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Analysis of Efforts to Overcome Voltage Drops by Installing Substations in Low Voltage Networks with ETAP Simulation

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Abstract

Electric power is an energy of secondary that generated, transmitted and distributed to consumers and used to many activities. Electrical power system is electrical power installation system is consists of generation system, transmitting system, and distribution system that integration and function to supply electric power consumption. For this purpose, both of quantity and quality also continuity in PT PLN wished can be provides and distributes electric power to consumers and all of people. One of the main materials of the distribution network to distribute electric power to customers is the distribution substation in which there is a transformer. Transformer as a means of distribution of electrical energy is susceptible to interference. Distribution substation SM 0075 Feeder Bajera is one of the distribution substations that experienced a voltage drop at the end of the JTR in the C direction. So, to fix the problems that occurred, PT. PLN has added a substation. With the addition of substations, it is necessary to pay attention to the power losses that arise, not to cause greater power losses. Based on the results of the calculations at the distribution substation SM0075 Bajera feeder before and after the addition of the insertion substation, it was found that the voltage drop at the end of the JTR direction C at the SM0075 distribution substation was 22.638% in the R phase, 15.745% in the S phase and 14.005% in the T phase. the result of the addition of the substation is a smaller power loss with the difference before and after that is equal to 2739.986472 Watt. then viewed from the quality of the voltage and environmental conditions, the C18D6A1D3 pole is better for insertion substations than the C18D6A1D2 pole based on the Etap 12.6 simulation.

Keywords

Transformer, Transformer Management, Repeater, Distribution Network

INTRODUCTION

PT PLN (Persero) is a State Electricity Company engaged in electricity as an element of providing electricity, electricity needs will increase along with the development of both the population and the amount of investment that will lead to new industries, this is indicated by an increase in energy sales in 2020 at PT PLN (Persero) South Bali Customer Service Implementation Unit (UP3). Therefore, with this increase, the main task of PT PLN (Persero) is to maintain the continuity of the distribution of electrical energy supply to customers. To maintain this continuity, PT PLN continues to strive to distribute electrical energy as well as possible to provide the best service to customers. Maintaining the continuity of electrical energy in question includes voltage and frequency in accordance with the standards set by PLN, especially the voltage at low voltage customer service, namely 230/400 volts, with the determination that the variation in service voltage is partly due to voltage drop due to load changes of maximum +5% and minimum -10% of the nominal voltage 230/400V [1]. With the increase in growth, there is an expansion of the electricity network, which results in increased loading of distribution transformers, where distribution transformers function to transform electrical energy from 20 kV medium voltage to 230/400 V low voltage.

The voltage drop at the end of the low-voltage network of the distribution substation SM 0075 of the bajera repeater, based on the data that the author obtained from PT PLN (Persero) that at the end of the low-voltage network major C distribution substation SM 0075 bajera repeater indicated experiencing a voltage drop. This indication originated from a report from a customer who felt a voltage drop such as flashing lights, besides that the customer also used electrical machines to manage chicken drums which caused the electrical machines to heat up quickly due to voltage drops, then this report was followed up by checking the average voltage measured at the customer and obtained the correct results of the exact voltage drop of 191.5 Volts so that the percentage of voltage drop measured was -20.09% of 230 Volts, based on PLN standards for the allowable standard voltage drop of 207 Volts or -10% of 230 Volts. [Based on this, the problem can be determined, namely what is the percentage of voltage drop that occurs at the end voltage of the Low Voltage Network (JTR) of the SM 0075 distribution substation before and after the installation of the insert substation (SM0246) and how much the transformer loss (SM 0075 and SM 0246) and the low voltage network line loss of the SM0075 substation before and after the installation of the insert substation (SM0246) and where is the right point for installing the insert transformer using ETAP.

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METHODS

Data collection carried out by the author is to conduct interviews with stakeholders, ULP managers, ULP Engineering supervisors, personnel who do the work, vendor supervisors of the work and employees at the PLN office. The research was conducted at distribution substation SM 0075 located in Tegal Mengkeb Village. East Selemadeg District, Tabanan.

