GENERATOR AND POWER GRID ANALYSIS

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GitHub Link

https://github.com/Generator-and-Power-Grid-Analyzer-Simulation

YouTube Video Link

https://youtube/Generator-and-Power-Grid-Analyzer-Simulation

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EEE 3003 Electromechanical Energy Conversion

CONTENTS

ABSTRACT

This report presents a steady-state analysis of a generator that delivers power to a high voltage grid via a step-up transformer. The per-unit system simplifies the analysis by expressing all system parameters on the same reference basis.Phasor analysis is used to investigate system behavior, specifically the relationships between voltage, current, and power factor.The terminal voltage and internal voltage behind the reactance are measured to determine the generator's operating conditions, providing insight into the effect of loading on performance.An equivalent circuit model is used to support the analysis and clarify the impedance characteristics of the system.Overall, the study demonstrates the practical application of power system analysis methods in assessing generator-grid interconnections.

1.INTRODUCTION

Accurate analysis of the interaction between generators, transformers, and power grids is critical for electrical power system safety, stability, and efficiency. Step-up transformers, in particular, play an important role not only in voltage level conversion, but also in determining system impedances and power flow characteristics.

This report examines the operation of a three-phase synchronous generator that provides power to a high-voltage power system via a step-up transformer. Using the per-unit system, the analysis aims to convert the generator and transformer impedances to a common base, construct the system phasor diagram under a specified loading condition, and determine the generator terminal voltage and the internal voltage underlying its reactance.

Additionally, the overall behavior of the power system is interpreted from an engineering perspective, and the generator output power and power factor are evaluated under specific operating conditions. In order to give an in-depth review of the analyses that were conducted, the system's equivalent circuit diagram is finally shown.

The purpose of this study is to achieve decent capability for examining electrical systems in the Electromechanical Energy Conversion course, using the theoretical understanding gained from electrical system analysis to solve a real-world engineering problem.

2. SYSTEM DESCRIPTION AND PROBLEM EXPLANATION

The solution process begins by converting all system components to a common base value and continues with a vector analysis of the electrical magnitudes under the specified load conditions.

In the first stage of the analysis, the generator's reactance, originally given on its own base of 800 MVA, was adapted to the transformer's base values of 850 MVA, which serve as the system's reference base. To perform this conversion, the transformer-based impedance was first calculated as 0.795 ohms and the generator-based impedance as 0.845 ohms. By applying this ratio, the generator reactance was adjusted to 1.36 per-unit (pu). To visualize the physical behavior of the system, a phasor diagram was constructed. Given that the load has a 0.90 leading power factor, it was noted that the current leads the voltage. In this diagram, the transformer's high-voltage side (V_{grid}) was established as the reference axis ($1.0 \angle 0°$ pu), with the current phasor drawn at a positive angle. The voltage drops across the transformer and generator were then added vectorially to this reference to determine the final voltage points.

In the numerical analysis phase, the line current was calculated as $0.9804\angle 25.84°$ pu, based on the 750 MW load and 1.0 pu grid voltage. By utilizing this current and the transformer's series impedance ($0.0025 + j\,0.057$), the generator terminal voltage (V_t) was determined to be 0.980 pu, which equates to an actual value of 25.48 kV. Following this, the internal voltage (E_{int}) was found to be 1.313 pu, or 34.14 kV, by adding the voltage drop across the generator's internal reactance to the terminal voltage. Finally, the power loss resulting from the transformer's internal resistance was calculated as 2.04 MW, bringing the total generator output power to 752.04 MW. The generator's operating power factor was determined to be 0.92 leading, derived from the phase angle difference between the current and the terminal voltage.

3.BRIEF INTERFACE REASONING

The developed **"Generator and Power Grid Analyzer"** interface consists of three main sections designed to provide a comprehensive simulation environment. On the first tab, that stated as *'Simulation'*, the ***Interactive Control Panel*** allows for instantaneous adjustments to critical parameters such as Active Power (MW) , Power Factor (PF) , and Generator Reactance (Xg) through manual sliders.

