Original Research Article

CONSTRUCTION OF A SIMPLE TRANSFORMER TO ILLUSTRATE FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION ALONG SIDE MUTUAL INDUCTANCE

Abstract

The concept of mutual induction which arises from Faraday's law of electromagnetic induction is a major concerned about the size of the magnetic flux cutting across a wire which is directly proportional to the induced Electromotive Force (e.m.f.), this is often time being thought without reference to a physical device. The methodology employed includes the construction and testing of a simple device called transformer. This device is made up of copper wire, thin insulated iron, output display meter, switch, fuse, simple handle and structural wooden case. With this device, an experiment is conducted to illustrate Faraday's law of electromagnetism. This work presents a suitable reproducible device for illustrating mutual induction of a coil. Using an analytical approach, the result obtained signified a step-down transformer. Base on the output result, the transformer can function effectively to give a low voltage output to electrical gadgets.

Keywords: Faraday's law of electromagnetic induction, mutual inductance, testing, transformer, Electromotive Force (e.m.f.)

1. Introduction

Almost every modern device or machine has electric circuits as its heart. Electromotive force (e.m.f.) is required for current flow in a circuit where the source of EMF is the battery. But for vast majority of electric devices that are used in industry and in home (including any device that you plug on a wall socket), the source of e.m.f. is not battery but an electric generating station. Such a station produces electrical energy by converting other forms of energy. But how is this energy conversion done? [1]. The answer is a phenomenon known as electromagnetic induction. If the magnetic flux through a circuit changes, an e.m.f. and a current are induced in the circuit. In generator, magnet moves in relative to coils of wire to produce a changing magnetic flux in the coils and hence an e.m.f. [1]. The central principle of electromagnetic induction and the key note of this work is illustration of Faraday's law. In electromagnetism and electronics, inductance is the property of an electrical conductor by which a change in current flowing through it induces an electromotive force in both the conductor itself and in any nearby conductors by mutual inductance. These effects are derived from two fundamental observations of physics: a steady current creates a steady magnetic field described by Oersted's law; [2] and a time-varying magnetic field induces an electromotive force in nearby conductors, which is described by Faraday's law of induction [2]. Mutual inductance occurs when the change in current in one inductor induces a voltage in another nearby inductor. It is important as the mechanism by which transformers work, but it can also cause unwanted coupling between conductors in a circuit [3]. Referring to the above, the interest of this work is on a device that aided the transmission of electrical power. This device is called the transformer. A transformer can be defined as a static device which helps in the transformation of electrical power in one circuit to electric power of the same frequency in a circuit, but with a proportional increase or decrease in the current ratings [4]. In 1831 Michael Faraday formulated a law on the bases of his experiment. This law is called Faraday's Law of Electromagnetic induction, which states that whenever there is a change in magnetic flux linked with a circuit the induced e.m.f. is proportional to the rate of change of flux. [5].

2.0 Working Principle of the Transformer

The transformer works on the principle of mutual induction of coils. When electric current in primary coil is changed, the flux linked to the secondary coil also changed. Consequently, an electromotive force (e.m.f.) is induced in the secondary coil, thereby inducing electric current through the coil [6]. If $N_{p,}$ N_s are the number of turns in primary and secondary coils respectively, their linkage with the flux, ϕ are considered using the equation below.

$$\phi_p = N_p AB \tag{1}$$

$$\phi_s = N_s AB \tag{2}$$

where A: is the cross-sectional area and B is the flux density [6].

The voltage applied to the primary, from the source of current is used simply in overcoming the back e.m.f. $E_{p,}$ if the resistance of the wire is neglected therefore; it is equal in magnitude E_p. This can be written as:

$$\sum \text{turns} = \frac{\partial \phi B}{\partial t} = \frac{Vp}{Np} = \frac{Vs}{Ns} \qquad (3)$$

$$V_s = V_P \frac{Np}{Ns} \qquad (4)$$

$$V_P = V_s \frac{Np}{Ns} \qquad (5)$$

where N_s = number of turns in secondary Winding, N_p = number of turns in primary winding, V_s = Voltage in primary winding and V_P = Voltage in secondary winding.

Conversely the current relation is:

$$\text{Ip} = \frac{Np}{Ns}.\text{Is} \qquad (6)$$

$$\text{Is} = \frac{Np}{Ns}.\text{Ip} \qquad (7)$$

where: I_s is the current through the secondary winding, I_p is the current through the primary winding (the one connected to a power source), N_s is the number of turns in the secondary winding, and N_p is the number of turns in the primary winding [7].

