2023

Name / Amr Wael Fathallah Mohamed Aboelwafa

ID / 52-12977

Tutorial / T31

[Power Electronics Project]

3 PHASE-FULL WAVE RECTIFIER REPORT

Table of Contents

Abstract:

This project focuses on the design and implementation of a three-phase full-wave rectifier using Simulink, a powerful simulation tool. The rectifier converts alternating current (AC) into direct current (DC) and plays a crucial role in various industrial applications, including power supplies and motor drives. By utilizing Simulink's intuitive graphical interface and built-in electrical components, we developed a comprehensive model of the rectifier system, allowing us to analyze and evaluate its performance. This report presents the abstract, introduction, methodology, results, and conclusion of our project, providing a detailed account of the design process, simulation setup, and the rectifier's operational characteristics.

Introduction:

A three-phase full-wave rectifier is a vital component in electrical power systems, converting alternating current (AC) into direct current (DC) for industrial applications. Unlike single-phase rectifiers, three-phase rectifiers utilize three separate AC input phases, allowing for higher power handling capacity and improved efficiency.

The rectifier's main function is to convert the entire AC waveform into a pulsating DC waveform. This process involves diodes that allow current flow in one direction, resulting in a smooth DC output with reduced voltage ripple. Three-phase rectifiers also offer improved power factor and can handle higher power levels due to load distribution across multiple phases.

This report focuses on the design and simulation of a three-phase full-wave rectifier using Simulink. The simulation will analyze the rectifier's behavior under different load conditions, evaluate performance parameters such as voltage ripple and power factor, and ultimately optimize its design for practical applications.

Understanding three-phase full-wave rectifiers is crucial for advancing power electronics and enhancing the efficiency and reliability of electrical systems. By investigating their operation and performance, we can contribute to the development of more efficient industrial power solutions.

Electrical Circuit:

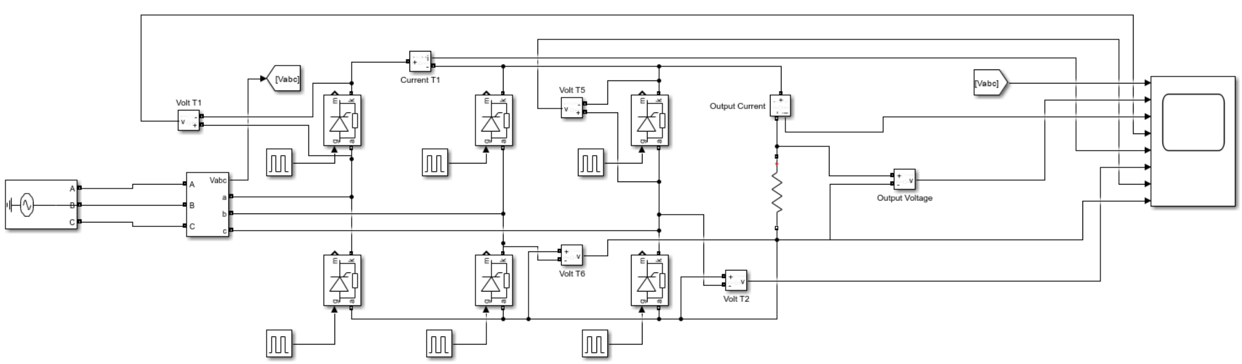
The circuit components of a three-phase full-wave rectifier with load variation, including resistive (R) and highly inductive (RL) loads, consist of the following elements:

1- Three-Phase AC Source: The AC source provides the three-phase input voltage to the rectifier circuit. It typically consists of three separate phases (A, B, and C) with a fixed voltage magnitude of 400V, a fixed phase shift of 120 degrees between each phase, and a frequency of operation of 50HZ.

2- Thyristors: The rectifier circuit employs six thyristors, with each thyristor connected to one of the three input phases with their pulse generator.

3-Load: Which could be resistive (R load) , resistive with an inductor(R-L load), or resistive with highly inductive(R-L load & L high).

