Reduction Technique of Drop Voltage and Power Losses to Improve Power Quality using ETAP Power Station Simulation Model

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Abstract. The effect of electric loads growth emerged direct impact in power systems distribution. Drop voltage and power losses one of the important things in power systems distribution. This paper presents modelling approach used to restructrure electrical network configuration, reduce drop voltage, reduce power losses and add new distribution transformer to enhance reliability of power systems distribution. Restructrure electrical network was aimed to analyse and investigate electric loads of a distribution transformer. Measurement of real voltage and real current were finished two times for each consumer, that were morning period and night period or when peak load. Design and simulation were conduct by using ETAP Power Station Software. Based on result of simulation and real measurement precentage of drop voltage and total power losses were mismatch with SPLN (Standard PLN) 72:1987. After added a new distribution transformer and restructrured electricity network configuration, the result of simulation could reduce drop voltage from 1.3 % - 31.3 % to 8.1 % - 9.6 % and power losses from 646.7 watt to 233.29 watt. Result showed, restructrure electricity network configuration and added new distribution transformer can be applied as an effective method to reduce drop voltage and reduce power losses.

INTRODUCTION

Increasing demand for electricity in distribution systems may cause overloading of feeder capacity[1]. Unbalanced loading increases energy loss, deteriorates power quality and rise in electricity cost[2]. However, the consumer at the end of the feeders have been experiencing low voltage levels, for some time now, in all the countries. PLN as Indonesia electricity provider have a duty to ensure that customers are always supplied with required voltage level[3]. Today, Indonesia facing power energy crisis because unbalance both consumers growth and increment of power station capacity[4]. Although voltages are well balanced at the supply side level, the voltages at the consumers side become unbalance due to the unequal systems impedances, single phase loads, or large number of single phase transformer[5] The distribution system configuration needs to be changed from time to time to meet the load demand and to facilitate the expansion feeders[6].

Drop voltage is major concern in low voltage distribution systems and not very particular about voltage drop in the high voltage side leaving it unattended[3]. This problem cannot be completely solved, but could be reduce by either technical or non technical way. A through inspection of feeders reveal that the high impedance is caused by[7,8]:

1. Poor jointing and terminations: poor joint and terminations are resulted from loose contact between two conductors which are joined together. When current flows through a loose contact, there will be high opposition to current flow which generates heat at that point. This leads to an increase in resistance and subsequently result to drop voltage at that point.

Engineering International Conference (EIC2017)
AIP Conf. Proc. 1941, 020030-1–020030-12; https://doi.org/10.1063/1.5028088
Published by AIP Publishing. 978-0-7354-1633-8/$30.00

2. Use of undersized conductors : voltage can be throught of as the pressure pushing charges along a conductor, while the electrical resistance of a conductor is a measure of how difficult it is to push the charges along
3. Use of different types of conductor material: corrosion is an important factor to be considered in the selection of conductor materials. The two types of corrosion which exhibit greatest influence on the electrical properties of a metal are oxidation and galvanic corrosion. Galvanic corrosion, which is caused by the difference in electrical potential between two or more metals has to be given careful consideration when selecting conductor metals.
4. Hot spots : whenever a mecahically joint or termination is made, high resistance point is created. Thus the joint or termination will undergo a progressive failure. High resistance cretaes localized heating and since heating increses oxidation and creep, the connection become less tight and further heating occurs, until the contacts tends glow

Power losses refers to difference between the amount of energy delivered to the distribution system and the amount of energy customers are billed. The delivery of power from sources to customer points is always accompined with power losses[8,9]. The causes of power losses in distribution networks usually divided into two major parts technical and non-technical losses. Technical losses relates to the physical characteristic of the conductor and equipment and refers to the electric loss due to the carrying current of conductors, magnetic loss in transformers, resistive losses in windings and the core losses, resistive losses in service line and losses in KWH meter. These losses cannot be eliminated but can be reduced by some precautions[9]. Non-technical losses are the losses which include, power theft by hooking the lines, unauthorized connections from power line, loss at the loose connection ends, power metering deficiencies, inappropriate meter reading, miss billing and unlisted meters, trees in contact with the overhead lines, etc[9,10]. Networks reconfiguration, capacitor placement, VAR Compensation, installation of smart mettering for non technical losses and distributed generation are among different ways to reduce losses[6,7].

