

Analysis of Deviation Values of Electrical Energy Measuring and Limiting Instruments in the Indirect Measuring System of PT PLN UP3 Belitung

Syafira Saharani, Muhammad Erpandi Dalimunthe, Parlin Siagian

Abstract

This study aims to analyze the deviation value of the Measuring and Limiting Device (APP) in the indirect measurement system of medium voltage customers at PT PLN (Persero) UP3 Belitung. Measurements were carried out using two approaches, namely manually using the WS2330 Portable Standard Meter and digitally through the PLN Daily Performance Monitoring (DPM) system. Tests were conducted on industrial customers, namely PT Tommy Utama, PT Timah TBK, and PT Hafidar Sukses Nusantara. The measurement results showed a significant decrease in the deviation value after technical repair actions. Before the repair, the highest deviation value of 3.2% occurred in PT Timah TBK customers. The average deviation value after the repair was within the tolerance limit of SPLN 34-2:2012 ($\pm 0.5\% - 1\%$). In addition, the measurement data were used to build a Random Forest Classifier model to automatically classify APP conditions based on the WS2330 and DPM output parameters. The simulation results showed an accuracy of 83.8% indicating the great potential of applying machine learning in supporting the early detection system for APP deviations. This study recommends the development of a Hybrid Monitoring System based on the integration of field and digital data to improve the reliability of the measurement system at PLN.

Keywords: APP, Measurement Deviation, PLN, Machine Learning, WS2330

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Introduction

Electrical energy is one of the fundamental necessities of modern society, playing a crucial role in supporting economic, social, and technological development [1], [2]. As the national electricity provider, PT PLN (Persero) is responsible for ensuring reliable electricity distribution and accurate recording of energy consumption. This recording process is carried out through the Measuring and Limiting Device (Alat Pengukur dan Pembatas, APP), which serves as the basis for electricity energy transactions between customers and PLN [3].

Accurate APP performance not only ensures fairness for customers in billing processes but also directly contributes to the reduction of energy losses, which represent one of PLN's key performance indicators [4]. Deviations or inaccuracies in APP measurements lead to discrepancies between actual energy consumption and recorded values, potentially resulting in financial losses for both PLN and customers [5]. On a broader scale, undetected and systematic APP deviations may undermine PLN's operational accountability and affect tariff policies as well as long-term energy planning.

Medium-voltage (MV) customer metering systems generally employ indirect measurement methods involving Current Transformers (CTs) and Potential Transformers (PTs) [6]. Although this approach is more practical and safer for high-capacity customers, the use of CTs and PTs introduces additional sources of error within the measurement system [7]. Several factors may contribute to APP deviation, including CT/PT failures that alter current or voltage ratios, installation or wiring errors that lead to measurement mismatches, burdens that do not comply with SPLN standards, and environmental conditions such as high humidity, flooded cubicles, or exposure to extreme temperatures.

Previous studies have emphasized the importance of APP accuracy and the impact of CT/PT errors on measurement results [8], [9]. However, most existing research remains limited to manual analysis using calibration instruments and has not yet integrated data-driven analytical approaches to support early detection of measurement deviations [10], [11].

Advancements in digital technology have enabled real-time collection of customer energy consumption data through Automatic Meter Reading (AMR) systems such as Amicon. The generated data include load profiles, voltage, current, power factor, and event logs, which have significant potential for further analysis to detect anomalies or APP deviations. Nevertheless, in practice, these data have not been optimally utilized for predictive or classification purposes [12].

On the other hand, Machine Learning (ML) methods have been widely applied in power systems, including load forecasting, fault detection, and reliability prediction of distribution networks [13]. The application of ML for detecting APP measurement deviations remains relatively limited, despite its substantial potential to enhance PLN's operational efficiency [14].

Along with the ongoing digitalization of power systems, data from Daily Performance Monitoring (DPM) or Amicon (Automatic Meter Reading) platforms can be leveraged for automatic deviation detection. By employing Machine Learning techniques, historical customer energy consumption data can be analyzed to identify deviation patterns (anomalies) and classify APP operating conditions.

The research problems addressed in this study are formulated as follows:

1. To determine the calculation and measurement of deviation values in the Measuring and Limiting Device (Alat Pengukur dan Pembatas, APP) within an indirect metering system.
2. To evaluate APP performance through field measurements using the WS2330 Portable Standard Meter and digital data analysis obtained from the Daily Performance Monitoring (DPM) system.
3. To identify the causes of measurement errors in APP installed for medium-voltage customers at PT PLN (Persero) UP3 Belitung.