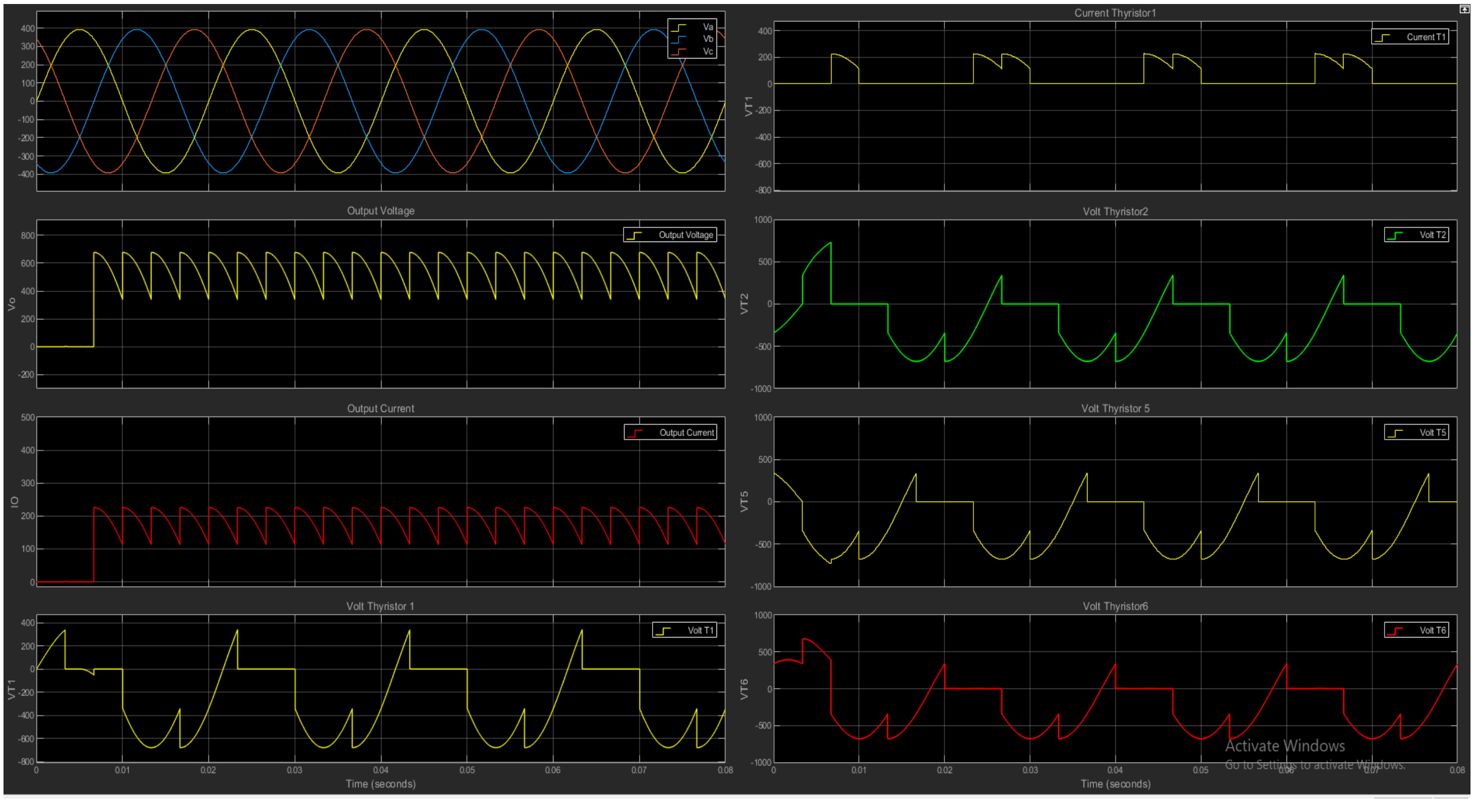
4-Measurement tools: Include Voltage and Current tools such as (Voltmeter, Ammeter) to specify and test the characteristics of each component inserted in the circuit and to test the functionality of the circuit.



