EE234 Experiment 2: Open Circuit and Short Circuit Tests on a Single Phase Transformer

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1 Overview of the experiment

- The aim of this experiment is to understand working principle of a transformer.
- Furthermore, this experiment expects us to calculate the equivalent circuit parameters of a transformer through open circuit and close circuit tests and to evaluate efficiency and regulation with various loads.

2 Procedure

2.1 No-Load Test

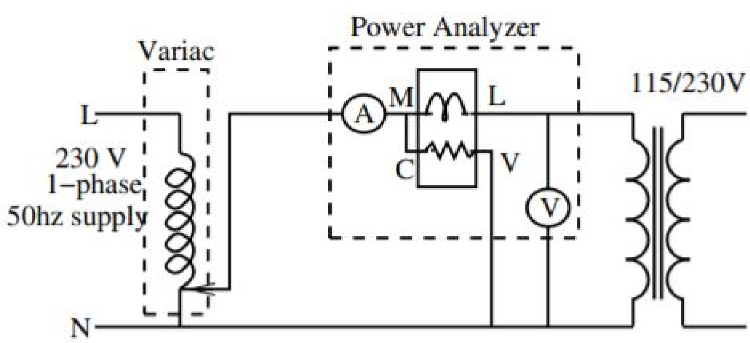


Figure 1: No-Load Test Connections

- Connect the circuit with the **HV side left open**.

- Apply voltage to the LV side in steps up to the rated voltage and for each case record primary current and power drawn from the circuit. Observe the current waveform on the power analyzer.
- Increase the applied voltage to approximately 110% of the rated voltage and repeat the above step.
- Reduce the output voltage of the variac to zero and switch off the power supply.

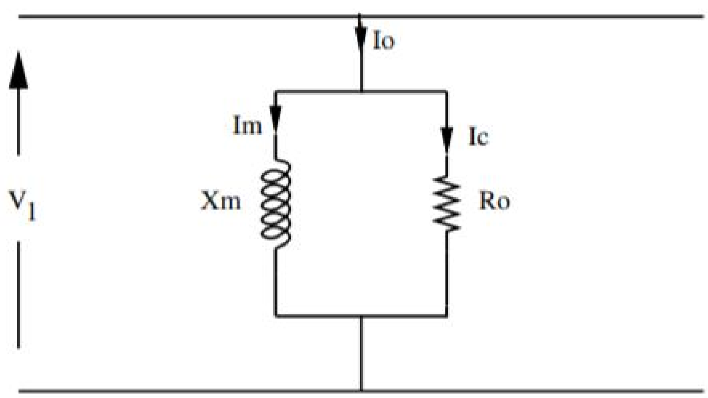


Figure 2: No-Load Test Equivalent Circuit

2.2 Short-Circuit Test

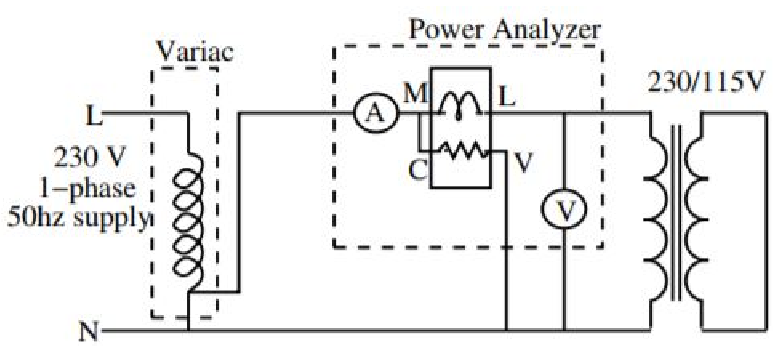


Figure 3: Short Circuit Test Connections

- Connect the circuit with the **LV side shorted**.

- Set the autotransformer output to zero.
- Adjust the output of the autotransformer such that rated current flows through the windings. Record the applied voltage, current and input power.
- Reduce the output voltage of the autotransformer to zero and switch off the power supply.

