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An assessment of distribution transformers performance within Kaduna metropolis, Nigeria

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Abstract

In this paper, is an assessment to ascertain the performance of distribution transformers. The simple Transformer Performance Model (TPM) was adopted to determine essential parameters required for calculations with the resultant percentage deviations. Three (3) samples of transformers within Kakuri area in Kaduna State, Nigeria were used as case study. Results from the study indicated that the Insulation resistance for T1 was more than 200MΩ while those of T2 and T3 fell within a very low range of 60MΩ to 82MΩ. Also, the percentage deviation of T1 was 8.92% with respect to the voltage transformation. This showed that T1 had a relatively good voltage transformation ratio as well as insulation resistance. Though values obtained from its short circuit test deviated by an average of 14.91% (higher than the standard limit of $\pm 10\%$), $T1$ was still found to be in good (but not perfect) working condition compared to the T2 and T3 which needed immediate overhauling. The calculated efficiencies for all the three transformers were found to be 60% respectively. The condition of these transformers has therefore, made it necessary for performance assessment to be replicated on all other distribution transformers within the Kaduna electricity distribution network and beyond to achieve an optimal system.

Keywords

Distribution transformer; performance test; TPM; voltage transformation; insulation resistance.

1.0 Introduction

The Nigerian distribution network comprises of eleven distribution companies and each has their robust network of distribution transformers. The distribution transformers have been found to be the most common and important component in the distribution network. These, therefore, require proper care in order for them to yield optimum performance and last longer

(Stanley & Ulasi, 2018). Unfortunately, the erratic power supply to end users in Nigeria over the years has received its main contribution from losses at the distribution level within the Electricity Supply Industry (ESI). The amount of power outages within a given period of time, in a given locality, has been attributed especially to partial or complete collapse of distribution transformers. Some of the factors peculiar to the poor state of distribution transformer in Nigeria are not farfetched. Most emanate from the negligence on the part of the technical personnel responsible for these devices (Bala, 2014). Some faults could be avoided if there are consistent checks on the operating status of the transformers.

In addition, transformer overloads; under-sizing of cables at the low-tension side in design and implementation as well as poor maintenance culture contribute to distribution transformers failing. Other factors include lack of grid reinforcements, vandalism and economic bottleneck (a large percentage of the customers within the distribution network fails to settle their bills especially the unmetered category).

The study focus, Kaduna Electric, happens to be one of the newly created distribution companies in Nigeria following the liberalization of the power industry in Nigeria. It serves as a distribution company to Kaduna, Sokoto, Kebbi and Zamfara States. With respect to capacity for distribution, it is the seventh largest, and the sixth largest with respect to number of households. It has a customer size of about 490,000 (Kaduna Electric, 2019, para. 1&2). However, energy injustice has been observed over the years either from customers/consumers engaged in vandalization of power equipment, energy theft etc, or from the appropriate authorities through the use of Methodological Estimated Billing (MEB) within the service area and the Nation at large. In 2019, Nigerian Bulk Electricity Trading (NBET) Plc. put the performance ratio of Kaduna Electric in the January report at 8% while Eko and Ikeja distribution companies both had the highest performance ratio of 35% (Nigerian Bulk Electricity Trading Plc, 2020) as shown in **Table** 1.

This index indicated how poorly the system has performed. Consequently, from **Table 1**, it was observed that Kaduna Electric has the lowest performance ratio with respect to invoice value and payment from DISCOs. Hence, this necessitated the need to carry out performance studies with focus on distribution transformers as key element of the electricity distribution network. This paper, therefore, is aimed at carrying out an assessment on the performance of selected transformers within Kakuri area of

Kaduna State. The nature of tests carried out on the selected transformers, the method used, the importance of tests etc. are presented in subsequent sections of this work.

