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The Impact of Voltage on Coils with 500 and 1000 Windings on the Performance of a Transformer in the Integrated Physics Laboratory at Campus B of Raden Fatah State Islamic University in Palembang: An Experiment of Physics Education

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Abstrak

Hal yang melatar belakangi penelitian ini ialah belum adanya pengetahuan perbedaan penggunaan 500 dan 100 kumparan terhadap transformator. Penelitian ini menguji dampak variasi jumlah lilitan pada kumparan transformator terhadap tegangan yang dihasilkan. Metode penelitian yang digunakan adalah eksperimen. Hasil analisis data menunjukkan bahwa transformator step up memiliki tegangan primer yang lebih rendah dibandingkan dengan tegangan sekundernya, sementara transformator step down memiliki tegangan primer yang lebih tinggi dari tegangan sekundernya. Hal ini disebabkan oleh perbedaan jumlah lilitan pada kumparan sekunder dan primer. Transformator step up memiliki lebih banyak lilitan pada kumparan sekunder, sehingga menghasilkan tegangan sekunder yang lebih besar. Sebaliknya, transformator step down memiliki lebih banyak lilitan pada kumparan primer, yang mengakibatkan tegangan sekunder yang lebih kecil. Penelitian ini menegaskan bahwa terdapat korelasi antara jumlah lilitan pada kumparan transformator dengan tegangan yang dihasilkan. Dengan demikian, tegangan transformator dapat bervariasi sesuai dengan perubahan jumlah lilitan pada kumparan.
Kata Kunci: Hukum Faraday, Induksi Elektromagnetik, Kumparan lilitan, Tegangan, Transformator.

Abstract

The premise of this study is the lack of understanding regarding the distinction between utilizing 500 and 100 coils for transformers. This study investigates the influence of altering the number of windings on transformer coils on the generated voltage. The employed research methodology is experimental. The data analysis results indicate that a step-up transformer exhibits a primary voltage that is lower than its secondary voltage. By contrast, a step-down transformer exhibits a primary voltage that is greater than its secondary voltage. This is a result of the disparity in the number of windings between the secondary and primary coils. A step-up transformer is designed with a greater number of windings on the secondary coil, which leads to an increased secondary voltage. In contrast, a step-down transformer is designed with a greater number of windings on the primary coil, resulting in a reduced secondary voltage. This investigation validates the existence of a correlation between the quantity of windings on transformer coils and the voltage generated. Hence, the voltage of a transformer might fluctuate based on alterations in the quantity of windings on the coils.
Keywords: *Coil Windings, Electromagnetic Induction, Faraday's Law, Transformer, Voltage.*

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INTRODUCTION

With the advancement of electronic technology, the demand for electrical energy is increasing. Electricity has become a basic human need, making people indirectly dependent on it. For instance, transformers play a crucial role as they are used to step up and step down voltage levels. A transformer is an electrical device that transfers and converts electrical energy from one or more circuits to another through magnetic coupling. It is based on the principle of electromagnetic induction without changing its frequency. Generally, a transformer consists of a core made of laminated iron and two primary and secondary coils. Typically, these coils are made of copper wire wound around the "legs" of the transformer core (Mahmood et al., 2022; Siburian, 2019).

A transformer's primary function is to change a circuit's electrical magnitude, with voltage being the central magnitude altered. Transformers are widely used daily, such as in household appliances that utilize transformers for PLN electricity, including battery chargers, TVs, etc. Generally, transformers can step up or down voltage depending on the number of wire windings. To increase voltage, the number of primary windings should be less than that of secondary windings. Conversely, to decrease voltage, the number of primary windings should be greater than the number of secondary windings (Prasetyo et al., 2023; Tondok et al., n.d.).

Electrical energy needs to determine the voltage produced by a transformer. High-voltage networks are typically used to transmit electrical power to load centers in an electrical power system. Daily electricity from PLN cannot be used directly because the output voltage is very high, necessitating a device capable of stepping up or down the voltage. This device is the transformer (Podajow et al., 2023; Syahputra & Arrozak, 2017).

In addition to stepping up and down voltage, a transformer transfers alternating current voltage from one circuit to another. Therefore, this study aims to understand how a transformer works in electrical systems with specific voltages, particularly in electronics, by examining the impact of voltage on transformer coil windings. The novelty of this study, which makes this paper different, is the number of coil windings, place, and the dependent variable (Pratiwi et al., 2022; Sadi, 2020; Sedjati, 2022).

METHOD

This research employs an experimental method (Emzir, 2020; Rizky et al., 2023; Sudaryono, 2018; Sugiyono, 2019) at the Integrated Physics Laboratory of Raden Fatah State Islamic University in Palembang. The steps conducted in this experiment are as follows:

1. Prepare all the tools and materials that have been arranged.
2. Assemble the circuit as shown in the diagram.
3. Attach the 500-winding coil on one side of the U-core and the 1000-winding coil on the other, with the 500-winding coil as the primary coil.
4. Close the U-core with the I-core and secure it with the provided tightening bolts.
5. Connect the switch to the primary coil, ensuring the switch is in the open position.
6. Use an analog multimeter as a voltmeter with a 50 Vac limit.
7. Set the power supply output voltage to 3 Vac.
8. Double-check the assembled circuit.
9. Turn on the power supply.
10. Close the switch and read the voltage displayed on the multimeter.
11. Repeat steps 9 and 10, varying the power supply voltage to 9 Vac and 12 Vac.
12. Swap the positions of the coils to configure the transformer as a step-down transformer.

