Energy Conversion Laboratory:
Experiment Report
Experiment #2: Lab 2: Single Phase Transformers
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Objective:

The objective for this lab was to determine and understand the different models of transformer circuits, while examining voltage regulation, efficiency and the polarity within single phase transformers. Here the task is to better understand how these electrical concepts act within these circuits.

Data and Tables:

Part A: Tables:

Figure 1	V1 (V)	V2 (V)
Measurement	190.9	125.3

Table 2. Voltage measurement

Figure 2	V1 (V)	V2 (V)
Measurement	190.8	125

Table 3. Voltage measurement

Figure 3	V1 (V)
Measurement	126.2m

Table 4. Voltage measurement

Part B: Tables:

Figure 4	Voltage (V)	Current (A)	Power (W)
Measurement	125.2	0.35 RMS	25.22

Table 5. Open circuit test.

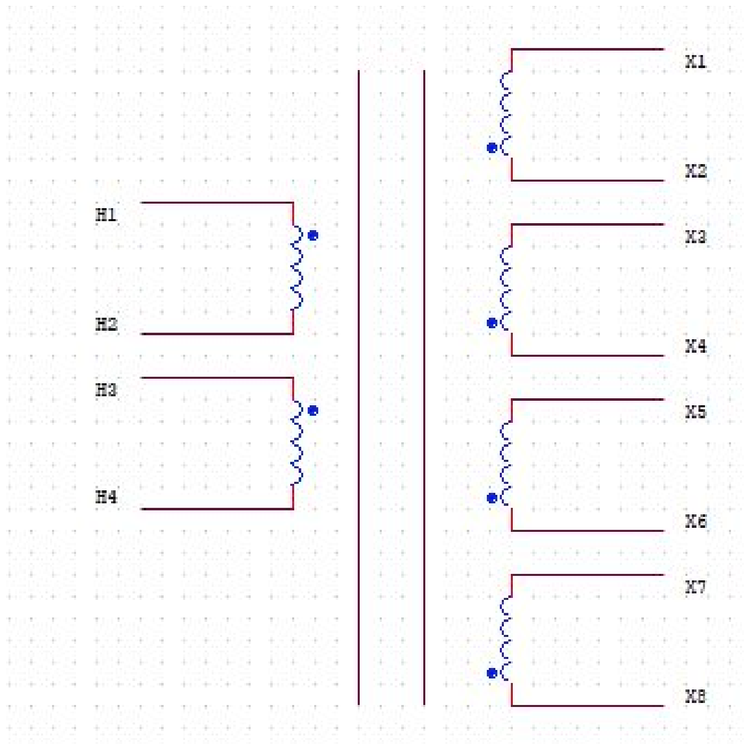
Part C: Tables

Figure 5	Voltage (V)	Current I1 (A)	Current I2 (A)	Power (W)
Measurement	3.03V	3.96A	4.17A	11.25 W

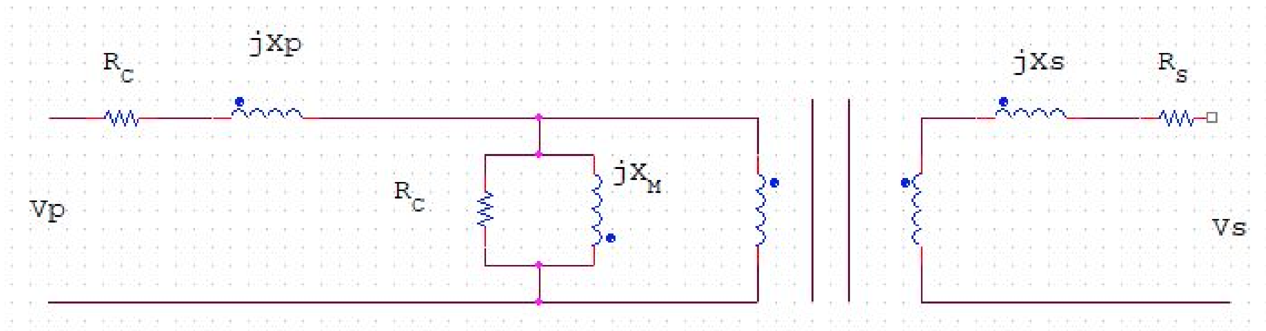
Table 6. Short circuit test.

