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Optimization of the use of 1 phase distribution transformer in the Kaliwungu 03 feeder at PT PLN (Persero) Kendal

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Abstract

The distribution transformer has two secondary windings as output namely X1 and X2. Wherever it is used in the field, the load between X1 and X2 is very difficult to balance. So it also affects the amount of neutral current flowing in the transformer. The very large neutral current of the transformer affects the loading on the transformer. So that makes the transformer overload. This can shorten the life of the transformer.

Therefore, it is necessary to balance the transformer load. Where the loads X1 and X2 must be balanced. Thus reducing the amount of neutral current that comes out. Balancing is done by shifting the load so that X1 and X2 are the same load. After balancing, the neutral current that flows is small. If the neutral current that flows is reduced, it can add to the value of the efficiency of the transformer. In accordance with the calculations in this study, the transformer can achieve efficiency of 91.49% -99.8% when the average imbalance is 0% to 9.04%, efficiency is 81.29% - 89.10% when the average imbalance is 11, 17% to 23.22%, efficiency 70.01% - 76.61% when the average imbalance is 30.23% - 41.97%. Then the lower the unbalance average, the higher the efficiency of the transformer.

Keywords: Distribution Transformer, Neutral Current, transformer efficiency

Introduction

Electrical energy plays a very important role in supporting all community activities, so that the distribution of electrical energy is needed to supply existing loads. Transformers are needed in distributing electrical energy that can transform voltage from one level to another. Over time, many people complain about the increase in the price of electricity bill payments, even though the thing that causes the electricity bill price to increase is caused by several losses from loads that affect the efficiency of the transformer. The impact on the transformer becomes easily heated and results in a large voltage drop so that the power supply from PLN becomes large, which makes the power providers lose both.

It can be seen from the various losses experienced by PT PLN, including losses caused by losses that occur in the transformer, for example: Loss due to large neutral currents, losses caused by rubbing against particles of particles on the core of the transformer due to flux changes. magnetism or what is called hysteresis, there is also a result of induction in the transformer core or eddy current, as well as copper losses. And as an alternative to these problems, PT PLN supplies more power which results in losses for PLN.

Transformers provide a simple way to convert voltages from one value to another. If a transformer receives energy at a lower voltage and converts it to a higher voltage, it is called a step up transformer. If a transformer is energized at a certain voltage and converts it to a lower voltage, it is called a step down transformer. Each transformer can be operated as either a step-up or step-down transformer, but transformers designed for a given voltage must be used for that voltage. The objectives to be achieved in this study are to obtain a transformer efficiency value based on the incoming power with the output power and to obtain a comparison of the efficiency of one transformer with another with a measure of the average value of the imbalance.

2. Research Methods

2.1 Transformer Working Principles

The transformer consists of two coils (primary and secondary) which are inductive. These two coils are separated electrically but are connected magnetically through a path that has a low reluctance. The following is a picture of a two-winding transformer with no load in Figure 1.

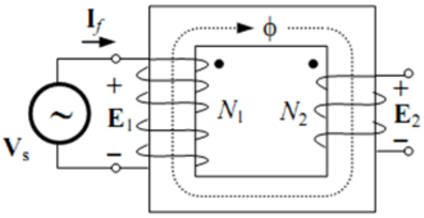

Fig 1: A two-winding loadless transformer

If the flux in the magnetic circuit is, ϕ = ϕ_maks sin ωt then This flux will induce a voltage in the primary winding of: [10]

$$e_1 = N_1 \frac{d\phi}{dt} = N_1 \phi maks\ \omega \cos \omega t \qquad (2.1)$$

Or in the form of a phasor

$$E_1 = E_1 \angle 0^0 = \frac{N_1 \omega \phi_{maks}}{\sqrt{2}} \angle 0^0 \ ; \ E_1 = Effective\ value \qquad (2.2)$$

Because $\omega = 2\pi f$ then

$$E_1 = \frac{2\pi f\ N_1}{\sqrt{2}} \phi_{maks} = 4.44\ f\ N_1 \phi_{maks} \qquad (2.3)$$

