Electric Machines Laboratory (EE2P003)

EXPERIMENT-4

BACK-TO-BACK TEST OF TWO 1-ØTRANSFORMER

Shorya Sharma
19EE01017

Aim:

To determine the equivalent circuit parameters, phasor diagram & efficiency of a given pair of 1-phase Transformers by conducting a Back-to-Back test (Sumpner's test).

APPARATUS:

INSTRUMENTS / EQUIPMENTS

Sl. No	Instruments / Equipment	Type	Specification	Quantity
1	Voltmeter	MI	(0-150/300 V)	2 No s
2	Ammeter	MI	0-1 A	1 No.
3	Wattmeter	LPF	2A, 300V, 0.2 pf	1 No.
4	Voltmeter	MI	0-150 V	1 No.
5	Ammeter	MI	0-5 A	1 No.
6	Wattmeter	UPF	5A, 150 V	1 No.
7	1- ∅ variac	Iron core	230 V, 30A	2 No.
8	Connecting Wires	Cu	1.5 sq.mm	As required

MACHINES REQUIRED

SL.NO	MACHINE	SPECIFICATION	QUANTITY
1	Single Phase Transformer	1 kVA, Primary-230V, 4.3A Secondary-230V, 4.3A	2 Nos

Theory:

Two very simple tests are used to determine the equivalent circuit parameters and the power losses in the transformer. These consist in measuring the input voltage, current, and power to the primary, first with the secondary short circuited and then with secondary open circuited. The copper losses are determined from the short circuit test. The core losses are determined from the open circuit test.

Stray load loss consists of the losses arising from the non-uniform current distribution in the copper and the additional core losses produced in the iron by distortion of the magnetic flux by the load current. It is difficult to determine such losses accurately by conventional no-load and short circuit load tests.

To obtain exact equivalent circuit and losses, the input and output parameters are directly measured under different loading conditions. This is easy for small rating transformers. However, for large transformers, it is difficult and expensive to take direct measurements. A Back-to-Back Test is used in this case.

Back-to-Back test is also known as Sumpner's test/Heat run test. This test requires two identical transformers. Primary winding of both the transformers are connected in parallel across the same supply and the Wattmeter connected in primaries reads the core losses (Iron losses) of both transformers. These are fed by rated voltage at rated frequency. The secondary winding of both the transformers is connected in phase opposition so that their potentials are in opposite to each other. By connecting so there would be no secondary current flowing around the loop formed by the two secondary. By this test, the equivalent Circuit parameters, efficiency, regulation & heating of both the T/F can be determined.

This test facilitates the collection of data for open and short circuit test simultaneously. On secondary side a low voltage just sufficient to flow the full load current is connected.

We can justify that the current is just twice the no load current. This means the wattmeter connected on the primary side reads the total iron loses of both the transformers.

The iron loss of one transformer=1/2Wo.

