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EFFORTS TO OVERCOME LOAD UNBALANCE ON LOW VOLTAGE NETWORKS USING PHB – SR EQUIPMENT (CONNECTION EQUIPMENT FOR HOME CONNECTIONS) AT PT. PLN PERSERO ULP BINJAI TIMUR

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ABSTRACT

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Load imbalance in an electric power distribution system often occurs in the field. This is a single-phase load on different Low Voltage Network subscribers due to the large number of additional electrical loads that do not pay attention to system load imbalances. As a result of this imbalance, a current appears in the neutral of the transformer. The current flowing in the neutral of this transformer causes losses (technical losses/losses), namely losses due to the neutral current in the neutral conductor of the transformer and losses due to neutral current flowing to the ground. By realizing PHB SR (Connecting Equipment for House Connections) it is able to balance the load on the Low Voltage Network on a regular and continuous basis so as to reduce technical losses (losses), simplify the Splicing Field in technical connection of House Connections (SR) on the Pole, improve aesthetics and neatness Network System.

Keywords: Load Imbalance, PHB SR

1. Introduction

Need for electrical energy in Indonesia continues to increase in line with economic growth and technological advances. In meeting the demand for electricity, there was a distribution of loads that were initially evenly distributed, but due to differences in usage time, it caused an imbalance in the load. To maintain the stability of the load, a loading analysis is needed which aims to identify the load imbalance between phases (R, S, T) which causes current to flow in the transformer neutral. The current flowing in the neutral of the transformer can result in losses (losses), namely losses due to the presence of a neutral current in the neutral conductor of the transformer and losses due to neutral current flowing to the ground. The current load equalization process is quite difficult to carry out continuously and periodically, the high current limiting disturbance (NH-Fuse) due to an unbalanced load can cause power outages. Therefore, the author made a dividing device, namely the PHB SR (Connecting Equipment for Home Connections) as a Low Voltage Network (JTR) divider to Home Connections (SR). The occurrence of load imbalance in each phase (RST), so that a fairly high current flows in the Neutral and Grounding. The current load equalization process is quite difficult to carry out continuously and periodically. The high current limiting disturbance (NH-Fuse) due to uneven loading can cause power outages. Aesthetics & tidiness of JTR

2. LITERATURE REVIEW

2.1 Electric Power

System Electric power system has the meaning of a unit of power generation unit, power transmission unit, and electricity distribution unit that distributes electricity from producers to

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consumers equipped with a protection system on the unit. In general, the Electric Power System is divided into three segments, namely Generation, Transmission and Distribution.

2.2 Components of the Distribution Network

1. Substation
2. Primary
3. Distribution
4. Network Distribution Substation Secondary Distribution Network

2.3 Energy Loss in the Distribution Network Energy

loss in this distribution network can be divided into several parts, including:

1. Energy loss at the feeder
2. Energy loss at distribution transformer
3. Energy loss at point Jointing (jointing)

Non-Technical Loss is a loss or loss of power due to non-technical factors, in the sense that it is a shrinkage that really cannot be accounted for as a cause of this shrinkage. Some examples of the causes of this non-technical shrinkage are the theft of electricity. Another cause that often occurs is due to an error in recording the value. More clearly the parameters that must be considered which are often the cause of non-technical losses are as follows:

1. Electrical Energy Measurement
2. Customer Meter Recording
3. Own use
4. Loss calculation and reporting procedures
5. Customer contact
6. Network Composition

While technical losses are losses that occur due to system imperfections, in other words a definite loss and a calculation model can usually be made. In general, the formula for calculating technical losses is derived from the following formula:

Shrinkage = I^2Channel x Rcable

I = the current flowing in the network (Amperes)

R = the resistance in the conductor (Ω)

Then the resistance of the cable is defined by the equation

$$R = xl / A$$

R = Resistance in conductor (Ω)

= resistance of conductor type (meter)

l = Length of conductor (meter)

A = cross-sectional area of conductor (meters ^{2})

From the above equation it can be seen that simply network losses are caused by large currents that flows, this is influenced mainly by load centers, the more loads that work, the greater the current flowing in the network. Then also caused by the conductor will also be smaller.

