

Experimental simulation analysis for single phase transformer tests

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ABSTRACT

Transformer is one of main components in electrical power system which role to increase or reduce voltage. Characteristics of transformer would be vital to ensure the voltage is fully transferred. A single-phase transformer is a type of power transformer that utilizes single-phase alternating current, meaning the transformer relies on a voltage cycle that operates in a unified time phase. This article describes a workflow executed with Mat lab simulation and practical measurements for single-phase power transformer, no-load, short-circuit test and load test are achieved in this work. The test procedures are implemented on areal transformer (terco-type) which has a specification (1 KVA, 220/110 V, 50 Hz). Finally, the simulation results are appeared a proximately seminar from the practical results. The results indicated that the the technique and manner which presented in the current study can be depended as a miniproject in electrical technology mater for undergraduate studies.

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1. INTRODUCTION

The energy is transferring from primary side (first electrical circuit) to another secondary side (second electrical circuit) by magnetic field intermediate without a change in frequency by using transformer. Primary winding is taken the energy from the applied voltage and transferring it to the load is called the secondary winding. In a transformer there are no movable parts so that, the efficiency is obtained with negligible amount of maintenance [1-10].

2. MATERIALS AND METHODS

A transformer (terco type) is used in this study as shown in Figure 1. The following parts were used for simulation and practical test:

- Voltmeter
- Ammeter
- Wattmeter
- Load

Transformer specifications are:

- Single-phase: 1KVA
- Frequency: 50-60 Hz

- Primary voltage $230V \pm 5\%$
- Secondary: $4 \times 5,7 V \pm 5\%$

The transformer test procedures are demonstrated in Figure 2.



Figure 1. Real 1KVA transformer (terco-type)

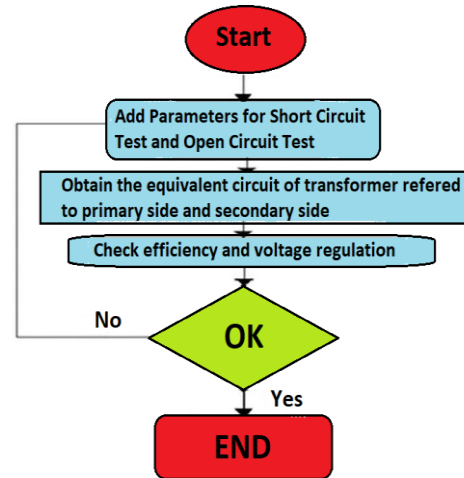


Figure 2. Transformer tests procedures

2.1. Transformer model

Referring to primary side, the equivalent circuit of a single-phase transformer is shown in Figure 3. To delimitation the pertinence between the mutual flux, current and voltages in the core of the transformer is given as:

$$E = R.I + L \frac{\Delta I}{\Delta T} + L \frac{\Delta \Phi}{\Delta T} \quad (1)$$

Assuming the shunt branch impedance to be very large as compared with series branch. R_c and X_m can be neglected. Also, the series parameters R_{eq} is very small than X_{eq} . Therefore, the series impedance can be neglected. Therefore, the transformer model can be represented by the leakage reactance X_{eq} only as shown in Figure 4 [11-17].

The working methodology of simulation is based on open-circuit and short-circuit tests of transformer. Simulation model is designed using MATLAB package. This model needs only current, voltage and power calculations of the transformer primary side but the calculations of the current; voltage and efficiency are taken on the secondary side [18-22].

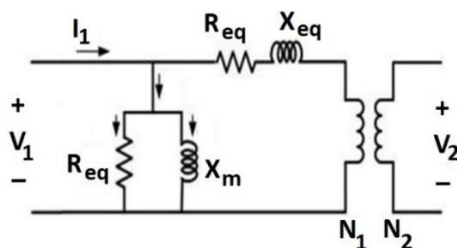


Figure 3. Transformer model

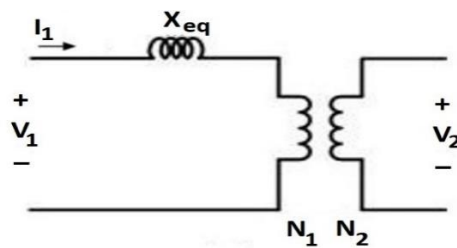


Figure 4. Simplified equivalent circuit of transformer

3. RESULTS

3.1. Transformer open-circuit test

Figure 5 shows the transformer equivalent circuit at no-load (open-circuit) test [23]. To confirm the suggested simulation models, the equivalent circuit parameters that calculated from practical connection are compared with those from simulation results. The real transformer 1 KVA, 50 Hz. (Terco-Company) which tested in the Lab. is shown in Figure 6. The readings that obtained from above test are given in Table 1.