In the secondary winding, this flux induces a voltage of

$$E_2 = 4.44\ f\ N_2 \phi_{maks} \qquad (2.4)$$

If the Transformer is Ideal then:

$$P_{in} = P_{out} \qquad (2.5)$$

$$V_1 I_1 = V_2 I_2 \qquad (2.6)$$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} \qquad (2.7)$$

From the equation (2.3), (2.4), and (2.7) then obtained:

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} \equiv a = rasio\ transformasi \qquad (2.8)$$

2.2. Distribution Transformer

Distribution transformer is a very important component in distributing electricity from distribution substations to consumers. Damage to the distribution transformer causes continuity of service to consumers to be disrupted (there is a power outage or blackout). A blackout is a loss that causes generation costs to increase depending on the unsold KWH price. Selection of a distribution transformer rating that is not in accordance with the load requirements will cause the efficiency to be small, as well as the placement of an unsuitable distribution transformer location affects the end voltage drop on the consumer or the drop / drop in the end voltage of the line / consumer.

The right distribution, rating according to load requirements will keep the voltage drop on the consumer and will increase the efficiency of using the distribution transformer. So the distribution transformer is one of the equipment that needs to be maintained and used as well as possible (as efficiently as possible), so that the reliability / continuity of service is guaranteed. The following is a general distribution transformer construction in Figure 2.

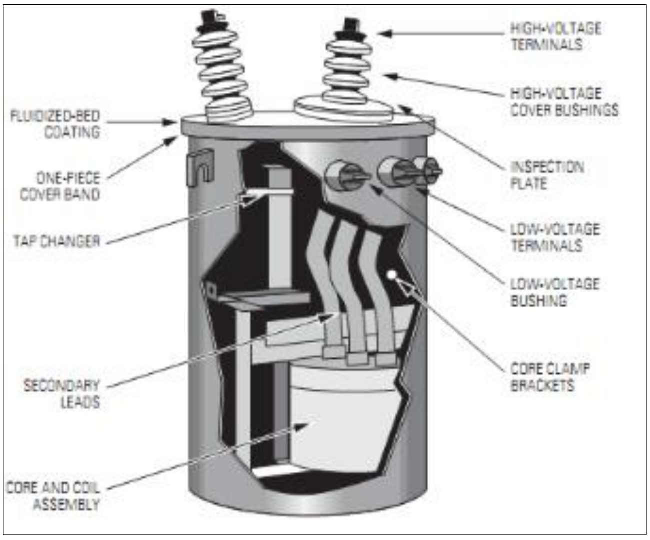

Fig 2: Distribution Transformer Construction

Basically, a transformer consists of a core of primary and secondary coils, iron, insulation, and a container or tank. The addition of other equipment such as Tap Changer, Circuit Breaker, Fuse, and Lightning Arrester. The greater the power of the transformer, the more equipment that will be added such as the oil conservator tank, coolant pipe, oil-filled bushing and heat indicator equipment. The distribution transformer has a secondary winding with two bushings, three bushings, up to four bushings. The following is a picture showing the transformer secondary wiring in Figure 3.

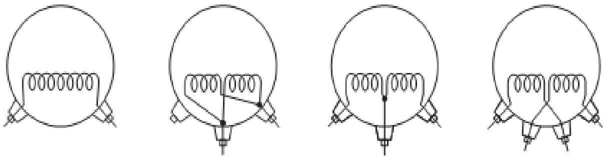

Fig 3: Transformer Secondary Windings Based on the Number of Bushing

Currently, the transformer used in Central Java-DIY uses four bushings, each of which is named X1, X3, X4, X2 respectively. Where X1 and X2 will be used as phase output. While X3 and X4 are coupled and used as a neutral transformer.