3. METHOD

3.1 Technical

Data carried out in this study are in the form of profile data of Distribution Substations and Low Voltage Networks. Where this research was taken based on the results of the evaluation, so that it was used as a research sample. This study aims to determine the imbalance in the Low Voltage Network and how much energy is lost/shrunk from the Voltage Network. Low which supplies energy to the people who use electricity.

Image 1 Pole Transformer Pole

Transformer Specifications :

Substation	: TP 15P
Brand / Type	: Trafindo / Outdoor
Power	: 200 kVA
Working Voltage	: 21/20,5/20/19,5/19 kV // 400 V
Current	: 6.8 – 359 A
Relationship	: Dyn5
Impedance	: 4%
Transformer	: 1 x 3 phase

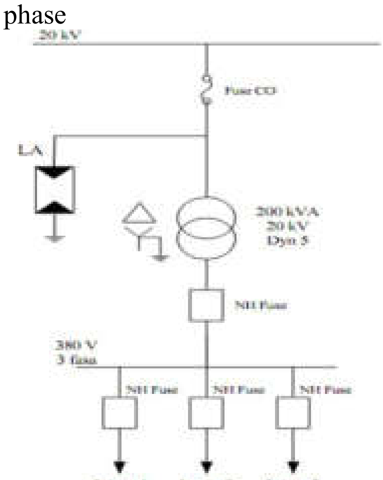


Figure 2 Transformer Loading Line (I)

3.2 Initial Low Voltage Network Schematic

Table 1 Transformer Loading Data (I)

Phase	S(kVA)	Vp-n (V)	I(A)
		Night Measurement	
R	50.42	226	223.1
S	37.29	226	165
T	20.57	227	90.6
IN		118.6 A	
IG		62.1 A	
RG		3.8Ω	
		Night Measurement	
R	68.31	225	303.6
S	42.42	226	187.7
T	37.38	226	165.4
IN		131.7 A	

IG		58.9 A	
RG		3.8	

The wire size for the transformer neutral conductor is 50 mm2 with R = 0.6842 /km, while the phase conductor wire is 70 mm2 with R = 0.5049 /km .

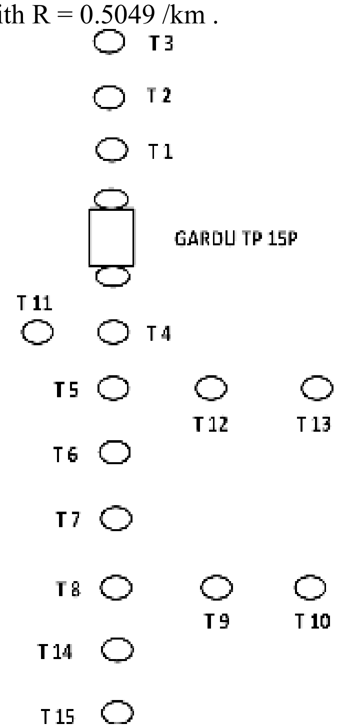
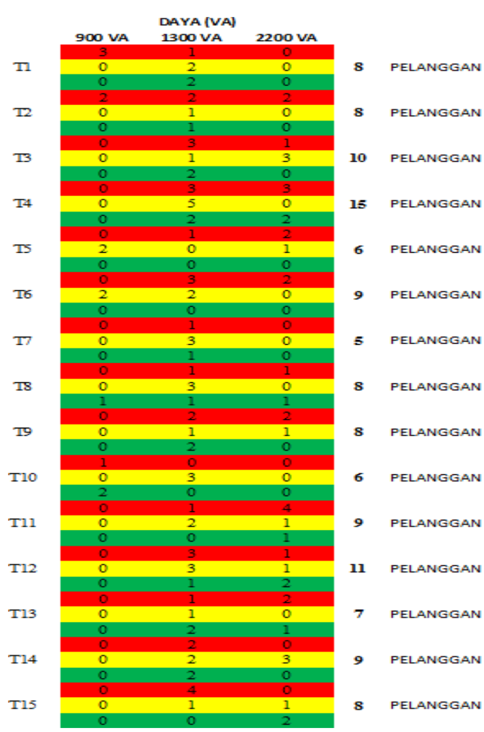