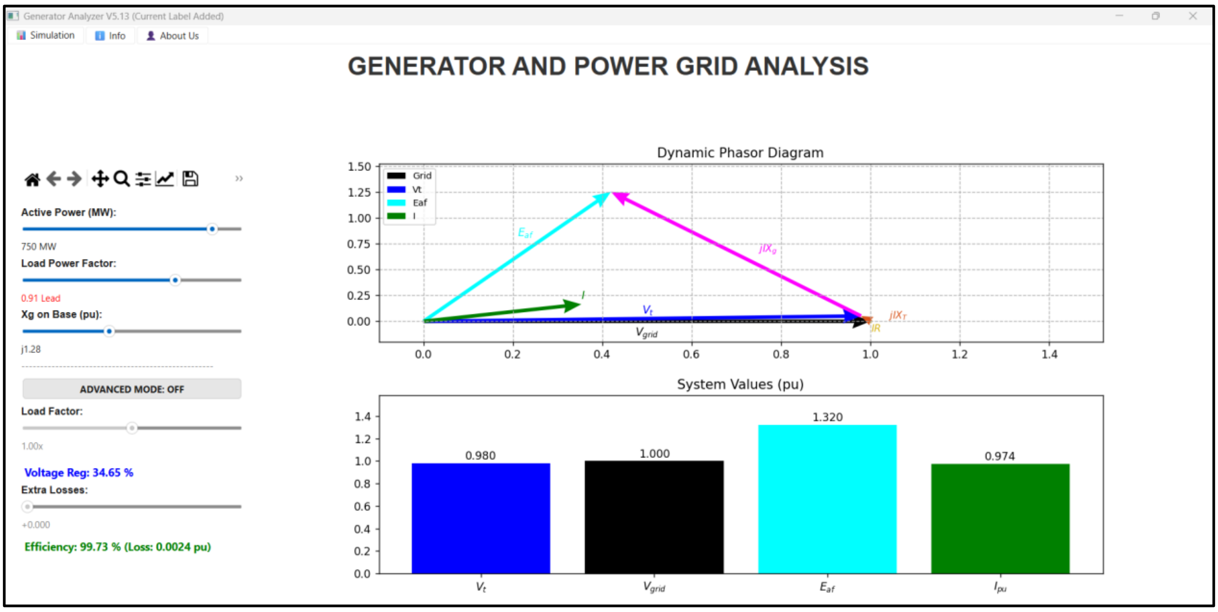

Figure 1. Simulation Tab

Within this panel, the ***Advanced Mode*** extends the analysis beyond standard problems by allowing the addition of extra losses and load factors , thereby transforming the software into a flexible engineering tool that updates Voltage Regulation (VR) and Efficiency (Eff) values in real-time.

