International Journal of Global Sustainable Research (IJGSR)
Vol.2, No.4, 2024 : 223-230

Evaluation of Distribution Transformer Placement Optimal Based on Load Balance

Aris Triwiyatno, Bambang Winardi
Diponegoro University, Semarang
Corresponding Author: Bambang Winardi bbwinar@gmail.om

A R T I C L E I N F O

Keywords: Distribution System, Load Balance, Losses, Transformer Placement

Received : 12, February
Revised : 20, March
Accepted: 25, April

A B S T R A C T

The distribution network is the part of the electric power system that is closest to customers or loads compared to the transmission network. Currently the condition of the electricity network throughout Indonesia has decreased by 5% which is caused by various factors such as the large diameter of the conductors used, so that at the furthest SR the overvoltage value is 10%, the allowable voltage falls and must anticipate an increase in electricity load of 22.7% , the placement of the transformer is less than optimal so that the transformer capacity and voltage are not optimal. Given these conditions, a re-evaluation is needed that takes into account planning criteria such as allowable voltage drops so that optimization of the network used can emerge. After optimization on the SRL01.014 feeder the voltage dropped from 6.06 V to 5.76 V.

DOI Prefix: https://doi.org/10.59890/ijgsr.v2i4.1784
ISSN-E: 2828-1519
https://journal.multitechpublisher.com/index.php/ijgsr

INTRODUCTION

Electric power systems require a continuous balance of energy in the prime mover with the electrical load in order to operate stably. Electrical loads continue to vary, such as lighting loads, electrical equipment, or electric motors. Changes in a load may be relatively small compared to the electrical power system as a whole, but every time the load increases or decreases it must be accompanied by a change in power in the generator's initial drive. If the mechanical power on the initial drive shaft does not immediately adjust to the magnitude of the electrical load, the frequency and voltage will shift from the normal position. Worse situations can occur if there is a loss of generation or large loads in the system, such as transmission lines. The presence of control equipment such as a governor on the turbine and a voltage regulator is expected to return the voltage and frequency to a normal position or within acceptable limits. However, oscillations generally occur around the final position. In most cases this oscillation will be damped and the system will return to stability. If instability occurs, it can disrupt the continuity of power services to some or even all consumers.

One of the methods used to analyze load balance is by calculating the values of losses and drop voltage on the distribution network conductors, calculating the voltage drop and voltage losses in the KTL feeder SRL01 area so as to obtain the values of losses and VD from the number of transformers installed on the line. By knowing the calculation results, the load balance between the loaded phases can be described so that the load on each phase is at least balanced. The image displayed is a diagram of a 20 kV single line UPJ South Semarang which can be phase shifted to achieve load balance and reduce the value of losses.

METHODOLOGY

Basic Calculation of Voltage Drop in the Electricity Orderly Area (KTL) feeder SRL01 Srondol South Semarang

This voltage drop calculation is only specifically for calculating the channel from GI Srondol SRL01 Srondol, for example to the channel (Feeder) entering the Slawi network unit. What will be calculated here is the line on SRL01 to the transformer furthest from the GI in the Orderly Electricity Area (KTL), namely from the three-phase 20 kV main line, single-phase branching. The VD (voltage drop) formula is:

$$VD = r\int_0^K ixdx\cos\phi + \int_0^L ixdx\sin\phi$$

$$= \frac{L.r}{2} I\cos\phi + \frac{L.x}{2} I\sin\phi$$

The following is the calculation of cos Ø recorded on June 2023 from the SRL01 transformer (data taken from the 20 kV UPJ South Semarang single line diagram) at night peak load.

Is known :

Real power (P) = 13.8 MW
Reactive power (Q) = 5.8 Mvar
Cos Ø = 0,9225

Next for the SRL01 transformer (data taken from the 20 kV single line diagram UPJ South Semarang)
in the morning load,
Is known :

Real power (P) = 11.6 MW
Reactive power (Q) = 4.9 Mvar
Cos Ø = 0,92136

Then the power factor at load and other times is calculated in the manner above and the results are entered in the table below:

Table 1. Primary data on Power Factor in June 2023

Date	Load at 05.00			Peak load at night		
	MW	MVar	Cos Ø	MW	MVar	Cos Ø
1 – 6– 23	11,6	4,9	0,9	13,8	5,8	0,9
1 – 6– 23	15,6	7,9	0,9	16,2	8,2	0,9

As a further note, a table will be shown which states the standard provisions for main line voltage drop, branches which are compared with the results of the calculations.

