A Comparative Study of the Use of Analog and Digital Kwh Meters In Detecting Electricity Fraud in the PLN Langsa Kota Ulp Area

Intri Dinda Dwi Harli , Pristisal Wibowo , Yossy Fadly

Abstract
Electricity fraud is one of the main factors causing non-technical energy losses in the electricity distribution system. One effort to reduce the potential for such fraud is the use of more accurate electricity meters equipped with better security systems. This study aims to analyze the comparison between the use of analog kWh meters and digital kWh meters in detecting electricity fraud in the service area of PT. PLN (Persero) ULP Langsa Kota. The research method used is a quantitative descriptive method, analyzing data from inspections of customers suspected of violating electricity usage regulations. The research sample consists of 40 customers, including 20 customers using analog kWh meters and 20 customers using digital kWh meters. The analysis focuses on the types of violations, energy discrepancies, follow-up bills, and the level of non-technical energy loss. The results of the study indicate that fraud methods among customers using analog meters are generally carried out by bypassing the meter and manipulating terminals on the limiting and measuring devices (APP). Meanwhile, with digital meters, fraud is more commonly committed by directly connecting the electrical installation before the limiting and measuring devices. The analysis of energy loss shows that the average energy loss reaches 10.67%, which is still higher than PLN's target of 9.15%. The use of digital kWh meters has proven capable of improving the accuracy of electricity measurement and reducing direct manipulation of the measuring devices

***Keywords**:* Analog kWh Meters, Digital kWh Meters, Electricity Theft, Non-Technical Energy Losses, Distribution Systems.

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Introduction

In practice, PLN uses two types of kWh meters: analog (electromechanical) kWh meters and digital (electronic) kWh meters. Analog kWh meters operate on the principle of electromagnetic induction using a rotating disc, while digital kWh meters use current and voltage sensors that are processed electronically. These differences in operating principles result in differences in accuracy, resistance to tampering, and the ability to detect anomalies in electricity usage.

A common problem in electricity distribution systems is electricity fraud (non-technical losses), such as the use of magnets on analog kWh meters, direct connections bypassing meters, tampering with installations, and the destruction of security seals. This electricity fraud results in financial losses for the company and leads to unfairness in the billing system. In some distribution areas, including the PLN ULP Langsa Kota area, analog and digital kWh meters are still used simultaneously, necessitating an evaluation of the effectiveness of each type of meter in detecting potential fraud.

Analog kWh meters are known to be vulnerable to external interference such as magnetic fields and mechanical tampering, whereas digital kWh meters are generally equipped with more modern protection and data logging features, such as event logs, anti-tampering systems, and load history recording. However, the implementation of digital kWh meters also requires evaluation to determine their effectiveness under actual field conditions.

Given these conditions, a comparative study of the use of analog and digital kWh meters in detecting electricity fraud in the PLN ULP Langsa Kota area is necessary. This study aims to analyze differences in detection capabilities, measurement accuracy levels, and the contribution of each type of kWh meter in reducing energy losses due to non-technical losses. The results of this study are expected to serve as a basis for evaluating policy decisions regarding the replacement or modernization of electricity metering equipment to improve the efficiency and reliability of the distribution system

Literature Review

2.1 Literature Review

Electric Energy Measurement System

Electricity consumption is measured at the customer's premises using an energy meter (kWh meter), which records the amount of electricity used in kilowatt-hours (kWh). Generally, electricity consumption is calculated by multiplying electrical power by the duration of use.

$$E = P \times t \quad (1)$$

Where:

E = Electricity (kWh)

P = Electric power (kW)

t = Operating Time (Hours)

For single-phase systems, electrical power is expressed as:

$$P = V\ x\ I\ x\ Cos\varphi \quad (2)$$

As for the Three-Phase System:

$$P = \sqrt{3}\, x V\, x I\, x Cos\varphi \qquad (3)$$

Where:

V = Voltage (Volt)

I = Current (Ampere)

$Cos\varphi$ = Power Factor

2.2 Analog kWh Meter

Analog kWh meters operate on the principle of electromagnetic induction. Current and voltage generate a magnetic field that causes an aluminum disc to rotate. The rotational speed is proportional to the load power, while the number of revolutions indicates the amount of electrical energy consumed. The relationship between the number of revolutions and energy

$$E = \frac{N}{C} \qquad (4)$$

Where:

