ESTIMATION OF VOLTAGE RATIO, VECTOR RELATIONSHIP, IMPEDANCE VOLTAGE/SHORT CIRCUIT IMPEDANCE, LOAD LOSSES & NO LOAD CURRENT AND LOSSES OF 3 PHASE, 16 KVA, 11OOO/433V OIL IMMERESED TRANSFORMER

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ABSTRACT

A transformer may be used as a safe and efficient voltage converter to change the AC voltage at its input to a higher or lower voltage at its output. Other uses include current conversion, isolation with or without changing voltage and impedance conversion. This paper consists specification of transformer to be checked and its procedure of measurement of voltage ratio between HV and LV winding for every terminal by Bridge technique and vector relationship between HV and LV winding, its actual results before and after short circuit test. Also measurement of short circuit impedance and load loss at working temperature and its actual results before and after short circuit test.

KEY WORDS: *Transformer, Voltage Ratio, Vector Group, Impedance, Short Circuit Impedance, Load losses, No load current*

Specification of Transformer

1. Type	:	Out door, Oil cooled
2. KVA rating	:	16
3. Rated voltage H.V. (Volts)	:	11000
L.V. (Volts)	:	433
4. Rated current H.V. (Amp.)	:	0.84
L.V. (Amp.)	:	21.33
5. Number of phases	:	3
6. Connection H.V./L.V.	:	Delta/Star
7. Frequency (Hz.)	:	50
8. Type of cooling	:	ONAN
9. Temperature rise of oil	:	45oC
10. Percentage Impedance	:	4.5 % + IS Tolerance
11. Primary winding conductor	:	Aluminum bare wire dia. 0.89 mm
12. Secondary winding conductor	:	Aluminum strip (8.9mm x 2.7mm) bare
13. Quantity of oil (Liter)	:	53
14. Weight of oil (Kg.)	:	44
15. Weight of core and winding (kg.)	:	75
16. Total weight (Kg.)	:	207
17. Vector group	:	Dyn-11
18. Year of manufacture	:	2009
19. Insulation level H.V.	:	28kVrms
20. Insulation level L.V.	:	3kVrms
21. Total losses at 75 0C (Watts)	:	60 (at 50 % load)
22. Total losses at 75°C (Watts)	:	360 (at 100 % load)

I. Introduction

A theoretical (ideal) transformer does not experience energy losses, i.e. it is 100% efficient. The power dissipated by its load would be equal to the power supplied by its primary source. In contrast, a real transformer is typically 95 to 99% efficient, due to several loss mechanisms, including winding resistance, winding capacitance, leakage flux, core losses, and hysteresis loss. Larger transformers are generally more efficient than small units, and those rated for electricity distribution usually perform better than 98%. Experimental transformers using superconducting windings achieve efficiencies of 99.85%[6] .

The increase in efficiency can save considerable energy in a large heavily loaded transformer; the trade-off is in the additional initial and running cost of the superconducting design. As transformer losses vary with load, it is often useful to express these losses in terms of no-load loss, full-load loss, half-load loss, and so on. Hysteresis and Eddy current losses are constant at all load levels and dominate overwhelmingly without load, while variable winding joule losses dominating increasingly as load increases. The no-load loss can be significant, so that even an idle transformer constitutes a drain on the electrical supply. Designing energy efficient transformers for lower loss requires a larger core, good-quality silicon steel, or even amorphous steel for the core and thicker wire, increasing initial cost. The choice of construction represents a trade-off between initial cost and operating cost[7].

II. Measurement Of Voltage Ratio And Check Of Phase Displacement

The no-load voltage magnitude relation between two windings of a transformer is termed as turn ratio. The aim of measurement is; confirming the no-load voltage ratio given within the client order specifications, deciding the conditions of each the windings and therefore the connections and examining the issues (if any) measurements are created at all tap positions and every one phases[1].

