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PERFORMANCE STUDY OF UNBALANCED LOAD ON OPEN DELTA TRANSFORMERS

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Abstract: A transformer is a device that can transfer (transmit) and change electrical energy from one electrical circuit to another with the same frequency based on the principle of electromagnetic induction.
The transformer that will be used in this research is a three-phase open delta connection transformer, which is connected to a delta connected load. If one of the three phase windings in the delta connection transformer is damaged, then the remaining two windings can be implemented or designed into three phase open delta connections, which can be used to distribute three phase electrical power to the load.
The performance of the unbalanced load influence on the open delta transformer, when it is loaded with an unbalanced load that is not the same size on each phase, causes an increase in current on each phase, resulting in an increase in the input power absorbed by the unbalanced load resulting in power loss. larger (losses) with reduced efficiency.
The aim of the research is to study the performance of unbalanced loads on open delta transformers and the research method is an experimental method in the laboratory, which includes testing on three-phase open delta transformers in unbalanced load conditions.
The measurement results show that there are differences in performance (output results) in the influence of unbalanced loads between the average current and losses and the efficiency of the open delta transformer.
Keywords: Open Delta Transformer, Unbalanced Load.

INTRODUCTION

A transformer is a device that can transfer (transmit) and change the amount of electrical power from one electrical circuit to another with the same frequency based on the principle of electromagnetic induction. Panjaitan, R. (1989), explains that the voltage received can be increased or decreased according to the size of the current in the circuit. The electrical power that is transferred and changed is voltage and alternating current (AC).

The types of transformers vary greatly, but in general, they can be classified into three types, namely Power Transformers, Distribution Transformers, and Measurement Transformers. In general, the type of transformer used as a Power Transformer and Distribution Transformer is a three-phase transformer, as a distributor of electrical power from the generator to the load. A three-phase transformer has two main winding connections, namely a delta connection and a star connection. The delta-delta connection (Δ-Δ) is the most effective connection used for low voltages with large load currents. This winding connection is also the most widely used winding connection when compared to various other types of winding connections.

Abdul Kadir, (1993), explains that if only two single-phase transformers are available, it is still possible to create a three-phase system using two single-phase transformers or the remaining two windings can be used to distribute electrical power using open-winding connections. delta.

Removing one of the windings can also be done on a three-phase delta-delta connection transformer, if the load being served is too small for the present, but it needs to be anticipated if load growth occurs in the future, namely by reinstalling the opened winding.

These three-phase open delta (V) connection transformers are usually available with lower power capacities compared to Delta (□) connection transformers. The use of an open delta transformer is to overcome the loss of electrical power due to one of the windings of the Delta connection transformer being damaged. So this open delta connection transformer is really needed temporarily to transfer electrical power.

The power capacity capability of a delta transformer can serve 100% of the load system, while an open delta transformer has a lower power capacity than a delta transformer. The two windings of an open delta connection transformer should be able to serve 66.6% of the capacity of a delta connection transformer, but these two windings are only can serve 57.7% of the delta transformer capacity. So the open delta transformer can only serve a system load of around 57.7/ 66.6 = 0.866 or 86.6% of the two transformer windings when under load.

The advantages and disadvantages of a three-phase open delta connection transformer can be described as follows: the advantages of this open delta connection are that it overcomes long outages, can send three-phase power to a specially made load and can be used temporarily before a new transformer is replaced, while the disadvantages are is the average power capacity of an open delta (V–V) transformer operating approximately 66.6% of the delta transformer power capacity or required power.

In general, the load served by a transformer is tried to be balanced. But in reality, the load served by a transformer is often unbalanced. Load imbalance causes the current in each phase to be unbalanced so that the resultant load current is not equal to zero. As a result, for the same output power, a transformer with an unbalanced load will have greater losses and will absorb more power so that its efficiency will be smaller. Unbalanced currents in each phase can occur because the impedance of the per-phase load is unbalanced. If the open delta transformer is unbalanced, the phase currents will be unbalanced, resulting in an unbalanced secondary voltage on the transformer, which can reduce the input power (Pin) distributed to the load. So before operating it needs to be tested. The test is intended to discuss the performance of unbalanced loads on open delta transformers.

RESEARCH METHOD

The methodology used in this research is the testing/measurement and analysis method, namely carrying out tests in the laboratory to obtain test data.