Table 1: Performance Ratio of DISCOs in Nigeria (Nigerian Bulk Electricity Trading Plc, 2020)

Discos	Invoice Value (₦)	Payment from Discos (₦)	Performance Ratio (%)
ABUJA	7 628 261 159	1 800 000 000	24.00
BENIN	5 388 683 280	1 213 635 975	23.00
EKO	6 684 318 354	2 339 511 739	35.00
ENUGU	4 882 669 472	700 000 000	14.00
IBADAN	7 030 961 074	2 038 978 712	29.00
IKEJA	7 173 840 827	2 510 844 290	35.00
JOS	2 647 691 875	250 000 000	9.00
KADUNA	4 812 203 917	400 000 000	8.00
KANO	3 327 199 678	450 000 000	14.00
PH	4 015 449 669	622 042 952	15.00
YOLA	2 191 486 308	262 978 357	12.00

2.0 Review of related Literature

As a result of fast technological advancement and power demand, research is being carried out in the field of transformer design and construction to optimize the performance of distribution transformers. In order to achieve efficient flux linkage, a low reluctance magnetic path (the core) common to the windings is provided. The material used in the core (such as amorphous steel, carbonyl iron base, ferrite ceramics, solid iron silicon steel etc.) play a vital role on the efficiency of the transformer because hysteresis losses, eddy current losses, temperature withstanding capability and permeability depend upon the core material (Kumar, Raj, Arun & Vishnu, 2018). Earlier, Herlow (2007) developed a simple model referred to as the Transformer Performance Model (TPM) used for the evaluation of the characteristic's performance of transformers. This consisted of certain parameters such as the transformer impedance, short-circuit current, voltage regulation, percentage all-day efficiency of the transformer among others, which are determined mathematical relationships. TPM is a simple and more straight forward approach and will therefore, be more convenient for technicians and experts in the field to carry out performance analysis of distribution transformers. Kalyan & Prasad (2013) presented Power Electronic Transformer (PET) to improve the performance of distribution transformers. The transformer is based on power electronics that perform certain features such as power factor correction, voltage flicker reduction, voltage regulation, swell elimination, and voltage sag. By using power electronics on both primary and secondary sides of the transformer, the PET has fundamentally different and more complete method in the transformer model. The designing process includes the use of AC/DC, DC/AC, AC/AC and transformer of high frequency. The configuration consists of three parts; the first, input stage, is an AC/DC converter performing the input current shaping function to correct the input power factor and to control the primary voltage of the DC bus. The second part is called the isolation stage. It makes provision for the galvanic isolation between the primary and the secondary sides. Also, the DC voltage is converted to a high-frequency square wave signal and interconnected to the high-frequency transformer. It further rectified for a DC connection voltage. Finally, the third part, which is the output stage, is a source voltage inverter that recovers the desired form of AC wave. The flexibility of the voltage or current of PET to be regulated by modulation of the pulse width on either side of the high-frequency transformer improves its performance (Kalyan & Prasad, 2013).

Examining the types, frequency, and the severity of distribution transformers' failures, and the causes of these failures, recommends that a periodic maintenance, inspection, and performance tests can significantly improve the service life and performance of distribution transformers. Bartley (2003), while focusing on faulty distribution transformers within Port Harcourt, demonstrated in practical terms the various tests that could be carried out on such transformers to determine their levels of performance. Some of the tests carried out were based on voltage transformation ratio (one phase) with respect to the input and output, insulation resistance and earthing (Bala, 2014). Consequently, Carl (2013) proved that the method of analysing the materials used in the core of the transformer will sufficiently improve the performance of the transformer. The performance is limited as a result of the leakage flux which flows beyond the transformer core to structural components such as tank, frames, flitch plates and bush mounting plates. The eddy current loss will stir up stray loss in the form of heat.

