EE 255 – SINGLE PHASE TRANSFORMER

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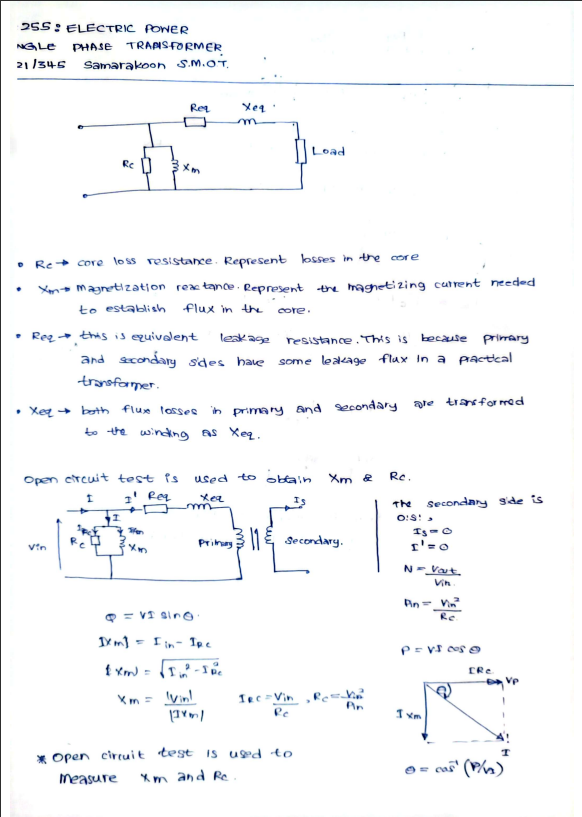
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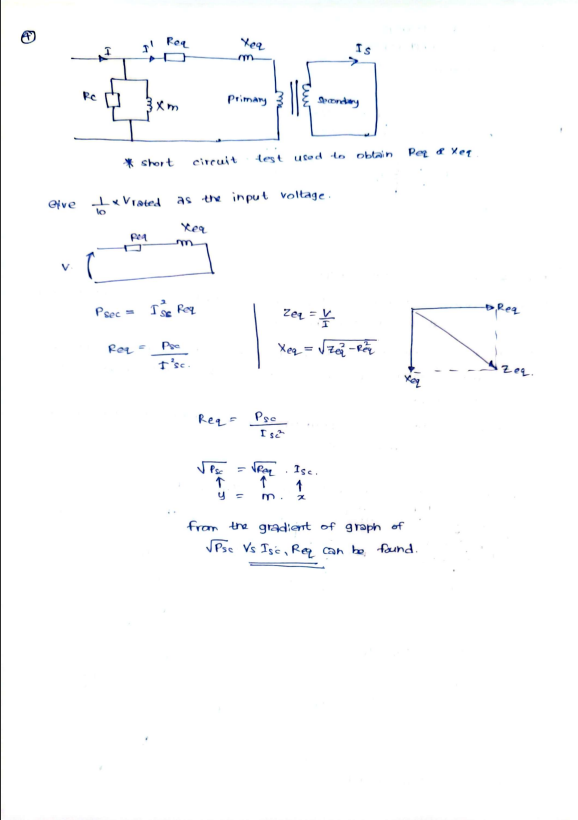
GROUP EE.21.B.23

SEMESTER 04

16.07.2025

**PRELAB**





**EE 255: ELECTRIC POWER**

**Experiment: Single Phase Transformer**

**(3 hours)**

**DATE: 16/07/2025**

**REG. NO: E/21/345**

**INTRODUCTION:**

Students are given hand on experience in determining the approximate equivalent circuit of a single phase transformer by using the results obtained from the open circuit test and the short circuit test.

Students can get an idea about the losses associate with a transformer at the same time typical variation of the efficiency and the voltage regulation of a single phase transformer for different loadings.

**LEARNING OUTCOMES:**

LO 1: Describe different magnetic circuits, their properties and appreciate losses associated with them.

LO 2: Perform the open circuit and short circuit tests on a single phase transformer.