The research methodology steps that will be carried out in this thesis proposal are shown in the flow chart in Figure 1

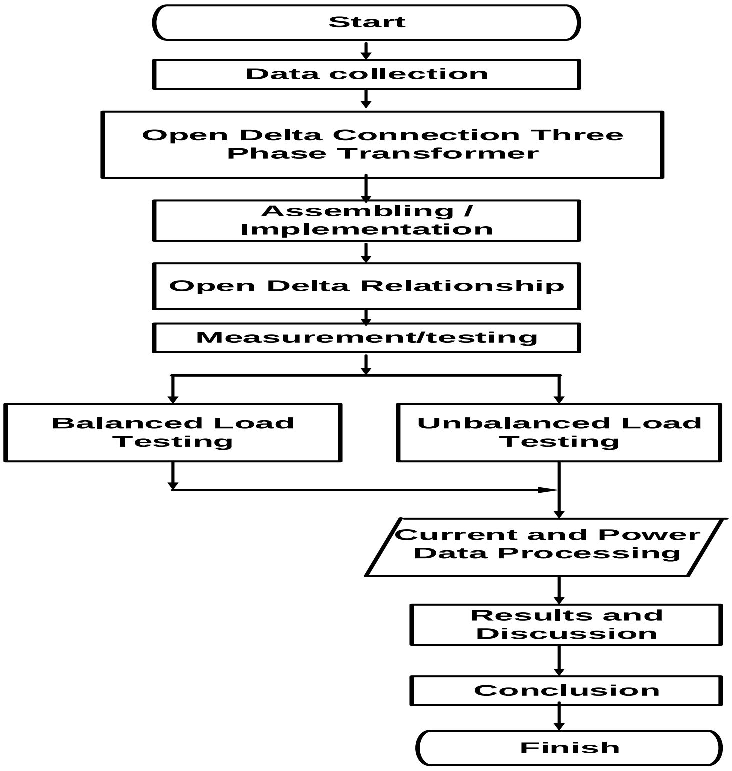

Figure 1 Research Methodology Flow Diagram

The Name Plate data printed on the three-phase transformer body is as follows:

Transformer Capacity	: 2100 VA
Frequency	: 50 Hz
Primary side voltage	: 50-64 Volts
Primary side current	: 22 Amperes
Secondary side voltage	: 110 – 220 Volts
Secondary side current	: 10 Amperes

The transformer is made into a three-phase open delta and delta connection transformer with a step up setting, so that for the Open Delta transformer connection we get:

Transformer Capacity	: 2100 x 0.577 = 1212 VA, 50 Hz
Primary / secondary side voltage	: 64 / 220 Volts

Primary side current $$Ip = \frac{1212}{\sqrt{3}\ x\ 55} = \frac{1212}{95{,}26} = 12{,}7\ A$$

And

Secondary side current $$Is = \frac{1212}{\sqrt{3}\ x\ 220} = \frac{1212}{380} = 3{,}2\ A$$

3 phase power capacity in open delta transformer;

0.577 . 2100 = 1212 VA

3 phase current capacity (line current) in open delta transformer:

$$I_{3Fasa} = \frac{VA}{\sqrt{3}.\,55}$$

$$= \frac{1212}{1{,}73.\,55}$$

$$= \frac{1212}{95{,}15}$$

= 12,7 A

Perphase current capacity in open delta transformer;

$$I_{Fasa} = \frac{I_L}{\sqrt{3}} = \frac{12{,}7 \quad A}{1{,}73} = 7 \quad A$$

The circuit of an open delta transformer with a 3-phase system, which is connected to a 3-phase unbalanced load, is connected by a delta, to explain the arrangement of a balanced 2-phase load while the other phases are not loaded, as shown in Figure 4.1 as follows:

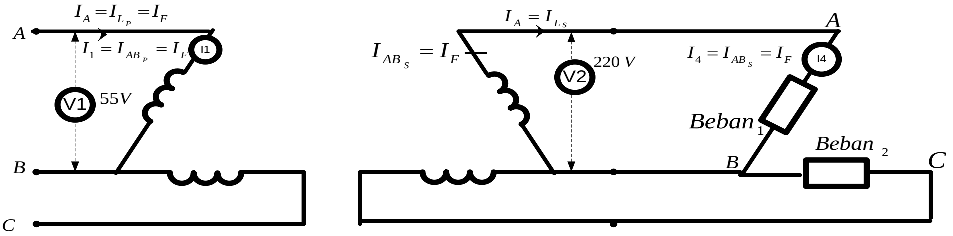

Figure 2. phase open delta transformer circuit with load, 2 phases are balanced while the other phase is not loaded.

