Analysis of Power Distribution Loss Using Non-Technical Methods at the ULP Bagan Batu

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Abstract

This study aims to calculate the energy lost due to the handling of prepaid kWh meter disturbances in household tariffs. Non-technical losses are influenced by networks in homes and buildings that do not meet PLN specifications, causing power losses. This can be detrimental to PLN. Losses have become one of the specific parameters that PT PLN (Persero) always pays attention to. The higher the loss value, the lower the system efficiency. Therefore, various efforts must be made to reduce the loss value to achieve good efficiency, ensuring customer satisfaction and safeguarding PT PLN's revenue lost due to losses. The research results indicate that the kWh lost due to the handling of prepaid kWh meter malfunctions through direct connection over 30 days amounts to 312,971.2 kWh. The total energy loss, when converted into rupiah, amounts to Rp. 254,103,331. Losses due to prepaid kWh meter malfunctions accounted for 0.18% of the 1.19% non-technical losses in the first semester. Monitoring the turnover of spare prepaid kWh meter materials in malfunctioning units and monitoring unusable materials is one way to minimize non-technical energy losses due to malfunctions in prepaid meters without direct connection..

Keywords: ***Electricity Distribution Losses, Non-Technical Methods***

Introduction

State Electricity Company PT PLN (Persero) is a state-owned enterprise whose primary task is to provide electricity for public use in adequate quantity and quality, generate profits, and carry out government assignments in the field of electricity in order to support development by applying the principles of a limited liability company. Continuity and quality are essential aspects that PLN must fulfill in meeting the public's electricity needs. Continuity refers to the uninterrupted flow of electricity to consumers, minimizing outages caused by disruptions, as electricity has become a basic necessity for the public to support their daily activities. In the event of a disruption, PLN must swiftly address the issue to prevent disruption to public activities. The quality of voltage referred to here means that the standard voltage received by customers must comply with the specified standards (SPLN No. 1-1995), which stipulate a voltage variation of +5% and -10%.

Literature Review

PT PLN (Persero) is required to maintain the continuity of electricity supply distribution to customers. One of the issues in the distribution sector is energy loss, which affects the electricity system. High energy loss can potentially reduce revenue, whereas lower energy loss leads to greater efficiency and increased revenue. Energy loss is categorized into two types: technical loss, which occurs due to impedance in power generation/transmission equipment during transmission and distribution, resulting in power loss in the form of heat, and non-technical loss, which refers to the loss of electrical energy consumed by customers or non-customers that is not recorded in sales.

Electricity losses, commonly referred to as losses, are energy losses caused by technical and non-technical issues. Technical issues are generally caused by the quality of electrical conductivity. The better the quality of electrical conductivity, the lower the losses. Non-technical losses are influenced by electrical systems in homes and buildings that do not meet PLN specifications, leading to power losses. This can be detrimental to PLN. Losses have become one of the key parameters consistently monitored by PT PLN (Persero). The higher the loss value, the lower the system efficiency. Therefore, various efforts must be made to reduce loss values to achieve good efficiency, ensuring customer satisfaction and safeguarding PT PLN's revenue, which is otherwise lost due to losses.

The factors causing technical and non-technical losses are the direct connection to prepaid kWh meters that are experiencing temporary disruptions. The number of prepaid kWh meter disruptions that occurred at PT PLN (Persero) ULP Bagan Batu until the end of June 2025 was 199 customers, while the number of replacement materials for the disruptions was limited. Meanwhile, it is not feasible to procure dummy kWh meters as a remedial measure. The direct connection method used for remediation results in unmeasured electricity consumption by customers, necessitating remedial actions to address the direct connection of prepaid kWh meters. This staff review will discuss the process of follow-up billing for prepaid kWh meters experiencing malfunctions to minimize losses

A prepaid kWh meter is a device that measures electrical energy (kWh) at the customer's premises, as well as a transaction tool between PLN and the customer, operated through a token facility. The operating principle of a prepaid kWh meter involves the flow of current and voltage through a processor, which converts the data into digital form displayed on an LCD screen in kWh units. The kWh value represents the credit balance. When electricity is consumed, an indicator light or pulse will flash, and the LCD display will show the credit balance decreasing from a high value to a low value. If the kWh credit is depleted, the electricity supply to the customer's installation will be interrupted.