Data collection techniques using descriptive quantitative methods, in this study that will be presented in the form of numbers to be processed and descriptions of these numbers. The data needed by the author is data obtained through direct measurements taken in the field, besides that the author also takes the supporting data needed in this final project obtained from PT PLN (Persero) and related parties who are experts in their fields. In collecting data, the author uses methods, namely the observation method, the author makes observations on the SM 0075 substation of the bajera reinforcement and on the network. The author obtains visual data such as distribution substation construction, low voltage cable lines, house lines and conditions around the distribution substation. 3.1.2 Literature Study In the literature study method, the author looks for and studies references related to the issues raised, which can be taken from research journals that have been conducted regarding the end voltage drop. In addition, the author also looks for references to the formulas used to solve the problems discussed. In the observation method, the author conducts direct observation of the work performed. In addition, the author also conducts network inspections of the three reinforcements and takes measurements of voltage and current. And analyze the data through ETAP simulation.

RESULT AND DISCUSSION

Distribution Substation SM0075 is one of the distribution substations on the Bajera Repeater located on Jl. N. Kobot, Tegal Mengkeb Village, East Selemadeg District, Tabanan Regency Bajera Repeater is one of the repositories in the work area of PT PLN (Persero) Tabanan Customer Service Unit (ULP) which is supplied through Power Transformer II (60 MVA) at Antosari Substation. Distribution Substation SM 0075 has a portal type substation construction. The outgoing of the distribution substation is divided into two departments, namely department A (north direction) and department C (south direction), both of which use the Low Voltage Air Line (SUTR) distribution system with the type of LVTC conductor 3 x 70 + 1 x 50 mm2 and. The total number of customers at distribution substation SM 0075 is 269 customers. In this final project, the author analyzes the voltage drop at the end of the low voltage network in department C, the total power loss at distribution substation SM 0075 Bajera Substation before and after the installation of the insert substation and the right point in the installation of the insert substation.

For primary data collection, data was collected before the addition of the insert substation on April 25, 2021, which was taken every hour for 24 hours at distribution substation SM0075 Bajera Repository. Meanwhile, data collection after the addition of the insert substation was carried out on July 6, 2021, which was taken every hour for 24 hours at distribution substations SM0075 and SM0246.

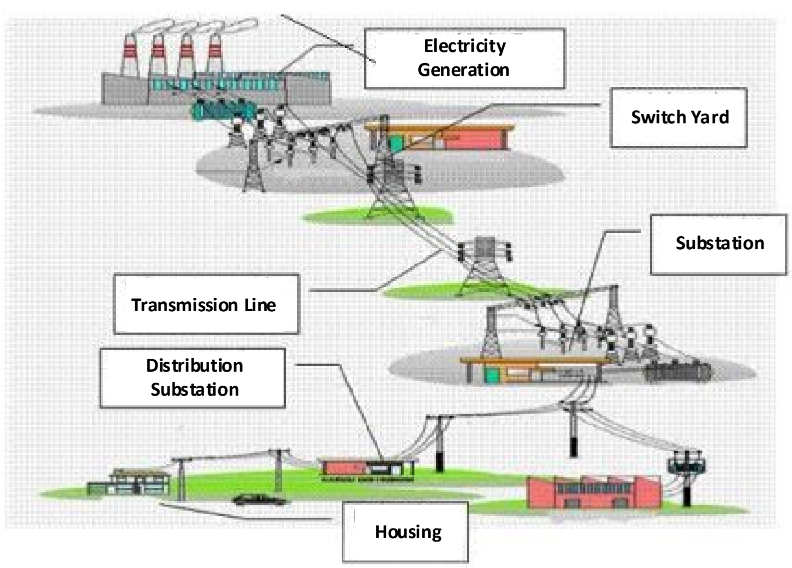

Figure 1. Distribution Network Structure (Source: PT PLN (Persero), 2020)