In the literature[4,8], it has proposed some formulas to calculate drop voltage and power losses in power systems distribution, caused of drop voltage and impact of drop voltage and power losses for reliability of distribution systems. Using some formulas to calculate drop voltage is the simple and easy method to determine drop voltage in existing distribution networks. But, the result of calculation is preciseless because it has big different value between calculation and simulation. Using combination of calculation and simulation or modelling by ETAP Power Station is better way to minimize fault in using some formula.

In this paper, study focused on modelling and measuring existing distribution networks. Using ETAP Power Station Software to simulate drop voltage of existing distribution network and take some formulas to calculate power losses in distribution network systems. Before simulate the existing distribution network in ETAP Power Station, monitoring and measuring voltage and current profile for each consumers be the first step. The result from monitoring and measuring voltage and current using as input data in ETAP Power Station Software and calculate with some formula analyze and find out percentage of drop voltage and power losses in distribution network systemsAfter simulation of adding transformer and restructure house connection was done, the result show significant alteration of drop voltage and power losses.

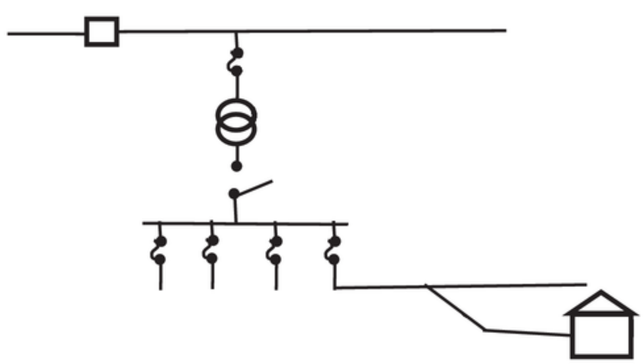

FIGURE 1. Distirbution of Electricity from Power Source to Consumer

EXPERIMENTAL METHODOLOGY

Whereseas, ETAP Power Station Simulation Model is analysis platform for design, simulation, operation, control, optimization, automation of generation, transmission, distribution, and industrial power systems. ETAP offers a suite of fully integrated software solutions including arc flash, load flow, short cicrcuit, relay coordination, cable capacity, transient stability, optimal power flow, and more[11]. ETAP also provide many kind tools of electricity such as bus, transformer, power grid, cable, transmission line, impedance, generator,synchronus motor, lumped load, static load and more. In drop voltage analysis simulation model use several tools in ETAP Power Station such as power grid, bus, transformer, cable and lumped load. For each tools which used in ETAP Power Station, input and change parameters appropriate with measuring data.

Overall modelling of Power Systems Distributon in study area shown in Fig.2, which is the block diagram system. As shown in Fig.2, the systems divided into some parts; there are Survey, Existing Data, Criteria condition in field, Measurement of drop voltage and power losses, Simulation model in ETAP Power Station, and Reconfiguration plan

