Study of Technical and Non-technical Factors in Energy Consumption on 20 kV Distribution Networks

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Abstract

This research aimed to find the technical and non-technical losses that occurred on the 20 kV Tawangrejo Feeder network by calculating the electricity losses after measurement and the calculated losses, made an application to calculate the losses, and determined the improvement alternative from the suitable electricity losses. Based on the data analysis, the conclusions were: Tawangrejo Feeder used mesh configuration with a three-phase four-wire construction model. The values of power and energy losses in total, technical, and non-technical were fluctuating, depended on the current value that was sent from the primary substation to the load. This power loss calculation application had a high accuracy because the error occurred at a maximum of 0.0021%. The most effective power loss improvement was replacing the conductor duct that reduces 56% of power and energy losses.

Keywords
The distribution network, Energy consumer, Technical losses, Power system

1. Introduction

Electrical energy is the primary energy to operate devices that needed electricity. Many industrial, housing, offices, and commercial devices require electricity. The development of industrial, housing, offices and commercial sectors increases the demand for electricity [1]–[4]. The massive electricity demand in the city area is caused by its industrial, office, housing, and commercial aspects. East Java is a province with significant electricity demand due to the development in those sectors. The electricity demand in East Java experiences a surplus. Currently, the demand reaches 2,800 MW and is predicted to reach 6,000 MV load. With the high development, electrical power needs to be increased to meet the demand.

To meet the increasing demand, there are several factors to be considered, one being the power loss. Power loss can be seen in the various electricity network, from generation, transmission, and distribution. There are two types of power loss: technical and non-technical. Technical loss is a loss that occurred due to the impedance from the generation, transmission, and distribution devices so that consumers received less energy than what is sent by the generator [5]–[8]. The non-technical loss occurs due to non-technical issues such as errors from the reading of electric measuring devices, inappropriate calibration errors, electric theft and other errors outside of technical matters.

The electrical energy in Indonesia is managed by the government, it is a state-owned enterprise that is engaged in the field of electricity supply. The operation is divided into various areas to manage the generation, transmission and load management, and distribution for consumers. However, there are separated into units for areas that are interconnected in Java-Bali.

2. Main Current Research

The distribution section consists of several network service area as sub-units around Indonesia. This functions as a customer service and distribution electricity network [3], [9]–[11]. This system supervises district subunits. Then, the district serves to help manage the distribution network services closer to the consumers. APJ Pasuruan supervises several district units; they are Prigen, Pandaan, Bangil, Sukorejo, Pasuruan City, Gondangwetan, Grati, Probolinggo, and Kraksaan Districts. The electricity distribution network is divided into two, primary and secondary electricity distribution networks. The primary electricity distribution network is also called the medium voltage; it is a network that connects the main substation with distribution substation, usually uses distribution voltages of 6 kV, 7 kV, 12 kV, and 20 kV. The secondary electricity distribution network is also called the low voltage; it is a network that connects the distribution substation with consumers [4], [4], [9]. The primary electricity network is a three-phase while the secondary distribution network which is a single-phase and three-phase four-wire. In Indonesia, the universal voltage is 380/220 V.

A feeder supports the distribution of electricity from the primary substation to a distribution substation. There many feeders are operated Pasuruan District, such as Tawangrejo Feeder. Tawangrejo Feeder connects the Pandaan Main Substation with the industrial distribution substation around the Cow Statue in Pandaan area. The distribution network is a part of the electricity network system with more significant power loss compared to other parts. This occurrence is caused by the low voltage distribution network that resulted in a high current; hence, the power loss has the value of the squared current multiplied by the magnitude of the distribution resistance of electrical energy [3], [8], [11], [12]. From this problem, the researcher conducted a study in power loss and non-technical consumption of electricity in 20 kV distribution network in Tawangrejo Feeder, Pandaan District, Pasuruan. This study aimed to find the power loss that occurred technically and non-technically. The study was focused on Tawangrejo Feeder, Pandaan District, Pasuruan to obtain the power loss and improved alternative to reduce the power loss.

3. Method

This method used the descriptive analysis by analyzing the loss description due to technical or non-technical causes in the feeder conductor and each distribution transformer in one feeder. The procedure in this research was conducted by comparing the measured energy losses with the calculated energy losses to get the technical and non-technical loss in the 20 kV distribution network. The stages of this research were (1) pre-research, (2) research, (3) post-research, and (4) final stage.

a. **Pre-research Stage.** The pre-research stage was also the initial research or preparation stage. This stage prepared anything related to the research requirements.
b. **Research Stage.** The research stage covered the data on power loss. The data that was collected consisted of the loss in the feeder and transformer. The collection was conducted through observation, documentation, and interview.
c. **Post-research Stage.** The post-research is a data processing stage. The process was performed following the research design and theories correlated with technical and non-technical loss.

