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Evaluation of Technical Shrinkage of Express Extension PL 03 and LW 09 at PLN Lhoksukon Using ETAP Software

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Abstract

The electricity distribution system generally starts from the generation, transmission, and distribution systems. In the distribution system, there are two channels, namely primary distribution with a voltage value of 20 kV and secondary distribution with a voltage of 220/380 V. Distributing electrical energy often experiences problems, one of which is the occurrence of energy losses during the distribution of electrical power to customers. Energy losses are energy losses due to technical and non-technical factors. This study evaluates energy losses due to technical factors in the express extension PL 03 and LW 09 PT PLN (Persero) ULP Lhoksukon. The method used to assess energy losses due to technThe calculation results show that theological factors with ETAP software simulations and more detailed technical shrinkage calculations, namely by calculating conductor and transformer shrinkage on the repeater. From the results of the ETAP simulation, it is obtained that the voltage losses of the PL 03 and LW 09 Lhoksukon ULPs still meet the standards according to SPLN 1: 1995 for a voltage of 20 kV where the limits set are +5% maximum and -10% minimum of the system voltage. The drop Voltage of PL 03 Extension is 7.6%, and LW 09 Extension is 8.25% of the nominal voltage of 20 kV. From the calculation results, of Drop Voltage of the PL 03 Repeater is 5.5%, and the LW 09 Repeater is 8.5% of the nominal voltage of 20 kV.

Keywords: *Electrical Energi, Conductors, Transformers, Technical Shrinkage, ETAP.*

1. Introduction

Electricity is a form of energy produced by the motion of electrically charged particles, such as electrons. Electricity can be used for a variety of purposes, from lighting to operating machinery and electronic devices. Electricity has many advantages over other energy sources, such as being easily distributed through a network of wires and can be generated using various types of natural resources, such as water, wind or the sun [1].

Indonesian people get electricity through PT PLN (Persero). Where, PT PLN (Persero) is a State-Owned Enterprise (BUMN) that manages electricity in Indonesia. As the population in Indonesia increases and in line with technological advances at this time, the need for electricity continues to increase and has become a basic need for the community. As in 2022, electricity consumption per capita in Indonesia reached 1,173 kWh/capita, an increase of about 4% from 2021 [2].

The electricity distribution system generally starts from the generation system then continues to the transmission system, and ends in the distribution system before going to the customer. In the distribution system there are two channels which are primary distribution with a voltage value of 20 kV and secondary distribution with a voltage of 220/380 V. The distribution system is the final stage of the electricity system before reaching the customer [3] [4].

The distribution system generally starts from a repeater that comes out of a 20 kV substation (GI) which is then divided and distributed to the Customer Service Unit (ULP). In the distribution of electrical energy, various problems arise, and one of the main problems faced is energy losses during the process of distributing electricity to customers. This energy shrinkage can occur due to technical factors such as the distance between the power plant and the customer, cable resistance, unbalanced load, leakage current, and transformer losses [5]–[7]. Non-technical factors such as natural conditions (wind, temperature, trees, etc.), poor recording and calculation, and theft [8], [9] [10] [11]. Energy losses can also be seen using ETAP Electrical and Analysis Program Software) specifically for technical factors such as cable resistance, transformer impedance, network length, and load. As conducted by previous research on analyzing the improvement of technical shrinkage and voltage losses on the KLS 06 extension at GI Kalisari using ETAP Software. Energy losses are very influential on the quality and efficiency of electricity so it is necessary to know the factors that cause energy losses [12]. From the results of the calculation of the voltage drop on the wheat reinforcement in the Angke substation, there is a slight difference between manual calculations and calculations using the ETAP 12.6.0 simulation program. The voltage drop results obtained from manual calculations show the largest voltage percentage value of 1.94%, while the results of the ETAP 12.6.0 program show the largest voltage percentage value of 2.01%. This shows that the use of ETAP software in simulating is still relatively accurate [13].

Energy losses also occur at PT PLN (Persero) ULP Lhoksukon, precisely on the express extension PL 03 and LW 09. Which Lhoksukon City gets electricity supply from GI Panton Labu and GI Bayu. The energy shrinkage affects the reliability of the existing electricity system in Lhoksukon City. So it is necessary to research the cause of the shrinkage on the repeater. However, this study specifically discusses the technical shrinkage on the PL 03 and LW 09 express repeater using ETAP Software. Which this study aims to determine the level of technical shrinkage that occurs in the repeater system and identify sources of power loss. The results of this evaluation will provide important information to ULP Lhoksukon to determine the corrective actions needed to improve the quality and efficiency of the power system [14].

