Power Network Protection Study by Considering Losses in the Electrical System of PT. Pertamina Cepu Semanggi

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Abstract. The need for electrical energy has become a daily necessity for the entire community. In reality in the field, there are constraints that may occur in electric power distribution. One of the obstacles in the distribution of electricity is power losses. Power losses in the distribution of electricity are power losses in the distribution network and transmission network. The main parameter in the calculation of losses in the distribution of electricity is caused by the current flowing in the conductor. Power losses in the distribution network need to be considered because they can cause considerable power losses. The purpose of this research is to calculate how much voltage drop and power loss is in the distribution network of PT Pertamina EP Unit Cepu Semanggi. This research was conducted by determining the data of conductor and load parameters with the method of calculation and simulation of ETAP 19.0 software. After that, manual calculations are carried out along with running simulations on ETAP 19.0 software. The average analysis results for voltage drop obtained a voltage drop of (0.2056%). The results of the analysis for the average active power loss obtained an average active power loss of (0,9358 %). This is still within PLN standards, where according to the State Electricity Company Standard (SPLN) 72: 1987, the maximum or maximum voltage drop is 4%.

Keywords: Power, Energy, Voltage Drop, Losses

1 Introduction

Electricity systems are critical infrastructure in modern life. Vulnerabilities in the power grid can cause modern life, and vulnerabilities in the power grid can have a significant impact on society and the economy. Therefore, therefore, the security and reliability of the power grid must be taken seriously, especially in the face of threats such as system failures, cyber-attacks, or natural disasters. natural disasters. The electricity distribution network is a system used to distribute electrical energy from power plants to customers or consumers. electrical energy from power plants to customers or consumers. This network consists of various equipment such as transformers, cable networks, and safety equipment such as fuses and circuit breakers. safety equipment such as fuses and circuit breakers. The reliability of the electrical power network safety system is very important to prevent power outages

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can cause significant losses to communities, industries, and businesses. communities, industries, and businesses. To improve the reliability of the safety system power network, several ways can be done, such as good planning, good protection and control systems. good planning, proven protection and control systems, use of appropriate technology, training, and certification of personnel, monitoring of appropriate technology, personnel training and certification, regular monitoring and maintenance, and the availability of power reserves. All these factors must be considered and implemented seriously to ensure the reliability of the power grid safety system. power grid safety system.

In this research, losses in the electricity distribution network will be analyzed, and an effective security strategy designed. In this study, losses in the electricity distribution network will be analyzed and an effective security strategy to improve network security will be designed. improve network security. The network security system includes several important components that support system reliability such as circuit breakers, fuses, surge arresters, grounding, voltage regulators, relays, and transformers. Transformers. By paying attention to losses, the value of power losses that occur in the electric power network will be known and can be used as a security system. By paying attention to the power losses that occur in the electric power network will be known and can be used as a reference to reduce the power supplied. the power that is distributed. The results of this research are expected to contribute to improving the security and reliability of the electricity network, and provide guidance for network operators in designing security strategies. provide guidance for network operators in designing appropriate security strategies. strategy.

2 Method

The research was conducted at PT Pertamina EP Cepu Semanggi Unit has main equipment which includes generators, transformers, circuit breakers (CB), cables, loads, and buses. PT Pertamina EP Cepu Semanggi Unit has main equipment which includes generators, transformers, circuit breakers (CB), cables, loads, and buses. Generators are used to produce electricity needed in field operations. The transformer serves to change the voltage into a voltage that suits your needs. A circuit breaker (CB) functions as an electrical safety that can cut off the flow of electricity in the event of a disturbance. Cables are used to connect electrical equipment, while loads and buses are used to regulate and control the flow of electricity. used to regulate and control the flow of electricity. This equipment data includes the rating and working voltage of each component, as well as the technical specifications required for effective and efficient operation. required for effective and efficient operation. Information about the main equipment at PT Pertamina EP Cepu Unit Semanggi Unit includes data on generators, circuit breaker (CB) transformers, cables, loads, and buses. cables, loads, and buses. Equipment data includes the rating and working voltage of each component or instrument by displaying data with their respective specifications components.