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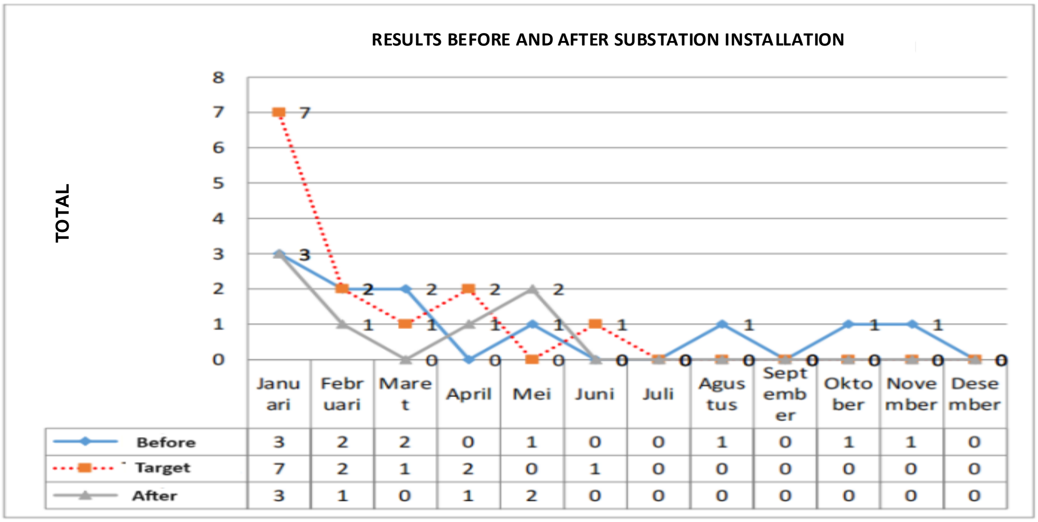

	Januari	Februari	Maret	April	Mei	Juni	Juli	Agustus	September	Oktober	November	Desember
Before	3	2	2	0	1	0	0	1	0	1	1	0
Target	7	2	1	2	0	1	0	0	0	0	0	0
After	3	1	0	1	2	0	0	0	0	0	0	0