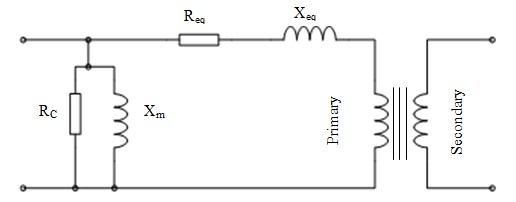
LO 3: Estimate the parameters in the equivalent circuit of a single phase transformer.

LO 4: Calculate voltage regulation and efficiency of a transformer using the equivalent circuit.

LO 5: To perform the load test on a single phase transformer and determine its voltage regulation and efficiency at each of the loading level.

**THEORY:**

Approximate equivalent circuit of a single phase transformer is shown below.



R

C

X

m

R

eq

eq

Secona

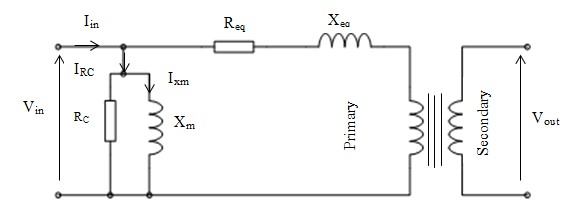
Prima

Figure 01: Approximate Equivalent Circuit of a Single Phase Transformer

# Open Circuit Test

The purpose of this test is to determine the shunt branch parameters of the equivalent circuit of the transformer.

In this test one of the windings is connected to supply at rated voltage, while the other winding is kept open – circuited.



## Figure 02: Open Circuit Test

As secondary is open circuited, the current through Xeq and Req can be neglected.

Turns ratio N,

N = Vout / Vin

Pin= Vin2/ RC

Pin, Iin, Vin and Vout can be measured in the practical. Therefore, RC can be found using the above equation.

IRC = Vin / RC ixm = iin - iRc

|Ixm|= (Iin2 – IRc2 )1/2

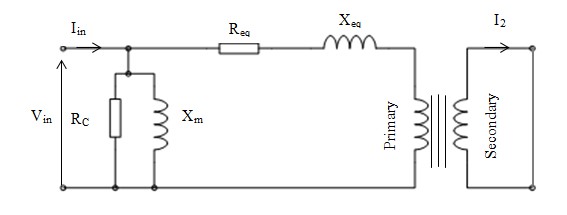
|Xm|= |Vin| / |Ixm|

Xm can be found by using above equations.

# Short Circuit Test

This test serves the purpose of determining the series parameters of a transformer.

For convenience of supply arrangement and voltage and current to be handled, the test is usually conducted from the HV side of the transformer while the LV side is short-circuited.



## Figure 03: Short Circuit Test

RC and Xm can be neglected as a lower voltage are applied.

PSC = ISC2 \* Req

(PSC)1/2 = (Req)1/2. ISC

Y = m1. X

From the gradient m1 of the graph of (PSC)1/2 Vs. ISC, Req can be found.

Zp = |VSC |/ |ISC|

VSC =Zp .ISC

Y = m2. X

From the gradient m2 of the graph VSC Vs. ISC, Zp can be found.

Zp = (Req2 +Xeq2)1/2

From the above equation Xeq can be found.

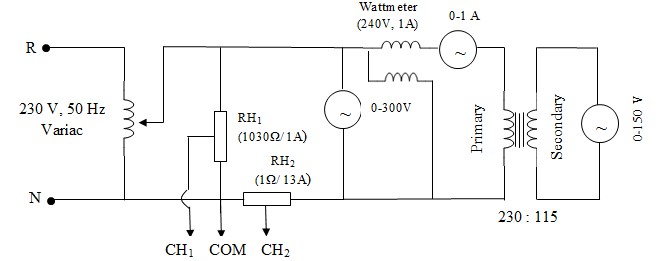
**PROCEDURE:**

# (a). Open Circuit Test

## Apparatus

1. Single phase transformer (230/115V, 1.1 kVA,50 Hz)
2. Variac (230V, 50 Hz)
3. Rheostats – 2 Nos (1030Ω/1A & 1Ω/13A)
4. Wattmeter (240V/1A)
5. Voltmeters – 2 Nos(0-300V & 0- 150V)
6. Ammeter (0-1A)