Based on the phenomena described above, the researchers are interested in conducting a study entitled "Evaluation of Technical Shrinkage of Express Extension PL 03 and LW 09 at PLN Lhoksukon Using ETAP Software".

2. Literature Review

2.1. Electrical Power Systems

Electric power systems have an important role in delivering electricity from bulk power sources to consumers. This system consists of various components and networks that work in an integrated manner to generate, transmit, and distribute electricity to various places [15]. Large power plants generally produce electrical power with a voltage between 6-24 kV. To transmit the electrical power to consumers, a substation is needed that will increase the voltage using a voltage boosting transformer to a higher voltage, such as 70 kV, 154 kV, 220 kV, or 500 kV. This process of increasing the voltage has an important benefit, which is to reduce power losses in the distribution journey. When the voltage is increased, the electric current flowing will be smaller, so the power loss will also be smaller. This is due to the mathematical relationship between voltage, current, and power, which indicates that by increasing the voltage, the electrical power lost in the course of distribution can be suppressed to a lesser extent [16].

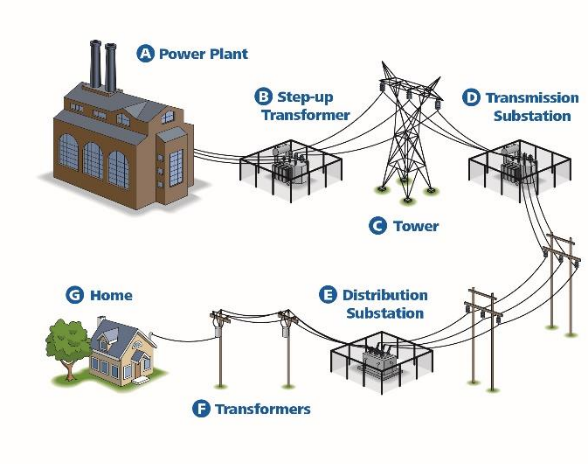

Fig 1. Electrical Power Systems [17]

2.2. Electrical Power

An electric power system consists of three interconnected electrical energies and is affected by the power factor (Cos φ). An alternating current (AC) power supply provides electrical energy in the form of real and reactive power. Reactive power only exists when the load in the system consists of inductive or capacitive loads. Real power (P) is the component of energy that actually operates in a circuit, such as generating heat, light, or mechanical motion. Active power is measured in watts (W) and is the main determinant of the electricity bill that customers receive. Active power is the component of electrical power that effectively produces useful work, such as driving a motor or generating heat in equipment [18], [19].

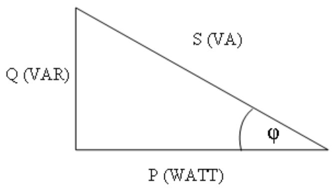

Fig 2. The Power Triangle [20]

2.3. Energy Shrinkage

The energy losses referred to in this context are energy losses that occur in electricity distribution channels. When electrical energy is transmitted through a distribution network, there is a difference between the amount of energy put into the network (input) and the amount of energy removed from the network (output). This difference is known as distribution losses. Distribution losses occur naturally and are the result of various factors. One of the main factors is the resistance of the conductors in the distribution line, which causes power loss in the form of heat. This power loss is caused by the resistance of the conductor and causes some of the energy delivered to the distribution line to be wasted and cannot be utilized by consumers [21].

Energy losses are classified based on several aspects. One way to classify it is by looking at where it occurs, its nature, and its causes. In terms of where it occurs, it is divided into two main parts, namely transmission line shrinkage and distribution line shrinkage:

1. Transmission losses: Transmission losses occur when electrical energy generated from generation is transported through the transmission network to the substation.
2. Distribution Shrinkage: Distribution line losses occur when electrical energy that has arrived at the substation is then distributed through the distribution network to customers.