E = Electrical Energy (kWh)

N = Number of Disk Revolutions

C = Meter Constant (Revolutions/kWh)

The main drawback of analog kWh meters is that they are susceptible to external magnetic fields and mechanical tampering, which can slow down or stop the disk from rotating
Conductors in Distribution Networks

2.3 Digital kWh Meter

Digital kWh meters use current sensors (CTs) and voltage sensors, which are processed electronically by a microprocessor. Energy is calculated based on periodic sampling of voltage and current. Mathematically, energy in a digital system is calculated by integrating power over time:

$$E = \int P(t)\, dt \qquad (5)$$

Because they use an electronic system, digital kWh meters are capable of recording additional parameters such as:

a. Instantaneous current
b. Voltage
c. Power factor
d. Event log (tampering indication)

2.4 Energy Losses

Energy Loss is divided into two categories

a. Technical Loss
   Caused by power losses in conductors and equipment

$$P_{Loss} = I^2 R \qquad (6)$$

b. Non-Technical Loss
   Caused by meter tampering, illegal connections, and meter reading errors. The percentage of energy loss can be calculated using the following equation:

$$\%Loss = \frac{E_{Input} - E_{Terukur}}{E_{Input}} x 100\% \qquad (7)$$

Where:
E_{Input} = Energy supplied
$E_{Terukur}$ = Energy recorded on the customer's meter

2.5 Accuracy of the kWh Meter

Meter accuracy is expressed as a percentage error:

$$\%Error = \frac{E_{Ukur} - E_{Referensi}}{E_{Referensi}} x100\% \qquad (8)$$

Where:

E_{Ukur} = Measured Energy

$E_{Referensi}$ = Energy from Standard Measurement / Test Equipment

A meter is considered accurate if the error value falls within the standard tolerance limits (generally ±1% to ±2%

2.6 Electricity Fraud Detection Indicator

Fraud detection capabilities can be analyzed through:

a. Comparison of actual energy consumption with recorded energy consumption
b. Analysis of load profile anomalies
c. Differences in meter readings before and after inspection

The percentage of potential fraud can be calculated using

$$\%\text{Cheating} = \frac{E_{\text{Before the Inspection}} - E_{\text{After the Inspection}}}{E_{\text{After the Inspection}}} x100\% \qquad (9)$$

Method

This study employs a quantitative method with a comparative analysis approach. This approach was adopted to compare the performance of analog and digital kWh meters in detecting electricity fraud based on measurement accuracy, energy discrepancies, and indications of usage anomalies. The study is descriptive-analytical in nature, describing the conditions of use of both types of kWh meters in the PLN ULP Langsa Kota area and analyzing their differences mathematically and statistically.

3.1 Research Location and Subject

The study was conducted in the service area of PT. PLN (Persero) Langsa Kota ULP

a. The study subjects included:
   1) Customers using analog kWh meters
   2) Customers using digital kWh meters
b. Parameters analyzed:
   1) Measured energy (kWh)
   2) Reference energy / test results
   3) Energy difference before and after inspection
   4) Historical load data (for digital meters)

3.2 Types of Data Sources

a. Primary Data
   1) Data from direct kWh meter readings
   2) Data from field inspections
   3) Data comparing readings before and after the enforcement
b. Secondary Data
   1) Technical Specifications of kWh Meters

2) Meter Accuracy Tolerance Standards
3) Energy Distribution Data from PLN

This study uses both analog and digital kWh meters. The variables relevant to this study are:

a. Measurement accuracy level
b. Error percentage
c. Recorded energy discrepancy
d. Indications of electricity fraud