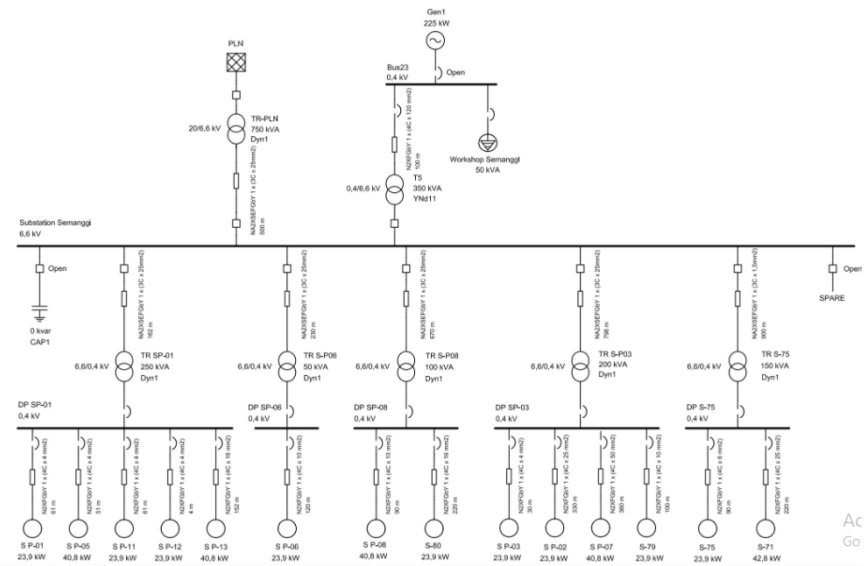


Figure 1. SLD at PT Pertamina EP Cepu Semanggi

The main source in a company engaged in resources cannot be separated from the presence of electrical energy as a supplier of various components and equipment. In this case PT Pertamina EP Cepu Semanggi Unit uses electricity supply from PLN. In running some equipment, a large source is needed, in this case the Semanggi Unit takes electricity supply from PLN of 20 kV.

Table 1. Grid Specification Data

Grid Specification Data	
Source ID	PLN
Tegangan	20 kV Balance
Rating	554,256 MVAsc
Tipe	3 Phase

In the electrical system of PT Pertamina EP Unit Cepu Semanggi, electrical equipment such as transformers are needed to provide voltage with various ratings. Transformer data used at PT Pertamina EP Cepu Semanggi Unit as follows

Table 2. Transformers Specification Data

Unit	Rating	Teg. Kerja		FLA		Sistem Kerja
		Prim	Sec	Prim	Sec	
TR PLN	750	20 kV	6,6 kV	21,65	65,61	Step Down
TR Gen	350	0,4	6,6	505,2	30,62	Step Up
TR SP-01	250	6,6	0,4	21,87	360,8	Step Down
TR SP-02	50	6,6	0,4	4,374	72,17	Step Down
TR SP-03	100	6,6	0,4	8,748	144,3	Step Down
TR SP-04	200	6,6	0,4	17,2	288,7	Step Down
TR SP-05	150	6,6	0,4	13,12	216	Step Down

Electrical safety components are components that function to secure an electrical network that functions to disconnect and connect the line. In this case PT Pertamina EP Unit Cepu Semanggi uses two types of breakers, namely those that work in high voltage and low voltage. This breaker works at a voltage of 6.6 kV for high voltage and 0.4 kV for low voltage.

Table 3. Breakers Specification Data

Unit	Teg		Rating	Bagian
	Prim	Sec		
CB PLN	20 kV	6,6 kV	1,01 kV	Sumber
CB TR-Sub	6,6 kV	6,6 kV	1,01 kV	
CB Gen	0,4 kV	6,6 kV	1,01 kV	
CB Gen-Sub	6,6 kV	6,6 kV	1,01 kV	
CB SP-01-1	6,6 kV	6,6 kV	1,01 kV	Section 1
CB SP-01-2	6,6 kV	0,4 kV	1,01 kV	
CB DP-01-1	0,4 kV	0,4 kV	1,01 kV	
CB DP-01-2	0,4 kV	0,4 kV	1,01 kV	
CB DP-01-3	0,4 kV	0,4 kV	1,01 kV	
CB DP-01-4	0,4 kV	0,4 kV	1,01 kV	
CB DP-01-5	0,4 kV	0,4 kV	1,01 kV	
CB SP-02-1	6,6 kV	6,6 kV	1,01 kV	Section 2
CB SP-02-2	6,6 kV	0,4 kV	1,01 kV	
CB DP-02-1	0,4 kV	0,4 kV	1,01 kV	