   Energy depreciation in power distribution systems can be classified based on its causes into two parts, namely technical shrinkage and non-technical shrinkage. This classification helps in understanding the factors that cause energy depreciation in the distribution system.
   a. Technical Shrinkage: Technical shrinkage refers to the energy depreciation that occurs in the power distribution system as a result of technical factors that are strongly influenced by the fluctuation and nature of the load. These factors include the size of the conductor, the length of the line, the voltage system used, the level of insulation present, and other factors directly related to the I2R (energy-to-heat transfer) phenomenon.
   b. Non-Technical Shrinkage: Non-technical shrinkage refers to the energy depreciation that occurs in the power distribution system as a result of non-technical factors. These factors include customer data collection errors, errors when reading and recording electricity meters, cases of violations such as stolen electricity, and other non-technical factors.

3. Methods

The type of research used is a combination of qualitative and quantitative research. This research was conducted to analyze the value of voltage drop and power loss in the ULP Lhoksukon distribution network.

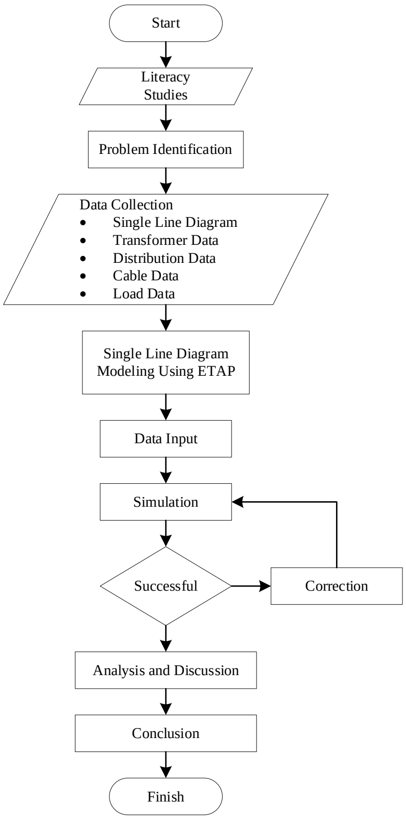

Fig 3. Research Flowchart

The following are the steps for evaluating technical shrinkage using ETAP software:

a. Literacy study, which is conducting a literature review related to the issues discussed so as to provide confidence that the research can be carried out and reduce errors in research.
b. Identification of problem formulation, namely identifying and formulating problems to be solved in the research.
c. Data collection, collecting data in the form of load data, generator data, bus data and transmission lines.
d. Single line diagram modeling, which is modeling in ETAP with the system that will be applied according to the research so that it makes it easier for researchers to analyze the data.
e. Analyzing the power distribution network: After the power distribution network has been modeled, the next step is to analyze the power distribution network on the PL 03 and LW 09 express lines. This analysis will help to determine the level of technical losses on the two lines.
f. Determining the technical shrinkage rate: After analyzing the power distribution network, the next step is to determine the technical shrinkage rate on the two power lines. The level of technical shrinkage will be determined based on the data of tegan-gan and current, power consumption data of the power distribution network.

3.1. Data Collecting

1. One Line Diagram PL 03 dan LW 09

   The one-line diagram used in this study is the one-line diagram of the Express Extension PL 03 and LW 09 as shown in Figure 4 and Figure 5 below.