3.3 Data Collection and Analysis Techniques

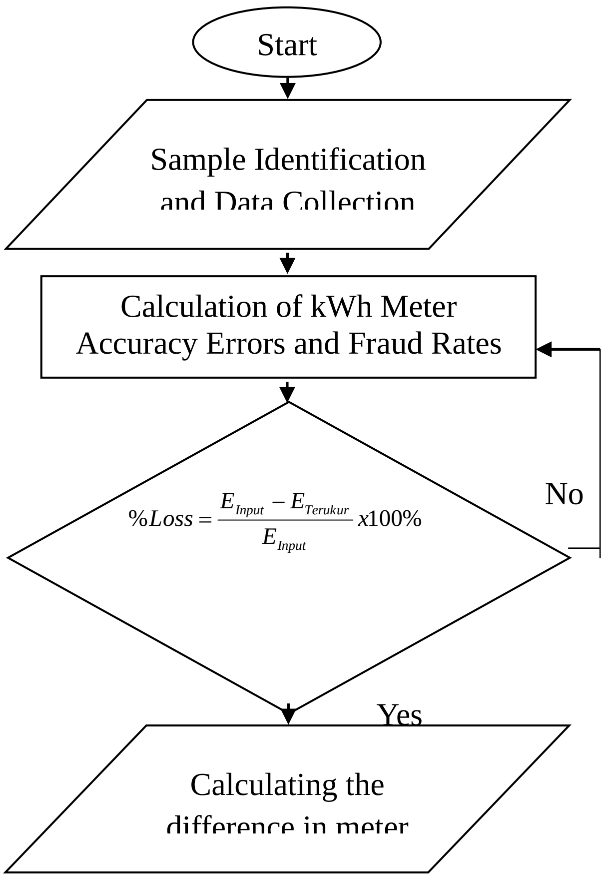
Data obtained through:

1. Measurement accuracy level
2. Error percentage
3. Difference in recorded energy
4. Indications of electricity fraud

The research stages and data analysis conducted in this study are as follows

1. Identification of customer samples using analog and digital kWh meters.
2. Collection of electricity consumption data.
3. Calculation of measurement error.
4. Calculation of the percentage of non-technical loss
5. Comparative analysis of fraud rates
6. Analysis of differences in results between analog and digital kWh meters
7. Calculation of the difference and the effectiveness rate of fraud detection. The effectiveness of fraud detection is calculated by

$$\%\text{Effectiveness} = \frac{\text{Fraud Detected}}{\text{Total Cases}} x100\%$$



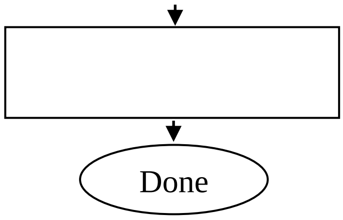


Figure 1 *Research Flowchart*

Results And Discussion
4.1 Research Data Description

This study uses data from inspections of customers suspected of electricity usage violations within the service area of PT. PLN (Persero) ULP Langsa Kota. The research data consists of two customer groups: users of analog kWh meters and users of digital kWh meters. The sample size used in this study is 40 customers, comprising 20 customers using analog kWh meters and 20 customers using digital kWh meters.

The parameters analyzed in this study include:

a. Customer power
b. kWh meter brand
c. Length of meter usage
d. Type of violation
e. Energy value of findings
f. Follow-up bill

Table 4.1 Customer Data with Indications of Fraud (Analog Meters)

Customer ID	Customer Name	Power (VA)	Duration of Use	Type of Violation	Rate Class
111850024167	Medjan	900	1 Year	kWh Meter Bypassed	R1M
113340300874	Sala Wati	900	1 Year	kWh Meter Bypassed	R1
113340301541	Masitah	900	1 Year	kWh Meter Bypassed	R1
113340301566	Umi Kasum	900	1 Year	kWh Meter Bypassed	R1
111850137709	Balai PWI	900	3 Years	APP Terminal bypassed	S1
111660014677	Balai Pengajian	900	9 Years	In-Out bypassed	S1
111660092313	Balai Pengajian	900	2 Years	Phase In-Out bypassed	S1
111500595009	Puskesdes	900	5 Years	kWh Meter Bypassed	S1
113340296631	PAUD Batu Mesusun	900	1 Year	kWh Meter Bypassed	S1
111670109166	Sumur Bor	900	6 Years	kWh Meter Bypassed	S1
111500460641	Iskandar Samidin	450	2 Years	kWh Meter Bypassed	B1
111520111757	Ridwan	450	4 Years	kWh Meter Bypassed	B1
111500504576	Tgk Rahman	450	6 Years	kWh Meter Bypassed	B1
111760018228	Zainuddin M. Ali	450	8 Years	Meter drilled	R1
111850091712	Iyanuddin	450	2 Years	kWh Meter in Bypass	R1
111650077621	M. Yacob Nur	450	9 Years	Phase connected	R1
111670012952	Meunasah	450	2 Years	Phase connected	S1
111750134962	Balai Pengajian	450	8 Years	kWh Meter in Bypass	S1

