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Analysis of power – losses in 20 kvs distribution line

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ABSTRACT

This study aims to know the magnitude of losses in line at 20 KV distribution network. Power losses is measure of efficiency of an electric power system operation. This study receipts simulation methods to calculate the power flow using ETAP Power Station 4.0 software, and then determine losses in line at 20 kV distribution network of electrical systems Banda Aceh. The results showed that the energy loss (losses) in the conduits between the bus with the other one was still below 10%. The greatest Losses in line BA-15 (GI - Merduat)I is 0.48% (for active power losses) and 0.64% (for reactive power losses).

Keywords: *Losses, power flow, the distribution network.*

INTRODUCTION

The process of generating electrical energy distribution to the consumer of energy loss occurs (losses). Losses on the electrical system will naturally emerge and cannot be reduced to 0%. Based on the national standards, losses on the transmission line and distribution ideally 8 to 10%, the optimal value of less than 5%. [Basri]

The amount of losses that occurred in Indonesia, for each area of each region has its differences. Problem occurs if the losses are on fairness level, because the occurrence of losses, there is under control and out of control PLN.

Increase in losses can be caused by several things, such as the difference between the growth of the network with load growth and also by the limitation of the new installation and can be influenced by natural factors[4]. From the description it is necessary to analysis and research techniques, especially related to the *losses,* in order to improve the efficiency of electrical energy usage in electric power systems PT. PLN. In the case study in PT. PLN (Persero) Banda Aceh is an object of this study.

POWER FLOW SOLUTION

Power flow studies, commonly known as load flow, form an important part of power system analysis. They are necessary for planning, economic schedulling, and control of an existing system as well planning its future expansions. The problem consists of the determining the magnitudes and phase angle of voltages at each bus and active and reactive power flow in each line.

In solving a power flow problem, the system is assumed to be operating under balanced condition and single phase model is used. Four quantities are associated with each bus. These are voltage magnitude lVl, phase angle δ, real power P, and reactive power Q[7].

Power Flow Equation [2][5][7][8]

Consider a typical bus of a power system network as shown in Figure 1. Transmission line are represented by their equivalent π models where impedances have been converted to per unit admintances on a common MVA base [Saadat].

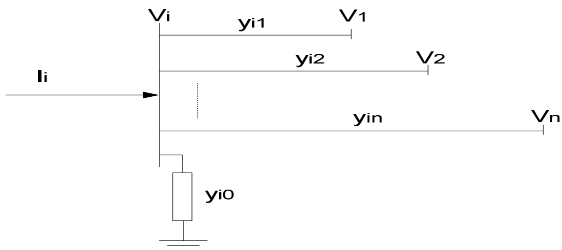

Figure 1: A Typical Bus of The Power System

Application of KCL to this bus results in:

$$I_i = y_{i0} + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + ... + y_{in}(V_i - V_n)$$

$$I_i = (y_{i0} + y_{i1} + ... + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - ... - y_{in}V_n$$

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \qquad j \neq i \qquad (1)$$

The real and reactive power at bus I is:

$$P_i + jQ_i = V_i I_i^* \qquad (2)$$

Or

$$I_i = \frac{P_i - jQ_i}{V_i^*} \tag{3}$$

Substituting for *Ii* in (1)

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \qquad j \neq i \tag{4}$$

From the relation, the mathematical formulation of the power flow problem results in a system of algebraic nonlinear equations which must be solved by iterative techniques.

Line Flows and Losses [7]

After the iterative solution of bus voltage, the next step is the computation of line flows and losses. Consider the line connecting the two busses *i* and *j* in Figure 1. The line current I*ij*, measured at bus i and defined positive in the direction $i \rightarrow j$ is given by:

$$I_{ij} = I_l + I_{i0} = y_{ij}\left(V_i - V_j\right) + y_{i0} V_i \tag{5}$$

Similarly, the line current I*ji* measured at bus *j* and defined positive in the direction $j \rightarrow i$ is given by:

$$I_{ji} = -I_l + I_{j0} = y_{ij}\left(V_j - V_i\right) + y_{i0} V_j \tag{6}$$

The complex power Sij from bus i to j and Sji from bus j to i are:

$$S_{ij} = V_i I_{ij}^{\ *} \tag{7.a}$$

$$S_{ji} = V_j I_{ji}^{\ *} \tag{7.b}$$

The power loss in line i – j is the algebraic sum of power flows determined from (7. a) and (7.b), i,e.,

$$S_{Lij} = S_{ij} + S_{ji} \tag{8}$$

Newton-Raphson Power Flow Solution [6][7]

