



Modelling and Simulation of Transformer using Python Programming

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Abstract—Transformers are the backbone of electrical power systems, enabling efficient voltage transformation and power transmission. Accurate modelling and simulation are essential for understanding their behaviour and designing reliable systems. This project presents a Python-based platform for simulating single-phase transformers using NumPy and Matplotlib. The platform computes key parameters including voltage regulation, efficiency, and performance under varying load conditions. By combining a mathematical model with interactive simulations, students gain practical, hands-on experience with electrical machines. The generated graphs clearly visualise how changes in variables affect transformer performance. This approach is cost-effective and requires no specialised laboratory equipment, providing an accessible and interactive environment for learning about electrical machines and power systems.

Keywords—*Transformer; Single-Phase Transformer; Modelling; Simulation; Python Programming; Equivalent Circuit; Open Circuit Test; Short Circuit Test; Efficiency; Voltage Regulation; Copper Losses; Core Losses; NumPy; Matplotlib; Tkinter GUI; Electrical Machines; Power Systems*



I. INTRODUCTION

People need more power than ever, and managing it well matters greatly. This has made advanced monitoring systems a significant priority. Traditional methods of analysing transformers—manual calculations and physical laboratory tests—are time-consuming and do not provide a real-time picture of system behaviour [1], [2].

With advances in programming tools and simulation capabilities, Python has emerged as a cost-effective solution for modelling transformer behaviour. Modern Python-based systems not only perform complex calculations but also present results through clear graphics, enabling in-depth analysis of transformer operation under a variety of conditions [3], [4].

This work presents a Python-driven platform for modelling and simulating transformers. The platform calculates key parameters including efficiency, voltage regulation, losses, and equivalent circuit elements, and features an interactive graphical interface that allows engineers and students to visualise and understand transformer behaviour with ease and accuracy [5], [6].

II. MATERIAL AND METHODS

This study was carried out in the Electrical & Electronics Engineering Department at G. Pulla Reddy Engineering College, Kurnool, India, during the 2025–2026 academic year. The system was built and tested using Python to model transformer performance and display results visually. The study focuses on three key aspects: transformer efficiency, voltage regulation, and energy losses under varying load conditions.

Study Design: Simulation-based system built and tested using Python to analyse transformer performance.

Study Location: Electrical & Electronics Engineering Laboratory, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India.

Study Duration: Academic year 2025–2026.

Sample Size: A single simulation platform based on a prototype software model.

System Design Consideration: The system was built using the equivalent circuit model of a single-phase transformer, with data from Open Circuit (OC) and Short Circuit (SC) tests. The software tools were

selected for their simplicity, efficiency, graphical capability, and compatibility with Python.

Subjects & System Configuration: The system is a Python-based model using NumPy for calculations, Matplotlib for graphical output, and Tkinter for the user interface. Users enter rated voltage, rated power, frequency, and OC/SC test results through the GUI. The system then simulates performance across different load conditions.

Computed parameters include primary and secondary currents, resistance, reactance, efficiency, voltage regulation, copper losses, and core losses. Results are displayed in real time with graphs showing how efficiency, voltage regulation, and losses change with load.

The system comprises three main modules:

System A: Mathematical calculation module for transformer parameters using NumPy.

System B: Performance visualisation module using Matplotlib.

System C: User interface module for data entry and results display using Tkinter.

III. PROCEDURE METHODOLOGY

The system monitors transformer parameters in real time, including rated power, primary and secondary voltages, frequency, and OC/SC test data. Data is entered via a simple Python interface. Once entered, the system processes the inputs using a transformer equivalent circuit model, incorporating Gaussian Elimination and numerical iteration methods to compute equivalent resistance, reactance, efficiency, voltage regulation, and both copper and core losses.

Results are displayed on screen through a Tkinter-based interface, accompanied by interactive Matplotlib graphs showing Efficiency vs. Load, Voltage Regulation vs. Load, and Losses vs. Load, enabling comprehensive analysis of transformer behaviour under varying conditions.