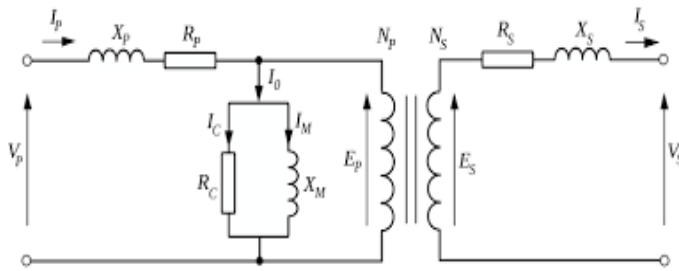


Figure 5. Transformer equivalent circuit (open-circuit)



Figure 6. Practical connection of transformer open-circuit test

Table 1. Transformer open-circuit test readings

Voc (V)	I ₁ (A)	P (W)	Q (VAR)
220	0.19	20	110
200	0.1	12	100

3.2. Transformer short-circuit test

Copper losses calculated based on short-circuit test transformer which shown in Figure 7, the secondary winding of the transformer is shorted, after that a low voltage supply will connect to the primary side. As the maximum flowing in the secondary windings, V_{sc} , I_{sc} represent the short circuit voltage and current as respect to the primary side. P_{sc} , Q_s represent the input active and reactive power [24-28].

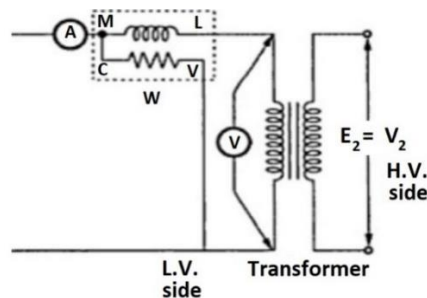


Figure 7. Transformer short-circuit connection

R_{sc} , X_{sc} represent the short-circuit resistance and reactance which can be calculated from these equations.

$$R_{sc} = \frac{P_{sc}}{I_{sc}^2} \quad (2)$$

$$X_{sc} = \frac{Q_{sc}}{I_{sc}^2} \quad (3)$$

where, the inductance L_{sc} is:

$$L_{sc} = \frac{X_{sc}}{2 \times \pi \times f} \quad (4)$$

The transformer short-circuit test is realized practically on the same real transformer that used in the previous test (open-circuit test) as shown in Figure 8. The readings that obtained from above circuits are given in Table 2. To prove the ability of the simulation model as compared with practical connection. The transformer equivalent circuit parameters that obtained from the experimental tested is given in Table 3.



Figure 8. Practical connection of transformer short-circuit test

Table 2. Transformer short-circuit test readings

V_{sc} (V)	I_{sc} (A)	P_{sc} (W)	I_2 (A)
59	5	47	9.25
50	4	30	7.6

Table 3. Equivalent circuit parameters of the experimental transformer

$R_p(\Omega)$	$R_c(\Omega)$	$R_p(\Omega)$	$R_m(\Omega)$	$R_s(\Omega)$	$R_s(\Omega)$
0.94	2420	5.81	1318.6	0.23	1.44

3.3. Transformer modeling

The single phase transformer which is built in MATLAB/Simulink show in Figure 9, consists of four main blocks, (AC supply block), (voltage measurement block), (current measurement block), and the last block (transformer) and the others are represent the assistant blocks to take all readings. The power, current and voltage versus time that obtained from the simulation circuit are shown in Figure 10.