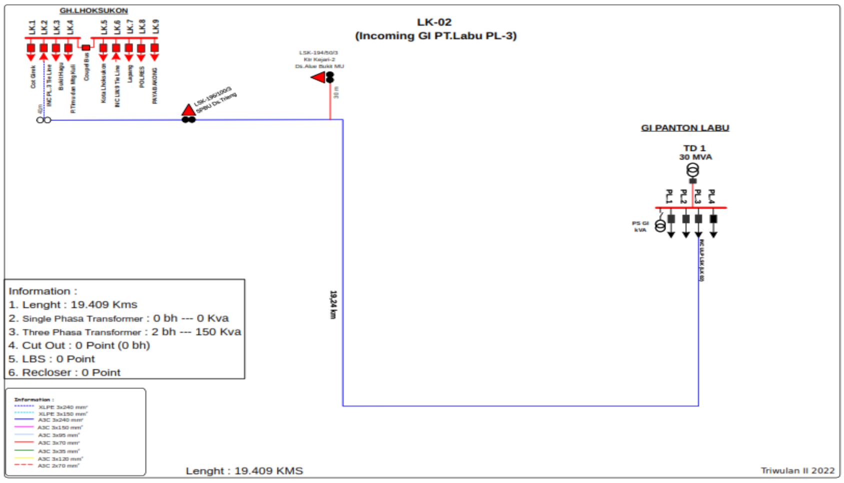

Fig 4. Single Line Diagram of PL 03

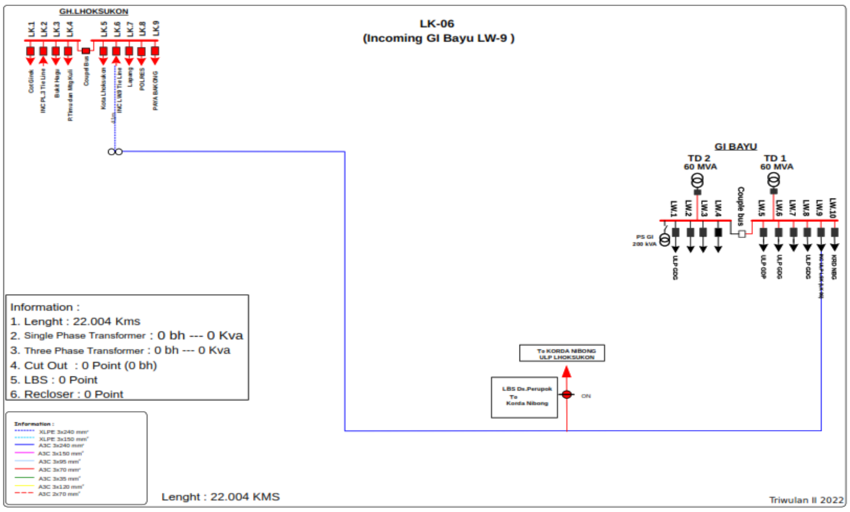

Fig 5. Single Line Diagram of LW 09

2. Transformator Daya
   The power transformer used in the Single Line Diagram (SLD) of the PL 03 and LW 09 Express Repository can be seen in Table 1 below.

Table 1. Transformer Capacity

No	Code	Merk	Capacity (kVA)	P_{fe} (W)
1.	LSK-194	STARLITE	50	250

3. Channel
   The type and size of the channel used in the PL 03 and LW 09 Express Transmission distribution network can be seen in Table 2 as follows.

Table 2. Cable Data

No	Channel	Conductors	Diameter (mm^2)	Length of Channel (km)	Impedance of the Cable (ohm/km)
1.	PL 03	XLPE/AAAC	3 x 240	19,409	0,1344 + j 0,3158
2.	LW 09	XLPE/AAAC	3 x 240	22,004	0,1344 + j 0,3158

4. Loads
   The load data on the PL 03 Express Extension can be seen in Table 3.3 and the load data on the LW 09 extension can be seen in Table 3.4 as follows.

Table 3. PL 03 Repository Data

Date	Transmit Voltage (kV)	Receive Voltage (kV)	ΔV (kV)	Trans-mit Power (MW)	Accept-ability (MW)	ΔP (MW)	Trans-mit Current (A)	Receive Current (A)	ΔI (A)
1/4/2023	21.2	20.51	0.69	3.55	3.55	0	113	113	0
2/4/2023	21.2	20.51	0.69	3.3	3.27	0.03	110	109	1
3/4/2023	21.2	20.51	0.69	3.3	3.27	0.03	105	104	1

4/4/2023	21	20.31	0.69	3.58	3.27	0.31	114	104	10
5/4/2023	21	20.21	0.79	3.61	3.27	0.34	115	104	11
6/4/2023	21	20.11	0.89	3.61	3.58	0.03	115	114	1
7/4/2023	21	20.11	0.89	3.02	3.01	0.01	96	96	0
8/4/2023	21	20.46	0.54	3.3	3.23	0.07	105	103	2
9/4/2023	21	20.3	0.7	3.58	3.23	0.35	114	103	11
10/4/2023	21	20.03	0.97	3.71	3.67	0.04	118	117	1
11/4/2023	21.1	20.14	0.96	3.61	3.61	0	115	115	0
12/4/2023	21.1	20.14	0.96	3.74	3.14	0.6	119	100	19
13/4/2023	21	20.2	0.8	3.62	3.61	0.01	115	114.7	0.3
14/4/2023	21	20.2	0.8	3.62	3.61	0.01	115	114.7	0.3
15/4/2023	21.1	20.14	0.96	3.74	3.71	0.03	119	118	1
16/4/2023	21.1	20.2	0.9	3.74	3.67	0.07	119	117	2
17/4/2023	21.1	20.14	0.96	3.74	3.74	0	119	119	0
18/4/2023	21.1	20.27	0.83	4.71	4.68	0.03	150	149	1
19/4/2023	21.1	20.03	1.07	4.65	4.62	0.03	148	147	1
20/4/2023	21.1	20.16	0.94	4.02	3.96	0.06	128	126	2
21/4/2023	21.1	20.16	0.94	4.33	4.245	0.085	138	135	3
22/4/2023	21.1	20.26	0.84	4.33	4.19	0.14	138	135	3
23/04/2023	21.1	20.26	0.84	3.74	3.71	0.03	119	118	1
24/4/2023	21.1	20.35	0.75	4.4	4.4	0	98	96	2
25/4/2023	21.1	20.35	0.75	3.08	3.01	0.07	126	126	0
26/4/2023	21.1	20.35	0.75	3.96	3.96	0	144	143	1
27/4/2023	20	20	0	4.52	4.49	0.03	140	140	0
Average	21.037	20.237	0.800	3.782	3.693	0.089	120.6	117.79	2.763

