

# Design and Analysis of Transformer using MATLAB

**Nileema Patil**

*PG Student*

*Department of Electronics & Telecommunication  
Engineering*

*D.N. Patel College of Engineering, Shahada, Nandurbar, India*

**Prof. J.H. Patil**

*Department of Electronics & Telecommunication Engineering*

*D.N. Patel College of Engineering, Shahada, Nandurbar,  
India*

## Abstract

Essentially, transformers consist of two electrical conductors called the primary winding and the secondary winding which are coupled magnetically together by a magnetic circuit. 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 a power transformer. The GUI is designed in such a way to allow the user to enter the resistances and reactance of the primary and the secondary sides, the resistance and reactance that represent the core, the rating of the transformer and the transformer turn ratio. This program performs the calculations with respect to the exact and approximate models of transformers for both cases, referred to primary and to secondary. In addition, the MATLAB-based software presented in this paper will serve as a useful teaching and laboratory tool.

**Keywords: MATLAB, Transformer, GUI, Analysis, Power Factor, Etc**

## 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.

A transformer works 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 the magnetic field, which is necessary for induction of voltages between the windings. A path of low reluctance (that is, low resistance to magnetic lines of force), is normally used for this purpose. In addition to providing allow reluctance path for the magnetic field, the core is designed to prevent the circulation of electric currents within the core. Such circulating currents, called eddy currents cause heating and energy loss in the transformer. In addition, in transformer design, engineers must ensure that compatibility with the imposed design specifications is met, while keeping manufacturing costs low [1, 2]. Consequently, the complexity of transformer design demands reliable and rigorous solution methods. In view of the challenges, a user-friendly and effective way for calculating the magnetic circuit parameters of power transformers through the use of software are seriously required. Given that MATLAB is one of the most popular mathematical programs used in engineering analysis, in this paper a MATLAB-based software tool will be developed for the design of the magnetic circuits of power transformers. In this case, the software tool will make use of the MATLAB Application Program Interface (API) to extend the functionalities of MATLAB application to include the Design of the magnetic circuit of power transformers.

Specifically, this paper presents the design of the magnetic circuit of power transformers using MATLAB-based software presented in this paper. Sample design problem is used to demonstrate the effectiveness of the software solution.

## TRANSFORMER OVERVIEW

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.

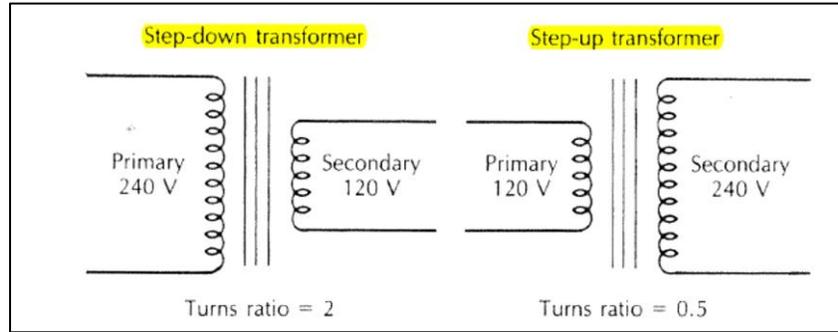


Fig. 1: Schematic Diagram of Step-Down and Step-Up Transformer

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.

**A. Exact Model of Transformer:**

The exact model of a transformer is shown in Figure 2. The parameters involved are the primary terminal voltage -PV, secondary terminal voltage- SV, primary current-PI, secondary current- SI, excitation current-FI, primary resistance- RP, secondary resistance- RS, primary leakage reactance-XP, secondary leakage reactance-XS, core resistance, RC, and magnetize in reactance-XM. 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 will simplify the calculation involved and results will be obtained in a faster manner.

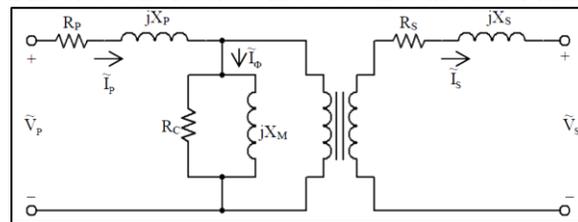


Fig. 2: Exact Model of Transformer

The transformer exact model when it is referred to its primary and secondary shown below. Primary side is input side or it is called source. The alternating voltage  $V_p$  Whose magnitude is to be change is applied to the primary. Secondary is connected to the load.