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3. To identify the causes of measurement errors in APP installed for medium-voltage customers at PT PLN (Persero) UP3 Belitung.

Based on these problems, this study aims to analyze the calculation and measurement of APP deviation values in an indirect metering system, to conduct both manual (WS2330-based) and digital (DPM-based) APP testing in order to evaluate measurement accuracy, to identify the technical and data-related factors contributing to APP measurement errors, to apply a Random Forest Classifier algorithm for automatic classification of APP operating conditions, and to develop a Hybrid Monitoring System concept as an early detection mechanism for APP deviation at PLN. Consequently, this research provides a practical contribution to PT PLN (Persero) in enhancing the reliability of its electrical energy metering system.

Literature Review

1.1 Measuring and Limiting Device (APP)

The Measuring and Limiting Device (Alat Pengukur dan Pembatas, APP) is the primary equipment used by PT PLN (Persero) to record customer electrical energy consumption. The APP consists of a kWh meter, a power limiter, a Current Transformer (CT), and a Potential Transformer (PT). For customers with high power demand or medium-voltage levels, an indirect metering system is applied, which relies on CTs and PTs to enable safe measurement of current and voltage values [17]. Sistem Pengukuran Tidak Langsung

1.2 Indirect Metering System

For medium-voltage (MV) customers, an indirect metering system is employed because high current and voltage levels cannot be measured directly by energy meters. Therefore, CTs and PTs are used to step down current and voltage to safe levels for metering equipment. However, mismatched CT/PT ratios, wiring errors, and environmental conditions such as temperature and humidity may introduce measurement deviations. CT errors in the range of 2–3% can significantly affect kWh measurement results. Consequently, routine APP testing is required to ensure that measurement accuracy remains in compliance with SPLN standards.

1.3 APP Measurement Deviation

Measurement deviation refers to the difference between the APP measurement results and the actual electrical energy consumed. The primary causes of deviation include CT/PT failures—such as CT core saturation or winding damage, which alter the current ratio delivered to the meter—installation or wiring errors, including phase or polarity mismatches that may lead to negative or inaccurate power calculations, non-compliant burden conditions in which excessive secondary loads increase measurement error, and adverse environmental conditions such as high humidity, extreme temperatures, or flooded cubicles that affect insulation performance and measurement accuracy. CT errors can impact measurement accuracy by several percentage points, leading to significant implications for energy billing values [6]. Meanwhile, the WS2330 Portable Standard Meter manual explains that portable testing can directly detect kWh and CT deviation errors in the field, thereby supporting technical inspection of APP installations [12].

1.4 APP Testing Using the WS2330 Instrument

The WS2330 Portable Standard Meter is a field testing instrument used by PLN to directly evaluate the accuracy of kWh meters, CTs, and PTs. The WS2330 is capable of detecting installation errors and CT/PT mismatches with high accuracy. The testing procedure includes measurements of current, voltage, power, and power factor, which are then compared against

standard reference values. Despite its effectiveness, this method has limitations, as it is manual in nature and not performed continuously.

1.5 Application of Machine Learning in Metering Systems

Advances in Machine Learning (ML) have created significant opportunities for improving power system management. Previous studies [15] have demonstrated that ML models such as Random Forest and Decision Tree algorithms can identify system fault patterns with high accuracy. In this study, a Random Forest Classifier algorithm is employed to classify APP operating conditions based on PLN’s Daily Performance Monitoring (DPM) data into three categories: Normal, Minor Deviation, and Major Deviation [18], [19].

Research Methodology

The research was conducted within the operational area of PT PLN (Persero) UP3 Belitung. Data were collected using two primary methods:

1. Field measurements using the WS2330 Portable Standard Meter on customers PT Tommy Utama, PT Timah Tbk, and PT Hafidar Sukses Nusantara.
2. Digital data obtained from PLN's Daily Performance Monitoring (DPM) system, including parameters of active energy, load current, voltage, and power factor.