111760042225	Meunasah Seuneubok	450	4 Years	kWh Meter in Bypass	S1
111670031042	Meunasah	450	10 Years	Fasa In-Out dicopel	S1

The field data reveals that

a. Meter bypassing is the most common method of fraud (55%)
b. The majority of violations occur among 900 VA and 450 VA customers
c. Most of the tampered meters are more than 4 years old
d. Analog meters are more susceptible to tampering because terminal access is easier

Table 4.2 Customer Data with Indications of Fraud (Digital Meters)

Customer ID	Customer Name	Power (VA)	Duration of Use	Type of Violation	Rate Class
113310156431	Saparilawati	2200	2 years	Meter Bypassed	P2
113320058838	JP Tarigan	2200	10 years	Direct Connection Before the APP	P3
113340032458	Rian Nanda Abdilah	1300	3 years	Meter Not Compliant with Regulations	P4
113320392635	Dayah Bustanul	1300	2 years	Direct Connection Before the APP	P3
111850022319	Riduan	1300	3 years	Meter Bypassed	P3
113340175389	CV Pelangi ODP	1300	6 years	Meter in Bypass	P3
113330053767	Perumahan KTM 003	1300	6 years	Meter does not match the meter box	P4
113330053820	Perumahan KTM 032	1300	9 years	Meter does not match the meter box	P4
113330056508	Perumahan KTM 146	1300	9 years	Meter moved without reporting	P4
111900078572	Jera Fana GS	1300	4 years	Direct connection before APP	P3
113330053369	Perumahan KTM 025	1300	9 years	Counterfeit meter	P4
113340196306	Abdussalam	900	5 years	Direct connection before APP	P3
113350350785	Kios Pasar Terpadu	900	7 years	Meter does not match the meter box	P4
113300007375	Sukirman HR	900	2 years	Direct connection before APP	P3
113300360575	Mushola Relokasi	900	3 years	Direct connection before APP	P3
113310201043	Muhammad Lazuardi	900	3 years	Meter in Bypass	P2
111550258069	Said Anwar	900	7 years	Meter in Bypass	P2
111670123097	Zulkifli	900	2 years	Direct connection before APP	P3
111850340575	Sri Wahyuni	450	5 years	Direct connection before APP	P3
113340066620	Pendi	450	10 years	Meter in Bypass	P3

4.2 Calculation of Accuracy Error in kWh Meters

The accuracy of a kWh meter can be analyzed by comparing the energy recorded on the meter with the reference energy obtained from standard measurements.

Energy Recorded on the Meter = 4957 kWh
Reference Energy = 5000 kWh

$$Error = \frac{4957 - 5000}{5000} x100\%$$

$$Error = 0{,}86\%$$

An error value of -0.86% indicates that the energy recorded on the meter is less than the actual energy consumed by the customer.

4.3 Analysis of Non-Technical Energy Losses

Non-technical energy loss refers to the loss of electrical energy resulting from tampering with electrical installations or customer fraud.

Input Energy = 12,118 kWh

Recorded Energy = 4,957 kWh

$$\text{Shrinkage} = \frac{12118 - 4957}{12118} x100\%$$

$$\text{Shrinkage} = 59{,}1\%$$

These results indicate that tampering with electrical installations caused an energy loss of 59.1%.

