

Transformer Testing and Analysis using MATLAB/Simulink

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Abstract

The Transformers working is based on the principle that energy can be efficiently transferred by magnetic induction from one winding to another winding by a varying magnetic field produced by alternating current. The magnetic circuit or core of a transformer is designed to provide a path for magnetic field, which is necessary for induction of voltages between the windings. In this paper, we have a MATLAB-program that utilizes a Graphical User Interface (GUI) to calculate the circuit parameters and efficiency of single phase ac transformer. This project has been designed and developed by using MATLAB & SIMULINK for developing the graphical user interface (GUI) of AC transformer. This GUI could be used in the form of simulation for an electrical software application in laboratory session. It is also can be used as e-learning of teaching and learning process in terms on how to analyses practically through the software. This paper has presented a virtual instrument (VI) of AC transformer by using MATLAB & SIMULINK which it is a user-friendly programming language and easy to be learnt by new programmer. It practices the user-friendly application which the user just needs to give a desired data for processing stage and output performance result. This paper consisted of three sections which are single phase transformer, Transformer Tests and Performance, Performance (Z_1 , Z_2 , R_c , X_m), Performance (Z_{eq} , R_c , X_m) These analyses focused on the performance of the AC transformer and other aspect Lagging, Leading, Efficiency, Performance Graph & analysis. The MATLAB & SIMULINK result have been verified and compared with manual calculation in order to ensure they are correct and reliable.

Keywords: MATLAB, Transformer, GUI, Analysis, power factor, etc.

I. INTRODUCTION

The transformer is a valuable apparatus in electrical power systems, for it enables us to utilize different voltage levels across the system for the most economical value. A transformer is a static device that transfers energy from one electrical circuit to another purely by magnetic coupling. The purpose of a transformer is to change electrical voltage to a different value. Essentially, a transformer consists of two or more windings coupled by mutual magnetic flux. If one of these windings, the primary, is connected to an alternating-voltage source, an alternating flux will be produced whose amplitude will depend on the primary voltage, the frequency of the applied voltage, and the number of turns. A portion of this flux, referred to as mutual flux, will link a second winding of transformer.

The input winding to a transformer is called the primary winding. The output winding is called the secondary winding. If there are more turns of wire on the primary than on the secondary, the output voltage will be lower than the input voltage. For a step-down and a step-up transformer. Notice that the winding with the greater number of turns has the higher voltage. one winding has twice as many turns as the other. In one case the voltage is stepped down to half, while in the other the voltage is stepped up to double. It is important to know the ratio of the number of turns of wire on the primary winding as compared to the secondary winding. This is called the turns ratio of the transformer. Transformers can be modeled as either ideal transformers or actual transformers. In the case of ideal transformer, many assumptions have to be considered.

Some of these assumptions are the magnetic material is infinitely permeable and does not saturate, negligible core loss, all flux is confined within the magnetic core and each winding has no resistance. While in the case of actual transformer, these assumptions are no longer applicable.

II. REVIEW OF RELATED WORK

A transformer has been defined by ANSI/IEEE [3] as a static electric device consisting of a winding, or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits [2]. Transformers operation depends on electromagnetic induction between two stationary coils (the electric circuit) and a magnetic flux of changing magnitude and polarity (the magnetic circuit). In practice, transformers transform electrical energy into magnetic energy, and then back into electrical energy. Given its importance, transformer design is a big business in the electric power industry.

Basically, the aim of transformer design is to obtain the dimensions of all parts of the transformer in order to supply these data to the manufacturer. The transformer design should be carried out based on the specifications given, using available material economically in order to achieve low cost, low weight, small size and good operating performance. The transformer design is worked out using various methods based on accumulated experience realized in different formulas, equations, tables and charts [4]. Transformer design is a complex task in which engineers have to ensure that compatibility with the imposed specifications is met, while keeping manufacturing costs low [1, 2]. In addition, in order to compete successfully in the global economy, transformer manufacturers need design software capable of producing manufacturable and optimal designs in a very short time. Over the years, several design procedures for transformers have appeared in many literatures [5, 6, 7]. Some of the literatures are targeted at transformer design for teaching and hands-on training purposes [8, 9]. Furthermore, other literatures presented the development or the use of various computer programs for transformer design. Specifically, this paper presents the design of the magnetic circuits of power transformer and the implementation of sample design problem using the MATLAB-based software presented in this paper.

