduction environments. In manufacturing tasks, the purpose is to verify that a product is free of defects before installation in the next level of assembly or final distribution to the customer. In non-production environments, the objective is to determine whether the features indicative of a "target" are present and prevent potential negative impacts[9].

In this problem, a visual inspection process will be carried out to find physical damage and irregularities that should not be found in the power supply. Physical damage found in the power supply may be the reason for the power supply malfunction. This method will result in visual inspection data presented in the form of a table and then the data will be displayed in the form of a bar chart. Some of the categories of irregularities that will be included in the visual inspection table are the findings of burning, corrosion and bulging. These categories are most likely to be present in an electronic device and can cause partial or total malfunction of the device. Table 5 below is the form used to present the visual inspection data and will be included in the appendix.

TABLE 5  
VISUAL INSPECTION FORM

Burn	Corroton	Bloating	Pict	Description

After the visual inspection method produces the suspected component data, the component measurement inspection method will be applied to quantitatively confirm the suspicion. This will confirm whether the component with the physical anomaly (physical damage) is actually damaged.

### D. Component Measurement

Measurement is the activity of giving or assigning numbers to the object being measured, adjusted to the object's criteria[10]. In this research, component measurement is a component inspection method with calibrated measuring instruments carried out to confirm the value of each component that has previously been suspected. Components that have physical anomalies such as burning, corrosion, and bulging will be measured according to the component parameters. Avometers will be implemented to measure resistance, capacitance, and other necessary parameters. In essence, this activity will directly provide data on the location of power supply damage and prove the relationship between this data and the data from the FMEA analysis that was previously carried out.

## III. RESULT

This chapter will presents the results of an analysis of the causes of damage to the AMR modem PSU in use, with the main objective of comprehensively identifying and analyzing the factors that contribute to the failure of the device and determining what components are damaged. The methods used include Fishbone analysis, which serves to identify potential failure modes and map the various contributing factors systematically. Next, Failure Mode and Effects Analysis (FMEA) was applied to assess the impact and risk of each identified failure mode, taking into account severity, likelihood of occurrence, and detectability. To validate the findings of this theoretical analysis, visual inspections and direct component measurements were conducted on the damaged PSUs. The visual inspection method allows the

identification of visible physical damage, such as burnt or broken components, while component measurements provide quantitative data on the change in component value due to damage. The combination of these methods allows for holistic and specific identification of the cause of the damage, both in terms of potential failure modes and the specific components that have failed. The results of the analysis in this study can be seen in the following Sections 3.A, 3.B, 3.C and 3.D.

### A. Analysis Fishbone

Based on the mapped fishbone analysis diagram, the analysis focused on the potential causes of damage to the 12V power supply used to power the AMR hardware. The results of the analysis are presented in Table 6 below.

TABLE 6  
FISHBONE TABLE ANALYSIS RESULT

Process	Potential Failure Mode	Current Control	Do?
man	work error in installing process	the installation steps are informed in the device's manual book	
machine	frequency of use ( always on 24 hours)	there are no regulations that discipline to rest the performance of the power supply periodically. so that the power supply is always active 24 hours.	√
machine	standart of unit	this is regulated in the official regulation spln_d3.023_2021.	
method	installing position in app	this is regulated in the official regulation spln_d3.023_2021.	
material	quality of component	this is regulated in the official regulation spln_d3.023_2021.	
material	quality of app	this is regulated in the official regulation spln_d3_015-1_2011.	
environment	temperature	there is no cooler that can handle high temperatures.	√
environment	input voltage	this is regulated in the official spln regulations.	
environment	animal	this is regulated in the official spln regulations. refer to the app standard which has been designed to be inaccessible to animals.	

Based on table 6, it can be seen that the 2 (two) potential failure modes identified and considered most relevant are frequency of use (always on 24 hours) and temperature.

This power supply operates continuously for 24 hours a day without ever being turned off. This continuous use raises a strong suspicion that the damage that occurs in the power supply is caused by a high frequency of use factor. The components in the power supply experience constant working pressure, thus potentially accelerating the occurrence of wear and tear of components. Looking at the current control there is also no regulation to rest the performance of the power supply periodically.

In addition to the frequency of use, the temperature factor is also a major concern. This power supply is placed inside the PLN electricity app box. The conditions inside the box tend to have high temperatures, especially when using electricity with high amperage. Plus this device is used for electricity use with

power ranging from 41,500 VA and above. High temperatures can accelerate the degradation of electronic components inside the power supply, increasing the risk of damage.

The combination of high frequency of use and high ambient temperature is thought to be the main cause of damage to the 12V power supply on the modem. Furthermore, in order to find out the potential causes and potential failure effects of the two failure potential modes, a deeper analysis will be carried out using the FMEA analysis method.

### B. Analysis FMEA

The FMEA analysis identified two main potential failure modes that contribute to the failure of the AMR modem PSU based on the results of the fishbone analysis, namely is frequency of use (Always on 24 Hours) and temperature.

All about potential effect, potential causes and current controls as shown in Table 7 as a FMEA Result table.