Figure 3 Electric Pole Sketch



	DAYA (VA) 900 VA	1300 VA	2200 VA		
	3	1	0		
T1	0	2	0	8	PELANGGAN
	0	2	0		
	2	2	2		
T2	0	1	0	8	PELANGGAN
	0	1	0		
	0	3	1		
T3	0	1	3	10	PELANGGAN
	0	2	0		
	0	3	3		
T4	0	5	0	15	PELANGGAN
	0	2	2		
	0	1	2		
T5	2	0	1	6	PELANGGAN
	0	0	0		
	0	3	2		
T6	2	2	0	9	PELANGGAN
	0	0	0		
	0	1	0		
T7	0	3	0	5	PELANGGAN
	0	1	0		
	0	1	1		
T8	0	3	0	8	PELANGGAN
	1	1	1		
	0	2	2		
T9	0	1	1	8	PELANGGAN
	0	2	0		
	1	0	0		
T10	0	3	0	6	PELANGGAN
	2	0	0		
	0	1	4		
T11	0	2	1	9	PELANGGAN
	0	0	1		
	0	3	1		
T12	0	3	1	11	PELANGGAN
	0	1	2		
	0	1	2		
T13	0	1	0	7	PELANGGAN
	0	2	1		
	0	2	0		
T14	0	2	3	9	PELANGGAN
	0	2	0		
	0	4	0		
T15	0	1	1	8	PELANGGAN
	0	0	2		

Figure 4 Number of Customers (I)

3.3 Calculation and Percentage of Loading Transformer (I)

S = 200 kVA , V = 400 V (phases)

$$I_{FL} = \frac{s}{\sqrt{3 x v}} = \frac{20000}{\sqrt{3 x 400}} = 288{,}68\ A$$

$$I_{Rata\ Siang} = \frac{I_R + I_S + I_T}{3} = \frac{223{,}1 + 165 + 90{,}6}{3} = 159{,}67\ A$$

$$I_{Rata\ Malam} = \frac{I_R + I_s + I_T}{3} = \frac{303{,}6 + 187{,}7 + 165{,}4}{3} = 218{,}90\ A$$

Percentage of Transformer

$$\frac{I_{Rata\ Siang}}{I_{FL}} = \frac{159{,}67}{288{,}68} = 55{,}31\%$$

$$\frac{I_{Rata\ Malam}}{I_{FL}} = \frac{218{,}90}{288{,}68} 75{,}83\%$$

Load Peak load time (WBP) is 75.83%

3.4 Calculation load on Transformer (I)

3.4.1 During the Day

By using equation (6), the magnitude of the coefficients a, b, and c can be known, where the magnitude of the phase current in a balanced state (I) is equal to the average current (Irata)

$$I_R - a x I, maka : a - \frac{I_R}{I} - \frac{223{,}1}{159{,}67} - 1{,}40$$

$$I_S - b x I, maka : a - \frac{I_S}{I} - \frac{165}{159{,}67} - 1{,}30$$

$$I_T = c x I, maka : a = \frac{I_T}{I} = \frac{90{,}6}{159{,}67} = 0{,}57$$

In a balanced state, the magnitude of the coefficients a, b and c is 1. Thus, the average load imbalance (in %) is:

$$\frac{\{|a-1+|b-1+|c-1\}}{3} x 100\%$$

$$\frac{\{|1{,}4-1|+|1{,}3-1|+|0{,}57-1|\}}{3} x 100\% = 28.67\%$$

3.4.2 At Night

Using equation (6), the coefficients a, b, and c can be determined magnitude, where the magnitude of the phase current in a balanced state (I) is equal to the average current (Irata)

$$I_R = a x I, maka : a = \frac{I_R}{I} = \frac{303{,}6}{218{,}9} = 1{,}39$$

$$I_S = b x I, maka : a = \frac{I_S}{I} = \frac{187{,}7}{218{,}9} = 0{,}86$$

$$I_T = c x I, maka : a = \frac{I_T}{I} = \frac{165{,}4}{218{,}9} = 0{,}75$$

In a balanced state, the coefficients a, b and c are 1. Thus, the average load unbalance (in %) is:

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$$\frac{\{|a-1+|b-1|+|c-1|\}}{3}x100\%$$

$$\frac{\{|1{,}39-1|+|0{,}86-1|+|0{,}75-1|\}}{3}x100\%=26\%$$

From the calculations above, it can be seen that both during the day and at night, the load balance is quite high (> 25%), this is due to the use of uneven load between customers.

