DESIGN AND IMPLEMENTATION OF A DIGITAL TRANSFORMER TRAINER

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ABSTRACT

The digital transformer trainer is an electrical instrument design in the electric power and machine laboratory used extensively to demonstrate the operation and performance of the single phase transformer. It allows easy setup on all laboratory exercises on transformer and to check the transformer efficiency and performance. In this paper, the design and implementation of a digital transformer trainer is presented. The digital transformer trainer was constructed and it aims is to incorporate the necessary measuring instrument used to determine the behaviour of a single phase transformer in one inter-connection to become a single instrument for that specific purpose. It was constructed according to specification tested and found to give reliable results on test performed with higher efficiency.

Keywords: *Digital transformer, Phase, efficiency, trainer*

1.0 INTRODUCTION

The digital transformer trainer is designed to simplify designing of digital and analogue circuits. It contains most of the necessary test equipment needed to build and test these circuits. The digital transformer trainer is a set of trainer invented in place of the analogue trainer. It is a portable trainer designed to allow engineers to develop the skills required to connect a single phase transformer ac power network. The trainer is fault able in order to develop sound techniques for troubleshooting a single phase transformer banks. The analogue trainer whose output was normally displayed in a continuous variable physical quantity with fluctuations in data displayed but digital trainer is designed for the output data or reading gotten to displayed in discrete variable form [1] .

This realistic training device replicates the conditions and circumstances that an electrical worker encounters when making common power transformer trainer connections in the industry. A wide variety of activities can be performed, all at reduced voltages for safety [2].

In this design, the single-phase applications are provided. Using banana jacks and plugs, all ground connections, primary connections, and secondary connections are easily made.

Two complete sets of single phase transformers are provided so that transformer paralleling can be explored [3].

Eight instructor-accessible fault switches are provided, in the rear of the device in order to simulate failure conditions and allow troubleshooting during training.

The training aid provides a safe, inexpensive, efficient, yet realistic alternative to paper-based learning without the danger of full-voltage field experience. The tutor is design to demonstrate on any single phase transformer provided that the test load current and voltage values do not exceed the current and voltage rating of the instruments to avoid being damage. The rating power of the trainer must not exceed 4KVA.

2.0 TRANSFORMER TRAINER

A Transformer trainer work at its designed voltage but at a higher frequency than intended will lead to reduced magnetizing current. At a lower frequency, the magnetizing current will increase. Operation of a transformer at other than its design frequency may require assessment of voltages, losses, and cooling to establish if safe operation is practical. For example, transformers may need to be equipped with 'volts per hertz' over-excitation relays to protect the transformer from overvoltage at higher than rated frequency [4].

One example is in traction transformers used for electric multiple unit and high-speed train service operating across regions with different electrical standards. The converter equipment and traction transformers have to accommodate different input frequencies and voltage (ranging from as high as 50 Hz down to 16.7 Hz and rated up to 25 kV) while being suitable for multiple AC asynchronous motor and DC converters and motors with varying harmonics mitigation filtering requirements.

Large power transformers are vulnerable to insulation failure due to transient voltages with high-frequency components, such as caused in switching or by lightning. At much higher frequencies the transformer core size required drops dramatically: a physically small and cheap transformer can handle power levels that would require a massive iron core at mains frequency. The development of switching power semiconductor devices and complex integrated circuits made switch-mode power supplies viable, to generate a high frequency from a much lower one (or DC), change the voltage level with a small transformer, and, if necessary, rectify the changed voltage [5].

The instrument tutor is simply a Circuit comprising of measuring instrument- voltmeter, ammeter and wattmeter of which the addition of wattmeter on the system is optional. The trainer is constructed of a metal sheet or frame where it is mobilized and mounted on a four inch.
During construction, nodes are created for plugging in the banana wires when running test, the mains of the source of a.c is terminated at the power section and it is switched with the aid of a circuit breaker.
The instrument is assembled and made of portable wooden box depending on the choice of the designer if to be l-shape, flat shape or flip shape [6]. With the upper chamber displaying the test instrument (digital voltmeter, digital ammeter and digital wattmeter) and the lower chamber displays the nodes and the terminal point in accordance with designed circuit diagram to show the internal connection of conductors.

3.0CIRCUIT DESIGN
Figure1 shows the Panel circuit of a Transformer trainer

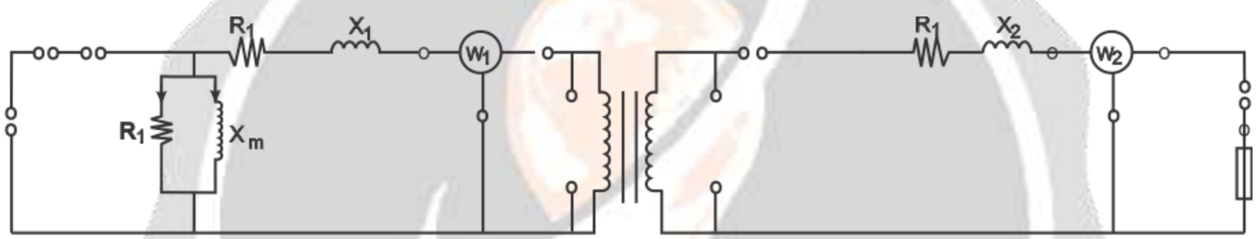

Figure1: Panel circuit

The operational voltage is at 220-240V, rated frequency: 50Hz, rated power: 4KVA and current rating: 5A