The research stages consisted of the following steps:

1. A literature review covering SPLN 34-2:2012 standards and the fundamental theory of indirect metering systems.
2. Collection of field measurement data and digital monitoring data.
3. Data preprocessing, including the removal of missing values, time alignment, and data verification.
4. Deviation calculation using the following equation:

$$\text{Deviation (\%)} = \frac{E_{\text{actual}} - E_{\text{measured}}}{E_{\text{measured}}} \times 100$$

5. Classification of APP operating conditions into three categories: Normal (<0.5%), Minor Deviation (0.5–1%), and Major Deviation (>1%).
6. Implementation of the Random Forest Classifier algorithm using combined WS2330 and DPM measurement data, with an 80% training set and 20% testing set split.
7. Validation of the classification results using accuracy as the evaluation metric

The research workflow is illustrated in Figure 1, encompassing the stages of literature review, data collection, deviation analysis, implementation of the machine learning model, and result validation.

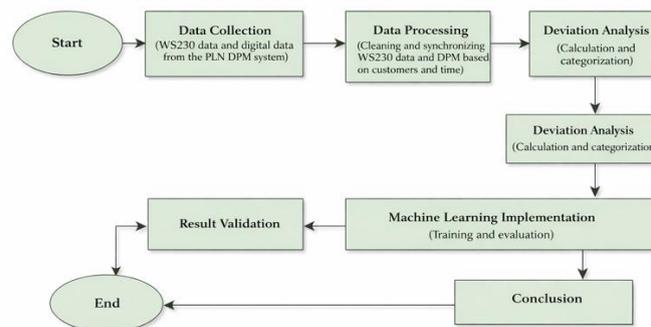


Figure 1. Research Workflow Diagram.

Results

Test Results

The study was conducted within the operational area of PT PLN (Persero) UP3 Belitung, involving three medium-voltage customers: PT Tommy Utama, PT Timah Tbk, and PT Hafidar Sukses Nusantara.

1. PT Tommy U***

a. Monthly kWh Consumption Analysis (DPM Monitoring)

The DPM monitoring results indicate that this customer experienced a 39% decrease in monthly kWh consumption compared to the previous six months. The kWh consumption data are presented in Figure 2.

NAMA	TARIF	DAYA	PEM KWH (MON DPM)											
			JAN	FEB	MAR	APR	MEI	JUN	JUL	PERSEN				
PT MEHADA ***	I3	277000	326400	312000	250000	266100	702200	787100	752200	-39%				
SWP KERNEL ***	I3	1730000	329340	338040	322780	279730	364720	529000	578750					
PT KURNIA ***	I3	1110000	178520	158920	183100	152560	196180	175180	202100	10%				
PT INDRAMAJUR ***	I3	1110000	192720	171884	113056	87938	129216	166368	171696	31%				
PT TIMAH P ***	I3	3050000	168800	154100	171460	131260	263760	144800	168740					
PT HAFIDAR ***	I3	555000	109824	111088	159104	139672	84120	98920	138528	1%				
RSU ***	S3	345000	113264	111880	120632	114776	138084	132288	135304	1%				
PT TIMAH ***	I3	1110000	83804	101728	123792	111392	28384	103744	56422	-14%				
PT CIPUK ***	I3	1110000	288020	179360	156456	158496	212080	170704	90784	-18%				
PT WIDA ***	I3	555000	118496	59152	151784	181080	211944	73912	81048	-44%				
PABRIK ***	I3	555000	0	10304	88800	61384	76416	78416	68224	-3%				
PT BELITUNG ***	I3	1110000	124064	118954	101576	32718	57904	53192	48864	7%				
PT SWP ***	I3	555000	35800	25176	37712	20160	25080	38824	41872	2%				
CV BELTIM ***	I3	690000	83800	98488	123280	39938	4720	12784	32120	50%				
POMPA PT ***	I3	345000	32488	23728	26788	14884	27036	27644	28864	10%				
PT TOMMY ***	I3	240000	0	0	0	0	0	0	0	-99%				
PT ALFRIGO ***	I3	1110000	0	0	0	0	1832	4580	12336	100%				
PT BAREL ***	I3	240000	8000	8140	8000	7140	8180	7980	7460	-20%				
PT ANTASENA ***	I3	345000	0	0	0	0	0	0	1480	-				
PROCESING ***	I3	240000	0	0	0	0	0	0	1096	-				
PT KARYA ***	I3	1110000	0	0	0	0	0	0	0	-				

Figure 2. Monthly kWh Consumption (DPM Monitoring) of PT Tommy U* **

b. AMR Reading Inspection Using the Amicon Application

Based on the AMR readings obtained through the Amicon application, an anomaly was identified in the secondary current of the kWh meter, where the recorded secondary current value was zero (0). The AMR reading results for customer PT Tommy* are presented in Figure 3.