Table 4. LW 09 Repository Data

Date	Transmit Voltage (kV)	Receive Voltage (kV)	ΔV (kV)	Trans-mit Power (MW)	Accepta-bility (MW)	ΔP (MW)	Trans-mit Cur-rent (A)	Re-ceive Current (A)	ΔI (A)
1/4/2023	21.4	19.88	1.52	5.47	5.27	0.2	174	167	7
2/4/2023	21.3	19.88	1.42	5.37	5.18	0.19	171	165	6
3/4/2023	21.2	19.95	1.25	5.06	4.93	0.13	161	157	4
4/4/2023	21	19.98	1.02	5.37	5.15	0.22	171	164	7
5/4/2023	21	19.52	1.48	5.37	5.34	0.03	171	170	1
6/4/2023	21	19.7	1.3	5.66	5.28	0.38	180	168	12
7/4/2023	21	19.79	1.21	5.37	5.22	0.15	171	166	5
8/4/2023	21	19.84	1.16	5.47	5.32	0.15	174	168	6
9/4/2023	21	19.61	1.39	5.53	5.32	0.21	175	168	7
10/4/2023	21	19.69	1.31	5.5	5.34	0.16	175	170	5
11/4/2023	21.2	19.59	1.61	5.53	5.34	0.19	176	170	6
12/4/2023	21.2	19.59	1.61	5.62	5.5	0.12	179	175	4
13/4/2023	21.4	20	1.4	5.58	5.43	0.15	177	172.7	4.3
14/4/2023	21.4	20	1.4	5.58	5.43	0.15	177	172.7	4.3
15/4/2023	21.2	19.59	1.61	5.66	5.59	0.07	180	178	2
16/4/2023	21.2	19.56	1.64	5.75	5.59	0.16	183	178	5

17/4/2023	21.2	19.59	1.61	5.56	5.5	0.06	177	175	2
18/4/2023	21.2	19.63	1.57	5.81	5.5	0.31	185	175	10
19/4/2023	21.1	19.6	1.5	5.5	5.5	0	175	175	0
20/4/2023	21.1	19.7	1.4	5.25	5.16	0.09	167	165	2
21/4/2023	21.1	19.7	1.4	5.84	5.78	0.06	186	184	2
22/4/2023	21.1	19.76	1.34	5.78	5.34	0.44	172	138	34
23/04/2023	21.1	19.76	1.34	5.03	4.96	0.07	160	158	2
24/4/2023	21.1	19.86	1.24	5.62	5.22	0.4	179	166	13
25/4/2023	21.1	19.86	1.24	5.47	5.25	0.22	174	167	7
26/4/2023	21.19	19.97	1.22	5.53	5.37	0.16	176	171	5
27/4/2023	21.1	19.86	1.24	5.44	5.31	0.13	173	169	4
Average	21.14	19.76	1.39	5.51	5.338	0.17	174.8	168.61	6.17

