EEL101: Basic Electrical Lab

Experiment No. 07

Open Circuit and Short Circuit Tests of Single-Phase Transformer

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OBJECTIVE:

1) To perform open circuit and short-circuit tests on a single phase transformer to calculate its equivalent circuit parameters, and to find the efficiency at various loads.

2) Draw efficiency vs load curve, find out the load at which the efficiency is maximum.

3) Draw the approximate equivalent circuit of transformer referred to LV side by using the calculated parameters.

APPARATUS REQUIRED			
Sl. No.	Apparatus	Technical Specification	Quantities
1			
2			
3			
4			
5			
6			

THEORY

Transformer Testing

In order to determine the efficiency, circuit constant and voltage regulation of a given transformer, two types of tests are performed open circuit test and short circuit test.

I. Open Circuit Test

This test is performed to measure the no load current and the iron losses of the transformer. Generally, HT side is kept open-circuited and the rated voltage at rated frequency is applied to LT winding. The wattmeter, ammeter and the voltmeter are connected to their primary winding. The connections are made as shown in Figure 1. Rated voltage is supplied through an auto-transformer. The readings of wattmeter, voltmeter and ammeter are noted.

Let W_0, V_0 and I_0 be the readings of wattmeter, voltmeter, and ammeter respectively.
The iron losses,

$$Pi = W_0 \tag{1}$$

$$W_0 = V_0 I_0 \cos\phi_0 \tag{2}$$

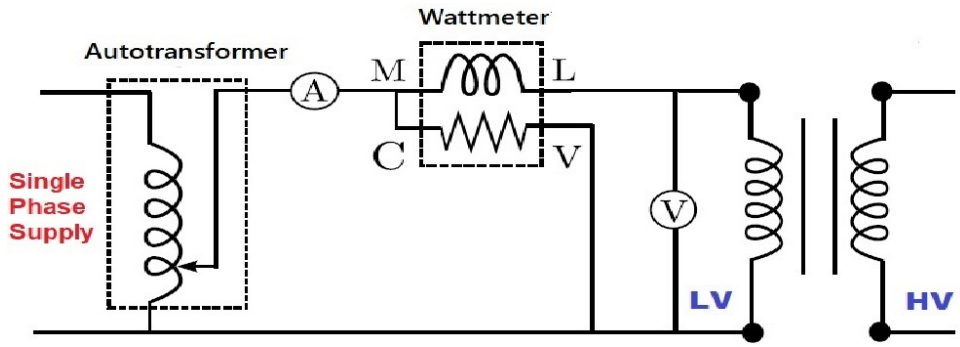

Figure 1: Open Circuit Test on Transformer

The no-load power factor is

$$\cos\phi_0 = \frac{W_0}{V_0 I_0} \tag{3}$$

The various parameters can be calculated as under

$$I_w = W_0/V_0 = I_0 \cos\phi_0 \tag{4}$$

$$I_m = \sqrt{(I_0^2 - I_w^2)} = I_0 \sin\phi_0 \tag{5}$$

$$R_0 = V_0/I_w \tag{6}$$

$$X_0 = V_0/I_m \tag{7}$$

where, I_m = Magnetizing component current, I_w = Working component current

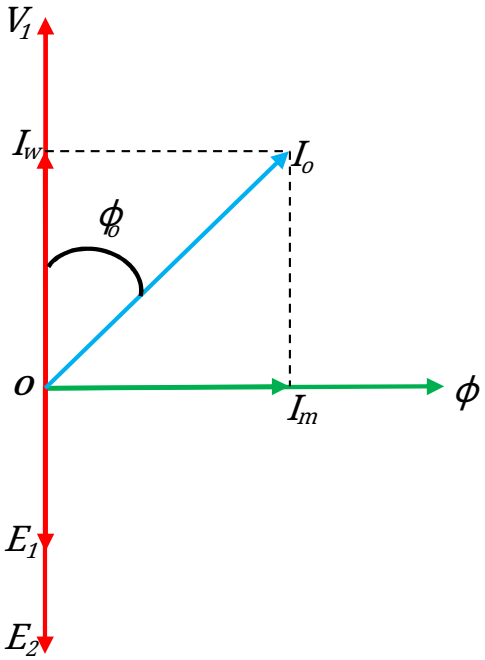

Figure 2: Phasor Diagram of Open Circuit Test

Figure 2 shows the phasor diagram of the transformer when an open circuit test is performed. This test gives the core loss of transformer and shunt parameter of the equivalent circuit. The iron losses measured by the open circuit