III. TRANSFORMER PARAMETER

Using this Method we analyze and design the parameter of AC transformer. The exact equivalent circuit with its parameter is shown in figure 1.

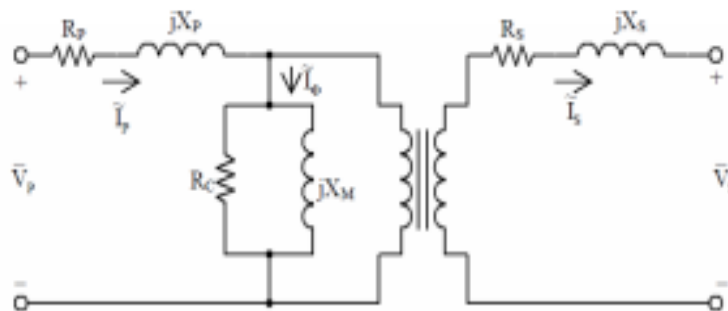


Fig. 1: Exact Model of transformer

The parameters involved are the primary terminal voltage - V_p , secondary terminal voltage- V_s , primary current- I_p , secondary current- I_s , excitation current- I_0 , primary resistance- R_p , secondary resistance- R_s , primary leakage reactance- X_p , secondary leakage reactance- X_s , core resistance, R_c , and magnetize in reactance- X_m . Usually it is preferred to reflect the secondary side of the transformer to its primary side or the primary side to its secondary side. This Parameter can be calculated by open circuit test and short circuit test procedure as well as we finds voltage regulation and maximum efficiency of transformer.

IV. TRANSFORMER TESTS

The circuit constants, efficiency and voltage regulation of transformer can be determine by two simple tests. i)Open circuit test or No load test and ii)Short circuit test or Impedance test.

These test are very convenient as they provide the required information Without actually loading transformer. Further, the power required to carry out these tests is very small as compared to full load output of the transformer. The power required for these open circuit test and short circuit test on transformer is equal to the power loss occurring in the transformer.

A. Open Circuit Test

In this test, the rated voltage is applied to the primary, while the secondary is opened. The V_1 Keep the high voltage side of the transformer open-circuited. Connect one ammeter, two voltmeters, two wattmeter's as shown in the connection circuit diagram. Measure, the applied primary voltage is measured by volt meter, no load input current I_0 by ammeter and no load input power P_0 by wattmeter.

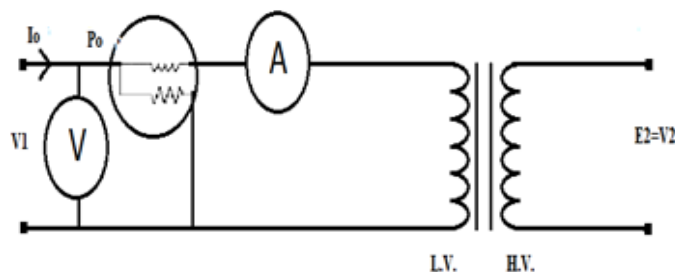


Fig. 2: Open circuit test of transformer

There is no copper loss in the secondary because there is no secondary current. Let's consider P_0

$$P_0 = V_1 / R_m^2$$

Where, R_m is shunt branch resistance of transformer.

If, Z_m is shunt branch impedance of transformer.

$$\text{Then } Z_m = V_1 / I_c$$

Therefore, if shunt branch reactance of transformer is X_m ,

$$\text{Then, } (1/X_m)^2 = (1/Z_m)^2 - (1/R_m)^2$$

These values are referred to the LV side of transformer as because the test is conducted on LV side of transformer. These values could easily be referred to HV side by multiplying these values with square of transformation ratio

B. Short Circuit Test

The test is conducted on the high-voltage (HV) side of the transformer where the low-voltage (LV) side or the secondary is short circuited. The supply voltage required to circulate rated current through the transformer is usually very small and is of the order of a few percent of the nominal voltage and this 5% voltage is applied across primary. The core losses are very small because applied voltage is only a few percentage of the nominal voltage and hence can be neglected. Thus the wattmeter reading measures only the full load copper loss. The connection diagram for short circuit test on transformer is shown in the figure. A voltmeter, wattmeter, and an ammeter are connected in HV side of the transformer as shown in figure 3. The voltage at rated frequency is applied to that HV side with the help of a variac of variable ratio auto transformer.