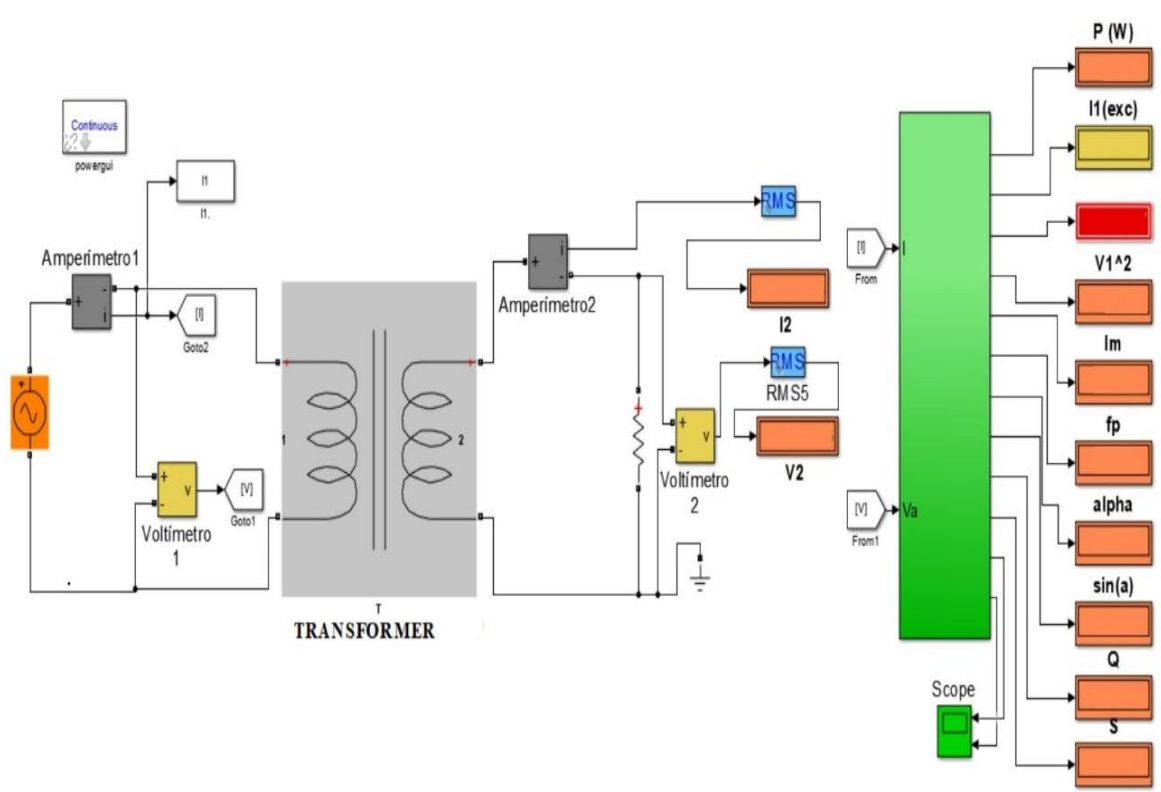


Figure 9. Modeling of open-circuit test on transformer

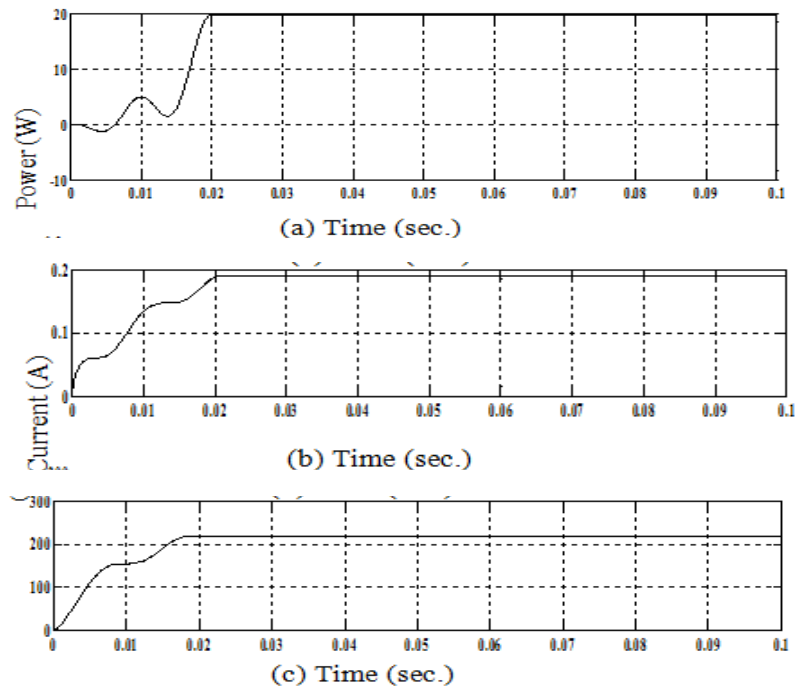


Figure 10. Transformer open-circuit simulation results, (a) Open-circuit power vs. time, (b) Open-circuit current vs. time, (c) Open-circuit voltage vs. time

