KARADENİZ TECHNICAL UNIVERSITY

Engineering Faculty

Electric-Electrical Engineering Department

Electrical Machines I Laboratory

SINGLE PHASE TRANSFORMER

Tool Set:

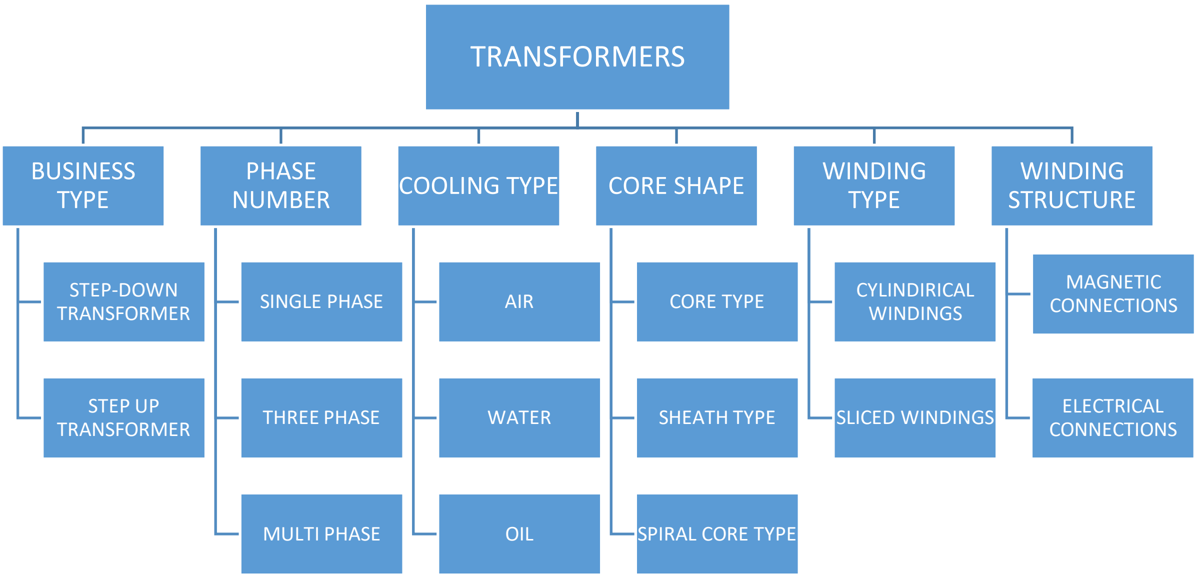
- Experiment Table with Energy Unit
- A.C Measurement Unit
- Energy Analyzer
- Single Phase Transformer
- Multimeter

TRANSFORMERS

1. Introduction

"A device that alters the magnitude of current and voltage without any moving parts by utilizing magnetic fields is referred to as a transformer. In transformers, the form of electrical energy remains unchanged, while the magnitude is modified. The classification of transformers in the market based on various criteria is presented in Table 1.

Table 1. Classification Of Transformers



Stationary electrical machines do not have friction and windage losses, therefore those are more efficient than the others. The transformer, as a stationary electrical machine, experiences only iron, copper, and stray losses. The power range of industrial transformers may vary between VA and MVA, and the output voltage may vary from V to kV.

The structure of a single-phase transformer is illustrated in Figure 1. On the left side of the figure is the primary section, while the right side represents the secondary section. The flux shown on the core is the magnetic field resulting from the current passing through the reluctance, which corresponds to the current in the electrical circuit.

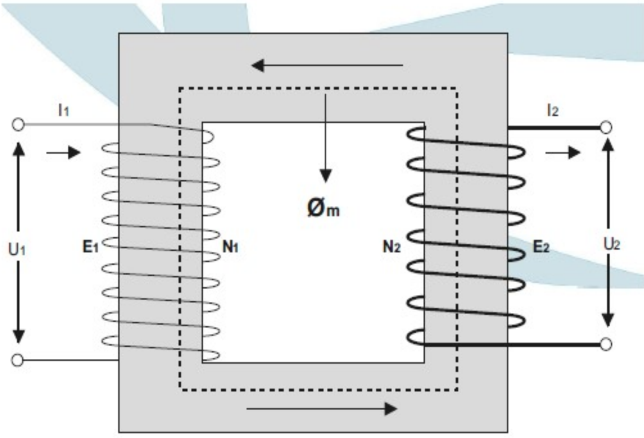


Figure 1. Single Phase Transformer Structure

2. The Operating Principle

Transformers consist of core (magnetic) and windings (electrical). When an AC voltage is applied to the primary winding of a transformer, according to Ampere's law, a variable magnetic field is generated in this winding. This magnetic field intersects the secondary windings through the magnetic core. Since the direction and magnitude of the applied voltage change, the direction and magnitude of the magnetic field in this section also change, resulting in a variable voltage induced in the secondary windings. Due to low losses in transformers, the power received should be equal to the power delivered in ideal conditions. From this equality, the transformation ratio (a) emerges. This ratio is given by Equation 2.1.

