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Calculation of 20 kV Distribution Network Energy Losses and Minimizing Effort Using Network Reconfiguration in Region of PT PLN (Persero) UPJ Bantul

Slamet Suripto*[1]

[1]Department of Electrical Engineering, Universitas Muhammadiyah Yogyakarta
Jl Lingkar Selatan Tamantirto Kasihan Bantul, (0274)387656
*Corresponding author, e-mail: slametsuripto@yahoo.com

Abstract – *Power distribution system is a component of electric power system to deliver electricity energy from substation to customer location. In power distribution system, there are some power loss was changed as heat. Power distribution losses is a natural occurrence, so one gets to be done only minimize to support global energy efficiency. The way to reduce power loss in the power distribution system is by reconfiguration the existing line. Reconfiguration means a process of operating the switch (NO and NC) and change the topology line. Then, power loss in the power distribution system is computed with "ETAP" simulation software. From computing result of distribution network losses on existing line at PT. PLN UPJ. Bantul BNL 6, BNL 7 and BNL 11 feeders are gotten energy losses as 2,669,328 kWh per year or 1.72 %. Network reconfiguration that involves BNL 6, BNL 7 and BNL 11 feeder gets energy losses decrease as 1.00 % per year.*

***Keywords**: Distribution system, energy losses, reconfiguration, efficiency*

I. Introduction

Distribution of electricity through the distribution network from substations to loads give results in energy lost on the channel since turned into heat. This energy lost is called losses or network energy losses. Losses are naturals, and then cannot be avoided. Losses are energy lost experienced by providers that eventually to be borne by consumers in form of energy price which is increasing. Therefore efforts are needed to minimize energy lost to support global energy efficiency and cheap electricity price for consumers.

As an illustration, energy lost that occurs in region PT. PLN APJ Yogyakarta or Yogyakarta Province in 2005 until 2009 recorded an average of 9 %. For 2009, energy lost in APJ Yogyakarta was 160,825,155 kWh. Energy lost in Bantul Regency was an average of 9.65 % that is 15,519,316 kWh.

II. Literature Review

Distribution network that connects distribution transformer with low-voltage consumers called Low-voltage Distribution Networks (JTR) or Secondary Distribution Networks. LDN/JTR that serves huge loads usually use 3-phase 4-wire network with voltage of 380 volt between phases. As for small load services, includes households, using single-phase 2-wire network with voltage of 220 volt phase to neutral.

There are several types of distribution network systems, including radial and ring system. On radial distribution network, a substation is used to serve a lot of loads through several feeders, which is each feeder are not interconnected. Construction costs are relatively cheap and simple to manage, because the flow of power in only one direction. The weakness is continuity of service is not good, because if there is disturbance on feeders resulting in damages, then all connected loads are not served.

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Weakness on radial system could be overcome using ring or loop system, which is aligned to be connected between adjacent feeders. If there is disturbance on one of the feeders, loads could be diverted to other adjacent feeders by opening/closing the separator switch (ABSW). Management certainly more complicated and also more expensive construction costs, but result in better services.

2.1 Distribution Network Performance

Distribution network performance is related in the quality of electric power that can be served by the distribution network. The quality includes voltage fluctuations up to consumers and the continuity of service. Another thing that should be considered was power loss on network. The power loss will determine efficiency of the distribution network.

2.2 Calculation of Network Energy Losses

Distribution Network energy losses is differences between energy that sent from substation to distribution network with the amount of energy sold to consumers. For feeders, energy losses are differences between energy measured at the substation by the number of kWh sold to consumers connected to the feeders. Energy losses usually expressed as percentage of energy losses of incoming energy to the grid.

$$Energy\ losses = Energy_{measured\ at\ substation} - kWh_{sold\ to\ consumers} \quad (1)$$

$$\%\ Energy\ losses = \frac{Energy\ losses}{Energy_{measured\ at\ substation}}\ x\ 100\ \% \quad (2)$$

Energy losses is certain on management of electrical energy, so the effort is reduce the amount of energy losses becomes more efficient. Network energy losses divided into two:

a. Technical energy losses

Technical energy losses are power loss that occurs naturally because of the current flows in network and equipments. This power loss is defined as square of the current flows on network and its equipments multiplied by its resistance. This includes loss of power in Medium-voltage Distribution Network (MDN/JTM), transformers, JTR/LDN, and other equipment used on the network.

b. Non-technical energy losses

Non-technical energy losses are caused by errors of measurements and recording, and not good in monitoring of energy usage. Efforts that can be done are improving the accuracy of measurement system, records administrative, and supervision of illegal electrical energy consumption.