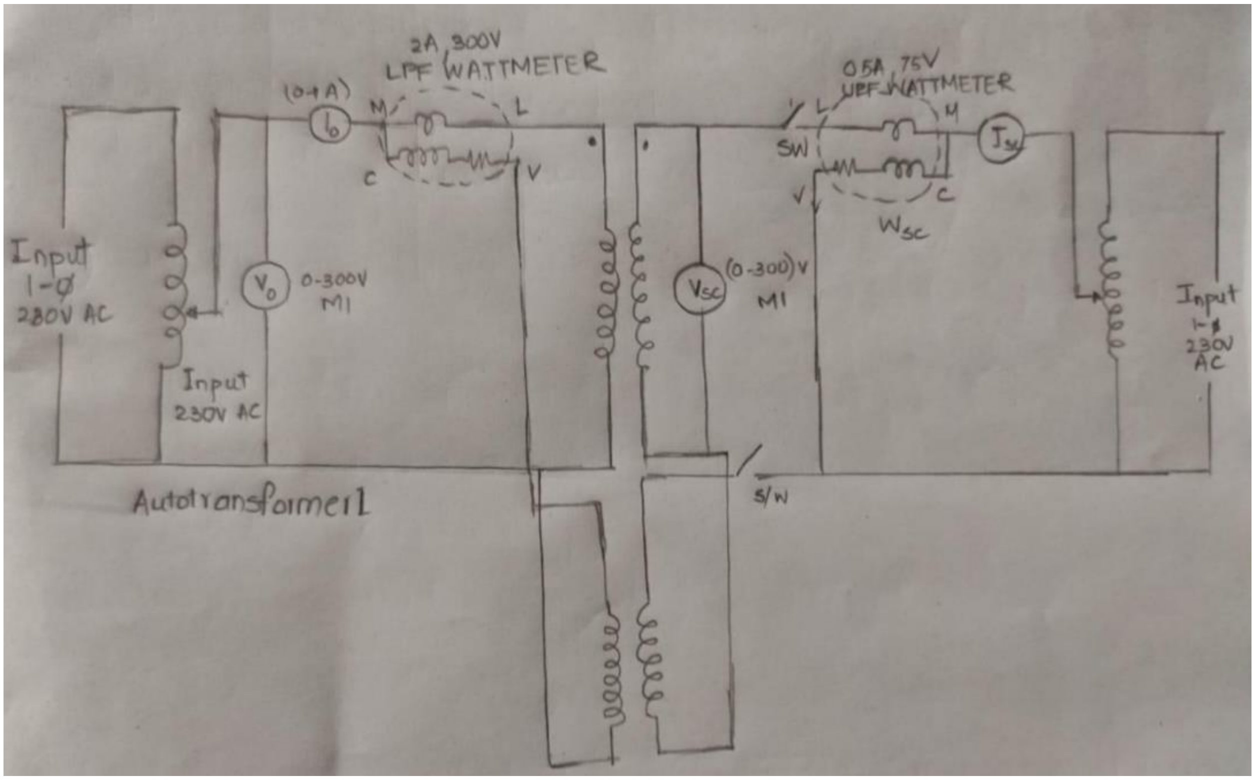
The copper loss of one transformer=1/2Wsc.

The total losses of one transformer=1/2(W0+Wsc)

Why Back-to-back test used in case of large transformers?

- The short circuit test is difficult to be applied, since applying a reduced voltage is very difficult and impractical.
- This test can simulate the loading conditions on the transformer without using real loads.
- A large transformer supplying large essential loads usually has a second identical transformer installed in the same location for back-up, so using back-to-back transformers in this case is very practical.

CIRCUIT DIAGRAM:



Precaution:

- Connection should be right and tight.
- Check the circuit connection thoroughly before switching on the supply.
- Instruments should be connected in proper polarity and range.
- Do not touch any non-insulated part of any instrument or equipment.
- Be ensured the zero setting of the instrument is in the right position. Avoid parallax error.
- Before switching on the supply, be sure that the variable point of Variac should be at zero.

Procedure:

I). **Open circuit test**

- Make connections as per the circuit diagram.
- Switch-ON the supply keeping the polarity switch open and autotransformer 2 at zero position and apply rated voltage to the primary winding by using the auto transformer1. Now check the correctness of polarities of the two transformers. If V2 = 0 then polarities of connected transformers are correct i.e. connections are back to back and emf induced in secondaries are in phase opposition but if V2 = 2xKxV1, then secondary emfs are in phase, in that case change the polarities of any one secondary

winding.

- Note the readings of Ammeter (Io), Voltmeter (Vo) & Wattmeter (Wo).

2). **Short circuit Test**

- Keeping the primary supply as it, Switch-ON the supply and close the polarity switch.
- Vary the autotransformer 2 till rated full load current flows through transformers.
- Note the readings of Ammeter (Isc), Voltmeter (Vsc) & Wattmeter (Wsc) while doing so, the values Vo, Io and Wo should not deviate from their earlier readings.

