

Experimental Simulation Analysis for Single Phase Transformer Tests

Ali N. Hamoodi^{1*}, Bashar A. Hammad¹, Fawaz S. Abdullah¹

1- Engineering Technical College, Northern Technical University, Mosul, Iraq.

Email: alihighvoltage@yahoo.com (Corresponding author)

Email: basharabd95@gmail.com

Email: sofia196022@yahoo.com

Received: May 2019

Revised: August 2019

Accepted: October 2019

ABSTRACT:

This article describes a workflow executed with MATLAB simulation and practical measurements for single phase power transformer. In addition, no-load, short-circuit test and load test are achieved in this work. The test procedures are implemented on a real transformer (terco-type) which has specifications of (1KVA, 220/110V, 50Hz). Finally, the simulation results are appeared proximately similar from the practical results.

KEYWORDS: Single-Phase Transformer, No-Load Test, Short-Circuit Test, Load Test, Transformer Efficiency.

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].

2. MATERIALS AND METHODS

A transformer (Terco type) is used in this study as shown in Fig. 1 [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 Fig. 2.

3. TRANSFORMER MODEL

Referring to primary side, the equivalent circuit of a single phase transformer is shown in Fig. 3. To

delimitation the pertinence between the mutual flux, current and voltages in the core of the transformer is given as:



Fig. 1. Real 1KVA transformer (Terco-type).

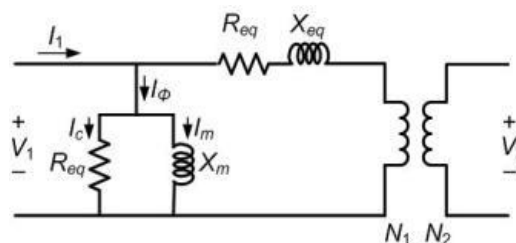


Fig. 2. Transformer Model.

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

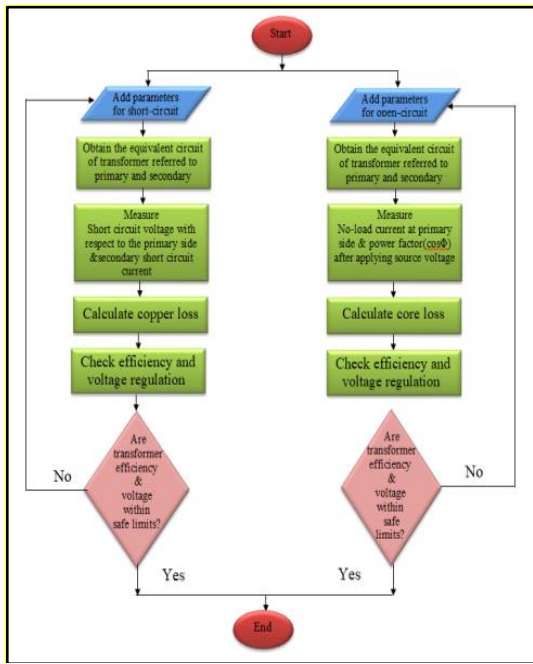


Fig. 3. Transformer tests procedures.

Assuming that the shunt branch impedance to be very large as compared with series branch, R_c and X_m can be neglected. Moreover, the series parameter 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 Fig. 4 [3].

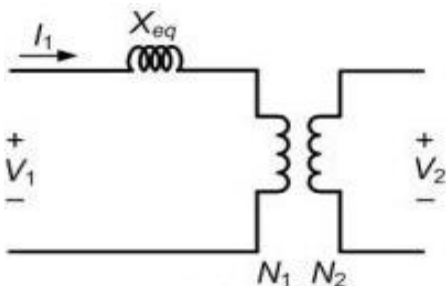


Fig. 4. Simplified equivalent circuit of transformer.

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 [4].

3.1. Transformer Open-circuit Test

Fig. 5 shows the transformer equivalent circuit at no-load (open – circuit) test [5].

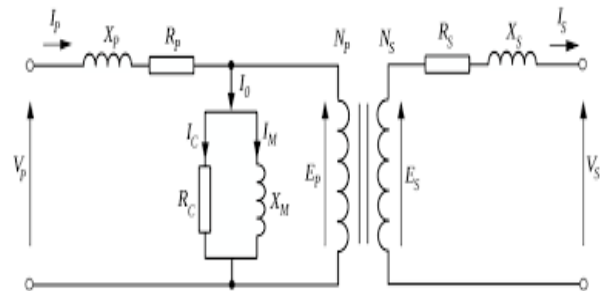


Fig. 5. Transformer equivalent circuit (open-circuit).

To confirm the suggested simulation models, the equivalent circuit parameters which are obtained from practical connection are compared with those from simulation results. The real transformer is 1KVA, 50H, Terco-Company (which was tested in the Lab) is shown in Fig. 6.



Fig. 6. Practical connection of transformer open-circuit test.

The readings obtained from above test are given in table 1 below.