Report Questions

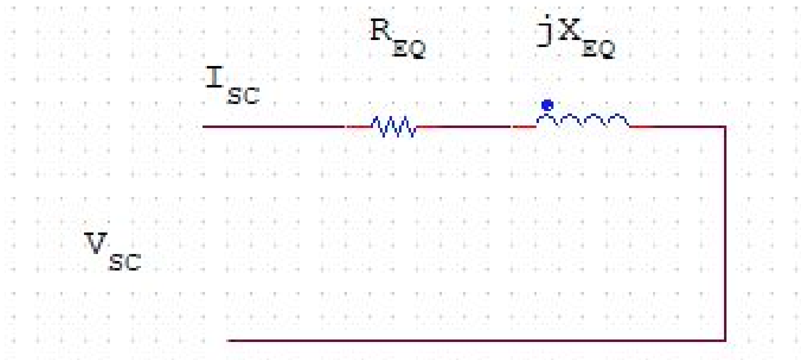
1.) Draw a diagram of T-1000A and place the polarity marks (dot).



2.) Draw the transformer equivalent circuit.



3.) Draw the transformer equivalent circuit for short circuit test. Calculate the values of Req and Xeq from short circuit test.



$$|Zsc| = \frac{Vsc}{Isc} = \frac{3.03V}{3.96A} = 0.765\Omega$$

Since PF = P/S and S =VI* you get the expression below

$$PF = Cos\theta = \frac{Psc}{Vsc * Isc} = \frac{11.25}{3.03V * 3.96} = 0.093$$

$$Cos^{-1}(PF) = \theta$$

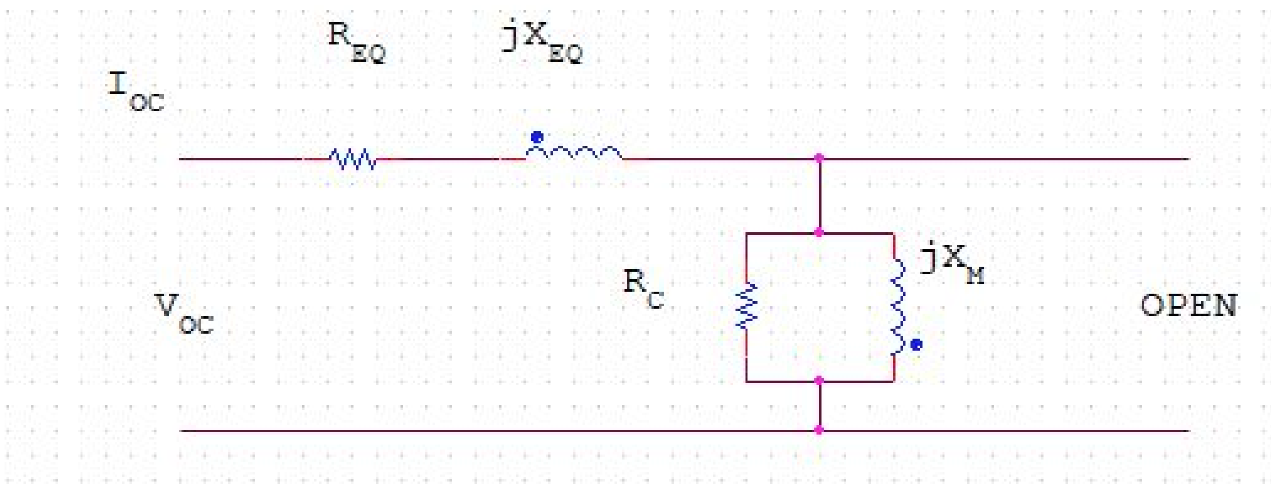
$$\theta = Cos^{-1}(0.09376)$$

$$\theta = 20.35^{\circ}$$

$$\boxed{|Req| = |Zsc|cos\theta = |0.0765\Omega|cos(20.35^{\circ}) = 0.07173\Omega}$$