Observations:

Sl. no	Primary voltage (V_0)	Primary current (I_0)	Primary power Iron loss (W_0)	Secondary voltage (V_{sc})	Secondary current (I_{sc})	Secondary power Cu loss (W_{sc})
1	230 V	0.62 A	28*2 = 56 W	18.2 V	4.3 A	70*1 = 70 W

Calculations, Equivalent Circuit and Phasor Diagram:

Calculations:- Short Circuit Test:-

Secondary:-

$$Z_{sc} = \frac{V_{sc}}{I_{sc}} = \frac{18.2}{4.3} = 4.2325\,\Omega$$

$$R_{sc} = \frac{W_{sc}}{I_{sc}^2} = \frac{70}{(4.3)^2} = 3.7858\,\Omega$$

$$X_{sc} = \sqrt{Z_{sc}^2 - R_{sc}^2} = \sqrt{(4.2325)^2 - (3.7858)^2}$$

$$X_{sc} = 1.8925\,\Omega$$

Open Circuit Test:-

Primary:-

$$W_0 = V_0 I_0 \cos\phi_0$$

$$\cos\phi_0 = \frac{W_0}{V_0 I_0} = \frac{56}{230 \times 0.62} = 0.3927$$

$$\boxed{\phi_0 = 66.8769^\circ}$$

$$I_\omega = I_0 \cos\phi_0 = 0.62 \times 0.3927 = 0.24347\,A$$

$$I_\mu = I_0 \sin\phi_0 = 0.62 \times 0.91966 = 0.57019\,A$$

$$* \quad X_0 = \frac{V_0}{I_\mu} = \frac{230}{0.57019} = 403.37431\,\Omega$$

$$* \quad R_0 = \frac{V_0}{I_\omega} = \frac{230}{0.24347} = 944.67490\,\Omega$$

Iron Loss per Transformer $\Rightarrow W_i = W/2 = 28\,W$

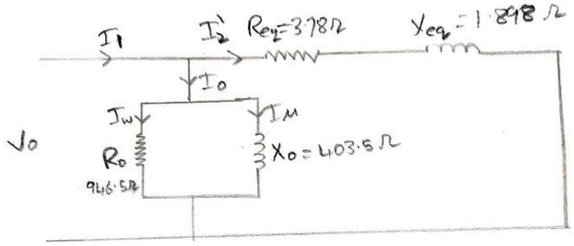
Copper Loss per Transformer $\Rightarrow W_{cu} = W_{sc}/2 = 35\,W$

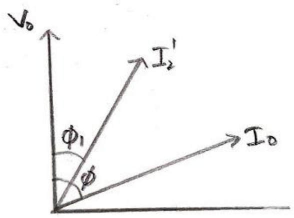
Efficiency:-

$$\%\,\text{efficiency} = \frac{\text{Output power}}{\text{Out power} + \text{Cu loss} + \text{Iron Loss}} \times 100$$

$$= \frac{1\,KVA \times 0.3927}{1\,KVA \times 0.3927 + 28\,W + 35\,W} \times 100$$

$$= \frac{392.7}{455.7} \times 100 = 86.175\,\%.$$





$$\cos\phi_1 = \frac{R_{eq}}{\sqrt{X_{eq}^2+R_{eq}^2}}$$

$$\Rightarrow \phi_1 = 26.6^\circ$$

$$\phi = 66.9^\circ$$

DISCUSSION

1. Why two transformers, and that too identical are needed in this test ?

The Sumpner's test is just another way of determining transformer efficiency with the added benefit of extrapolating voltage regulation and heating under loaded conditions without having to do full load tests.

We need identical transformers because often in large distribution substations you are required to have two or more transformers running in parallel to accommodate the required peak load. You would order these transformers from a single manufacturer and specify that they be identical with the same impedance. This is to avoid wasting power in circulating currents between the transformers.

2. What are the advantages of the test?

1. Power expenditure for performing the test is very less (equal to losses of both the machines)
2. Big capacity transformers can be tested.
3. Core loss, copper loss, efficiency, voltage regulation, temperature rise can be determined.

Conclusion

We have successfully done the back-to-back test or Sumpner's test for two 1-phase transformers. We have also done no-load test and short-circuit test by taking different voltmeter and ammeter readings and have found the required parameters required to draw the equivalent diagram and have also drawn the phasor diagram. So, we have successfully accomplished our aim to determine the equivalent circuit parameters, phasor diagram & efficiency of a given pair of 1-phase Transformers by conducting Back-to-Back test (Sumpner's test).