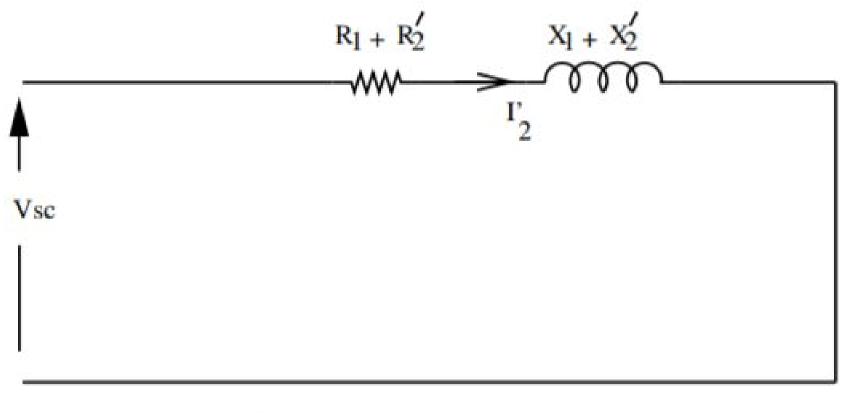


Figure 4: Short Circuit Test Equivalent Circuit

3 Observations and Calculations

3.1 Transformer Ratings

Apparent Power	2000 VA
HV Voltage	230 V_{RMS}/50 Hz
HV Current	9 A
LV Voltage	115 V_{RMS}/50 Hz
LV Current	17.44 A

3.2 No-Load Test

The following table summarizes the result obtained:

Voltage(V_{rms})	Current(mA)	Power(mW)
25.73	39.59	789.0
50.13	70.15	2826.0
75.0	110.80	6034.0
100.0	186.53	10307.0
115.0	293.3	13759.0
126.5	451.5	16825.0

We calculate the magnetizing inductance(X_m) and core resistance(R_c) with reference to LV side.

$$cos\phi = \frac{P_c}{I_{oc} \times V_{oc}}$$

$$\implies cos\phi = 0.408$$

$$R_o = \frac{V_{oc}}{I_{oc} \times cos\phi} = 0.96k\Omega$$

$$X_m = \frac{V_{oc}}{I_{oc} \times sin\phi} = 0.43k\Omega$$

Note that these values are referred with respect to LV side.

3.3 Short-circuit Test

The Following table summarizes the result obtained:

V_{sc}	11.662 V
I_{sc}	8.954 A
Power	96.28 W

We calculate the winding resistance and reactance referred to HV side.

$$cos\phi = \frac{P_c}{I_{oc} \times V_{oc}} = 0.922$$

$$Z_{sc} = \frac{V_{sc}}{I_{sc}} = 1.302\Omega$$

$$\implies R_{sc} = Z_{sc} \times cos\phi = 1.201\Omega$$

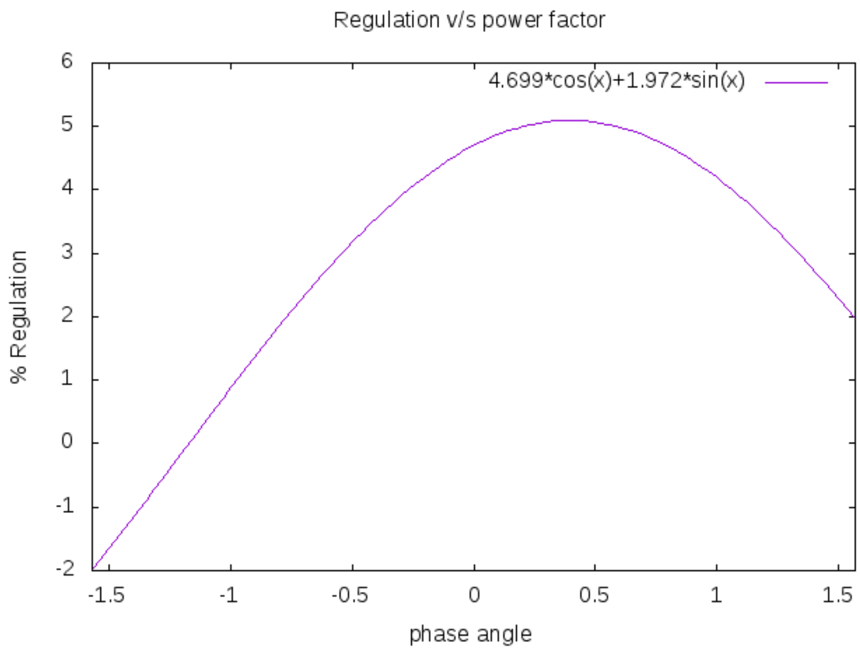
$$and\ X_{sc} = Z_{sc} \times sin\phi = 0.504\Omega$$

