EE 340L – Experiment 4: Single-Phase Two-Winding Transformer

The Transformer Bank in Fig. 1 below consists of three independent power transformers. The polarity of each winding is indicated by a small dot on the module front panel. Electronic fuses protect the primary and secondary windings of each transformer against over-currents. Fuse status lamps on the module front panel turn on when the electronic fuses detect an overcurrent condition.

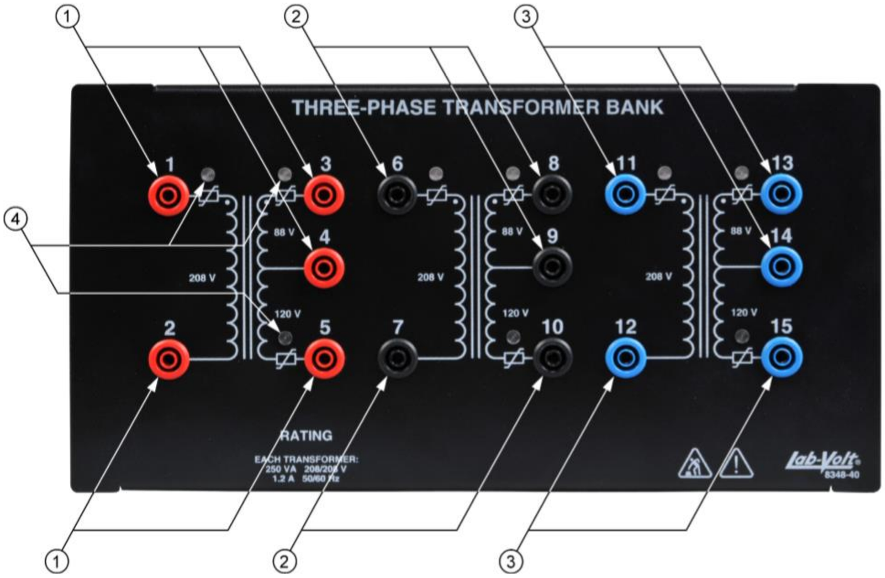


Fig. 1

In this experiment we consider one of these transformers, say the one to the left with red safety banana jacks. We use secondary terminals 4-5, and ignore terminal 3. In essence, the transformer is designed to convert 208 V down to 120 V, and can carry up to 250 VA. Hence the rated currents on the primary and secondary sides are respectively equal to 250/208 = 1.2 A and 250/120 = 2.08 A.
The transformer rating is as follows:

- Apparent power S = 250 VA,
- Primary voltage = 208 V,
- Secondary voltage = 120 V (across terminals 4-5), or 88 V (across terminals 3-4), or 208 V (across terminals 3-5)

A picture of this transformer is shown in Fig. 2 below along with the dimensions of the ferromagnetic core.

Length: 4.5 in, Height: 3.25 in, depth: 2 in.

Fig. 2

A. Transformer turn ratio:

The turn ration is achieved by simply applying the rated voltage to the primary winding (across 1-2) and measuring the induced voltage on the secondary winding (across 4-5). The utility voltage that is available may be a bit less or a bit more that 208 V which is just fine. Record these values:

Vp = …… V

Vs = …….V

Turn Ratio = a = Vp/Vs = ……….

B. Transformer Polarity:

Transformer polarity can be verified can be verified by displaying the instantaneous values of both voltages on the same graph: If they are in phase, then the dot markings are at terminals 1 and 4. If they are 180 degrees out of phase, then the dot markings are at terminals 1 and 5. Take a photo of the voltage waveforms of the voltage of terminal 1 w.r.t. 2 and that of terminal 4 w.r.t. 5 and attach below. Repeat this step by taking the voltage of terminal 5 w.r.t. 3.

C. Copper Winding Resistance:

The resistance of the windings can be measured by a simple multi-meter. Record the copper resistance of the primary winding across terminals 1-2. Repeat the same for the secondary winding across terminals 4-5.

$R_{primary}$ = …………Ω

$R_{secondary}$ = …………Ω

D. No load Test

The no-load test allows you to determine the transformer shunt impedance (i.e., the magnetizing reactance Xm and core loss resistance Rc (when referred to the primary side). The test consists of applying near rated voltage (whatever value is available at the time) to the primary winding while the secondary winding is open (i.e., with no load connected to it), and measuring the current flow into the transformer (i.e., excitation current Iex), real power P and reactive power Q supplied to the transformer. Conduct such a test and record these measurements:

Vp = ………V

Iex = …….A

P = ………W

Q = ……. VAR

Then Rc and Xm can simply be computed by

$$R_C = \frac{V_p{}^2}{P} = \text{..........}\Omega$$

$$X_M = \frac{V_p^{\ 2}}{Q} = \ldots\ldots\ldots\ldots\Omega$$

Excitation current waveform: Display the waveforms of the supply voltage and excitation current on the same graph (since this current is very small, increase to current scale to a large value in order to view its waveform). Display a photo of these waveforms below, and note the distortion in the current. This is an indication that the transformer is designed to operate past the linear region and more under partial saturation.