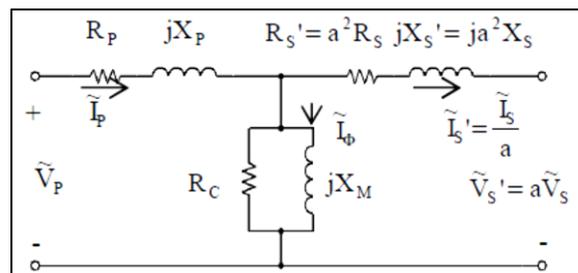


Fig. 3: Transformer Exact Model When It Is Referred To Its Primary Side

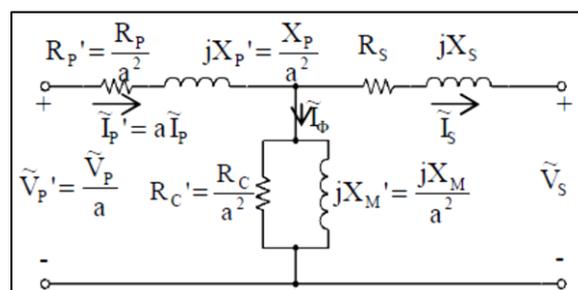


Fig. 4: Transformer Exact Model When It Is Referred To Its Secondary

**B. Approximate Models of Transformer:**

In engineering analysis involving the transformer as a circuit element, it is customary to a doptone of several approximate forms of the equivalent circuit of Figure 1 rather than the full circuit. The approximations chosen in a particular case depend largely on physical reasoning based on orders of magnitude of the neglected quantities. Figure 5 shows an approximate model that the shunt branch is moved to primary side and the transformer is referred to its primary.

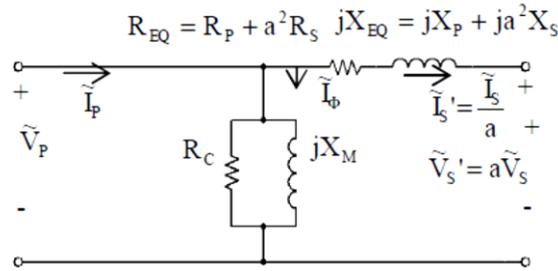


Fig. 5: Approximate Models of Transformer

The approximate model when the shunt branch is moved to secondary side and the transformer Is referred to its primary is shown in Figure 6. Figure 7 shows the model when the shunt branch is moved to primary and the transformer is referred to its secondary while Figure 8 shows the same case with the shunt branch moved to secondary.

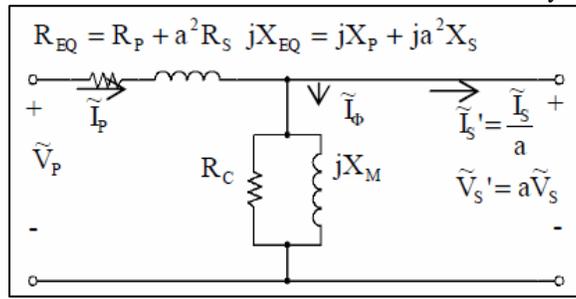


Fig. 6: Transformer Referred To Its Primary With Shunt

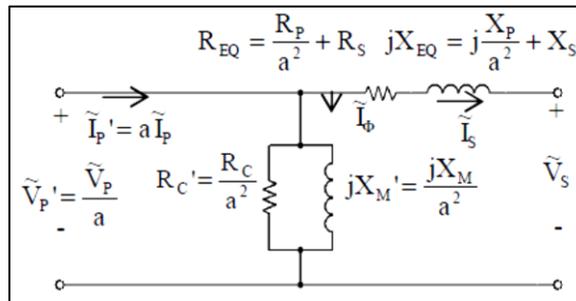


Fig. 7: Transformer Referred To Its Secondary With Shunt

Also, we can use approximate models with negligible shunt branch. Figure 8 shows an approximate model for this case and the transformer is referred to its primary. The same case when transformer is referred to its secondary is shown in Figure 9.

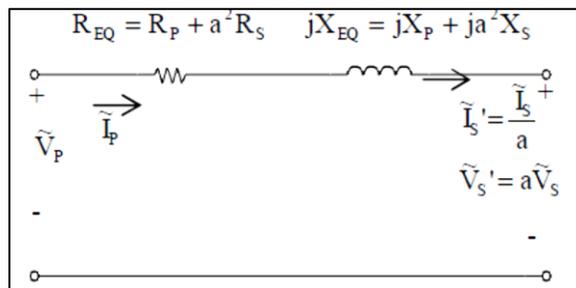


Fig. 8: Transformer Is Referred To Its Primary with Negligible Shunt Branch

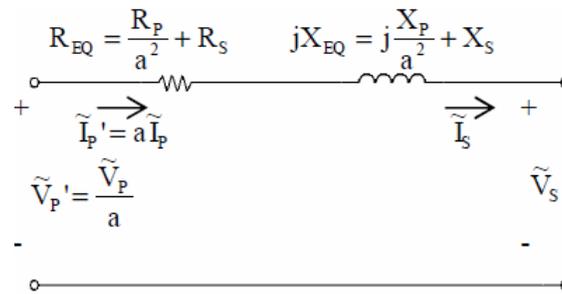


Fig. 9: Transformer Is Referred To Its Secondary with Negligible Shunt Branch

## RELATED WORKS

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 [5, 10, 11, 12]. 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.