## Procedure



### Figure 04: Open Circuit Test Circuit Diagram

1. Connect the circuit as shown in Figure 04. (Do not connect the C.R.O. probes to the circuit until the instructor checks the circuit.)
2. Show the connected circuit to the instructor.
3. Set the **Variac to zero** **position** and Rheostat 1 (RH1) and Rheostat 2 (RH2) to the minimum position.
4. Power on the AC voltage supply.
5. Adjust the Variac and set the secondary voltage to 115V.
6. Record the readings of Wattmeter, ammeter and Voltmeters.
7. Connect the C.R.O. probes and adjust the rheostats (RH1 and RH2) slightly to get the full waveform on the screen.
8. Record the voltage and magnetizing current waveforms.
9. Now bring the Variac to zero volts and Switch off the power supply.

## Observations

Table 1: Observations

|  |  |  |
| --- | --- | --- |
| Voltmeter reading | Ammeter reading | Wattmeter reading |
| 230 V | 0.11 A | 14 W |

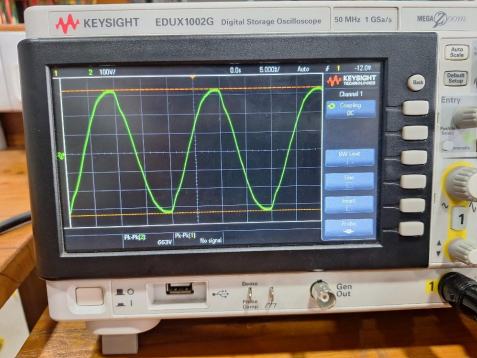


Figure 05: Open circuit voltage waveform

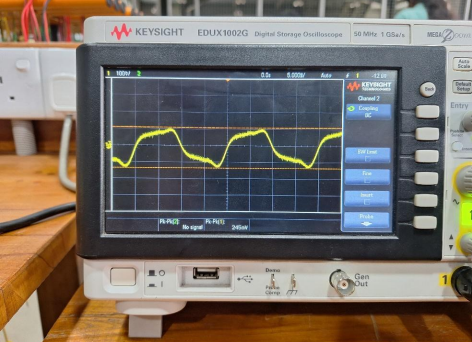


Figure 06: Magnetization current waveform

## Calculations

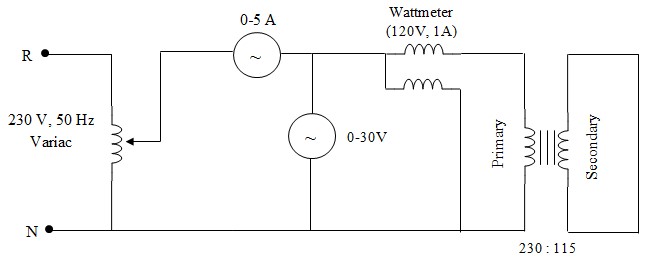
• Calculate RC and Xm referred to the primary side of the transformer by using Open Circuit Test results.

# (b). Short Circuit Test

## Apparatus

1. Single phase transformer (230/115V, 1.1 kVA,50 Hz)
2. Variac (230V, 50 Hz)
3. Wattmeter (120V/1A)
4. Voltmeter (0-75V)
5. Ammeter (0-5A)

## Procedure



### Figure 07: Short Circuit Test Circuit Diagram

1. Connect the circuit as shown in Figure 05.
2. Show the connected circuit to the instructor.
3. Make sure the **Variac is at Zero volt position**.
4. Power on the AC supply.
5. Adjust the Variac and record the readings of the voltmeter, ammeter and wattmeter for ammeter readings from 0 to 4 A by 0.5 A steps. (**Do not exceed the current beyond 4 A.**)
6. Rotate the Variac to zero and switch off the power supply after the experiment.

## Observations

Table 2: Observation

|  |  |  |
| --- | --- | --- |
| Ammeter Reading | Voltmeter Reading | Wattmeter Reading |
| 0.0 | 0.0 | 0 |
| 0.5 | 2.0 | 2 |
| 1.0 | 5.0 | 5 |
| 1.5 | 7.0 | 10 |
| 2.0 | 10.0 | 17 |
| 2.5 | 12 | 26 |
| 3.0 | 14.5 | 40 |
| 3.5 | 16.5 | 54 |
| 4.0 | 19.0 | 71 |

## Calculations

* Plot the following graphs.