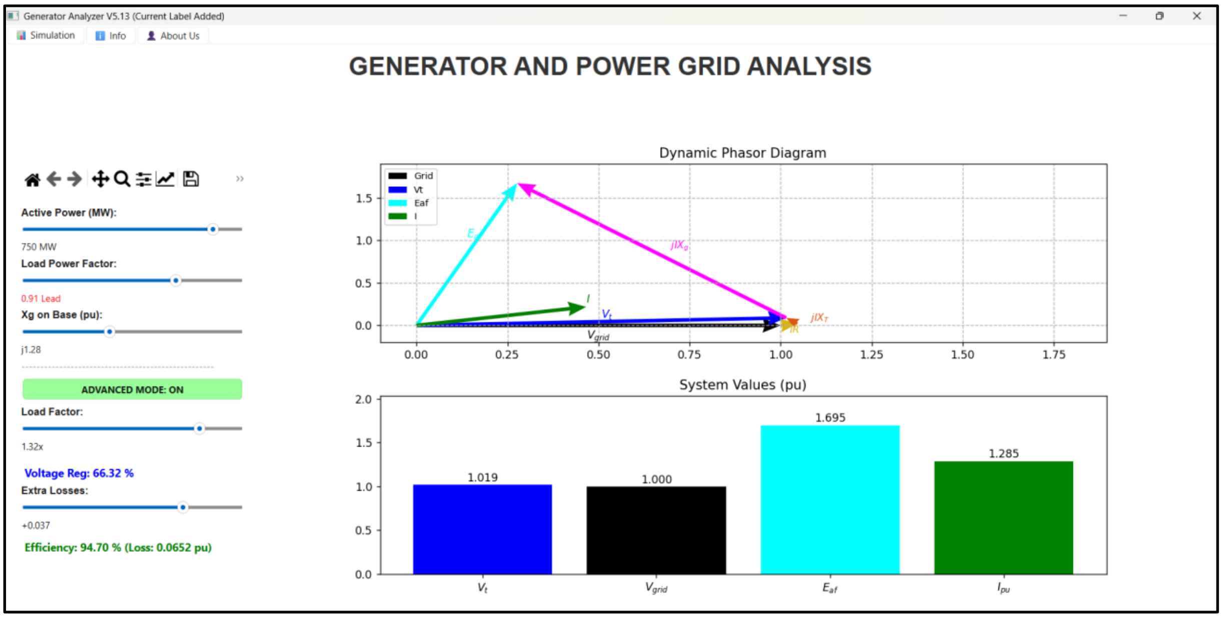

Figure 2. Advanced Mode on Simulation Tab

The Visualization and Analysis Panel on the right side is divided into two primary sections. ***The Dynamic Phasor Diagram*** at the top represents the vectorial relationship between the internal EMF (E_{af}) , terminal voltage (V_t) , and grid voltage (V_{grid}) using vectors, which visually simulate whether the current is leading or lagging based on slider movements. Complementing this, the ***Voltage and Current Bar Chart*** at the bottom provides a magnitude analysis that alerts the user to **"Under-Excitation"** risks through red visual warnings.