CB SP-03-1	6,6 kV	6,6 kV	1,01 kV	Section 3
CB SP-03-2	0,4 kV	0,4 kV	1,01 kV	
CB DP-03-1	0,4 kV	0,4 kV	1,01 kV	
CB DP-03-2	0,4 kV	0,4 kV	1,01 kV	
CB SP-04-1	6,6 kV	6,6 kV	1,01 kV	Section 4
CB SP-04-2	6,6 kV	0,4 kV	1,01 kV	
CB DP-04-1	0,4 kV	0,4 kV	1,01 kV	
CB DP-04-2	0,4 kV	0,4 kV	1,01 kV	
CB DP-04-3	0,4 kV	0,4 kV	1,01 kV	
CB DP-04-4	0,4 kV	0,4 kV	1,01 kV	
CB SP-05-1	6,6 kV	6,6 kV	1,01 kV	Section 5
CB SP-05-2	6,6 kV	0,4 kV	1,01 kV	
CB DP-05-1	0,4 kV	0,4 kV	1,01 kV	
CB DP-05-2	0,4 kV	0,4 kV	1,01 kV	

To flow electric current to all loads in the electrical system, electrical equipment such as cables is needed. PT Pertamina EP Unit Cepu Semanggi uses various types of cables with different specifications. as a conducting component in the electric power network which here uses NA2XSEFGbY as high voltage (source) and N2XFGbY (section) as low voltage with XLPE-Mag specifications.

Table 4. Cable Specification Data

Tipe	ID Cable	Panjang
Sumber	Cable to SS SMG	500 m
	Cable GEN	100 m
Section 1	Cable TR SP-01	167 m
	Cable DP 01-1	61 m
	Cable DP 01-2	51 m
	Cable DP 01-3	61 m
	Cable DP 01-4	40 m
	Cable DP 01-5	152 m
Section 2	Cable TR SP-02	230 m
	Cable DP 02-1	120 m
Section 3	Cable TR SP-03	670 m
	Cable DP 03-1	90 m

	Cable DP 03-2	220 m
Section 4	Cable TR SP-04	798 m
	Cable DP 04-1	30 m
	Cable DP 04-2	330 m
	Cable DP 04-3	360 m
	Cable DP 04-4	100 m
Section 5	Cable TR SP-05	900 m
	Cable DP 05-1	90 m
	Cable DP 05-2	220 m

Most of the loads in the PT Pertamina EP Cepu Unit Semanggi electrical system consist of induction motors, which have an important role in the electrical energy generation process. These induction motors run at a voltage of 0.4 kV, and further information can be identified in the following Table

Table 5. Load Specification Data

Unit	Teg. Kerja	Rating	FLA
SP-01-1	0,4 kV	23,3 kW	51,31
SP-01-2	0,4 kV	40,8 kW	86,61
SP-01-3	0,4 kV	23,9 kW	51,31
SP-01-4	0,4 kV	23,9 kW	51,31
SP-01-5	0,4 kV	40,8 kW	86,61
SP-02-1	0,4 kV	23,9 kW	51,31
SP-03-1	0,4 kV	40,8 kW	86,61
SP-03-2	0,4 kV	23,9 kW	51,31
SP-04-1	0,4 kV	23,9 kW	51,31
SP-04-2	0,4 kV	23,9 kW	51,31
SP-04-3	0,4 kV	40,8 kW	86,61
SP-04-4	0,4 kV	23,9 kW	51,31
SP-05-1	0,4 kV	23,9 kW	51,31
SP-05-2	0,4 kV	42,8 kW	86,61

Bus is the connecting point of a network. At PT Pertamina EP Unit Cepu Semanggi there are several buses that divide several sections with a working voltage of 6.6 kV to 0.4 kv which is divided into each section in the PT Pertamina EP Unit Cepu Semanggi network.