## MATLAB IMPLEMENTATION

MATLAB apps are self-contained MATLAB programs with GUI front ends that automate a task or calculation. The GUI typically contains controls such as menus, toolbars, buttons, and sliders. Many MATLAB products, such as Curve Fitting Toolbox, Signal Processing Toolbox, and Control System Toolbox, include apps with custom user interfaces. You can also create your own custom apps, including their corresponding UIs, for others to use. GUIs (also known as graphical user interfaces or UIs) provide point-and-click control of software applications, eliminating the need to learn a language or type commands in order to run the application. Computer simulation provides a simplification of reality due to its role in the design, analysis and evaluation of systems. A variety of software tools is available to simulate engineering applications. The most popular software is MATLAB. One difficulty students have in programming MATLAB scripts is in keeping the code organized. Developing a flow chart of the pseudo-code steps helps the students to visualize the operation of the script, which is useful for planning development and for debugging specific problems. The flow chart for the transformer model simulation is shown in Figure 10. The segments above the dashed line in the figure deal with the GUI implementation, and the segments below the dashed line deal with the calculation and result output.

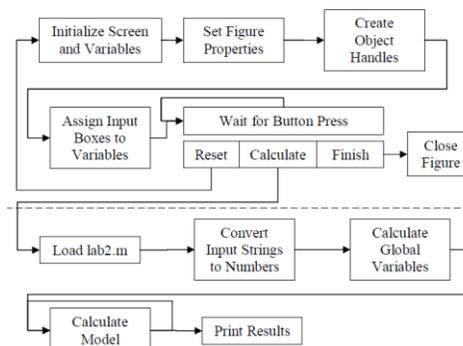


Fig. 10: Flow Chart of Code Organization

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.

Figure 11 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.

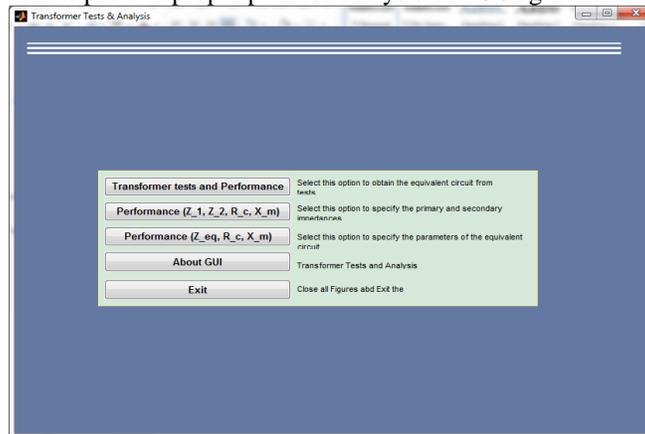


Fig. 11: Starting Home Window

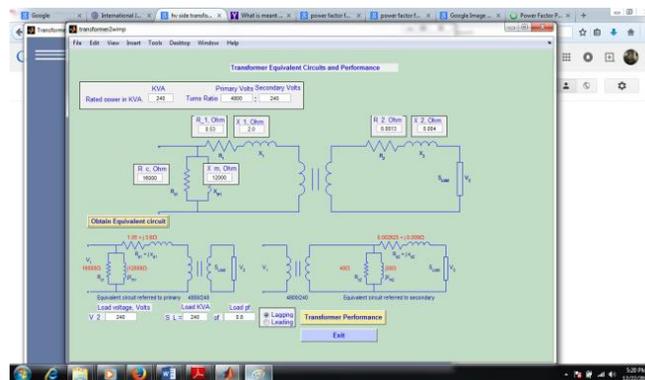


Fig. 12: Transformer Test and Performance Window

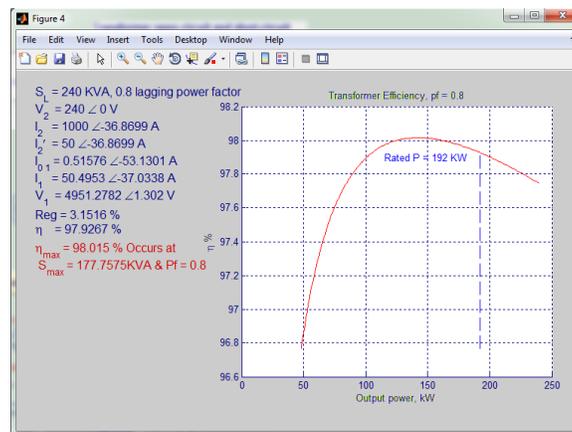


Fig. 13: Performance Analysis Window

Figure 12 and 13 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.

## 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.

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