SIMULATION BASED PERFORMACE ANALYSIS OF CURRENT LOADING EFFECT ON A SINGLE PHASE TRANSFORMER

Adil Farooq, Rafi U Zaman, Omais Khan
Department of Electronic Engineering, Faculty of Engineering and Technology
International Islamic University Islamabad, Pakistan
*Corresponding author email: adil.farooq@iiu.edu.pk Tel: +92-322-5360038

ABSTRACT: *We present in this paper a Matlab based simulation model to compute current-loading parameters required to demonstrate the performance of a single-phase transformer. The method is simple and efficient using the indirect loading technique by performing short and open circuit tests, determined current, voltages and power dissipation. By this we can obtain the efficiency and voltage regulation of any single phase transformer. Our system provides a user friendly graphical user interface to observe the effect of loading input parameter variations. With this model we can accurately analyze the variations of a single phase transformer providing the input specifications. A 230V/200V single phase transformer is simulated and the obtained result graphs are discussed.*

Key words: Efficiency, Regulation, Simulation, Single Phase Transformer

1. INTRODUCTION

Transformers are widely used as a static machine in power distribution system. It transfers electrical energywithout change in frequency from one side to another [1]. Increasing loads especiallynon-linear on a transformer causes various effects decreasing the efficiency [2]. A lot of studies have been carried out for evaluating performance giving the detail of a tested single phase transformer. Yet most of them have focused only on the losses occurred due to harmonic effects [3-5]. Voltage regulation and efficiency are the main parameters of any transformer. To obtain open circuit and short circuit tests are conducted. The current is measured by applying single phase to primary side of a step down transformer. The variation of current in the transformer is observed at the primary side with respect to changing loads [6]. Efficiency is measure of output power of transformer delivered to load. Therefore it is important to calculate the efficiency of a transformer and voltage regulation [7].

In this paper Section 2 shows the single phase transformer model, section 3 describes the working methodology. Section 4 shows and explains the simulation setup in GUI. Section 5 shows loading effect on efficiency. Section 6 shows the loading effect on regulation. Finally, the main conclusions is presented and future recommendation given in Section 7 and section 8 respectively .

2. TRANSFORMER MODEL

An equivalent circuit referred to primary side of a single phase transformer is shown in Figure 1.

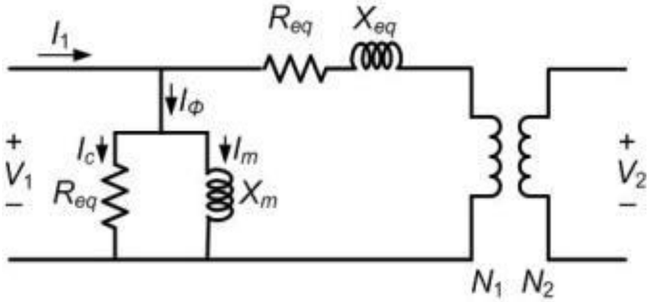

Figure 1 Equivalent circuit of a single-phase transformer

The general expression to determine the relationship between the voltages, currents and mutual flux in the transformer core is given as below

$$E = R.I + L\frac{\Delta I}{\Delta T} + L\frac{\Delta \phi}{\Delta T}$$

Where

V_1 : Primary voltage (Volts)
V_2 : Secondary voltage (Volts)
I_1 : Primary current (Ampere)
R_c : Core loss component (Ohm)
X_m : Magnetizing reactance (Ohm)
X_{eq} : Leakage inductance (Henry)
R_{eq} : Transformer winding resistance (Ohm)
$N_1 : N_2$ Turns ratio of the transformer
E : Voltage (Volts)
R : Winding resistance (Ohm)
I : Winding current (Ampere)
L : Winding leakage inductance (Henry)
ΔI : Incremental current (Ampere)
$\Delta \phi$: Incremental magnetic flux (Weber)
ΔT: Incremental time (Seconds)

Assuming the impedance of shunt branch to be very large as compared to series branch. We can therefore neglect R_c and X_m. Also the series parameters, R_{eq} is very small than X_{eq}. Thus we can neglect the series impedance. The transformer model therefore can be represented by the leakage reactance X_{eq} only.