3.4 Computing Regulation

For computing regulation following formula was used:

$$\%\ Regulation = \frac{I_2 R_{eq} cos\phi \pm I_2 X_{eq} sin\phi}{V_2} \times 100\%$$

Load	Power factor	Regulation
25%	1	1.175 %
75%	1	3.525 %
100%	1	4.7 %
25%	0.6 lag	1.099 %
75%	0.6 lag	3.300 %
100%	0.6 lag	4.400 %
25%	0.6 lead	0.310 %
75%	0.6 lead	0.932 %
100%	0.6 lead	1.242 %



3.5 Computing Efficiency

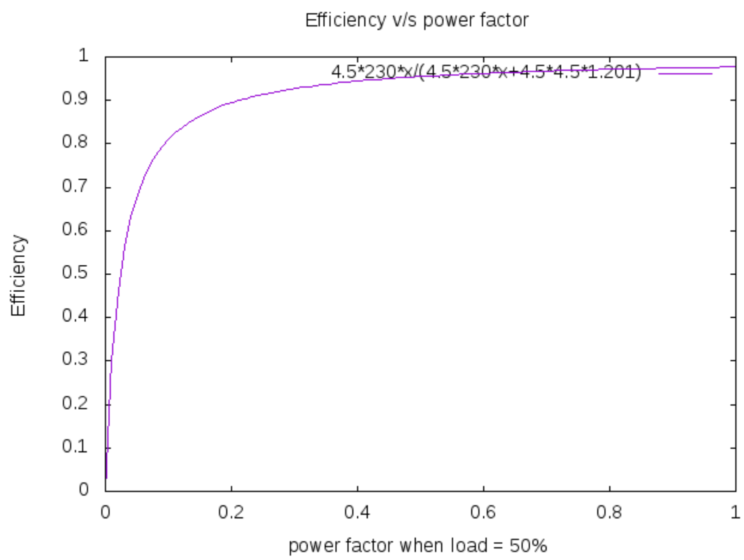
For calculating the efficiency following formula is used:

$$\eta = \frac{Output\ Power}{Output\ Power + Copper\ losses}$$

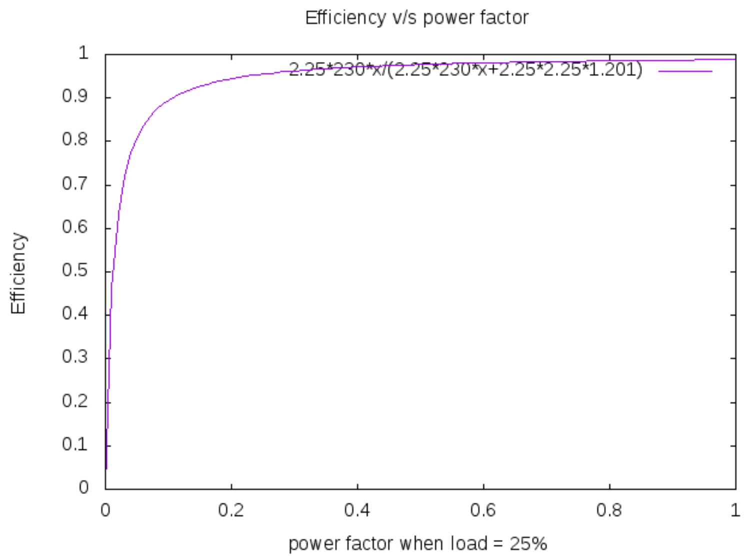
For calculating the power losses, we have: $I_l \times R_{sc}$

