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DESIGNING THE CIRCUIT OF A 30WATTS STEP DOWN 1 PHASE TRASNFORMER, WITH RATED PRIMARY RESISTANCE 0.03OHM AND PRIMARY INDUCTANCE $0.006H$, USING THE SHORT CIRCUIT AND OPEN CIRCUIT TESTS

ENGR. NWOSU NDUBUISI O.; & & AMAECHI M. C.
Department of Electrical/Electronic Engineering, Federal Polytechnic, Oko

Abstract
This paper examines the experimental design of a 30 watts step down transformer's circuit. The actual circuit is the equivalent circuit with all the parameters referred to the primary. The parameter values in the primary section was obtained through open circuit test and supplemented with calculations. In the section referred to the primary, the values were got and substituted in the parameters referred to the primary was realized. Initially, when designing a transformer, the first requirement is the specification of the transformer and the performance expected from it. The output equation usually employed was output rating $S = 2.22, FM_M A. A_w SK_w X10^{-3} KVA$*, where* f *is the source frequency,* B_m *is the maximum flux density,* A *is the area of cross-section,* A_w *is the window area,* S *is the specific magnetic loading,* K_w*, is the window space factor. However, there are a lot of short comings using this output rating method. Because of this, a direct approach method of open circuit, short circuit tests and supplementary calculations was used.*

INTRODUCTION
There are many misconceptions about transformers, generators, motors and other electronic machines, especially among the lay man and in terms of principle of operation, many people cannot make a distinction between machines. In many occasions people are overheard complaining about faulty transformers for problems that have to do with power outage, whereas in actual

sense, synchronous generators are responsible for power generation. The transformer merely steps up and down the generated voltage (Pavella *et al.*, 2000).

A transformer is a machine that transfers power from one circuit to the other. It increases or decreases the value of alternating voltage as a result of mutual induction between the two circuits and in accordance to Faraday's laws of electromagnetic induction between the two circuits (Theraja, B. L., 2006). A transformer consists of two inductive coils which are separated electrically but magnetically linked together. When one coil is connected to a source of alternating voltage, an alternating magnetic flux is set up in the laminated iron core, most of which is linked with the other coil in which it produces mutually induced E.M.F.

The transformer circuit gives information about the transformer on different circumstances. For instance, when the transformer is ideal, when it is open-circuit and when it is loaded. It gives the data of the transformer both in the primary and in the secondary section. However, for convenience, the parameters of the transformer are either referred to the primary or secondary. With this, it gives the circuit data of the transformer with reference either to the primary or the secondary.

TRANSFORMER CIRCUIT REFERRED TO THE PRIMARY

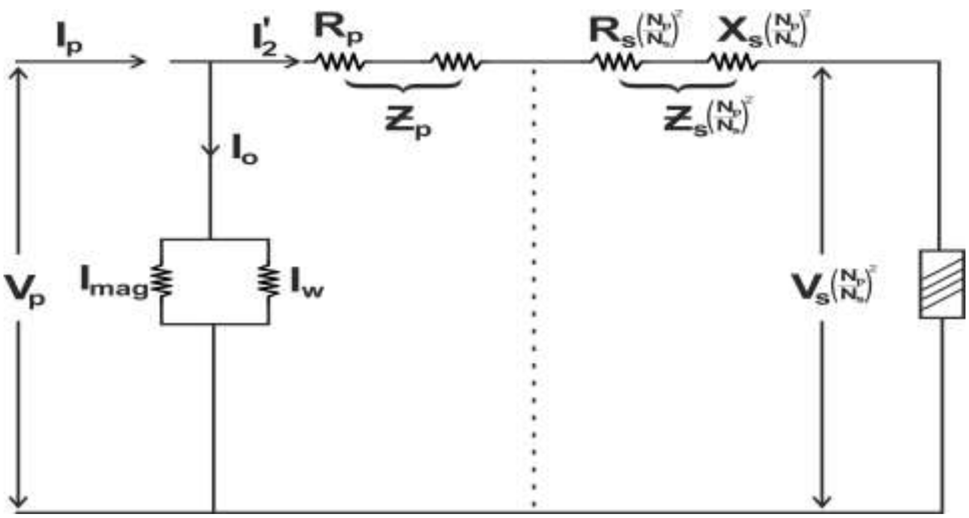

Fig. 1.1

Fig. 1.1 gives the circuit representation of a transformer with all the parameters referred to the primary. Here, I_p = primary current, V_p = applied voltage, I_o = open circuit current, I_{mag} = magnetizing current, I_s^1 = primary additional current, R_p = primary resistance, R_s = secondary resistance, X_s = secondary reactance, Z_L = load impedance, V_s = secondary voltage, N_p = primary turns and N_s = secondary turns.

METHODOLOGY

Substituting the above parameters in fig.1.1 with actual figures obtained from calculations, experiments or tests, gave a full test design of the equivalent circuit of the $30w$ step down transformer.