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 are calculated based on short-circuit test transformer which shown in Fig. 7, the secondary winding of the transformer is shorted, after that a low voltage supply will be connected to the primary side. As the maximum is 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_{sc} represent the input active and reactive power [6].

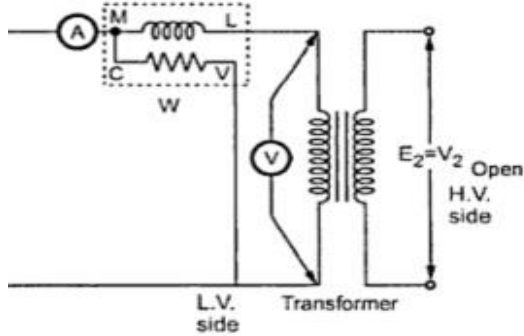


Fig. 7. Transformer short-circuit connection.

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

$$R_{sc} = \frac{P_{sc}}{I_{sc}^2} \tag{2}$$

$$X_{sc} = \frac{Q_{sc}}{I_{sc}^2} \tag{3}$$

Where, the inductance L_{sc} is:

$$L_{sc} = \frac{X_{sc}}{2 \times \pi \times f} \tag{4}$$

The transformer short-circuit test is realized practically on the same real transformer which are used in the previous test (open-circuit test) as shown below [see Fig. 8].



Fig. 8. Practical connection of transformer short-circuit test.

The acquired data obtained from above circuits are given in Table 2.

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

To prove the ability of the simulation model, it was compared with practical connection. The transformer equivalent circuit parameters, which are obtained from the experimental, tested are given in Table 3.

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 is shown in Fig. 9. This transformer 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.

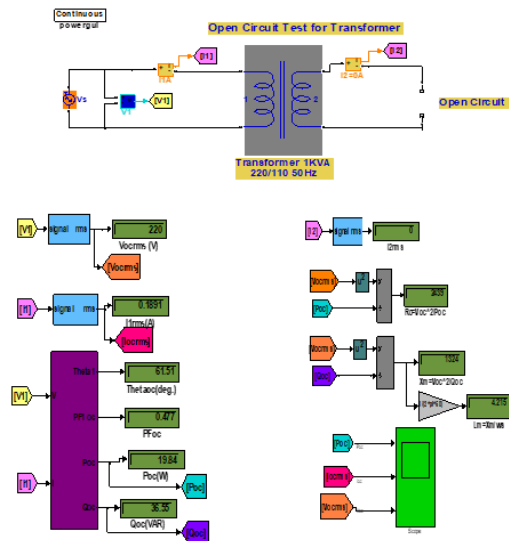
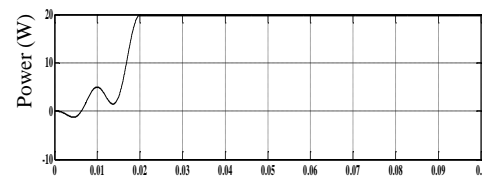
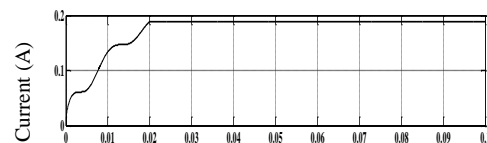


Fig. 9. Modelling of open-circuit test on transformer.

The power, current and voltage versus time that obtained from the simulation circuit are shown below [see figure 10].



(a) Time (sec.)



(b) Time (sec.)

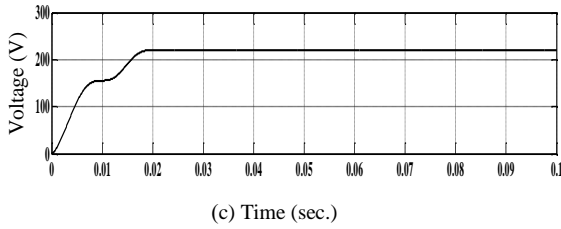


Fig. 10. Transformer open-circuit simulation results.
 (a) Open-circuit power vs time.
 (b) Open-circuit current vs time.
 (c) Open-circuit voltage vs time.

3.4. Modeling Circuit of Transformer

Modeling circuit of open- circuit transformer test is depicted in Fig. 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.

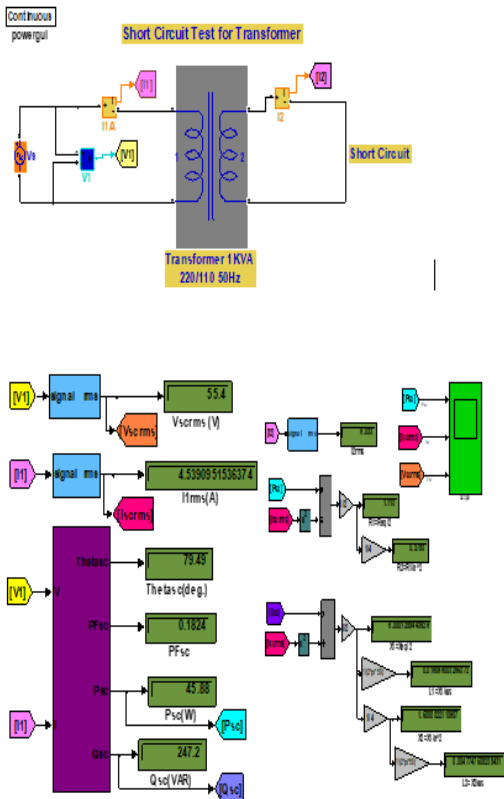


Fig. 11. Modelling of short-circuit test on transformer.