$$P_1 = P_2 \Rightarrow U_1 \cdot I_1 = U_2 \cdot I_2 \Rightarrow \frac{\mathrm{U_1}}{\mathrm{U_2}} = \frac{\mathrm{I_2}}{\mathrm{I_1}} = \frac{\mathrm{N_1}}{\mathrm{N_2}} = \mathrm{a} \tag{2.1}$$

3. Transformers Induced EMF - Transformation Ratio

According to Faraday's law, A coil in a variable magnetic field experiences an induced voltage. The magnitude of this induced *Electro-Motive Force (EMF)* is proportional to the frequency (f) of the applied voltage (for the variating magnetic field), magnetic flux (Øm), and the number of turns in the coil (N), shown in (3.1.)

$$E = (4.44 f \varphi_m N) \times 10^{-8} \qquad (V) \tag{3.1}$$

4. Transformer Losses and Efficiency

The losses that occur in transformers are divided into two categories: iron losses and copper losses. Since transformers are stationary static electrical machines, there are no friction and wind losses. Therefore, transformers are the most efficient machines among electrical machines.

Iron losses can be determined through the no-load test as they occur in the core. Copper losses, on the other hand, occur due to the heating of the primary and secondary windings of the transformer. Therefore, they are determined through the short-circuit test (a fault condition beyond the full load). Considering that iron losses occur in the core, they are determined by taking voltage into account, while copper losses, occurring in the windings, are determined by considering the current

The efficiency in transformers is the ratio of the output power (P2) to the input power (P1). This ratio is expressed in Equation 4.1.

$$\mu = \frac{P_2}{P_1} = \frac{(\text{Output Power} = \text{Input Power} - \text{Losses})}{(\text{Input Power})} \tag{4.1}$$

5. Voltage Regulation in Transformers

The difference between the secondary voltage of a transformer in no-load and loaded conditions is referred to as voltage variation or voltage regulation. The percentage voltage regulation is obtained by multiplying the ratio of the nominal secondary voltages by 100. The equation for the percentage voltage regulation of a transformer is provided in Equation 5.1.

$$\%\text{Reg} = \frac{U_{20} - U_2}{(U20)} \tag{5.1}$$

The percentage regulation of a known transformer can be easily calculated when it is loaded to determine how much the secondary voltage changes. The smaller the percentage regulation of transformers, the lower the leakage flux. Ideally, the regulation should be zero, meaning that the measured voltage is the same as the nominal voltage. However, in practice, it may not be entirely ideal, and a certain amount of regulation may be acceptable. Keep in mind that transformer regulation can vary depending on factors such as the transformer's design, material quality, load condition, and other factors.