The replacement of M19 high grade silicon steel provides an energy efficient transformer with increased load withstanding capability and reduced voltage drop with increase in load because of its best conducting properties, high permeability and high temperature withstanding capability (Kumar et al., 2018). Stanley & Ulasi (2018), in an attempt to improve the performance of distribution transformers in Nigerian power system, carried out an analysis on the effect of linear and non-linear loads on a distribution transformer (11KV/415V). One of the main challenges encountered with distribution transformers in Nigeria is the amount of losses in the transformer which are no-load losses (core losses) and load losses (copper losses). Under linear load condition, the current flowing through the conductor is directly proportional to the voltage across it. For a purely resistive linear load, the voltage and current waveforms are in phase and the losses are minimal. For a capacitive or inductive linear load, the voltage and current waveforms are not in phase which lead to decrease in power factor and the efficiency of the distribution transformer due to winding losses. For a Non-linear loading condition, when the current is not in direct proportion to the applied voltage, harmonics is generated on the current and voltage waveform as a result of higher order frequencies added to the fundamental frequency on the transmitted signals. These harmonics introduce a distortion power factor to the signal which reduces the true power factor, as a result, loss in the transformer increases. To reduce these losses, capacitor bank or filters are connected to the system.

Also Idoniboyeobu, Braide, & Adokiye (2018), analysed the electric power distribution network for Udi (11kV), mile 2, Diobu, Port Harcourt to improve it. Load flow analysis using the Gauss-Seidel power flow equation was conducted with the use of a simulation tool called Electric Transient Simulation Program (ETAP). Findings deduced from the analysis showed that the two existing 300 kVA distribution transformers were being overloaded. However, an upgrade of each of them to 500kVA was recommended to achieve improved performance of the entire network.

Samples of transformers in Kaduna metropolis were considered in this study. The study area was selected due to its uniqueness in terms of Geographical location and role in the electrical distribution service area. and compared to the other States in Northern Nigeria. Also, with the rapid industrial, commercial transformation presently going on within the metropolis it is envisaged that studies of this nature could be seen as an advisory note to the appropriate authorities with respect to determine aging infrastructure within the electrical network and channelling resources appropriately for improvement of the system.

3.0 Methodology

The model that was adopted according to Herlow (2007), called the Transformer Performance Model (TPM), was used to assess the distribution transformer characteristics because it offers a simpler and more straight forward approach. It focused on impedance, short-circuit current, regulation and efficiency parameters. The scope of the tests carried out on sampled transformers, however was limited to insulation resistance, single-phase voltage transformation, short circuit, dielectric and break down voltage. It was on this basis that the percentage (%) deviations of the respective cases were determined and evaluated based on the guidelines stipulated protection and testing guidelines used by Engineers in the Nigerian electricity sector.

Hence, three sample distribution transformers (Transformer 1, Transformer 2 and Transformer 3) were selected for the tests. Their respective ratings and other parameters on the name plate are presented in **Tables 2**, **3** and **4**.

Table 2: Transformer 1 (T1) Data

TRANSFORMER 1 (T1) DATA				
MAKE		--NA--	**IMPEDANCE**	5.47%
SERIAL NUMBER		--NA--	**VECTOR GROUP**	Dyn1
CAPACITY (KVA)		2500	**YEAR OF MANF.**	2010
VOLTAGE	**HV (KV)**	11	**DATE**	
	LV (KV)	0.415		
CURRENT	**HV (Amps)**	43.74		
	LV (Amps)	131.2		

The following tests, according to model specified above were carried out:

a) Insulation Resistance (IR) test (with the use of an 80kV Hipotronics Insulation Tester) to test if there were leakages between phases or the transformer body. This was also carried out to check the integrity of insulation due to moisture or impurity contents of the insulation materials.

Table 3: Transformer 2 (T2) Data

TRANSFORMER 2 (T2) DATA				
MAKE		--NA--	**IMPEDANCE**	12.04%
SERIAL NUMBER		--NA--	**VECTOR GROUP**	Dyn1
CAPACITY (KVA)		15000	**YEAR OF MANF.**	1988
VOLTAGE	**HV (KV)**	33	**DATE**	
	LV (KV)	11		
CURRENT	**HV (Amps)**	262.5		
	LV (Amps)	787.3		

Table 3: Transformer 3 (T3) Data

TRANSFORMER 3 (T3) DATA				
MAKE		--NA--	**IMPEDANCE**	11.94%
SERIAL NUMBER		--NA--	**VECTOR GROUP**	Dyn1
CAPACITY (KVA)		15000	**YEAR OF MANF.**	1988
VOLTAGE	**HV (KV)**	33		
	LV (KV)	11		
CURRENT	**HV (Amps)**	262.5		
	LV (Amps)	787.3		

b) Single-phase voltage transformation ratio (or output) test using Fluke 117 Avometer. This test category was necessary to determine the turn's ratio between the primary and secondary coils so that the error ratio between the designed values and the values obtained while taking measurements would be determined.