1. Voltage Vs. Current

**ii.** (Power)1/2 Vs. Current

* Calculate Req and Xeq referred to the primary side of the transformer by using Short Circuit Test results.

## RESULTS

Table 3: Results of transformer approximation model parameters

|  |  |
| --- | --- |
| RC |  |
| Xm |  |
| Req |  |
| Xeq |  |

• Draw the approximate equivalent circuit of the single phase transformer referred to primary side with mentioning calculated parameter values.

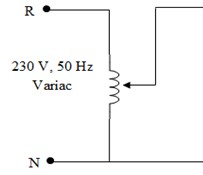
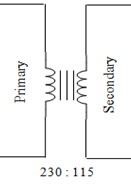
# (c). Load Test

## Apparatus

1. Single phase transformer (230/115V, 1.1 kVA,50 Hz)
2. Variac (230V, 50 Hz)
3. Wattmeters – 2 Nos (240V/25A)
4. Voltmeters – 2 Nos (0-300V & 0-150V)
5. Ammeters – 2 Nos (0-5A & 0-25A)
6. Water Load

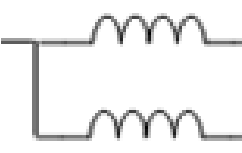
## Procedure

**v**

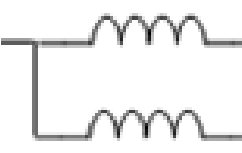


V

A



V



A

0

-

300

V

Wattmeter

240

V

/25A

0

-

A

5

0

-

15

V

0

Water

Load

Wattmeter

240

V

/25A

0

-

25

A

### Figure 08: Load test circuit diagram

1. Connect the circuit as shown in figure 6 and set the variac to zero position.
2. Set water load positions to “Low”.
3. Adjust the variac and set the primary voltage to 230V.
4. Record the readings of Wattmeters, ammeters and voltmeters for different water load positions.

**Observations**

Table 4: Primary side and Secondary side readings against percentage full load

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Water  Load position | Percentage full load(%) |  | Primary Side |  | Secondary Side | | |
| Voltmeter/V | Ammeter/A | Wattmeter/W | Voltmeter/V | Ammeter/A | Wattmeter/W |
| LLL | 30 | 230 | 1.9 | 430 | 112 | 3.6 | 420 |
| LLM | 40 | 230 | 2.5 | 570 | 112 | 4.9 | 540 |
| LMM | 50 | 230 | 1.55 | 350 | 114 | 2.9 | 340 |
| MMM | 60 | 230 | 2.00 | 460 | 112 | 3.9 | 440 |
| MMH | 80 | 230 | 2.95 | 680 | 110 | 5.8 | 650 |

## Calculations

Considering the 5th data set of the table,

PP=VP.IP.Cos(θ),

Power Factor, Cos(θ) = PP / (VP.IP)

= 680/(230\*2.95)

= 1.002

Voltage regulation = (VNL – VFL) × 100

VFL

=((115-110)\*100)/110

= 4.55

Efficiency = POUT × 100

PIN

=(650/680)\*100

=

## Results

Table 5: Results

|  |  |  |  |
| --- | --- | --- | --- |
| Percentage full load (%) | Power Factor | Voltage Regulation (%) | Efficiency (%) |
| 30 | 0.984 | 2.68 | 97.67 |
| 40 | 0.991 | 2.68 | 94.74 |
| 50 | 0.982 | 0.877 | 97.14 |
| 60 | 1.000 | 2.68 | 95.65 |
| 80 | 1.002 | 4.55 | 95.59 |

• Plot the variation of Voltage regulation Vs. percentage full load and Efficiency Vs. Full load

## PROBLEM

Using the approximate equivalent circuit shown in Figure 01 and equivalent parameters calculated from Open circuit and Short circuit test, calculate the **Voltage Regulation** and **Efficiency** of the transformer for 30%, 40%, 50%, 60% and 80% of full load. Assume a unity power factor. Tabulate the results.