2.3 Equivalent Circuit

Equivalent circuit need to be made to simplify the circuit analysis when calculating technical energy losses of MDN/JTM which generally have a load attached to transformers. It also required when drawing and simulating circuit diagram in application program. The equivalent circuit is created by collecting all the existing loads then put it at a certain distance from the sources. Distance of load from this source should be selected so that analytical results obtained through equivalent circuit approach the results obtained from the original circuit.

For example, a circuit comprising of n number of equal loads and resistance between load on the same circuit, as shown in Figure 1, so that R1 = R2 = ... = Rn dan I1 = I2 = ... = In. Then it creates an equivalent circuit as shown in Figure 2 with load current for the sum of all load currents, and mounted on a specific resistance value of the source. This resistance value (RX) is resistance that passed by total load currents, which would affect value of power losses in circuit resistance. The value RX should be selected in order to value of power losses in circuit resistance approach the value of power losses from the original circuit.

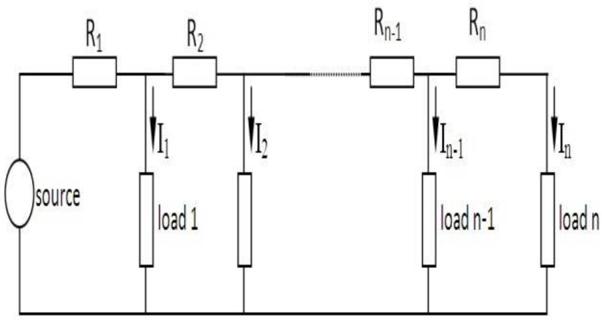

Fig. 1. Circuit with n number of equal loads

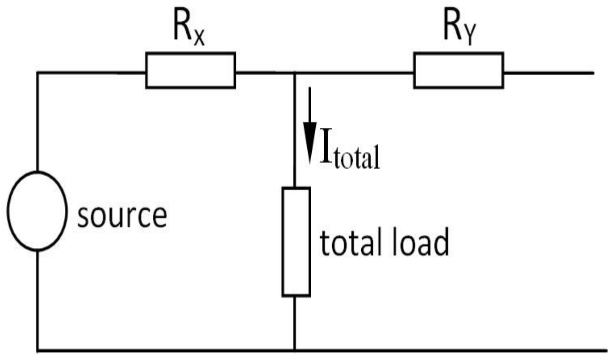

Fig. 2. Equivalent circuit

From calculation it was found that the percentage of the exact RX for equivalent circuit is not equal to the number of loads of different circuit, as shown on Table 1. Percentage of RX in the table below is comparison between RX resistance against total circuit resistance (RX + RY).

Table 1. R_X percentage in equivalent circuit

No.	Number of loads	R_X percentage
1	2	62.50 %
2	3	51.85 %
3	4	46.88 %
4	5	44.00 %
5	10	38.50 %
6	20	35.88 %
7	40	34.59 %
8	80	33.96 %

From the calculation above obtained that if the circuit consists of 3 loads, then the value of RX is about 52 % or be mounted on the middle of the circuit. When the number of load is more than 80 pieces, then the value of RX is about 33 %, or the load are installed on first in one-third of the total resistance.

III. Research Methodology

In this research there are several steps work done to achieve the desired end result according to the procedure below.

1. Collection of physical network data, loads for each feeders, and current curve of daily load of feeders.
2. Loads grouping for each sections of the feeders and data collection of transformers capacity on installed loads.
3. Simulations of network for several load conditions and network configurations.
4. Simulations of power flow and calculate network energy losses of every condition.
5. Forecasting of load growth and evaluate the network capacity of each feeders.

IV. Results and Discussion

Reconfiguring of distribution network is a change of network compositions in order to raise the network performance. This reconfiguration can be done within several ways, namely:

a. Moving loads from certain feeders to another.
b. Moving the connection within one-phase network at three-phase network, from one phase to another.
c. Changing the one-phase network becoming three-phase network.
d. Install special feeders to connect a certain loads directly to substation.

From the results by regrouping of feeder's loads data BNL-6, BNL-7, and BNL-11 could be drawn the channel length and total loads (kVA installed) in each sections that shown in Table 2, Table 3, and Table 4.