The total loss is found using Equation (1).

$$E_{total} = E_{purchase} - E_{sell} \tag{1}$$

Note:

E_{total} = Total energy loss (kWh)

$E_{purchase}$ =Purchased energy from the primary substation (kWh)

E_{sell} = Selling energy from the district (kWh)

Equation 1.2 is used to know the total power loss.

$$P_{total} = \frac{E_{total}}{F_{LS}.t} \tag{2}$$

Note:

P_{total} = Total power loss (kW)

E_{total} = Total energy loss (kWh)

F_{LS} = Losses factor (kWh)

t = time (hour)

The losses factor is obtained by adding up the 0.2 load factor and 0.8 of the square of the load factor, as written in Equation (3).

$$F_{LS} = 0{,}2L_f + 0{,}8\,L_f^2 \tag{3}$$

Note:

F_{LS} = Losses factor

L_f = Load factor

The load factor is obtained from dividing the average current with the peak current from a feeder, as written in Equation (4).

$$L_f = \frac{I_{average}}{I_{peak}} \tag{4}$$

Note:

L_f = Load factor

$I_{average}$ = The average current of a feeder (A)

I_{peak} = The peak current of a feeder (A)

Technically, the energy loss on a feeder can be known by adding the conductor wire loss and transformer loss. The conductor wire loss and resistance can be found using Equation (5) and Equation (6).

$$P_{conductor} = I^2 . R_{conductor} \tag{5}$$

$$E_{conductor} = P_{conductor} . t . F_{LS} \tag{6}$$

Note:

E_{wire} = Energy loss in conductor wire (kWh)

I = The average current (A)

F_{LS} = Losses factor

R_{wire} = Conductor wire resistance value (Ohm)

t = time (hour)

Transformer loss can be obtained using Equation (7) and Equation (8)

$$E_{tranformer} = (P_{Fe} + P_{Cu}) . F_{LS} . t \tag{7}$$

$$P_{Cu} = I^2 . R_{Cu} \tag{8}$$

Note:

$E_{transformer}$ = Transformer energy loss (kWh)

P_{Fe} = Iron loss (kW)

P_{Cu} = Copper loss (kW)

F_{LS} = Losses factor

R_{Cu} = Copper resistance (Ohm)

I = Current (A)

t = Time (hour)

The non-technical energy loss can be found from the reduction of total energy losses with technical energy losses.

$$E_{non-technical} = E_{total} - E_{technical} \tag{9}$$

Note:

$E_{non-technical}$ = Non-technical energy loss (kWh)

E_{total} = Total energy loss (kWh)

$E_{technical}$ = Technical energy loss (kWh)

d. **Final Stage.** This stage consisted of conclusions and suggestions from the conducted research. Also, this stage answered the formulated question and gave a useful suggestion to Pandaan District.

4. Result

a. Configuration of 20 kV distribution network in Tawangrejo feeder

Tawangrejo Feeder was a unique feeder that follows the East Java construction model, or the three-phase four-wire conductor. The configuration used a mesh model with two types of land and air conductor cables and six distribution transformers that were connected to the feeder. The supporting components were also suitable for the feeder network specification.

b. Total calculation of yearly Loss in 20 kV distribution network in Tawangrejo Feeder

In 2017, there was 18,445.94 W power loss and 116,498 kWh energy loss in Tawangrejo Feeder. The highest total power and energy losses occur in November with the values of 20,461.65 W and 12,312 kWh. The lowest power and energy losses occur in June with 13,752.26 W and 4,896 kWh.

c. Technical Loss Calculation of 20 kV Distribution Network in Tawangrejo Feeder

In 2017, there were 15,060.98 W power loss and 95,119.78 kWh energy losses. The highest power and energy losses in April and May with a value of 17,187.37 W and 10,623.89 kWh. The lowest power and energy losses occur in June with the values of 11,719.04 W and 4,172.15 kWh.

d. Non-technical Loss Calculation of 20 kV Distribution Network in Tawangrejo Feeder

In 2017, there were non-technical losses in Tawangrejo with a value of 3,384.96 W power loss and 21,378.22 kWh energy loss. The highest non-technical power and energy losses is in August and July with the values of 4,015.90 W and 2,057.07 kWh. The lowest power and energy losses occur in June with the values of 2,033.21 W and 723.85 kWh.

e. Electricity Loss Calculation Application of 20 kV Distribution Network in Tawangrejo Feeder

In the technical loss, the error only occurred in the transformer calculation with the average power loss of 0.0021% and an energy loss of 0.0008%. In the non-technical loss, there was no difference between the application and excel, or 0% error.

f. Determining the Energy Loss Alternative Improvement in Tawangrejo Feeder

In this research, the researcher determined the four improvement alternatives to be applied, such as replacing the conductor duct in the feeder, increasing the feeder voltage, making the conductor duct parallel, and reload the transformer.

g. Losses Comparison After Replacing the Conductor duct

Power loss before replacing the conductor duct occurred around 2.70 kW while replacing the conductor duct occurred around 1.19 kW. The reduction percentage is calculated below.

