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Study of Calculation and Causes of Energy Loss In Electricity Distribution Networks

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Abstract: *The rapid progress of science and technology today causes the need for electrical energy in society to increase. Not only because of the rapid progress of science and technology, the increasing need for electrical energy is also caused by the increasing rate of population growth, especially in Indonesia. This certainly raises new problems for electricity companies in Indonesia. The electrical energy that is distributed is not entirely acceptable to the consumer's burdens because of the shrinkage. Losses can be divided into two types based on where they occur, namely transmission losses and distribution losses. Distribution losses generally occur in distribution networks which include losses in medium voltage networks, distribution substations, low voltage networks, house connections, as well as limiting and measuring devices.*

Keywords— electrical energy; losses; distribution losses

1. INTRODUCTION

The electrical energy that is distributed is not entirely acceptable to the consumer's burdens due to shrinkage or losses. Losses or losses themselves can be divided into two types based on where they occur, namely transmission losses and distribution losses. Transmission loss is the loss of electrical power that occurs in the transmission network. This transmission loss includes losses in high-voltage transmission lines or losses in substations. The parameters used to determine the amount of transmission loss are based on the kWh value of the net transmission locomotive, kWh of substation self-use, and kWh of transmission line ready [1].

Meanwhile, distribution loss is a loss of energy that occurs in the distribution network which includes losses in high voltage distribution networks, losses in medium voltage distribution networks, losses in low voltage distribution networks, house connections, as well as on limiting and measuring devices for high voltage, medium voltage customers. , and low voltage [2]. The parameters used to determine the amount of distribution loss are the value of kWh ready for distribution channel [3], kWh for distribution system use, and kWh sold (TUL III-09).

Therefore, this study aims to study the study of the calculation of losses and analyze the causes of losses that occur in the distribution network. Thus, the value of distribution loss from July to November 2021 in the distribution network can be known and compared and find out the causes of the shrinkage that occurred during the months of July to November 2021.

2. LITERATUR REVIEW

2.1 Electronic Power Distribution System

The distribution system is part of the electric power system. This distribution system is useful for distributing electric power from bulk power sources to consumers. The electric power generated by large power plants with voltages from 11 kV to 24 kV is increased by a substation (GI) with a voltage-boosting transformer to 70 kV, 154 kV, 220 kV or 500 kV and then distributed through transmission lines. The purpose of increasing the voltage is to minimize the loss of electrical power in the transmission line, where in this case the power loss is proportional to the square of the current flowing ($I^2 R$).[4]

With the same power, when the voltage value is increased, the current flowing is smaller so that the power loss will also be small. From the transmission line, the voltage is lowered again to 20 kV with a voltage-lowering transformer at the distribution substation, then with this voltage system the distribution of electricity is carried out by the primary distribution line. It is from this primary distribution channel that the distribution substations take the voltage to lower the voltage with a distribution transformer into a low voltage system, namely 220/380 Volts. Furthermore, it is distributed by secondary distribution channels to consumer customers.

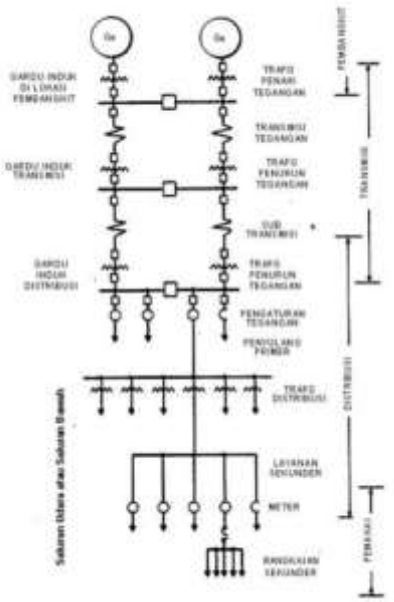

Fig. 1. *Electric Power Distribution System Grouping*

In long-distance power distribution systems, always use the highest possible voltage, using a step-up transformer. This very high voltage value has several consequences, including: it is dangerous for the environment and the high price of the equipment, besides that it also does not match the required voltage value on the load side. Thus, in the load center areas this high line voltage is lowered again using a step-down transformer. In this case it is clear that the distribution system is an important part of the overall electric power system [5].

2.2 Distributing Network Configuration

By in general, the configuration of an electric power network has only 2 configuration concepts:

a. Radial Network

It is a simple and economical primary distribution system network. In this system there are several feeders that supply several distribution substations radially.