Figure 2. Disturbance Graph Curve Before and After Installation

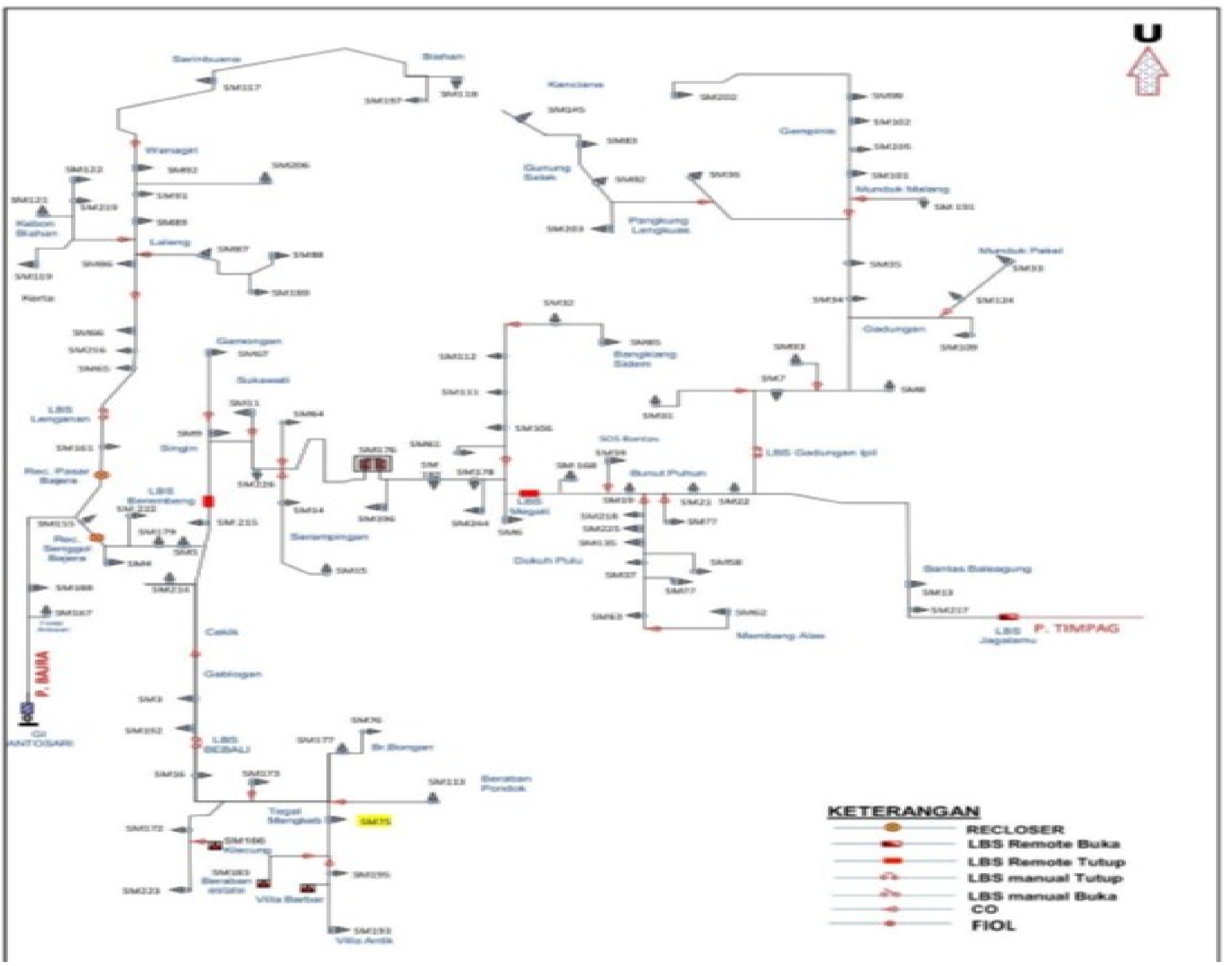

Figure 3. Single Line Diagram of the Repeater

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Figure 4. Substation Installation

Calculation of the percentage of end voltage drop in the C phase R department every hour for 24 hours, namely the percentage of end voltage drop in the C phase R department at 08.00 WITA before the addition of the insert substation at the SM 0075 distribution substation was obtained:

$$VR = \frac{VSource - VR}{VR} \times 100\%$$

$$VR = \frac{234.9 - 177.08}{177.08} \times 100\%$$

$$VR = 32.6519\%$$

Calculation of the percentage of end voltage drop in department C every hour for 24 hours, namely the percentage of end voltage drop in department C phase R at 08.00 WITA after the addition of the insert substation at distribution substation SM 0075 is obtained:

$$VR = \frac{VSource - VR}{VR} \times 100\%$$

$$VR = \frac{235.1 - 227.11}{227.11} \times 100\%$$

$$VR = 3.5\%$$

Based on the data from the measurement of current and mains voltage on the transformer at distribution substation SM 0075 with a capacity of 100 KVA, the power of each phase can be found every hour for 24 hours, namely the apparent power for phase R, Phase S and Phase T obtained:

$$S = (VR \times IR) + (VS \times IS) + (VT \times IT)$$

$$S = (234.9 \times 77) + (234.9 \times 75.1) + (235.5 \times 64.5)$$

$$S = 41311.62\ VA$$

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By using the same method as above, the output apparent power and the percentage of loading per hour for 24 hours can be known:

$$\%load = \frac{s}{sTrafo} \times 100\%$$

$$\%load = \frac{51311.62}{100000} \times 100\% = 51.31162\%$$

$$\%load = 51.31162\%$$

By referring to the 100 KVA transformer efficiency data from the manufacturer and referring to the percentage of transformer power that has been calculated every hour for 24 hours previously, the efficiency value can be found every hour for 24 hours, namely the efficiency of the transformer at the distribution substation SM 0075 Bajera repeater:

$$Y = \frac{(Y2 - Y1)}{(X2 - X1)} \times (X - X1) + Y1$$

$$Y = \frac{(0.987 - 0.9888)}{(75 - 50)} \times (51.31162 - 50) + 0.9888$$

$$Y = 0.9886898239$$

After obtaining the efficiency value for each hour for 24 hours that has been obtained in the previous calculation, it can be known the input power of the transformer at the SM 0075 distribution substation every hour for 24 hours, namely the apparent input power of the SM 0075 Bajera Substation transformer before the addition of the insert substation:

$$S_{input} = \frac{s2}{\varphi}$$

$$S_{input} = \frac{51311.62}{0.988689824}$$

$$S_{input} = 51898.60233\ VA$$

After obtaining the value of the apparent power (S input)) of the transformer at the SM 0075 distribution substation every hour for 24 hours as in the previous calculation, the power loss of the transformer at the SM 0075 distribution substation before the addition of the insert substation every hour for 24 hours can be found, namely the amount of transformer power loss at the SM 0075 distribution substation:

$$Apparent\ power\ loss = S\ input - S\ output = S1 - S2$$

$$Apparent\ power\ loss = 51898.60233 - 51311.62 = 586.982331\ VA$$

Based on the current data of A and C majors every hour for 24 hours before the addition of the substation insert, the average value of the current in the C phase majors.

$$Average\ IR = \frac{IRtotal}{total\ data}$$

$$Average\ IR = \frac{793.4}{25} = 31.736\ A$$

With the known amount of apparent power loss per hour as the previous result and the power factor per hour, then to find the active power loss per hour after the addition of the insert substation at the SM0075 distribution substation of the Bajera Substation can be obtained:

$$P = P_{in} - P_{out}$$

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$$P = (S1 \times Cos\ phi) - (S2 \times Cos\ phi)$$

$$P = Apparent\ power\ loss \times Average\ Cos\ phi$$

Based on the results of the calculation of active power loss per hour for 24 hours before the addition of the insert substation, the average power loss value is obtained as follows

$$Average\ P = \frac{12337.27346}{25}$$

$$Average\ P = 493.4909384\ Watt$$

Based on the current data of department A and department C every hour for 24 hours after the addition of the insert substation obtained in the previous results, the average value of the current in department A phase is equal to:

$$Average\ IR\ = \frac{IRtotal}{total\ data}$$

$$Average\ IR\ = \frac{1458.2}{25} = 58.328\ A$$

So that the need for periodic monitoring for the placement of substation inserts is not only carried out by location surveys, but still carried out calculations in order to get a wiser decision. calculations are carried out in order to get a wiser decision for PLN and the community.

TABLE 1

AVERAGE CURRENT OF EACH PHASE

AVERAGE CURRENT OF EACH PHASE OF THE DEPARTMENT A			AVERAGE CURRENT OF EACH PHASE OF DEPARTMENT C		
R	S	T	R	S	T
59.8	27.46	50.532	31.736	58.256	38.376

These problems include the voltage drop at the end of the low voltage network in department C, the total power loss before and after the installation of the insert substation as well as at the insert substation, and the selection of the right point in the installation of the insert substation which is reviewed from the results of field measurements, calculations, and data obtained from PT PLN. For the analysis of the calculation of the percentage of the end voltage of department C at distribution substation SM0075, end voltage data is taken using AMR (Automatic Meter Reading) communication media installed at the end of the customer network every hour for 24 hours before and after the addition of the insert substation. Based on these data, the calculation of the percentage of end voltage in department C every hour for 24 hours before and after the addition of substation inserts as in the table, then from the results of the calculation of the percentage of end voltage in department C every hour for 24 hours before and after the addition of substation inserts, the percentage of end voltage in department C before and after the addition of substation inserts can be found in Table 2.

TABLE 2

PERCENTAGE OF VOLTAGE AT THE END OF DEPARTMENT

Phase	Percentage of Voltage at the End of Department C (Volt)	
	Before	After
R	26.53329955 %	3.894612824 %
S	19.36071092 %	3.61478723 %
T	19.88339738 %	5.877485266 %

Based on the calculation of the percentage of JTR end voltage drop in department C before and after the addition of the insert substation, the end voltage in department C distribution substation SM0075 has decreased the percentage of voltage drop in each phase.

To analyze the right point in the placement of the insert substation, a simulation is carried out using ETAP where the placement of the insert substation is taken from the center point of department C based on field conditions where in the future it is estimated that there will be an increase in the market because the area is close to the tourist area. Based on the end voltage data from the simulation results using ETAP 12.6 which can be seen in table 4.45, in the first condition of placing the substation insert on the C18D6A1D3 pole, the quality of the voltage obtained is better than the second condition of placing the substation insert on the C18D6A1D2 pole when compared by percentage.