## DISCUSSION

1. Does the core loss vary with the load? Why?
2. In the open circuit test, why the copper loss in the primary can be neglected?
3. In the short circuit test, why can the core loss be neglected?
4. Discuss any three points, which you have gained from this experiment. If any practical problems observed that can also be included in this discussion.
5. Compare voltage regulation and efficiency obtained during load test with theoretically calculated values in PROBLEM.

**CALCULATIONS**

**Part a)**

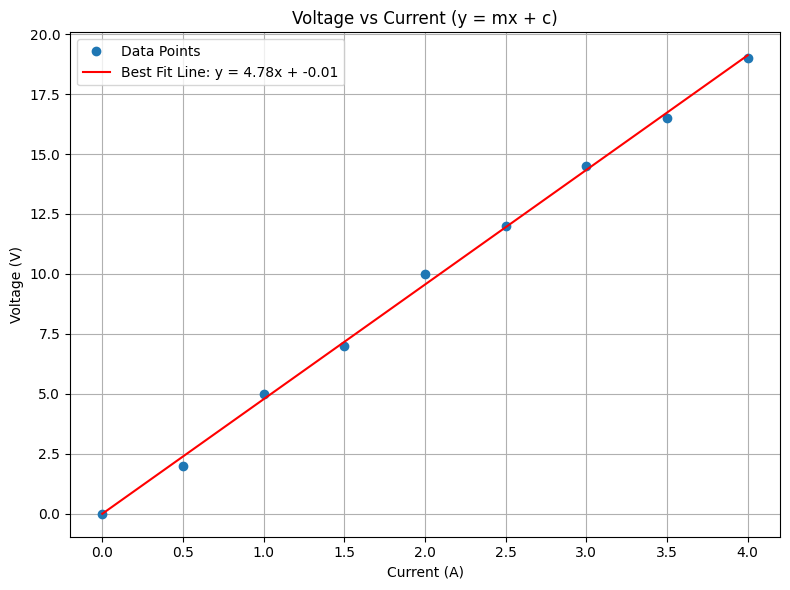
Calculate RC and Xm referred to the primary side of the transformer by using Open Circuit Test results.

**Part b)**

**TABULATION**

Table 6: Variation of voltage with current

|  |  |
| --- | --- |
| Current (A) | Voltage (V) |
| 0.0 | 0.0 |
| 0.5 | 2.0 |
| 1.0 | 5.0 |
| 1.5 | 7.0 |
| 2.0 | 10.0 |
| 2.5 | 12.0 |
| 3.0 | 14.5 |
| 3.5 | 16.5 |
| 4.0 | 19.0 |