E. Short-Circuit Test

The short-ciruit test allows you to determine the transformer series impedance (i.e., the equivalent series reactance Xs and copper resistance Rs. The test consists of applying a **small** voltage to the primary winding while the secondary winding is shorted out (i.e., terminals 4-5 connected together), and measuring the primary voltage, current flow into the transformer, real power P and reactive power Q supplied to the transformer. Conduct such a test and record these measurements.

Very Important: Make absolutely sure that you use the variable voltage source and that it is set at zero initially. Then increase the voltage in small increments till the source (i.e., primary) current reaches its rated value of 1.2 A, the stop and record the values below. Applying a larger voltage will lead to an overload that causes fuses blow, and circuit breakers to open.

Vp = …. V

Ip = 1.2 A

P = ………W

Q = ……. VAR

Then Rs and Xs can simply be computed by

$$R_S = \frac{P}{I_P{}^2} = \ldots\ldots\ldots\ldots\Omega,$$

$$X_S = \frac{Q}{I_P{}^2} = \ldots\ldots\ldots\ldots\Omega.$$

Calculate ($R_{primary} + a^2 R_{secondary}$) = …………Ω

Then compare the result to R_S. What is the error between the two?

Error = ………..%

F. Load Test.

Now connect a resistive load (i.e., with unity power factor) across the secondary terminals and measure both the primary and secondary voltages and currents as indicated Figure 2 below. Start 1200 Ω, then decrease the load resistance in increments according to the attached table below. For each load resistance, record Ip = I1, Pp, Is = I2, Vs = E2, Ps, and calculate the transformer efficiency, while Vp = E1 is equal to the utility supply which should be near 208 V. Fill in the Table below. Then compute (afterwards) the transformer efficiency *η* and voltage regulation (VR) under each load. Record Vp only once since this changes very little during the experiment.

Vp = ………… V

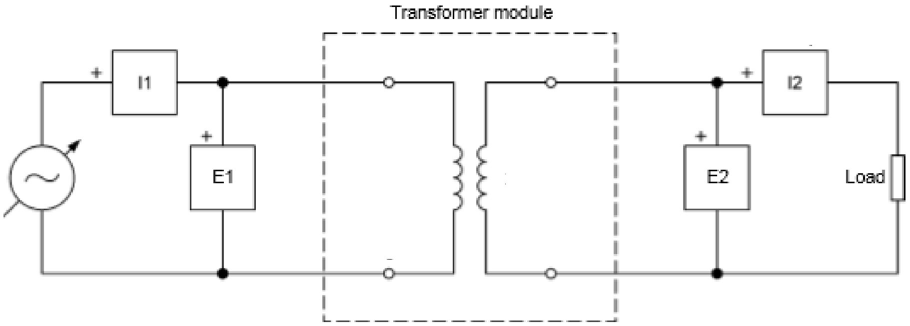


Fig. 2

R (Ω)	Ip (A)	Pp (W)	Vs (V)	Ps (W)	η= (Ps/Pp) (%)	VR = (120-Vs)/Vs (%)
0				0	0	0
1200						
600						
400						

300						
240						
200						
171						
150						
133						
120						
100						
86						
75						
86						
80						
67						
57						

Repeat the above procedure with an R-X_L load with 70.7% power factor. This can be obtained by placing an inductive reactance in parallel with the resistance with $R = X_L$.