There are 2 choices of substation insert installation points based on the midpoint of the C department network, namely precisely on the existing pole with pole number C18D6A1D3 and on pole number C18D6A1D2. With the simulation results in ETAP, a comparison of the end voltage quality results is obtained in Table 3.

TABLE 3

PERCENTAGE OF VOLTAGE DROP AT THE END

Phase	Percentage Voltage Drop at the End of Department C	
	Option I Pole C18D6A1D3	Option II Pole C18D6A1D2
R	2.01 %	2.283 %
S	1.807 %	1.898 %
T	1.807 %	1.818 %

Based on the results of the calculation of the percentage of JTR end voltage in department C, condition I placement of substation insert on pole C18D6A1D3 and condition II placement of substation insert on pole C18D6A1D2, it is known that the amount of voltage drop in both conditions of pole placement of substation insert is still within the permissible limits in accordance with SPLN in 2013 regarding voltage standards is 10%.

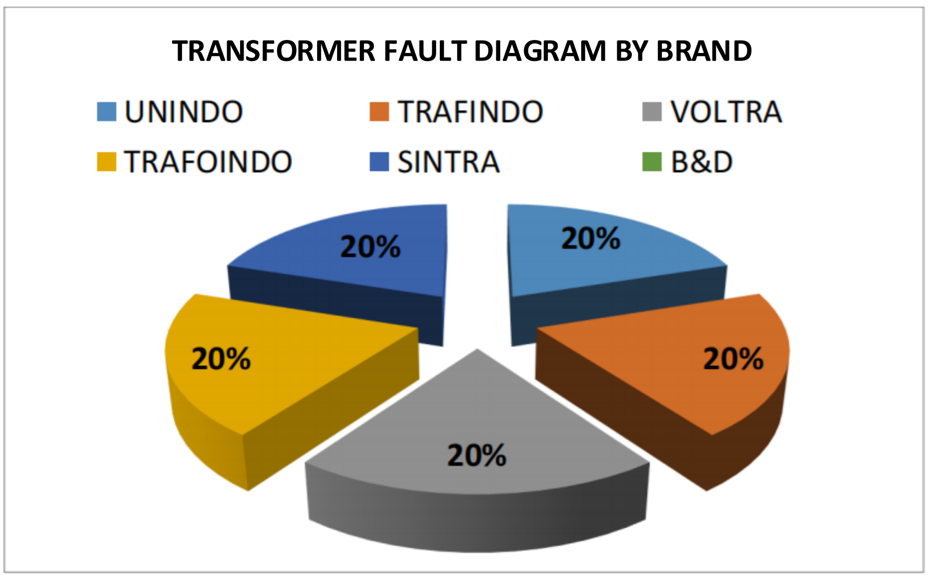

Figure 5. Transformer Fault Diagram

CONCLUSIONS AND SUGGESTIONS

Based on the above analysis, it can be concluded and at the same time become material for consideration to related parties several things as follows. The magnitude of the percentage of the end voltage drop at JTR major C distribution substation SM0075 before the addition of the substation insert is: 26.53329955% on phase R, 19.36071092% on phase S, and 19.88339738% on phase T. Meanwhile, the percentage of end voltage drop at JTR major C distribution substation SM0075 after the addition of the substation insert is: 3.894612824% on phase R, 3.61478723% on phase S, and 5.877485266% on phase T. From the results of the comparison of the percentage of the end voltage, it is obtained that the amount of decrease is 22.638% on phase R, 15.745%, and 14.005%. This means that the addition of the substation can already reduce the percentage of the JTR end voltage drop that occurs in department C of the SM0075 distribution substation of the Bajera Substation. The total power loss of distribution substation SM 0075 before the addition of the insert substation is 10993.54607 Watt, while the total power loss of distribution substation SM 0075 after the addition of the insert substation is 6340.415064 Watt and the total power loss at distribution

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substation SM 0246 (the insert substation itself) is 1913.144533 Watt. This means that the addition of the insert substation can reduce the total power losses that occur in the distribution substation SM0075 Bajera Substation, as well as those that affect the power loss, namely from Transformer loading with efficiency, measured power factor, and low voltage network distance. In selecting the installation point of the insert substation (SM0246), 2 choices of pole installation points were obtained based on taking the midpoint of department C of distribution substation SM0075. The 2 choices of pole points are pole no C18D6A1D3 for the first choice and pole no C18D6A1D2 for the second choice, from these two points different end voltage quality and different environmental conditions are obtained. When viewed from the quality of the tip stress and environmental conditions.