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RESULTS AND DISCUSSION

Results

The data analysis results for the transformer can be seen in the following table:

Table 1. The data analysis results for the step-up transformer

Power Supply Voltage (V)	Number of Windings		Vp (V)	Vs (V)	$\frac{Np}{Ns}$	$\frac{Vp}{Vs}$
	Primary Coil Voltage (NP)	Secondary Coil Voltage (NS)				
3	500	1000	5	2	0,5	2,5
9	500	1000	15	4	0,5	3,7
12	500	1000	20	5	0,5	4

Table 2. The data analysis results for the step-down transformer

Power Supply Voltage (V)	Number of Windings		Vp (V)	Vs (V)	$\frac{Np}{Ns}$	$\frac{Vp}{Vs}$
	Primary Coil Voltage (NP)	Secondary Coil Voltage (NS)				
3	1000	500	1	9	2	0,1
9	1000	500	4	13	2	0,3
12	1000	500	7	18	2	0,4

In this study, an analog multimeter with a 50 Vac limit and a maximum scale of 10 Vac for each reading scale was used to determine the voltage value of a transformer. In the analysis of primary and secondary voltage data, the following equation was used:

$$\boldsymbol{V = \frac{Reading\ Scale}{Maximal\ Scale}\ x\ Limit\ Scale}$$

Determining $\frac{\boldsymbol{Np}}{\boldsymbol{Ns}}$ in Step up trafo

$\frac{Np}{Ns} = \frac{500}{1000} =$ 0,5 Windings

Determining $\frac{\boldsymbol{Np}}{\boldsymbol{Ns}}$ in Step down trafo

$\frac{Np}{Ns} = \frac{1000}{500} =$ 2 Windings

Determining $\frac{\boldsymbol{Vp}}{\boldsymbol{Vs}}$ in Step up trafo

1. Voltage 3 volt
   $\frac{Vp}{Vs} = \frac{5}{2} =$ 2,5 volt
2. Voltage 9 volt
   $\frac{Vp}{Vs} = \frac{15}{4} =$ 3,7 volt
3. Voltage 12 volt
   $\frac{Vp}{Vs} = \frac{20}{5} =$ 4 volt

Determining $\frac{Vp}{Vs}$ in Step down trafo

1. Voltage 3 volt
   $\frac{Vp}{Vs} = \frac{1}{9} = 0{,}1$ volt
2. Voltage 9 volt
   $\frac{Vp}{Vs} = \frac{4}{13} = 0{,}3$ volt
3. Voltage 12 volt
   $\frac{Vp}{Vs} = \frac{7}{18} = 0{,}4$ volt

Discussion

This study employed two transformers: a transformer that increases voltage (step-up transformer) and a transformer that decreases voltage (step-down transformer). A step-up transformer is a device that amplifies voltage, while a step-down transformer is a device that reduces voltage. A transformer consists of two wire coils, namely the primary and secondary coils.

Table 1 shows that a step-up transformer has a greater number of windings on its secondary coil and a higher primary voltage compared to its secondary voltage. In a step-up transformer, the primary and secondary coil voltages are related in such a way that if the primary coil has fewer windings than the secondary coil ($N_p < N_s$), the primary voltage is greater than the secondary voltage ($V_p > V_s$) (Nasution et al., 2019).

When an alternating current (AC) voltage is delivered to the primary coil of a transformer, it creates a fluctuating magnetic field that in turn produces an AC voltage of the same frequency in each of the secondary coil windings. Nevertheless, the voltage generated will fluctuate based on the quantity of windings in each coil (Polivka et al., 2022).

According to prior research, when the primary coil is linked to a voltage source, it experiences the passage of an alternating current. The presence of a core within the coil results in the production of a fluctuating magnetic flux. When a load is connected to the secondary circuit, the coil will allow the flow of current, serving as a device that transforms voltage and current (Siburian, 2019).

Based on the data from Table 2, it can be seen that a step-down transformer is the opposite of a step-up transformer. A step-down transformer has more windings on the primary than the secondary coil. In a step-down transformer, the relationship between the primary and secondary coil voltages is such that if the primary coil has more windings than the secondary coil ($N_p > N_s$), this causes the secondary voltage to be greater than the primary voltage ($V_s > V_p$) (Sogen, 2018).

According to Faraday's law, which explains how an electric current generates a magnetic field and how a magnetic field can generate an electric current in a voltage or induced EMF in the secondary coil, the input voltage on the primary coil is related to the output voltage on the secondary coil. However, in a transformer, any change in the magnetic field in the coil will induce an electromotive force (EMF) proportional to the rate of change of flux, hence $N_s > N_p$ (Giancoli, 2001).

This study demonstrates that transformers function on the basis of electromagnetic induction, wherein two electrically insulated coils are magnetically linked. This aligns with the fundamental theory, which asserts that the functioning of a transformer is rooted in the principle that an electric current has the ability to produce a magnetic field. When an alternating current is applied to one of the transformer coils, the quantity of magnetic field lines will fluctuate(Permata & Lestari, 2020).

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SUMMARY

Based on research, it can be concluded that the number of turns in a transformer coil affects its voltage output. Transformers operate on the principle of electromagnetic induction, where changes in electric current in the primary coil create a changing magnetic field, which then induces voltage in the secondary coil. In other words, if the secondary coil has more turns than the primary coil, the secondary voltage will be higher than the primary voltage (step-up transformer). Conversely, if the secondary coil has fewer turns, the secondary voltage will be lower (step-down transformer).

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