Evaluation Of Voltage Profile In ETAP (Electric Transient And Analysis Program) At Ahuru Feeder 20 Kv Medium Voltage Distriution

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Abstract.

Ahuru feeder is the feeder with the longest network of all Ambon city distribution networks. So it is predicted that losses will occur in the network because the longer the distribution channel, the greater the voltage drop. Voltage drops in the network cause energy losses (losses) which need to be evaluated and anticipated whether they occur within normal and reasonable limits. So in this research an evaluation of the voltage profile of the Ahuru feeder was carried out using the power flow analysis method using ETAP 12.6.0 software. Based on the simulation results, under installed load conditions, there is a voltage drop below the PLN standard on the BusL-ERIE3 line of 18.99kV or 95% up to the end of the BusL-WAYOMAR series network of 18.907kV or 94.5% of the nominal voltage of 20 kV. Meanwhile, the base, middle and end line voltage profiles are based on simulation results, the installed load conditions produce a base voltage level of 19.77kV with a voltage drop of 1.2%, the middle of the line 19.09kV with a voltage drop of 3.3% and the end of the line 18.907kV with a voltage fell by 4.3%. Repairing the line voltage profile using capacitor banks on lines and buses that experience voltage drops, namely on BusL-ERIE3 of 2x400 kVAR, is able to improve the voltage profile at the base of the line by 19.804kV or 99%, the middle of the line 19.24kV or 96.2% and the end 19,074kV line or 95.4%.

Keywords: *Voltage profile; losses; feeder; medium voltage 20 kV and ETAP.*

I. INTRODUCTION

The increase in the supply of electrical energy is shown by the electrification ratio in Indonesia in the first quarter of 2022 reaching 99.5%, higher than the electrification ratio in the third quarter of 2021, namely 99.4% [1]. With the increasingly rapid need for electrical energy, it must also be supported by quality channels and services. The quality of channels and services shows the reliability of an electric power system in providing and distributing electrical energy. However, ideal conditions are rarely found because deviations still occur, namely disturbances. Disturbance is a condition or condition that deviates from the standard limits of a certain quantity [2].Voltage drop is a disturbance that often occurs in distribution systems. This is because the location of the load center is far from the generator or main substation (the longer the distribution channel) and the configuration of the distribution network is generally radial. The amount of load also affects the voltage drop, the more load the more current increases [3].

As a result of the large load current and line length, the voltage at load points in the low voltage distribution network is smaller than the standard 220/380 Volts. If the voltage drop is more than the tolerance limit and repairs are not carried out, the impact will be damage to the equipment because it does not work according to the operating voltage.The Sirimau Main Substation, located in Batu Merah Village, Ambon City, supplies 6 feeders including the Karpan 2 feeder, the Manusela feeder, the Upper Tantui feeder, the Stain 1 feeder, the Karpan 1 feeder and the Ahuru feeder. Ahuru feeder is the feeder with the longest channel of all distribution networks in the city area. Ahuru feeder serves areas towards the outskirts of Ambon city such as Mahia village, Kilang village, Latuhalat and Seri villages. The length of the channel on the Ahuru feeder will certainly influence the voltage profile in the distribution network. This research will evaluate the voltage profile on the 20kV Ahuru medium voltage distribution network by analyzing the power flow and providing recommendations for improving the voltage profile through network reconfiguration. This research will use ETAP 12.6.0 software.

1. Voltage Drop

In distribution systems, the issue of voltage is very important, both in operating conditions and in planning, so the voltage must always be considered at each line point. So the selection of conductors (conductor cross-section) for medium voltage must be considered. The amount of voltage loss in the distribution line is measured at the farthest point (end). The voltage equation underlying the phasor diagram is [4]:

$$V_S = V_r + I\,(R\,\cos\theta + jX\,\sin\theta) \quad (1)$$

$$\Delta V = I\,(R\,\cos\theta + jX\,\sin\theta) \quad (2)$$

For conductor length L:

$$\Delta V = I.L\,(R\,\cos\theta + jX\,\sin\theta) \quad (3)$$

To calculate the three-phase voltage drop:

$$\Delta V = \sqrt{3}.I.L\,(R\,\cos\theta + jX\,\sin\theta) \quad (4)$$

with:

ΔV	: Voltage drop	(volt)
$\%\Delta V$	: Voltage drop presentation	(%)
V_s	: Voltage source	(volt)
R	: Resistance line	(Ω/km)
jX	: Reactance	(Ω/km)
I	: Current line	(A)
L	: Conductor length	(km)

II. RESEARCH FRAMEWORK

The following is a research framework for evaluating voltage profiles in the Ahuru feeder 20 kV medium voltage distribution network.