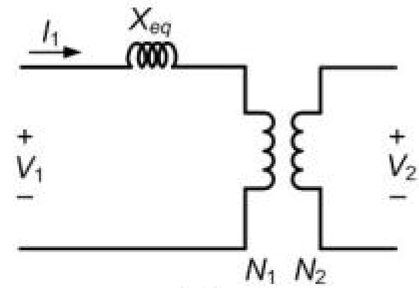

Figure 2 Simplified equivalent circuit of a single-phase transformer

3. WORKING METHODOLOGY

The working methodology of our simulation is based on open and short circuit test of transformer to analyze it by plotting its efficiency and regulation against load. Our simulation model is designed using Matlab. A user defined GUI is developed to observe the response of transformer. We have interfaced different key bottoms to calculate and show the response. The model requires only two input parameters. We have voltage, current and power of the primary side of the transformer while calculate the voltage, current, efficiency and voltage regulation of and the secondary side of the transformer.

4. SIMULATION SETUP

Our developed a GUI based simulation model is as shown in

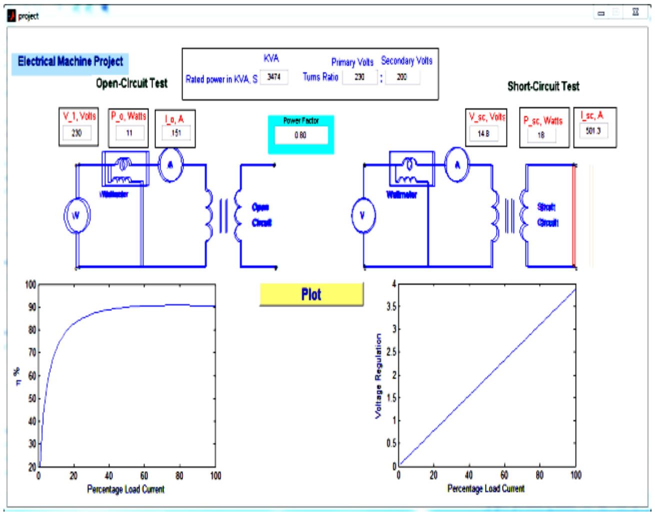

Figure 3.

Figure 3 Transformer Simulation Model

The setup is performed for 230V/200V transformer and the open circuit test results are calculated at the low voltage side while the short circuit test is calculated at the high voltage. We get the current measurements from the open and short circuit tests. Finally the load equalent resistance and impedance is computed as shown in Table I below.

Table I

Input Data					
KVA Rating	**Primary Voltage (V_1)**		**Secondary Voltage (V_2)**		**K**
0.347	230		200		1.15
Open Circuit Test					
V_o(v)		***I_o (A)***		***P_c (Watt)***	
230		0.051		11.73	
Short Circuit Test					
V_{sc} (v)		**I_{sc} (A)**		**P_{cu} (Watt)**	
14.4		1.3		18.72	
Output Data					
I_c (A)	**I_m (A)**	**R_c (Ω)**	**X_m (Ω)**	**R_{eq} (Ω)**	**X_{eq} (Ω)**
0.47	0.014	4893.6	1608.3	10.65	3.0422

Here

$K=\frac{V1}{V2}$

The rating of a single phase transformer is given by:

$P_{(watt)}= V_{(V)} \times I_{(A)}$

And the apparent power *S* or the KVA rating of single phase transformer is calculated as:

$S_{(kVA)} = I_{(A)} \times V_{(V)} / 1000$

Above parameters are calculated using the relations:

$I_c = P_c/V_o,$

$I_m=(Io^{2-} I_c^{2})^{1/2}$

$R_c=V_1/I_c$

$X_m=V_1/I_m$

$Z_{sc}=P_{cu}/I_{sc}$

$R_{eq}=P_{cu/}\ I^2_{sc}$

$X_{eq}= (Z^2_{sc}-R_{eq}^{2})^{1/2}$

The Graphical User Interface block diagram setup is shown in Figure 4 below.