test is used for calculating the efficiency of the transformer. Hence, calculated R_0 and X_0 are the shunt parameters of the transformer equivalent circuit.

II. Short Circuit Test

This test is carried out to determine the equivalent resistance and the leakage reactance of the transformer. The connections are made as shown in Fig. 3. The LT winding is short circuited. A low voltage is applied to HT side using an auto transformer. This voltage is adjusted so that the full-load current flows through the HT and LT windings. Since low voltage is applied, the iron loss is negligibly small as compared to the copper loss. Therefore, the wattmeter reading gives the copper loss.

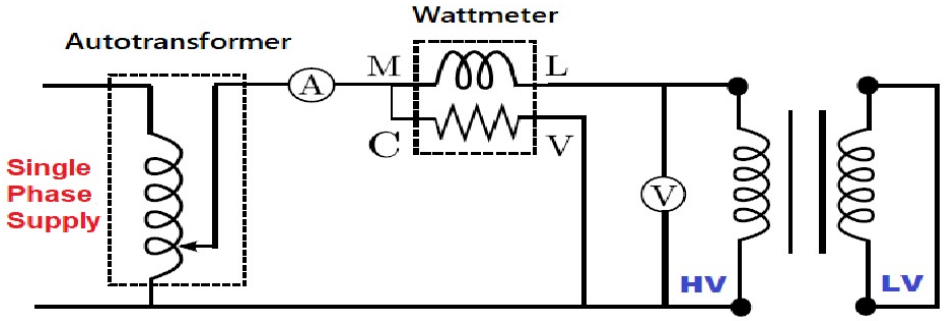

Figure 3: Short Circuit Test on Transformer

Let W_{sc}, V_{sc}, and I_{sc} be the reading of wattmeter, voltmeter and ammeter respectively.

$$R = \frac{W_{sc}}{{I_{sc}}^2} \tag{8}$$

$$Z = \frac{V_{sc}}{I_{sc}} \tag{9}$$

$$X = \sqrt{Z^2 - R^2} \tag{10}$$

Where, R is the equivalent resistance, X is the equivalent leakage reactance and Z is the equivalent impedance. These parameters refer to the winding on which measurements are made. From these, the various parameters as referred to other winding can also be calculated.

P_o = VI $\cos\phi$ (Output Power)

Efficiency of the transformer is given by,

$$Efficiency = \frac{Outputpower}{OutputPower + Ironloss + Copperloss} pu$$

$$\eta = \frac{P_0}{P_0 + W_0 + W_{sc}}$$

Our next objective: - For any other load, which is factor of x of full load the current will be changed. The core/iron loss will be constant but the copper loss will be changed by a factor x^2. Therefore, the efficiency is given as,

By taking different values of x, the efficiency of the transformer can be calculated using the above equation. An efficiency curve taking load factor x on horizontal axis and efficiency on vertical axis should be drawn. You should roughly get a curve as shown in Fig. 4.