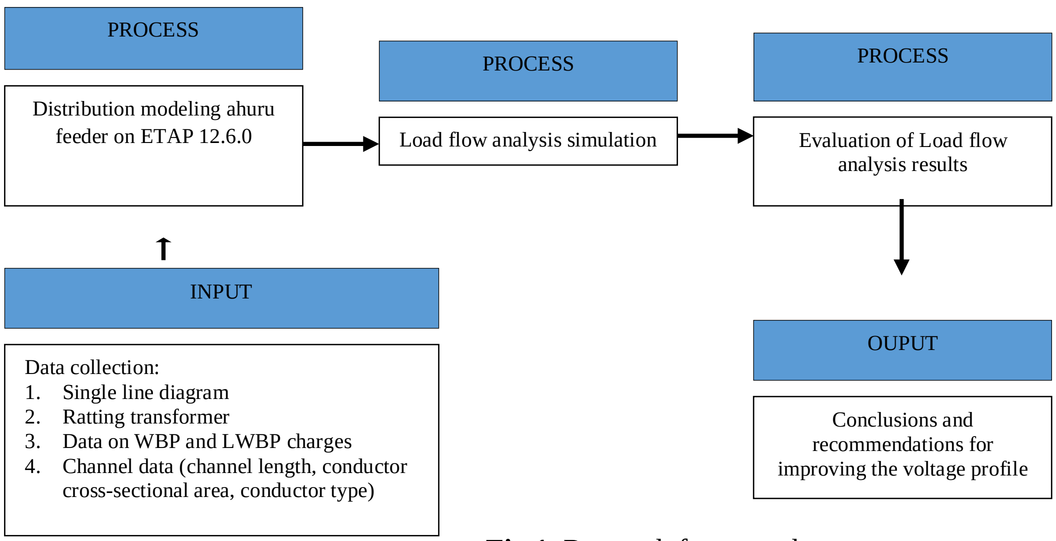

Fig 1. Research framework

2. Ahuru Feeder Profile

The Ahuru feeder is the longest of a number of feeders in the city of Ambon. The length of the Ahuru feeder from GI Sirimau to Wayomar Seri village is 33.91 kms, where the Ahuru feeder is supplied from the Sirimau Main Substation (GI) and serves mountain towns such as a small part of Yakobus-Ahuru, Kayu Tiga, Kayu Putih Soya Village, Refinery Village, Naku village, Kusu-Kusu-Mahia village, Wara, Air Salobar-Latuhalat to Seri village. Figure 4.1 shows a section of the single line diagram (SLD) for the Ahuru feeder which is marked with an orange line connected from the base of the Sirimau GI plant to Seri village.

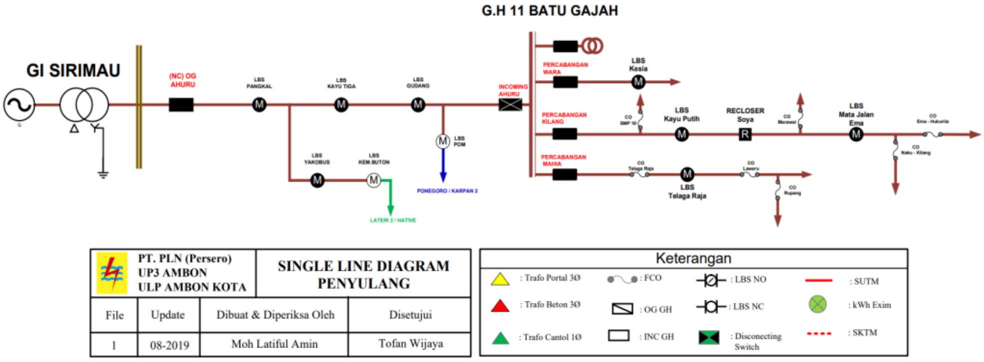

Fig 2. Short form of SLD for Ahuru feeder (ULP Ambon, 2019)

The Sirimau Main Substation is a source of electricity from the Ahuru feeder with a capacity of 2 x 20 MVA Sirimau GI which has two main transformers with a transformer capacity of 20MVA each. The transmission voltage at the Sirimau substation is 70kV with a step down to 20kV. GI Sirimau apart from serving the Ahuru feeder also serves the Upper Tantui feeder, Karpan 1 feeder, Karpan 2 feeder, Manusula-Expres Kota feeder as shown in figure 3 which is a piece of a one-line diagram of the Sirimau Main Substation.