TABLE 7  
FMEA RESULT

Potential Failure Mode	Potential Failure Effect	S	Potential Causes	O	Current Control	D	R	P	N
Frequency of use	Decreased performance and component damage	7	Component wear and Insufficient cooling for continuous use	5	There is no disciplined rule to rest the performance of the Power Supply periodically. So that the power supply is always active 24 hours.	5	1	7	5
Temperature	Component degradation and component value change	7	High ambient temperature and poor ventilation	7	There are no supporting tools/ devices that can cope with temperatures high enough to overcome the temperature inside the APP	5	2	4	5

### 1. Frequency Of Use (Always on 24 Hours)

Berdasarkan tabel 7, mode kegagalan "FREKUENSI PENGGUNAAN" mendapatkan nilai RPN sebesar 175 (7 x 5 x 5), menunjukkan risiko karena penggunaan PSU secara terus-menerus selama 24 jam. Efek kegagalan potensial dari mode ini adalah penurunan kinerja PSU, yang dapat menyebabkan kegagalan fungsional total pada modem, serta kerusakan pada komponen penting seperti kapasitor, transistor, atau dioda karena keausan berlebihan. Penyebab kegagalan potensial utamanya adalah keausan komponen karena penggunaan terus-menerus dan pendinginan yang tidak memadai untuk mendukung penggunaan 24 jam. Skor (Severity) 7 diberikan karena risiko dari mode kegagalan ini dapat menyebabkan keseluruhan sistem mengalami kegagalan, sesuai dengan indikator severity "loss of primary function" yang dapat diberikan nilai 7. Skor (Occurrence) 5 diberikan karena hal ini terjadi dan ditemukan di setiap bulan. Karena

hal ini terjadi setiap bulan, maka merujuk pada indikator *Occurrence*, hal ini mendapatkan nilai 5. Skor Tingkat Deteksi (Detection) 5 diberikan karena deteksi kegagalan membutuhkan pembongkaran dan analisis komponen yang kompleks. Maka hal ini merujuk pada “difficult but possible to detected” yang pantas diberikan nilai 5. Berdasarkan RPN indikator, nilai 175 masih tergolong kedalam low level.

## 2. Temperature

Furthermore, based on table 7 the “TEMPERATURE” failure mode gets an RPN value of 245 (7 x 7 x 5). Indoors, PSUs with loads run at temperatures of 28 - 30(°C). Severity pada mode kegagalan suhu pada PSU diberi nilai 7 “Loss of Primary Function” karena PSU adalah pilar utama yang memastikan seluruh perangkat dalam sistem AMR berfungsi. Jika PSU mengalami kegagalan akibat suhu, seluruh sistem AMR akan mati total, menyebabkan hilangnya fungsi utama sistem untuk mengumpulkan data dan beroperasi. Nilai 5 diberikan untuk *occurrence* karena kegagalan akibat suhu ini dapat ditemui setiap minggu. Untuk *detection*, mode kegagalan komponen yang disebabkan oleh temperatur ini diberi nilai 5. Merujuk pada detecion indikator nilai 5 diberikan untuk “difficult but possible to detected”. Meskipun masalah ini dapat dideteksi, prosesnya memerlukan pengecekan yang kompleks dan pembongkaran keseluruhan PSU. Ini berarti masalah suhu tidak bisa langsung terlihat atau dideteksi dengan mudah tanpa prosedur diagnostik yang mendalam dan memakan waktu. Berdasarkan RPN indikator, nilai 275 ini sudah tergolong kedalam moderate risk.

The following table 8 is secondary data showing the temperature value at the PLN APP box. The temperature data measurement process is carried out as shown in Figure 3.

TABLE 8  
TEMPERATURE DATA IN BOX APP

Device	Value (°C)
APP Box	31,0
Digital Meter	54,6
MCCB	48,7
Bursbar	52,7
PSU	62,4

It can be seen in table 8 that the temperature on the PSU (Power Supply Unit) rises to 62.4 °C when operated inside the APP box. This increase in PSU temperature occurs because the ambient temperature around it tends to be high, influenced by several factors. One reason is that the APP box is exposed to direct sunlight, causing its internal temperature to reach 31 °C. Additionally, other devices within the APP box also emit heat; the digital meter reaches 54.6 °C, the MCCB 48.7 °C, and the busbar 52.7 °C. All these contribute to the PSU's temperature increasing to 62.4 °C, especially during maximum customer current usage.



Fig. 3. Measurement Temperature Data Documentation

The potential failure effect of this mode is the degradation of components, especially electrolytic capacitors, and changes in component values, which affect the performance of the PSU. The main potential failure causes are poor ventilation inside the PLN APP box and high ambient temperature. A Severity score of 7 is assigned because PSU failure can lead to overall system failure. Occurrence score of 7 is given because high ambient temperatures occur frequently and are difficult to control. Detection score of 5 is given because failure detection requires complex component disassembly and analysis.

TABLE 9  
ACTION RECOMMENDED

Potential Failure Mode	Action Recommended	Responsibility Person	Action Taken	SPV Sign
Frequency of use	Implementation Timer Eksternal (Time Delay Relay)	TECHNICIAN/ENGINEERING	NO ACTION HAS BEEN TAKEN YET	A.
Temperature	Implementation active cooling system blower	TECHNICIAN/ENGINEERING	NO ACTION HAS BEEN TAKEN YET	A.

The recommended actions that have been formulated based on the results of the FMEA analysis are as shown in Table 9. To mitigate this risk, the use of an external timer (time delay relay) to control the operational time of the PSU and AMR modem is recommended, as well as the implementation of an active cooling system (temperature-controlled blower) in the PLN APP box.