3.4. Modeling circuit of transformer

Modeling circuit of open-circuit transformer test is depicted in Figure 11. The secondary winding of the transformer is remaining opened and AC supply with variable value and constant frequency is fed to the primary winding. No-load current can be obtained by current measurement block, the primary voltage (V_p) can be obtained by voltage measurement block and subsystem of wattmeter gives no-load power (P_0), which gives core loss. The power, current and voltage values versus time are obtained from simulation circuit as shown in Figure 12. After the open-circuit and short-circuit tests are implemented in the lab, the transformer equivalent circuit parameters are determined. These parameters are putted in the simulation circuit which represents the simulation equivalent transformer circuit and the model. Simulation results for active power, reactive power, current and voltage are given in Table 4. The error ratio into the form of a percentage for voltage and current that calculated by a comparison between the simulation results and the practical results are shown in Table 5.

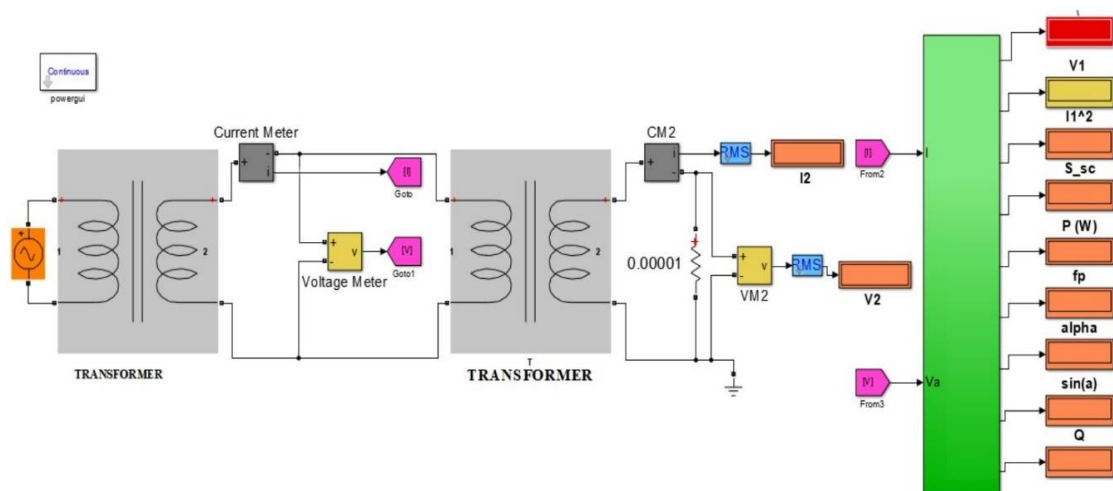


Figure 11. Modeling of short-circuit test on transformer

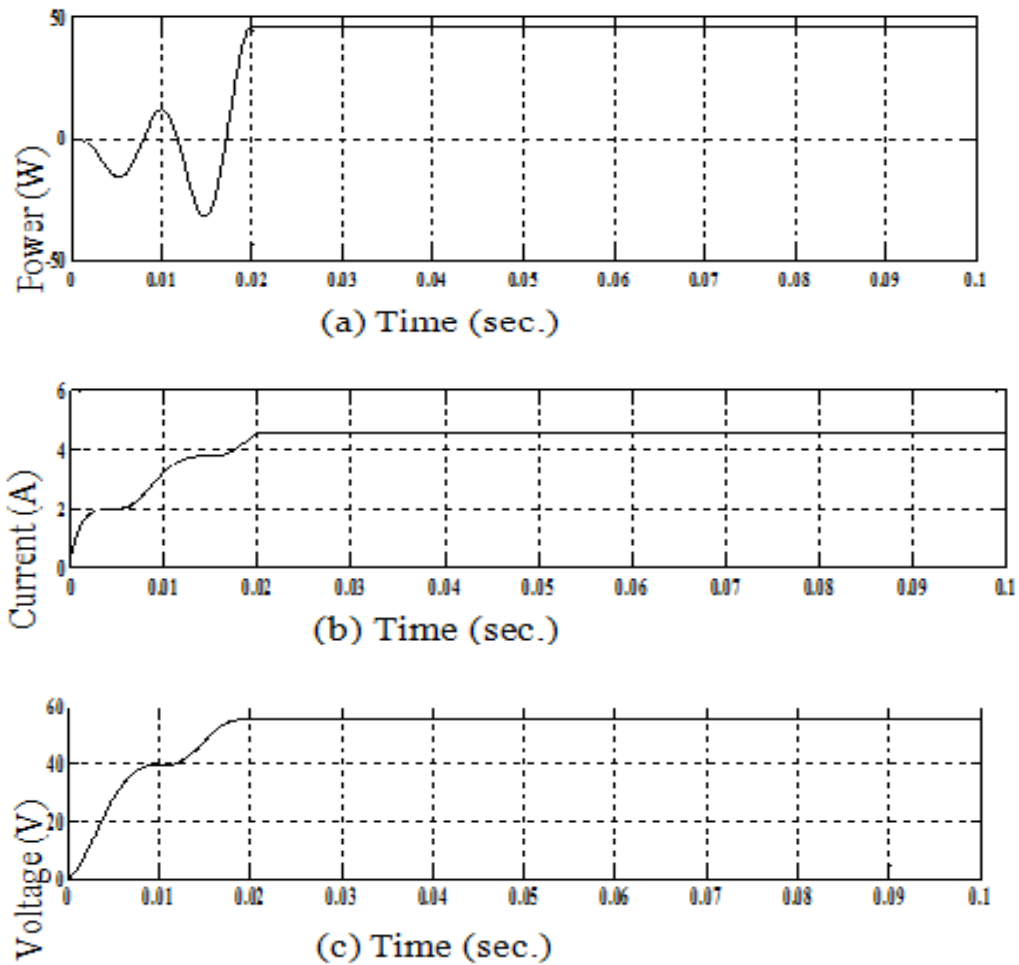


Figure 12. Simulation results of transformer short-circuit test, (a) Short-circuit power vs time, (b) Short-circuit current vs time, (c) Short-circuit voltage vs time