5. One Line Diagram circuit with ETAP
   The circuit that has been described in ETAP is as follows:

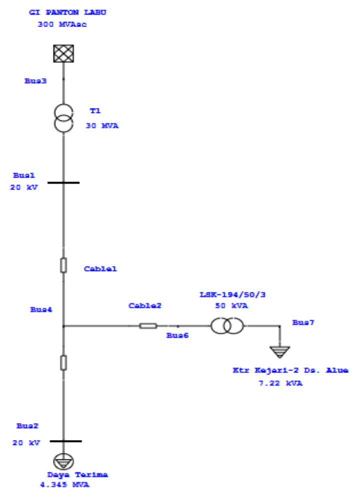

Fig 6. One Line Diagram of PL 03 with ETAP

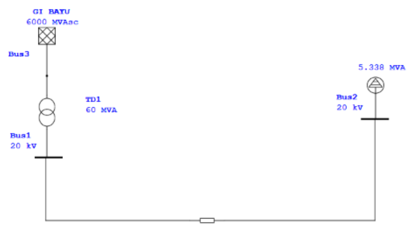

Fig 7. One Line Diagram of LW 09 with ETAP

4. Results and Discussion

The Lhoksukon power system is sourced from GI Panton Labu and GI Bayu with a 20 kV Medium Voltage Air Line (SUTM), which has been synchronized with GH (Substation) Lhosukon. The Panton Labu GI line to GH Lhoksukon uses an Express Extension with the channel code PL 03, while the Bayu GI line to GH Lhoksukon uses an Express Extension with the code LW 09. The length of the PL 03 channel is 19.409 Kms, while the length of the LW 09 channel is 20.004 Kms.
Lhoksukon Electric Power System precisely on the PL 03 and LW 09 channels there are several problems, one of which is the problem of energy losses. From the data obtained by researchers in April 2023, the average voltage loss on the PL 03 line was 0.80 kV or 800 V and on the LW 09 line was 1.39 kV or 1390 V. Therefore, this chapter will analyze what causes the energy losses on the channel.
Based on the data obtained, the energy loss on the PL 03 extension is 89.074 kW or 2137.8 kWh with an average current of 120.519 A and a peak current of 149 A. On the LW 09 extension, the total energy loss is 170.37 kW or 4088.89 kWh with an average current of 174.70 A and a peak current of 186 A. The data is the result of direct field measurements.

The results of the Single Line Diagram simulation using ETAP software on the PL-03 Express Extension can be seen in Figure 8 as follows:

1. Results of Single Line Diagram Simulation of PL 03 Repeater

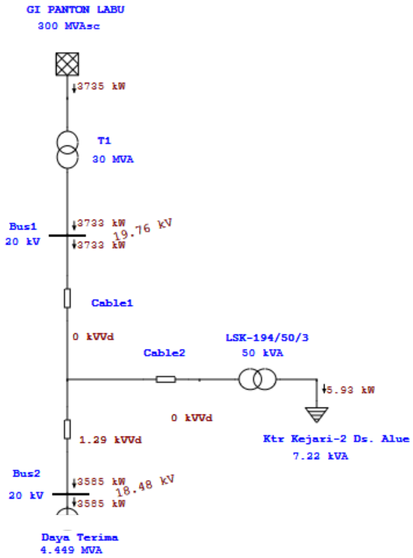

Fig 8. Simulation Results of Single Line Diagram of PL-03

From the simulation results, the power flow can be seen in Table 5 and Branch Losses in Table 6 as follows:

Table 5. Power Flow of PL 03

Bus	Voltage	Load Flow				
ID	**kV**	**ID**	**MW**	**Mvar**	**Amp**	**%PF**
Bus1	20.000	Bus4	3.733	2.706	134.7	81.0
		Bus3	-3.733	-2.706	134.7	81.0
Bus2	20.000	Bus4	-3.585	-2.409	135.0	83.0
Bus3	150.000	Bus1	3.735	2.797	18.0	80.0
Bus4	20.000	Bus1	-3.733	-2.706	134.7	81.0
		Bus6	0.006	0.004	0.2	84.9
		Bus2	3.727	2.702	134.5	81.0
Bus6	20.000	Bus4	-0.006	-0.004	0.2	84.9
		Bus7	0.006	0.004	0.2	84.9
Bus7	0.380	Bus6	-0.006	-0.004	10.8	85.0

Based on Figure 8 and Table 5, it can be seen that there are no problems with power flow and can be said to be in a normal state. It can be seen from the sending voltage of 20 kV and the receiving voltage at the base is 18.48 kV.