c) Short circuit test: single phase circulating current and single-phase capacity tests were carried out to measure the positive sequence impedance of the transformer. A clamp meter was used in this case.

d) In addition to the materials used above, a 3.7kVA mobile generator was used to energize the transformer 1, 2 and 3 required to be tested.

Other materials used, included recording (tabular) chart, tool box as well as safety gadgets.

Data generated from the tests were used to determine the short circuit current, rated current, rated kVA, % deviation and voltage ratio when inputted in to the following mathematical formulas:

i. Expected short circuit current.

$$I_{SC_{\exp}} = \frac{I_{rated\,\sec} \times 100 \times V_{app}}{Z \times V_{rated\ pri}} \qquad 1$$

ii. Rated secondary current.

$$I_{rated\ Exp} = \frac{I_{sc\ Obt} \times Z \times V_{rated\ Pri.}}{100 \times V_{App}} \qquad 2$$

iii. KVA rating of the transformer.

$$Rated\ KVA = \sqrt{3} \times I_{rated\ Pri.} \times V_{sec.}$$

$$Rated\ KVA = \frac{I_{sc\ Obt} \times Z \times V_{rated\ Pri.} \times \sqrt{3} \times V_{sec.}}{100 \times V_{App}} \qquad 3$$

iv. Percentage deviation.

$$\%Deviation = \frac{Expected\ - Obtained}{Expexted} \times 100 \qquad 4$$

v. Expected current at the primary end.

$$I_{Pri.Exp.} = \frac{KVA}{V_{Pri.} \times \sqrt{3}} \qquad 5$$

vi. Expected secondary current.

$$I_{Sec.Exp.} = \frac{KVA}{V_{Sec.} \times \sqrt{3}} \qquad 6$$

vii. Expected transformer voltage ratio

$$V_{Ratio.Exp.} = \frac{V_{App} \times V_{Sec.}}{V_{Pri.} \times \sqrt{3}} = (Phase/neutral) \qquad 7$$

where,

$I_{SC\ Exp} = Expected\ Short\ Circuit\ current\ (from\ calulations),$

$I_{rated\ Sec} = Rated\ Secondary\ Current\ of\ the\ transformer\ (deduced\ from\ the\ name\ plate)$

$I_{rated\ Exp}$= Expected current rating of the transformers (based on calculations)

$I_{SC\ obt} = Obtained\ Short\ Circuit\ current\ from\ measurements$
$I_{rated\ pri} = Rated\ primary\ current$
$V_{app} = Applied\ voltage\ at\ the\ primary\ sides$
$V_{rated\ pri}$
$= Rated\ primary\ voltage\ defined\ fromthename\ plate\ of\ transformer$

The efficiency of a transformer is defined as the percentage ratio between the output power to the input power of the transformer at full load condition. But distribution transformer is designed for a maximum efficiency of 50% to 70%. It operates at 60% to 70% full load all day. Distribution transformer cannot be operated at constant load throughout 24 hours; its load depends on distribution demand. The idea of *all day efficiency* is considered. In this concept, the output and input ratio are taken within the span of 24 hours because load at the secondary fluctuates within this period while the primary is permanently connected to the supply. The output is always less than expected because of the losses that will always occur in the core (at no load) and the windings (load losses) (Stanley & Ulasi, 2018; Okakwu, Oluwasogo, & Airoboman, 2015)

The all-day efficiency is expressed as, the ratio of total Kilowatt hour, KWh output (at the secondary) to the total KWh input (at the primary) of the transformer over a specific period of time preferably 24 hours. It is always less than its ordinary efficiency.

$$percentage\ All\ day\ efficiency = \frac{Output\ power\ in\ KWh}{Input\ power\ in\ KWh} \times 100\ \ (for\ 24\ hours) \quad 8$$

$$percentage\ All\ day\ efficiency = \frac{L \times KWh \times cos\theta}{(L \times KWh \times cos\theta) + NL + L^2 \times LL} \times 100 \quad 9$$

In equation 9, $KVA \times cos\theta$ is the real energy fed to the load, with power factor, $cos\theta$. NL and LL are the No-load losses and Load Losses of the transformer respectively, assuming that such transformers are loaded to about 50% of nameplate rating on the average.