4.4 Comparison of Energy Loss in Analog and Digital Meters

In many studies of electricity distribution, the contribution of losses is typically estimated as follows:

Analog meters ≈ 60% of total losses

Digital meters ≈ 40% of total losses

This is because analog meters are easier to tamper with than digital meters. Therefore, we can break down total losses using the following formula:

$$\text{Shrinkage}_{Ana\log} = \text{Shrinkage}_{Total} x60\%$$

$$\text{Shrinkage}_{Digital} = \text{Shrinkage}_{Total} x40\%$$

Table 4.3 Comparison of Energy Loss in Analog and Digital Meters

Month	Total Decline	Analog (60%)	Digital (40%)
January	-3,52%	-2,11	-1,41
February	-0,92%	-0,55	-0,37
March	12,75%	7,65	5,10
April	14,89%	8,93	5,96
May	13,21%	7,93	5,28
June	10,73%	6,44	4,29
July	10,89%	6,53	4,36
August	9,28%	5,57	3,71
September	9,89%	5,93	3,96
October	10,41%	6,25	4,16
November	-4,14%	-2,48	-1,66
December	45,59%	27,35	18,24

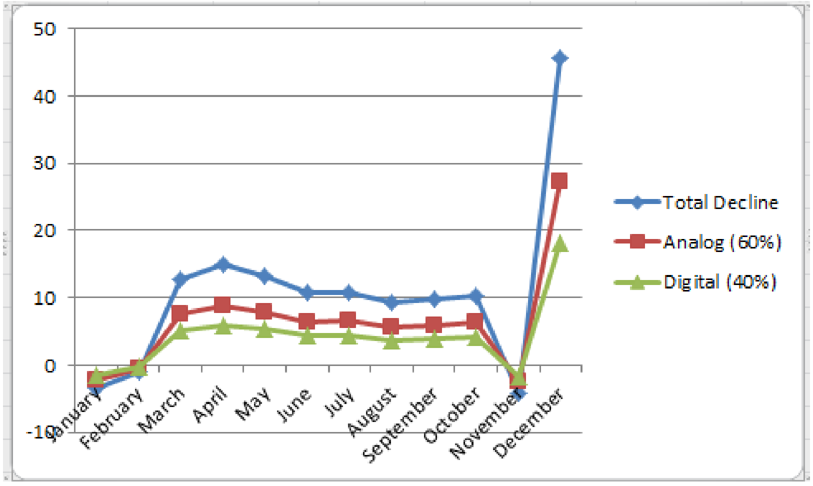


Figure 4.1 Comparison Chart of Analog vs. Digital Energy Loss

Based on the graph comparing monthly energy losses, it is evident that energy losses among customers using analog kWh meters tend to be higher than those among customers using digital kWh meters. This indicates that the use of digital meters can improve the accuracy of electricity metering and reduce the potential for meter tampering by customers. Additionally, the use of digital metering systems also enables more effective monitoring of energy consumption

4.5 Monthly Energy Loss Analysis

The results of the energy loss calculations for one year are shown in the following table

Table 4.4 Energy loss over the course of one year

Month	Monthly Decline	Cumulative Decline	PLN Target	Gap
January	-3,52%	-3,52%	9,15%	-12,67%
February	-0,92%	-2,23%	9,15%	-11,38%
March	12,75%	3,35%	9,15%	-5,80%
April	14,89%	6,35%	9,15%	-2,80%
May	13,21%	7,85%	9,15%	-1,30%
June	10,73%	8,35%	9,15%	-0,80%
July	10,89%	8,75%	9,15%	-0,40%
August	9,28%	8,82%	9,15%	-0,33%
September	9,89%	8,94%	9,15%	-0,21%
October	10,41%	9,09%	9,15%	-0,06%
November	-4,14%	8,10%	9,15%	-1,05%
December	45,59%	9,54%	9,15%	0,39%