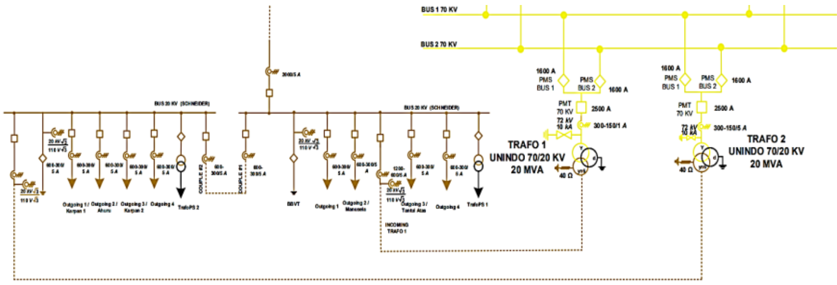

Fig 3. SLD GI Sirimau (UPPM Ambon, 2021)

III. RESULTS AND DISCUSSION

The simulation results of the Ahuru feeder power flow under installed load conditions are shown in the picture below, where the voltage level on the 20kV medium voltage (TM) network has experienced a voltage drop so that the voltage level is below 95%, already below the SPLN provisions.

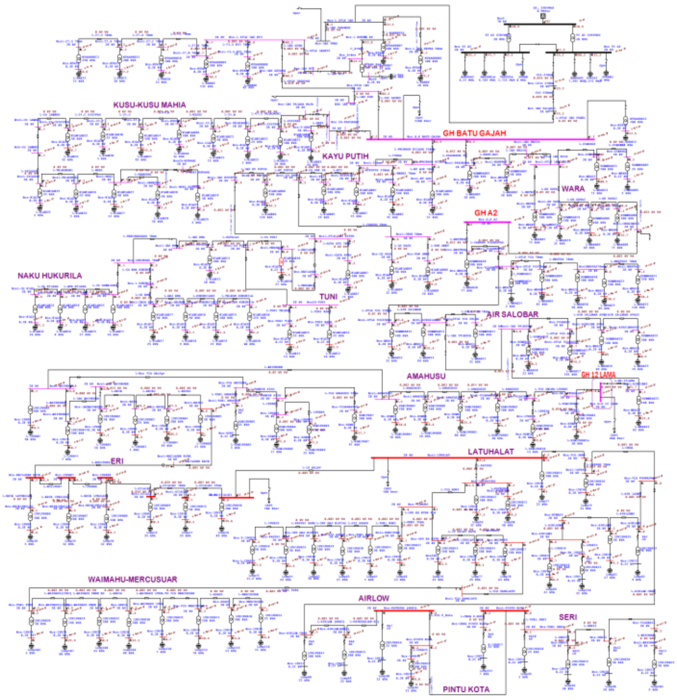

Fig 4. Simulation of power flow under installed load conditions

Based on the power flow analysis simulation results, it can be seen that the TM network has a voltage drop level below 95% as shown in Figure 4.22. The highest critical voltage level is 18.99kV (95%) and the lowest critical voltage level is 18.88kV (94.4%) while the average critical voltage level is 18.92kV (94.6%).The distribution of critical voltage levels resulting from power flow simulations under installed load conditions which provides an illustration of the occurrence of voltage drops reaching critical conditions is shown in table 4.6 below. Based on power flow simulation data, it was found that the lowest voltage level was 18.88kV at the Bus-ANAHU, Bus-ARHIA, Bus-FCO MERCUSUAR, Bus-WAIMAHU LT06, and Bus-WAIMAHU PBRK ES locations. Meanwhile, the maximum voltage drop of 18.99kV occurs on BusL-ERIE3 where this bus is the initial bus where the critical voltage drop on the Ahuru feeder is below 95%.