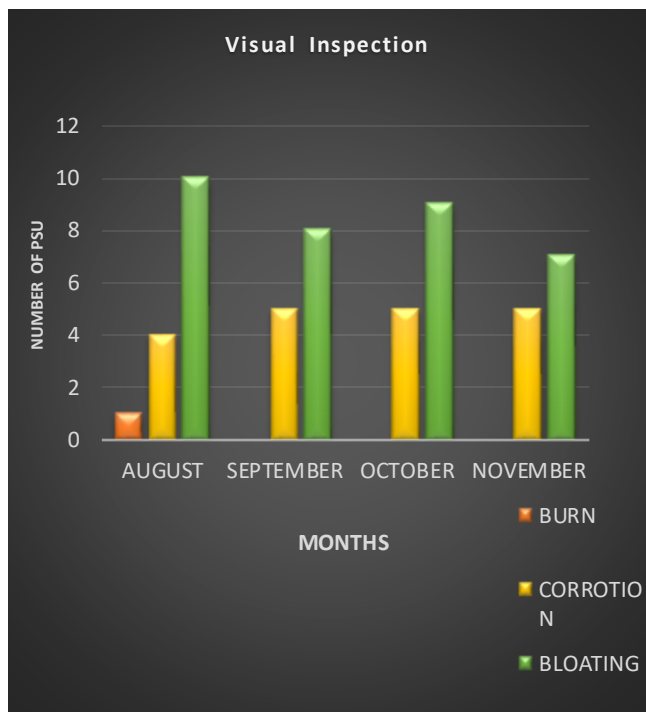
However, these recommended preventive measures could not be implemented due to cost and time considerations. Because of this, it has not been possible to complete the corrective and mitigative action tables. Even so, these measures are considered important to improve PSU reliability and extend device life.

### C. Visual Inspection

Visual inspection activities are carried out thoroughly to produce data called visual inspection result data. Some physical conditions of concern are burning, corrosion, and bulging of components. PSUs that have been burned usually have a blackish color in the PCBA area, indicating that the spot has been burned. For corrosion conditions, it is usually indicated by the condition of the pad or lead components that look dirty. The dirt is in the form of rust or others that have the potential to cause a short / bridge between one pad and another

pad, or between one lead component and another lead component. The last is a bulging condition, this is usually experienced by components such as capacitors or ic that have overheated. Capacitors can bulge due to prolonged use without rest, which causes high temperature conditions and subsequently increases the pressure inside them[11]. This inflation is characterized by a change in the condition or physical size of the component from the condition or physical size it should be.

Fig. 4. Visual inspection chart



The graph in figure 4 presents data on the number of visual inspections of defective AMR modem PSUs during the period August to November. These inspections identified three main visual findings: burn, corrosion, and bloating. In August, there was 1 case of burn, 4 cases of corrosion, and 10 cases of bloating. These burnt findings were likely caused by high electrical current surges. In September, October and November, there were no cases of burnt findings. However, corrosion and bulging cases remained dominant. In September, 5 cases of corrosion and 8 cases of bulging were found. In October, 5 corrosion cases and 9 inflation cases were found. In November, 5 corrosion cases and 7 inflation cases were found. Clearly, the corrosion cases were dominated by the feet of the led indicator components and the inflation cases all occurred on the 220 uf electrolytic capacitor.

The graph in figure 4 clearly shows a consistent trend of visual findings, where bulging and corrosion are the most frequent findings. However, these two trends of findings still cannot be confirmed to be the cause of PSU damage, considering that the PSU damage found in the field is that the PSU output voltage always drops shortly before the modem is connected to the network (reaching peak load). These findings will be further validated by measuring the visual inspection findings, to confirm whether the visual inspection findings are really the cause of the PSU output voltage drop. Figure 5

below is documentation of the physical conditions obtained during the visual inspection process.



Fig. 5. Documentation of Visual Inspection Result

#### D. Component Measurement

These measurements were taken using a calibrated digital AVO Meter to obtain quantitative data on component values, such as resistance, capacitance, and inductance. As well as ascertaining corrosion linkages in suspected bridge/short on component legs and pads. This measurement data will be compared with the component's standard values to identify changes in values that indicate damage or breakdown.

As a result, for corrosion, which occupies the second position on the chart, none of the corrosion findings caused bridge/short. This was proven when the corroded pads were measured using the resistance mode on the AVO Meter.

However, for the inflation findings on the capacitor, after measurement, a significant deviation in capacitance value was found. The data from the component measurements are presented in Table 10 below.