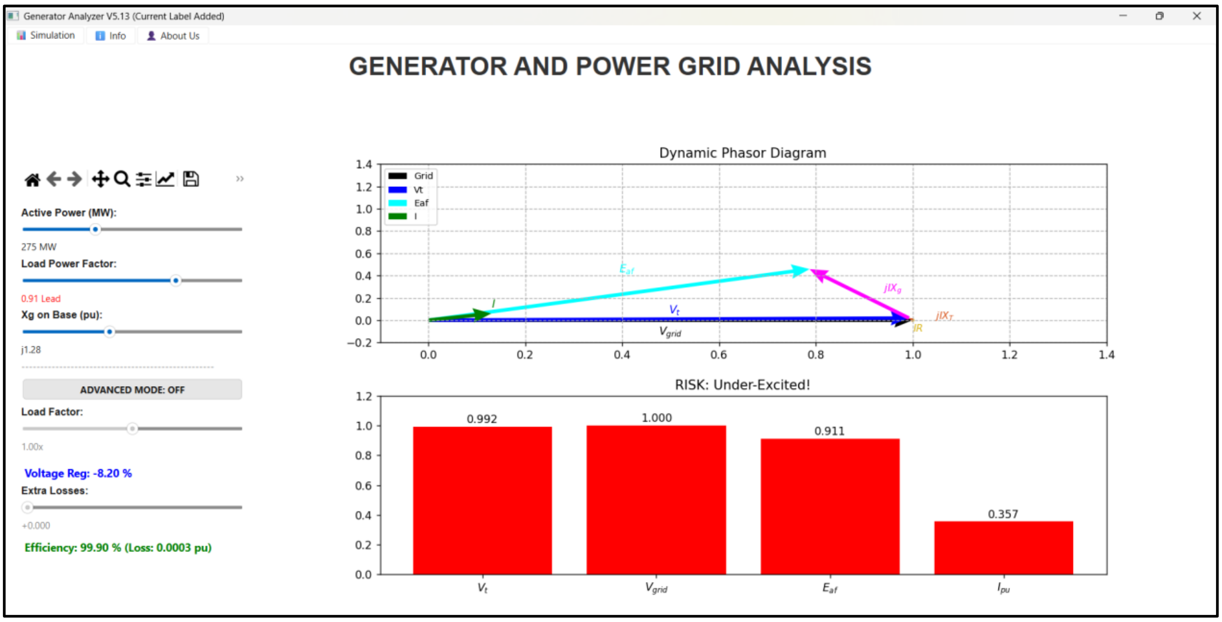

Figure 3. 'RISK:Under-Excited!' Alert is Seen

The software also functions as an educational resource through its *‘Info’* and *‘About Us’* tabs. The *‘Info’* tab provides theoretical definitions for terms such as “Per-Unit”, “Efficiency”, “Voltage Regulation” ,”Transformer Impedance (Z_T)”, “Generator Internal Voltage (E_{int})”, “Generator Terminal Voltage (V_t)” and, “Generator Reactance (X_g)”.

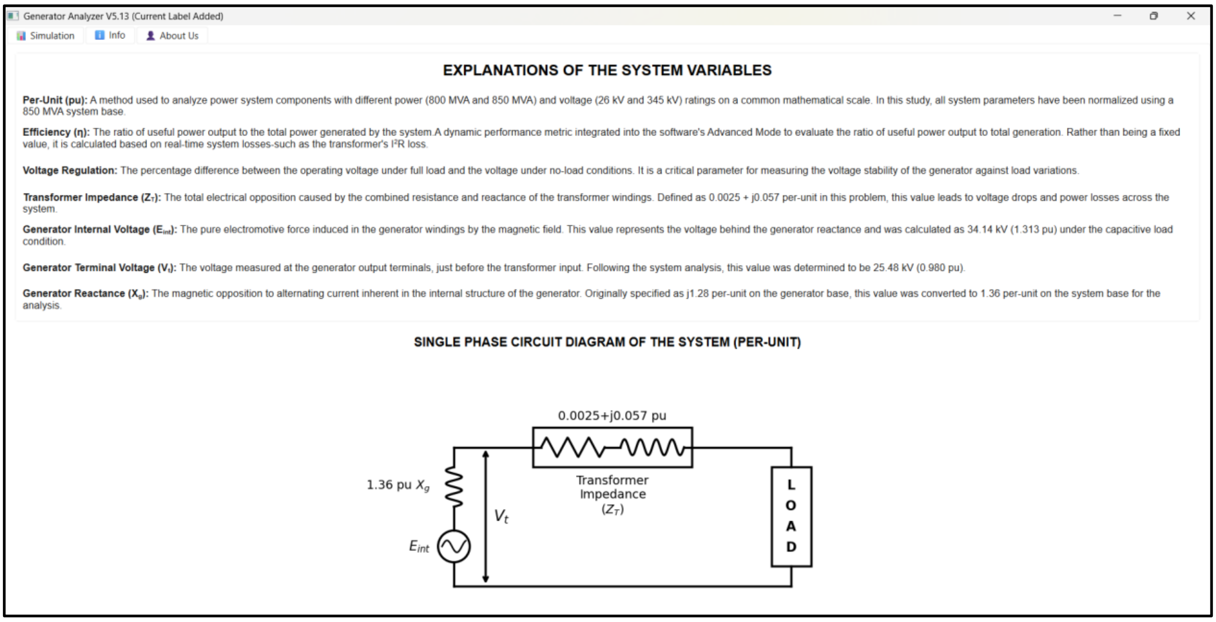

Figure 4. Information Tab

Such as *‘Info’* tab, *‘About Us’* also features a professional scrolling credits animation identifying the project team, the academic advisor, and the reference to Fitzgerald and Kingsley's Electric Machinery. Finally, advanced technical features such as a home button—which resets the simulation to the initial 750 MW and 0.90 leading conditions —and a mouse wheel zoom function on the phasor diagram enable the detailed examination of even the smallest voltage drops within the system.