III. Turn Ratio Measurement

Measurement of turn ratio is based on, applying a phase voltage to one of the windings using a bridge (equipment) and measuring the ratio of the induced voltage at the bridge. The measurements are repeated in all phases and at all tap positions, sequentially **[4].** During measurement, only turn ratio between the winding couples which have the same magnetic flux can be measured, which means the turn ratio between the winding couples which have the parallel vectors in the vector diagram can be measured. In general, the measuring voltage is 220 V a.c. 50 Hz. However, equipments which have other voltage levels can also be used. The accuracy of the measuring instrument is ≤ 0,1% and connection for measuring turn ration showing in figure 1.

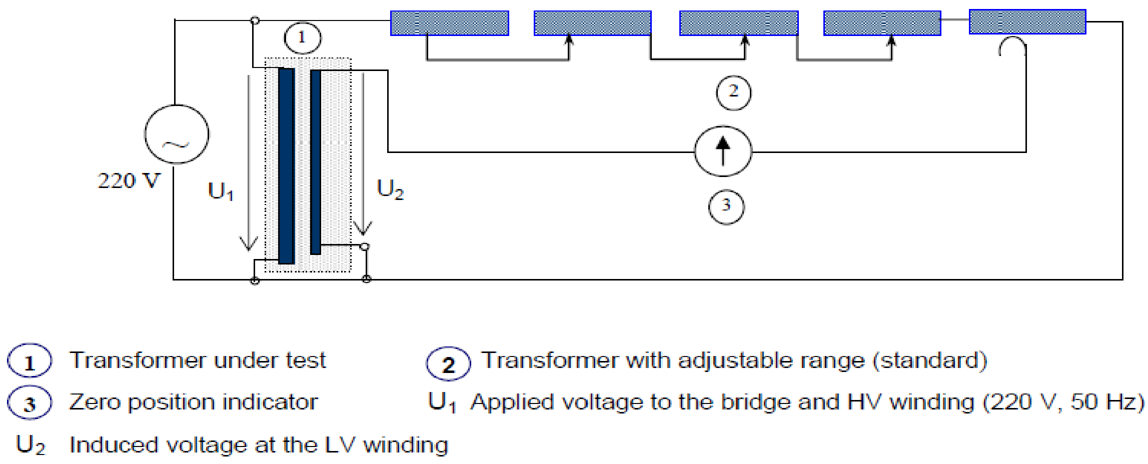

Fig. 1: Bridge connection for measurement of turn ratio

$$\text{Theoretical turn Ratio} = \frac{\text{HV winding Voltage}}{\text{LV winding Voltage}} \quad (1)$$

The theoretical no-load turn ratio of the transformer is adjusted on the equipment by an adjustable transformer, itschanged until a balance occurs on the % error indicator. The value read on this error indicator shows the deviation of the transformer from real turn ratio as %.

$$Deviation = \frac{(Measured\ Turn\ Ratio) - (Expected\ Turn\ Ration)}{Ex[ected\ Turn\ Ratio} * 100\% \quad (2)$$

DETERMINING THE CONNECTION GROUP

Depending on the type of the transformer, the input and output windings of a multi-phase transformer are connected either as star (*Y*) or delta (*D*) or zigzag (*Z*). The phase angle between the high voltage and the low voltage windings varies between *0˚* and *360˚*.

Representing as vectors, the HV winding is represented as *12 (0*) hour and the other windings of the connection group are represented by other numbers of the clock in reference to the real or virtual point. For example, in *Dyn 11* connection group the HV winding is delta and the LV winding is star and there is a phase difference of 330˚ (11x30˚) between two windings. While the HV end shows *12 (0)*, the LV end shows 11 o'clock *(after 330˚*) **[4].**Determining the connection group is valid only in three phase transformers. The high voltage winding is shown first (as reference) and the other windings follow it. If the vector directions of the connection are correct, the bridge can be balanced. Also, checking the connection group or polarity is possible by using a voltmeter. Direct current or alternating current can be used for this check. The connections about the alternating current method are detailed in standards. An example of this method is shown on a vector diagram below **[5].**