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REFERENCES

[1] W. S. Baykuni "Evaluasi Perhitungan Susut Daya Listrik Pada Jaringan Distribusi Penyulang JJR-7 Gardu Induk Jajar," Sekrepsi diterbitkan. Univeristas Muhammadiyah Surakarta, 2019.
[2] Faridah, "Evaluasi Sistem Pembumian Penyulang Gontang Gardu Induk Tanjung Bunga Makasar," *ILTEK*, vol 11, no 02, ISSN: 1907- 0772, 2016.
[3] Laginda, Tumaliang dan Silimang, "Perbaikan Kualitas Tegangan Pada Jaringan Distribusi Primer 20 KV Di Kota Tahuna*," Jurnal Teknik Elektro dan Komputer*, vol 7, no 2, 2018.
[4] Permana Kadek Adi, "Analisis Simulasi Perencanaan Rekonfigurasi Penyulang Ponjok Batu untuk Meningkatkan Efisiensi penyaluran daya listrik dan Kualitas Tegangan," Tugas Akhir tidak diterbitkan. Politeknik Negeri Bali, 2021.
[5] D. Peukasa, "Analisa Jatuh Tegangan Jaringan Distribusi 20 kV Pada Feeder Syiah Kuala PT.PLN (Persero) UPT Tragi Banda Aceh," Sekrepsi diterbitkan. Universitas Syiah Kuala, 2014.
[6] PT PLN (Persero). *SPLN 72: 1987 Spesifikasi Desain untuk Jaringan Tegangan Menengah (JTM) dan Jaringan Tegangan Rendah (JTR).* Jakarta Selatan.1987.
[7] Shokooh Farrokh. *ETAP (Electric Transient and Analysis Program) software*. Irvin California. 1986.
[8] I. M. Sajayasa, I. N. Sunaya, I. G. N Sangka, I. G. S. Widharma, "Analisa Pengaruh Robek Deck Seal pada Transformator Distribusi dengan Manajemen Trafo pada PT PLN ULP Kuta," *Jurnal Vastuwidya*, vol. 7 no. 1, 2024.
[9] I. N. Sunaya, I. G. S. Widharma, I. M. Sajayasa, "Analisis Posisi Recloser Terhadap Keandalan Kinerja Penyulang Sempidi Berbasiskan Software ETAP Power Sation," *Logic*, vol 17, no. 3, 2017.
[10] I. G. Suputra Widharma, P. A. W. Santiary, D. A. I. C. Cewi, I. M. Sajayasa, I. N. Sunaya, I. G. N. Sangka. "Studi Pengaruh Pemasangan Sistem Counterpoise pada Lightning Arrester di Gardu Distribusi Berbasis Software ETAP," 2024.
[11] Surat Edaran Direksi PT PLN (Persero) No. 0017.E/DIR/2014, Metode Pemeliharaan Trafo Distribusi Berbasis Kaidah Manajemen Aset, PT PLN (Persero), 2014.
[12] I. G. S. Widharma, I. N. Sunaya, I. G. P. Arka, I. M. Sajayasa, "Effect of using ground wire to lightning surge interference at 20 KV medium voltage distribution system based on genetics algorithm," *IRJEIS*, vol 3, no. 3, 2017.
[13] Yosua Seto Dwi Nugroho, Proteksi Trafo Distribusi 20 kV terhadap Bahaya Sambaran Petir dengan Menggunakan Lightning Arrester di Gardu Distribusi MB 053 PT PLN (Persero) Rayon Tuban Jawa Timur, 2015.
[14] Yuntyansyah, Wibawa and Utomo, "Studi Perkiraan Susut Teknis dan Alternatif Perbaikan pada Penyulang Kayoman Gardu Induk Sukorejo," *Jurnal Mahasiswa Teknik Elektro*, 2015.