For large power system, the Neowton-Raphson method is found to be more efficient and practical. The number of iteration required to obatain a solution is independent of the system size but more functional evaluations are required at iteration. Since in the power flow problem real power and voltage magnitude are specified for the voltage controlled buses, the power flow equation is formulated in polar form. For the typical bus of the power system shown in figure 1 the current entering bus i given by (1). This equation can be rewritten in terms of the bus admittance matrix as:

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \quad (9)$$

In the above equation, j includes bus i. Expressing this equation in polar form:

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \quad (10)$$

The complex power at bus i is:

$$P_i - jQ_i = V_i * I_i \quad (11)$$

Separating the real and imaginary parts:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta i_j - \delta_i + \delta_j) \quad (12)$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta i_j - \delta_i + \delta_j) \quad (13)$$

So there are two non-linear equations for each bus, the real power P and reactive power Q. to continue the process of power flow from bus, in Taylor's series about the initial estimates and the neglecting all higher order terms results in the following set of linear equations.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\partial P_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_2}{\partial \delta_n}^{(k)} & \frac{\partial P_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_2}{\partial |V_n|}^{(k)} \\ \vdots & & \vdots & \vdots & & \vdots \\ \frac{\partial P_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial P_n}{\partial \delta_n}^{(k)} & \frac{\partial P_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial P_n}{\partial |V_n|}^{(k)} \\ \hline \frac{\partial Q_2}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(k)} & \frac{\partial Q_2}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_2}{\partial |V_n|}^{(k)} \\ \vdots & & \vdots & & & \\ \frac{\partial Q_n}{\partial \delta_2}^{(k)} & \cdots & \frac{\partial Q_n}{\partial \delta_n}^{(k)} & \frac{\partial Q_n}{\partial |V_2|}^{(k)} & \cdots & \frac{\partial Q_n}{\partial |V_n|}^{(k)} \end{array}\right] \begin{bmatrix} \Delta \partial_2^{(k)} \\ \vdots \\ \Delta \partial_n^{(k)} \\ \hline \Delta |V_2|^{(k)} \\ \vdots \\ \Delta |V_n|^{(k)} \end{bmatrix} \quad (14)$$

In the above equation, bus 1 is assumed to be the slack bus. The Jacpbian matrix gives the linearized relationship between small changes in voltage angle $\Delta\delta i^{(k)}$ and voltage magnitude $\Delta|Vi|^{(k)}$ with the small changes in real and reactive power ($\Delta Pi^{(k)}$ and $\Delta Qi^{(k)}$. Elements of the Jacobian matrix are the partial derivatives of (12) and (13), evaluated $\Delta\delta i^{(k)}$ and $\Delta|Vi|^{(k)}$. In the short form, it can be written as

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \quad (15)$$

Electric Power Distribution System Line [1][3]

The sub transmission circuits deliver energy from bulk power source to the distribution substations. The sub transmission voltage is somewhere between 12.47 and 245 kV. The distribution substation, which is made of power transformer together with the necessary voltage-regulating apparatus, busses, and switchgear, reduces the sub transmission voltage to a lower primary system voltage for local distribution. The three-phase primary feeder, which is usually operating in the range of 4.16 to 34.5 kV, distributes energy from the low-voltage bus of the substation to its load centre where it branches into three-phase sub-feeders and single laterals.

