EXPERIMENT 3: Single Phase Transformer

Part A  : Off-Load, Loaded, Short-circuit

Objectives:

1. Operate a single phase transformer off-load, with a load applied and with a short circuit applied
2. Deduce the relationship between the secondary voltage and the loading and give reason for the deduction
3. Measure the off load voltage
4. Measure the short-circuit voltage and from this, calculate the short circuit current
5. Define the terms, short circuit voltage, continuous short circuit current

Circuit Diagram

Fig 3.1
**Instrument/Component**

1 Variable/isolating transformer
1 Single phase test transformer
2 resistors, $47\,\Omega/11\,\text{W}$
2 Multimeter
1 Universal Watt Meter (LM 1010)

**Introduction**

The single phase exercise transformer used in this experiment, has a transformation ratio $t$, of 1:1, i.e. the windings in the primary and the secondary coils have the same number of turns, $N_1$ and $N_2$. Therefore when no load is applied, the primary voltage, $U_1$ is the same as the voltage in the secondary, $U_2$

$$t = \frac{N_1}{N_2} = \frac{U_1}{U_2} = 1/1$$

When loaded, the winding resistance of the transformer has a similar effect as the internal resistance of a voltage source, across which part of the source voltage dropped. The transformer is designed so that at the nominal current in the secondary of $I_{2N} = 1\,\text{A}$, the voltage available at the secondary is the nominal voltage, $U_{2N}$ of 22V. When off load, no voltage is dropped internally, so the off load voltage, $U_{2o}$ is larger than the nominal voltage, $U_{2N}$
The short circuit voltage, $U_{SC}$ is the voltage which must be applied to the primary, when the secondary is short circuited, so that the nominal current, $I_N$, flows in the primary winding. It is usually quoted as a percentage of the nominal voltage.

$U_{SC} = \frac{U_{1SC}}{U_{1N}} \times 100\%$

The magnitude of the short circuit voltage $U_{SC}$ is a measure of the change in voltage which occurs in the secondary and thus the internal resistance of the transformer. The smaller the short circuit voltage, the less dependent is the output voltage on load.

The continuous short circuit current, $I_{SC}$, is the current which flows in the secondary circuit when it is permanently short circuited. The value of $I_{CSC}$ is larger for a smaller internal resistance of the transformer and thus the short circuit voltage is also smaller.

$I_{CSC} = \frac{I_{2N}}{U_{SC}} \times 100\%$

**Exercise**

1. Construct the circuit as shown in the fig. 3.1.

   Slowly increase the voltage from the variable transformer, until the secondary voltage of the test transformer is at the nominal value of $U_{2N} = 22V$

   Measure the load current, $I$ and check the measured value by calculation.

   $U_2 = U_{2N} = \ldots \ldots V$

   $R = \ldots \ldots \Omega$

   Calculated $I_2 = \ldots \ldots A$

   Measured $I_2 = \ldots \ldots A$

2. Measure the load current $I_2$ at the nominal secondary voltage, $U_{2N}$ of $22V$ and enter the value into table 3.1.

   Remove one of the load resistors, measure the values of $I_2$ and $U_2$ and enter the values into table 3.1.

   Remove the other load resistor, measure the values of $I_2$ and $U_2$ and enter the values into table 3.1.
Evaluate the results

<table>
<thead>
<tr>
<th>R (Ω)</th>
<th>I₂ (A)</th>
<th>U₂ (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>∞</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.1**

3. Construct the circuit shown in fig. 3.2 (short circuit operation)

Slowly increase the voltage from the variable transformer until the nominal current of 1A flows in the primary circuit.

Measure the voltage applied at the primary, U_{SC}

U_{1SC} = ....................V

Calculate the value of U_{SC} in % of the nominal voltage and the value of continuous short circuit current I_{CSC}.

U_{SC} = x 100% = ................ %

I_{CSC} = x 100% = ................ %

**Question**

1. Give reasons from any deviation of the measured from the calculated value in step 1
Part B  : Losses and Efficiency

Objectives

1. Measure the delivered power of a transformer when off load, or when a short circuit is applied
2. Determine, by measurements, the losses which occur in the iron core and the windings of a transformer
3. Calculate the efficiency of a transformer, from the values obtained by measurement

Circuit Diagram

![Circuit Diagram](image)

Fig 3.3
**Instrument/Components**

1 Variable/Isolating transformer
1 Single phase test transformer
2 Resistors, 47Ω/11W
2 Multimeter
1 Universal Watt Meter (LM 1010)

**Introduction**

The power losses, $P_L$ in a transformer, consist of iron losses, $P_{fe}$, and copper losses in the windings, $P_{cu}$

$$P_L = P_{fe} = P_{cu}$$

Iron losses are dependent on the loading of the transformer and can be determined in an off load test. The copper losses which occur here can be ignored since the off load current is very small.

Copper losses change, corresponding to the square of the current strength and are measured in a short circuit test at the nominal current. The iron losses are ignored here because the magnetic flux in short circuit operation is very small.

The efficiency of a transformer, is given by the ratio of output power to input power

$$\eta = \frac{P_{out}}{P_{in}}$$
Exercise

1. Construct the circuit shown in fig. 3.3

   Slowly increase the voltage from the variable transformer, until the secondary voltage of the test transformer is at the nominal value of $U_{2N} = 22V$

   Measure the power consumed by the test transformer, $P_{in}$

   \[ P_{in} = \ldots\ldots\ldots\ldots W \]

   Calculate the delivered power at the load resistor, $P_{out}$, and determine the power losses, $P_L$ and the efficiency $\eta$ of the transformer

   \[ P_{out} = \ldots\ldots\ldots\ldots W \]
   \[ P_L = \ldots\ldots\ldots\ldots W \]
   \[ \eta = \ldots\ldots\ldots\ldots\% \]

2. Remove both load resistors and measure the power consumed by the test transformer when off load, $P_{in}$

   \[ P_{in} = \ldots\ldots\ldots\ldots W \]

   Construct the circuit shown in fig. 3.4

   Slowly increase the voltage from the variable transformer until the nominal current of 1A flows in the primary circuit

   Measure the power consumed by the test transformer when the output is short circuited, $P_{in}$

   \[ P_{in} = \ldots\ldots\ldots\ldots W \]

3. Determine the total power losses $P_L$, from the iron and copper losses.

   \[ P_L = \ldots\ldots\ldots\ldots W \]
1. State which type of losses the value of $P_{in}$ represents in step 2

2. State which type of losses the value of $P_{in}$ represents in step 3

3. Explain why there is a difference in $P_L$ between the value determined in step 1 and step 3

4. Use the information given to complete the table below

<table>
<thead>
<tr>
<th>No</th>
<th>Turns Ratio</th>
<th>Primary Voltage (V)</th>
<th>Secondary Voltage (V)</th>
<th>Primary Current (A)</th>
<th>Secondary Current (A)</th>
<th>Step Up or Step Down</th>
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</thead>
<tbody>
<tr>
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<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6:1</td>
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<td>20</td>
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<td>0.6</td>
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</tr>
<tr>
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<td></td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td>0.03</td>
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<td></td>
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<td>0.2</td>
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<td>50</td>
<td>1</td>
<td></td>
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<tr>
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<td>6</td>
<td>120</td>
<td>1</td>
<td></td>
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