$$|Zeq| = |Zsc|sin\theta = |0.0765\Omega|sin(20.35^{\circ}) = 0.2660\Omega$$

4.) Draw the transformer equivalent circuit for open circuit test. Calculate the values of Rc and Xm. Calculate Rc and Xm referred to high voltage side.



$$Ioc = 0.35A$$

$$Voc = 125.2V$$

$$P = 25.22W$$

$$S = VI^* = (125.2V)(0.35A) = 43.82VA$$

$$S = 43.82VA$$

$$Rc = \frac{Voc^2}{Poc}$$

$$Rc = \frac{(125.2V)^2}{25.22W} = 621.53\Omega$$

$$Rc = 621.53\Omega$$

$$S = \sqrt{P^2 + Q^2}$$

Manipulating the last equation to find reactive power instead of apparent power:

$$Qoc = \sqrt{Soc^2 - Poc^2} = \sqrt{43.82VA^2 - 25.22W^2}$$

$$Qoc = 35.8VARS$$

$$Xm = \frac{Voc^2}{Qoc}$$

$$Xm = \frac{125.2^2}{25.22} = 437.85\Omega$$

$$\boxed{Xm = 437.85\Omega}$$

$$\boxed{Rc = 621.53\Omega}$$

5.) Assume a rated load (I = 4.17A) is connected to the high voltage side (V = 240 V) of the transformer. Calculate % voltage regulation, efficiency from the following power factor.

a.) 0.6 PF lagging

$$Vregulation = \left(\frac{\frac{Vp}{a} - Vs_{FL}}{Vs_{FL}}\right) * 100$$

$$Vs_{NL} = Vp = Vs_{FL} + Is(Req + jXeq)$$

$$PF = 0.6Lagging$$

$$cos^{-1}(0.6) = -53.13^{\circ}$$

$$Is = 4.17\angle - 53.13^{\circ}$$

$$\frac{Vp}{a} = 240\angle 0^{\circ} + 4.17\angle - 53.13^{\circ}(0.717\Omega + j0.266\Omega) = 243.06\angle - 0.21^{\circ}V$$

$$Vs_{NL} = \frac{Vp}{a}$$

$$Vs_{NL} = 242.7\angle - 0.41^{\circ}V$$

$$Vregulation = \frac{(Vs_{NL} - Vs_{FL})}{Vs_{FL}}(100)$$

$$Vregulation = \frac{(242.7 - 240)}{240}(100)$$

$\boxed{Vregulation = 1.125}$ %

θ = inverse(cos(PF))

$cos^{-1}(0.6) = -53.13^{\circ}$

The current's angle is found from the PF

$Is = 4.17\angle - 53.13^{\circ}$

$$Pcore = (\frac{(\frac{Vp}{a})^2}{Rc})$$

$$Pcore = \frac{242.7^2}{621.53}$$

$Pcore = 94.77W$

$Pcu = (Is^2)(Req) = (4.17)^2(0.717)$

$Pcu = 12.47W$

$$\eta = \frac{(Vs)(Is)(cos\theta)}{(Pcu + Pcore + (Vs)(Is)(cos\theta))}(100)$$

$$\eta = \frac{(240)(4.17)(cos(-53.13^{\circ}))}{(12.47 + 94.77 + (240)(4.17)cos(-53.13^{\circ}))}(100)$$

$\boxed{\eta = 84.85}$ %

b.) 0.8 PF lagging

$\theta = cos^{-1}(PF) = -36.87$

From the angle obtained by the PF we get the current expression for Is

$Is = 4.17\angle - 36.87^{\circ}$

$$\frac{Vp}{a} = 240\angle 0^{\circ} + 4.17\angle - 36.873^{\circ}(0.717\Omega + j0.266\Omega) = 243.06\angle 0.21$$