Thus, percent all day efficiency is often calculated at $L = 0.5$. The efficiency is at maximum when the copper losses equal the iron losses. The pictures during the test on the transformers are presented in **Figure 1**.

Figure 1: *Picture during the tests*

4.0 Results

The outcome of the Insulation Resistance (IR) tests for T1 –T3 and voltage transformation test (for T1) are presented in Tables 5 - 8 and the results obtained were graphically interpreted using excel software as shown in **Figures 2 – 4**. Consequently, **Tables 9 -10** presents the dielectric test result for T2 and T3 and the circulating current and single-phase capacity test results for T1 respectively. This was done due to insufficient information from the other transformers.

Defining the phases as R (Red), Y (Yellow) and B (Blue); the line to line connections (conn.) as R-Y, Y-B and R-B; the phase to phase connections as r-n, y-n and b-n; HV as high voltage end as well as LV as low voltage end, the following results are presented in **Tables 5** to **10**.

Table 5: Insulation resistance test result for T1

Description	Injected voltage (kV)	Duration (minutes)	Insulation resistance (MΩ)	Remark
HV – LV	20	1	$\geq 200M\Omega$	OK
HV – GND	20	1		OK
LV – GND	2	1		OK

Table 6: Insulation resistance test result for T2

Description	Injected voltage (kV)	Duration (minutes)	Insulation resistance (MΩ)	Remark
HV – LV	50	1	65	Not Okay
HV – GND	50	1	78	Not Okay

Table 7: Insulation resistance test result for T3

Description	**Injected voltage (kV)**	**Duration (minutes)**	**Insulation resistance (MΩ)**	**Remark**
HV – LV	50	1	60	Not Okay
HV – GND	50	1	82	Not Okay
LV – GND	20	1	75	Not Okay

Table 8: Single-phase voltage transformation ratio (or output) test

Tap Position	**Conn.**	**Applied Primary Voltage (V)**			**Induced Secondary Voltage (V)**						**Deviation (%)**	**Remark**
		R-Y	Y-B	B-R	r-y	y-b	b-r	r-n	y-n	b-n		
Nominal	R-Y	224.7	113.8	109.6	57.5	57.8	0.77	19.5	**39.3**	19.8	12.02	Not Okay
	Y-B	172.3	224.9	52.1	20	68	48.2	9.2	29.2	**38.9**	9.95	Okay
	B-R	165.8	58	224.7	67.9	18.3	49.8	**39.8**	28.3	9.9	7.8	Okay

Table 9: Di-electric test

TRANSFORMER	ELECTRODE GAP (mm)	ASTM	BDV (kV)	Remark
T2	2.5	25kv	26.9	OK
T3	2.5	25kv	45.3	OK

Table 10: Single phase circulating current test (short-circuit)

Conn.	**Applied Voltage(V)**	**I_{r-n} (A)**	**I_{y-n} (A)**	**I_{b-n}(A)**	**Remark**
R-Y	222	0	14.2	0	Okay
Y-B	222	0	0	13.4	Okay
B-R	222	13.6	0	0	Okay