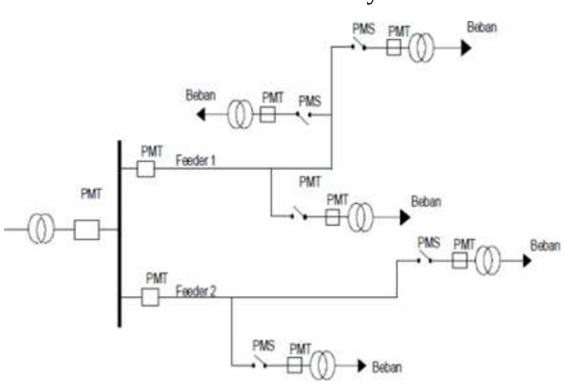

Fig. 2. *Radial System Channel Schematic*

However, the reliability of this system is lower than other systems. The lack of reliability is due to the fact that there is only one main line that supplies distribution substations, so that if the main line is interrupted, all substations will be extinguished. Another disadvantage is that the voltage quality at the distribution substation at the very end is not good, this is because the largest voltage drop is at the end of the line. [6]

b. Closed form network (loop)

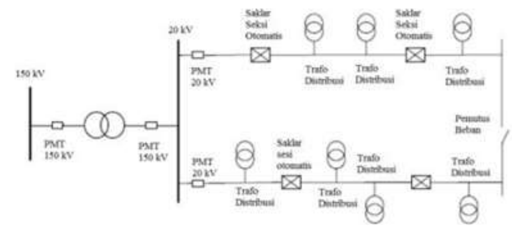

Fig. 3. *Closed System (Loop) Channel Schematic*

This type is a primary distribution network, a combination of two types of radial networks where the PMT is attached to both ends of the network. Under normal circumstances this type works radially and when there is a disturbance the PMT can be operated so that the disturbance can be localized. This type is more reliable in distributing electric power than the radial type, but the investment cost is more expensive.

2.3 Electronic Power

Power is the amount of energy that changes with time in terms of voltage and current. Electrical power can be divided into 3, namely real power (P), reactive power (Q), and apparent power (S) [7].

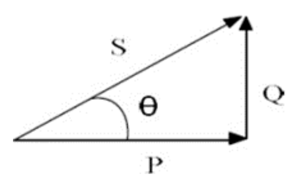

Fig. 4. *Power Triangle*

- Real power (P) is the actual power required by electrical loads or household appliances. The actual unit of power is the watt (W). Real power can be calculated by the formula:

$$P = V \times I \times Cos\varphi \tag{1}$$

- Reactive power (Q) is the power that arises due to the formation of a magnetic field in inductive loads. The unit of reactive power is volt ampere reactive (VAR). Reactive power can be calculated by the formula:

$$Q = V \times I \times Sin\varphi \tag{2}$$

- Apparent power (S) is the resultant between real power and reactive power. The unit of apparent power is the volt ampere (VA). Apparent power can be calculated by the formula:

$$S = V \times I \tag{3}$$

The power factor ($Cos\varphi$) is a multiplier constant with a value of 0 to 1, which shows how much real power is absorbed by the resistive load from the apparent power in a total load.

2.4 Shrinkage in the Electric Power Distributing System

Losses is a form of loss of electrical energy that comes from the difference between the amount of electrical energy available and the amount of electrical energy sold. Guidelines for Preparation of Energy Balance Reports (kWh), the types of losses (losses) of electrical energy can be divided into two, namely by nature and based on the place of occurence. based on the nature there is a technical loss and non-technical shrink. Based on the place of occurrence there is a transmission loss and distribution shrink [8].

- Technical losses are the loss of electrical energy at the time of distribution from the generator to the customer because it turns into heat. This technical loss cannot be eliminated because it is a congenital condition or shrinkage that occurs due to technical reasons where the shrinking energy turns into heat in the High Voltage (JTT) network, Substation (GI), Medium Voltage Network (JTM), Substation Distribution (GD), Low Voltage Network (JTR), Home Connection (SR) and Measuring and Limiting Equipment (APP).

- Non-technical losses are the loss of electrical energy consumed by customers and non-customers because they are not recorded in sales. There are several causes of non-technical losses, including electricity theft, meter reading errors, measurement tool errors and others.

In the distribution system, there are many modes of theft of electricity, one of which is by using special equipment. To minimize electricity theft, persuasive prevention is carried out by informing the public about the consequences of electricity theft, either through the media or by direct socialization. In addition to persuasive methods, corrective actions are also carried out, namely the implementation of controlling the use of electricity with high intensity and accuracy.

Meter reading errors cause a mismatch between the kWh used by the customer and the recorded one. If what is used turns out to be greater than what was recorded, the difference will certainly be reduced. There are efforts to overcome these problems, one of which is by providing guidance and training for human resources involved in the meter reading process to the application of meter reading applications and methods.