The highest percentage of disruptions occur in prepaid kWh meters, such as the appearance of the word “check,” power outages in one house, the appearance of a hand image, and so on. Prepaid kWh meters that experience frequent disruptions cause the kWh meters to break down quickly, requiring rapid replacement. However, the availability of new kWh meters

cannot be guaranteed, and a bypass becomes an alternative so that electricity can continue to be distributed, ensuring that customers do not feel disadvantaged. The longer it takes to replace a damaged kWh meter, the greater the kWh loss that occurs, and the losses incurred by PLN also increase.

Efforts made to address prepaid kWh meter malfunctions occurring in the PT PLN (Persero) ULP Bagan Batu area can result in losses. Losses refer to electricity that is not sold to customers because, during kWh meter malfunctions, the electricity supply must continue to flow by being connected directly. This situation is obviously very detrimental to the company because the electricity (kWh) consumed by customers is not measured by the kWh meter or converted into rupiah. Therefore, to recover the unsold kWh, billing must be conducted while customers are using electricity to resolve the issue.

Research Methodology

To obtain more accurate data in this study, the following research tools were used:

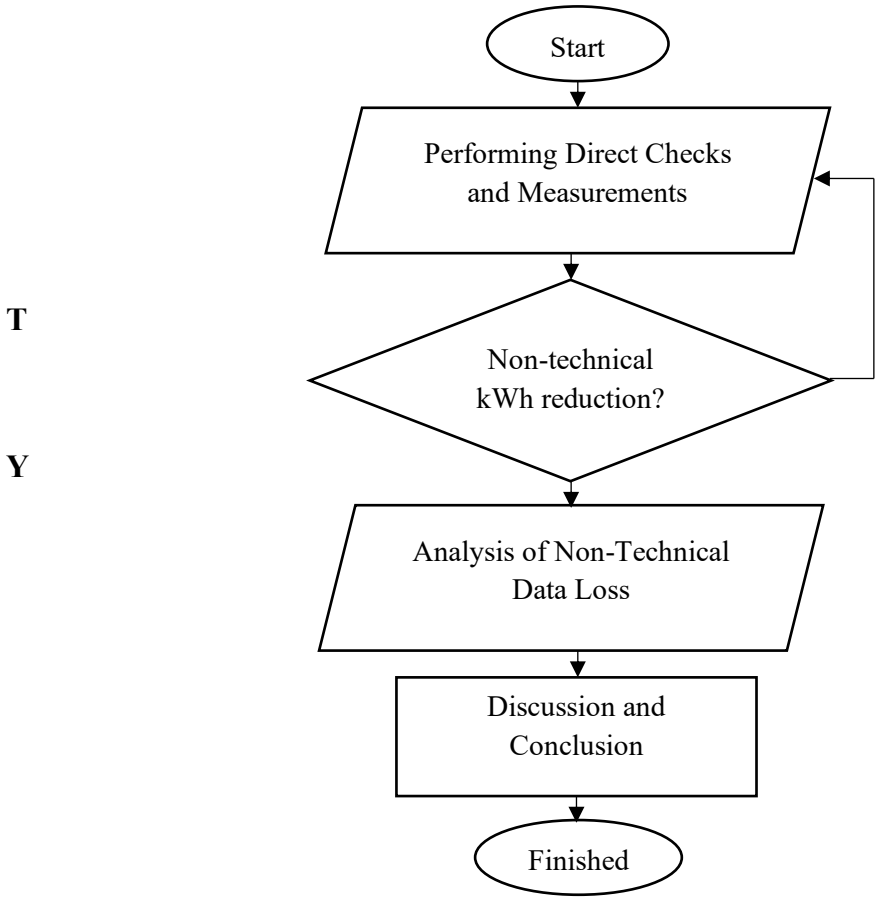

Figure 1. Research Flow Chart

3.1 Literature Review

At this stage, the author conducted a literature review or study of references, journals, and basic theories related to non-technical loss analysis in household customers whose prepaid kWh meters were experiencing problems. The author also deepened his understanding of the object to be studied as background for this research

3.2 Case Analysis

Case analysis is a method used to investigate and study events and phenomena related to individuals. Looking at and focusing on customers whose electricity usage has decreased based

on phenomena such as grouping data by type, respondent variables, and data on technical and non-technical disturbances on prepaid kWh meters.

