ANADOLU UNIVERSITY

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING

EEM 311  Principles of Energy Conversion Laboratory

Fall  2014-2015

Experiment  3 :  Measuring the Winding Resistances and Transformation Ratio of Single-Phase Transformer
Purpose :

The purpose of the experiment is to measure the winding resistances and transformation ratio of a single phase transformer.

Background and Theoretical Discussion :

As we have learned, a dc current flowing through a coil of wire creates a magnetic field about the coil. The magnetic field has a north and a south pole, depending on the direction of current in the coil. The strength of the magnetic field depends on, among other things, the amount of current and the number of coils of wire. The strength of the magnetic field will also increase if the coil surrounds a ferromagnetic material as its core.

Electromagnet principles governing a Transformer

Moving a magnet along, or near, the axis of a coil of wire induces an electromotive force at the terminals of the coil. The polarity of this EMF changes sign as the direction of movement of the magnetic field changes. The magnitude of the induced EMF depends on, among other things, the strength of the magnetic field and the speed with which it changes. It is essential to remember that the magnetic field must be changing to induce a voltage in the coil. As might be expected, an ac current flowing in a coil will create an alternating magnetic field about the coil.

These principles of electromagnetism explain the operation of a transformer. A transformer consists of two separate coils of wire that are in close physical proximity to assure good magnetic coupling between the two coils. The close physical proximity facilitates magnetic coupling between the two coils. The input coil is called the **primary coil**, and the output coil is called the **secondary coil**.

An ac current flowing in the primary creates an alternating magnetic field that is close enough to the secondary to induce a voltage across the secondary's terminals. The alternating magnetic field created by the primary appears to be the same in effect as if a magnet were being moved through the secondary to induce a voltage at the terminals of the secondary.
The Transformer

Only a changing magnetic field can induce an EMF in a coil of wire. So, a transformer will not operate with a dc signal. A transformer is exclusively an ac device. The strength of the magnetic field and the corresponding induced voltage depends on the number of coils of wire in the primary and in the secondary. If \( N_p \) and \( N_s \) are the number of turns in the primary and in the secondary, respectively, and if \( E_{in} \) and \( E_{out} \) are the rms input and output voltage, then,

\[
\frac{E_{out}}{E_{in}} = \frac{N_s}{N_p}
\]

or

\[
E_{out} = \frac{N_s}{N_p} \times E_{in}
\]

As a result, by choosing the appropriate number of turns it is possible to change ac voltages with a transformer. The quantity of \( \frac{N_s}{N_p} \) is called the transformation ratio, \( n \). If \( n \) is greater than one, the output voltage will be greater than the input voltage. If \( n \) is less than one, the output voltage will be less than the input voltage. In this way, ac voltages can be stepped up or down. A transformer with a transformation ratio greater than one would be accordingly called a step-up transformer.

The transformer is called a passive device since it cannot generate power. Its input power \( E_{in} \times I_{in} \) must equal its output power \( E_{out} \times I_{out} \), with the exception of internal power losses in the transformer itself. This equality can be used to derive a relation for the current transformation properties of a transformer, namely,

\[
I_{out} = \frac{N_p}{N_s} \times I_{in}
\]

In other words, if the output voltage increases, the output current must decrease proportionately, to keep the output power constant.
Use of the 'Turns Ratio' to calculate Output Voltage

The polarity of the output EMF depends on the direction of the winding of the coils of wire. Small dots are sometimes used on the symbol for a transformer to indicate the polarity.

Transformer Turns Ratio and Polarity

Some transformer coils are coupled magnetically through the air. Others are wound around a piece of iron in such a way that the two coils share the same iron core. This improves the magnetic coupling between the two coils. One or two vertical lines drawn between the two coils symbolize an iron-core or ferromagnetic transformer.

Core Types

The secondary coil can be tapped or connected at various points to give multiple output EMFs. The transformation ratio for each particular secondary coil gives the appropriate output EMF for an ac signal at the primary.
Transformer with Multiple Taps

In addition to its use for transforming voltages and currents, a transformer can also be used to transform resistances. Later, it will be shown that the "resistance" to an ac current involves more complex effects than simply resistance. The resistance to an ac current will be called an *impedance*. Transformers can scale or transform both impedances and purely resistive loads.

**Impedance Matching**

If a resistor of $R$ ohms is connected as a load to the secondary of a transformer, the resistive effect will be reflected into the primary as if it were a resistive load of $(N_p/N_s)^2$ multiplied by $R$. When used this way, a transformer can transform a resistor or an impedance from one value to another. Transformers are used this way in amplifiers to match the impedance required by the output power devices to the impedance of the load. (Recall the Maximum Power Transfer theorem).

Transformers are some of the most efficient electrical machines with some large units able to transfer 99.75% of their input power to their output. Transformers come in a range of sizes from a
thumbnail-sized coupling transformer hidden inside a stage microphone to huge gigavolt-ampere-rated units used to interconnect portions of national power grids. All operate with the same basic principles, though a variety of designs exist to perform specialized roles throughout home and industry.

Equipment List:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DL 1013M2</td>
<td>Power Supply</td>
</tr>
<tr>
<td>1</td>
<td>DL 1031</td>
<td>Digital Power Measuring Unit</td>
</tr>
<tr>
<td>1</td>
<td>DL 1093</td>
<td>Single Phase Transformer</td>
</tr>
<tr>
<td>1</td>
<td>Wavetek</td>
<td>Hand Multimeter</td>
</tr>
</tbody>
</table>

Procedure:

Part 1
- Connect the high voltage winding to the L+/L- terminals
- Switch on the power supply
- Measure the value of the voltage for each current value on the ammeter while adjusting the knob
- Switch off the supply module
- Connect the low voltage after disconnect the high voltage winding
- Switch the supply module on
- Measure the value of the voltage for each current value on the ammeter while adjusting the knob
- Switch off the main supply module.

Measurement table

<table>
<thead>
<tr>
<th>Winding</th>
<th>Ammeter (A)</th>
<th>Voltmeter (V)</th>
<th>$R_x$ (Ω)</th>
<th>$R_{xm}$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Voltage</td>
<td>0.6</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>220 V</td>
<td>0.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Voltage</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110 V + 110V</td>
<td>0.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(series)</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculation formulas:

\[ R_x = \frac{V}{I} \]

\[ R_{xm} = \left( \frac{R_{x1} + R_{x2} + R_{x3}}{3} \right) \]
Part 2
- Switch the supply module on by setting the circuit breaker to on
- Read on the voltmeter V the supply voltages and voltages of the secondary winding
- Switch off the module.

Measurement table

<table>
<thead>
<tr>
<th>Test</th>
<th>Primary Voltage (V)</th>
<th>Secondary Voltage (V)</th>
<th>$K_X$</th>
<th>$K_{Xm}$</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>240</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td>Secondary is series connected 110V+110V</td>
</tr>
<tr>
<td>2</td>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td>Auto transformer</td>
</tr>
<tr>
<td>3</td>
<td>240</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculation formulas:  
\[ K_X = \frac{V_{pri}}{V_{sec}} \]  
\[ K_{Xm} = \frac{(K_{X1} + K_{X2} + K_{X3})}{3} \]