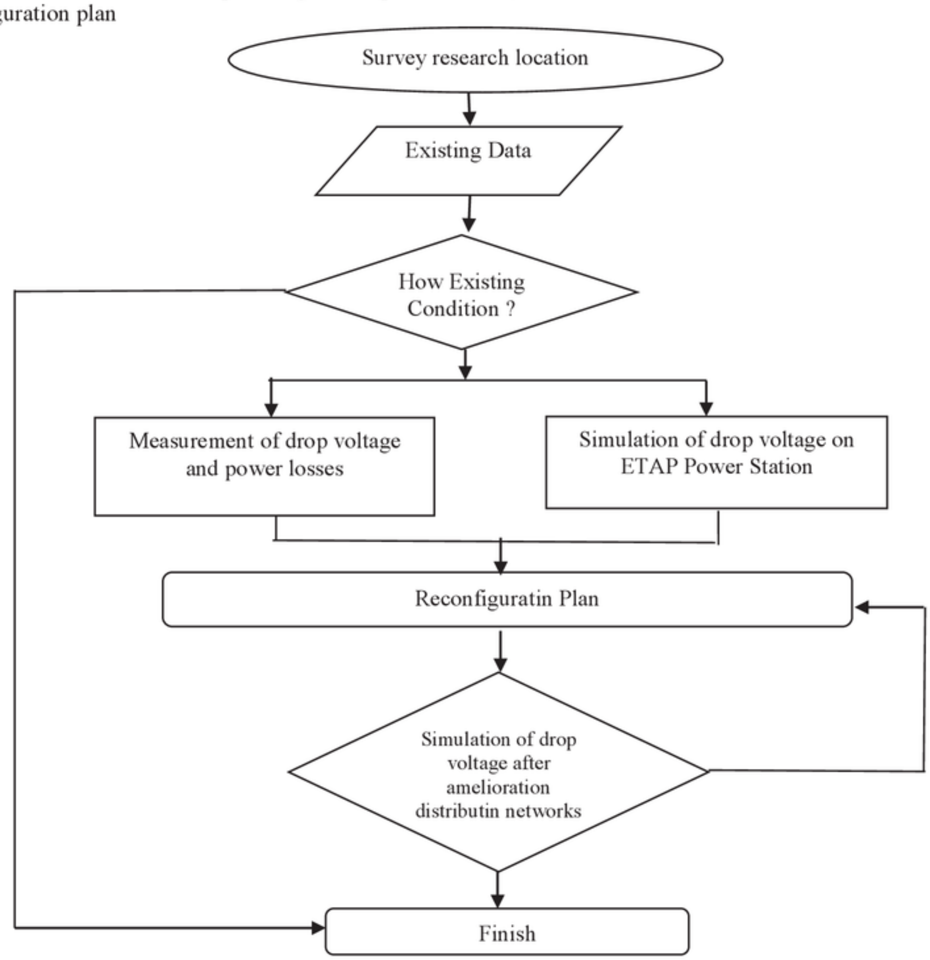

FIGURE 2. ETAP Power Station Simulation Block Diagram

SURVEY RESEARCH LOCATION

This stage is aimed to identification problem such as analysis of drop voltage in location, identification cause of drop voltage, and total traction of house connections. Existing distribution networks systems shown in Fig.3.

FIGURE 3. Existing Distribution Networks Systems

EXISTING DATA

Data was taken from measuring voltage and power profile for each house, observation distribution network systems in field also from PLN as electricity provider. Table 1 shown, voltage receiver in consumer house particulary in peak load or night time not suitable with voltage regulation service or drop voltage permitted 5-10% in voltage service.[12, 13].

TABLE 1. Consumer of electricity in existing distribution networks

No	Consumer ID	Power	Measuring Voltage (Morning)	Measuring Voltage (Night)	Current
1	523030492976	2200 VA	220 V	217 V	10.5A
2	523030432722	900 VA	215V	212 V	2.3A
3	523030372681	450 VA	209 V	207V	1.5 A
4	523030492744	450 VA	196 V	192 V	1.5 A
5	523030221648	450 VA	197 V	195 V	1.4 A
6	523030221648	450 VA	189 V	189 V	1.5A
7	523030492503	900 VA	195 V	185 V	3.5A
8	523030492376	900 VA	191 V	183 V	3.5A
9	523030224006	900 VA	189 V	175 V	3.5A
10	523030490100	900 VA	188 V	174 V	3.5 A
11	523030492769	900 VA	186 V	170 V	3.5 A
12	523031447452	900 VA	187V	170 V	3.5 A
13	523030492984	900 VA	187 V	170 V	3.5 A
14	523030492777	450 VA	187 V	170 V	1.5 A
15	523030492935	450 VA	210 V	208 V	1.6 A
16	523030493062	900 VA	186 V	170 V	3.5 A
17	523030492499	900 VA	171 V	168 V	3.5 A
18	523030492481	450 VA	170 V	160 V	1.5 A
19	523030492594	900 VA	170 V	160 V	3.5 A
20	523031224035	900 VA	170 V	160 V	3.5 A
21	523030492465	900 VA	170 V	160 V	3.5 A
22	523030221536	450 VA	170 V	160 V	1.5A
23	533030492736	900 VA	170 V	160 V	3.3 A
24	523030493044	450 VA	209 V	205 V	3.3 A
25	523030852892	1300 VA	203 V	199 V	5.7 A
26	523030491273	900 VA	200 V	197 V	3.5 A
27	523030492871	450 VA	200 V	196 V	1.5 A
28	523031717057	900 VA	200 V	196 V	3.2 A
29	523031382395	450 VA	200 V	196 V	1.7 A
30	523030492968	900 VA	199 V	194 V	3.5 A
31	523030492545	900 VA	193 V	191 V	3.5 A
32	523030492537	450 VA	194 V	191 V	1.4 A
33	523030493051	450 VA	190 V	189 V	1.5 A
34	523030492578	450 VA	189 V	188 V	1.5 A
35	523030493107	900 VA	190 V	187 V	3.4A
36	523030497143	1300 VA	190 V	184 V	5.1 A
37	523030492950	900 VA	190 V	185 V	3.5A
38	523031619572	900 VA	190V	180 V	3.5 A
39	52303049259	900 VA	189 V	171 V	3.5 A
40	523030492785	900 VA	175 V	167 V	3.5 A
41	52303046165	2200 VA	175 V	165 V	9.3 A
42	523031616185	1300 VA	175 V	165 V	5.3 A
43	523030492863	900 VA	175 V	165 V	3.4 A
44	52303049684	900VA	165 V	158 V	3.5 A
45	52303049583	900 VA	165 V	158 V	3.5 A
46	52303049541	1300 VA	165 V	151 V	5.3 A
47	52303049125	450 VA	165 V	151 V	1.2 A
48	52303049175	450 VA	165 V	151 V	1.5 A
49	52303049524	900 VA	165 V	151 V	3.4 A
50	52303049356	900 VA	165 V	151 V	3.5 A
51	52303049753	450 VA	165 V	151 V	1.5 A