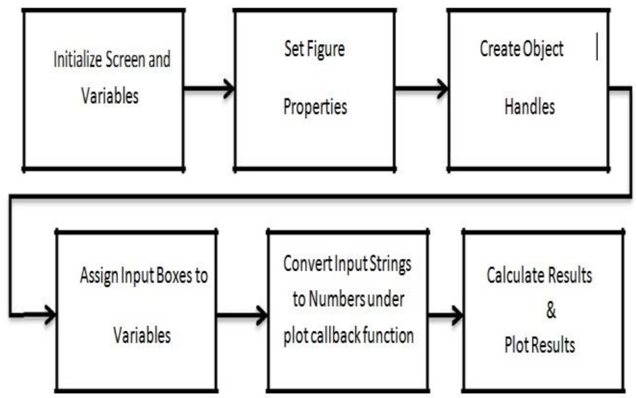

Figure 4 Graphical User Block Diagram

This graphical user interface (GUI) enable there user to perform various tasks. There are three main parts required to create a Graphical User Interface in MATLAB

A. Components

All labeled pushbuttons boxes represent graphical components. They can also be static elements called frames, text strings etc.

B. Figures

The GUI is arranged within a window like screen called the figure.

C. Callbacks

Different ways to perform an action clicking buttons by a user. Such event is called a call back.

5. LOADING EFFECT ON EFFICIENCY

By analyzing the efficiency plot of a single phase transformer we can estimate losses in transformer due to winding resistance and armature reaction. Graph obtained by direct loading method is shown in Figure 5 below.

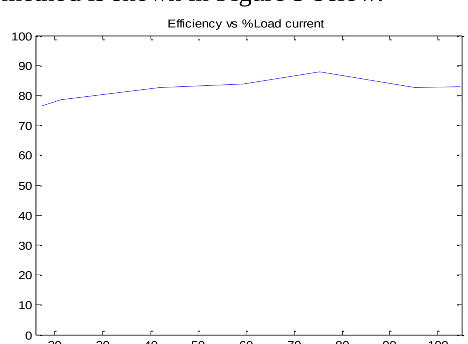

Figure 5 Direct Loading and Efficiency

This graph is obtained by applying a load to transformer and measuring its efficiency. This graph plot shows that transformer has maximum efficiency of about 90% at 77% load current and is increasing from 0 to 75% load. It has maximum value at 75% load current. Then it starts decreasing till maximum load current. So we have a point at which transformer has maximum efficiency. We use transformer under this region. This graph also shows that as load increases power delivered to load also increases till we reach a point where efficiency is maximum. Increasing further load the efficiency decreases due to increasing losses. Hence the gap between input power and output power also increases as shown in Figure 6 below.

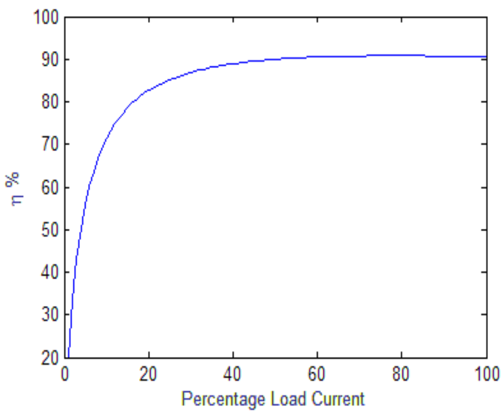

Figure 6 Indirect Loading and Efficiency

This graph also shows that maximum efficiency of transformer is about 90% at about 75% load. Both graphs are approximately the same. Thus we can analyze the performance of transformer by indirect loading method. This graph show that efficiency increases as load current increases. It increase exponentially from 0 to 20% load current then its increase in slow at it has maximum value at a point called maximum efficiency point. Then it starts decreasing. So efficiency is maximum at 77% load current.

6. LOADING EFFECT ON REGULATION

When the load current is increased, the voltage across load terminal becomes low. To measure this effect we use the term of regulation called voltage regulation. Graph Obtained by direct loading method is shown in Figure 7.

This graph is obtained by applying a load to transformer and measuring its terminal voltage. This plot shows that transformer has maximum regulation of about 3.8%. This graph is also measure of voltage drop across terminal of transformer due to copper losses in winding and armature reaction.

Graph obtained by indirect loading method is show in Figure 8. The graph also shows that maximum Regulation of transformer is about 3.9 %. This Graph is very close to that obtained by practically loading the transformer. Thus if we know the open and short circuit test result we can analyze transformer's efficiency and regulation. In other words we can analyze transformer's Performance.