Time	Meter	Date	V1	V2	V3	I1	I2	I3	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
01:00:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:05:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:10:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:15:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:20:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:25:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:30:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:35:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:40:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:45:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:50:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:55:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:00:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:05:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:10:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:15:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:20:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:25:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:30:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:35:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:40:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:45:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:50:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:55:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:00:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:05:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:10:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:15:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:20:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:25:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:30:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:35:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:40:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:45:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:50:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:55:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04:00:00	PT TOMMY	2023-07-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3. AMR Reading Results from the Amicon Application

c. APP Testing through On-Site Measurements Using Measuring Instruments

On 26 July 2023, an inspection was conducted using the WS2330 Portable Standard Meter to identify the cause of the secondary current mismatch with the multiplication factor. The inspection covered the APP system, the PLN-side cubicle, as well as the condition of the equipment and building facilities. The results are presented in Figure 4.

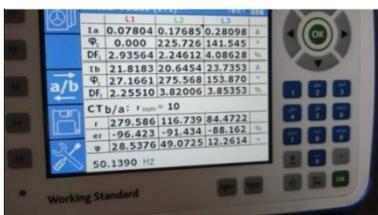


Figure 4. Results of CT Error Inspection on Customer APP

The measurement results indicate significant CT errors, namely -96.423% (R phase), -91.434% (S phase), and -88.162% (T phase). The corresponding primary currents were 21.8183 A, 20.6454 A, and 23.7353 A, while the secondary currents were 0.07804 A, 0.17685 A, and 0.28098 A, respectively. The CT ratio applied was 50/5. The error calculation is presented in the following equation.

$$Error\ CT = \frac{(Kt \times Is) - Ip}{Ip} \times 100 = \% \dots\dots\dots(1)$$

Dimana Kt adalah Ration CT = 10

- $Error\ CT\ Phasa\ R = \frac{((10 \times 0,07804) - 21,8183)}{21,8183} \times 100 = \% \dots\dots\dots(2)$

$$Error\ CT\ Phasa\ R = \frac{(0,7804 - 21,8183)}{21,8183} \times 100 = \% \dots\dots\dots(3)$$

$$Error\ CT\ Phasa\ R = (-0,96423) \times 100 = \% \dots\dots\dots(4)$$

$$Error\ CT\ Phasa\ R = -96,423\%$$

- $Error\ CT\ Phasa\ S = \frac{((10 \times 0,17685) - 20,6454)}{20,6454} \times 100 = \% \dots\dots\dots(5)$

$$Error\ CT\ Phasa\ S = \frac{(1,7685 - 20,6454)}{20,6454} \times 100 = \% \dots\dots\dots(6)$$

$$Error\ CT\ Phasa\ S = (-0,91894) \times 100 = \% \dots\dots\dots(7)$$

$$Error\ CT\ Phasa\ S = -91,894\%$$

- $Error\ CT\ Phasa\ T = \frac{((10 \times 0,28098) - 23,7353)}{23,7353} \times 100 = \% \dots\dots\dots(8)$

$$Error\ CT\ Phasa\ T = \frac{(2,8098 - 23,7353)}{23,7353} \times 100 = \% \dots\dots\dots(9)$$

$$Error\ CT\ Phasa\ T = (-0,881619) \times 100 = \% \dots\dots\dots(10)$$

$$Error\ CT\ Phasa\ T = -88,1619\%$$

Accordingly, the average CT error for this customer was -92.0063%. Visual inspection revealed that the PLN-side cubicle ducting was flooded and corroded, and the cubicle CT was burnt and cracked. These conditions are illustrated in Figure 5.



Figure 5. Flooded Cubicle Ducting and Burnt, Physically Cracked CT on the PLN-Side Cubicle

- Corrective Actions for Customer PT Tommy*

1. Replacement of the CT in accordance with the installed CT ratio, as shown in the figure below.

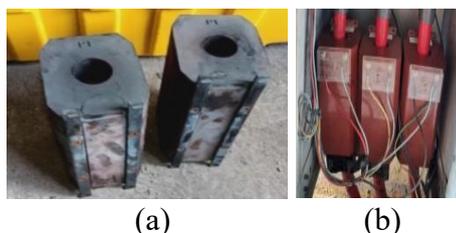


Figure 6. (a) CT condition before replacement, (b) newly installed CT after replacement

2. Rehabilitation of the cubicle room by draining the accumulated water around the cubicle ducting and renovating the cubicle room. The rehabilitation process of the cubicle room is shown in the figure below.