3.3 Identification

Identify prepaid kWh meter malfunctions in residential customers. The cause of the malfunction can be determined by looking at the actual malfunction data on the prepaid kWh meter usage of the residential custome

3.4 Losses

PT PLN (Persero) ULP Bagan Batu is the victim, resulting in unmeasured electricity consumption by consumers due to damaged prepaid kWh meters

3.5 Case Handling

This case will discuss prepaid kWh meters that have suffered physical damage. Physically, this damage can be seen in the form of the words “check” appearing, a hand image appearing, a damaged keypad, a dead LCD screen, an open relay image appearing, and so on. The cause of the decreased accuracy of the kWh meter cannot be determined. An example of this is an older meter. This is done to monitor and evaluate consumers' electricity usage. Additionally, supervision is conducted in the handling of issues related to prepaid kWh meters

Results

The case analysis in this study is the increase in the rate of power loss (energy loss) due to both technical and non-technical factors. The monthly loss rates of PT.PLN (Persero) ULP Bagan Batu from January to March 2025 were 11.27%, 8.15%, and 10.71%. The cumulative loss realization from January to March 2025 can be seen in the following table:

Table 1. Percentage of ULP Shrinkage in Bagan Batu

Unit	Description	Unit	Realisasi			
			January	February	March	I Smester
Customer Service Unit (ULP) Bagan Batu	Ready to Distribute	kWh	58.480.339	51.794.902	59.728.100	170.003.342
	Sell	kWh	51.466.399	47.144.577	52.900.637	151.511.614
	P2TL	kWh	203.632	222.379	329.710	755.721
	Multipurpose	kWh	181.768	749.991	241.431	1.173.196
	Energy Loss	kWh	1.242.206	832.357	1.262.971	3.337.534
	Kom Loss	%	11,27%	9,80%	10,12%	10,12%
	Monthly Decline	%	11,27%	8,15%	10,71%	

In the table above, the cumulative loss realization for ULP Bagan Batu increased along with the monthly loss increase. With a monthly loss increase of 2.56% from February to March, this has become a special concern for electricity providers. This monthly loss is a combined calculation of technical and non-technical losses. Technical losses occur due to technical reasons where electricity is lost as it converts into heat in the Medium Voltage Network (MVN), Distribution Substations, Low Voltage Network (LVN), Household Connections (HC), and Metering and Limiting Devices (MLD). Non-technical losses, on the other hand, occur due to inaccuracies in energy measurement devices. The percentage of technical and non-technical losses at the Bagan Batu ULP can be seen in the table below.

Table 2. Percentage of ULP Shrinkage in Bagan Batu

Moon	Losses %	
	Teknis	Non Teknis
January	9,09	2,26
February	8,79	0,64
March	8,99	1,72
I Semester	8,94	1,19

From Table 2 above, it can be seen that for the percentage of technical and non-technical losses, the highest non-technical loss was in January at 2.26% and the lowest was in February at 0.64%. This study focuses on reducing non-technical losses caused by an increase in the percentage of losses from February to March. One case involves physical indications of malfunction in prepaid kWh meters. Physically, there are several indications of malfunction in kWh meters or installation errors, such as the appearance of the word “check,” the appearance of a hand image, a damaged keypad, a dead LCD screen, the appearance of an open relay image, and others

4.1 Identification Analysis

Prepaid Metering and Limiting Devices (APP) installed for residential tariff customers sometimes experience kWh meter malfunctions. These malfunctions are reported by customers through the PLN Mobile app or by visiting the PLN office in person. Technical Service Officers must conduct inspections accompanied by report data, either directly or via the PLN Mobile app. Additionally, Technical Service personnel do not carry spare kWh meters for handling malfunctions and monitoring their components, which poses the risk of kWh meters being lost or misused. In such cases, the responsible party is the Technical Service personnel, resulting in the continued recording of malfunctions in customers' prepaid kWh meters. As shown in the table below, the data on the number of malfunctions in prepaid kWh meters for residential customers is as follows