3-phase full wave rectifier using Simulink

Simulations and case studies:

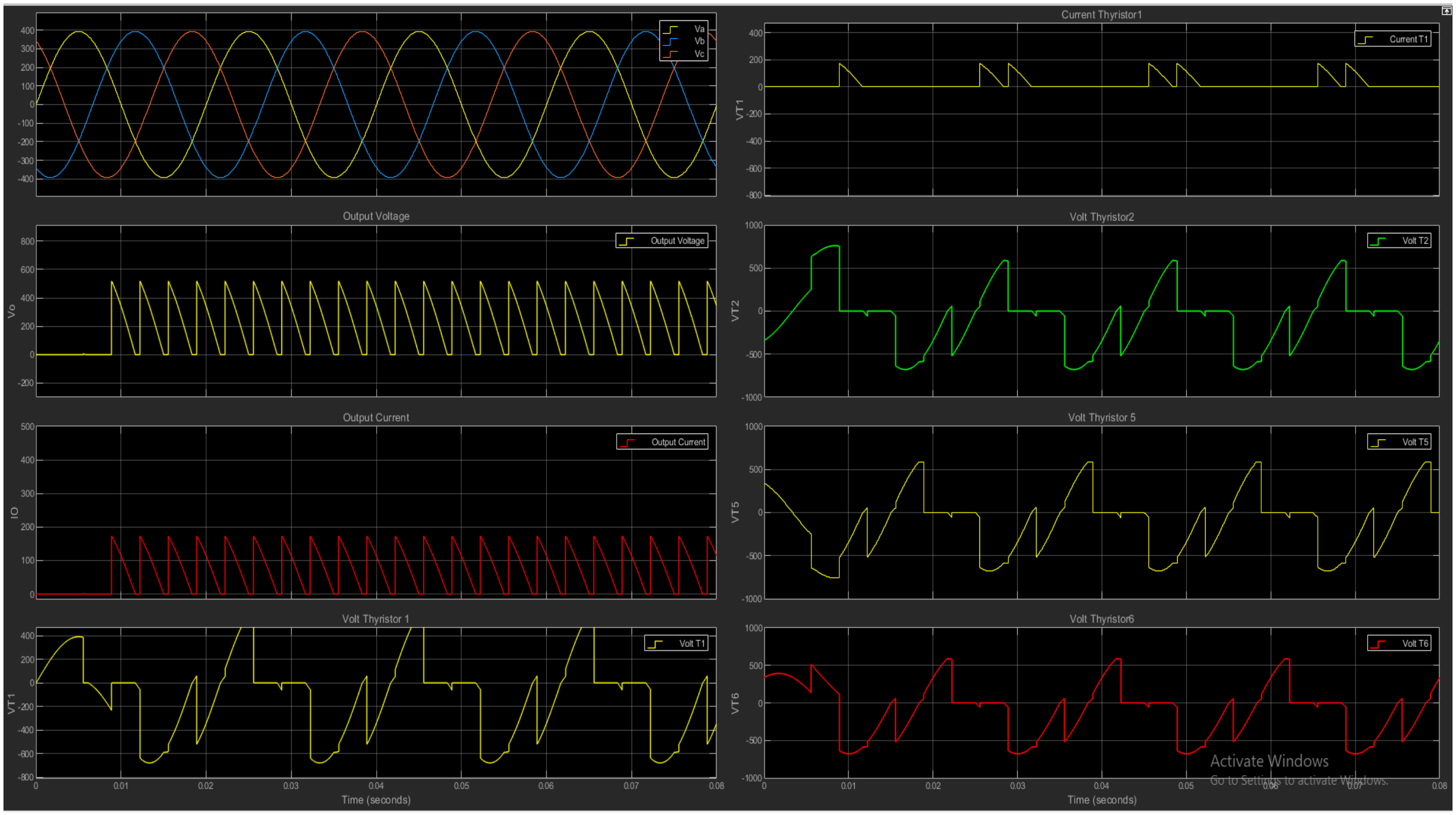
A- Resistive Load with firing angle α=30 °



Comments on the result:

For a resistive load and a firing angle (α) of 30 degrees, which is less than 60 degrees, the three-phase full-wave rectifier exhibits continuous and positive output voltage. The output current follows a sinusoidal waveform due to the proportional relationship with the output voltage and resistive load. The chosen relatively small load results in a higher output current. The voltage across each thyristor is divided into distinct regions based on the conducting phase at any given moment. The thyristor currents are appropriately regulated to ensure the rectifier operates effectively. These findings provide valuable insights into the rectifier's behavior under specific conditions.