TABLE 10  
COMPONENT MEASUREMENT RESULT

PSU No.	Component	Value	Measurement Result	Status
PSU 1	Capacitor Polarized	220uf	249,7 nf	Not Good
PSU 1	Red LED	-	Normal	Good
PSU 2	Capacitor Polarized	220uf	1.004,8nf	Not Good
PSU 3	Capacitor Polarized	220uf	2.241 nf	Not Good
PSU 4	Capacitor Polarized	220uf	864,5 nf	Not Good
PSU 5	Capacitor Polarized	220uf	246,6 nf	Not Good
PSU 5	Capacitor Polarized	220uf	246,6 nf	Not Good
PSU 6	Capacitor Polarized	220uf	749,7 nf	Not Good
PSU 7	Red LED	-	Normal	Good
PSU 8	Capacitor Polarized	220uf	807,3 nf	Not Good
PSU 9	Capacitor Polarized	220uf	750,7 nf	Not Good
PSU 10	Red LED	-	Normal	Good
PSU 11	Capacitor Polarized	220uf	1.115,0nf	Not Good
PSU 11	Red LED	-	Normal	Good
PSU 12	Capacitor Polarized	220uf	873,0 nf	Not Good
PSU 13	DC Output pad	-	Normal	Good
PSU 13	Capacitor Polarized	220uf	434,2 nf	Not Good

PSU 14	DC Output pad	-	Normal	Good
PSU 14	Capacitor Polarized	220uf	129,57 nf	Not Good
PSU 15	Capacitor Polarized	220uf	1.136,8 nf	Not Good
PSU 16	DC Output pad	-	Normal	Good
PSU 17	Capacitor Polarized	220uf	559,2 nf	Not Good
PSU 18	Capacitor Polarized	220uf	230,7 nf	Not Good
PSU 19	Capacitor Polarized	220uf	274,8 nf	Not Good
PSU 20	LED Pad	-	Normal	Good
PSU 20	Capacitor Polarized	220uf	1759,3 nf	Not Good
PSU 21	LED Pad	-	Normal	Good
PSU 21	Capacitor Polarized	220uf	1.499,5 nf	Not Good
PSU 22	Capacitor Polarized	220uf	796,8 nf	Not Good
PSU 23	Capacitor Polarized pad	100uf	Normal	Good
PSU 23	Capacitor Polarized	220uf	855,0 nf	Not Good
PSU 24	Red LED	-	Normal	Good
PSU 24	Capacitor Polarized	220uf	1.152,1 nf	Not Good
PSU 25	Capacitor Polarized	220uf	210,4 nf	Not Good
PSU 26	Capacitor Polarized	220uf	1.112,2 nf	Not Good
PSU 27	AC Input pad	-	Normal	Good
PSU 28	Capacitor Polarized	220uf	364,6	Not Good
PSU 29	Red LED	-	Normal	Good
PSU 29	Capacitor Polarized	220uf	912,1	Not Good
PSU 30	Capacitor Polarized	220uf	2.151 nf	Not Good
PSU 31	Capacitor Polarized	220uf	1.086,0 nf	Not Good
PSU 32	Red LED	-	Normal	Good
PSU 33	Capacitor Polarized	220uf	1.055,0 nf	Not Good
PSU 33	Red LED	-	Normal	Good
PSU 34	Capacitor Polarized	220uf	981,9 nf	Not Good
PSU 34	Red LED	-	Normal	Good
PSU 35	AC Input pad	-	Normal	Good
PSU 36	AC Input pad	-	Normal	Good
PSU 37	Capacitor Polarized	220uf	309,5 nf	Not Good
PSU 38	AC Input pad	-	Normal	Good
PSU 39	Capacitor Polarized	220uf	375,5 nf	Not Good
PSU 40	Capacitor Polarized	220uf	1,9uf	Not Good
PSU 41	Capacitor Polarized	220uf	77,1uf	Not Good
PSU 42	Capacitor Polarized	220uf	49,6	Not Good

PSU 1 until 12 found in August. PSU 13 until 21 found in September, PSU 22 until 32 found in Oktober, PSU 33 until 42 found in November.

Based on the component measurement data in Table 10, the component measurement results show a very significant degradation of capacitance in the 220uF electrolytic capacitor that is inflated. This highly significant degradation indicates that the capacitor has experienced severe damage or breakdown. This degradation confirmed the visual inspection findings that identified bulging in the capacitor, and validated that a breakdown had indeed occurred in the component. Figure 6 below are some examples of images documenting when measurements were taken on capacitors that experienced physical bulging and deviation in capacitance values.

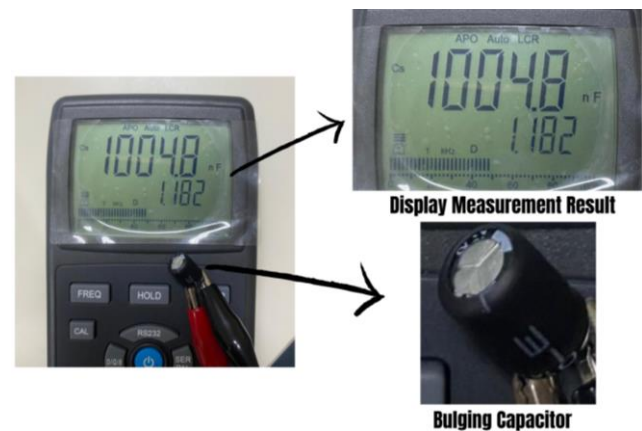


Fig. 6. Component measurement Documentation

Based on the data in table 10, it can be concluded that the percentage of damage to a total of 42 PSUs checked in 4 months is 83.33%. This is because the total defective capacitors of the 42 PSU units inspected were 35 capacitors. The calculation is as follows :

$$\text{Percentage} = \frac{x}{y} \times 100\% \quad (2)$$

x = PSU Checked

y = PSU whose capacitor is damaged

$$\text{Percentage} = \frac{35}{42} \times 100\%$$

**Percentage = 83.33%**

Furthermore, this finding reinforces the previous FMEA analysis that had identified continuous use and high temperature as the main contributing factors to electrolytic capacitor damage. The quantitative data from the measurement of these components provided concrete evidence that supported the qualitative analysis from the FMEA, thus strengthening the overall validity of the study.