Table 2. Length and amount of installed loads for each section in BNL 6 feeder

No	Sections	No. of initial pole	No. of end pole	Total poles	Channel length (kms)	Total loads (kVA)
1	A6	PMT	S6-5	5	0.25	300
2	B6	S6-5	S6-32	27	1.35	700
3	C6	S6-32	S6-38	6	0.3	100
4	D6	S6-38A	S6-38H	8	0.4	310

5	E6	S6-38	S6 -94	56	2.8	1,520
6	F6	S6-94A	S6-94K	15	0.75	365
7	G6	S6 -94	S6 -113	17	0.85	550
8	H6	S6 -113	S6 -144	31	1.55	425
9	I6	S6 -143A	S6 -143/26	26	1.3	250
10	J6	S3-27/59	S3-125Z/45	18	0.9	475
11	K6	S3-125Z/45	S3-125Z/75	30	1.5	650
12	L6	S3-125Z/75	S3-125Z/90	15	0.75	725
13	M6	S3-125Z/38	S3-125Z/90	42	2.1	1,250
14	N6	S3-125Z/90	S3-125Z/141	51	2.55	635
15	O6	S3-125Z/141	S3-125Z/151	10	0.5	-
16	P6	S3-125Z/151	S3-125Z/199	48	2.4	1,925
17	Q6	S3-125Z/75A	S3-75X	25	1.25	550
18	R6	S3-125Z	S3-157	27	1.35	500
19	S6	S3-75X/1	S3-75X/11	10	0.5	1,125
20	T6	S3-75X/11	S3-75X/89	78	3.9	1,175
			Total			**13,530**

Table 3. Length and amount of installed loads for each section in BNL 7 feeder

No.	Sections	No. of initial pole	No. of end pole	Total poles	Channel length (kms)	Total loads (kVA)
1	A7	PMT 7	S1-24	24	1.2	275
2	B7	S1-24/1	S1-24/10	10	0.5	775
3	C7	S1-24/10A	S1-24/10C	3	0.15	200
4	D7	S1-24/10	S1-24/20	10	0.5	325
5	E7	S1-24/18	S1-44/18	20	1	550
6	F7	S1-24/20	S1-24/88	68	3.4	2,485
7	G7	S1-34/1	S1-34/4	4	0.2	250
8	H7	S1-24/88	S1-24/123	35	1.75	2,885
9	I7	S1-123/1	S1-128C/6	14	0.7	3,625

10	J7	S1-128C/6	SI-41/19L	66	3.3	3,365
11	K7	S1-128	S1-137	9	0.45	100
12	L7	S1-137	S1-163	26	1.3	200
13	M7	S1-163	S1-172P	25	1.25	450
14	N7	S1-172P	S1-172Z/35	45	2.25	1,675
15	O7	S1-172Z/35	S1-172Z/80	45	2.25	475
16	P7	S1-172Z/80	S1-172Z/179	99	4.95	1,580
17	Q7	S1-172Z/80A	S1-172Z/80B	2	0.1	-
			Total			**19,215**

Table 4. Length and amount of installed loads for each section in BNL 11 feeder

No	Sections	No. of initial pole	No. of end pole	Total poles	Channel length (kms)	Total loads (kVA)
1	A11	PMT 11	S3-2/88	88	4.4	3,495
2	B11	S3-2/88	S3-2/122	34	1.7	1,560
3	C11	S3-2/122	S3-2/149	27	1.35	700
4	D11	S3-2/149	S3-2/248	99	4.95	1,350
5	E11	S3-2/248	S3-2/255	7	0.35	-
6	F11	S3-2/255	S3-2/299	44	2.2	500
7	G11	S3-2/299A	S3-2/299R	18	0.9	375
8	H11	S3-2/353	S3-2/364	11	0.55	75
9	I11	S3-2/364	S3-2/462	98	4.9	950
10	J11	S3-2/122	S1-5C/13	16	0.8	160
11	K11	S3-149/1	S3-149/3	3	0.15	-
12	L11	S3-255/1	S3-255/3	3	0.15	1,250
13	M11	S3-299/1	S3-299/47	47	2.35	610
14	N11	S3-299N/1	S3-299N/24	24	1.2	875
15	O11	S3-364	S3-364/54	54	2.7	350
16	P11	S3-328K/35A	S3-353	71	3.55	1,150

17	Q11	S3-248	S3-248/34H	42	2.1	1,540
18	R11	S6-193	S6-218	25	1.25	175
19	S11	S6-193/1	S6-193/57	57	2.85	875
20	T11	S6-193	S6-177	16	0.8	150
21	U11	S6-144	S6-177	33	1.65	290
22	V11	S6-177/1	S6-177/83	83	4.15	1,435
23	W11	S6-83/1	S6-83/32	32	1.6	1,605
			TOTAL			**19,470**

To determine the level of feeder loads, it needed the average curve of current of daily loads for each feeder. Daily loads curve for BNL-6, BNL-7, and BNL-11 feeders at November 17th 2011 shown at Figure 3.