Figure 7. The process of draining the accumulated water around the cubicle ducting

● Results of Monthly kWh Consumption Inspection (DPM Monitoring)

The monthly kWh consumption of PT Tommy* after the corrective actions is shown in Figure 8.

NAMA	TARIF	DAYA	PEM KWH (MON DPM)							AVERAGE	PERSEN	STATUS
			AGT	SEPT	OKT	NOV	DES	SELISIH				
SWP KERNEL ***	IS	1730000	582400	234180	403080	417020	373540	69560	396089	-15%	RATA-RATA NORMAL	
PT KURNIA ***	IS	1110000	202560	209480	196220	0	196960	28920	176223	-5%	RATA-RATA NORMAL	
PT INDOMAKMUR ***	IS	1110000	115904	175072	280256	287136	172056	5328	147668	NAK		
PT TIMAH ***	IS	1385000	176020	171520	171380	198320	189140	17260	172246	-10%	RATA-RATA NORMAL	
PT. HAFIDAR ***	IS	555000	129240	108184	91844	15816	3000	37668	119884	27%	RATA-RATA NORMAL	
RSU ***	S3	345000	143732	136028	133004	125020	124828	3016	123747	175%	NAK	
PT TIMAH ***	IS	1110000	145208	146240	140128	146856	144752	-11312	92197	14%	RATA-RATA NORMAL	
PT DPOH ***	IS	1110000	35224	74752	134888	193808	184144	-79520	178858	24%	RATA-RATA NORMAL	
PT. WIDA ***	IS	555000	178468	200144	193084	70152	94488	7136	125345	10%	RATA-RATA NORMAL	
PABRIK ***	IS	555000	70968	85848	73168	75744	88776	-10192	53649	104%	NAK	
PT BELTUNG ***	IS	1110000	66904	69240	73888	132112	125408	-4528	76679	23%	RATA-RATA NORMAL	
PT SWIP ***	IS	555000	43576	37024	33904	42536	46104	8040	37318	120%	NAK	
CV. BELTI ***	IS	890000	72652	108400	158152	184096	98872	18336	58447	6%	RATA-RATA NORMAL	
POMPA PT ***	IS	345000	21700	30748	50272	46944	33928	-780	25633	131%	NAK	
PT TOMMY ***	IS	885000	11220	81600	8680	175880	228240	-15760	28180	197%	NAK	
PT BABEL ***	IS	240000	8400	7660	6480	7920	6540	-520	7843	240%	NAK	
PT ANTASENA ***	IS	345000	7424	27616	30004	69880	89880	1468	210	513%	NAK	
PROCESING ***	IS	240000	3912	5984	8048	10264	5324	1096	157	174%	NAK	
PT KARYA ***	IS	1110000	0	0	0	32	1776	0	0	-	RATA-RATA NORMAL	

Figure 8. Monthly kWh Consumption (DPM Monitoring) of PT Tommy*

Based on the DPM monitoring results shown above, the customer’s monthly kWh consumption increased by up to 197% after corrective actions were implemented on the field-installed equipment.

2. PT Tima* T**

a. Monthly kWh Consumption Inspection (DPM Monitoring)

DPM monitoring shows a decrease in monthly kWh consumption in May 2023 to 28,000 kWh, down from the previous average of 100,000 kWh per month. The data are presented in Figure 9.