3.1 COMPONENT DESCRIPTION
a. Panel meters
This consists of the voltmeter and ammeter for indicating the primary and secondary voltages and currents.
b. Ammeter
Ammeter is a digital meter that displays the current reading as the current increases or decreases and having a rating of 5A.
c. Voltmeter
This is a digital meter that displays voltage reading as the voltage increases or decreases and having a rating of 240V
d. Switch
The type of switch use is toggle switch; it has one set of contact (single pole) and having one switching position which conduct. The switching mechanism has two position open (off) and close (on) the switch is properly rated for the voltage and current required for its application.

3.2 PROCEDURES
The procedures for the construction of the transformer trainer are as follow;
1. The wooden frame is first cut into require size of 60cm by 43cm by 58cm to form a skeletal frame of how the trainer will look like.
2. The pointed board of the transformer shows the parameters of the transformer circuit to required shape and length.
3. The placing of the sockets at the relevant areas to show the current, voltage and power is done by the drilling to give the reading for the connection to the ammeter, voltmeter and wattmeter of the board.
4. Wiring of the socket after drilling is done so that the readings can be shown at the ammeter and voltmeter.

5. Placing the ammeter, voltmeter, circuit breaker and toggle switch was done at their respective position.
6. The wiring was done in such a way that a return path was made so that a complete circuit was established.
7. After the connection of the equipment it is then wrapped with suitable leather to give it ecstatic value.

3.3 FRAME CONSTRUCTION

The trainer is enclosed in an L-shape cast wooden frame with a vertical position slightly bent backwards.

The meters are mounted on a vertical section while the mimic diagram data is covered with vanished ½ plywood board screwed into the meter frame. The front panel where the meters are mounted is covered with velvet cloth to enhance its ecstatic.

The trainer frame rests on four legs, the material for the Trainer construction was chosen with the utmost regard to their reliability, durability, maintainability and readability attributes.

4.0 RESULTS AND DISCUSSION

4.1. **TRANSFORMERTEST**

The importance tests can be carried on the transformer to help determine the transformer efficiency and regulation without actually loading the transformer. The tests include the open circuit test and short circuit test. This test helps to give more accurate results than direct reading of the input and output powers and voltages. Also the power required to carry out the test in very small compared with full load output current of the transformer.

a. THE OPEN CIRCUIT TEST

Carrying out this test helps to determine the iron loss of the transformer. Where the secondary side of the transformer is set open, there is no current flows.

On the primary side of the transformer, the rated voltage is applied on the primary which causes no-load current I_0 to flow. This is read off in the ammeter. At the wattmeter there is a no-load current power reading.

The no load current is usually less than 5% of the full load current.

During this text, the greater part of no-load current serves as the magnetic current I_M to produce the working flux and there is no power consumption.

The smaller active component I_C gives rise to iron-loss and negligible I^2R, that is Copper loss.

The wattmeter reading can be taken as the iron-loss of the transformer.

$P_O = V_i I_i \cos\Theta$

Where the no load power factor is $\cos\Theta = Po/V_i\ I_i$

The iron loss is the sum of losses in the magnetic circuit of the transformer at the no load situation due to hysteresis and eddy-current losses.

At the point no load condition Io=Ii. The iron-loss is constant at no-loads for a given frequency, the iron-loss is dependent upon the flux density and the current density in the windings.

TABLE 1: OPEN CIRCUIT TEST

Primary voltage is Rated V1	Primary current Io	Power Po	Secondary voltage V2
200	0.08		52

From the above test carried out

V1= 200
Io= 0.08
P0=?
V2= 52

In open circuit test, the supply voltage input received by the primary side of the transformer without load is 200V. the primary current is 0.08A and Vs= secondary voltage. The open circuit test power P_o is calculated by using open power formula $P_0 = V_1 I_1 \cos\Theta$

Where $P_0 =$ Open power, $V_1 =$ input voltage, $I_1 =$ input current

Cost=angle where cosΘ=0.999

$Po = 200 \times 0.08 \times \cos\Theta$

=200×0.08×0.999=160watts.

b. SHORT CIRCUIT TEST

The short circuit test is conducted so has to determine the loss of the transformer. The fig2 shows the connection for the test. Since the full load current is flowing, the copper loss is as that on full load on the applied voltage is about 5% of the rated voltage. The flux is small because the voltage applied during the test is usually small.

Hence the reading of the wattmeter can be taken in the copper loss in the winding.