- Transmission loss is the loss of electrical energy generated when it is distributed through the transmission network to substations or technical losses that occur in the transmission network which includes losses in the High Voltage network.

Medium (JTM), Distribution Substation (GD), Low Voltage Network (JTR), Home Connection (SR) and Limiting and Measuring Equipment (APP) for TT, TM and TR customers. If there is a high-voltage network that functions as a distribution network, this network loss is intended as a distribution loss. The amount of distribution loss can be obtained through the formula:

$$Loss\ Dis\ = \ kWh\ Production\ PSSD\ kWh\ Distributed \quad (4)$$

- Distribution shrink

Distribution loss is the loss of electrical energy distributed from substations through distribution networks to customers or technical and non-technical losses that occur in distribution networks which include medium voltage network losses (JTM), distribution substations (GD), low voltage networks (JTR), Home Connections (SR) and Limiting and Measuring Devices (APP) for TT, TM and TR customers. If there is a high-voltage network that functions as a distribution network, this network loss is intended as a distribution loss. The amount of distribution loss can be obtained through the formula:

$$Loss\ Dis\ = \ kWh\ Production\ PSSD\ kWh\ Distributed \quad (5)$$

3. DISCUSSION

3.1 Data on Net kWh, PSSD, and Cumulative Selling kWh

The following Table 1 is data on net kWh, PSSD, and cumulative selling kWh.

Table 1: Net kWh, PSSD and dataSelling kWh (TUL III-09) Cummulative in 2021

Month	net kWh	PSSD	kWh Selling (TUL III-09)
January	342.863.175	298,909	339,465,601.80
February	646,914,889	569,621	6322,995,863.80
March	1.010.097.095	870,257	960,541,776.26
April	1,368,401,889	1,165,396	1,296,002,045,26
May	1,709,245,214	1,474,234	1,626,441,559.06
June	2,062,384,880	1,776,429	1,963,566.164.80
July	2,405,178,706	2,089,805	2,286.133,817.80
August	2,766,675,193	3,025,146	2,625,535,640,80

September	3,131,556,196	3,944,508	2,970,583,592.80
October	3,511,475,540	4,900,931	3,327,697,255.80
November	3,873,235,847	5,832,666	3,676,407,963.80

3.2 Minimum Energy Data (EMIN) Cumulative

The following Table 2 is minimum energy data:

Table 2*:* Minimum Energy Data (EMIN) Cumulative

Month	EMIN
January	1.591.810
February	3,340,303
March	18,815,406
April	20,419,122
May	22,053,034
June	27,527,612
July	33,935,973
August	39,753,025
September	53,384,818
October	58.394.175
November	63,457,121

3.3 Cumulative Loss Target Data

The following Table 3 is the cumulative loss target data (without minimum energy)

Table 3*:* Cummulative Loss Target Data

Month	Cumulative Loss Target (%)
January	6.48
February	6.47
March	6.46
April	6.45
May	6.44
June	6.44
July	6.44
August	6.44
September	6.43
October	6.43
November	6.43

3.4 Calculation of Loss in Distribution Networks

Based on the data obtained from Table 3.1, Table 3.2, and Table 3.3, it is possible to calculate the losses that occurred in the distribution network from January to November 2021. The calculation of loss is carried out at the time with minimum energy and without minimum energy, which for the calculation of loss with minimum energy uses the formula [9]:

$$Shrink\ Dis = Net\ kWh\ PSSD\ kWh\ Selling \quad (6)$$

while for the calculation of loss without minimum energy using the formula:

$$Shrink\ Dis = Net\ kWh\ PSSD\ (kWh\ Selling\ EMIN) \quad (7)$$

From the shrinkage value that has been obtained, it can also be calculated the percentage of the shrinkage value, where the percentage of shrinkage with minimum energy can be calculated by the formula:

$$Loss\ Dis\ (\%) = \frac{kWh\ NetPSSD - kWh\ Selling}{Gross\ kWh} \times 100\% \quad (8)$$

and for the percentage of loss without minimum energy can be calculated by the formula:

$$Loss\ Dis\ (\%) = \frac{kWh\ NetPSSD - (kWh\ Selling - EMIN)}{Gross\ kWh} \times 100\% \quad (9)$$

From the calculations using these formulas, the values and percentages of losses with EMIN and without EMIN are obtained in each month starting from January to November 2021 which can be summarized in Table 4 and Table 5 below.