The power, current and voltage values versus time are obtained from simulation circuit as shown below [see Fig. 12].

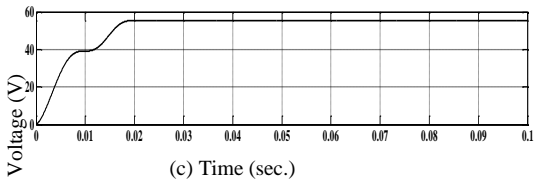
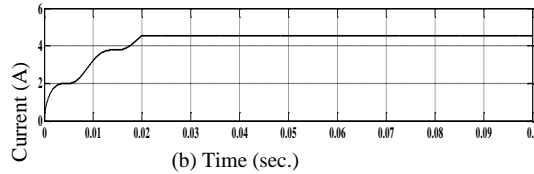
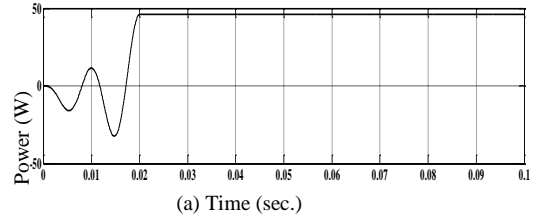


Fig. 12. Simulation results of transformer short-circuit test.
 (a) Short-circuit power vs time.
 (b) Short-circuit current vs time.
 (c) Short-circuit voltage vs time.

Subsequently, 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.

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

The error ratio into the form of a percentage for voltage and current calculated by a comparison between the simulation results and the practical results are shown in Table 5.

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 assignment, where, updating steady state model of the transformer to amendment the simulation model of transformer test is given by adding a load of the terminal of the transformer secondary winding. Fig. 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 Fig.13. It shows the load type and power factor on the transformer efficiency.

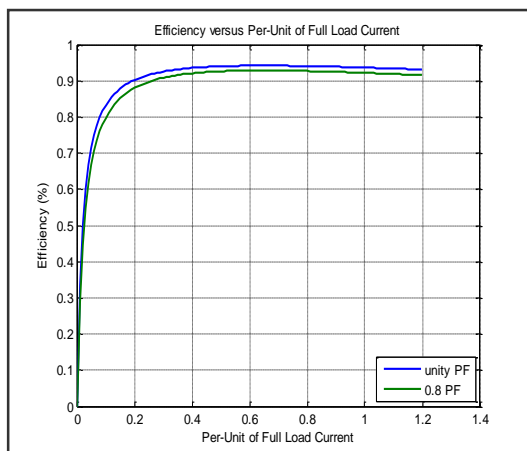


Fig. 13. Load test (efficiency vs. load current).

4. APPENDIX

R List of symbols:

- V1: Primary voltage (V).
- V2: Secondary voltage (V).
- I1: Primary current (A).
- Rc: Core loss components (Ω).
- Xm: Magnetizing reactance (Ω).

- Xeq: Leakage inductance (Ω).
- Req: Transformer winding resistance (Ω).
- N1: N2: Turns ratio of the transformer.
- E: Voltage (V).
- R: Winding resistance (Ω).
- I: Winding current (A).
- L: Winding leakage inductance (H).
- ΔI : Incremental current (A).
- $\Delta \Phi$: Incremental magnetic flux (Web).
- ΔT : Incremental time (Sec).

REFERENCES

- [1] R. Singuor, P. NeefiPathak & D. S. Babu, "Simulation of Single Phase Transformer with Different Supplies", *International Journal of Scientific and Research Publications*, India, Vol. 2, Issue 4, ISSN 2250-3153, April 2012.
- [2] KV Atransformer, on website: www.tercosweder.com
- [3] Andrea Ljubljana, "Basic Principle and Operation of a Transformer", *University of Ljubljani Fakulteta 20 electrofebniko Trzaka 25, 1000 Ljublijana, Slovenija*, March 2018.
- [4] G. Aponte, H. Cadavid, J. C. BURGDS, "A Methodology for Obtaining by Measurements the Transformer Physical-circuitual Model Parameters", *Universidad Carlos III (3)*, ISSN 0033-2097, R. 88 NR 9a/2012.
- [5] J. Baraniak, K. Pachowicz, A. Nafalski, H. Considine, & Zorica, "Determination of Parameters of an Equivalent Circuit of a Single-Phase Transformer using a Remote Laboratory", *World Transactions on Engineering and Technology Education*, Vol. 14, No. 4, 2016.
- [6] R. Majumder, S. Ghosh, R. Mukherjee, "Transient Analysis of Single Phase Transformers Using State Model", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 5, Issue 3, March 2016.