No	Consumer ID	Power	Measuring Voltage (Morning)	Measuring Voltage (Night)	Current
52	52303049117	900 VA	165 V	151 V	3.2 A
53	52303049358	450 VA	165 V	151 V	1.4 A
54	52303049852	900 VA	165 V	151 V	3.5 A

REAL CONDITION IN LOCATION

According Book I Kriteria Desain Enjinering Konstruksi Jaringan Distribusi Tenaga Listrik, maximum connections in one feeder are five house connections with maximal distance per connections as 50 meters and in a house connection maximum connections are six traction house connections or power losses permitted in low voltage distribution system was 3 % from low voltage distribution network connection point[14].

SIMULATION MODEL OF DROP VOLTAGE ON ETAP POWER STATION

This study is conducted by calculation existing data with some formula. There are the formula

Drop Voltage Formula :

$$\Delta V(\%) = \frac{vs - vr}{vs} \, x100\ \% \qquad (1)$$

Note:
VS = Voltage Source (220 Volt as Indonesia Voltage Standard)
VR = Voltage Receiver (Voltage in consumer side)

Power Losses Formula:

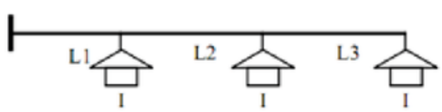

FIGURE 4. Tractions of house connections

If L1=L2=L3....= Ln, thus Power losses formula is

In traction of house connection, total connection house S(watt) 2C for 2 houses, current flow per line (I), conductor resistance variabel (R)

$$S\ (watt)\ 2\ C = \frac{1}{2} 2(I^2 + (2.I)^2).RL = 5.I^2RL \qquad (2)$$

For 3 house connections

$$S\ (watt)\ 3\ C = \frac{1}{3} x2\ (I^2 + (2.I)^2 + (3.I)^2)\ .\ RL = 9{,}33.I^2\ RL \qquad (3)$$

For 4 house connections

$$S\ (watt)\ 4\ C = \frac{1}{4} x2\ (I^2 + (2.I)^2 + (3.I)^2 + (4.I)^2).\ RL = 15.I^2\ RL \qquad (4)$$

For 5 house connections

$$S\ (watt)\ 5\ C = \frac{1}{5}\, x2(I^2+(2.I)^2+(3.I)^2+(4.I)^2+(5.I)^2).RL = 22.I^2.RL \qquad (5)$$

Note:

S(watt)	= Power Losses
C	= Total Consumer in a line
I	= Total current per line
RL	= 0.106 Ohm (Resistance of NFA2X 2x10 mm x 0.003 km)

Simulation model could be execute after single line diagram was made in ETAP Power Station. Simulation must be watched some parameters such as bus voltage, load voltage, length of network, kind of cable also transformer capacity.In this study, simulation model of low distribution network systems is designed by using ETAP Power Station Software. Capacity of distribution transformer set to 50 kV, bus voltage set to 220 V, lumped load used as load in single line diagram and the average length of cable is 0.04 km. After total components of single line diagram were inputed, single line diagram shown in Fig 4.