Table 1. Bus areas with critical voltage levels below 95%

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus-AIRLOW CBNG	Bus	Under Voltage	20,000	kV	18,912	94,6	3-Phase
Bus-AIRLOW(AR02)	Bus	Under Voltage	20,000	kV	18,911	94,6	3-Phase
Bus-AIRLOW1	Bus	Under Voltage	20,000	kV	18,912	94,6	3-Phase
Bus-AIRLOW2	Bus	Under Voltage	20,000	kV	18,912	94,6	3-Phase
Bus-AIRLOW3	Bus	Under Voltage	20,000	kV	18,911	94,6	3-Phase
Bus-ANAHU	Bus	Under Voltage	20,000	kV	18,887	94,4	3-Phase
Bus-ARHIA	Bus	Under Voltage	20,000	kV	18,889	94,4	3-Phase
Bus-CBNG PINTU KOTA	Bus	Under Voltage	20,000	kV	18,910	94,5	3-Phase
Bus-DPN EX KNTR POS	Bus	Under Voltage	20,000	kV	18,902	94,5	3-Phase
Bus-DPN GRJ ELPIDO	Bus	Under Voltage	20,000	kV	18,898	94,5	3-Phase
Bus-ERIELTKOLAN	Bus	Under Voltage	20,000	kV	18,990	95,0	3-Phase
Bus-ERIELTKOLAN2	Bus	Under Voltage	20,000	kV	18,984	94,9	3-Phase
Bus-ERIELTKOLAN3	Bus	Under Voltage	20,000	kV	18,978	94,9	3-Phase
Bus-FCO MERCUSUAR	Bus	Under Voltage	20,000	kV	18,887	94,4	3-Phase
Bus-FCO PUSKESMAS	Bus	Under Voltage	20,000	kV	18,912	94,6	3-Phase
Bus-FCO SERI	Bus	Under Voltage	20,000	kV	18,915	94,6	3-Phase
Bus-FCOMURI	Bus	Under Voltage	20,000	kV	18,904	94,5	3-Phase
Bus-FCOSERI2	Bus	Under Voltage	20,000	kV	18,907	94,5	3-Phase
Bus-HATEUNG (AR03)	Bus	Under Voltage	20,000	kV	18,910	94,6	3-Phase
Bus-KYBESI	Bus	Under Voltage	20,000	kV	18,912	94,6	3-Phase
Bus-LBSPATIRU	Bus	Under Voltage	20,000	kV	18,909	94,5	3-Phase
BusL-ERIE3	Bus	Under Voltage	20,000	kV	18,996	95,0	3-Phase
BusL-FCO NAMALATU	Bus	Under Voltage	20,000	kV	18,898	94,5	3-Phase
BusL-HATEUNG	Bus	Under Voltage	20,000	kV	18,909	94,5	3-Phase
BusL-LAPANG	Bus	Under Voltage	20,000	kV	18,913	94,6	3-Phase
BusL-LTHALAT	Bus	Under Voltage	20,000	kV	18,915	94,6	3-Phase
BusL-MURI35mm	Bus	Under Voltage	20,000	kV	18,903	94,5	3-Phase
BusL-PINTU KOTA	Bus	Under Voltage	20,000	kV	18,910	94,6	3-Phase
BusL-RECLOSER EIRE	Bus	Under Voltage	20,000	kV	18,995	95,0	3-Phase
BusL-SILALE	Bus	Under Voltage	20,000	kV	18,962	94,8	3-Phase
BusL-SILALE2	Bus	Under Voltage	20,000	kV	18,927	94,6	3-Phase
BusL-SILALE3	Bus	Under Voltage	20,000	kV	18,920	94,6	3-Phase
Bus-LTH007	Bus	Under Voltage	20,000	kV	18,984	94,9	3-Phase
Bus-LTH008	Bus	Under Voltage	20,000	kV	18,978	94,9	3-Phase
Bus-LTH045	Bus	Under Voltage	20,000	kV	18,910	94,6	3-Phase
Bus-LTH046	Bus	Under Voltage	20,000	kV	18,911	94,6	3-Phase
Bus-LTHALAT RATA	Bus	Under Voltage	20,000	kV	18,900	94,5	3-Phase
BusL-WAYOMAR	Bus	Under Voltage	20,000	kV	18,907	94,5	3-Phase
Bus-PA_LTH013	Bus	Under Voltage	20,000	kV	18,911	94,6	3-Phase
Bus-PANTAI NAMA	Bus	Under Voltage	20,000	kV	18,898	94,5	3-Phase