#### IV. DISCUSSION

This chapter presents a discussion of the results of analyzing the causes of the AMR modem PSU malfunction, obtained through the Fishbone, FMEA, visual inspection, and component measurement methods. The main focus of this

discussion is to explain the interrelationship between the results of each method and how they validate each other. Fishbone analysis and FMEA provided the theoretical basis for the potential causes of the malfunction, while visual inspection and component measurement provided empirical evidence supporting the findings.

#### A. Analysis Fishbone dan FMEA Discussion

The fishbone analysis identified two main categories of causes for PSU damage: environmental factors (temperature) and operational factors (constant use). These factors were further broken down into more specific causes, such as poor ventilation, high ambient temperatures and component wear. These findings provided an initial overview of the potential causes of PSU damage.

The FMEA analysis confirmed the Fishbone findings and provided a more quantitative risk assessment. The two main failure modes identified were “FREQUENCY OF USE (ALWAYS ON 24 HOURS)” and “TEMPERATURE”. The “FREQUENCY OF USE” failure mode received an RPN value of 175, which indicates a high risk due to continuous use of the PSU for 24 hours. This value indicates that 24 hours of non-stop use can cause components to wear out and accelerate damage, resulting in decreased performance or even damage to the modem. The “TEMPERATURE” failure mode received an RPN value of 245, which indicates a higher risk due to uncontrolled ambient temperature. High temperatures can accelerate the degradation of components, especially electrolytic capacitors, and change component values, ultimately affecting PSU performance. A Severity score of 7 is assigned to both modes because PSU failure can lead to overall system failure. An Occurrence value of 5 in “FREQUENCY OF USE” indicates possible component wear, while an Occurrence value of 7 in “TEMPERATURE” indicates the frequency and difficulty of controlling high ambient temperatures. A Detection value of 5 is assigned to both modes due to the complexity of failure detection.

Furthermore, regarding the recommended actions, the following are the implications and recommendations that have been formulated, which can be seen in table 11 and table 12.

TABLE 11

IMPLICATION AND RECOMMENDATION FOR FREQUENCY OF USE

No	Implication	Recommendation
1	Relentless use causes components to work beyond their long-term tolerance	Implementation of an external timer (time delay relay) to manage the operational cycle of the power supply and AMR devices.
2	Without regulations governing device downtime, the risk of failure increases exponentially.	Periodic scheduling of rest periods, especially at times of low network load, to reduce stress on device components.

TABLE 12

IMPLICATION AND RECOMMENDATION FOR TEMPEARATURE

No	Implication	Recommendation
	High temperatures	Evaluation and implementation of

1	accelerate the aging process of components and reduce the life of the PSU.	a temperature-controlled active cooling system (blower) inside the PLN APP box
2	Inadequate ventilation creates a greenhouse effect inside the PLN APP box, exacerbating the temperature problem.	Improved circulation to ensure optimal air circulation and placement of the PLN APP box away from direct sunlight.

The Corrective and Mitigative Action columns in the FMEA table are not filled in due to several reasons that hinder the implementation of preventive actions. This is also the reason why action taken cannot be done yet. First, the implementation of external timers and active cooling systems requires careful planning and rigorous testing to ensure their effectiveness. Second, the investment cost for procuring and installing these devices is quite large and requires budget approval. Third, the implementation process takes a considerable amount of time and may disrupt system operations. Therefore, although recommended actions have been identified, the company cannot take corrective or mitigative actions at this point.

#### B. Visual Inspection and Component Measurement Discussion.

Visual inspection identified three main findings: burning, corrosion and bulging. Burning cases, which were likely caused by electrical surges, were only found in August. Meanwhile, corrosion and bulging dominated the visual findings in the following months. Corrosion was mainly found on the LED indicator component legs, while bulging consistently occurred on the 220uF electrolytic capacitors. This trend indicates that environmental factors and continuous use may have played a role in the deterioration of the PSU. Component measurements thereafter focused on the visual findings of corrosion and bulging. Measurements showed that corrosion on the LED indicator legs did not cause significant damage such as a short circuit, so the alleged involvement of corrosion in PSU damage was not proven. In contrast, component measurements confirmed the finding of bulging in the 220uF electrolytic capacitor. The degradation found validated the visual inspection findings and proved that damage had indeed occurred to the 220uF electrolytic capacitor. The data showed that 83.33% of PSU failures stemmed from damage to the capacitors that were undergoing bulging.

#### C. Validation and Linkage of Results

##### 1) Validation of FMEA Results with Visual Inspection

Visual inspection revealed physical damage to the PSU components, such as corrosion of component bearings and bulging capacitors. The bulging capacitors supported the FMEA findings of component degradation due to high temperature and wear. However, for the corrosion findings, after observation, this occurred because the PCBA was not completely cleaned after the production process, so that a lot of residual flux was still left on the pad. Over a long period of time, this residual flux dries out and causes corrosion. However, based on measurements, none of the corrosion

caused a short between pads. Below shows a documented example of a corroded and bulging component.