The system operates in real time, allowing interactive simulation. It also incorporates a diagnostic function: if poor voltage regulation, high copper losses, or low efficiency under overload conditions are detected, the system issues a warning on the results screen, enabling early identification and correction of problems.



Comparative analysis across different load levels or lagging power factors is also supported. Significant changes in efficiency, losses, or regulation are clearly indicated in both the numerical output and the graphical display.

Overall, this simulation eliminates the need for physical laboratory tests, reducing both time and cost while providing students and researchers with a practical, hands-on method for studying transformer behaviour.

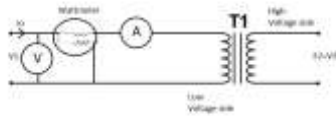


Fig. 1: Open Circuit Test of Transformer

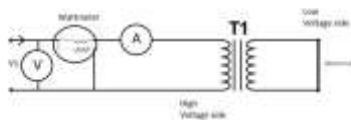


Fig. 2: Short Circuit Test of Transformer

IV. STATISTICAL ANALYSIS

The performance of the system was evaluated in terms of accuracy, computational speed, and reliability. To verify calculation accuracy, results for transformer efficiency, voltage regulation, copper and core losses, and equivalent circuit parameters were compared with standard theoretical values and results from conventional transformer tests.

The system was then subjected to multiple simulations with varying load and power factor conditions to assess consistency. Results confirm that the system operates smoothly, delivers reliable and accurate numerical outputs, and accurately represents real-time transformer behaviour across all tested conditions.

V. RESULT

The transformer modelling and simulation system accurately computes all key parameters—including efficiency, voltage regulation, copper loss, core loss, and equivalent circuit elements—in real time. Users input the transformer ratings along with OC and SC test data, and the system immediately displays results with

graphical representations that clearly illustrate performance changes as load or conditions vary.

When tested under different loads and lagging power factors, the system tracks performance instantaneously with consistent accuracy and reliability. The analytical model detects anomalies such as significant voltage drops or elevated copper losses, and clearly indicates when efficiency deteriorates under overload conditions.

Side-by-side graphs allow comparison of transformer behaviour at no load, part load, and full load conditions. The simulation results are reliable, clear, and representative of real-world transformer behaviour.

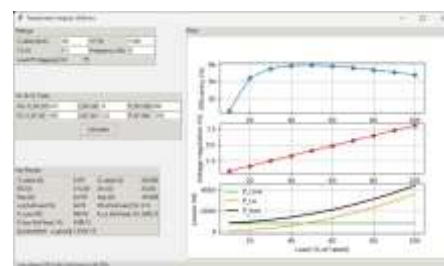


Fig. 3: Simulation Results — Efficiency, Voltage Regulation, and Losses vs. Load

VI. DISCUSSION

A Python-based system for transformer modelling and simulation effectively brings electrical engineering concepts to life. Instead of relying on manual calculations or traditional laboratory techniques, the system provides real-time data, clear visualisations, and interactive parameter analysis, enabling automatic performance testing and immediate results.

NumPy ensures quick and accurate numerical computation, while Matplotlib produces clear and informative transformer characteristic graphs. The Tkinter interface allows users to input data and observe results with minimal effort. The system responds efficiently to load fluctuations, making it suitable for real-time analysis.

The platform is also extensible. It can readily be expanded to support three-phase transformer analysis, fault diagnosis, harmonic analysis, predictive maintenance, and integration with smart grid monitoring systems. This versatility makes it valuable not only as a learning tool but also as a component of contemporary power system research and classroom instruction.



VII. CONCLUSION

This Python-based transformer modelling and simulation system effectively meets its design objectives. It is fast, reliable, and enables real-time analysis of transformer performance. By leveraging Python libraries—NumPy for computation, Matplotlib for visualisation, and Tkinter for the user interface—the system delivers accurate calculations, clear graphical output, and a user-friendly experience.

Validation tests confirm stable performance, precise transformer parameter computation, and smooth operation across varying load and power factor conditions. The software-based nature of the system makes it cost-effective and practically deployable for educational instruction, laboratory experimentation, and power system analysis.

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