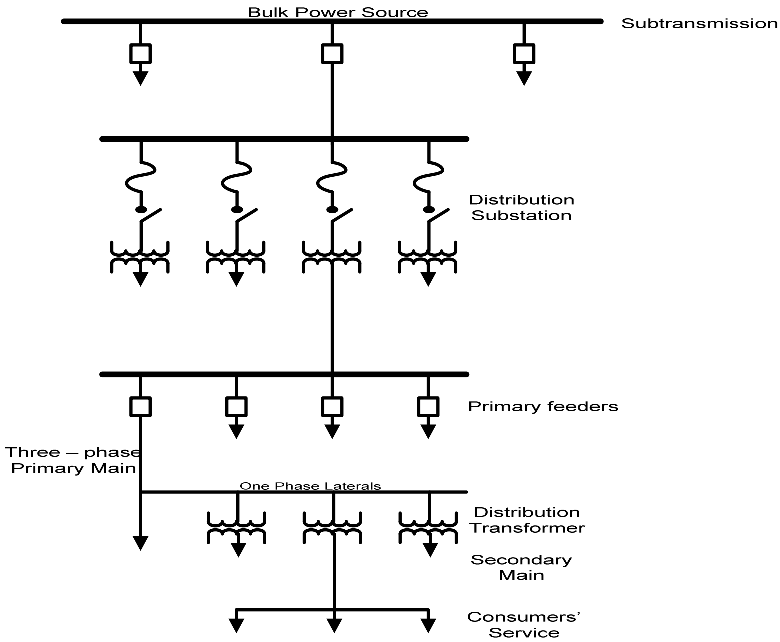

Figure 2: One-Line Diagram of a Typical Distribution System

Tests Performed on the System

Tests performed on the system network configuration Banda Aceh. The network system has 7 busses.

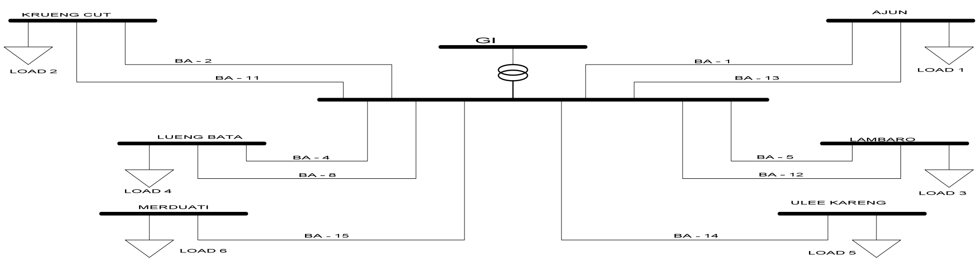

Figure 3: Distribution Network Configuration of Banda Aceh System

Table 1: Line/Cable Data

No.	From – to bus	Length (km)	Total Impedance	
			R (ohm)	X (ohm)
1	GI – AJUN (BA-1)	7.02	0.93	1.95
2	GI – KRUENG CUT (BA-3)	11.8	1.48	1.14
3	GI – LUENG BATA (BA-4)	4.2	0.53	0.41
4	GI – LAMBARO (BA-5)	2.2	0.28	0.21
5	GI – LUENG BATA (BA-8)	4.2	0.53	0.41
6	GI – KRUENG CUT (BA-11)	11.8	1.48	1.14
7	GI – LAMBARO (BA-12)	2.2	0.28	0.21
8	GI – AJUN (BA-13)	7-1	0.88	0.68
9	GI – KRUENG CUT (BA-14)	10.7	1.41	2.38
10	GI – MERDUATI (BA-3)	6.96	0.91	1.75

Tabel 2: Load Data

No.	GH	Load		Generation	
		P (kW)	Q (kVA)	P kW	Q kVAR
1	AJUN	14323	10742.25	0	0
2	KRUENG CUT	10516	7887	0	0
3	LUENG BATA	15818	11863.5	0	0
4	LAMBARO	14414	10810.5	0	0
5	ULEE KARENG	2067	1550.25	0	0
6	MERDUATI	6220	4665		