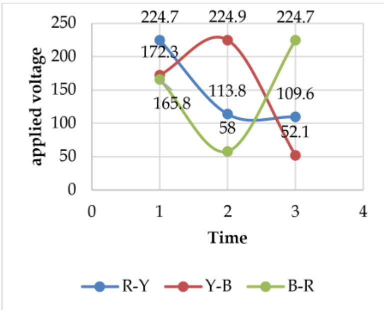

Figure 2: *Graph showing the applied Line-Line primary voltage*

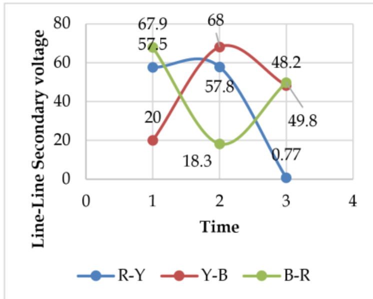

Figure 3: *Graph showing the Secondary induced Line-Line voltage*

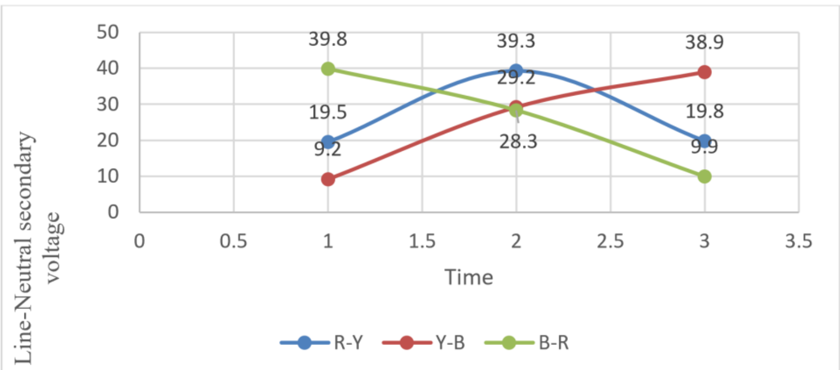

Figure 4: *Graph showing the respective Phase Voltages (secondary)*

In all the Figures, R=Red phase, Y = Yellow phase, B = Blue phase and R-Y, Y-B, R-B represents phase to phase connections.

The *expected output voltage (*R-Y line to line connection from Table 8*)* is computed thus:

$$If\ 33kV\ input\ gives\ an\ output\ of\ {}^{11kV}/_{\sqrt{3}}$$

$$\text{then, } 224.7V\ input\ gives\ an\ output\ of\ \frac{224.7 \times {}^{11kV}/_{\sqrt{3}}}{33kV} = 43.24V.$$

$$From\ equation\ (1), I_{sc\ exp.} = \frac{131.2 \times 100 \times 222}{5.47 \times 33000} = 16.14A$$

$$from\ equation\ (4), \%Deviation(for\ R - Y) = \frac{16.14 - 14.2}{16.14} \times 100\% = 12.02\%$$

(which is not okay since it does not fall within the maximum acceptable deviation of ±10%)

Similarly, % deviation for Y-B and B-R connections were calculated to yield 9.95% and 7.8% respectively.

For T1:

Under full load condition,

131.2A ⟶ 70%

I ⟶ 60%

$$I = \frac{131.2 \times 60}{70} = 112.457A$$

The output power, P_{out} per phase,

$$P_{out} = \frac{11000}{\sqrt{3}} \times 112.457 = 714.2KW.$$

The input power, P_{in} per phase,

$$P_{in} = \frac{33000}{\sqrt{3}} \times 43.74 = 833KW.$$

$$All\ day\ Performance\ Efficiency = \frac{714.2KW}{833KW} \times 70 = 60\%$$

For T2,

Under full load condition,

787.3A ⟶ 70%

I ⟶ 60%

$$I = \frac{787.3 \times 60}{70} = 675A$$

The output power, P_{out} per phase,

$$P_{out} = \frac{11000}{\sqrt{3}} \times 675 = 4287KW.$$

The input power, P_{in} per phase,

$$P_{in} = \frac{33000}{\sqrt{3}} \times 262.5 = 5001KW.$$

$$All\ day\ Performance\ Efficiency = \frac{4287KW}{5001KW} \times 70 = 60\%$$

For T3

Under full load condition,

787.3A ⟶ 70%

I ⟶ 60%

$$I = \frac{787.3 \times 60}{70} = 675A$$

The output power, P_{out} per phase,

$$P_{out} = \frac{11000}{\sqrt{3}} \times 675 = 4287KW.$$

The input power, P_{in} per phase,

$$P_{in} = \frac{33000}{\sqrt{3}} \times 262.5 = 5001KW.$$

$$All\ day\ Performance\ Efficiency = \frac{4287KW}{5001KW} \times 70 = 60\%$$

It can be seen that the all-day performance efficiency of 60% was constant for all transformers. This therefore validates the assertion of (Stanley & Ulasi, 2018) that all-day performance efficiency should not exceed 60%.