Table 2. Comparison of Standard Voltage Drop with Calculation Results

Equipment Systems	**VD Standart**			**VD Calculation Results**	
	%	**Volt**	**Feeder**	**%**	**Volt**
1. The channel from the GI to the primary side of the last distribution transformer	5,45	12	SRL01	16,151	35,532
2.Distribution Transformer	1,36	3	SRL01	0,6239	137,248

RESEARCH RESULTS AND DISCUSSION

Voltage Drop Calculation

From the calculation of the branching feeder, a table of results for the current and voltage drop calculations is produced.

Table 3 Results of Current and Voltage Drop Calculations

Feeder	The calculation results	
	Ap (A)	Vd (V)
SRL01.018	4,3255	0,169612
SRL01.021	8,65103	0,101767
SRL01.021.B003	4,3255	0,149141
SRL01.021.B011	8,65103	0,695991
SRL01.021.B004.U005	4,3255	0,248568

Transformer Losses at Branch Feeders

The value of each branch pole or feeder can be tabled as below:

Table 4 Transformer Losses Calculation

Feeder	Loose Calculation Results		
	Real	Reaktif	Pseudo
S1.018	39,82799	30,48357	50,1549
S1.021	1,4598	1,1173	1,8383
S1.021.B003	1,2932	0,3157	1,3312
S1.021.B011	12,0704	2,9465	12,4248
S1.021.B004.U005	2,15568	0,5258	2,2188

Transformer Placement Optimization Calculations Based on VD

Based on the known voltage drop value, the PLN decision is:

Table 5. Table of Allowable PLN Voltage Determinations

Minimum voltage	Maximum voltage
10%	5%
198 V	231 V

With the nominal voltage determined by PLN, the minimum voltage and maximum voltage permitted are known so that the reliability of electricity distribution to consumers can be stable. Therefore, the maximum and minimum allowable voltage drop can be calculated as follows:

Calculation of Maximum and Minimum Voltage Drop Values

Table 6. VD Calculation Table Based on Allowable PLN Voltage

FEEDER	VD_MAKS	VD_MIN
S1.014	5,763546	5,460201
S1.019	3,537113	3,350949
S1.020	3,267263	3,095302
S1.021.B001	1,357211	1,285779
S1.021.B005	10,54285	9,987964
S1.021.B011	2,325629	2,203227
S1.021.B004.U005	3,095376	2,932461

Calculation Results After Optimization Occurs

Real power losses

After calculating the optimization values for the maximum and minimum voltage drop (VD) to obtain the maximum and minimum distances after optimization, the losses are quite small and the reliability is getting better according to field data. Next, calculate the losses after entering the balance values as in the table below:

Table 7. Comparison of Losses Values Before and After Optimization

Feeder	Losses_Maks	Losses
SRL01.014	2031,697348	2138,629
SRL01.019	574,428672	604,6618
SRL01.020	479,434752	504,6682
SRL01.021.B001	338,1803251	355,9793
SRL01.021.B005	5102,001746	5370,528
SRL01.021.B011	331,012224	348,4339
SRL01.021.B004.U005	586,395936	617,2589

Real Power

After calculating the optimization value for the maximum and minimum voltage drop (VD) to obtain the maximum and minimum distance after optimization so that fairly small losses are obtained and reliability is getting better according to field data, then calculate the real power after the balance value is entered as in the table below:

Table 8 Comparison of Real Power Values Before and After Optimization

Feeder	Real Power_Min	Real Power
SRL01.014	1829074,699	1829938,8
SRL01.019	842425,0836	842669,4

SRL01.020	769642,205	769846,12
SRL01.021.B001	1292986,514	1293130,3
SRL01.021.B005	2509118,268	2511288,3
SRL01.021.B011	738473,4059	738614,19
SRL01.021.B004.U005	982857,6767	983107,08

Secondary Phase Voltage

After calculating the optimization values for the maximum and minimum voltage drop (VD), the maximum and minimum distances are obtained after optimization so that fairly small losses are obtained and reliability is getting better according to field data. Next, calculate the Secondary Phase Voltage after entering the balance value as in the table below :

Table 9. Comparison of Phase Voltages Before and After Optimization

Feeder	Phase Voltage_Min	Phase Voltage
SRL01.014	11553,75339	11553,1469
SRL01.019	11555,89964	11555,52726
SRL01.020	11556,18926	11555,84907
SRL01.021.B001	11557,93791	11557,79505
SRL01.021.B005	11548,91958	11547,80981
SRL01.021.B011	11556,70432	11556,45951
SRL01.021.B004.U005	11556,23371	11555,90788