Table 6. Bus Specification Data

Bus	Nominal kV	Operating %
Bus Gen	0,4	100
Substasion Semanggi	6,6	97,03
Bus SP-01	0,4	93,83
Bus SP-02	0,4	94,49
Bus SP-03	0,4	93,63
Bus SP-04	0,4	93,99
Bus SP-05	0,4	93,79

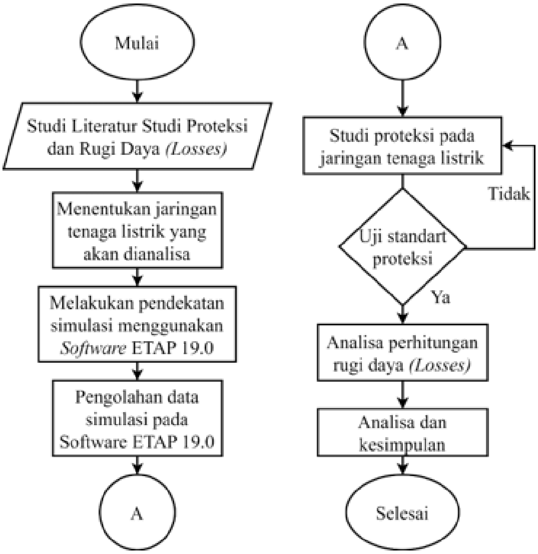


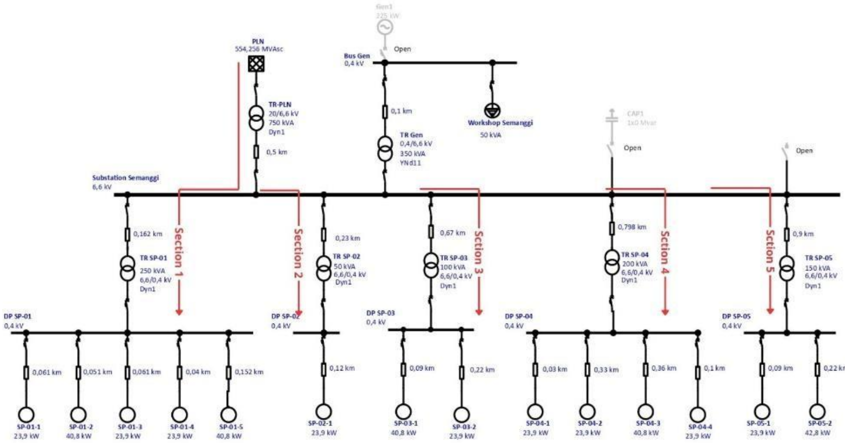
Figure 2. Data processing flow chart

3 Results and Discussion

PT Pertamina EP Unit Cepu Semanggi Section

In calculating the value of losses, there are influencing factors as stated in the formula Equation. Using these equations and formulas, the value of losses is determined and divided into several conditions that represent or represent each condition in each section.

Figure 3. SLD ETAP



The section division in Figure 4.1 includes channels that are burdened by each transformer which has a different load per section. From PLN 20 kV is divided into 5 sections which will be distributed to loads that have different ratings. The various sections have different characteristics in the power flow of the power system.

Voltage Drop Analysis of PT Pertamina EP Cepu Semanggi Unit

In the calculation of voltage drop with Equation, the PT Pertamina EP Unit Cepu Semanggi network obtained the results of each section with data for each section

Table 7. Data of each section at PT Pertamina EP Unit Cepu Semanggi

Trafo	I (A)	R (Ω)	X (Ω/km)	cos Φ	sin Φ	L (km)
250	52,6	2,33	0,1008	0,8932	0,999847	0,61
	65,8	1,46	0,096	0,9055	0,999916	0,51
	52,6	2,33	0,1008	0,8932	0,999847	0,61
	52,1	2,33	0,1008	0,8932	0,999847	0,40
	89	1,46	0,096	0,906	0,894791	0,152
50	52,7	2,33	0,1008	0,8932	0,999847	0,120
100	88,2	1,46	0,096	0,906	0,894791	0,90
	52,9	0,927	0,0984	0,8932	0,999847	0,220
200	52.2	2,33	0,1008	0,8932	0,999847	0,30
	53,1	0,927	0,0984	0,8932	0,999847	0,330
	88,5	0,494	0,0948	0,906	0,894791	0,360

	52,8	2,33	0,1008	0,8932	0,999847	0,100
250	52,8	2,33	0,1008	0,8932	0,999847	0,90
	93,1	0,927	0,0984	0,9071	0,999930	0,22

At PT Pertamina EP Cepu Unit Semangi section 1 there are 5 substations that have different ratings, ranging from cable length, induction motor and resistance.