Table 4*:* Value Gain and Percentage Loss with EMIN

Month	Shrinkage Value (kWh)	Percentage Loss (%)
January	3,098,663.76	0.87

February	13,349,404.20	1.99
March	48,685,061.74	4.65
April	71,234,447.74	5.03
May	81,329,420.94	4.59
June	97,042,286.20	4.54
July	116,955,083,20	4.70
August	138,114,406.20	4.82
September	156,978.095,20	4.84
October	178,877,353.20	4.92
November	190,995,217,20	4.76

Table 5: Value Gain and Percentage of Loss Without EMIN

Month	Shrinkage Value (kWh)	Percentage Loss (%)
January	4,690,473.76	1.32
February	16,689,707,20	2.49
March	67,500,467.74	6.45
April	91,653,569.74	6.47
May	103,382,454.94	5.84
June	124,569,898,20	5.83
July	150,891,056.20	6.06
August	177,867,431,20	6.21
September	210,362,913.20	6.48
October	237,271,528.20	6.53
November	254.452,338.20	6.34

Based on Figure 3.1, it can be seen that the value of shrinkage with EMIN tends to have a lower value than the value of shrinkage without EMIN.

Likewise, the percentage of shrinkage with EMIN tends to be lower than the percentage of shrinkage without EMIN as seen from the graph in Figure 3.2. This is because shrinkage without EMIN is a real value of shrinkage in the absence of a minimum energy. The minimum energy itself can be defined as the energy used for 40 hours, which can be calculated by the formula 40 hours multiplied by the power value divided by 1,000. Therefore, the value of shrinkage without EMIN is used as a benchmark to measure the achievement of shrinkage.

Then it can also be seen from Figure 3.2 that the highest percentage of losses without EMIN was obtained in October at 6.53%, while the lowest percentage was obtained in January at 1.32%. Similarly, the percentage of shrinkage with EMIN where the highest percentage was also obtained in October of 4.92% and the lowest percentage was obtained in January of 0.87%. The value and percentage of shrinkage in January was very low itself due to the remaining subsidies from December 2020 which were included in January and February 2021, so that the value and percentage of shrinkage in January and February 2021 had a low value and had quite a large difference. when compared to March to November 2021. Based on Figure 3.1, it can be seen that the value of depreciation with EMIN tends to have a lower value than the value of depreciation without EMIN.

Based on Figure 3.1, it can be seen that the value of shrinkage with EMIN tends to have a lower value than the value of shrinkage without EMIN.

3.5 Achievement Loss

For the achievement of shrinkage in each month in 2021 itself, it can be seen through the following percentage graph.

Fig. 5. *Graph of Achievement of Loss Without EMIN in 2021*

Based on Figure 3.3, it can be seen that in January, February, March, May, June, July, August, and November the target for the distribution network has been achieved. This can be seen through the percentage of loss obtained is lower than the percentage of the predetermined loss target.

Where in January the percentage of loss without EMIN obtained was 1.32% while the target of shrinkage was 6.48%, then in February the percentage of shrinkage without EMIN obtained was 2.49% while the target of shrinkage was 6.47%, then in February in March the percentage of shrinkage without EMIN obtained was 6.45% while the target of shrinkage was 6.46%, then in May the percentage of shrinkage without EMIN was obtained 5.84% while the target of shrinkage was 6.44%, then in June the percentage of shrinkage was without EMIN obtained 5.83% while the target for shrinkage is 6.44%, then in July the percentage loss without EMIN obtained is 6.06% while the target for shrinkage is 6.44%, then in August the percentage loss without EMIN obtained is is 6.21% while the target for shrinkage is 6.44%, and lastly in November the percentage of shrinkage without EMIN obtained is 6.34% while the target for shrinkage is 6.43%.

On the other hand, in April, September, and October, the target for shrinkage in the distribution network was not achieved. This can be seen through the percentage of losses that have been obtained which exceeds the percentage of the predetermined loss target. Where in April the percentage of shrinkage without EMIN obtained was 6.47% while the target of shrinkage was 6.45%, then in September the percentage of shrinkage without EMIN obtained was 6.48% while the target of shrinkage was 6.43%, then the the last one was in October the percentage of shrinkage without EMIN obtained was 6.53% while the target for shrinkage was 6.43%.

3.6 Factors Causing Shrink

In identifying the factors that cause shrinkage, one must first look at the achievement of technical and non-technical losses each month. Meanwhile, non-technical losses can be obtained through the subtraction of global losses (distributed losses without EMIN) and technical losses [10]. The following is the cumulative technical loss gain on the distribution network from January to November 2021.