CONCLUSION AND RECOMMENDATIONS

In calculating the voltage drop from the South Semarang Srondol GI as in the table, there is a difference between each feeder before it is balanced and after it is balanced. On the SRL01.014 feeder the VD drops from 6.06490887 V to 5.761663427 V as the maximum limit and 5.458417983 V as the minimum limit. Feeder SRL01.019 VD decreased from 3.7237644 V to 3.53757618 V as the maximum limit and 3.35138796 V as the minimum limit. Feeder SRL01.020 VD decreased from 3.4019576 V to 3.23185972 V as the maximum limit and 3.06176184 V as the minimum limit. Feeder SRL01.021.B001 VD decreased from 1.42859233 V to 1.357162714 V as the maximum limit and 1.285733097 V as the minimum limit. Feeder SRL01.021.B005 VD decreased from 11.09773736 V to 10.54285049 V as the maximum limit and 9.987963624 V as the minimum limit.

Feeder SRL01.021.B011 VD decreased from 2.4480303 V to 2.325628785 V as the maximum limit and 2.20322727 V as the minimum limit. Feeder SRL01.021.B004.U005's VD decreased from 3.25829385 V to 3.095379158 V as the maximum limit and 2.932464465 V as the minimum limit.

REFERENCES

Arismunandar. A, DR, M.A.Sc, Kuwahara. S, DR, *Teknik Tenaga Listrik*, PT Pradnya Paramita, Jakarta, 1993.

Deshpande,M V. *"Electrical Power System Design".* Tata McGraw-Hill Publishing Company Limited. New Delhi. 1982

Dwiyanto T. (2018). Analisis Pengaruh Ketidakseimbangan Beban Terhadap Arus Netral dan Losses Pada Transformator di PT. PLN (Persero) Area Sorong. Electro Lucea, Vol. 4

Gonen Turan, *Electric Power Distribution System Engineering*, McGraw-Hill, United States of America, 1986.

Kushadiyono.MT ,Drs, *Dasar Teknik Elektro*, STT Wiworotomo, Purwokerto, 2003

Kafrawi M. T., Ahmad A. S., Adhi S., "Perancangan Penerapan Optimaslisasi Algoritma Pada Sistem Interkoneksi Jaringan Distribusi Enegi Listrik," Thesis. Teknik Mesin Universitas Gadjah Mada, 2018.

Hamles L. L. (2018). Analisa Umur Pakai Transformator Distribusi 20 KV di PT. PLN Cabang Ambon. Jurnal Simetrik, Vol. 8, No. 2.

Mucharam L. N., "Pengaruh Ketidakseimbangan Beban Terhadap Arus Netral Dan Losses Pada Transformator Distribusi 200 kVA." Undergraduate Thesis. Universitas Islam Sultan Agung, 2019.

Kadir, A, "Distribusi dan Utilitas Tenaga Listrik," UI-Press, Jakarta, 2006.

RC. Dugan, *Electrical Power System Quality*, McGraw-Hill, New York, 1996.

Saadat, Hadi. *"Power System Analysis".* WCB McGraw-Hill. Singapore. 1999

Stevenson. William D. Jr, *Analisis Sistem Tenaga*, Edisi ke empat, Alih Bahasa oleh ir. Kamal idris, Penerbit erlangga, jakarta, 1993.

Stieven N. R. (2019). Perancangan Distribusi Tenaga Listrik Terpusat Perpektif: Industri Kelapa Sawit. SETRUM, Vol. 8, No.1, Hal. 18 – 27.

Sulasno, Ir., *Teknik dan Sistem Distribusi Tenaga Listrik*, Badan Penerbit UNDIP, Semarang, 2001.

Saputro, Ahmad E Y, Agus S., "Analisis Pengaruh Ketidakseimbangan Beban Terhadap Efisiensi Transformator Distribusi di PT.PLN (PERSERO)

Rayon Palur Karanganyar," Skripsi. Universitas Muhammadiyah Surakarta, 2018.

Warman, "Pemilihan dan Peningkatan Penggunaan/Pemakaian Serta Manajement Trafo Distribusi," Digitized by USU digital library, Sumatera Utara, 2004

Zuhal, *Dasar Tenaga Listrik Dan Elektronika Daya*, PT Gramedia Pustaka Utama, Jakarta, 1992.

Zainal S., Tri R. (2019). Analisis Ketidakseimbangan Beban Transformator Distribusi 20 kV dan Solusinya Pada Jaringan Tegangan Rendah. Jurnal Teknik Elektro, Vol. 8, No.1.