First, the transformer was subjected to an open circuit test and with this test some values and figures were obtained. Also, supplementary calculations involving the open-circuit data was used to give a full design for the operation of the transformer.

A short circuit test was subsequently conducted and used to confirm the values given in the secondary section referred to the primary. This served as a confirmatory test for the equivalent resistance R_{eq} and equivalent reactance referred to the primary. $R_{eq} = R_s\left(N_p/N_s\right)^2$, $X_{eq} = X_s\left(N_p/N_s\right)^2$.

OPEN – CIRCUIT TEST

Open – circuit test of a transformer was conducted to determine the no – load or core loss ($VI_o \cos$) and no load current I_o which was helpful in finding X_o and R_o.

In this test, the low voltage winding was left open and the other connected to its supply of normal voltage and frequency. A wattmetre w, voltmeter V and an ammeter A was connected in the low voltage winding. With normal voltage applied to the primary, normal flux was set up in the core, hence normal iron losses occurred which were recorded by the wattmeter. The wattmeter readings present the core loss under no load condition.

$w = V_p I_o \cos\theta_o$

$\cos\theta_o = w/V_p I_o$,

$\theta_o = \cos^{-1}\{w/V_p I_o\}$

$I_{mag} = I_o \sin \Theta_o, I_w - I_o \cos \Theta_o$

$X_o = V_p / I_{mag}, R_o = \frac{V_p}{I_w}$

The following result was got from the open circuit test

	Voltage	No Load Current	Resistance	Power	Inductance
Primary	$220V$	$0.5A$	0.03Ω (given)	$30w$	$0.006H$ (given)
Secondary	$110V$	$---$	$---$	$---$	$---$

Calculations for the circuit design

Turns ratio $N_s/N_p = V_s/V_p = {}^{110}/_{220} = {}^{1}/_{2}$

$w = V_1 I_o \cos \Theta_o,$

$w = 30w, \cos \Theta_o = {}^{30}/_{220} \times 0.5 = 0.273$

$\sin \Theta_o = 0.962$

$\Theta_o = \cos^{-1}(0.273) = 74.1°$

$I_{mg} = I_o \sin \Theta_o = 0.5 \times 0.962 = 0.48A$

$I_w = I_o \cos \Theta_o = 0.5 \times 0.273 = 0.1365A$

$X_o = V_p / I_{mg} = {}^{220}/_{0.48} = 458\Omega$

$R_o = V_p / I_w = {}^{220}/_{0.1365} = 1611\Omega$

$R_p(given) = 0.03\Omega$

$L_p(given) = 0.006H$

Converting L_p to inductive reactance in ohms

$X_p = 2\pi f L_p$

$= 2 \times 3.1428 \times 50 \times 0.006$

$= 1.88\Omega$

In the secondary section to the primary

$R_s = R_p (N_s/N_p)^2$

$R_s = 0.03({}^{1}/_{2})^2 = 0.03 \times {}^{1}/_{4} = 0.0075\Omega$

$$X_s = X_p (N_s/N_p)^2 = 1.88({}^{1}/_{2})^2 = 1.88 \times {}^{1}/_{4} = 0.47\Omega$$