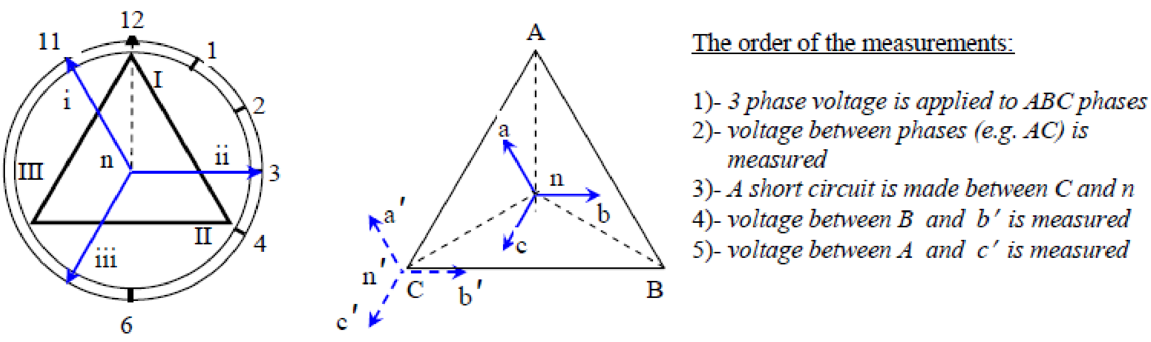

Fig. 2: Connection group representation and measurements

As seen from the vector diagram, in order to be Dyn 11 group, A.c◦ > AB >B.b◦ correlation has to realized. Taking the other phases as reference for starting, same principles can be used and also for determining the other connection groups, same principles will be helpful.

Voltage Ratio And Check Of Voltage Vector Relationship

Vector group: Dyn-11 was verified.

Rated voltage Ratio	Measured voltage ratio between Terminals					
	U-V/u-n	Difference %	V-W/v-n	Difference %	W-U/w-n	Difference %
44.001	44	-0.002	44.5	1.134	44.049	0.109

Table No: 1

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Table No: 2

Table No: 1 and **Table No 2** shows the actual results of voltage ratio of transformer to be checked and also verified vector group of winding and it's also shows % difference of voltage ratio before and after short circuit test.

Measurement of short-circuit impedance and load loss

The short-circuit loss and the short-circuit voltage show the performance of the transformer. These values are recorded and guaranteed to the customer and important for operational economy. The short-circuit voltage is an important criteria especially during parallel operations of the transformers. The short-circuit loss is a data which is also used in the heat test**[5].**

The short-circuit loss is composed of; "Joule " losses (direct current/DC losses) which is formed by the load current in the winding and the additional losses (alternating current/AC losses) in the windings, core pressing arrangements, tank walls and magnetic screening (if any) by the leakage (scatter) fluxes**[2].**

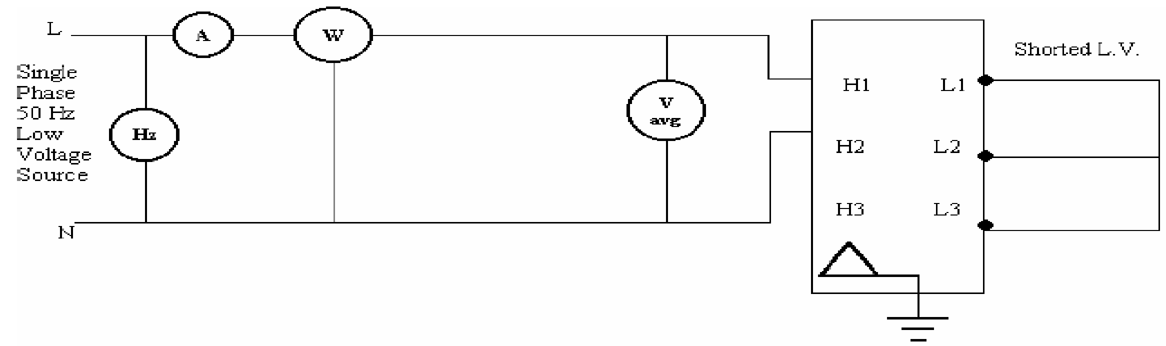

Fig. 3: Load loss test using low voltage supply

To avoid CT's and PT's, this method can be used at current levels of 2 to 5 A andMeasurement of load losses is done at this condition. This measured load loss is thenExtrapolated to actual load currents to obtain load losses at the operating current**[2].**

$$H.V.Side\ Full\ Load\ Current, I1 = \left(\frac{Full\ load\ kVA\ \times 1000}{\sqrt{3} \times H.V.line\ voltage}\right) \quad (3)$$