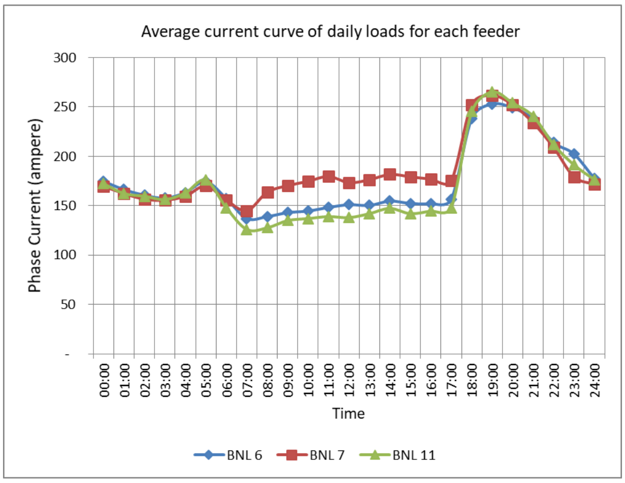

Fig. 3. Average current curve of daily loads for each feeder

From load curve in the picture above, calculation of percentage of loading at Peak Load Time (WBP) and Normal Load Time (LWBP), as shown in Table 5.

Table 5. Percentage of loading in feeders at WBP and LWBP

Loading Time	Feeders		
	6	7	11
WBP	69 %	50 %	50 %
LWBP	40 %	34 %	26 %

Next step is simulation in "ETAP" software with drawing the network and installed loads in existing condition. Program runs with WBP and LWBP loading scenario. From network power flow simulation, results load current, load power, and losses for each network at WBP and LWBP scenario in existing condition as shown in Table 6 and Table 7.

Table 6. Load current, Load power, and network losses at WBP

Feeders	BNL 6	BNL 7	BNL 11	Total
% of Loading	69 %	50%	50 %	
Power (kW)	8,643	9,023	8,881	26,547
Current (A)	264.7	275.2	277.4	
Losses (kW)	219.4	190.4	246.4	656.2
End-point Voltage (kV)	20,212	20,197	19,855	

Table 7. Load current, Load power, and Network losses at LWBP

Feeders	BNL 6	BNL 7	BNL 11	Total
% of Loading	40 %	34 %	26 %	
Power (kW)	5,197	6,274	4,818	16,289
Current (A)	157.4	189.9	148.3	
Losses (kW)	77.8	90.8	70.9	239.5
End-point Voltage (kV)	20,439	20,538	20,39	

Several chances of reconfiguring the distribution network with moving loads from feeders that includes BNL 6, BNL 7, and BNL 11 feeders are shown in Table 8.

To identify total network losses for each configuration, it did a power flow simulation. From the simulation can be drawn as shown on table 9.

Calculation of network energy losses done for several configuration conditions, and then the results are compared with existing condition. For complete calculation are shown on table 10.

Table 8. Chances of reconfiguring the distribution network at BNL 6, BNL 7, and BNL 11 feeders

No.	Condition	Feeders Section	Existing Position	New Position	ABSW Condition Changes
1	Configuration 1	O7 and P7	BNL 7	BNL 11	S1-172Z/35 OFF S3-255/3 ON
2	Configuration 2	M6 and N6	Connected with I6	Connected with L6	S3-125Z/90 ON S3-125Z/141 OFF
3	Configuration 3	H6 and I6	Connected with G6	Connected with L6	S6-142 OFF S3-125Z/90 ON

Table 9. Power and network losses at several configuration conditions of network

No.	Condition	Network Power (kW)			
		Input		Losses	
		WBP	LWBP	WBP	LWBP
1	Existing	26,547	16,289	656.2	239.5
2	Configuration 1	26,495	16,277	672.8	243
3	Configuration 2	26,566	16,295	649.8	237.1
4	Configuration 3	26,515	16,278	667.7	243.7