SIMULATION RESULTS

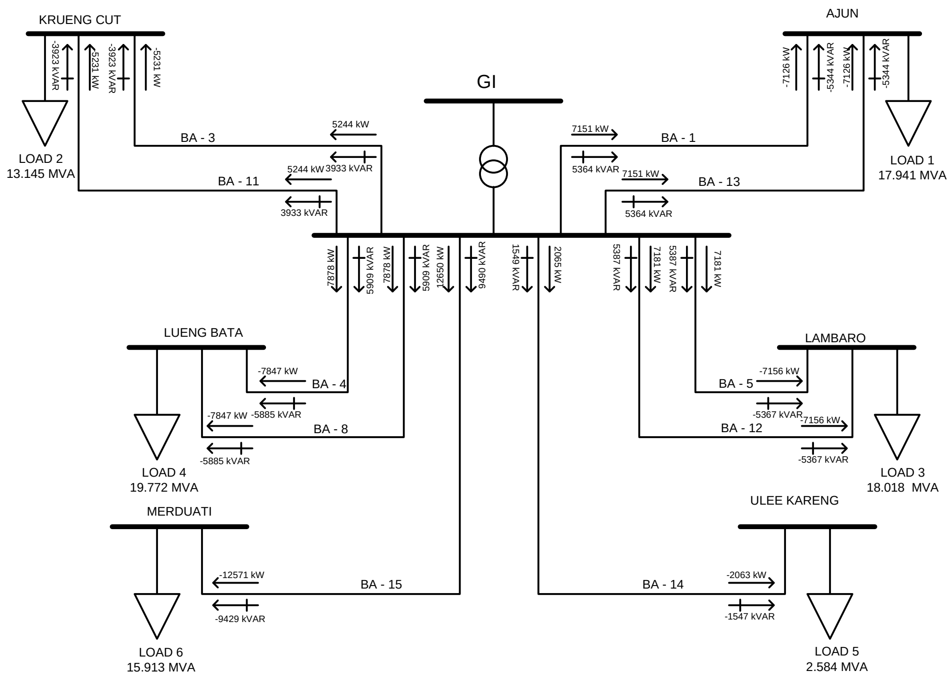

Figure 4: Network Configuration of Banda Aceh System

Analysis of the research object carried out by conducting tests and performing data entry is taken from the distribution system of Banda Aceh, the MVA base value of 30 MVA, 20 kV at a frequency of 50 Hz, then a power flow simulation program ETAP 4.0 is performed.

Load flow calculations in the 7 buses system analyzed by the Newton-Raphson method. Power flow calculation is performed to determine the magnitude of the voltage, active power and reactive power at each bus. The results obtained from the use of Newton-Raphson method obtained after first iterations with the value of ε = 0.0001, the computing time ± 1 second. The test results obtained are given in Table 3 and Table 4.

Table 3: The Power Flow Results

Name of Bus	Newton Raphson Method				
	Voltage % Mag	Phase Angle (deg)	P (MW)	Q (MVAR)	S (MVA)
GI	100	0.0	69.62	52.22	87.03
AJUN	99.64	-0.1	14.26	10.68	17.82
KRUENG CUT	99.74	-0.1	10.46	7.84	13.07
LUENG BATA	99.61	-0.1	15.7	11.78	19.63
LAMBARO	99.65	-0.1	14.32	10.74	17.90
ULE KAREENG	99.89	-0.1	2.06	1.55	2.58
MERDUATI	99.38	-0.2	12.57	9.43	15.71

Table 4: Power Flow from – to Bus and Losses in Line

ID	From Bus	To Bus	P (kW)	Q (kVAR)	Losses	
					P (kW)	Q (kVAR)
BA-1	GI	Ajun	7151	5364	25	19.4
BA-13	GI	Ajun	7151	5364	25	19.4
BA-3	GI	Krueng Cut	5244	3933	13.4	10.4
BA-4	GI	Lueng Bata	7878	5909	30.3	23.5
BA-5	GI	Lambaro	7181	5387	25.2	19.5
BA-8	GI	Lueng Bata	7878	5909	30.3	23.5
BA-11	GI	Krueng Cut	5244	3933	13.4	10.4
BA-12	GI	Lambaro	7181	5387	25.2	19.5
BA-14	GI	Ulee Kareng	2065	1549	2.1	1.6
BA-15	GI	Merduati	12650	9490	60.1	60.6

Table 3 and Table 4 show the results of power flow simulations using the *Newton-Raphson* method. The simulations are executed with the ETAP Power Station software. The simulation results show voltage magnitude and phase angle, active and reactive power *losses* in line. The simulation results illustrate the power flow diagram of active and reactive power from-to bus and losses as shown in Figure 7 and Figure 8.

Here are the results of Table 3 in the graph, shown in Figure 6.

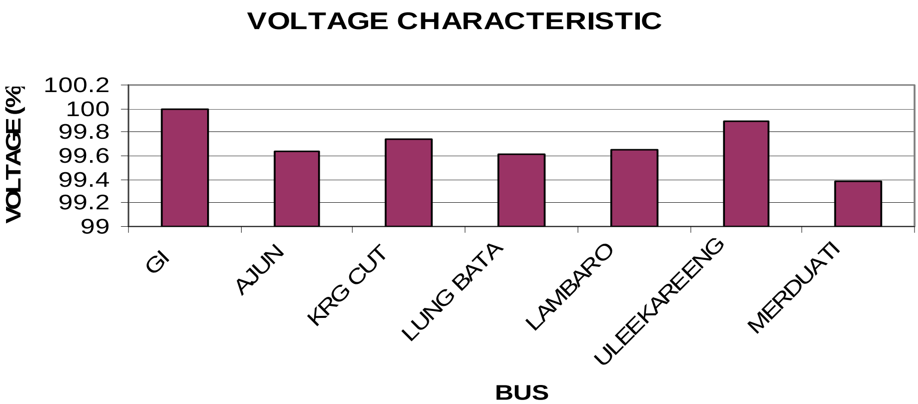

Figure 6: Voltage Characteristic

Figure 6 displays the magnitude of the voltage on each bus. With the y-axis as the voltage in % and the x-axis as the ID of the bus. GI is the reference bus voltage at 100%. Minimum voltage of 99.38% found in Merduati.