Table 8. Voltage Drop Calculation

Section	Jatuh tegangan (V)	% Jatuh Tegangan
Section 1	66,8542	0,201
	44,4815	0,134
	66,8542	0,201
	43,4221	0,131
	17,9320	0,054
Section 2	13,1767	0,250
Section 3	105,2219	0,746
	9,7040	0,069
Section 4	32,6291	0,132
	14,6110	0,059
	14,5132	0,059
	11,0014	0,045
Section 5	99,0124	0,679
	17,3404	0,119

Based on the data from Table 8, it can be concluded in the form of a graph that can see the comparison of the results of each section and each conductor. For the graph can be seen in Figure 4.2

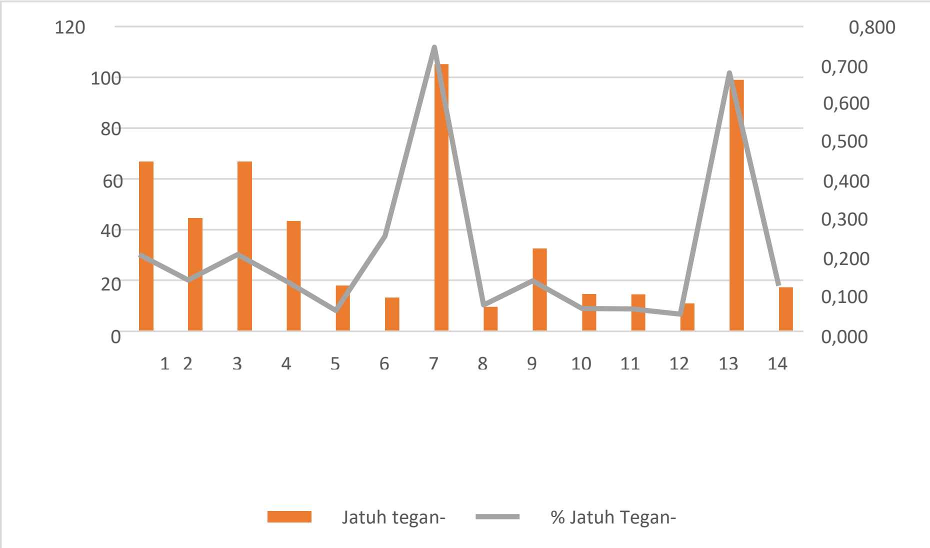


Figure 4. Relationship graph between voltage drop and % voltage drop

Figure 4 is a graphic representation that illustrates the analysis of power losses and the percentage of power losses in the PT Pertamina EP Unit Cepu Semanggi network. From the figure, it can be seen that the voltage drop in various parts of the installation shows a significant variation. For example, in section 1, the voltage drop ranges from 17.9320 V to 66.8542 V. The percentage of power loss in this section is also relatively low, ranging from 0.054% to 0.201%. This suggests that section 1 may have better conditions in terms of power distribution efficiency, although significant voltage drops can still be observed. On the other hand, section 2 displays a lower nominal voltage drop of about 13.1767 V, but with a higher percentage of power loss reaching 0.250%. This shows that although the nominal voltage drop is lower than section 1, the power distribution efficiency in this section may need to be improved to reduce the significant power loss. Section 3 recorded the highest voltage drop among all sections, reaching 105.2219 V with a power loss percentage of 0.746%. This high voltage drop may indicate the presence of bottlenecks or other issues affecting effective voltage distribution in this area. Remedial maintenance or infrastructure upgrades may be required to reduce the significant power loss in this section. Furthermore, section 4 and section 5 also show variations in voltage drop values. Section 4 has a range of voltage drop values from 11.0014 V to 99.0124 V, with the percentage of power loss varying between 0.045% to 0.679%.