Explanation regarding 2 phases in balance while the other phases are not loaded (3 phase load current is in an unbalanced state) meaning that 2 phases (phase current AB=3 A and phase current BC=3 A) are regulated/given a balanced load, while the other phase (current phase CA=0A) is not given/removed (emptied) the load from the capacity of the 3 phase system.

So the average unbalanced load phase current on 2 balanced phases while the other phase is not loaded = 3, 3, 0, with I = 2 A is the phase current in a balanced load condition, in an open delta transformer, namely;

IAB = a x I, then a = 1.5 A
IBC = b x I, then b = 1.5 A
ICA = c x I, then c = 0 A

So the average current is:

$$= \frac{\{|a-1| + |b-1| + |c-1|\}}{3} x100\%$$

$$\frac{\{|1{,}5-1\ | + |\ \ 1{,}5-1| + |0-1\ |\}}{3}\, x\, 100\,\% = \frac{2}{3} = 0{,}6666\, x\, 100 = 66{,}66\,\%$$

Unbalanced Load Measurement Data, For Each Phase Loaded Differently, On An Open Delta Connection Transformer.

With the setting V1 = 55 Volts, as attached in Table 1 below.

Table 1 Measurement data for each phase under different loads, on an open delta connection transformer, the following is obtained:

No	Arus Primer (Amp)			Daya Input (Watt)			Vout (Volt)	Arus Sekunder (Amp)			Daya Keluaran (Watt)		
	I_1	I_2	I_3	P_1	P_2	P_3	V_2	I_4	I_5	I_6	P_4	P_5	P_6
1	9,6	9,8	10,3	348	355	373	190	0,5	2,5	3	81	409	491

2	9,8	9,6	10,3	354	348	373	189,5	2,5	0,5	3	409	81	491
3	10,3	9,8	9,6	373	355	348	189	3	2,5	0,5	491	409	81
4	9,8	10,3	9,6	355	373	348	189,5	2,5	3	0,5	409	491	81
5	10,3	9,8	9,6	372	355	348	189	3	2,5	0,5	491	409	81
6	9,6	10,3	9,8	373	348	356	188,5	0,5	3	2,5	81	491	409
7	8,7	9,6	9,5	335	369	365	190	1	2	3	163	327	491
8	9,6	8,7	9,5	367	333	364	190,5	2	1	3	327	163	491
9	9,5	9,6	8,7	364	368	333	189,5	3	2	1	491	327	163
10	9,5	8,7	9,6	365	333	368	190	1	3	2	163	491	327
11	8,7	9,5	9,6	333	365	368	189,5	3	1	2	491	163	327
12	9,6	8,7	9,5	368	333	365	189	2	3	1	327	491	163
13	9,6	10,4	9,5	347	376	343	188	2	1,5	2,5	327	245	409
14	10,4	9,6	9,5	376	347	343	189,5	1,5	2	2,5	245	327	409
15	9,5	10,4	9,6	343	376	347	190	2,5	1,5	2	409	245	327
16	10,4	9,5	9,6	374	342	346	189,5	1,5	2,5	2	245	409	327
17	9,5	10,4	9,6	343	374	346	189	2,5	1,5	2	409	245	327
18	9,6	9,5	10,4	346	343	374	188	2	2,5	1,5	327	409	245

Analysis of unbalanced load measurement data, for each phase loaded differently, on an open delta connection transformer.

Example for No. 1:
P total input: P in = P1 + P2 + P3 = 348 + 355 + 373 = 1076 watts
P total output: P out = P4 + P5 + P6 = 81 + 409 + 491 = 981 watts
Transformer losses: Losses = P in – P out = 1076 - 981 = 95 watts

Transformer efficiency: $\eta = \frac{Pout}{P\ in} x\, 100\,\% = \frac{981}{1076} x\, 100 = 91{,}17\,\%$

Meanwhile, the average load current is:

A. For unbalanced load phase currents = (0.5 , 2.5 , 3)
With I = 2 amperes is the phase current in a balanced load condition.
IAB = a x I, then a = 0.25 A
IBC = b x I, then a = 1.25 A
ICA = c x I, then a = 1.5 A