$Vs_{NL} = 243.06\angle - 0.21^{\circ}V$

$$Vregulation = \frac{(Vs_{NL} - Vs_{FL})}{Vs_{FL}}(100)$$

$$Vregulation = \frac{(243.06 - 240)}{240}(100)$$

$\boxed{Vregulation = 1.275}$ %

$Pcore = 94.77W$, $Pcu = 12.47W$

$$\eta = \frac{(Vs)(Is)(cos\theta)}{(Pcu + Pcore + (Vs)(Is)(cos\theta))}(100)$$

$$\eta = \frac{(240)(4.17)(cos(-36.87^{\circ}))}{(12.47 + 94.77 + (240)(4.17)cos(-36.87))}(100)$$

$\boxed{\eta = 88.2}$ %

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c. 1.0 PF

$cos^{-1} = 0^{\circ}$

$Is = 4.17\angle 0^{\circ}$

$$\frac{Vp}{a} = 240 + 4.17\angle 0^{\circ}(0.717\Omega + j0.266\Omega)$$

$$Vs_{NL} = \frac{Vp}{a}$$

$$Vs_{NL} = 243\angle 0.26^{\circ}$$

$$Vregulation = \frac{(Vs_{NL} - Vs_{FL})}{Vs_{FL}}(100)$$

$$Vregulation = \frac{(243 - 240)}{240}(100)$$

$$\boxed{Vregulation = 1.25\ \%}$$

$$cos^{-1}(1) = 0^{\circ}$$

$Pcore = 94.77W$, $Pcu = 12.47W$

$$\eta = \frac{(Vs)(Is)(cos\theta)}{(Pcu + Pcore + (Vs)(Is)(cos\theta))}(100)$$

$$\eta = \frac{(240)(4.17)(cos0^{\circ})}{(12.47 + 94.77 + (240)(4.17)cos(0^{\circ}))}(100)$$

$$\boxed{\eta = 90.32\ \%}$$

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d. 0.8 PF leading

PF=0.8 Leading

$$cos^{-1}(0.8) = 36.87$$

$$Is = 4.17\angle 36.87^{\circ}$$

$$\frac{Vp}{a} = 240\angle 0^{\circ} + 4.17\angle 36.87^{\circ}(0.717\Omega + j0.266\Omega) = 241.74\angle 0.6V$$

$$Vs_{NL} = 241.74\angle 0.6V$$

$$Vregulation = \frac{(Vs_{NL} - Vs_{FL})}{Vs_{FL}}(100)$$

$$Vregulation = \frac{(241.74 - 240)}{240}(100)$$

$\boxed{Vregulation = 0.725}$ %

$Pcore = 94.77W$, $Pcu = 12.47W$

$$\eta = \frac{(Vs)(Is)(cos\theta)}{(Pcu + Pcore + (Vs)(Is)(cos\theta))}(100)$$

$$\eta = \frac{(240)(4.17)(cos36.87^{\circ})}{(12.47 + 94.77 + (240)(4.17)cos(36.87^{\circ}))}(100)$$