3.0 Materials and Methods

The transformer is planned based on the principle of step down transformer in which the numbers of turns in the input unit (primary winding) are more than the number of turns in the output unit (secondary winding). The procedures employed includes: construction and testing. The material used are ply wood, copper wire, volt meter, thin insulated iron, masking tape, fused, and a switch. While constructing the transformer, copper wire was wound on a rectangular insulated material. The primary winding was 300 turns, the secondary winding was 270 turns. With this, a step down transformer was anticipated as shown in the circuit diagram Figure 1 and Figure 2.

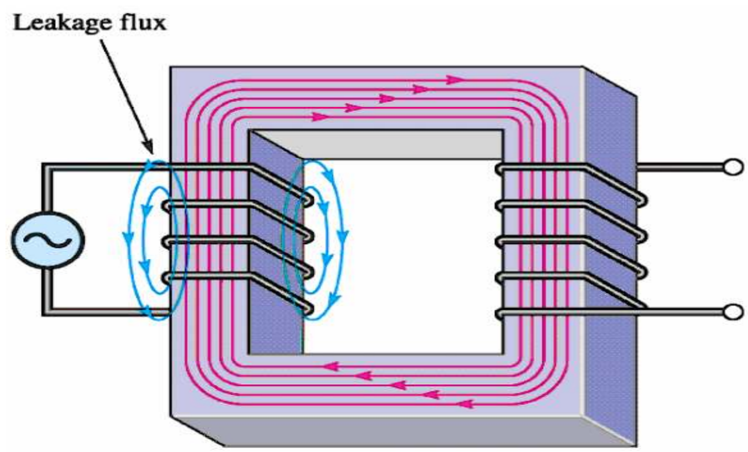

Figure 1: Primary and Secondary Winding (Prof. Andrew H A 2004)

A transformer in which the secondary voltage is greater than the primary voltage is called a step-up transformer while a transformer in which the secondary voltage is less than the primary voltage is called a step-down transformer. The amount by which the voltage is stepped down depends on the turns ratio, the turns ratio of a step-down transformer is always less than 1. When a load resistor is connected to the secondary winding, there is a current through the resulting secondary circuit because of the voltage induced in the secondary coil.

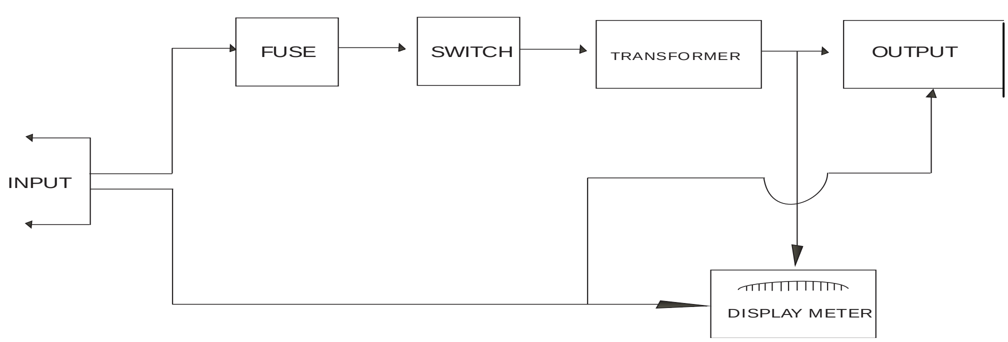

Figure 2: Circuit Diagram of the Constructed Device

After this has being done, a thin insulated soft iron usually E shaped slices were inserted into the space of the material tightly bound together so that magnetic flux does not pass through at all. Having done this, the secondary output wires were connected to a socket outlet which is mounted externally. An output display meter was attached to display the output voltage. At the back elevation, an alternating current (A.C) wire is connected to a fused from which the fuse is connected to a switch and the switch is connected to the primary input wire. Having constructed the transformer, it was cased in an improvised wooden case as shown in Figure 3.