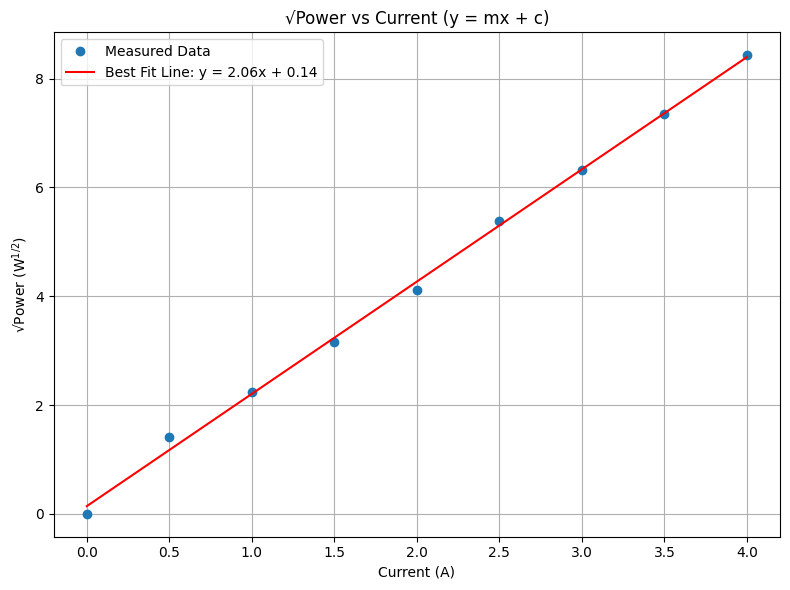


### Figure 09: Variation of voltage with current

**TABULATION**

Table 7: Variation of (Power)1/2 with current

|  |  |
| --- | --- |
| Current (A) | Power1/2 (W1/2) |
| 0.0 | 0.00 |
| 0.5 | 1.41 |
| 1.0 | 2.24 |
| 1.5 | 3.16 |
| 2.0 | 4.12 |
| 2.5 | 5.39 |
| 3.0 | 6.32 |
| 3.5 | 7.35 |
| 4.0 | 8.43 |



### Figure 10: Variation of Power1/2 with current

Let,

From figure 8,

From figure 7,

**Part c)**

Considering the 1st data set of the table,

**RESULTS**  
  
**Part a), b)**

|  |  |
| --- | --- |
| RC |  |
| Xm |  |
| Req |  |
| Xeq |  |

### 

Figure 11: Approximate equivalent circuit referred to primary side

Xeq = 4.16 Ω

Req = 4.16

Secondary

Primary

Xm = 2510.92 Ω

RC = 3778.57 Ω

**Part c)**

|  |  |  |  |
| --- | --- | --- | --- |
| Percentage full load (%) | Power Factor | Voltage Regulation (%) | Efficiency (%) |
| 30 | 0.984 | 2.68 | 97.67 |
| 40 | 0.991 | 2.68 | 94.74 |
| 50 | 0.982 | 0.877 | 97.14 |
| 60 | 1.000 | 2.68 | 95.65 |
| 80 | 1.002 | 4.55 | 95.59 |

**TABULATION**

Table 8: Variation of voltage regulation with percentage full load

|  |  |
| --- | --- |
| Percentage full load (%) | Voltage regulation (%) |
| 30 | 2.68 |
| 40 | 2.68 |
| 50 | 0.877 |
| 60 | 2.68 |
| 80 | 4.55 |