Table 6: Cumulative Technical Loss Gain

Month	Technical Loss (I2R)	
	kWh	***Percentage (%)***
January	14.980.434,74	4,22
February	28.460.532,67	4,25
March	46.830.246,35	4,48
April	63.531.472,78	4,48
May	79.291.598,57	4,48
June	95.396.111,88	4,47
July	111.837.535,14	4,49
August	129.083.025,90	4,51
September	146.445.337,02	4,51
October	164.223.212,34	4,51
November	180.585.886,47	4,50

Based on the calculation results, non-technical losses have a smaller percentage than the percentage of technical losses in each month. This indicates that the majority of the causes of shrinkage that occur are technical factors in the medium voltage network (JTM), distribution substation (GD), low voltage network (JTR), and house connections (SR).

Factors causing technical losses include:

- There is an unbalanced load and current flows in the neutral wire.
- The contact on the JTR or JTM connection is not good (loss contact).
- The cross-sectional area is too small or not in accordance with the load, where the shrinkage will be greater when the cross-sectional area is getting smaller.
- The power factor value ($Cos\varphi$) is too low.
- Network length, where the longer the network, the larger the current, so the voltage will decrease and a lot of electrical energy flowing through the network will be lost.

Apart from technical factors, where the non-technical factor that most influenced the amount of shrinkage in 2021 was the low kWh value of sales to medium-voltage customers. Prior to the pandemic, the value of shrinkage in the distribution network was not as high as the value of shrinkage experienced in 2020 and 2021. This can be shown through the following monthly percentage loss data in 2019 and 2020.

Table 7: Distribution Network Loss Percentage

Month	Loss Percentage (%)	
	Year 2020	***Year 2021***
January	5,54	6,34
February	6,37	5,85
March	6,17	6,50
April	6,18	6,16
May	6,11	6,38
June	5,99	6,39

July	6,10	6,17
August	6,15	6,31
September	6,20	6,07
October	6,28	5,96
November	6,26	5,87

Based on Table 3.7 above, it can be seen that in several months the percentage of shrinkage in 2020 increased compared to 2019. This happened because after entering the pandemic period in 2020, the number of users and medium voltage customers who took part in suppressing shrinkage decreased. . On the other hand, the use of electricity for low-voltage customers is increasing due to the large number of people who work and have activities at home, so that the shrinkage rate increases.

Therefore, to reduce technical losses, several efforts can be made, namely optimizing load capacity, optimizing transformer capacity, location, and the load served, increasing the cross-section of the conductor or replacing the type of conductor with a conductor that has a small resistance value, and shortening the network. Meanwhile, to reduce non-technical losses, it can be done by increasing the provision of stimulus to low-voltage customers during the pandemic. Thus, the value and percentage of global shrinkage that occurs can be suppressed so that it does not experience a significant increase.

4. CONCLUSION AND SUGGESTION

Energy losses that occur in the distribution network can be divided into two, namely losses with minimum energy (EMIN) and losses without minimum energy (EMIN). Energy loss with EMIN that occurs in the distribution network can be obtained by subtracting the value of Net kWh, PSSD, and Selling kWh (TUL III-09). The value of energy loss without EMIN that occurs in the distribution network can be obtained by subtracting the value of Net kWh, PSSD, Selling kWh (TUL III-09), and the value of EMIN.

The value of shrinkage with EMIN in the distribution network tends to have a lower value than the value of shrinkage without EMIN in the distribution network because the loss without EMIN is a real value of shrinkage without minimum energy. The highest percentage of losses without EMIN was obtained in October of 6.53%, while the lowest percentage was obtained in January of 1.32%. Similarly, the percentage loss with EMIN, where the highest percentage was also obtained in October of 4.92% and the lowest percentage was obtained in January of 0.87%.

Factors causing technical losses include an unbalanced load and current flowing in the neutral wire, poor contact at the JTR or JTM connection (loss contact), the cross-sectional area is too small or does not match the load, the power factor value (cos) is too low. too low, and the length of the network. In addition to technical factors, the fairly high shrinkage rate in 2021 was also caused by non-technical factors, where the non-technical factor that most influenced the amount of shrinkage in 2021 was the low kWh value of sales to medium-voltage customers.

Optimizing load capacity, optimizing transformer capacity, location, and the load being served, enlarging the cross-section of the conductor or replacing the type of conductor with a conductor with a low resistance value, shortening the network, and increasing the provision of stimulus to low-voltage customers are efforts that can be made to reduce the value and percentage of global shrinkage.

Although the main factor of shrinkage that occurred was the majority of technical factors, the performance of the implementation must be maintained because it has been running well, so as to maintain the stability of the non-technical depreciation value so that it continues to have a low value.

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