Fig. 7. Defect Component

### 2) Validation of FMEA Results with Component Measurements

Component measurements showed significant degradation in the value of the 220uF electrolytic capacitor, confirming the FMEA findings of changes in component values due to high temperatures. It was the deviation of the 220uF electrolytic capacitor measurement results that caused the PSU to suffer a voltage drop just before the modem successfully connected to the network (peak load), which in turn caused the modem to restart.

### 3) Results Linkage

The results of Fishbone analysis, FMEA, visual inspection, and component measurement are interrelated and support each other. Fishbone identifies potential causes, FMEA provides risk assessment, visual inspection provides physical evidence, and component measurement provides quantitative evidence.

Overall, the analyzed results from the visual inspection and component measurements consistently led to one conclusion: the deviation in capacitance value of the 220uF electrolytic capacitor was the main cause of the PSU output voltage drop. The visual inspection identified bulging in the capacitor, which was confirmed by the component measurements with the finding of a very significant drop in capacitance value, causing the capacitor to fail, accounting for 83.33% of the PSUs inspected. Given the function of electrolytic capacitors as voltage ripple absorbers and output voltage stabilizers, this severe degradation resulted in the PSU's inability to maintain a stable output voltage, especially during peak loads. As a result, the output voltage of the PSU drops shortly before the modem is connected to the network, causing the modem to restart and disrupting system operations.

### D. Recommendations for improvement / repairment

Based on the results of the in-depth analysis and validation, and considering that the initial countermeasure recommendations could not be implemented immediately, the PCBA Rework repair method was recommended as the primary solution to repair the damaged Power Supply Unit (PSU). This method is considered to be much more targeted and significantly easier to implement compared to the initial countermeasure option which may require further customization or greater resources. In a nutshell, PCBA Rework is a precision repair process performed on Printed Circuit Board Assembly (PCBA). The process specifically involves the replacement or repair of individual components that are identified as defective or not conforming to the set specification standards. In the context of this PSU repair, the

main focus of the rework process was to replace defective capacitor components. The decision to choose this PCBA Rework method was based on substantial efficiency considerations. When compared to replacing the entire PSU unit, the PCBA rework approach offered much greater cost savings. This is mainly because this remedial action would only involve replacing a single capacitor component on each faulty PSU instead of the entire unit. This approach not only minimizes material wastage but also reduces operational downtime that may result from procuring and replacing an entire new unit. To ensure the rework process runs according to standards and results in an optimal repair, a PCBA Rework Standard Operating Procedure (SOP) has been developed and can be seen in Figure 8.