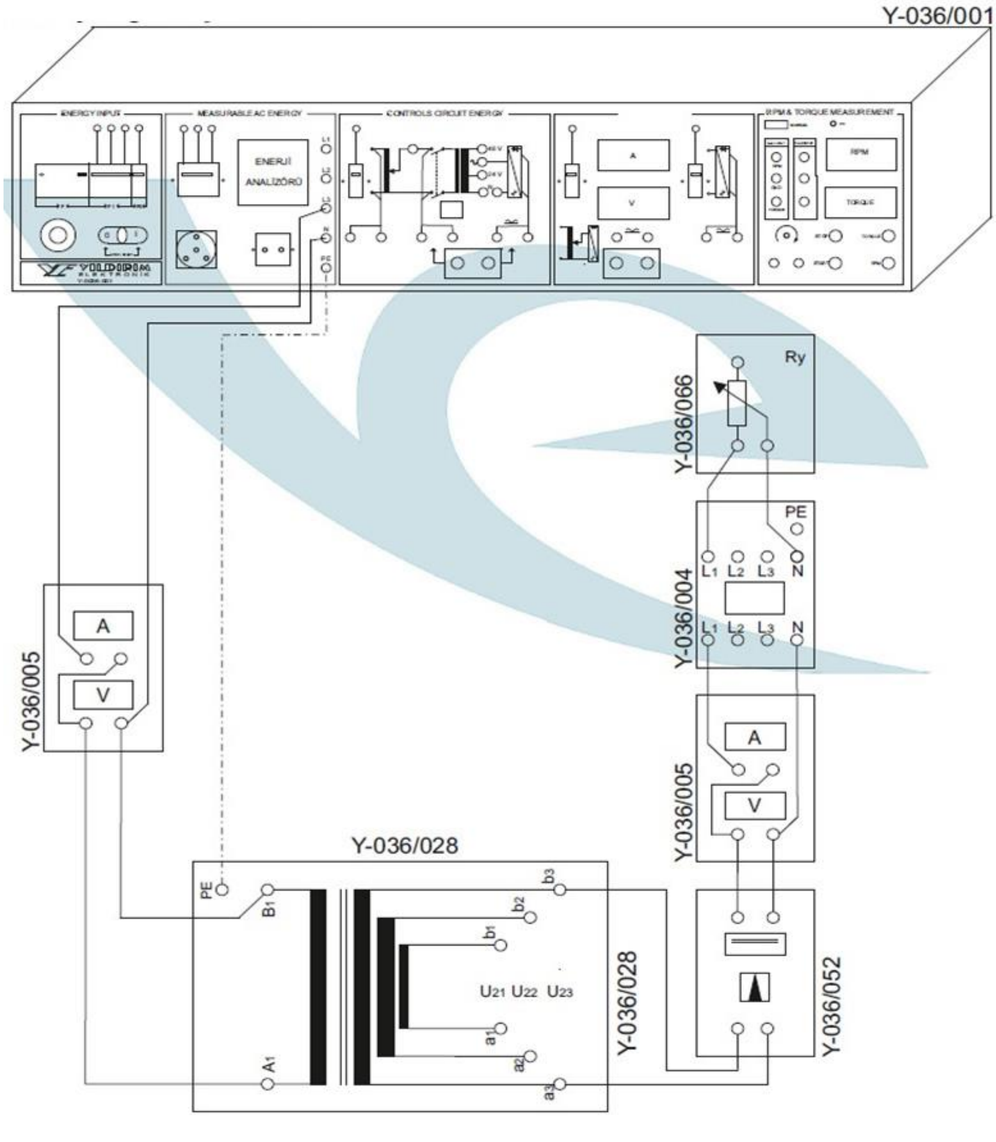


Figure 2. The Connection Diagram for the Loaded Operation Experiment of a Single-Phase Transformer

EXPERIMENT: SINGLE-PHASE TRANSFORMER

Under-Load Operation of Single-Phase Transformer, Regulation and Efficiency

Experiment Goal: To examine the loaded operation of transformers and analyze the factors affecting regulation and efficiency. The connection diagram of the experiment is provided in Figure 2.

- Experiment Procedure: The transformer allows feeding either with L-N or L-L according to the nominal voltage of the primary. Establish the experiment connection given in Figure 2.
- While the transformer operates without a load (no-load condition), it is necessary to select a measuring instrument that can measure smaller values for current (I-W) and power. Apply the nominal voltage to the primary circuit of the transformer when there is no load in the secondary circuit. Fill in the values listed in Table 4 for this condition.
- Load the transformer in increments of 0.25, 0.50, 0.75, 1, 1.25, and 1.5 ratios using the adjustable load rheostat. Fill in the values listed in Table 2 for each position.
- Cut off the power supply and terminate the experiment.

Table 2. Experiment Results

PRIMER DEVRE						SEKONDER DEVRE						Açıklama
U	I	cosφ	W	VA	VAR	U	I	cosφ	W	VA	VAR	

Analysis of Results and Report

Experiment reports must include a cover page. Each group will prepare one report, and everyone is required to contribute to the report. Grading will be based on this principle. Answer the following questions based on the values in the table provided on the sheet and the data recorded during the experiment. Submit the experiment report to the office of Research Assistant Furkan Muhammed KIRIKCI, Room 207-6.

QUESTİONS:

1. Calculate the transformation ratio of the transformer.
2. Explain how to determine the number of turns in the transformer winding.
3. Find the copper and iron losses of the transformer under nominal loading conditions.
4. Find the efficiency value for each condition. Interpret the transformer efficiency based on the load. Draw the transformer efficiency-current graph.
5. What is regulation in transformers? In what range should it be? What is the regulation value of the transformer used in the experiment?
6. List 3 domestic and 3 foreign transformer companies that operate in Turkey, both in production and sales. Describe one product from each, highlighting the three most important features (Your Opinion)