B-Resistive Load with firing angle α =70 °



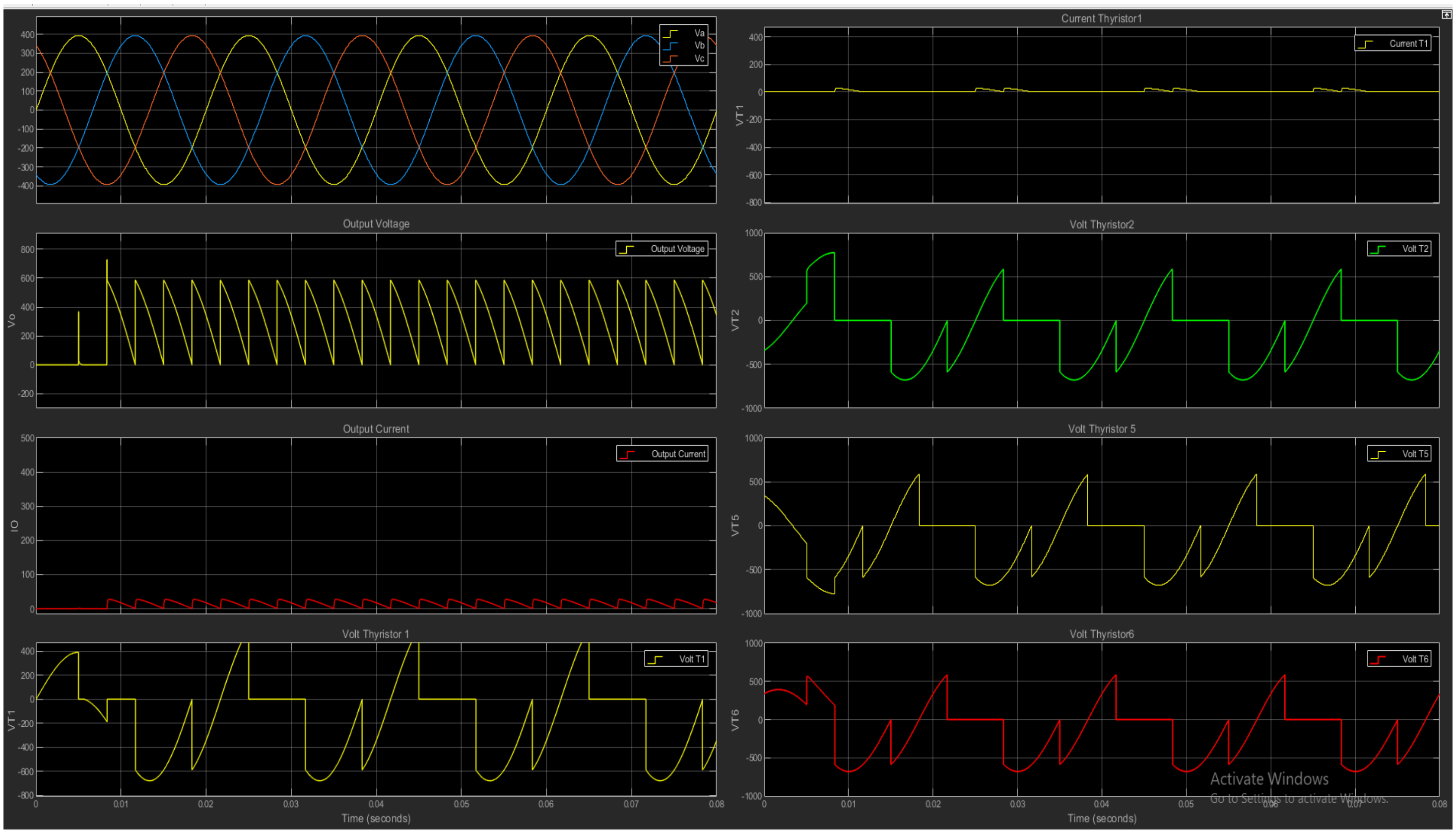
Comments on the result:

For a resistive load and a firing angle (α) of 70 degrees, which is greater than 60 degrees, the output voltage of the three-phase full-wave rectifier becomes discontinuous. This discontinuity occurs because the firing of the thyristors happens late, after the negative half-cycle of the input waveform has already started. As a result, the output voltage and current become zero at certain intervals, causing a non-continuous waveform.

Furthermore, the voltages on each thyristor in the circuit are divided into different regions depending on which phase is conducting at any given moment. The current through the thyristors follows a similar pattern. These divisions and variations in voltage and current distribution are a consequence of the firing angle and the phase conductance.

It's important to note that the chosen load, in this case, is assumed to be resistive, similar to the previous scenario. However, due to the delayed firing and resulting discontinuous waveform, the output voltage and current behavior may differ from the previous sinusoidal pattern observed when α was less than 60 degrees.

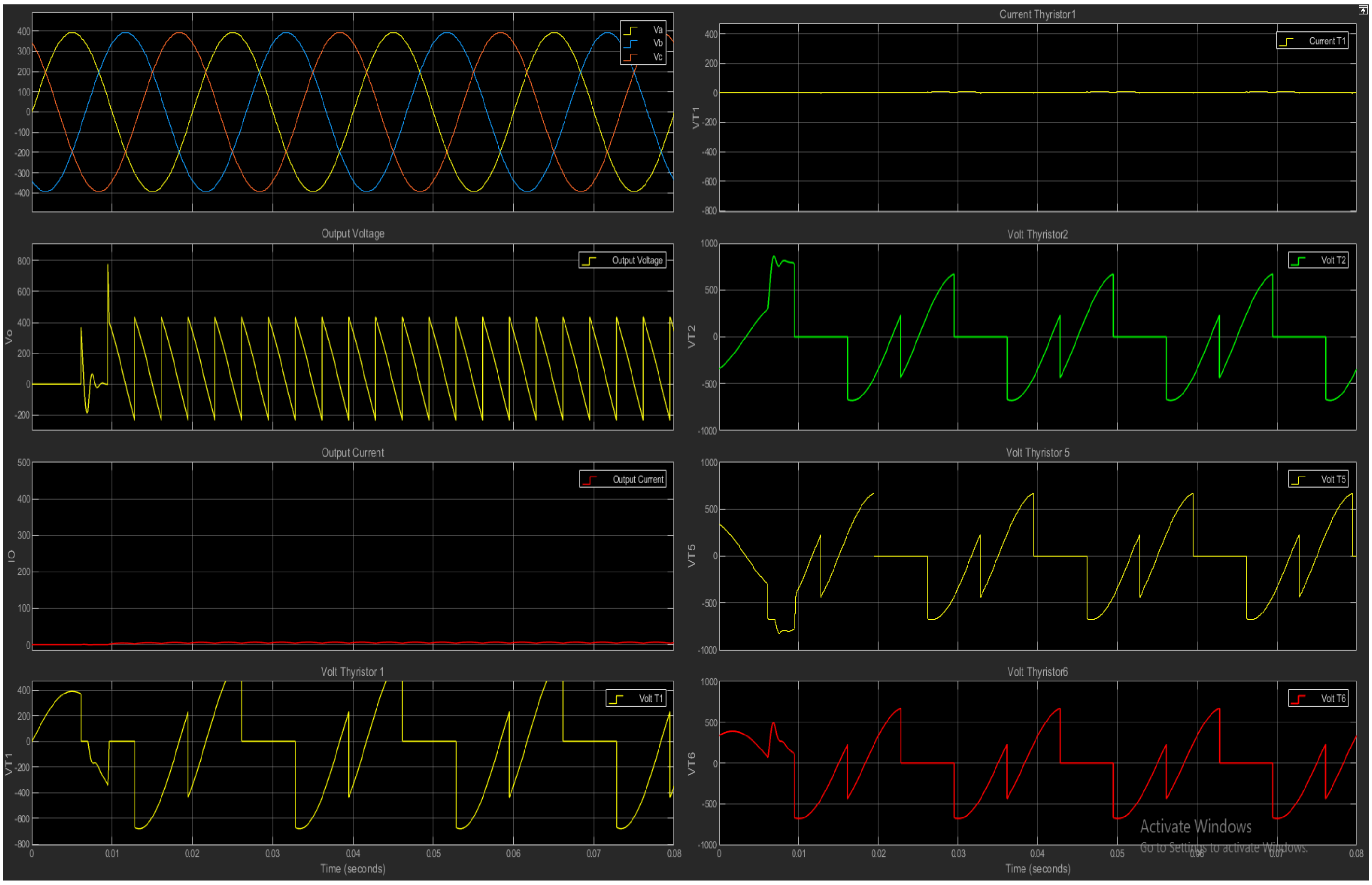
C- Resistor – inductor Load (R-L) with firing α =60 °