5.0 Discussion of results

The system is **OKAY** if the test values falls within the ±10% maximum acceptable deviation and **NOT OKAY** if it falls outside the limit. The results for the IR tests indicated that HV – LV, HV – GND and LV – GND is ≥200M**Ω**, for T1. This is within the standard limit of operation. Also, T2 and T3, from Tables 6 and 7 respectively, had their Insulation resistances within the range of 60MΩ to 82MΩ which were all far below the standard limits of operation. Therefore, T2 and T3 have very poor insulation resistance.

The voltage transformation test determined whether the supply at the consumer end is an over voltage supply (+10%) or an under-voltage supply (-10%). From Table 8, the obtained voltage (y-n) is 39.3V**.** Equation (4) was then used to compute for the percentage deviation which yielded 9.02%. The same approach was also repeated for Y-B and B-R yielding 9.95% and 7.8% respectively and an average deviation of 8.92% was obtained. This therefore showed that the turn ratio for T1 was correct and all the three phases y-n (yellow), b-n (blue phase) and r-n (red phase) supplied the required voltage to the consumers. The graphs in Figure 4 illustrated the line-to-line voltages applied at the primary end of the T1 at different instances while the response at the secondary end is illustrated in the graphs in Figures 5 and 6 above. These curves show the voltage transformation pattern for T1 when it was energised in the course of the test. From the dielectric test result shown in Table 8, the breakdown voltage (BDV) values of the oil is satisfactory since they are above the benchmark standard of (America society for testing materials-ASTM). The benchmark according to ASTM is greater than or equal to 25kV. Also, In the same vain, the average %deviation of the short circuit (Circulating current) test for T1 was calculated from the measured values in Table 10. The percentage deviation for Y-B and B-R are 17% and 15.7% respectively. Hence, the average percentage deviation of the circulating current capacity for T1 is 14.91%. Based on this average, the test shows that there might have been an alteration in winding design or the transformer is older than the year of manufacture indicated on the name plate. This implies that this transformer cannot be loaded at full load condition and may not work after ten years from now..

6.0 Conclusion

In this paper, the performance of some selected distribution transformers within Kaduna metropolis, Kaduna State, Nigeria were investigated with respect to their performances. The approach used centred on Transformer Performance Model (TPM) which made it possible for Insulation Resistance, Voltage Transformation, and Dielectric test to be carried out. Results obtained were analysed and interpreted graphically. Mathematical analysis was also carried out to determine and validate test responses. The approach used is simple, more direct and convenient. T1 had a relatively good voltage transformation ratio as well as insulation resistance but had high deviation on its short circuit test because it was above the $\pm 10\%$ threshold. This explains why it will not be able to sustain the expected maximum load demand without tripping. On the other hand, T2 and T3 which were of the same make and capacities as already presented in Tables 3 and 4 were found to be affected by ageing (manufactured in 1980s according to the transformer nameplate). They both had very poor insulation (less than 100MΩ) and were also overloaded due to the large number of customers connected to them (above 60% loading). It is then necessary to replace them with new ones. The overall efficiencies were calculated to yield 60% for T1, T2 and T3. Notwithstanding, on a comparative analysis therefore, T1 can still be said to be in a partially good working condition and could be made to serve the customers for some time before overhauling. On the other hand, the duo of T2 and T3 need immediate, rapid and total overhauling.

Based on this paper, the Transformer Performance Model (TPM) has been found to be a fast way in determining the performance of Distribution

Transformers. This model, which comprises mainly of numerical calculations, offers a more simpler and straight forward approach. In addition, it has been found to be a cheaper way that could be adopted in carrying out performance evaluation of transformers in Nigeria..

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