NAMA	TARIF	DAYA	PEM KWH (MON DPM)				
			JAN	FEB	MAR	APR	MAY
SWP KERNEL ***	IS	1730000	328440	388040	332760	279760	364720
PT KURNIA ***	IS	1110000	178520	158820	183120	152560	198160
PT INDOMAKMUR ***	IS	1110000	187280	171884	133688	178760	226240
PT TIMAH ***	IS	1385000	168880	154180	171480	131280	263760
PT. HAFIDAR ***	IS	555000	109824	111088	189184	139872	84120
RSU ***	IS	345000	113284	111880	128820	114784	130884
PT TIMAH ***	IS	1110000	28828	19128	12072	2436	2836
PT DPOH ***	IS	1110000	28828	179360	184488	158488	212880
PT. WIDA ***	IS	555000	118488	8932	151784	130188	211844
PABRIK ***	IS	555000	0	10304	8880	8136	7848
PT BELTUNG ***	IS	1110000	124904	118884	101576	32788	17564
PT SWIP ***	IS	555000	34960	35176	27112	30160	10180
CV. BELTI ***	IS	890000	8300	86488	13320	38936	4720
POMPA PT ***	IS	345000	32488	22728	26788	14884	2708
PT TOMMY ***	IS	885000	0	8640	3880	4268	4208
PT BABEL ***	IS	240000	8000	8140	8000	7140	8180
PT ANTASENA ***	IS	345000	0	0	0	0	0
PROCESING ***	IS	240000	0	0	0	0	0
PT KARYA ***	IS	1110000	0	0	0	0	0

Figure 9. DPM Monitoring

b. AMR Reading Inspection via the Amicon Application

The AMR readings obtained via the Amicon application (Figure 10) indicate an undervoltage anomaly, characterized by the loss of voltage in the R phase with a recorded kWh voltage value of zero.

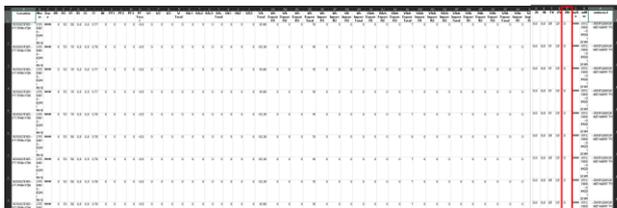


Figure 10. Instant Data Display from AMR Readings in the Amicon Application Showing Zero Voltage on the R Phase

c. On-Site APP Inspection

On 27 June 2023, the inspection results indicated an R-phase voltage of 0 V and a current of 0.77 A, as shown in Figure 11



(a) (b) (c)

Figure 11. (a) Vr, (b) Vs, (c) Vt



(a) (b) (c)

Figure 12. (a) Arus Phasa R, (b) Arus Phasa S, (c) Arus Phasa T

Test Results Using the Calibration Test Instrument Before Corrective Actions

After testing with the kWh calibration test instrument, the measured R-phase voltage was 11.01 V, the S-phase voltage was 49.73 V, and the T-phase voltage was 49.42 V. The kWh measurement results obtained using the calibration test instrument are shown in Figure 13 below.

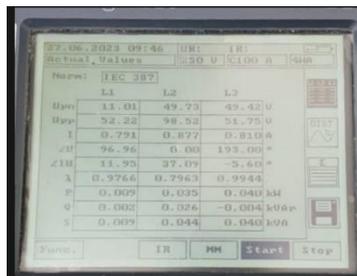


Figure 13. kWh Meter Test Results for PT Timah*

Physical Inspection Results for PT Timah***

The inspection process included examination of the CTs and PTs in the cubicle, wiring configuration, and the physical condition of each component. The inspection process is shown in the figure below.

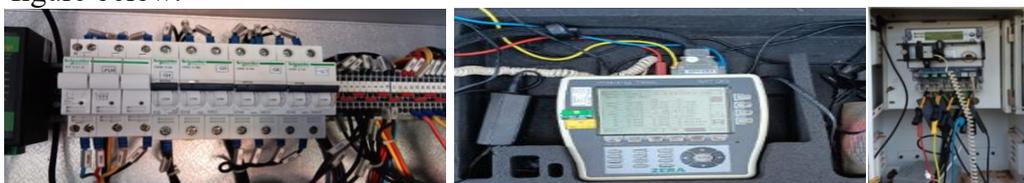


Figure 14. Inspection of Customer PT Timah***

The R-phase voltage loss was caused by the VT output cable becoming detached from the MCB bolt. In the Schneider cubicle, the VT cable supplying the kWh meter passes through a terminal block and an MCB; therefore, when the cable became detached, the voltage at the kWh meter was also lost. The configuration is illustrated in the following single-line diagram.