Power Loss Analysis of PT Pertamina EP Unit Cepu Semanggi

In electric power transmission lines, things that often occur are voltage drops and power losses. These power losses and voltage drops can occur due to various situations that can cause them to occur. These factors and situations include external and internal factors, in this case external factors include natural factors, the environment and human error, and internal factors include impedance, resistance, and power factors.

Table 9. Data of each section at PT Pertamina EP Unit Cepu Semanggi

Section	Trafo	I (A)	XL (Ω)	L(meter)
1	250	52,6	0,1008	0,61
		65,8	0,096	0,51
		52,6	0,1008	0,61
		52,1	0,1008	0,40
		89	0,096	0,152
2	50	52,7	0,1008	0,120
3	100	88,2	0,096	0,90
		52,9	0,0984	0,220
4	200	52.2	0,1008	0,30
		53,1	0,0984	0,330
		88,5	0,0948	0,360
		52,8	0,1008	0,100
5	250	52,8	0,1008	0,90
		93,1	0,0984	0,22

Table 10 displays the power losses or losses in the PT Pertamina EP Unit Cepu Semanggi network.

Section	Rugi Daya (kW)	% Rugi Daya
Section 1	170,123	0,5124
	211,979	0,6385
	170,123	0,5124
	109,445	0,3297
	115,583	0,3481

Section 2	33,594	0,6375
Section 3	672,126	4,7635
	60,580	0,4293
Section 4	82,399	0,3341
	91,558	0,3713
	267,299	1,0839
	28,101	0,1140
Section 5	252,913	1,7335
	187,636	1,2861

Based on the data from Table 4.4, conclusions can be drawn in the form of graphs that can see the comparison of the results of each section and each conductor. For the graph can be seen in Figure 4.3