3.5 Calculation of Technical Losses (I)

3.5.1 During the Day

Based on these data, the losses due to neutral current in the transformer neutral conductor can be calculated,
namely: = (^{2}. 118,6)^2 . 0.6842
= 9623.92 Watt 9.62 kW

Where is the active power of the transformer (P): P = S . cos , where cos used is 0.85 P = 200 . 0.85 = 170 kW So the percentage of losses due to the neutral current in the neutral conductor of the transformer are:

$$\%P_N = \frac{P_N}{P}x100\% = \frac{9{,}62}{170}x100\% = 5{,}66\%$$

Losses due to the neutral current flowing to the ground can be calculated, namely: G= ()^2 . 62.1)^2 . 3.8 = 146554,4 Watts 14.65 kW.

Thus the percentage of losses due to the neutral current flowing to the ground is:

$$\%P_G \quad \frac{P_G}{P}x100\% \quad \frac{14{,}65}{170}x100\% \quad 8{,}62\%$$

3.5.2 At Night

Losses due to the neutral current in the neutral conductor of the transformer can be calculated, namely: N= ()^2 . 131.76)^2 . 0.6842 = 11867.37 Watts 11.87 kW. So the percentage of losses due to the neutral current in the neutral conductor of the transformer is:

$$\%P_N = \frac{P_N}{P}x100\% = \frac{11{,}87}{170}x100\% = 6{,}98\%$$

Losses due to the neutral current flowing into the ground can be calculated in magnitude, namely: ^{2}= (). 58,9)^2 . 3.8 = 13183 Watt 13.18 kW.. Thus the percentage of losses due to the neutral current flowing to the ground is:

$$\%P_G = \frac{P_G}{P}x100\% = \frac{13.18}{170}x100\% = 7{,}75\%$$

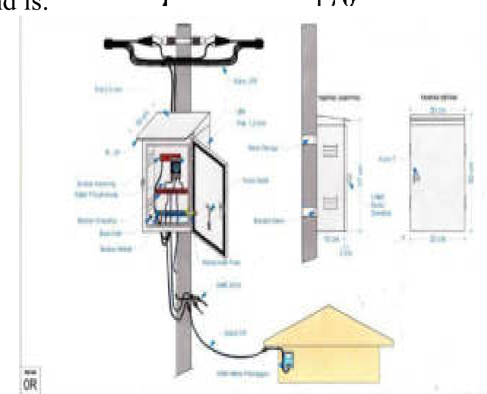

Figure 5 PHB-SR 1 phase

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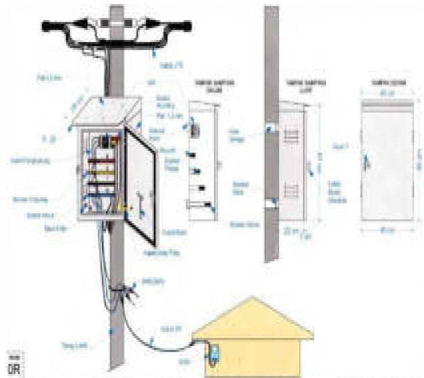

Figure 6 PHB-SR 3 phase

3.6 Technical

a. PHB SR consists of PHB 1 phase and 3 phase
b. PHB 3 phase PHB functions as a load maneuvering place (SR transfer from high phase to low phase)
c. 1 phase SR PHB is installed on each pole, in the order that the 1st pole is connected to the R phase, the 2nd pole is connected to the S phase, the 3rd pole is connected to the T phase, the 4th pole is installed with a 3-phase PHB SR (functions for maneuvering the load), the 5th pole and then a 1-phase PHB SR is installed sequentially following the phase
d. . Move the Home Connection (SR) cable to the SR PHB, then take measurements in each direction on the PHB-TR
e. After getting the day and night measurements, do a load maneuver at the 3-phase PHB SR
f. . The ideal load equalization results (<20%)
g. The load is unstable, within a certain time the load will increase. If the load distribution conditions are not ideal, then perform a load maneuver. With this PHB SR, the transfer of loads in the Low Voltage Network will be more effective, efficient and easy.