Based on the nameplate impedance value of Z%, the estimated line to line voltage forpassing 5 A on the H.V. side is calculated as given below **[4].**

$$Line\ to\ line\ Voltage, V_{I-SC} = \left(\frac{Line\ Voltage\ kV\ \times 1000\ \times Z\ \times 5}{0.866\ \times\ I_1\ \times 100}\right) \quad (4)$$

The test is repeated thrice, taking terminals HR and HY by applying voltage ERY and thenHY and HB with EYB and then HR and HB applying voltage ERB. The power readings with
corrections are PRY, PYB and PRB respectively. Current drawn on H.V. side I s1 is alsonoted.Since the current drawn on H.V. side is only about 5A in this test, CT's can be avoided
and hence phase angle error is not applicable.

$$Measured\ load\ loss, W_{SC} = \left(\frac{P_{RY} + P_{YB} + P_{RB}}{3}\right) \times 1.5 \quad (5)$$

Measurement Of Impedance Voltage/Short Circuit Impedance Load Losses

Frequency: 49.378Hz., Top oil temp.: 23.1°C

Test current (Amp.) Iavg.	Impedance voltage (V) Vavg.	Load loss measured (Watts)	Impedance Voltage (%Z) At 50 Hz.	Load loss computed at 75 °C (Watts)	%Z at 75 °C
0.842	449.281	284.743	4.126	357	4.344

Table No: 3

Measurement Of Impedance Voltage/Short Circuit Impedance Load Losses

Frequency: 49.346Hz, Top oil temp.: 39.2°C

Test current (Amp.) Iavg.	Impedance voltage (V) Vavg.	Load loss measured (Watts)	Impedance Voltage (%Z) At 50 Hz.	Load loss computed at 75 °C (Watts)	%Z at 75 °C
1.311	481.201	581.507	2.84	270	2.949

Table No: 4

Table No:3 and 4 shows actual results of Impedance voltage, Load losses and % Z at 75 °C before and after short circuit test.

IV. NO LOAD LOSS MEASUREMENTS

No-load losses (also referred to as core losses and iron losses) are a very small part of the power rating of the transformer, usually less than 1%. Since these losses are essentially constant for the each transformer (do not vary with load), they generally represent a sizable operating expense especially when energy costs are high. Therefore, accurate measurements are essential in order to evaluate individual transformer performance accurately . No-load losses are the losses in a transformer when it is energized but not supplying load **[8].**

No load losses can be measured from the L.V. side using an adjustable three phase voltage source with neutral. It can be derived from mains or a D.G. set. The voltage and frequency should be steady and at rated values and as near as possible to 50 Hz and itshould be measured. This test can give a basic value near rated conditions if allprecautions are taken**[3].**The L.V. side is energised at the rated tap at rated voltage and power is measured bythree watt meters or 3 phase, 4 wire single wattmeter/energy meter**[4].**

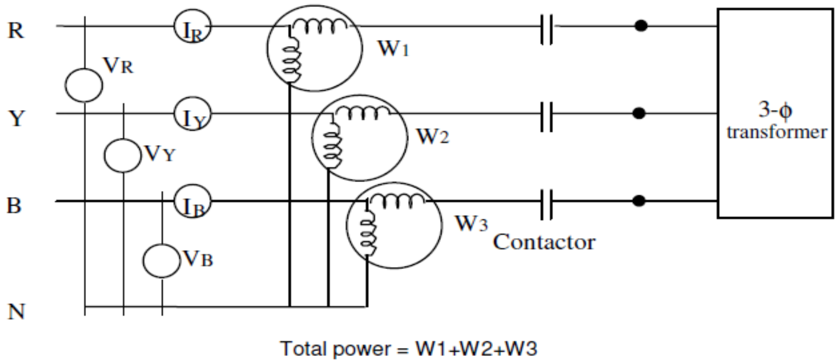

Fig. 4: No load test set up for 3 phase transformers

The following figure 5 shows connection diagram of a typical 3 phase 4 wire energymetering for measuring energy input to the transformer. All electrical parameters can bemonitored using this system**[3].**