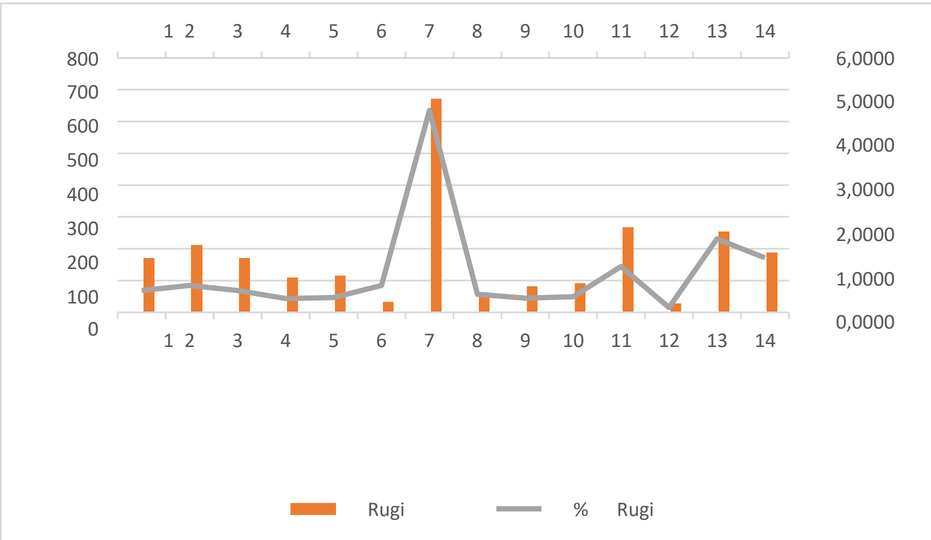


Figure 5. Relationship graph between power loss and % power loss

In Figure 5 the power loss graph for each section consists of several measurement points showing the amount of power loss in kilowatts (kW) and the percentage of power loss. In section 1, the power loss ranges from 100 to 200 kW with a power loss percentage of about 2%, indicating stability in energy efficiency. Section 2 shows a lower power loss, ranging from 50 to 150 kW with a slight but still within acceptable power loss percentage of around 1% to 1.5%. However, in section 3 there is a significant spike at the 7th data point, with power losses reaching around 700 kW and power loss percentages approaching 5%. This indicates a serious problem that requires immediate attention, such as equipment failure or uneven load distribution. In section 4, the power loss decreased again with a range between 50 to 100 kW and the power loss percentage stabilized in the range of 0.5% to 1%, indicating good efficiency. Section 5 shows more pronounced power losses, with values ranging from 50 to 300 kW and the percentage of power loss increasing at some points, especially at the end of the section, reaching around 2%. The spike seen at the 7th data point in section 3 indicates a problem that requires in-depth inspection and maintenance to reduce power loss. The more even distribution of power losses in other sections indicates better load distribution and possibly better-maintained equipment. Therefore, efforts to equalize load distribution across the system can help reduce power loss peaks.

Capacitor Bank Analysis

The value of power loss and voltage loss in the PT Pertamina EP Unit Cepu Semanggi network has a small power loss value when viewed in simulation and manual calculation. This is because the specifications and ratings of various components such as transformers, circuit breakers (CB), cables and loads are appropriate and have been adjusted to the incoming voltage. In the power flow at PT Pertamina EP Unit Cepu Semanggi, the value of losses is not more than 5%, this is in accordance with applicable SPLN standards where power and voltage losses do not exceed 5% of the source voltage. This can be seen in Figure 4.4

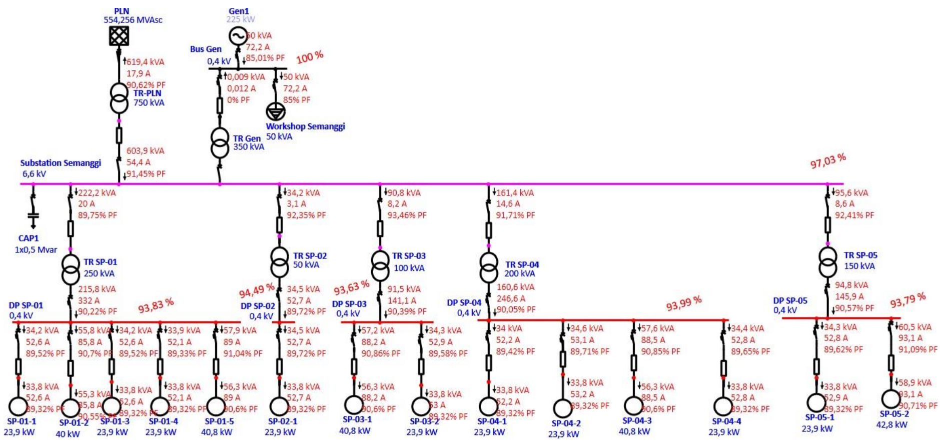


Figure 6. PT Pertamina EP Cepu Semanggi Unit network before capacitor bank installation

Thus PT Pertamina EP Unit Cepu Semanggi can still be improved in distributing electrical energy to be more efficient by adding capacitor banks that are useful for adding electrical energy at points that have high losses. In the PT Pertamina EP Cepu Unit Semanggi network in the condition of the capacitor bank, the value from the source to the Semanggi substation is 101.5% under normal conditions, the voltage flowing from the Semanggi substation to each bus section becomes 98.41% in section 1, in section 2 by 99.04%, section 3 by 98.22%, section 4 by 98.56% and in section 5 by 98.38%.

4 Conclusion

Analysis of the calculation of power losses and voltage drops when compared to the existing values in the load flow simulation and manual calculations obtained results that are close, but there are also different due to many factors including the length of the conductor, the resistance of the conductor and also the current flowing. The load flow of the PT Pertamina EP Cepu Semanggi Unit network under normal conditions and without supply from generators and capacitor banks, the value from the source to the Semanggi substation decreased to 97.03% under normal conditions, the voltage flowing from the Semanggi substation to each bus section decreased again to 92.83% in section 1, in section 2 by 94.49%, section 3 by 93.63%, section 4 by 93.99% and in section 5 by 93.79%. Utilize the latest technologies in monitoring and measurement, such as smart sensors and internet of things (IoT) devices, to obtain more accurate real-time data on current and voltage in the network. This will help in identifying and reducing losses more effectively.z

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