4. RESULTS AND DISCUSSION

4.1 Network Data

Comparison of transformer loading data before and after PHB-SR is installed to be able to measure and analyze imbalances loads that cause high losses in each substation, including: transformer load measurement results, current measurement results in the neutral conductor, current measurement results on the ground wire and the length of the Low Voltage Network

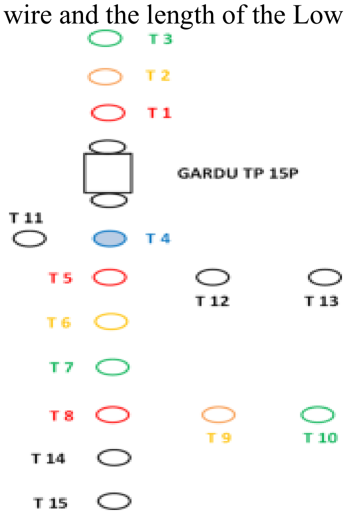

Figure 7 Electric Pole Sketch (II)

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	DAYA (VA) 900 VA	1300 VA	2200 VA		
T1	3	5	0	8	PELANGGAN
T2	2	4	2	8	PELANGGAN
T3	0	6	4	10	PELANGGAN
T4	0	5	2	7	PELANGGAN
	0	2	0	2	PELANGGAN
	0	3	3	6	PELANGGAN
T5	2	1	3	6	PELANGGAN
T6	2	5	2	9	PELANGGAN
T7	0	5	0	5	PELANGGAN
T8	1	5	2	8	PELANGGAN
T9	0	5	3	8	PELANGGAN
T10	3	3	0	6	PELANGGAN
T11	0	1	2		
	0	2	3	9	PELANGGAN
	0	0	1		
T12	0	3	1		
	0	3	1	11	PELANGGAN
	0	1	2		
T13	0	1	2		
	0	1	0	7	PELANGGAN
	0	2	1		
T14	0	2	0		
	0	2	3	9	PELANGGAN
	0	2	0		
T15	0	4	0		
	0	1	1	8	PELANGGAN
	0	0	2		
	13	74	40	127	TOTAL PELANGGAN

Figure 8 Number of Customers (II)

Table 2 Data Loading Transformer (I)

Phase	S(kVA)	Vp-n (V)	I(A)
Night Measurement			
R	35.78	226	158.3
S	37.85	225	168.3
T	33 ,81	226	149.6
IN		46.6 A	
IG		12.1 A	
RG		3.8Ω	
Night Measurement			
R	52.79	225	234.6
S	48.88	226	216.3
T	46.96	226	207.8
IN		64.1 A	
IG		21.4 A	
RG		3.8	

4.2 Calculation and Percentage of Loading Transformer (II)

S = 200 kVA , V = 400 V (phases)

$$I_{FL} = \frac{S}{\sqrt{3 x v}} = \frac{20000}{\sqrt{3 x 400}} = 288{,}68\ A$$

$$I_{Rata\ Siang} = \frac{I_R + I_S + I_T}{3} = \frac{158{,}3 + 168{,}2 + 149{,}6}{3} = 158{,}7\ A$$

$$I_{Rata\ Malam} = \frac{I_R + I_S + I_T}{3} = \frac{234{,}6 + 216{,}3 + 207{,}8}{3} = 219{,}57 A$$

Percentage of Transformer

$$\frac{I_{Rata\ Siang}}{I_{FL}} = \frac{158{,}7}{288{,}68} = 54{,}97\%$$

$$\frac{I_{Rata\ Malam}}{I_{FL}} = \frac{219{,}57}{288{,}68} = 76{,}06\%$$

Load Time Peak Load (WBP) is 76.0 6%.