Bus-PINTU KOTA	Bus	Under Voltage	20,000	kV	18,910	94,6	3-Phase
Bus-RECLOSER ERIE	Bus	Under Voltage	20,000	kV	18,990	95,0	3-Phase
Bus-SERI1	Bus	Under Voltage	20,000	kV	18,907	94,5	3-Phase
Bus-SERI2	Bus	Under Voltage	20,000	kV	18,907	94,5	3-Phase
Bus-SIS ANAHU	Bus	Under Voltage	20,000	kV	18,899	94,5	3-Phase
Bus-T-LTH026	Bus	Under Voltage	20,000	kV	18,897	94,5	3-Phase
Bus-TSEL MURI	Bus	Under Voltage	20,000	kV	18,899	94,5	3-Phase
Bus-TSEL SERI	Bus	Under Voltage	20,000	kV	18,909	94,5	3-Phase
Bus-TSEL TUPA	Bus	Under Voltage	20,000	kV	18,895	94,5	3-Phase
Bus-WAIMAHU	Bus	Under Voltage	20,000	kV	18,899	94,5	3-Phase
Bus-WAIMAHU LT06	Bus	Under Voltage	20,000	kV	18,888	94,4	3-Phase
Bus-WAIMAHU PBRK ES	Bus	Under Voltage	20,000	kV	18,890	94,4	3-Phase
Bus-WAIMAHU(LT04)	Bus	Under Voltage	20,000	kV	18,893	94,5	3-Phase

The results of the power flow simulation under installed load conditions show the voltage difference between the base of the feeder, the middle of the feeder and the end of the feeder where the base of the feeder has decreased to 19.8kV, the middle of the feeder has reached 19.1kV and at the end of the network the voltage has decreased to 18.91kV. The percentage of voltage drop at the base of the feeder reaches 99%, at the middle of the feeder 95% and at the end of the network 94.5%. The voltage drop between the base of the feeder and the end of the feeder network is 4.3% or a decrease of 0.859kV.

Table 2. Voltage Profile under Installed Load Conditions

Feeder	Current (A)	Medium voltage (kV)						Voltage Drop (base & end)	
		Base		Middle		End			
Ahuru	119,9	GI Sirimau		GH. A12 Lama		Wayomar Seri		(kV)	(%)
		19,766	98,8%	19,099	95,5%	18,907	94,5%	0,859	4,3

Manual calculation of the voltage drop on the BusL-ERIE3 channel using equation 4 and entering data on the channel where the voltage drop occurs in order to ensure that the power flow simulation results are in accordance with the manual calculation.

$$\Delta V_{3\emptyset} = \frac{\sqrt{3}.i(R\ \cos\varphi + X\ \sin\varphi)L}{1000}$$

where :

R = 0,265

X = 0,106

i = 27,5A

PF= 0,85

$$\Delta V_{3\emptyset} = \frac{\sqrt{3}.27{,}5\ (0{,}265\,.0{,}99 + 0{,}106\,.0{,}015)0{,}45}{1000}$$

$$\Delta V_{3\emptyset} = 0{,}0057kV$$

$$Profil\ tegangan\ pada\ BusL - ERIE3 = 19{,}001 - 0{,}0057 = 18{,}995kV$$

Manual calculation of the voltage drop at the end of the BusL-WAYOMAR line is as follows:

$$\Delta V_{3\emptyset} = \frac{\sqrt{3}.i(R\ \cos\varphi + X\ \sin\varphi)L}{1000}$$

where :

R = 0,343

X = 0,134

i = 1,9A

PF=0,85

$$\Delta V_{3\emptyset} = \frac{\sqrt{3}.1,9\ (0,343\ .0,99 + 0,134\ .0,015)2,1}{1000}$$

$$\Delta V_{3\emptyset} = 0,0024kV$$

$$Profil\ tegangan\ pada\ BusL - WAYOMAR = 18,91kV - 0,0024kV$$
$$= 18,907kV$$

The simulation of improving the voltage profile on the Ahuru feeder will use a capacitor bank on the side of the line that experiences a voltage drop, either in marginal conditions (approaching the critical limit) or on the line that experiences a voltage drop.Installing a capacitor bank functions to improve the line power factor to one. To find the most optimum placement location, it is necessary to carry out tests by placing calculated capacitor banks at each distribution substation along the feeder where the capacitor bank will be installed. One step to make it easier to place the capacitor bank is to use a power flow simulation on ETAP to determine the voltage drop below the 95% requirement, where BusL-ERIE3 is the starting point where the voltage drop below 95% occurs on the ahuru feeder when the simulation uses the installed load. Meanwhile, BusL-WAYOMAR is a bus that is at the end of the channel from the Ahuru feeder which has a voltage drop below 95%.