THE CIRCUIT IS PRESENTED

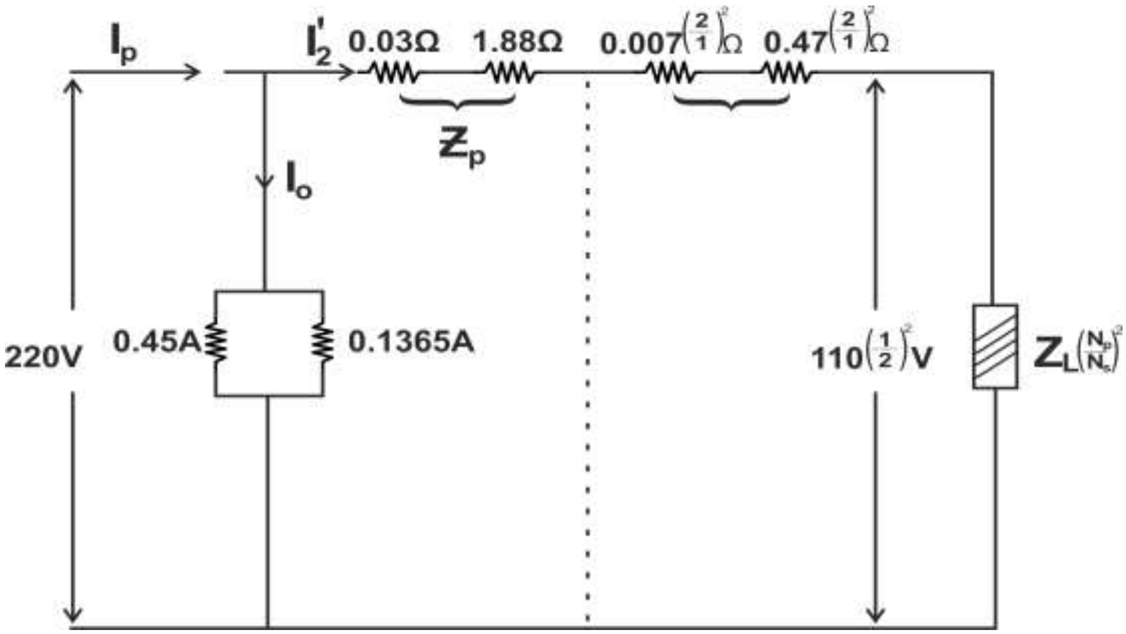

Fig. 1.2

$Z_L\left(N_p/N_s\right)^2$ (load impedance referred to primary) plus $0.47\left(2/1\right)^2\Omega$ plus $0.0075\left(2/1\right)^2\Omega$ give the equivalent impedance referred to the primary. $0.0075\left(2/1\right)^2\Omega + 0.47\left(2/1\right)^2\Omega$ gives the impedance referred to the primary. The impedance referred to the primary is $0.0075\left(2/1\right)^2\Omega + j0.47\left(2/1\right)^2\Omega$.

$= 0.03 + j1.88 = \sqrt{(0.03)^2} + (1.88)^2 = 1.88\Omega$

The equivalent impedance referred to the primary got from the short-circuit test minus the impedance referred to the primary, gives us the value of the load impedance referred to the primary $Z_L\left(N_p/N_s\right)^2$.

SHORT-CIRCUIT TEST

The purpose of this test is to determine the equivalent resistance, equivalent reactance and equivalent impedance referred to the primary. In this test, the terminals of the secondary windings were short-circuited by a thick wire or strip or through an ammeter and variable low voltage is applied to the primary

through auto transformer. The transformer is now equivalent to a coil having an impedance equal to impedance of both windings.
The applied voltage V_s to the primary was gradually increased till the ammeter A indicated full load rated current of the metering side. Since applied voltage was very low, flux linking with the core was very small and therefore iron losses were so small that these can be neglected. Thus, the power input (w) gives the total copper loss at rated load, output being nil. Let the readings of voltmetre, ammetre and wattmeter be V_s, is and W_s respectively.
Full-load copper loss $P_c = I^2 R_{eq} = W_s$
Equivalent resistance $R_{eq} = W_s / I_s^2$
Equivalent impedance $Ƶ_{eq} = V_s / I_s$
From the test
$W_s = 0.15w$

$$R_{eq} \text{ (from open circuit test)} = R_p + R_s\left(N_p/N_s\right)^2$$
$$= 0.03 + 0.03$$
$$= 0.06\Omega$$

$V_s = 15V$
$0.15 = I_s^2(0.06)$
$I_s^2 = {0.15}/{0.06} = 2.5$
$I_s = \sqrt{2.5} = 1.12A$
Equivalent impedance $Ƶ_{eq} = 15/1.12 = 13.4\Omega$
The load impedance referred to the primary

$$Ƶ_L \left({N_p}/{N_s}\right)^2 = \text{equivalent impedance – impedance referred to the primary}$$
$$= 13.4\Omega - \sqrt{(0.3)^2} + (1.88)^2\Omega$$
$$= 13.4\Omega - 1.904\Omega$$
$$= 11.49\Omega$$

RESULTS

After the open circuit test, short circuit test and calculations, the following results were obtained.

OPEN CIRCUIT TEST RESULT

	Voltage (V)	No Load Current (A)	Resistance (Ω)	Power (W)	Inductance (H)
Primary	$220V$	$0.5A$	0.03Ω	$30w$	$0.006H$
Secondary	$110V$	$-$	$-$	$-$	$-$

Table 3.1

RESULTS FROM CALCULATION

10	0	$I_{mag}(A)$	$I_w(A)$	$X_o(\Omega)$	$R_o(\Omega)$	$X_p(\Omega)$	$R_s(\Omega)$	$X_s(\Omega)$	$Z_s^1(\Omega)$	$Z_s(\Omega)$
0.5	74.1	$0.45A$	$0.1365A$	458Ω	1611Ω	1.88Ω	0.0075Ω	0.47Ω	2.41Ω	1.88Ω

Table 3.2

CONCLUSION

It is always desirable to know the behaviour of a transformer with a rated primary resistance and primary inductance, when it is ideal, open-circuit and loaded. The actual figures obtained through the open circuit test, short circuit test and some calculations will help in giving a full design of the transformer circuit.

The information given by this circuit can be used to predict the values of parameters referred to the primary of a higher wattage transformer. For instance, in the result of table 3.2, one can easily predict that copper loss $(I^2R\ loss)$ in the secondary is less than that in the primary. The same information is also given when the secondary becomes the reference point and the primary equivalents are referred to the secondary. So the information of the behaviour of a transformer is got when the transformer is either referred to the primary or secondary.

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