4.3 Calculation of load imbalance on Transformer (II)

4.3.1 During the Day

By using equation (6), the magnitude of the coefficients a, b, and c can be known, where the magnitude of the phase current in a balanced state (I) is equal to the average current (Irata)

$$I_R = a\,x\,I, maka: a = \frac{I_R}{I} = \frac{158{,}3}{158{,}7} = 0{,}99$$

$$I_R = b\,x\,I, maka: a = \frac{I_S}{I} = \frac{168{,}2}{158{,}7} = 1{,}05$$

$$I_T - c\,x\,I, maka: a - \frac{I_T}{I} - \frac{149{,}6}{158{,}7} - 0{,}94$$

In a balanced state, the magnitude of the coefficients a, b and c is 1. Thus, the average load imbalance (in %) is:

$$\frac{\{|a-1| + |b-1| + |c-1|\}}{3} x100\ \%$$

$$\frac{\{|0{,}99-1| + |1{,}05-1| + |0{,}94-1\}}{3} x100 = 4\%$$

4.3.2 At Night

Using equation (6), the coefficients a, b, and c can be known, where the magnitude of the phase current in a balanced state (I) is equal to the average current (Irata).

$$I_R = a\,x\,I, maka: a = \frac{I_R}{I} = \frac{234{,}6}{219{,}57} = 1{,}07$$

$$I_S = a\,x\,I, maka: a = \frac{I_S}{I} = \frac{216{,}3}{219{,}57} = 0{,}98$$

$$I_T = a\,x\,I, maka: a = \frac{I_T}{I} = \frac{207{,}8}{219{,}57} = 0{,}94$$

In a balanced state, the coefficients a, b and c are 1. Thus, the average load imbalance (in %) is

$$\frac{\{|a-1| + |b-1| + |c-1|\}}{3} x100\%$$

$$\frac{\{|1{,}07-1| + |0{,}98-1| + |0{,}94-1|\}}{3} x100\% = 4.6\%$$

From the above calculation shows that both during the day and at night, the load imbalance is quite low (< 25%) .

4.4 Calculation of Technical Losses (II)

4.4.1 During the Day

Based on these data, the losses due to neutral current in the transformer neutral conductor can be calculated, namely:

²₌ (). ². = (46.6)0.6842 = 1485.78 Watt 1.486 kW

So the percentage of losses due to the presence of a neutral current in the neutral conductor of the transformer is:

$$\%P_N = \frac{P_N}{P} x100\% = \frac{1,486}{170} x100\% = 0,87\%$$

Losses due to a neutral current flowing to the ground can be calculated, namely: G₌ ()² . ². = (12,1)3.8 = 556.36 Watt 0.556 kW.

Thus the percentage of losses due to the neutral current flowing to the ground is:

$$\%P_G = \frac{P_G}{P} x100\% = \frac{0,556}{170} x100\% = 0,33\%$$

4.4.2 At Night

Losses due to the neutral current in the neutral conductor of the transformer can be calculated, namely: N₌ ()² . ². = (64.1)0.6842 = 2811.25 Watts 2.81 kW. So the percentage of losses due to the neutral current in the transformer neutral conductor is:

$$\%P_N = \frac{P_N}{P} x100\% = \frac{2,811}{170} x100\% = 1,65\%$$

Losses due to the neutral current flowing to the ground can be calculated, namely: G₌ ()² . ². = (21.4)3.8 = 1740.25 Watts 1.74 kW.

Thus the percentage of losses due to the neutral current flowing to the ground is:

$$\%P_G = \frac{P_G}{P} x100\% = \frac{1,74}{170} x100\% = 1,02\%$$

4.5 Benefits of PHB-SR Financial Benefits

Reduce losses and savings by (based on data on the discussion of night loads). Rp.1.352 Rp.1.352 = 1 - 13.18 = Rp. 11,136,153= = 1 - 2 11.87 kW – 2.81 kW = 9.06 kW In 1 (one month) savings are obtained by: 9.06 kW × 720 × Rp. 1,352 = Rp.8,819,366. Reduces current limiting interference NH-Fuse, kWH lost due to blackouts and purchase of materials due to damage.

4.6 Non-financial Benefits

a. Facilitating the Connection Field in the technical connection of House Connections (SR) at the Pole
b. Supporting the PLN go green program through the aesthetics and neatness of the Electric Network

5. CONCLUSION

PHB SR is a device for dividing the Home Connection from the Low Voltage Network installed on the Electric Pole, the place for load maneuvering in the implementation of equalization/balancing. At Gradu TP 15P technical losses (losses) due to currents in the neutral cable and grounding cable reached 24.27 kW during the day and 25.05 kW at night. After equalization/maneuver the load dropped to 2.04 kW during the day and 4.55 kW at night, so technical losses (losses) can be reduced by about 80%.

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