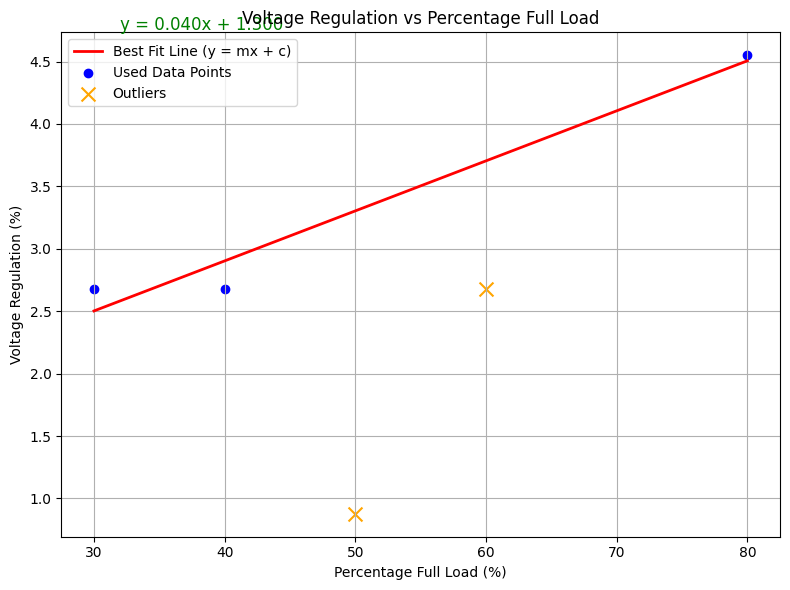


Figure 12: Variation of voltage regulation with percentage full load

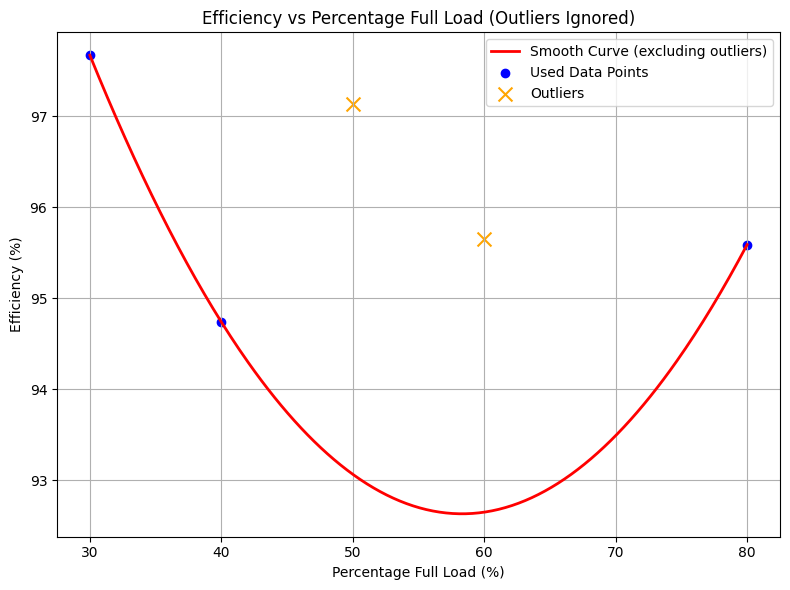
### 

**TABULATION**

Table 9: Variation of efficiency with percentage full load

|  |  |
| --- | --- |
| Percentage full load (%) | Efficiency (%) |
| 30 | 97.67 |
| 40 | 94.74 |
| 50 | 97.14 |
| 60 | 95.65 |
| 80 | 95.59 |

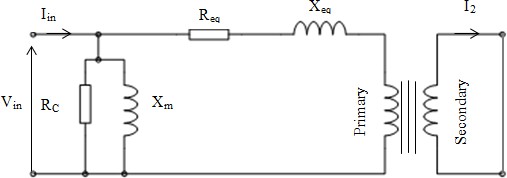
* Neglecting third and fourth data set because of fault in water load,



### Figure 13: Variation of efficiency with percentage full load

**PROBLEM**

Using the approximate equivalent circuit shown in Figure 01 and equivalent parameters calculated from Open circuit and Short circuit test, calculate the Voltage Regulation and Efficiency of the transformer for 30%, 40%, 50%, 60% and 80% of full load. Assume a unity power factor. Tabulate the results.



V1

E1

Ip

Is

115 V



Figure 14: Equivalent Circuit shown in Figure 1

KVL to primary,

## 1. 30% Full Load

* Secondary current ():
* Primary current ():

### **Calculations:**

1. Primary voltage ():
2. Voltage regulation (VR%):
3. Output power ():
4. Power loss ():
   * Copper loss:
   * Core loss:
   * Total loss:
5. Input power ():
6. Efficiency ():

## 2. 40% Full Load

* Secondary current ():
* Primary current ():

### **Calculations:**

1. Primary voltage ():
2. Voltage regulation (VR%):
3. Output power ():
4. Power loss ():
   * Copper loss:
   * Core loss:
   * Total loss:
5. Input power ():
6. Efficiency ():

## 3. 50% Full Load

* Secondary current ():
* Primary current ():

### **Calculations:**

1. Primary voltage ():
2. Voltage regulation (VR%):
3. Output power ():
4. Power loss ():
   * Copper loss:
   * Core loss:
   * Total loss:
5. Input power ():
6. Efficiency ():

## 4. 60% Full Load

* Secondary current ():
* Primary current ():

### **Calculations:**

1. Primary voltage ():
2. Voltage regulation (VR%):
3. Output power ():
4. Power loss ():
   * Copper loss:
   * Core loss:
   * Total loss:
5. Input power ():
6. Efficiency ():

## 5. 80% Full Load

* Secondary current ():
* Primary current ():

### **Calculations:**

1. Primary voltage ():
2. Voltage regulation (VR%):
3. Output power ():
4. Power loss ():
   * Copper loss:
   * Core loss:
   * Total loss:
5. Input power ():
6. Efficiency ():

Table 10: Results for theocratically obtained Voltage regulation and Efficiency

|  |  |  |
| --- | --- | --- |
| Percentage full load (%) | Voltage Regulation (%) | Efficiency (%) |
| 30 | 2.67 | 93.67 |
| 40 | 2.67 | 93.67 |
| 50 | 4.43 | 93.50 |
| 60 | 5.33 | 93.10 |
| 80 | 7.12 | 92.26 |

## DISCUSSION

1. Does the core loss vary with the load? Why?

No. Core loss stays almost the same regardless of load. It only depends on the supply voltage and frequency, which we kept constant. It's made of hysteresis and eddy current losses in the core. So even when load changes, this loss doesn't really change. That’s why in calculations and open circuit test, we treat it as constant.