Table 3. Data on the Number of Prepaid Meter Disruptions in kWh

Tariff	Power	number of customers
R1MT	900	855
R1T	450	2102
	900	511
	1300	472
	2200	96
R2T	3500	38
	4400	6
	5500	13
R3T	6600	1
	7700	1
	11000	2
	23000	1
Total		**4088**

Table 3 above shows that the number of prepaid kWh meter disruptions in ULP Bagan Batu, based on data collected from January to March 2025, was 4,088 for residential customers. The number of disruptions handled consisted of 855 customers with an R1MT tariff and 900 VA of power.

R1T tariff for 3,181 customers with 450 VA installed power for 2,102 customers, 900 VA for 511 customers, 1,300 VA for 472 customers, and 2,200 VA for 96 customers. R2T tariff for 47 customers with installed capacity of 3,500 VA for 28 customers, 4,400 VA for 6 customers, and 5,500 VA for 13 customers. R3T tariff type for 5 customers with installed capacity 6,600 VA for 1 customer, 7,700 VA for 2 customers, 11,000 VA for 1 customer, and 23,000 VA for 1 customer.

Based on the type of household tariff, the largest number of prepaid kWh meter disruptions occurred in the R1T tariff with a power of 450 VA, affecting 2,102 customers. Meanwhile, the smallest number of kWh meter disruptions occurred in the R3T tariff with a power of 6,600 VA, 7,700 VA, and 23,000 VA, affecting 1 customer each.

4.2 Loss Analysis

The loss analysis in this case involves the electricity provider, PT. PLN (Persero) ULP Bagan Batu, which experienced energy loss due to non-technical shrinkage. The loss resulting from the disruption to the prepaid kWh meter is calculated based on the kWh lost during the direct connection and the price of the lost kWh meter. The resolution of the prepaid kWh meter disruption by technical service personnel through direct connection resulted in unmeasured customer usage. Additionally, trusting Technical Service personnel with spare kWh meters poses a risk that the dismantled used kWh meters may be misused through Electricity Usage Abuse (P2TL) by perpetrators (individuals). This misuse results in energy losses (reduction) for PT. PLN Persero ULP Bagan Batu. Based on data from AP2T (Centralized Customer Service Application), the operating hours for each tariff and power can be seen in the electricity sales report. If the number of prepaid kWh meter disruptions for residential tariffs is 4,088 customers, assuming that the disruption handling time for each customer is 30 days, then the operating hours for 30 days can be seen below, which is the amount of lost electricity (kWh).

Table 4. Amount of Electrical Energy (kWh) Lost

Tariff	Power	Number of Customers	Light-Up Clock	30 Days	Lost kWh
R1MT	900	855	67	67	51.556,5
R1T	450	2102	166	166	157.019,4
	900	511	85	85	3.9091,5
	1300	472	76	76	46.633,6
	2200	96	61	61	12.883,2
R2T	3500	38	25	25	2.450
	4400	6	25	25	660
	5500	13	25	25	1.787,5
R3T	6600	1	15	15	99
	7700	1	15	15	115,5
	11000	2	15	15	330
	23000	1	15	15	345
Total		**4088**		**590**	312.971,2

From Table 4 above, we can see the percentage of non-technical losses due to prepaid kWh meter malfunctions from January to March 2025. In January, the percentage of non-technical losses due to prepaid kWh meter malfunctions was 0.54%, in February it was 0.60%, in March it was 0.52%, and in the first quarter it was 0.18%. The percentage of non-technical losses due to prepaid kWh meter malfunctions can be compared with the non-technical losses that occurred from January to March 2025, as shown in the graph below:

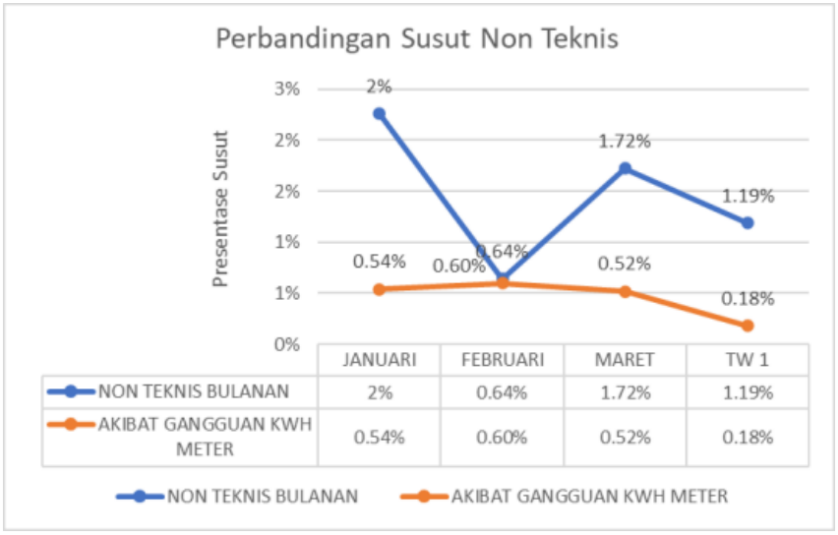

Figure 2. Graph Comparing Monthly Non-Technical Losses and Losses Due to Meter Malfunction

From the graph above, it can be seen that non-technical losses due to prepaid kWh meter disruptions in January amounted to 0.54% of the 2% monthly non-technical losses, in February it was 0.60% of the monthly non-technical loss of 0.64%, in March it was 0.52% of the monthly non-technical loss of 1.72%, and in the first quarter it was 0.18% of the monthly non-technical loss of 1.19%. In February, non-technical losses due to prepaid kWh meter malfunctions increased, contributing 94% of the monthly non-technical losses, and decreased again in March. These percentage results indicate that non-technical losses due to prepaid kWh meter malfunctions contribute significantly to monthly non-technical losses based on the realized losses of PT.PLN (Persero) ULP Bagan Batu.

The causes of prepaid kWh meter malfunctions from January to March 2025 include several types, such as KRN upgrades, faulty relays, outdated meter programs, customer installation issues (IML), meters damaged by fire/lightning strikes, meters damaged by natural disasters, non-functional keypads (damaged), and LCD displays showing “check.” This can be seen from the graph below, which shows the causes of kWh meter malfunctions.

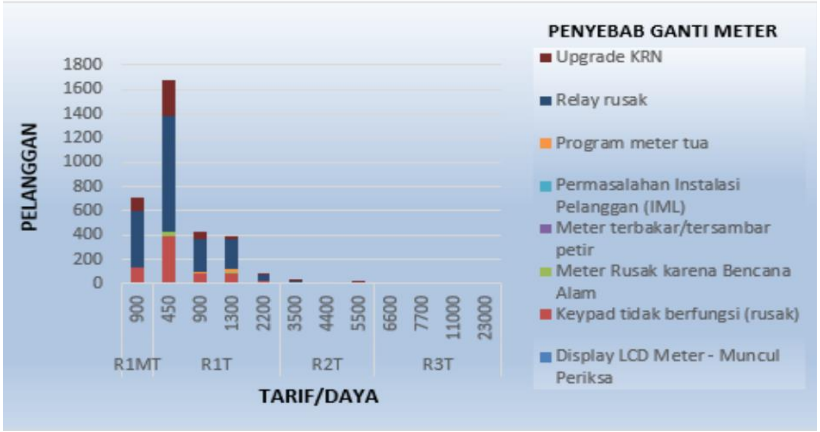

Figure 3. Graph showing causes of prepaid kWh meter malfunctions

The results of the study showed that the most common cause of kWh meter malfunction was a faulty relay, affecting 2,464 customers, while the least common cause was customer installation problems (IML), affecting 4 customers. Other causes of malfunction included KRN upgrades, affecting 521 customers; old meter programs, affecting 81 customers; meters burned/struck by lightning, affecting 16 customers; and keypads not functioning (faulty) A total of 891 customers and LCD displays appeared, checking a total of 66 customers. In addition, if

there is a loss of prepaid kWh meter material, PLN also suffers financial losses. The loss incurred by PLN due to the loss of prepaid kWh meters can be calculated based on the price of one prepaid kWh meter, which is Rp 273,237. Therefore, if 10 prepaid kWh meters are lost in a year, the total loss incurred by PLN is Rp 2,732,370. This rupiah value does not include the potential misuse of the lost kWh meters. The energy loss incurred by the electricity provider, in this case PLN, due to the loss of kWh can be calculated by converting the value of the lost kWh into follow-up bills, in this case rupiah. The energy loss can be calculated based on the type of tariff for handling customer disruptions.