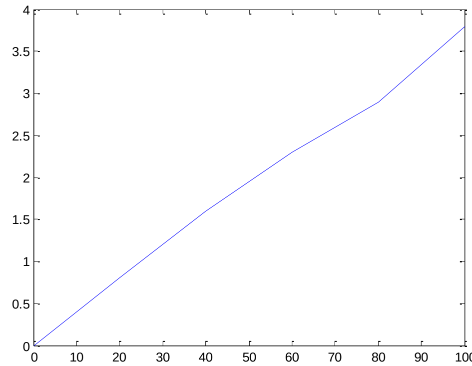

Figure 7 Direct Loading and Regulation

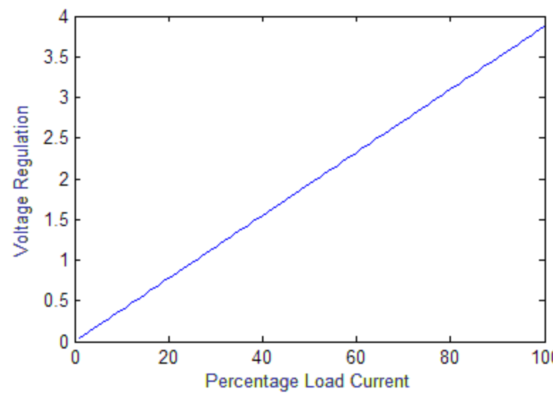

Figure 8 Indirect Loading and Regulation

For calculating efficiency and regulation

Efficiency (η) = $\frac{Power\ Output}{Power\ Output+Pc+Pcu}$

Regulation (R) = $\frac{E2-V2}{E2}$

Here E_2 is no load secondary terminal voltage

7. CONCLUSION

A GUI based simulation tool has been developed in MATLAB to display and analyze the performance of single phase transformers. This GUI demonstrates the performance using open circuit and short circuit tests, finds the efficiency and voltage regulation of transformers. This simulation interface provides a user-friendly GUI to help the user to analyze transformer behavior. The effect of variation of any input parameter can also be observed. Our developed simulation model tool is very helpful in analyzing of any single phase transformer under ideal conditions with no external losses.

8. FUTURE WORK

The results obtained by simulation can be verified by practically inspecting and measuring efficiency and regulation of single phase transformer taking internal factors and total losses into consideration.

REFERENCES

[1] R. Singuor, P. Solanki, N. Pathak, D.S. Babu, Simulation of Single Phase Transformer with Different supplies, *International Journal of Scientific and Research Publications*, **2(4)**,1-5,**(2012).**

[2] R.K. Tripathi, C.P. Singh, Power Quality Control of Unregulated Non Linear Loads,*International Conference on Power, Control and Embedded Systems (ICPCES)*, 1-6, **(2010).**

[3] S.B. Sadati, A. Tahani, Darvishi, B., Dargahi, M., Yousefi, H., Comparison of distribution transformer losses and capacity under linear and harmonic loads,*IEEE 2nd International Power and Energy Conference (PECon)*, 1265 – 1269, **(2008)**.

[4] S. BIRICIK, Ö.C. ÖZERDEM, A Method for Power Losses Evaluation in Single Phase Transformers under Linear and Nonlinear Load Conditions,

[5] *PRZEGLD ELEKTROTECHNICZNY (Electrical Review)*, 74-77, **(2011)**.

[6] B.T. Pung, M.S. Naderi, T.R. Balckburn and E. Ambikairajah, Effects of Currents and Harmonics on Distribution Transformer Losses, *International Conference on Conditioning and Diagnosis (CMD)*, 633-636, **(2012)**.

[7] D. T. Kefalas, A. G. Kladas, Harmonic Impact on Distribution Transformer No-Load Loss,*IEEE Transactions on Industrial Electronics*, **57(1)**, 193-200, **(2010)**.

[8] S. Biricik, O.C. Ozerdem, Experimental Study and Comparative Analysis of Transformer Harmonic Behaviour under Linear and Nonlinear Load Conditions, *10th International Conference on Environment and Electrical Engineering (EEEIC)*, 8-11, **(2011).**