Comments on the result:

Exploring a resistor-inductor load with a 60-degree firing angle reveals nuanced dynamics. The output voltage briefly touches zero, a result of controlled thyristor triggering. The introduction of the inductor yields a non-sinusoidal current waveform with a lag behind voltage. Notably, the dynamic current distribution among thyristors, dependent on varying phases, underscores the firing angle's intricate influence. This study unveils the complexity of electrical dynamics, offering practical insights for optimizing similar systems.

D- **Resistor – inductor Load (R-L Highly inductive) with firing α =80 °**



Comments on the result:

In the study of highly inductive loads with an 80-degree firing angle, a distinctive characteristic surfaces: the current assumes a DC-like nature due to the load's pronounced inductance. Notably, the late firing exacerbates this effect. Additionally, a compelling observation is made—part of the output voltage turns negative, impacting its average value. This unexpected behavior is attributed to the persistent current flow in the highly inductive load. To counter this, integrating parallel free-wheeling diodes proves to be an effective solution, mitigating negative voltage and ensuring a more controlled system response in the face of complex inductive dynamics.

Summary and Conclusion: Analysis of a 3-Phase Full-Wave Rectifier under Various Loads

In the comprehensive study of a 3-phase full-wave rectifier operating under distinct loads, encompassing resistive, R-L, and highly inductive R-L configurations, several critical insights have been gleaned.

Resistive Load: Under a resistive load, the rectifier operates with efficiency, converting alternating current to direct current seamlessly. The output waveform exhibits a smooth, purely pulsating DC voltage, and the rectifier proves effective in meeting the demands of resistive loads without significant distortions.

R-L Load: Introducing inductance to the load introduces complexities. While the rectifier still performs admirably, the current waveform deviates from pure sinusoidal due to the inductive nature. This lagging effect between voltage and current is observed, impacting the power factor and necessitating a nuanced understanding for system optimization.

Highly Inductive R-L Load: Moving to a highly inductive R-L load introduces additional challenges. The current waveform, now bearing a pronounced DC component, demands special attention. Notably, the delayed firing times and the persistent current flow result in part of the output voltage turning negative. This behavior underscores the intricate interplay of inductance, firing angles, and system response.

Conclusion: In conclusion, this study affirms the versatility of the 3-phase full-wave rectifier under diverse loads. While resistive loads pose minimal challenges, the introduction of inductance alters the dynamics, influencing current waveforms and necessitating considerations for power factor correction. In the case of highly inductive loads, careful management of firing angles and the incorporation of parallel free-wheeling diodes prove crucial to mitigate negative voltage excursions. This nuanced understanding of the rectifier's behavior under various loads lays the foundation for optimizing system performance in real-world applications, catering to the demands of diverse electrical loads with efficiency and reliability.

- References:

1- "Power Electronics: Essentials & Applications" by L. Umanand.

2- IEEE Transactions on Power Electronics.

3- "Power Electronics: Converters, Applications, and Design" by Ned Mohan, Tore M. Undeland, and William P. Robbins