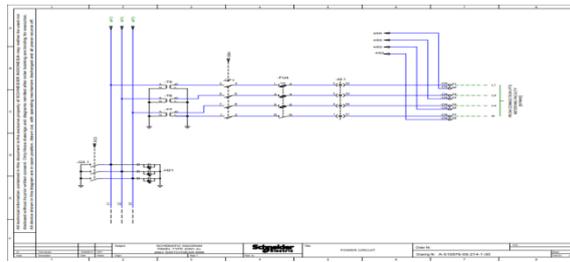


Figure 15. Single Line Diagram Wiring Kubikel Schneider

Corrective Actions for Customer PT Timah***

1. The cable that had become detached from the MCB bolt was reconnected, restoring the voltage supply to the kWh meter to normal conditions. The test results indicate that the R-phase voltage has returned to normal, as shown in **Figure 16**.



Figure 16. Measurement Results After Corrective Actions

Simulation of Measured Power and Meter Error Calculation for PT Timah***



Figure 17. Simulation of kWh Error Calculation After Corrective Actions

Normal Condition: Power Measured at the kWh Meter:

$$Pr = Vr \times Ir \times \text{COS } \varphi_r = 58,10 \times 0.803 \times 0.969 = 45,23 \text{ W} \dots\dots\dots (4.16)$$

$$Ps = Vs \times Is \times \text{COS } \varphi_s = 58,93 \times 0.853 \times 0.961 = 48,29 \text{ W} \dots\dots\dots (4.17)$$

$$Pt = Vt \times It \times \text{COS } \varphi_t = 58,5 \times 0.8024 \times 0.95 = 44,59 \text{ W} \dots\dots\dots (4.18)$$

Jumlah = 138,11W

Phase R Voltage Condition 0 (Zero), Power Measured on the kWh Meter:

$$Pr = Vr \times Ir \times \text{COS } \varphi_r = 0 \times 0.8034 \times 0.969 = 0 \text{ W} \dots\dots\dots (4.6)$$

$$Ps = Vs \times Is \times \text{COS } \varphi_s = 49.73 \times 0.8528 \times 0.961 = 40,75 \text{ W} \dots\dots\dots (4.7)$$

$$Pt = Vt \times It \times \text{COS } \varphi_t = 49.42 \times 0.8024 \times 0.95 = 37,67 \text{ W} \dots\dots\dots (4.8)$$

Jumlah = 78,42 W

Measured Power

$$P = \frac{78,42}{138,11} \times 100\% = 56,78 \% \dots\dots\dots (4.19)$$

Error

$$E = \left(\frac{78,42}{138,3} - 1 \right) \times 100 \% = -43,21 \% \dots\dots\dots (4.20)$$

Comparison of kWh Consumption Before and After Repair

NAMA	TARIF	DAYA	PEM KWH (MON DPM)												STATUS
			MEI	JUN	JUL	AGT	SEPT	OKT	NOV	DES	SELISIH	AVERAGE	PERSEN		
SVP KERNEL ***	G	1730000	364720	508200	578760	582400	234100	403080	417020	373540	69560	396009	-35%	RATA-RATA NORMAL	
PT KURNIA ***	G	1110000	198180	175180	202100	202560	203480	198220	#N/A	198960	26920	178223	-5%	RATA-RATA NORMAL	
PT RUDOMAKMUR ***	G	1110000	129216	166368	171696	115904	175872	200256	287136	172096	5328	147568	34%	NAK	
PT. TIMAR ***	G	1385000	263760	148480	186740	176020	171520	171360	195320	189140	17280	172246	-33%	RATA-RATA NORMAL	
PT. HAFIDAR ***	G	555000	84120	86920	138528	128340	108384	91944	15916	3000	37608	118994	27%	RATA-RATA NORMAL	
RSB ***	S3	345000	130904	132208	135304	143732	138032	133004	125020	134828	3916	123747	17%	NAK	
PT TIMAH ***	G	1110000	28328	127344	62432	148208	146560	146128	166928	146792	-17132	32107	14%	RATA-RATA NORMAL	
PT. DIPOH ***	G	1110000	212880	170704	90784	38224	74752	134856	192008	184144	-79820	178658	28%	RATA-RATA NORMAL	
PT WIDIA ***	G	555000	211944	73912	81048	179488	200144	182884	70152	94488	7136	125345	10%	RATA-RATA NORMAL	
PABRIK ***	G	555000	78416	78416	88224	78968	85840	73168	75744	80776	-18182	53848	16%	NAK	
PT BELTUNG ***	G	1110000	57904	53192	48664	66904	89240	73888	132112	125408	-4528	76679	-23%	RATA-RATA NORMAL	
PT SWP ***	G	555000	35880	38824	47672	43576	37024	33904	42536	46104	8848	37316	12%	NAK	
CV. BELTIM ***	G	690000	4720	12784	32120	72552	109400	158152	184096	98872	19336	56447	5%	RATA-RATA NORMAL	
POIMPA PT ***	G	345000	27036	27644	28664	21700	30748	50272	48944	33928	-780	25633	13%	NAK	
PT TOMMY ***	G	885000	42000	41060	25300	11220	81600	8680	175880	228240	-15760	28180	19%	NAK	
PT BABEL ***	G	240000	8180	7980	7460	8400	7660	8480	7920	6540	-520	7843	240%	NAK	
PT ANTASENA ***	G	345000	0	0	1488	7424	27616	30004	69880	89800	1488	210	573%	NAK	
PROCESING ***	G	240000	0	0	1096	3912	5984	8848	10264	5324	1096	157	174%	NAK	
PT KARVA ***	G	1110000	0	0	0	0	0	0	32	1776	0	0	-	RATA-RATA NORMAL	