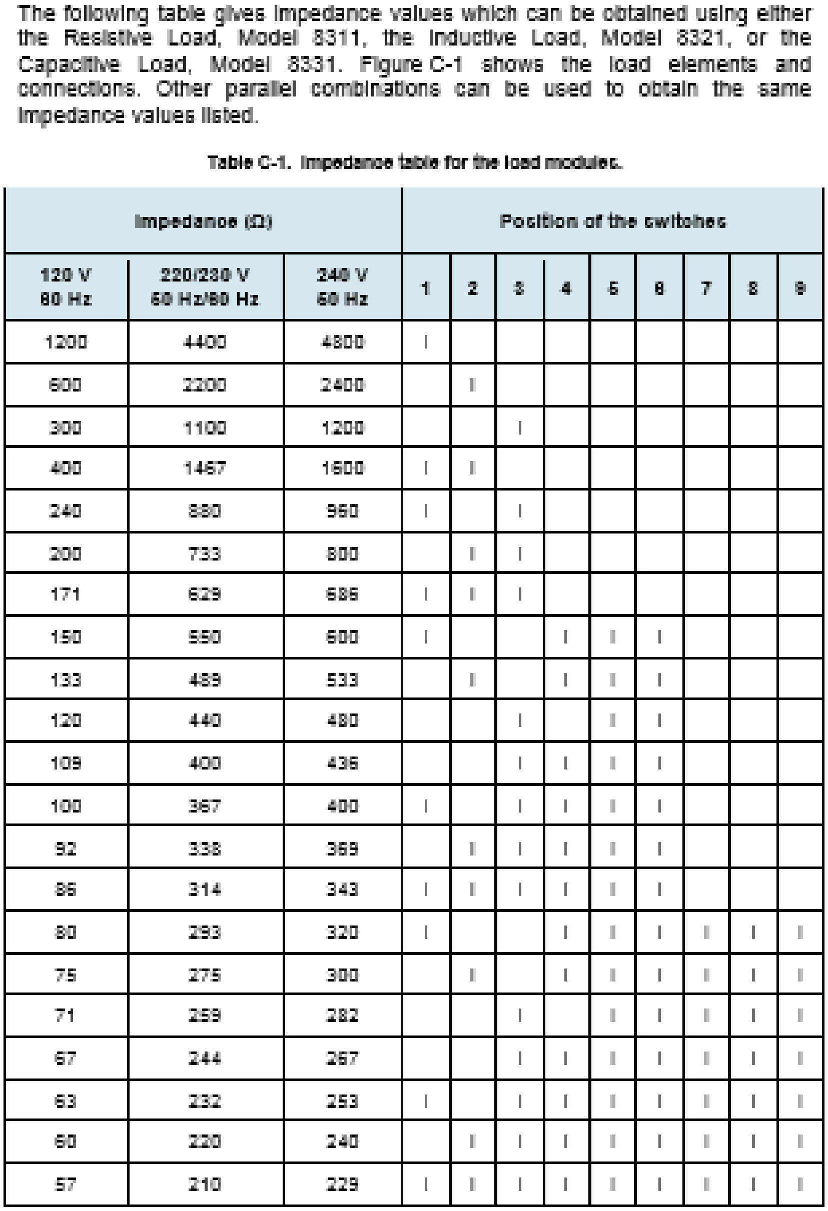
R & X_L (Ω)	**Ip (A)**	**Pp (W)**	**Vs (V)**	**Ps (W)**	**η= (Ps/Pp) (%)**	**VR = (120-Vs)/Vs (%)**
0				0	0	0
1200						
600						
400						
300						
240						
200						
171						
150						
133						
120						
100						
86						
75						
86						
80						
67						
57						

Finally plot the following:

a) Transformer efficiency as a function of load real power for both unity and 70.7% power factor load on the same graph.

b) Transformer voltage regulation as a function of load real power for both unity and 70.7% power factor load on the same graph.

Please use Excel or MATLAB (i.e., hand-drawn graph are not acceptable).



The following table gives impedance values which can be obtained using either the Resistive Load, Model 8311, the Inductive Load, Model 8321, or the Capacitive Load, Model 8331. Figure C-1 shows the load elements and connections. Other parallel combinations can be used to obtain the same impedance values listed.

Table C-1. Impedance table for the load modules.

Impedance (Ω)			Position of the switches								
120 V 60 Hz	220/230 V 50 Hz/60 Hz	240 V 50 Hz	1	2	3	4	5	6	7	8	9
1200	4400	4800	I								
600	2200	2400		I							
300	1100	1200			I						
400	1467	1600	I	I							
240	880	960	I		I						
200	733	800		I	I						
171	629	686	I	I	I						
150	550	600	I			I	I	I			
133	489	533		I		I	I	I			
120	440	480			I		I	I			
109	400	436			I	I	I	I			
100	367	400	I		I	I	I	I			
92	338	369		I	I	I	I	I			
86	314	343	I	I	I	I	I	I			
80	293	320	I			I	I	I	I	I	I
75	275	300		I		I	I	I	I	I	I
71	259	282			I		I	I	I	I	I
67	244	267			I	I	I	I	I	I	I
63	232	253	I		I	I	I	I	I	I	I
60	220	240		I	I	I	I	I	I	I	I
57	210	229	I	I	I	I	I	I	I	I	I