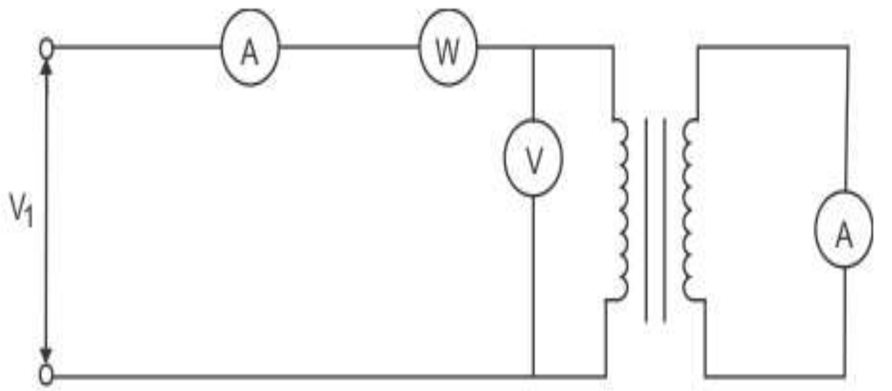

Figure2: Circuit diagram for short circuit

PROCEDURES:

The secondary terminals are short circuited through a suitable ammeter. Then a low voltage is applied on the primary to allow full load current to flow in the primary and secondary circuits.

Table 2: Short circuit test

Primary voltage V1	**Primary current Ip**	**Power**	**Secondary voltage V2**
200	**0.0 6**	**120**	**50**

From the above test carried out:

The primary voltage supplied was 200V and the primary current $Ip = 0.06A$

Calculating for the secondary voltage V2 when loaded $Ps = VsIp\cos\theta$

The V2(secondary voltage=50V when loaded with 60watts electric bulb)

$Ps =$ sending power or output power

$$Ps = 50 \times 0.06 = 120watts$$

From the above, we can say that when a transformer is loaded there will be an induced flow of current.

For instance, when the transformer was unloaded we had 52volt than when loaded. The voltage becomes 50volts due to the resistive load (ie electric bulb).

The readings of power given I_Y I^2R is not the same as the product of V_1I_I because the circuit contains an element of reactance X in series with R. short circuit tests can be perform on any other available transformer to compare result.

4.3 EFFICIENCY OF THE TRANSFORMER

The transformer trainer is a highly efficient. The efficiency of the transformer is achieved when there no friction or windage losses. However, the efficiency is never 100%.

But every designer must try to reduce the losses that might occur in the transformer.
The efficiency of transformer is given as;
N= output power P2/ Input power P1
Power output = P watts
Total copper loss=PC watts
Iron loss=PI watts
Total loss=PC+PI
Power input=output + losses
Ƞ= $\underline{P_2}$ /P1+Pc+Pi
The iron loss value can be gotten from the open circuit test. The iron loss remains constant at all loads; the iron loss is obtained from the short circuit test.
The efficiency may be also being derived from
Ƞ= Output power/input power
Ƞ= input power – losses/input power
= 1 – losses/input power
= 1 – losses/input power
Ƞ= 1 – losses/output power + losses

Figures 3 to 7 shows the picture view of the new digital transformer trainer

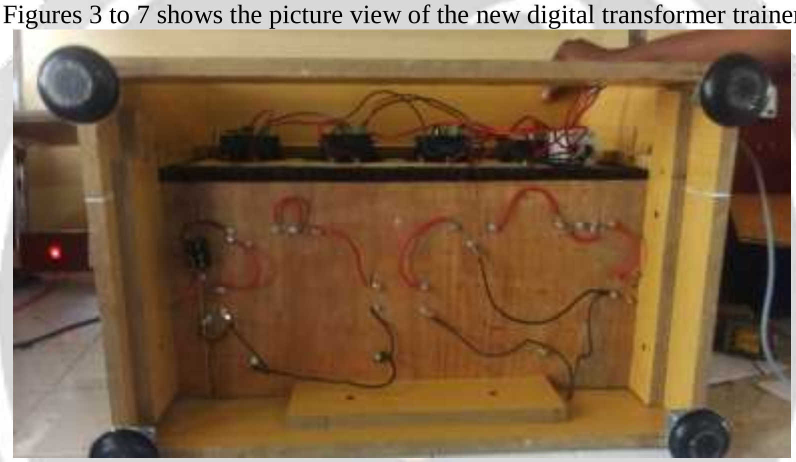

Figure 3: Internal connections of the digital trainer

Figure4: Front view of the digital meters

Figure5: Panel meters internal connection

Figure6: Transformer circuit board internal connection

Figure7: Front view of panel meter of the trainer

5.0 CONCLUSION

The digital transformer trainer was constructed and it aims is to incorporate the necessary measuring instrument used to determine the behaviour of a single phase transformer in one inter-connection to become a single instrument for that specific purpose.

It was constructed according to specification tested and found to give reliable results on test performed on experimental transformer for which the trainer was constructed. Basically, the transformer uses principles electromagnetic mutual induction which changes in the magnetic field around the primary winding cut across the secondary winding as an induced alternating voltage.

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