Figure 18. Monthly kWh Consumption Monitoring (DPM Monitoring) After Repair

From the figure above, a significant change in the monthly kWh consumption of this customer can be observed. In month 5, PT Timah***'s kWh consumption was only 28,000 kWh after the repair. In the following months, the kWh consumption increased considerably, remaining above 100,000 kWh per month. The test results are presented in Table 1.

Table 1. The Test Results

No	Customer Name	Deviation Before (%)	Deviation After (%)	Technical Notes
1	PT Tommy U**	2.5	0.3	CT malfunction occurred; current transformer replaced.
2	PT Timah ***	3.2	0.4	Broken cable on the VT output side; cable reconnected..
3	PT Hafidar Nusantara	1.8	1.5	Values within tolerance limits; no repair performed.

The test results indicate that the deviation values before repair were relatively high (>2%), suggesting the presence of energy measurement errors. After the repair, all customers showed a significant reduction in deviation to below 2%, indicating that the APP (energy metering device) had returned to accurate operation. These findings suggest that common errors in the APP are caused by:

- CT/PT transformer damage, resulting in disproportionate current and voltage readings.
- Disconnected cables on the VT output side, causing active energy to go unrecorded.
- Phase load imbalance, which affects power and power factor (cos φ) values.

Grafik Deviasi Pengukuran Sebelum dan Sesudah Perbaikan

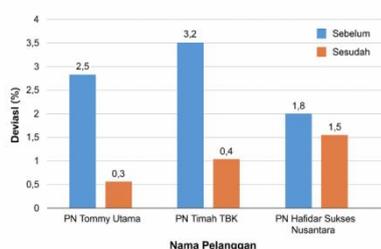


Figure 19. Measurement Deviation Graph Before and After Repair

Classification Analysis Using Machine Learning

To support the technical analysis, this study applies the Random Forest Classifier algorithm in the classification of APP (Energy Metering and Limiting Device) conditions. The purpose of

applying this model is to identify measurement deviation conditions based on digital data from PLN's Daily Performance Monitoring (DPM) system. The results of the Machine Learning model testing are shown in Figure 20 below.

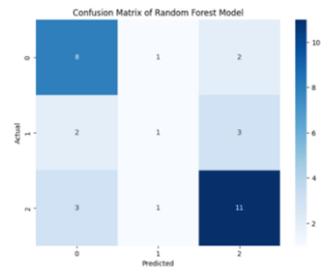


Figure 20. Confusion Matrix of APP Condition Classification Results (Random Forest Classifier)

The measurement data were used to train the Random Forest Classifier model. This model classifies APP conditions into three categories: Normal, Minor Deviation, and Major Deviation. The training results yielded an accuracy of 83.8%, a precision of 0.91, a recall of 0.89, and an RMSE of 0.42. These results demonstrate the potential of machine learning to assist PLN in implementing a DPM-based early warning system.

Conclusion

Based on the research results, it can be concluded that APP testing using WS2330 and PLN's DPM data provides consistent outcomes. After technical repairs were performed, all customers showed a significant reduction in deviation, bringing the values within the SPLN 34-2:2012 tolerance limits. The application of the Random Forest Classifier was able to automatically classify APP conditions with an accuracy of up to 83.8%. This approach can be further developed into a Hybrid Monitoring System, an integrated monitoring system combining field measurements and DPM digital data, to detect deviations early and support predictive maintenance of APP at PLN.

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