$\boxed{\eta = 88.2}$ %

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e. 0.6 PF leading

PF = 0.6 Leading

$$cos^{-1}(0.6) = 53.13^{\circ}$$

$$Is = 4.17\angle 53.13^{\circ}$$

$$\frac{Vp}{a} = 240 + 4.17\angle 53.13^{\circ}(0.717\Omega + j0.266\Omega)$$

$$Vs_{NL} = \frac{Vp}{a}$$

$$Vregulation = \frac{(Vs_{NL} - Vs_{FL})}{Vs_{FL}}(100)$$

$$Vregulation = \frac{239.11 - 240}{240}(100)$$

$\boxed{Vregulation = -0.37}$ %

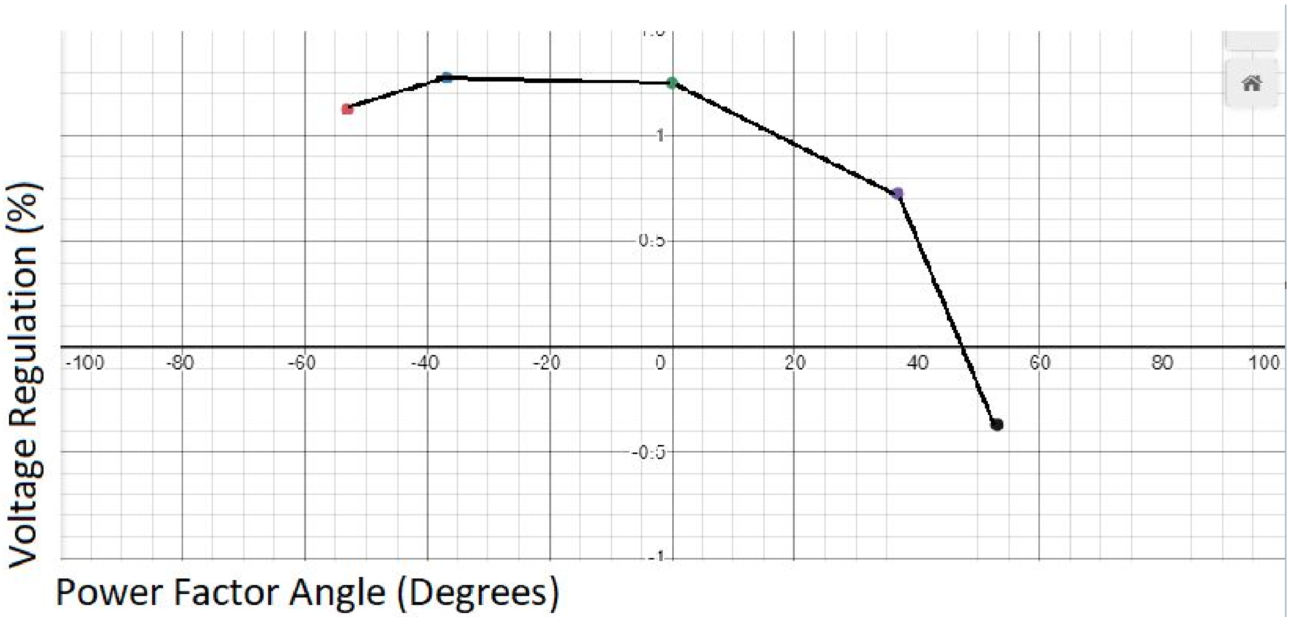
$Pcore = 94.77W$, $Pcu = 12.47W$

$$\eta = \frac{(Vs)(Is)(cos\theta)}{(Pcu + Pcore + (Vs)(Is)(cos\theta))}(100)$$

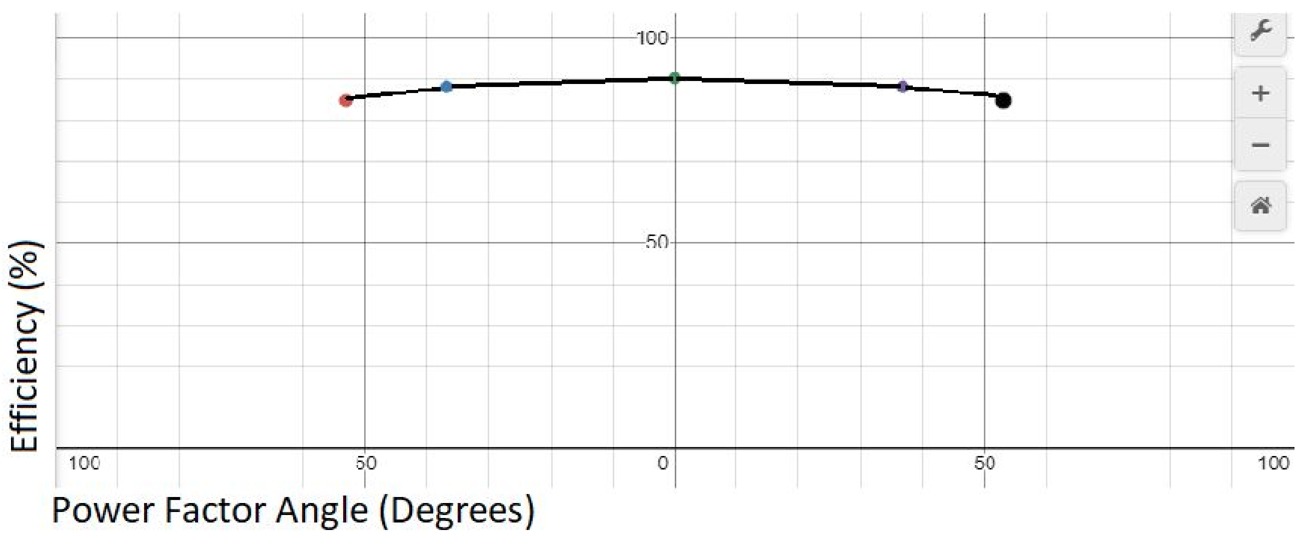
$$\eta = \frac{(240)(4.17)(cos(53.13^{\circ}))}{(12.47 + 94.77 + (240)(4.17)(cos\theta))}(53.13^{\circ})$$

$\boxed{\eta = 84.85}$ %

6.)



7.)



Conclusion:

In this lab I learned a multitude of concepts including how to examine voltage efficiency, voltage regulation and how to determine the polarity of a single phase circuit. Through applying appropriate dmm measurements, current clamp meter measurements, and wattmeter measurements across different wiring and circuit schematics, I applied techniques, such as open circuit tests, short circuit tests and polarity checking tests, to gather appropriate data for our tables, as set forth in the lab rubric guidelines. From this data, I was able to apply our values to several different circuit schematics, set out in the lab report section. I will now address a brief conclusion for my findings in the report questions.

For report question 1, I translated the T-1000A circuit schematic model to Pspice to act as my drawing. In report question 2 I interpreted the transformer equivalent circuit to Pspice, as well. Within report question 3 I used a PF equation (PF=P/S), transforming it into P/VI, thus solving for the power factor. From this equation, the angle was the cos^-1(PF) and it