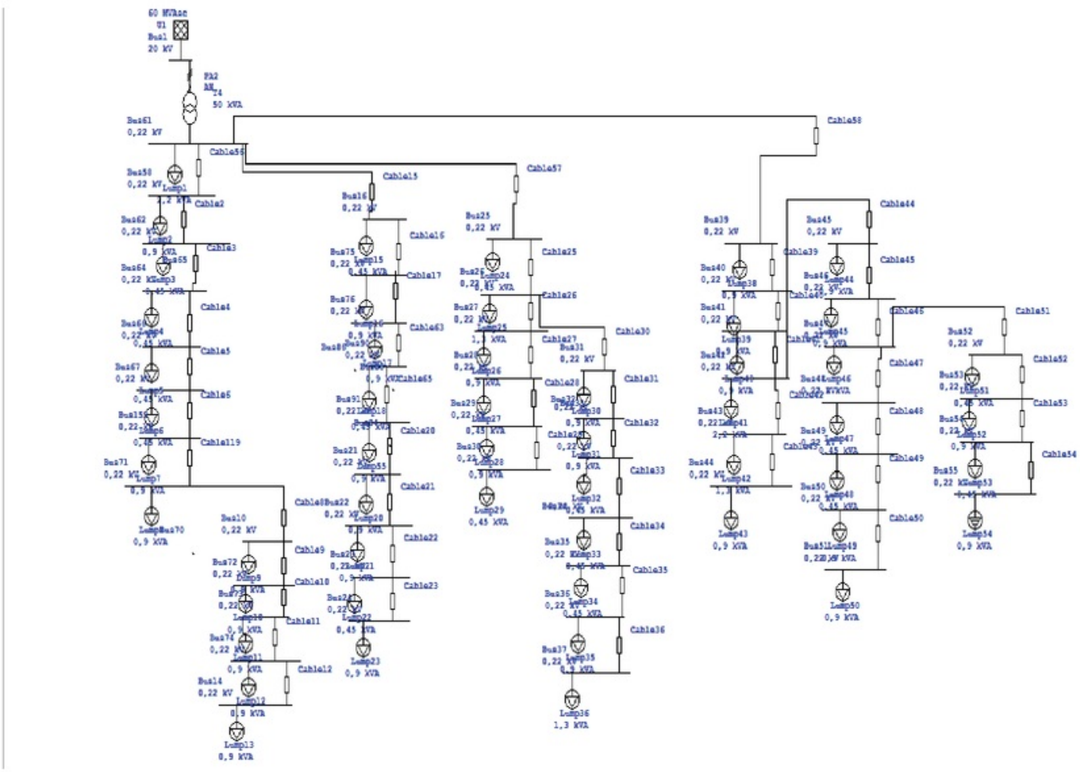

FIGURE 5. Simulation Model on ETAP Power Station

RECONFIGURATION PLAN

The purpose of reconfiguration plan is reduce power losses caused from traction of house connections inappropriate standart[2]. Reconfiguration plans are about added new feeders, replacement and added low voltage cable, added single phase distribution transformer and reconfiguration traction of house connections.

RESULT AND DISCUSSION

In this simulation model, there were 54 loads with various voltage regulation and current flow. Every loads connected one each other until 15 traction of house connections. However, maximum traction of house connections are 5 loads per feeder[15]. If more than it, can cause drop voltage significantly to distribution networks like shown in Table 2. Table 2 derive from calculation from Table 1 with drop voltage formula.

TABLE 2. Precentage Drop Voltage in Existing Distribution Network Systems

No	Voltage Service	Precentage of Drop Voltage
1	217 V	1.3 %
2	212 V	3.6%
3	207V	5.9 %
4	192 V	12.7
5	195 V	11.3 %
6	189 V	14.09 %
7	185 V	15.9 %
8	183 V	16.8 %
9	175 V	20.4 %
10	174 V	20.9 %
11	170 V	22.7 %
12	170 V	22.7 %
13	170 V	22.7 %
14	170 V	22.7 %
15	208 V	5.45 %
16	170 V	22.7 %
17	168 V	23.6 %
18	160 V	27.2 %
19	160 V	27.2 %
20	160 V	27.2 %
21	160 V	27.2 %
22	160 V	27.2 %
23	160 V	27.2 %
24	205 V	6.8 %
25	199 V	9.5%
26	197 V	10.4 %
27	196 V	10.9 %
28	196 V	10.9 %
29	196 V	10.9 %
30	194 V	11.8 %
31	191 V	13.1 %
32	191 V	13.1 %
33	189 V	14 %
34	188 V	14.5 %
35	187 V	15 %
36	184 V	16.3 %
37	185 V	15.9 %
38	180 V	18.1 %
39	171 V	22.2 %
40	167 V	26.8 %
41	165 V	25 %
42	165 V	25 %
43	165 V	25 %
44	158 V	28.1 %
45	158 V	28.1 %
46	151 V	31.3 %