1. In the open circuit test, why the copper loss in the primary can be neglected?

Because the current is very low in this test. Only a small magnetizing current flows to create flux in the core. Since copper loss = I²R, and I is tiny here, the copper loss is almost zero. So we ignore it and assume the whole wattmeter reading is due to core loss only.

1. In the short circuit test, why can the core loss be neglected?

In this test, we apply a very low voltage which just enough to push full current through the windings. Since voltage is so small, the flux in the core is also small. That means hysteresis and eddy current losses are minimal. So we ignore core loss and just focus on copper loss, which is dominant.

1. Discuss any three points, which you have gained from this experiment. If any practical problems observed that can also be included in this discussion.

* I now know how to practically find transformer losses using simple tests without loading it fully.
* I understood how voltage regulation works and how to measure it using load variation.
* I learned how equivalent circuit parameters like Req and Xeq actually come from the open and short circuit tests, not just theory.

One issue: water load wasn't stable at some points (like 50% and 60%), which gave weird data. We had to skip those values from the graphs.

1. Compare voltage regulation and efficiency obtained during load test with theoretically calculated values in PROBLEM.

Looking at the two tables, the observed voltage regulation and efficiency values are generally better than the theoretical ones.

Table 11: Results for theocratically obtained Voltage regulation and observed voltage regulation

|  |  |  |
| --- | --- | --- |
| Percentage full load (%) | Observed Voltage Regulation (%) | Theoretical Voltage Regulation (%) |
| 30 | 2.68 | 2.67 |
| 40 | 2.68 | 2.67 |
| 50 | 0.877 | 4.43 |
| 60 | 2.68 | 5.33 |
| 80 | 4.55 | 7.12 |

For voltage regulation, both observed and theoretical values are almost the same at 30% and 40% load — around 2.68%. That means the transformer behaved as expected at light load. But from 50% load onwards, there’s a big gap. At 50%, the theory says 4.43% regulation, but we measured only 0.877%. Same for 60% and 80%, where theory shows a rise, but the actual values are lower. This could be due to the transformer having tighter winding or lower leakage than we assumed. Also, maybe our load setup caused less voltage drop than what we expected in calculations.

Table 12: Results for theocratically obtained Efficiency and observed Efficiency

|  |  |  |
| --- | --- | --- |
| Percentage full load (%) | Observed Efficiency (%) | Theoretical Efficiency (%) |
| 30 | 97.67 | 93.67 |
| 40 | 94.74 | 93.67 |
| 50 | 97.14 | 93.50 |
| 60 | 95.65 | 93.10 |
| 80 | 95.59 | 92.26 |

For efficiency, the measured values are always higher than theory. At 30% load, we got 97.67%, which is a lot better than the 93.67% we calculated. Even at 80%, the observed value was 95.59%, still better than the theoretical 92.26%. So clearly, the transformer was running more efficiently in real life.

Overall, the real transformer worked better than theory predicted. That's a good thing, but also shows us that theoretical models are just approximations, the actual build and setup can perform better (or worse) depending on real-world factors.

**References**

[1]“Equivalent Circuit of Transformer,” Tutorialspoint.com, 2025. <https://www.tutorialspoint.com/electrical_machines/electrical_machines_equivalent_circuit_transformer.htm>

(accessed Jul. 27, 2025).

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[2]Electrical4U, “Voltage Regulation of Transformer | Electrical4U,” https://www.electrical4u.com/. <https://www.electrical4u.com/voltage-regulation-of-transformer/>

[3]https://www.facebook.com/electrical4u, “Efficiency of Transformer | Electrical4U,” Electrical4U, Aug. 04, 2018. <https://www.electrical4u.com/efficiency-of-transformer/>

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