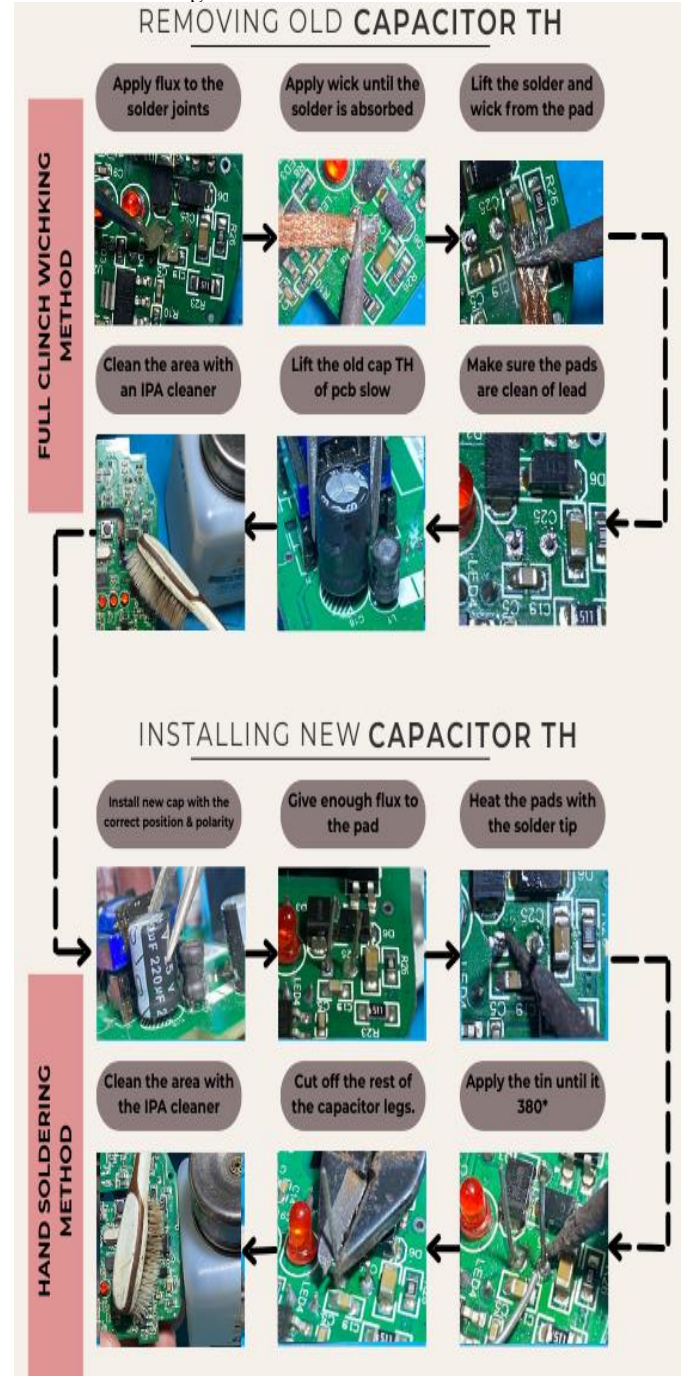


Figure. 8. Rework And Repair SOP

## V. CONCLUSION AND SUGGESTION

Based on the discussion in subchapters 3.A and 3.B, the cause of damage to the PSU as the AMR power supply has been successfully determined. The results of Fishbone and FMEA analysis identified two main causes of AMR PSU damage, namely continuous use (24 hours) that causes component wear and high ambient temperatures that accelerate component degradation. These two factors were corroborated by the findings of visual inspection and component measurements.

Based on the discussion in subchapters 3.C and 3.D, defective components in the power supply have also been found. Visual inspection and component measurements consistently showed that the 220uF electrolytic capacitor was the most frequently defective component.

Component measurements showed a very significant drop in capacitance value of the capacitor, indicating severe damage and contributing 83.33% of the total PSU damage examined. The deviation in the measurement results of the 220uF electrolytic capacitor was what caused the PSU to suffer voltage drop damage shortly before the modem was successfully connected to the network (peak load), which in turn caused the modem to restart. This capacitor damage caused the PSU output voltage to become unstable, especially during peak load, which resulted in the modem restarting.

Based on the research findings, it is recommended to perform PCBA rework on the damaged AMR PSU, focusing on replacing the 220uF electrolytic capacitor based on the PCBA rework SOP that has been given. This can restore the performance of the PSU as before. With this recommended repair action, it is hoped that it can restore the reliability of the damaged PSU, and replace the solution of replacing a new PSU with a much lower cost.







Then to prevent future damage, it is recommended to implement a more effective cooling system in the PLN APP box, as well as set the operational schedule of the PSU and AMR modem using an external timer to reduce continuous use. Further research can be conducted with a larger number of samples and a wider variety of environmental conditions in the hope of obtaining more comprehensive results.

















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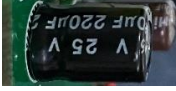










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## Attachment

### Appendix A - Visual Inspection Form

		VISUAL CHECK				
		Burn	Corroton	Bloating	PICT	Description
A U G U S T	PSU 1		√	√	 	Burn : On the Indicator LED pad Corroton : At 220 uf capacitor
	PSU 2			√		Corroton : At 220 uf capacitor
	PSU 3			√		Corroton : At 220 uf capacitor
	PSU 4			√		Corroton : At 220 uf capacitor
	PSU 5		√	√	 	Burn : On the Indicator LED pad Corroton : At 220 uf capacitor
	PSU 6			√		Corroton : At 220 uf capacitor
	PSU 7		√			Burn : On the Indicator LED pad
	PSU 8			√		Corroton : At 220 uf capacitor
	PSU 9			√		Corroton : At 220 uf capacitor
	PSU 10		√			Burn : On the Indicator LED pad
	PSU 11			√		Corroton : At 220 uf capacitor
	PSU 12			√		Corroton : At 220 uf capacitor

	PSU 13	√					
S E P T E M B E R	PSU 1		√	√			Burn : On the DC output pad Corrosion : At 220 uf capacitor
	PSU 2		√	√			Burn : On the DC output pad Corrosion : At 220 uf capacitor
	PSU 3			√			Corrosion : At 220 uf capacitor
	PSU 4						<i>Normal</i>
	PSU 5		√				Burn : On the DC output pad
	PSU 6			√			Corrosion : At 220 uf capacitor
	PSU 7			√			Corrosion : At 220 uf capacitor
	PSU 8			√			Corrosion : At 220 uf capacitor
	PSU 9		√	√			Burn : On the Indicator LED pad Corrosion : At 220 uf capacitor
	PSU 10		√	√			Burn : On the Indicator LED pad Corrosion : At 220 uf capacitor
O C T O B E R	PSU 1			√			Corrosion : At 220 uf capacitor
	PSU 2		√	√			Burn : At 100 uf capacitor pad Corrosion : At 220 uf capacitor

	PSU 3		√	√			Burn : On the Indicator LED pad Corroction : At 220 uf capacitor	
	PSU 4			√			Corroction : At 220 uf capacitor	
	PSU 5			√			Corroction : At 220 uf capacitor	
	PSU 6		√				Burn : AC input pad	
	PSU 7			√			Corroction : At 220 uf capacitor	
	PSU 8		√	√			Burn : On the Indicator LED pad C : At 220 uf capacitor	
	PSU 9			√			Corroction : At 220 uf capacitor	
	PSU 10			√			Corroction : At 220 uf capacitor	
	PSU 11		√				Burn : On the Indicator LED pad	
	NOVEMBER	PSU 1		√	√			Burn : On the Indicator LED pad Corroction : At 220 uf capacitor
		PSU 2		√	√			Burn : On the Indicator LED pad Corroction : At 220 uf capacitor
PSU 3			√				Burn : AC input pad	
PSU 4			√				Burn : AC input pad	
PSU 5				√			Corroction : At 220 uf capacitor	

PSU 6		√				Burn : AC input pad
PSU 7			√			Corrothion : At 220 uf capacitor
PSU 8			√			Corrothion : At 220 uf capacitor
PSU 9			√			Corrothion : At 220 uf capacitor
PSU 10			√			Corrothion : At 220 uf capacitor
<b>SPV</b> (Nugroho Adi Prabowo)						A.