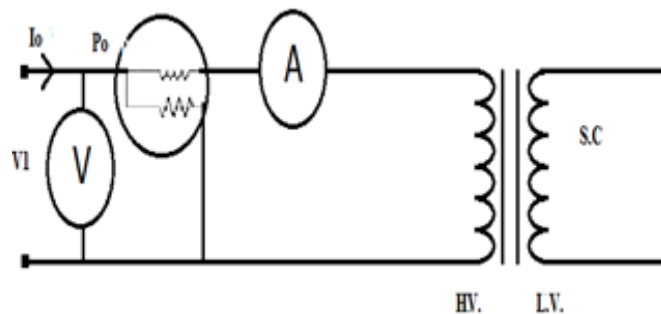


Fig. 3: Short circuit test of transformer

Let's say, voltmeter reading is V_{sc} . The input power during test is indicated by watt-meter reading. As the transformer is short circuited, there is no output; hence the input power here consists of copper losses in transformer. Since, the applied voltage V_{sc} is short circuit voltage in the transformer and hence it is quite small compared to rated voltage, so core loss due to the small applied voltage can be neglected. Hence the wattmeter reading can be taken as equal to copper losses in transformer. Let us consider wattmeter reading is P_{sc} .

$$P_{sc} = R_e I_L^2$$

Where R_e is equivalent resistance of transformer.

If, Z_e is equivalent impedance of transformer.

$$\text{Then } Z_e = V_{sc} / I_L$$

Therefore, if equivalent reactance of transformer is X_e

$$X_e^2 = Z_e^2 - R_e^2$$

These values are referred to the HV side of transformer as because the test is conducted on HV side of transformer. These values could easily be referred to LV side by dividing these values with square of transformation ratio. Therefore it is seen that the short circuit test on transformer is used to determine copper loss in transformer at full load and parameters of approximate equivalent circuit of transformer.

V. GUI IMPLEMENTATION

In propose system first, it is assumed that certain design specifications are given. Based on this assumption, the mathematical expressions for computing the values of various parameters of the magnetic circuit of power transformer are derived.

Secondly, an algorithm was developed for the software that will use the mathematical expressions to automatically compute the values of various parameters of the magnetic circuit of power transformer.

Thirdly, the MATLAB-based software was developed to read in the design specifications as input and then automatically compute and display the various parameters of the equivalent circuit of transformer. The development of the MATLAB software for designing and analysis the transformers consists of the following: MATLAB supports developing applications with graphical user interface features. MATLAB includes GUIDE (GUI development environment) for graphically designing GUIs. It also has tightly integrated graph-plotting features.

- 1) The design of different graphical user interfaces (GUIs) for entering the design input parameters

- 2) The design of program to automatically compute and display the remaining parameters of the transformer circuit of power transformer based on the mathematical expressions presented in this paper.
- 3) Aggregating the various GUIs and computation modules into a unified standalone application using the MATLAB deployment tool.

In all, the design and implementation of the MATLAB software was done using the MATLAB's GUI development environment, also known as the M-GUIDE. The methodology used for the design and testing of the GUI is given in Figure 4