No	Voltage Service	Precentage of Drop Voltage
47	151 V	31.3 %
48	151 V	31.3 %
49	151 V	31.3 %
50	151 V	31.3 %
51	151 V	31.3 %
52	151 V	31.3 %
53	151 V	31.3 %
54	151 V	31.3 %

Power losses caused from house tractions of existing distribution networks systems shown in Table 3.

TABLE 3. Average power losses per consumer in existing distribution networks

Line	SLP	Current Average	Power Losses Average
Line 1	8 House	3.4 A	62.49 watt
Line 2	9 House	3.05 A	62. 45 watt
Line 3	15 House	2.9 A	147. 38 watt
Line 4	6 House	3.15 A	34.86 watt
Line 5	10 House	3.24 A	85.67 watt
Line 6	6 House	4.75 A	72.58 watt
Line 7	11 House	3.79 A	140. 07 watt
Line 8	7 House	3.12	41.2 watt
Total			646.7 watt

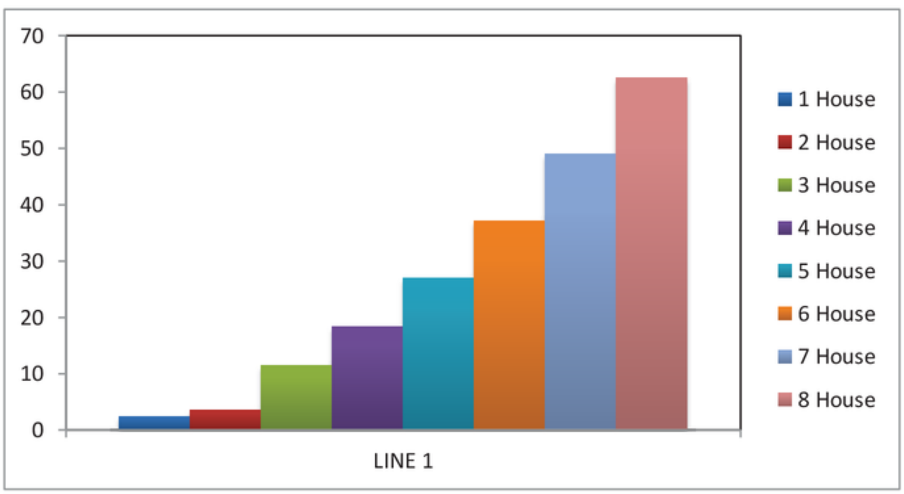

FIGURE 6. Graphics result of measurements average losses per consumer

Figure 6 shown house connections exceed of PLN Standard then the precentage of power losses will be excessively. Meanwhile, difference between result of measurement in the field and simulation ETAP Power Station shown in Fig 7.

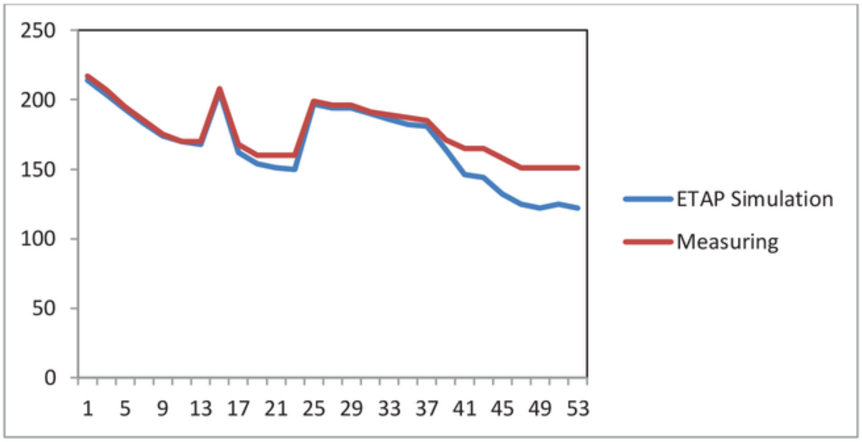

FIGURE 7. Graphics comparison of voltage simulation and voltage measurement

Attachment of harmonic filter in ETAP Power Station can reduce power losses like shown in Table 4.