$$P\% = \frac{P_0 - P_1}{P_0} \times 100\%$$
$$= \frac{2{,}70 - 1{,}19}{7{,}50} \times 100\%$$
$$= 56\%$$

The energy loss before conductor duct replacement was around 1,470.80 kWh for a month and total energy loss in 2017 was 17,036.70 kWh. The energy loss after conductor duct replacement was around 649,05 kWh for a month and the total energy loss in 2017 was 7,518.08 kWh. The reduction percentage is calculated below.

$$E\% = \frac{E_0 - E_1}{E_0} \times 100\%$$
$$= \frac{17.036{,}70 - 7.518{,}08}{17.036{,}70} \times 100\%$$
$$= 56\%$$

h. Loss Comparison After Increasing Feeder Voltage

Power loss before increasing the feeder's voltage occurred around 2.70 kW while increasing the feeder's voltage occurred around 2.58 kW. The reduction percentage is calculated below.

$$P\% = \frac{P_0 - P_1}{P_0} \times 100\%$$

$$= \frac{2{,}70 - 2.58}{2{,}70} \times 100\%$$
$$= 4\%$$

The energy loss before increasing the feeder's voltage was around 1,470.80 kWh for a month with total energy loss in 2017 was 17,036.70 kWh. After increasing the feeder's voltage, the energy loss was averaging 1,352.32 kWH for a month with total energy loss in 2017 was 15,692.53 kWh. The reduction percentage is calculated below.

$$E\% = \frac{E_0 - E_1}{E_0} \times 100\%$$
$$= \frac{17.036{,}70 - 15.692{,}53}{17.036{,}70} \times 100\%$$
$$= 8\%$$

i. Losses Comparison After Parallelling Conductor Duct

Power loss before paralleling the conductor duct occurred around 2.70 kW while paralleling occurred in 1.35 kW. The reduction percentage is calculated below.

$$P\% = \frac{P_0 - P_1}{P_0} \times 100\%$$
$$= \frac{2{,}70 - 1{,}35}{2{,}70} \times 100\%$$
$$= 50\%$$

The energy losses before paralleling the conductor duct were averaging 1,470.80 kWh for a month with the total energy loss in 2017 was 17,036.70 kWh. The energy loss after paralleling the conductor duct was averaging in 735.40 kWh for a month with total energy loss in 2017 was 8,518.35 kWh. The reduction percentage is calculated below.

$$E\% = \frac{E_0 - E_1}{E_0} \times 100\%$$
$$= \frac{17.036{,}70 - 8.518{,}35}{17.036{,}70} \times 100\%$$
$$= 50\%$$

j. Losses Comparison After Transformer Reloading

Power loss before transformer reloading occurred around 12,363.44 W while after transformer reloading occurred around 11,630.43 W. the reduction percentage is calculated below.

$$P\% = \frac{P_0 - P_1}{P_0} \times 100\%$$
$$= \frac{12.363{,}44 - 11.630{,}43}{12.363{,}44} \times 100\%$$
$$= 6\%$$

The energy loss before transformer reloading was averaging 6,685.18 kWh for a month with the total energy loss in 2017 of 78,083.08 kWh. The energy loss after transformer loading was averaging 6,275.54 kWh for a month with total energy loss in 2017 off 73,453.67 kWh. The reduction percentage is calculated below.

$$E\% = \frac{E_0 - E_1}{E_0} \times 100\%$$
$$= \frac{78.083{,}08 - 73.453{,}67}{78.083{,}08} \times 100\%$$
$$= 6\%$$

5. Conclusion

After the detailed discussion above, the researcher concluded that: Tawangrejo Feeder was a unique feeder that follows the East Java construction model with the three-phase four-wire conductor. The supporting components also followed the feeder's network specification. There were also LBS and DS to prevent Tawangrejo Feeder from losing the continuity of the electricity. The highest total power and energy losses occurred in November with the values of 20,461.65 W and 12,312 kWh. The lowest occurred in June with the values of 13,752.26 W and 4,896 kWh. The total losses were fluctuating depended on the current that was sent from the primary substation to the load. The highest technical power and energy losses occurred in April and May with the values of 17,187.37 W and 10,623.89 kWh. The lowest occurred in June with the values of 11,719.04 W and 4,172.15 kWh. The total losses were fluctuating depended on the current that was sent from the primary substation to the load. The highest non-technical power and energy losses occurred in August and July with the values of 4,015.90 W and 2,057.07 kWh. The lowest occurred in June with the values of 20,033.21 W and 723.85 kWh. The total losses were fluctuating depended on the accuracy of the electrical measurement device. The loss calculation application had a high accuracy because the error was only around 0–0.0021%. Thus, the results were almost identical with manual calculation using excel. The most effective improvement alternative for energy loss of 20kV distribution network in Tawangrejo Feeder, PLN Pandaan District, Pandaan was by replacing the conductor duct. The replacement could reduce the power and energy losses by 56%.

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