2.3 Distribution Transformer Performance

Distribution transformer performance is a condition of the transformer's ability to carry out work processes. This can be seen by knowing the ratio of the input and output power of the transformer. The amount of incoming power can be determined from the rated current. Then the current is multiplied by the nominal voltage on the medium voltage network. The calculation can be written as follows:

$$kVA\ in = P_p = I_p\ X\ V_p\ (VA) \qquad (2.9)$$

While the total output power of the transformer in a single-phase distribution transformer, the output is divided into two phases, so each measured current in phase one and phase two is multiplied by the nominal voltage on the low voltage network. the calculation can be written as follows: [1,2]

$$kVA\ out = P_s = I_s\ X\ V_s\ (VA) \qquad (2.10)$$

2.4 Transformer Efficiency

The performance parameters of a transformer are determined from its efficiency which is stated in the formula below:

$$\eta = \frac{P_k}{P_m}\ 100\% \qquad (2.11)$$

2.5 Measurement Implementation

Obtaining the measurement data of the one-phase distribution transfomator at PT PLN (Persero) Rayon Kendal on the Kaliwungu 03 feeder.The transformer measurement data includes currents on the medium-voltage side of 11.547 kV and currents on the low-voltage network side of 220 Volt, namely at X1, X2, and neutral. Then the following is a Single Line Digram Transformer on the Kaliwungu 03 feeder in Figure 4.

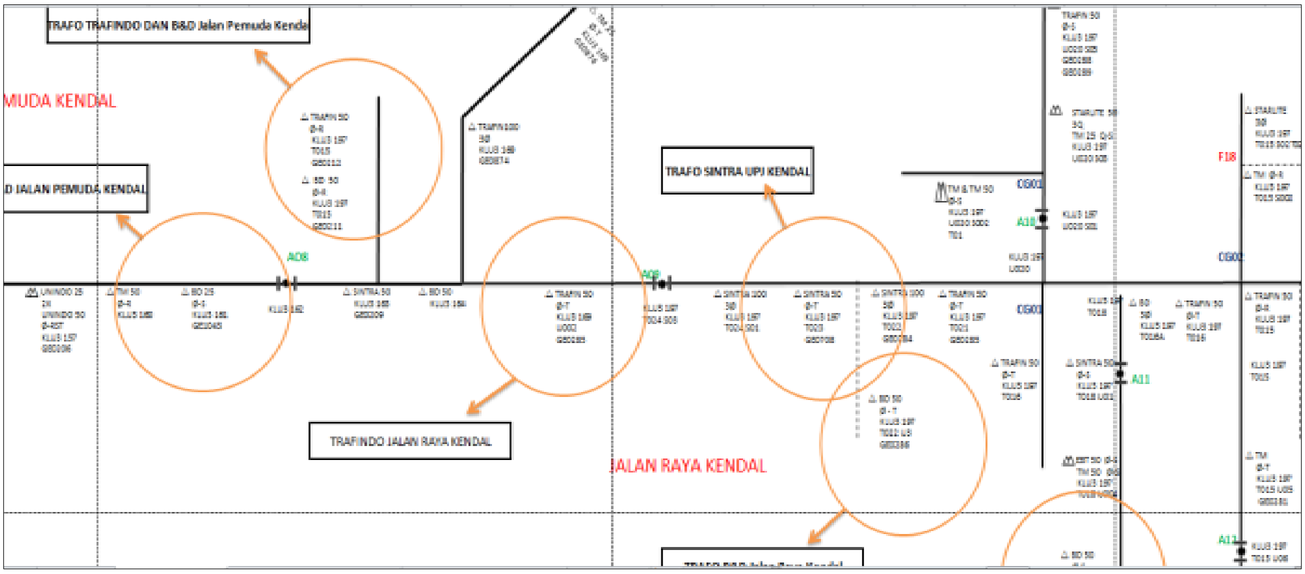

Fig 4: Single Line Diagram of KLU Feeder Transformer 03

So PT PLN (Persero) Rayon Kendal took measurements in stages where only 14 transformers were measured in the Kaliwungu 03 feeder. The measurement was done using an ampstick with a hotstick stick so that it could reach the transformer on the pole. So that the data in Table 1 is obtained for measurements in 2018 and Table 2 for measurements in 2019.