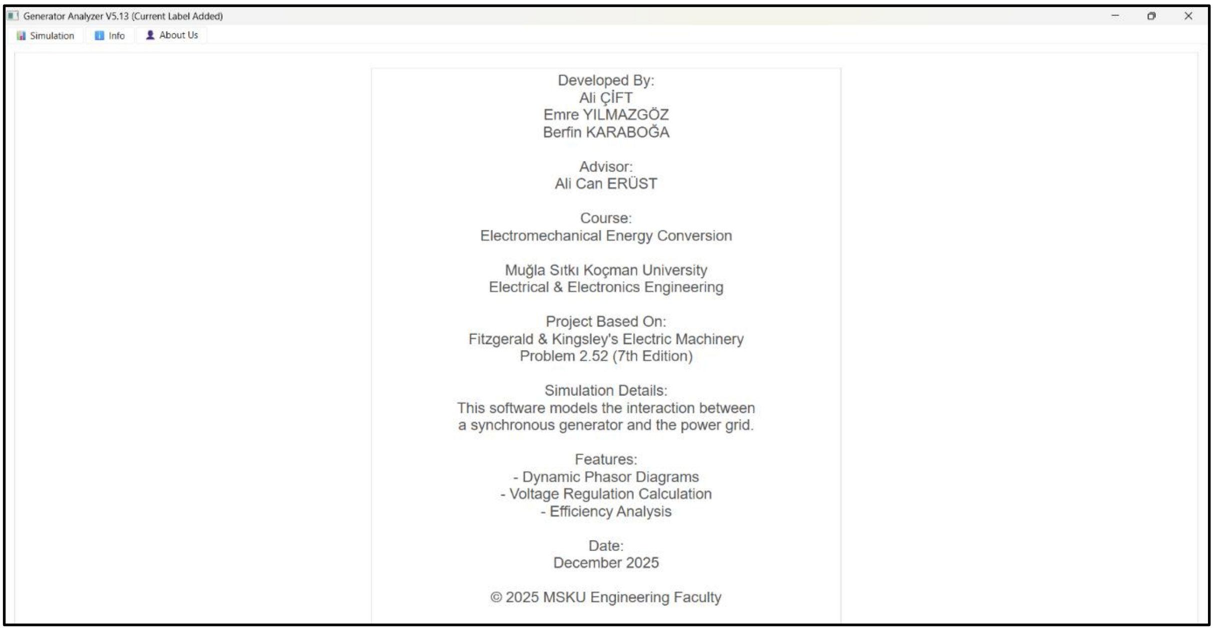

Figure 5. 'About Us' Tab

4.CONCLUSION

In conclusion,it has been successfully demonstrated the application of theoretical power system principles and modern computational tools to analyze a synchronous generator and step-up transformer system. Using the Per-Unit (pu) methodology, the varying parameters of the 800 MVA generator and 850 MVA transformer were combined on a common 850 MVA base, allowing for a precise evaluation of the system's performance under the power of 750 MW capacitive load. The numerical results confirmed that under the specified grid conditions, the generator terminal voltage is 25.48 kV, while the internal voltage behind its reactance is 34.14 kV. Furthermore, the analysis revealed that the transformer's internal resistance causes a 2.04 MW power loss, requiring a total generator output of 752.04 MW with an operating power factor of 0.92 leading.

5.REFERENCES

- *Umans, S., Fitzgerald, A., & Kingsley, C. (2013). Electric machinery: Seventh Edition. McGraw-Hill Higher Education.*

- *Chapman, S. (2004). Electric Machinery Fundamentals. McGraw-Hill Science/Engineering/Math.*