4.3 Amount of Loss

For all types of kWh meter malfunctions that may cause losses to electricity providers based on customer tariff types, malfunctions are not fully resolved or handled by technical service personnel through direct connection. Financial losses can be calculated from the kWh lost during direct connection. The amount of financial losses due to lost kWh can be seen in the table below:

Table 5. Amount of Financial Losses

Tariff	Power	Number of Customers	Light-Up Clock	JN 30 Days	Lost kWh	Rp/kWh	Rp Lost
R1MT	900	855	67	67	51.556,5	1.350	69.601.275
R1T	450	2102	166	166	157.019,4	415	65.163.051
	900	511	85	85	3.9091,5	1.443	23.611.266
	1300	472	76	76	46.633,6	1.444	67.292.285
	2200	96	61	61	12.883,2	1.699	18.603.341
R2T	3500	38	25	25	2.450	1.699	4.162.550
	4400	6	25	25	660	1.699	1.121.340
	5500	13	25	25	1.787,5	1.699	3.036.963
R3T	6600	1	15	15	99	1.699	186.201
	700	1	15	15	115,5	1.699	196.235
	11000	2	15	15	330	1.699	560.670
	23000	1	15	15	345	1.699	586.155
Total		**4088**		**590**	**312.971,2**		**254.103.331**

In Table 5 above, the total financial loss due to kWh lost from all types of tariffs for 4,088 residential customers with a total of 590 hours of use over 30 days is Rp 254,103,331. For the R1MT tariff with a capacity of 900 VA, 67 hours of usage over 30 days, and a rate of Rp 1,350 per kWh, the financial loss in rupiah amounts to Rp 69,601,275. For the R1T tariff, the financial loss due to kWh lost from 3,181 customers is Rp 174,669,942.6, with each operating hour and contracted power. The R1T tariff for 450 VA power, consisting of 2,102 customers with 166 hours of operation over 30 days and a rate of Rp/kWh = Rp 415, shows that the financial loss in rupiah amounts to Rp 65,163,051. The R1T tariff for 900 VA power, which consists of 511 customers with 185 hours of operation over 30 days and a rate of Rp/kWh of Rp 604, shows that the financial loss in rupiah is Rp 23,611,266. The R1T tariff for 1,300 VA power, consisting of 472 customers with 76 hours of operation over 30 days and a rate of Rp 1,443 per kWh, shows that the financial loss in rupiah amounts to Rp 67,292,285.8. R1T tariff with a power capacity of 2,200 VA, consisting of 96 customers with 61 hours of usage over 30 days and Rp/kWh is Rp 1,444, so it can be seen that the financial loss is Rp 18,603,340.8.

Under the R2T tariff, the total financial loss due to kWh lost from 47 customers is Rp 8,320,852.50, based on each hour of operation and contracted power. The R2T tariff for 3,500 VA power, consisting of 28 customers with 25 hours of operation over 30 days and a rate of Rp/kWh of Rp 1,699, shows that the financial loss in rupiah amounts to Rp 4,162,550. The R2T tariff for 4,400 VA power, consisting of 6 customers with 25 hours of operation over 30 days

and a rate of Rp/kWh of Rp 1,699, shows that the financial loss in rupiah is Rp 1,121,340. The R2T tariff for 5,500 VA power, consisting of 13 customers with 25 hours of operation over 30 days and a rate of Rp 1,699 per kWh, shows that the financial loss in rupiah amounts to Rp 3,036,962.5.