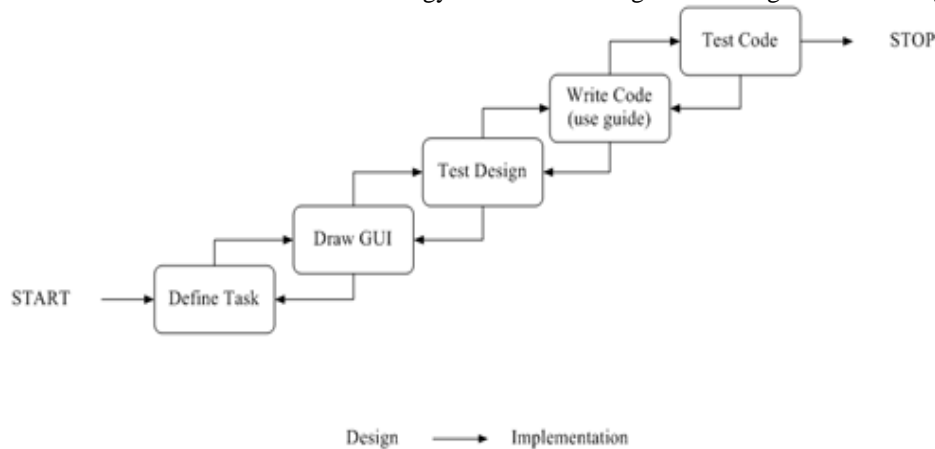


Fig. 4: GUI Design flow

The development of a MATLAB GUI is not straightforward for electrical engineers with little programming background. A brief discussion follows of a strategy for simple GUI implementation.

VI. METHOD OF PROPOSE SYSTEM

The overall Performance of the propose system can be explain by using flow diagram. This can be explain how the system perform.

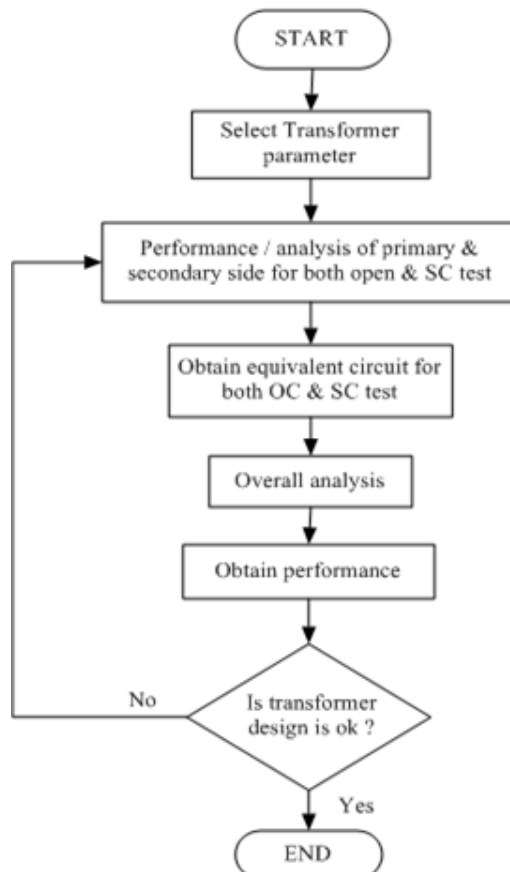


Fig. 5: Flow Diagram For Propose System

Figure 5 show home window of GUI. This window shows option to select the transformer test and performance, parameters of primary and secondary side as well as provide proper path for analysis and GUI guideline.