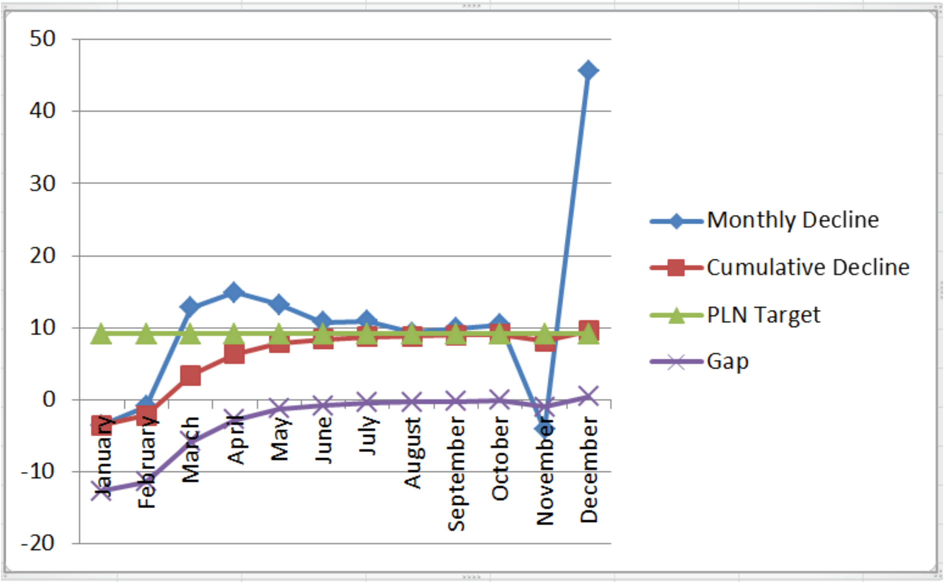


Figure 4.2 Graph of energy loss over the course of a year

4.6 Statistical Analysis of Energy Loss

The average energy loss can be calculated using the following equation:

$$\bar{X} = \frac{\sum X}{n}$$

Where:

X = Monthly Energy Loss

N = Number of Months

The total monthly energy loss is 128.06%, so the average energy loss

$$\bar{X} = \frac{128{,}06}{12}$$

$$\bar{\bar{X}} = 10{,}67\%$$

The average energy loss rate of 10.67% indicates that energy loss remains above PLN's target of 9.15%

4.7 Comparison of Analog and Digital Meter Cheating Rates

A comparison of the error rates of analog and digital meters is shown in the table below

Table 4.5 Comparison of Fraud Rates in Analog and Digital Meters

Parameters	Analog Meter	Digital Meter
Number of Samples	20	20
Dominant Violation Method	Bypass meter	Direct connection
Percentage of Major Violations	55%	55%
Meter Tampering	High	Low
Installation Tampering	Low	High

The results of the study indicate that there are differences in manipulation methods between customers using analog kWh meters and those using digital kWh meters. With analog meters, manipulation is generally carried out by bypassing the meter or disconnecting the terminals on the limiter and meter. This is due to the construction of analog meters, which are relatively easy to physically manipulate. Conversely, with digital meters, direct manipulation of the meter is relatively more difficult due to the presence of an internal protection system. Therefore, the most common method of fraud is to connect the electrical installation directly before the limiter and meter. Additionally, the results of the energy loss analysis indicate that the average annual energy loss is 9.54%, which is slightly higher than PLN's target of 9.15%. This indicates that electricity fraud remains one of the factors contributing to energy loss in the distribution system

Conclusion

Based on the results of the analysis of the effect of conductor temperature on energy loss in the LA-03 feeder of PT. PLN (Persero) Langsa ULP, the following conclusions can be drawn

a. Based on the results of field data analysis of 40 customer samples—comprising 20 customers using analog kWh meters and 20 customers using digital kWh meters—it was found that the methods of electricity fraud employed by customers exhibit different patterns for each type of meter
b. For customers using analog kWh meters, the most common methods of fraud involve bypassing the kWh meter and manipulating the terminals on the limiting and measuring device (APP). These methods allow electricity to be used without being accurately recorded by the meter
c. The results of the energy loss analysis show that the average electricity loss reached approximately 10.67%, which is still higher than PLN's energy loss target of 9.15%. This indicates that customer fraud continues to contribute to electricity losses in the distribution system

Recommendation

Based on the results of the research conducted, the following recommendations can be made:

a. PT. PLN (Persero) is advised to gradually replace analog kWh meters with digital kWh meters to improve the accuracy of electricity measurement and reduce the potential for meter tampering by customers
b. Supervision of customer electrical installations needs to be strengthened, particularly in the section of the installation upstream of the circuit breaker and meter, as tampering in that section still frequently occurs among customers using digital meters
c. Field inspections by the P2TL team should be conducted periodically to identify potential electricity fraud, thereby reducing non-technical energy losses

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