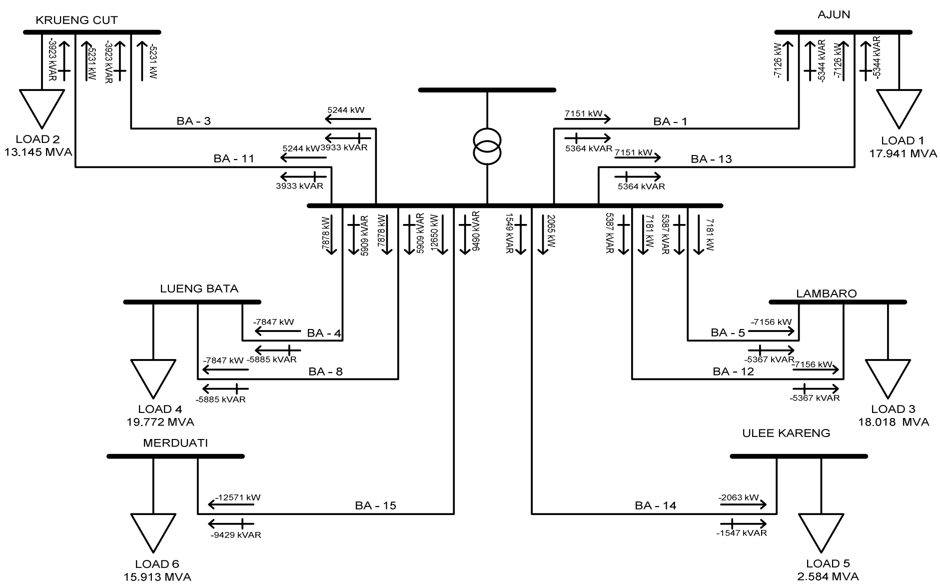

Figure 7: Power Flow Diagram in Banda Aceh Distribution Line

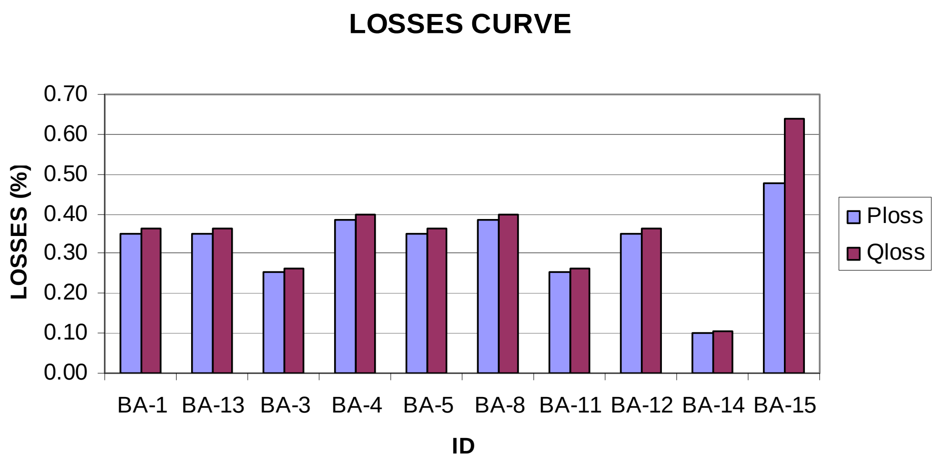

Figure 8: Characteristics of Losses

Power flow diagram can be seen in Figure 7, shows the direction of the bus line between both the send and receive at the end of the line. *Losses* can be determined from the difference in power sent to the power received in advance of connecting bus lines as shown in Figure 8. The greatest Losses in line BA-15 is 0.48% (for active power losses) and 0.64% (for reactive power losses). The smallest losses contained in line BA-14 are 0.10 % (for active and reactive power losses).

CONCLUSION

1. Power flow simulation results will provide an overview of power in sending and receiving ends in line, they are active and reactive power .The reference power in GI bus (slack bus) is 69.62 MW and 52.22 MVAR.
2. The greatest Losses in line BA-15 (GI- Merduati I is 0.48% (for active power losses) and 0.64% (for reactive power losses).

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