provided me the angle necessary to convert Z short circuit into both the X equivalent and R equivalent values , as required by the lab manual. Next, in report question 4 I transformed an equation for apparent power (S) into an equation to solve out for the reactive power (Q); then, using the reactive power I made an equation ((Voc^2)/Qoc) to solve for the X value for the magnetizing branch.

In this application of data to the report questions (specifically report question 5), I noticed that most of the voltage regulation values, when using the PF values provided by the lab manual, ended up being within almost 1% for most of the power factors. This particular data is good, as it means that the secondary voltage appears to be stable, given that these regulation percentage values are low; this means better regulation would be provided to these hypothetical circuits. Next, in examining voltage regulation versus power factor in our plots (report questions 6 and 7), I noticed a slight trend, whereby our voltage regulation percentage became smaller as our PF increased; also, the regulation percentage decreased if the PF became less negative (in terms of the angle provided by the PF). Lastly, in examining efficiency with regards to power factor, in report question 7, I noticed that efficiency percentages appeared to peak when the Power factor was zero, while the efficiency decreased when the power factor moved away, in either direction, from zero (either when the power factor became more positive, or more negative).

Overall, this lab served to provide me with a better understanding of voltage regulation, efficiency, and the behavior of electrical concepts within the single phase transformer. The application of polarity checking tests, open circuit tests, and short circuit tests, helped to further garnish my knowledge regarding single phase transformers.