Table 1: Transformer Measurement 2018

Transformer Measurement 2018					
No	**Ip**	**X1**	**X2**	**X0**	**Vs**
1	4.05	40	107	61.7	224
2	4.72	126	107	12.4	222
3	0.44	0	13.1	4.9	218
4	2.25	65	30.5	19.7	226
5	1.99	35.4	54.4	11.2	228
6	2.16	46.7	50.4	13.6	225
7	1.04	26	19.7	7.5	226
8	1.73	44.6	41.1	2.2	227
9	1.09	34.8	19.2	3	221
10	3.04	53.5	98.4	6.4	222
11	2.07	47.6	58	0	226
12	3.87	57.5	111	31.1	224
13	0.98	0	38.7	11.7	224
14	4.16	33.1	117	60.7	228

Tabel 2: Table 1 Transformer Measurement 2019

Transformer Measurement 2019					
No	Ip	X1	X2	X0	Vs
1	2.95	66.3	74.3	11.6	224
2	1.45	38.8	36.4	0	222
3	0.85	11.7	24.9	8.5	218
4	1.14	24.45	27.1	6.9	226
5	2.1	42.6	54.7	8.8	228
6	2.76	52.8	67.2	13.4	225
7	1.41	22.4	30.2	19.3	226
8	2.51	59.3	63	5.3	227
9	1.68	50.6	21.9	15.4	221
10	1.13	10.4	37.9	10.6	222
11	3.35	74	85.6	11.7	226
12	4.34	139	54.7	29.8	224
13	0.41	5.6	15.5	0	224
14	3.91	17.6	103	77.3	228

To find out the efficiency of a single-phase distribution transformer in 2018 and 2019, then enter equation 2.11 in Tables 1 and. 2. then you will get the results shown in Table 3 and Table 4 below:

Table 3: Transformer Efficiency 2018

Single Phase Distribution Transformer Efficiency 2018					
No	Power	MERK	Pp (VA)	Ps (VA)	Efisiensi
1	50	B&D	46765.35	32928	70.41%
2	50	Trafindo	54501.84	51726	94.91%
3	25	B&D	5080.68	2855.8	56.21%
4	50	B&D	25980.75	21583	83.07%
5	50	Trafindo	22978.53	20474.4	89.10%
6	50	B&D	24941.52	21847.5	87.59%
7	50	B&D	12008.88	10328.2	86.00%
8	50	B&D	19976.31	19453.9	97.38%
9	50	Trafindo	12586.23	11934	94.82%
10	50	B&D	35102.88	33721.8	96.07%
11	50	Trafindo	23902.29	23865.6	99.85%
12	50	Trafindo	44686.89	37744	84.46%
13	50	B&D	11316.06	8668.8	76.61%
14	50	Sintra	48035.52	34222.8	71.24%

Table 4: Transformer Efficiency 2019

Single Phase Distribution Transformer Efficiency 2019					
No	Power	MERK	Pp (VA)	Ps (VA)	Efisiensi
1	50	B&D	34063.7	31494.4	92.46%
2	50	Trafindo	16743.2	16694.4	99.71%
3	25	B&D	9814.95	7978.8	81.29%
4	50	B&D	13163.6	11650.3	88.50%
5	50	Trafindo	24248.7	22184.4	91.49%
6	50	B&D	31869.7	27000	84.72%
7	50	B&D	16281.3	11887.6	73.01%
8	50	B&D	28983	27762.1	95.79%
9	50	Trafindo	19399	16022.5	82.59%
10	50	B&D	13048.1	10722.6	82.18%
11	50	Trafindo	38682.5	36069.6	93.25%
12	50	Trafindo	50114	43388.8	86.58%
13	50	B&D	4734.27	4726.4	99.83%
14	50	Sintra	45148.8	27496.8	60.90%

3. Results and Analysis

After processing the data, the first thing to do is determine the average load imbalance by entering equation 2.12 into table 5:

$$Imbalance = \frac{X_0}{X_1+X_2}.100\% \qquad (2.12)$$

Where :

X0 = Neutral Current (A)

X1 = Current at X1 (A)

X2 = Current at X2 (A)

Table 5: Imbalance Average 2018

Imbalance				
No	X1	X2	X0	IMBALANCE
1	40	107	61.7	41.97%
2	126	107	12.4	5.32%
3	0	13.1	4.9	37.40%
4	65	30.5	19.7	20.63%
5	35.4	54.4	11.2	12.47%
6	46.7	50.4	13.6	14.01%
7	26	19.7	7.5	16.41%
8	44.6	41.1	2.2	2.57%
9	34.8	19.2	3	5.56%
10	53.5	98.4	6.4	4.21%
11	47.6	58	0	0.00%
12	57.5	111	31.1	18.46%
13	0	38.7	11.7	30.23%
14	33.1	117	60.7	40.44%