So the average current is:

$$= \frac{\{|0{,}25-1| + |1{,}25-1| + |1{,}5-1|\}}{3} \text{ x } 100\% = \frac{1{,}5}{3} = 0{,}5\, x\, 100 = 50\%$$

B. For unbalanced load phase currents = (1 , 2 , 3)

With I = 2 amperes is the phase current in a balanced load condition.
IAB = a x I, then a = 0.5 A
IBC = b x I, then a = 1 A
ICA = c x I, then a = 1.5 A

So the average current is:

$$= \frac{\{|0{,}5-1| + |1-1| + |1{,}5-1|\}}{3} \text{ x } 100\% = \frac{1}{3} = 0{,}3333\, x\, 100 = 33{,}33\%$$

C. For unbalanced load phase currents = (2, 1.5 , 2.5)

With I = 2 amperes is the phase current in a balanced load condition.

IAB = a x I, then a = 1 A

IBC = b x I, then a = 0.75 A

ICA = c x I, then a = 1.25, A

So the average current is

$$= \frac{\{|1-1| + |0{,}75-1| + |1{,}25-1|\}}{3} \text{ x } 100\% = \frac{0{,}5}{3} = 0{,}16666\, x\, 100 = 16{,}67\%$$

In the same way, and further can be determined, to obtain a data analysis table, as shown in table 4.2 below.

Table 2 Results of analysis of measurement data for each phase under different loads, in open delta connection transformers, as follows:

No	Daya Input (watt)	Daya output (watt)	Loses (watt)	Efisiensi (%)
1	1076	981	95	91,17
2	1075	981	94	91,25
3	1076	981	95	91,17
4	1076	981	95	91,17
5	1075	981	94	91,25
6	1077	981	96	91,51
7	1069	981	88	91,76
8	1064	981	83	92,19
9	1065	981	84	92,11
10	1066	981	85	92,02
11	1066	981	85	92,02
12	1066	981	85	92,02
13	1066	981	85	92,02
14	1066	981	85	92,02
15	1066	981	85	92,02
16	1062	981	81	92,37
17	1063	981	82	92,28
18	1063	981	82	92,28

If the data above is arranged based on the average load current per phase, a data analysis table is obtained, as shown in table 4.3 below:

Table 3 Results of data analysis of average current, losses and efficiency in open delta connection transformers, as follows:

Current average (%)	Loses (watt)	Efisiensi (%)
66,66	103	90,49
50	94,83	91,25
33,33	85,33	92,02
0	64	93,87

From the table of results of analysis of unbalanced load measurement data, the performance (characteristics) of linear regression of the relationship between average current and losses, in a three-phase transformer with open delta connection, is obtained, as shown in Figure 4.1, as follows:

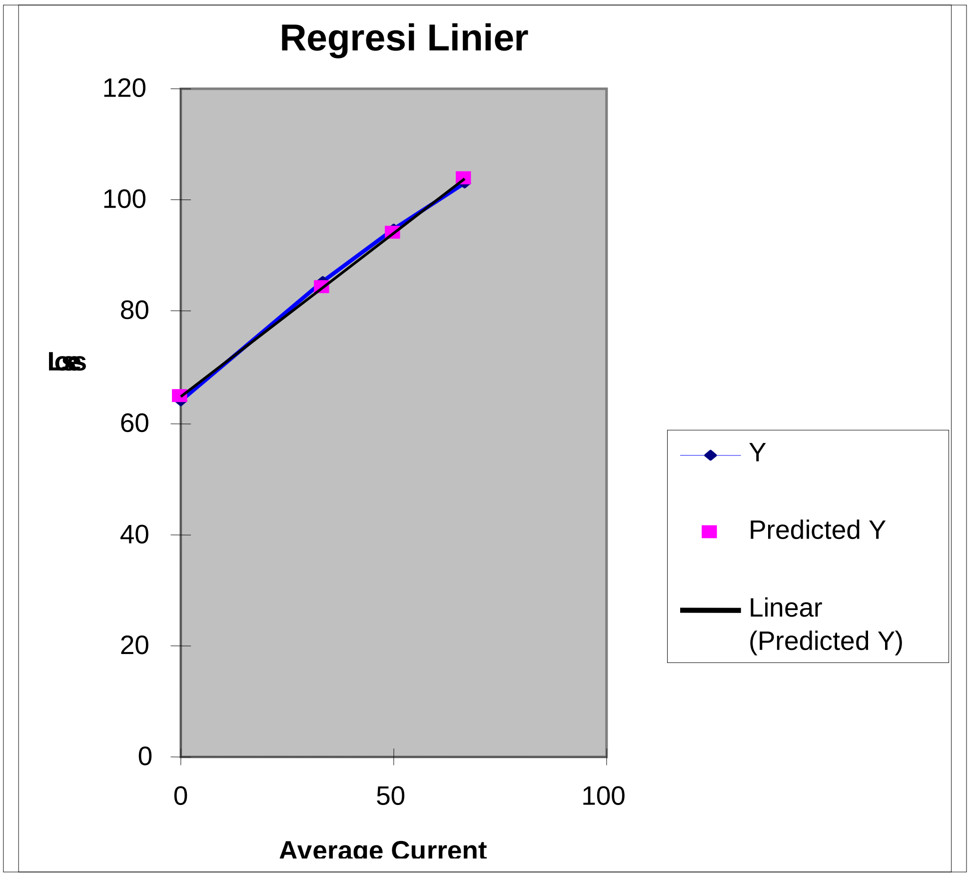

Figure 3 Linear regression characteristics of the relationship between average current and losses

In addition, from the table of results of analysis of unbalanced load measurement data, the linear regression performance (characteristics) of the relationship between average current and efficiency is obtained in a three-phase open delta connection transformer, as shown in Figure 4., as follows:

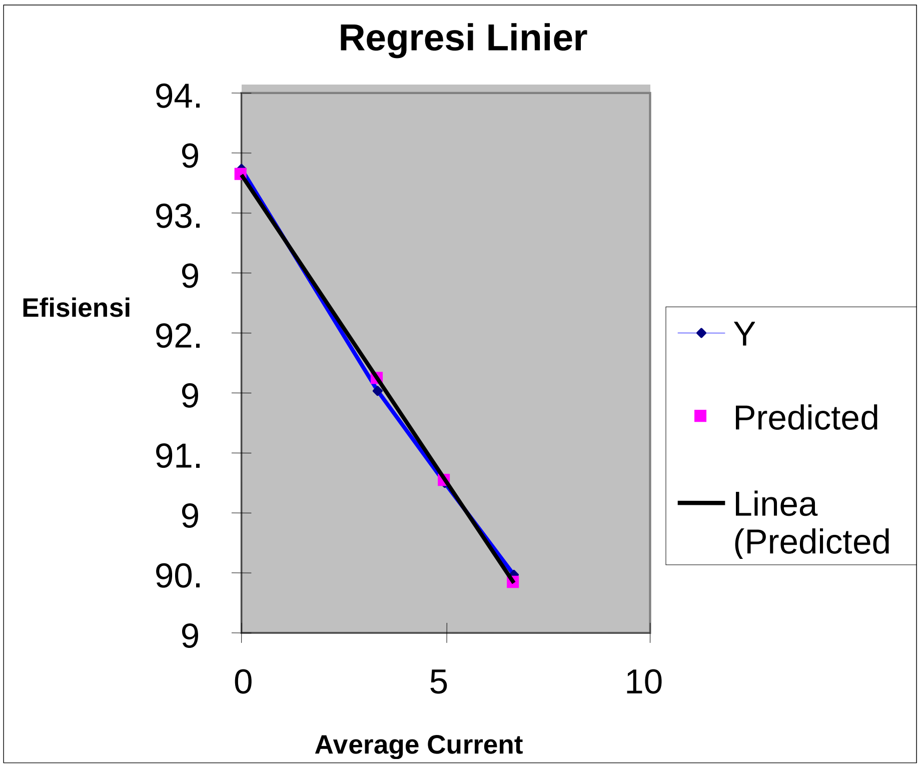

Figure 4. Linear regression characteristics of the relationship between average current and efficiency

CONCLUSION

Based on the discussion that has been carried out, the following conclusions are obtained:

1. Performance studies (output results) based on analysis of data obtained from open delta transformer experiments show that the average per-phase load current on open delta transformers is 66.6%, with the power capacity for open delta transformers being 0.577 of the active power capacity. used.
2. The performance of a balanced load is not the same as the performance of an unbalanced load on an open delta transformer, when it is loaded with a balanced load and an unbalanced load of the same size, this is due to the increase in current in each phase of the unbalanced load, resulting in increase in input power absorbed by unbalanced loads.

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