Under the R3T tariff, the total financial loss due to kWh lost from 5 customers is Rp 1,511,260.5, based on each hour of use and contract power. The R3T tariff for 6,600 VA power, consisting of 1 customer with 15 hours of operation over 30 days and a rate of Rp/kWh of Rp 1,699, shows that the financial loss in rupiah is Rp 168,201. The R3T tariff for 7,700 VA power, consisting of 1 customer with 15 hours of operation over 30 days and a rate of Rp/kWh of Rp 1,699, shows that the financial loss in rupiah is Rp 196,234.50. The R3T tariff for 11,000 VA power, consisting of 2 customers with 15 hours of operation over 30 days and a rate of Rp 1,699 per kWh, shows that the financial loss is Rp 560,670. The R3T tariff for 23,000 VA power, consisting of 1 customer with 15 hours of usage over 30 days and a rate of Rp 1,699 per kWh, shows that the financial loss in rupiah amounts to Rp 586,155.

Based on customer tariff types, the largest financial loss due to lost kWh is found in the R1T customer tariff type, amounting to Rp 174,669,942.6. Meanwhile, the smallest financial loss due to lost kWh is found in the R3T customer tariff type, amounting to Rp 1,511,560.5. For the R1T tariff type, the largest financial loss is found in the 1300 VA installed capacity category, amounting to Rp 67,292,284, while the smallest is found in the 2200 VA installed capacity category, amounting to Rp 18,603,340.8.

Discussion

The analysis of energy losses that occurred at the Bagan Batu ULP from January to March amounted to 3,337,534 kWh. These energy losses were caused by both technical and non-technical energy losses. When viewed from the percentage of energy losses, non-technical losses in the first quarter amounted to 1.19%. The percentage of non-technical energy loss due to kWh meter malfunctions contributed significantly, amounting to 0.18% of the 1.19% monthly non-technical energy loss. To minimize this energy loss, PLN is making concerted efforts to reduce these figures. For example, non-technical energy loss caused by issues with prepaid kWh meters. Identifying the cause is a method used to determine the extent of non-technical energy loss due to issues with prepaid kWh meter. Based on data collected from January to March 2023, there were 4,088 household customers consisting of R1MT, R1T, R2T, and R3T tariff types. The large number of disruptions to prepaid kWh meters was caused by technical service personnel not completing repairs or handling them directly. This was because the personnel did not bring spare kWh meters. Additionally, poorly controlled used kWh meters can lead to potential electricity misuse (P2TL) by certain individuals at specific locations. This results in energy losses because customer usage is not measured by the meters. As a result of these non-technical energy losses, the electricity provider, in this case PLN, suffers losses in terms of electricity distribution. Data obtained from the Bagan Batu ULP indicates that from January to March, energy losses amounted to 312,971.2 kWh.

Energy losses are calculated based on hours of operation, assuming that disruptions are handled directly for each customer for each type of tariff and contract power as seen in the electricity sales report. This yields the number of kWh lost over 30 days. When calculated financially, the number of kWh lost is obtained will be multiplied by rupiah/kWh based on each tariff and the customer's contracted power with PLN, then PLN's loss is Rp 254,103,331. Due to this energy loss, PLN monitors the turnover of spare prepaid kWh meter materials in the fault unit and monitors ex-unloaded materials. This ensures that technical service officers who are given spare kWh meters will not risk losing or misusing them. Handling cases such as this is one way to monitor and minimize non-technical energy losses due to faults in prepaid meters without a direct connection.

Conclusion

Based on the results of the above research, it can be concluded thatikut:

1. From January to March 2025, there were 4,088 electricity customers at PT. PLN (Persero) ULP Bagan Batu with 855 customers experiencing prepaid kWh meter disruptions for the R1MT household tariff, 3,181 customers for the R1T tariff, 47 customers for the R2T tariff, and 5 customers for the R3T tariff
2. Energy loss/kWh due to prepaid kWh meter malfunction for residential electricity consumption with 590 hours of use over 30 days is 312,971.2 kWh; 3). The financial energy loss amounts to Rp. 254,103,330.60 based on the total rupiah/kWh calculated according to tariff type, electricity capacity, and Rp/kWh
3. The percentage of loss due to prepaid kWh meter malfunctions in January was 0.54% of the 2% monthly non-technical loss, in February it was 0.60% of the 0.64% monthly non-technical loss, in March it was 0.52% of the 1.72% monthly non-technical loss, and in the first quarter it was 0.18% of the 1.19%.

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