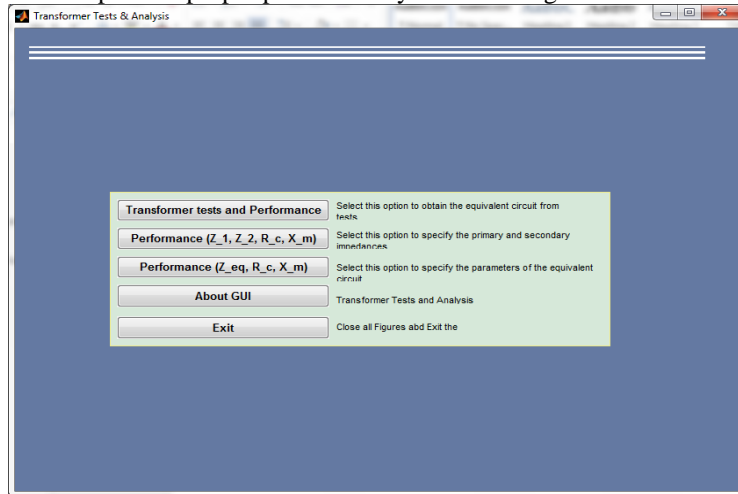


Fig. 5: Starting Home Window

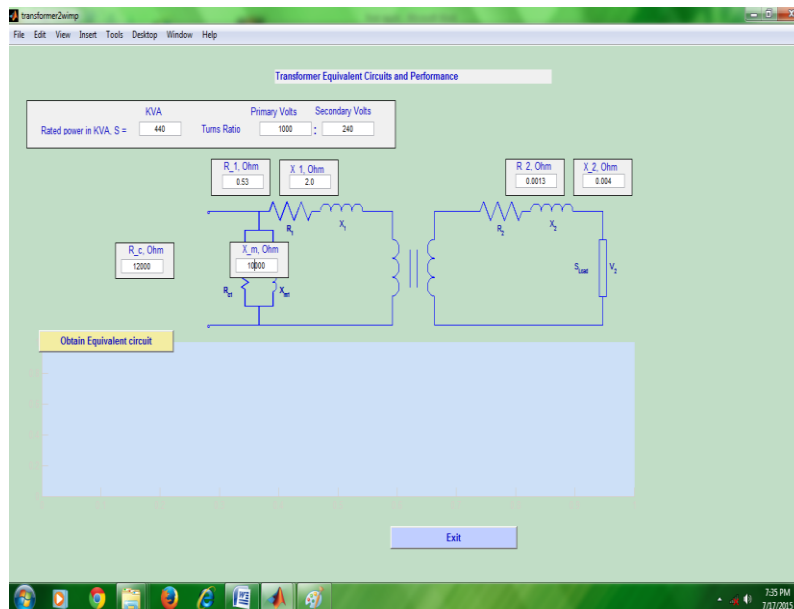


Fig. 6: transformer test and performance window.

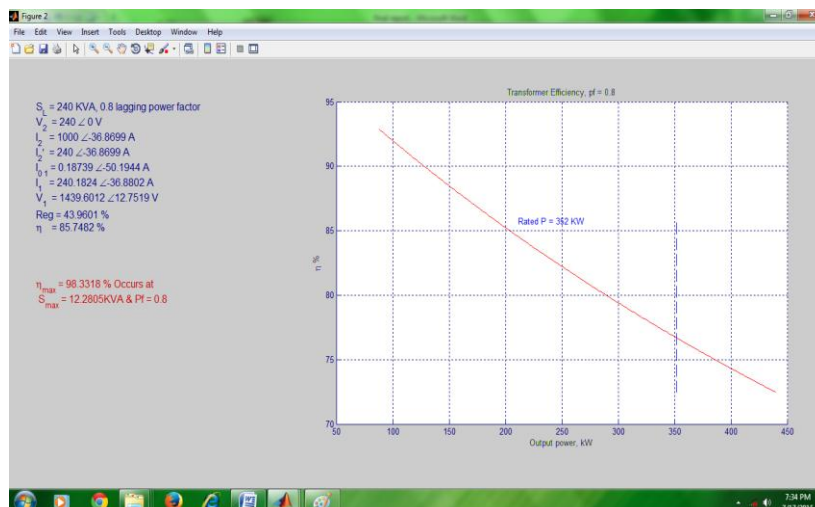


Fig. 7: Performance analysis window

Figure 6 and 7 show the performance of transformer. Above shows circuit diagram of transformer and its give its show the calculated parameters as well as efficiency of transformer with leading and lagging voltage.

VII. CONCLUSION

For the analysis of transformer's various parameters, programming was developed in to the MATLAB. Using Graphical User Interface the MATLAB code calculate the electrical quantities of transformer as well as it generate its equivalent circuit and performance graph of efficiency .This system is use in industry for analysis of transformer before actual manufacturing. Without analysis building and manufacturing of transformer become less efficient. Its easy to upgrade the Programs to calculated and accommodated the design of other kind of transformer use of other designs of methodology.

VIII. FUTURE WORKS

The scope of this paper covers only the design of the electrical parameter of single phase AC transformers. In particular. Further work is needed to cover other types of transformers and other form of winding. Consequently, further work is required to develop the mathematical models and program codes for those additional modules. Also, design optimization was not considered in this paper. However, the modular nature of the program makes provision for the program to be easily upgraded to include the optimization module.

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