### Appendix B - Visual Inspection Form

Process	Failure Mode Potential	Potential Failure Effect	Severity (1-10)	Potential Causes	Occurrence(1-10)	Current Controls
<b>MACHINE</b>	<b>FREQUENCY OF USE (ALWAYS ON 24 HOURS)</b>	<b>Penurunan Kinerja:</b> Power supply mungkin tidak lagi memberikan tegangan atau arus yang stabil, menyebabkan penurunan kinerja modem atau bahkan kerusakan pada modem.	<b>7</b>	<b>Komponen Aus:</b> Penggunaan terus-menerus menyebabkan komponen-komponen di dalam power supply bekerja tanpa henti, mempercepat proses keausan.	<b>5</b>	<b>Tidak ada aturan yang mendisiplinkan untuk mengistirahatkan kinerja Power Supply secara berkala. Sehingga power supply selalu aktif 24 jam.</b>
		<b>Kerusakan Komponen:</b> Keausan yang berlebihan dapat menyebabkan kerusakan pada komponen-komponen penting seperti kapasitor, transistor, atau dioda.		<b>Pendinginan yang Tidak Memadai untuk mendukung penggunaan terus menerus:</b> Jika power supply tidak memiliki sistem pendinginan yang memadai, panas yang dihasilkan selama penggunaan terus-menerus dapat mempercepat kerusakan komponen.		

ENVIRONMENT	TEMPERATURE	<p><b>Degradasi Komponen:</b> Suhu tinggi dapat mempercepat degradasi komponen elektronik, terutama kapasitor elektrolit. Hal ini juga merujuk pada dampak <b>Perubahan Nilai Komponen:</b> Suhu tinggi dapat menyebabkan perubahan nilai pada komponen-komponen tertentu, mempengaruhi kinerja power supply.</p>	7	<p><b>Ventilasi yang buruk:</b> Jika box app listrik PLN tidak memiliki ventilasi dan sirkulasi udara yang baik, panas yang dihasilkan oleh perangkat lain di dalam box dapat terakumulasi dan meningkatkan suhu. Jika keadaan merujuk pada <b>Suhu lingkungan yang tinggi:</b> Suhu lingkungan yang tinggi ini dapat mempengaruhi suhu di dalam box app listrik PLN. Misalnya pada saat musim kemarau, atau pada saat tersorot panas matahari secara langsung.</p>	7	<p>Tidak ada alat / perangkat pendukung yang dapat mengatasi temperature yang cukup tinggi untuk mengatasi suhu didalam APP</p>
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Failure Mode Potential	DETECTIO	RPN	ACTION RECOMENDED	RESPONSIBILITY PERSON	ACTION TAKEN	SPV SIGN
FREQUENCY OF USE	5	175	<p><b>Penggunaan Timer Eksternal (Time Delay Relay):</b> Ini adalah perangkat yang paling umum digunakan untuk mengontrol waktu operasional perangkat listrik. Penggunaan time delay relay memungkinkan mengatur waktu tunda untuk menghidupkan atau mematikan perangkat. Misalnya perangkat dapat dimatikan menggunakan time relay pada tengah malam hingga pukul 2 pagi, ketika aktivitas modem AMR mungkin paling rendah. Hal ini dapat dilakukan untuk mengistirahatkan perangkat tidak hanya power supply, namun juga modem AMR sehingga beban kerja dapat dikurangi dan memperpanjang umur perangkat.</p>	<p>TECHNICIAN OR ENGGINER</p>	<p>NO ACTION HAS BEEN TAKEN YET</p>	
TEMPERATURE	5	245	<p>Evaluasi dan implementasikan sistem pendinginan aktif blower yang dikontrol suhu, di dalam box APP PLN untuk menjaga suhu internal di bawah batas maksimal yang direkomendasikan untuk power supply AMR.</p>	<p>TECHNICIAN OR ENGGINER</p>	<p>NO ACTION HAS BEEN TAKEN YET</p>	

## Appendix C – Work Instruction for Rework and Repair

### REMOVING OLD CAPACITOR TH

FULL CLINCH WICKING METHOD

Apply flux to the solder joints



Apply wick until the solder is absorbed



Lift the solder and wick from the pad



Clean the area with an IPA cleaner



Lift the old cap TH of pcb slow



Make sure the pads are clean of lead



### INSTALLING NEW CAPACITOR TH

HAND SOLDERING METHOD

Install new cap with the correct position & polarity



Give enough flux to the pad



Heat the pads with the solder tip



Clean the area with the IPA cleaner



Cut off the rest of the capacitor legs.



Apply the tin until it 380°



## Curriculum Vitae



Name : Ikhsan Perdana  
TTL : Pekanbaru, 25 Mei 2003  
Religion : Islam  
Address : Kav. Tg Buntung Baru Blok H.19  
E-mail : ikhsanperdana032@gmail.com  
Educational background  
Elementary School : SDN 012 Bengkong  
Junior High School : SMPN 6 Batam  
Senior High School : MAN 2 Batam