Table 6. Branch Losses PL 03

ID	From		To		Losses		%Voltage		% Drop
	MW	Mvar	MW	Mvar	kW	kVAR	*From*	*To*	
Cable1	3.733	2.706	-3.733	-2.706	0.1	0.1	98.9	98.9	0.00
T1	-3.733	-2.706	3.735	2.797	2.0	90.7	98.9	100.0	1.19
Line1	-3.585	-2.409	3.727	2.702	142.0	293.1	92.4	98.9	6.43
Cable2	0.006	0.004	-0.006	-0.004	0.0	0.0	98.9	98.9	0.00
LSK-194/50/3	0.006	0.004	-0.006	-0.004	0.0	0.0	98.8	98.3	0.52
					144.1	383.9			

From the simulation results and data Table 6 and ETAP simulation, it is obtained that the voltage drop on the PL 03 extension is 1.52 kV or 7.6% of the nominal voltage and the power loss is 144.1 kW and 383.9 kVAR.

2. Simulation Results of Single Line Diagram of LW 09 Repeater
   The results of the simulation of the Single Line Diagram of the LW-09 Express Extension using ETAP Software can be seen in Figure 9 as follows.

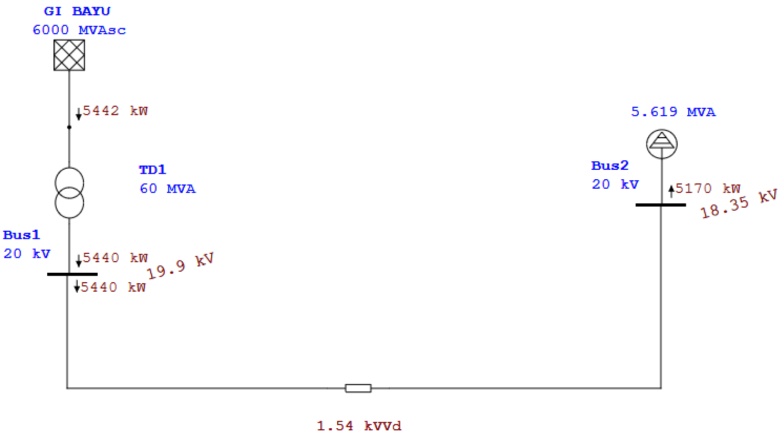

Fig 9. Simulation Results of Single Line Diagram LW 09

From the simulation results above, Load Flow data is obtained as in Table 7 and Branch Losses in Table 8 below.

Table 7. Load Flow for LW 09

Bus	Voltage	Load		Load Flow				
ID	kV	MW	Mvar	ID	MW	Mvar	Amp	%PF
Bus1	20.000	0	0	Bus2	5.440	2.254	170.8	92.4
				Bus3	-5.440	-2.254	170.8	92.4
Bus2	20.000	5.170	1.699	Bus1	-5.170	-1.699	171.2	95.0
Bus3	150.000	0	0	Bus1	5.442	2.327	22.8	91.9

Based on Figure 9 and Table 7, it can be concluded that there are no problems with power flow and can be said to be in a normal state. It can be seen from the sending voltage of 20 kV and the receiving voltage at the base is 18.35 kV.

Table 8. Branch Losses of LW 09

ID	From		To		Losses		Voltage		%Drop
	MW	Mvar	MW	Mvar	kW	kVAR	From	To	
Line1	5.440	2.254	5.170	1.699	270.3	554.7	99.5	91.8	7.72
TD1	5.440	2.254	5.442	2.327	1.6	72.9	99.5	100.0	0.50
					271.9	627.7			

From the simulation results and data in Table 8, it is obtained that the voltage drop on the PL 03 extension is 1.65 kV or 8.25% of the nominal voltage and the total power loss is 271.9 kW and 627.7 kVAR.

5. Conclusion

From the results of the calculation and simulation of the Single Line diagram of the PL 03 and LW 09 Extension using ETAP Software, the following conclusions can be drawn.

1. From the results of manual calculations, the technical shrinkage in the PL 03 Repeater is 170,693 kW and a voltage drop of 1.1 kV or 5.5%, while the simulation results with ETAP are 144.1 kW or 3.86% and a voltage drop of 1.52 kV or 7.6%.
2. From the results of manual calculations, the technical shrinkage in LW 09 is 279.04 kW and a voltage drop of 1.7 kV or 8.5%, while the simulation results with ETAP are 271.9 kW or 5% and a voltage drop of 1.65 kV or 8.25%.
3. From the results of ETAP simulations and technical shrinkage calculations on PL 03 and LW 09, the results obtained still meet the SPLN 1: 1995 and SPLN No.72 Year 1987 standards so there is no need to make improvements..

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