Table 6: Imbalance Average 2019

Imbalance				
No	X1	X2	X0	Imbalance
1	66.3	74.3	11.6	8.25%
2	38.8	36.4	0	0.00%
3	11.7	24.9	8.5	23.22%
4	24.45	27.1	6.9	13.39%
5	42.6	54.7	8.8	9.04%
6	52.8	67.2	13.4	11.17%
7	22.4	30.2	19.3	36.69%
8	59.3	63	5.3	4.33%
9	50.6	21.9	15.4	21.24%
10	10.4	37.9	10.6	21.95%
11	74	85.6	11.7	7.33%
12	139	54.7	29.8	15.38%
13	5.6	15.5	0	0.00%
14	17.6	103	77.3	64.10%

In Table 3 and Table 4, a number of efficiency values are obtained from each transformer in the Kaliwungu 03 feeder.The value of the efficiency is influenced by the magnitude of the load imbalance value which will be shown in Figure 5 and Figure 6.

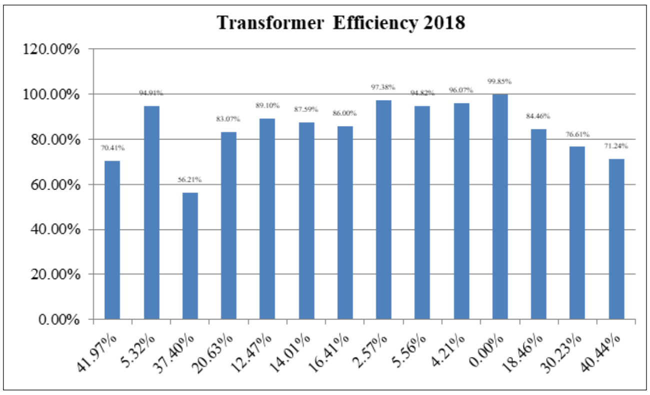

Fig 5: Transformer Efficiency Graph in 2018

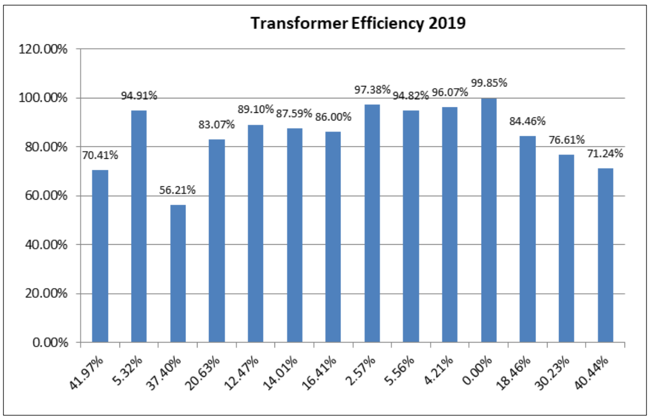

Fig 6: Transformer Efficiency Graph in 2019

So it can be concluded that the transformer will achieve efficiency of 91.49% - 99.55% when the average imbalance is 0% to 9.04%. Efficiency 81.29% - 89.10% when the average imbalance is 11.17% to 23.22%. Efficiency 70.01% - 76.61% when the average imbalance is 30.23% to 41.97%.

Based on the results of the efficiency calculations above, the transformer is an electrical equipment that has a high efficiency, reaching 99% when the load is in balance. that means the losses in the transformer are very small, so it can be concluded that the transformer is in very good condition and has high performance because the efficiency is close to and almost 100% when the load is balanced.

4. Conclusion

From the discussions and calculations that have been carried out in the previous chapters, the following conclusions can be drawn:

By using transformer measurement data in 2018 and transformer measurement data in 2019, transformer efficiency can be determined. The greater the difference in load between X1 and X2, the greater the current flowing in X0 or neutral. The transformer will achieve efficiency of 91.49% - 99.55% when the average imbalance is 0% to 9.04%. Efficiency 81.29% - 89.10% when the average imbalance is 11.17% to 23.22%. Efficiency 70.01% - 76.61% when the average imbalance is 30.23% to 41.97%.

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