The BusL-ERIE3 voltage quality is 18.996kV or 94.98% and is the starting point for the voltage drop. So by using the Optimal Capacitor Placemant simulation using ETAP, you can find out the capacity of the capacitor bank to improve the quality of the line voltage as shown in Figure 4.32, where the results of the ETAP analysis calculation require 706.99kvar and to adjust to the value of the capacitors in the field used 2 x 400kvar with a voltage of 20kV . Thus, the placement of the capacitor bank is carried out at the starting point of the voltage, namely the drop on BusL-ERIE3 as shown in the figure.

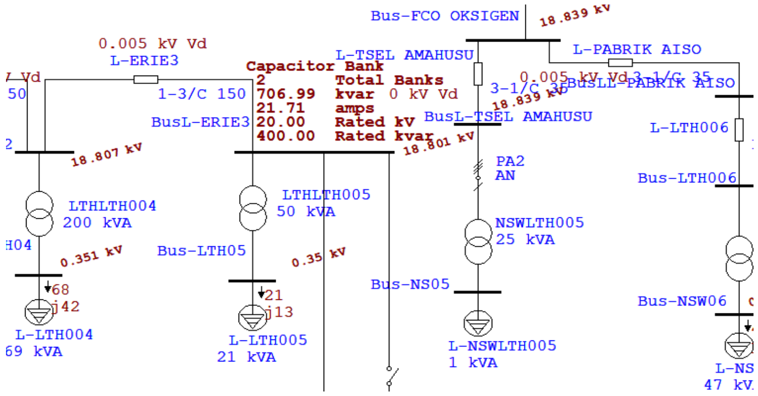

Fig 5. Simulation of determining the capacitor bank capacity on the BusL-ERIE3 Feeder Ahuru

The simulation results after installation of the 2x400kvar capacitor bank resulted in an increase in the voltage level from 18.996kV on BusL-ERIE3 to 19.163kV and 18.907kV to 19.074kV at the end of the BusL-WAYOMAR line. This condition proves that there has been an improvement in the voltage profile on the ahuru feeder, especially on lines experiencing critical stress conditions become marginal stress conditions or still have a tolerance value.The voltage levels at the base, middle and end after the voltage repair on the Ahuru distribution channel also experienced improvements between before and after using the capacitor with the results as in table 3.

Table 3. Voltage profile before and after using the capacitor bank

Feeder	Current (A)	Medium voltage (kV)						Voltage Drop (base & end)	
		Base		Middle		End			
		GI Sirimau		GH. A12 Lama		Wayomar Seri		(kV)	(%)
Sblm Cap Bank	119,9	19,766	98,8%	19,099	95,5%	18,907	94,5%	0,859	4,3
Stlh Cap Bank	112,7	19,804	99,0%	19,239	96,2%	19,074	95,4%	0,730	3,7

When the capacitor bank is placed on BusL-ERIE3 and affects the line voltage profile, it automatically influences the voltage conditions at the base, middle and end of the network line where the base voltage reaches 99%, the middle reaches 96.2% and the end of the line reaches 95.4%.

IV. CONCLUSION

Based on research conducted on the analysis of the stress profile on the Ahuru Feeder, it can be concluded:

1. Power flow simulation under the condition that the installed load has experienced a voltage drop below the PLN standard on the BusL-ERIE3 line of 18.99kV or 95% up to the end of the BusL-WAYOMAR series network of 18.907kV or 94.5%.
2. The installed load conditions produce a base voltage level of 19.77kV with a voltage drop of 1.2%, the middle of the line 19.09kV with a voltage drop of 3.3% and the end of the line 18.907kV with a voltage drop of 4.3%.
3. Repair the line voltage profile using the capacitor bank installation method with ETAP simulation on lines and buses that experience voltage drops, namely on BusL-ERIE3 of 2x400kvar, able to improve the voltage profile at the base of the line by 19.804kV or 99%, the middle of the line 19.24kV or 96.2% and the end of the line 19.074kV or 95.4%.

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