Condition for efficiency to be maximum

$$\eta_x = \frac{xP_0}{(xP_0 + W_0 + x^2 W_{sc})} \tag{11}$$

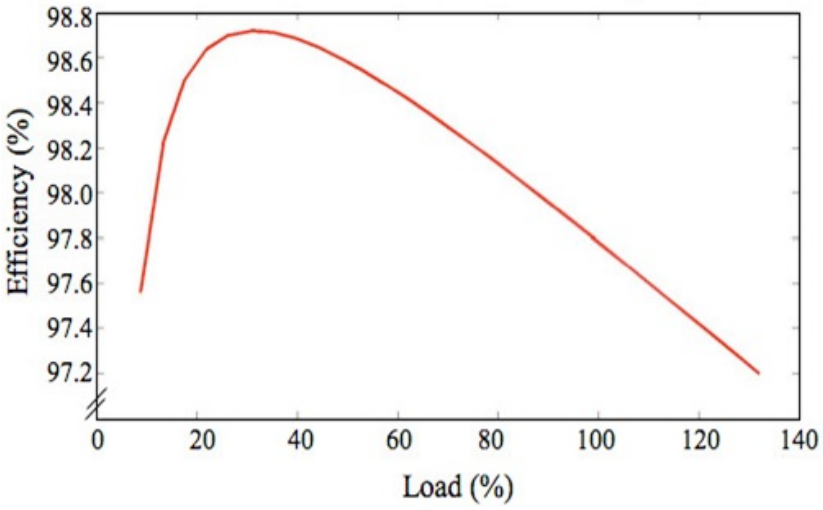

Figure 4: Efficiency Curve for a Transformer

$$\eta_x = \frac{P_0}{P_0 + \frac{W_0}{x} + xW_{sc}} \tag{12}$$

In the above equation, the n_x would be maximum if the denominator of the R.H.S. expression is minimum and for this, its first derivative should be zero i.e.

$$\frac{W_0}{x^2} + W_{sc} = 0 \tag{13}$$

$$W_0 = W_{sc}(Ironlosses = Copperlosses) \tag{14}$$

Therefore, a transformer has maximum efficiency at a load (x), when copper losses are to equal iron losses. From the curve (Fig. 4) obtain the value of X_m and verify that

$$W_0 = X_m^2 W_{sc} \tag{15}$$

PROCEDURE: - The stepwise procedure for conducting the open circuit test and short circuit test on a single phase transformer is given below:

(a) Open-Circuit Test: -

1) Connect the circuit as shown in Fig. 1.

2) Before switching-on the supply, ensure that the variac is at a low output voltage. Now, switch on the supply.

3) Adjust the variac output voltage to the rated voltage of the transformer.

4) Record no-load current, voltage applied and no load power from this set up and switch-off the supply.

(b) Short Circuit Test: -

1) Connect the circuit as shown in Fig. 3.

2) Before switching on the supply, ensure that variac is set at zero value. Now, switch-on the supply.

3) Increase the voltage applied slowly, so that the current flowing in the transformer winding equals the rated value.

4) Record the readings of ammeter, voltmeter and wattmeter; which correspond to short circuit current, corresponding applied voltage and power with full load flowing under short circuit conditions respectively. Then switch—off the supply.

OBSERVATIONS AND CALCULATIONS:

Observations for Open - Circuit Test			
Sl. No.	Voltage applied	No load current	Iron Loss
1			

Observations for Short - Circuit Test			
Sl. No.	Voltage applied	Short Circuit current	Copper Loss
1			

CALCULATIONS:

The calculations for this experiment can be done using the formula under theory. The Calculations of efficiency at various loads should be recorded in the following form. Rated output of the transformer = P_0

Calculations of η from SC and OC tests results				
Sl. No.	x	xP_0	x^2W_{sc}	η
1				
2				
3				
4				
5				

RESULTS: The approximate equivalent circuit parameters (referred to LV side) and rated value of losses for the transformer have been calculated and the values are as follows:

R_0 = ... X_0 = ... Req = ... Xeq = ... $IronLoss$ =..... $CopperLoss$ =.....

PRECAUTIONS:

Following precautions are important for conducting this experiment:

1) All connections should be tight and clean.

2) Special care should be taken while selecting the ranges of the meters for conducting Short-circuit test and open-circuit test.

3) While conducting the short—circuit test, the voltage applied should be initially set at zero, and then increased slowly.

Draw the approximate equivalent circuit of transformer referred to LV side