Table 10. Energy losses in several configuration conditions of network

No.	Condition	Standing Energy (kWh/year)	Network energy losses		Losses growth	
			(kWh/year)	Percentage	(kWh/year)	Percentage
1	Existing	155,508,480	2,669,328	1.72%	-	
2	Configuration 1	155,347,200	2,718,432	1.75%	-49,104	-1.81%
3	**Configuration 2**	**155,586,240**	**2,642,832**	**1.70%**	**26,496**	**1.00%**
4	Configuration 3	155,383,200	2,716,128	1.75%	-46,800	-1.72%

It can be drawn from calculation that at existing condition, energy that come to BNL 6, BNL 7, and BNL 11 feeders are 155,508,480 kWh per year. Energy losses that exist in this condition are 2,669,328 kWh or 1.72 % per year. Chance of reconfiguration that have smallest energy losses is configuration 2, with moving the loads on feeder BNL 6 section M6 and N6 that connected with section O6 before moved to section L6, with energy losses 2,642,832 kWh per year. With this configuration could be drawn that energy losses reduce for 26,496 kWh per year or 1.00 %. Assume that basic recommendation price (HPP) in 2012 are IDR 1,061 per kWh (RUPTL 2011-2020), then from the configuration we have savings IDR 28,112,256 per year.

Prediction of loads growth in Bantul Regency is adjusted with projection of national electricity and DI Yogyakarta Province. Growth rate of installed kVA for DI Yogyakarta in 1999 to 2009 are 6.47 % per year. Growth rate of installed kVA in Bantul Regency in 2007 to 2010 are 6.76 % per year. In RUPTL PT. PLN (Persero) 2011-2020 described that National Growth Rate of Peak Loads are 8.13%, and for DI Yogyakarta is 8% as shown in table 11.

From the data above are predicted that average growth loads in UPJ Bantul, includes feeder's loads that been observed are equal with average growth loads in DI Yogyakarta province which is 8 %.

Growth rate of 8 % is a number of peak loads growth denominated in megawatt (MW). With this growth number, then current that flow in network approximately also raise 8 % per year. The value of network power losses equal with squared value of current flowing, so that network power losses growth are become 16.64 % per year. With value of power losses of 16.64 %, estimation of energy savings at configuration 2 condition until 2020 are shown in table 12.

Table 11. Peak Loads Growth Projections

Year	National Peak Loads (MW)	Peak Loads of DIY (MW)
2010	25,177	300
2011	27,792	348
2012	30,345	377
2013	32,856	407
2014	35,456	438
2015	38,361	471
2016	41,444	507
2017	44,496	546
2018	47,768	589
2019	51,301	635
2020	55,053	685
Growth rate	**8.13 %**	**8.00 %**

Table 12. Projection of energy savings per year in configuration 2

Year	Energy Standing (kWh)	Energy losses (kWh)	Losses growth	
			(kWh)	(IDR)
2011	155,586,240	2,642,832	26,496	28,112,256
2012	181,475,790	3,082,599	30,905	32,790,135
2013	211,673,362	3,595,544	36,048	38,246,414
2014	246,895,809	4,193,842	42,046	44,610,617
2015	287,979,272	4,891,698	49,042	52,033,824
2016	335,899,023	5,705,676	57,203	60,692,252
2017	391,792,620	6,655,101	66,721	70,791,443
2018	456,986,912	7,762,509	77,824	82,571,139
2019	533,029,534	9,054,191	90,774	96,310,977
2020	621,725,649	10,560,808	105,879	112,337,123

V. Conclusion

Distribution Network energy losses in UPJ Bantul BNL 6, BNL 7, and BNL 11 feeders in existing condition are 2,669,328 kWh per year or 1.72 %. Network reconfiguring for BNL 6, BNL 7, and BNL 11 feeders can reduce network energy losses for 26,496 kWh or 1.00 % that means there is an energy savings of IDR 28,112,256 per year for configuration 2. With Peak Loads growth in UPJ Bantul area are average 8 % per year, then energy savings with option of network reconfigurations are predicted to reach IDR 112,337,123 per year in 2020. Next analysis that should be done to reduce technical losses in network reconfiguration is changing the one-phase network becoming three-phase networks.

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Author information

Slamet Suripto received B.Sc. degree from Universitas Gadjah Mada in 1987, M.Eng. degree from Department of Electrical Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia in 2012,
Mr. Slamet Suripto is a Lecturer in Department of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia. His research interests are in power system equipment, power system distribution, protection of power system, optimization, distributed energy resources, and renewable energy.