$$\eta = \frac{V_r I_r x \times cos\theta}{V_r I_r x \times cos\theta + x^2 I_r R_{sc}}$$

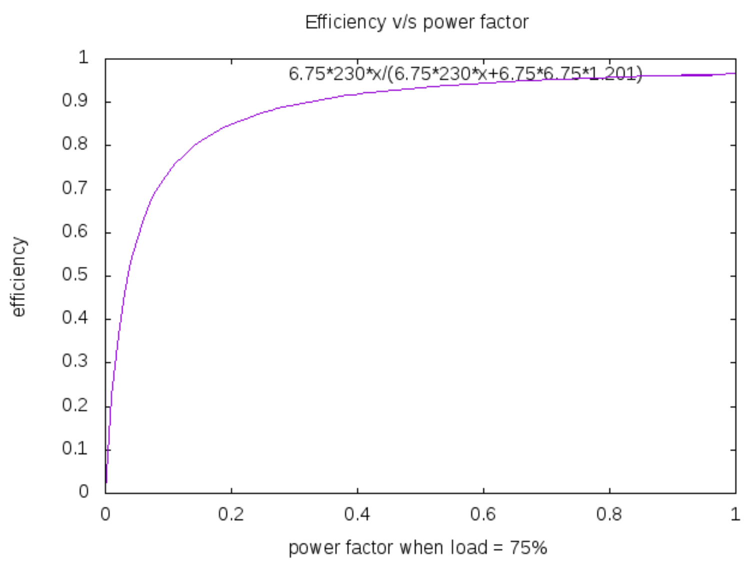
Load	Power factor	Efficiency
25%	1	99.480%
50%	1	97.704%
75%	1	96.595%
25%	0.8 lag	98.553%
50%	0.8 lag	97.146%
75%	0.8 lag	95.78%
25%	0.6 lead	98.079%
50%	0.6 lead	96.231%
75%	0.6 lead	94.451%



Efficiency at 50 percent load



Efficiency at 25 percent load



Efficiency at 75 percent load

4 Answers

1. For the open circuit test HV side is left open and input is applied to the low voltage side. Applying input to high voltage requires more insulations and higher security concerns for the operators. Therefore it is customary

to use HV side as open circuited part and input is applied at the LV side of the transformer.

2. 40KVA implies the power rating of the transformer. It is the product of rms value of rated voltage and current. 440V/11KV indicated the rated voltage of LV and HV respectively. 50 Hz is the frequency of applied voltage on primary and secondary side that is the operating frequency of the transformer.

3. Initially, at voltage value of 50 percent of rated volatege transformer is in linear region. As the voltage is increased to rated value transformer approaches saturation and we observe a distorted output.

4. A load of capacitive nature can lead to a negative regulation.

5. We have E approximately equal to V which is

$$V = 4.44FN\phi \tag{1}$$

   So, as the supply voltage in India is provided at frequency of 50 Hz therefore the rated voltage will decrease by corresponding factor. $V = 110 * 50/60 = 91.67V$

6. No load current is due to core losses which are relatively small compared to standard loads, therefore leading to higher value of current.

7. Again using the formula for rated voltage as in Q5 we observe that a high frequency with constant rated voltage will lead to decrease in N therefore leading to a reduction in size.

8. In order to have a maximum power transmission we need to match the device impedance with the load impedance. This idea is also used in transformers to minimize the reflected signal. This is known as impedance matching transformer. These are used in Televisions.