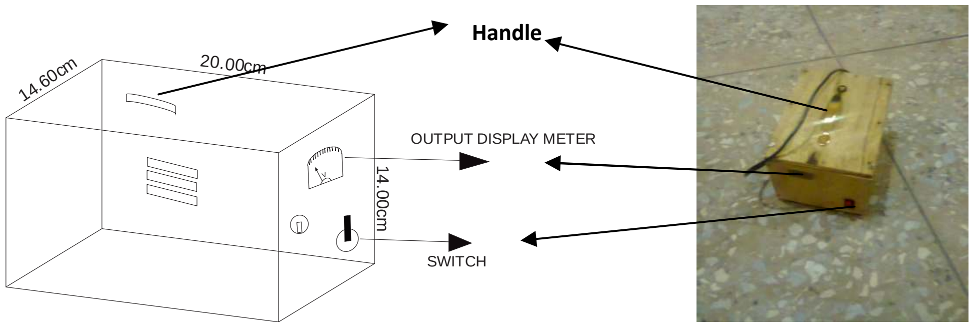

Figure 3a: Front View of the Cased Transformer

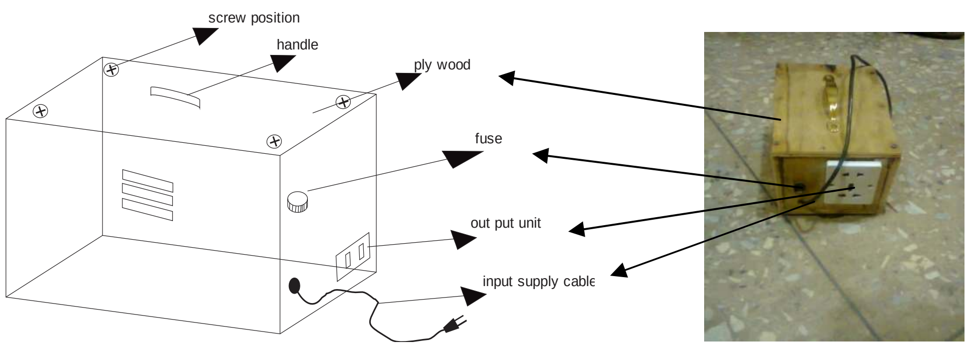

Figure 3b: Back View of the Cased Transformer

The device is constructed using a locally source material, 13 arm socket outlet and a fuse is mounted at the back elevation of the device as seen in figure 3b above, the voltage at the outlet as measured shows that the device can function effectively for any electrical equipments with plug input equal to 13 arm socket outlet, this device can serve in place of a voltage stabilizer.

4. Result and Discussion

The result of this transformer is based on the data recorded during the construction and testing of the transformer in figure 1.

Number of Primary Turns, N_p = 300, Number of Secondary Turns N_s= 270, Output Voltage recorded, V_s = 220 volt, Input Voltage recorded, V_p= ?

From equation (3)

$$Vp = Vs\,.\frac{Np}{Ns} \qquad (8)$$

$$\mathrm{Vp} = 220\,.\frac{300}{270} \qquad (9)$$

$$V_P = 220 \text{ x } 1.11 \qquad (10)$$

$$= 244 \text{ volt}$$

Table 4.1 Variation of V_s with V_p for the same number of turns in N_s and N_p

Number of turns in primary winding (N_p)	Number of turns in primary winding (N_s)	Output Voltage recorded, (Vs)	Input Voltage recorded, (V_p)
300	270	220	244
300	270	150	167
300	270	100	111
300	270	50	56
300	270	20	22

For different value of V_s recorded from the device so also different value of V_p will be obtained. This shows that the device is a step down transformer, since the input voltage is greater than the output voltage.

When the primary winding is connected to the power source, magnetic lines of force are developed around the windings and travels within the iron core as shown in Figure 1. By electromagnetic induction principle, these magnetic lines of force travelling around the core induce another voltage to the secondary windings which gives the idea although the primary and the secondary windings are separated, a lower or higher voltage can be produced in the secondary winding [8]. In Figure 2 above, is the circuit diagram showing the method in which the components were connected while Figure 3 is the physical appearance of the cased transformer showing the position of each component mounted externally.

5.0 Conclusion

A device for illustrating Faraday's law of electromagnetic induction was constructed and tested it was effective. The Faraday's law of electromagnetic induction was illustrated alongside mutual induction of two coils in Figure 1 above, the output voltage as seen on the indicator was 220

Volts. Using analytical approach, the input voltage was obtained to be 244 Volts signifying a step down transformer which confirmed the result for step down transformer. Voltmeter was used to measure the input voltage from a socket outlet (national grid) and was found to be 240 Volts while the calculated input is 244 Volts, the variations between these two values is 4 Volts which may be due to experimental error. Based on the output result of the transformer constructed, the transformer can function effectively at home to give low voltage output to electrical gadgets.

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