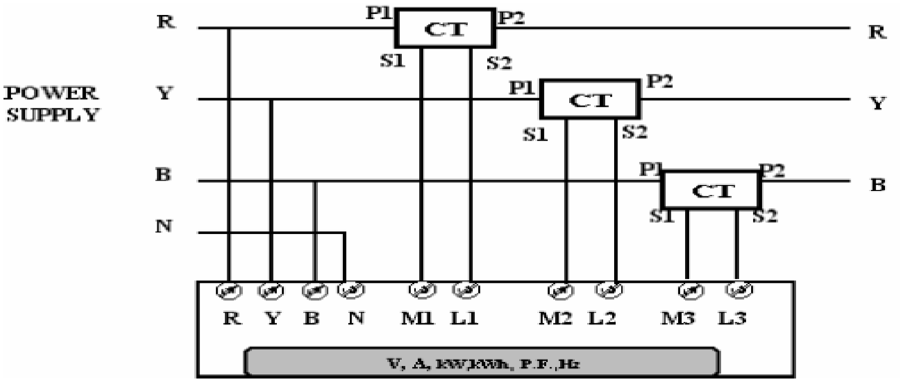

Fig. 5: Connection diagram using 3-phase 4 wire energy meter.

The no load energy consumption, Enl can be measured in the 3 phase – 4 wire meterconnected as in figure-5. Time taken, t, between initial and final readings are noted.Average no load power is estimated from average energy consumption and time taken.

$$Average\ no\ load\ power\ consumption, W_{nl'} = \left(\frac{Average\ energy\ consumption}{Time}\right)$$
$$= \left(\frac{E_{nl}}{t}\right) \times 360 \qquad (6)$$

No Load Current And Losses

Frequency: 50.046Hz., Top oil temp.: 25.6°C

Applied Voltage (V) Vavg.	Current (Amp.) Iavg.	Losses Measured (Watts)
433.427	0.109	56

Table No: 5

No Load Current And Losses

Frequency: 50.031 Hz, Top oil temp.: 39.2°C

Applied Voltage (V) Vavg.	Current (Amp.) Iavg.	Losses Measured (Watts)
433.729	0.232	60

Table No: 6

Table No: 5 and **6** shows actual results of No load current and No load losses before and after short circuit test.

V. CONCLUSION

Table no. 1 to 6 shows the results of voltage ratio, vector relationship, impedance voltage/short circuit impedanc, load losses & no load current and losses of 3 phase, 16 kva, 11ooo/433v oil immeresed transformer and all results are taken from industrial laboratory. From this available result we can compare the values of different parameters after and before the short circuit test. From the Turn Ratio Measurement test it is clear that Volatge ratio & voltage vector relationship remains unchanged before & after short circuit test. As shortcircuit test performed oil temperature of the transformer increases and the current will also increases accordingly the load losses is also increases. From the Voltage/

short circuit Impedance load loss test we can observe that the impedance voltage increased after shortcircuit test.

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[7] (i) "The turn ratio of a transformer is the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding",[6]common usage having evolved over time from 'turn ratio' to 'turns ratio',
(ii) A step-down transformer converts a high voltage to a lower voltage while a step-up transformer converts a low voltage to a higher voltage, an isolation transformer having 1:1 turns ratio with output voltage the same as input voltage.
(iii)Transformer windings are usually wound around ferromagnetic cores but can also be air-core wound. Heathcote, pp. 41-42.
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