TABLE 4. Effect of filter harmonic attachment in ETAP Power Station.

Line	Before Attachment Filter Harmonic			After Attachment Filter Harmonic		
	Losses	**THD Voltage**	**THD Current**	**Losses**	**THD Voltage**	**THD Current**
Line 1	83.4 watt	5.6 %	14.2%	40.7 watt	10.6 %	3.6 %
Line 2	82.6 watt	5.3 %	13.4 %	53.4 watt	11.2 %	3.5 %
Line 3	136.7 watt	5.2 %	14.6%	84.5 watt	10.8 %	3.5 %
Line 4	60.7 watt	5.5 %	13.6%	48.2 watt	11.3 %	3.3 %
Line 5	97.2 watt	5.7 %	13.4%	78.4 watt	9. 5%	3.4 %
Line 6	82.9 watt	5.3 %	14.8%	71.4 watt	10.2 %	3.7 %
Line 7	169. 7watt	5.6 %	14.4 %	138.5 watt	9.2 %	3.4 %
Line 8	63.4 watt	5.2 %	14.1%	59.4 watt	10.3%	3.8 %
Total	776.6 watt	43.4 %	112.5%	574.5 watt	11.1 %	3.2%

From Table 4, we can observe reduction power losses in existing power systems distributions before attchment of harmonic filter and after attachment of harmonic filter. Total power losses before attachment of harmonic filter is 776.6 watt and after attachment of harmonic filter, power losses reduce to 574.5 watt. Pairing harmonic filter in power systems distribution can be effective method to reduce power losses.

After reconfiguration and restructured distribution network systems was done, total power losses shown in Table 5.

TABLE 5. Average power losses per consumer after reconfiguration and restructured

Feeder	Line	SLP	Average Current	Average Losses
	Line 1	5 Houe	3.44 A	27.5 Watt
	Line 2	4 house	3 A	14.31 Watt
	Line 3	5 house	3.1 A	22.41 Watt
PDL09/100/U47/T03	Line 4	4 house	2.5 A	9.9 Watt
	Line 5	5 house	3.06 A	21.83 Watt
	Line 6	3 house	4.16 A	17.1 Watt
	Line 7	3 house	2.13 A	7.8 Watt
	Line 8	4 house	2.4 A	9.1 Watt
	Line 9	3 house	3.3 A	10.7 Watt
	Line 1	5 house	4.6 A	49.34 Watt
	Line 2	3 house	4.06 A	16.3 Watt
	Line 3	3 house	3.3 A	10.7 Watt
PDL10/100/U47/T03	Line 4	4 house	2.4 A	9.1 Watt
	Line 5	3 house	2.7 A	7.2 Watt
		Total	44.15 A	233.29 Watt

From the Table 5, after modelling of reconfiguration and restrutrured on ETAP Power Station, it can reduced power losses from 646.7 watt to 233.29 watt. Certainly, it is make positively impact to distribution networks systems in the field particulary for improvement of power quality in distribution network systems.

CONCLUSIONS

This paper presented that modelling distribution networks by reconfiguration existing distribution networks systems in ETAP Power Station can reduce drop voltage from 1.3 % - 31.3 % to 8.1 % - 9.6 % and power losses from from 646.7 watt to 233.29 watt. The result showed that added new feeders, replacement and added low voltage cable, added single phase distribution transformer and reconfiguration traction of house connections make significantly impact in distribution networks that is enhance power quality service. The result of modelling and reconfiguration existing distribution networks is better than before according PLN standard with SPLN 1:1995 and IEC 60038, where drop voltage maximum for each voltage regulation between 5-10%.. It can be choose as a solution for it and applicable to the field or existing distribution networks.

ACKNOWLEDGMENT

I would like to thank Department of Electrical Engineering. Faculty of Engineering, Universitas Negeri Semarang for supporting the reserach funding.

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