Table 4. Simulation results of the transformer tests

Test type	V (V)	I_1 (A)	I_2 (A)	P (W)	Q (V/R)
Open-circuit test	220	0.18	0	19.84	36.56
Short-circuit test	59	5.03	10.02	47.81	293.2

Table 5. Equivalent circuit parameters and relative errors

	R_p	R_c	X_p	X_m	R_s	X_s
Value (Ω)	0.94	2439	5.78	1324	0.23	1.44
Error (%)	0.27	0.78	0.51	0.40	0.25	0.02

3.5. Load test

Transformer load test is achieved by MATLAB's M. file, in order to find the efficiency on assignment is given to update steady state model of the transformer to amendment the simulation model of transformer test by adding a load of the terminal of the transformer secondary winding. Figure 13 depicts a typical efficiency curves generated by program. The relationship between the efficiency and load current for 0.8 unity power factor is given in Figure 13. It shows the load type and power factor on the transformer efficiency.

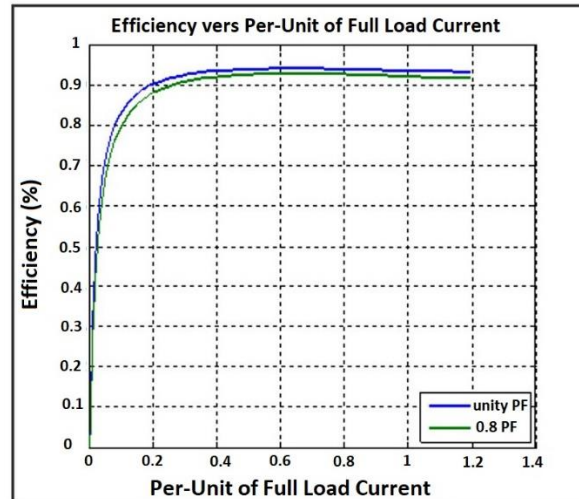


Figure 13. Load test (efficiency vs. load current)

4. CONCLUSION

The results that obtained from simulation are approximately similar to those obtained from practical connection. The technique and manner that presented in this article can be depended as a miniproject in electrical technology mater for undergraduate studies. The transformer efficiency that calculated after load is connected at the secondary terminals in MATLAB simulation is appeared very near from the real value.

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