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Optimization of 1 Phase AC Motor Rotation Regulation with Full-Wave Uncontrolled Rectifier Using PSIM Simulation in Electrical Control System

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Abstract

The rotation arrangement of a single-phase AC motor can be done by several methods, including frequency regulation, voltage, the use of variable motor resistors, or the addition of the number of poles to the motor. One effective technique for controlling the speed of the motor is to regulate the frequency of the motor rotation through the setting of a variable resistor value controlled by an unstable oscillator circuit. A full-wave rectifier is used to convert alternating current (AC) into direct current (DC), which is then passed to the inverter and oscillator to control the output frequency. In this system, the thyristor trigger circuit modifies the phase angle, which affects the frequency and ultimately regulates the rotational speed of the single-phase motor. The adjustment of the variable resistance value in the PSIM simulation directly affects the motor frequency, allowing for an in-depth analysis of the rotational characteristics of the motor based on the transformer output voltage modeling. PSIM simulations not only provide detailed visualization of basic electronic circuits, but also help minimize the possibility of failures in physical circuits. This study aims to model and analyze the rotation arrangement of a single-phase motor using PSIM simulation, which offers a practical solution in the design and evaluation of a full-wave uncontrolled rectifier-based motor control system.

Keywords: 1 Phase AC Motor Rotation Regulation, PSIM Simulation, Full Wave Rectifier, Motor Control, Thyristor, Oscillator

1. Introduction

AC motors, which are often referred to as induction motors, are divided into two main categories, namely three-phase AC motors and single-phase AC motors. Single-phase AC motors, although simpler in construction, have been widely used in a variety of industrial applications because they have high efficiency, low economical cost, and easier maintenance compared to DC motors. Therefore, single-phase AC motors are the main choice in many machine tool drive systems in the industry (Nugraha et al., 2020; Sari et al., 2021).

The rotation arrangement of a single-phase AC motor can be done in several ways, such as changing the torque, frequency, and stator voltage of the motor. However, one of the main challenges faced is the large starting current, which can reach 3 to 5 times the nominal current, which causes difficulties in regulating the speed of the motor (Pratama et al., 2022). Nonetheless, technological advances in control systems allow for more efficient regulation of the speed of single-phase AC motors. One of the most widely applied approaches is the use of full-wave single-phase power inverters or rectifiers, which can provide better control over motor speed and torque (Zainal et al., 2019).

A single-phase AC motor rotation arrangement circuit with a full-wave single-phase inverter can be simulated using PSIM (Power Simulation) software. PSIM is a simulation tool that is very useful in designing and analyzing electrical power circuits. With PSIM, simulation results can be presented in the form of graphs of voltage, current, motor rotation, and torque generated, which is very important in evaluating the performance of single-phase AC motor regulation systems (Setiawan et al., 2018). In addition, PSIM allows the identification of potential errors in the network design, thereby minimizing the possibility of failure during real-world implementation (Nugraha et al., 2023).

The use of PSIM in this simulation also helps researchers and practitioners to better understand the interaction between components in a single-phase AC motor control system, as well as provides a stronger foundation in the development of inverter-based motor regulation technology and full-wave rectifiers (Widodo et al., 2020).

2. Material and methods

2.1. Material

2.1.1. Full-Wave Single Phase Rectifier

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A full-wave single-phase rectifier works to convert alternating current (AC) into direct current (DC). This circuit utilizes both half-periods of waves from the AC source, which flow twice in a cycle to generate direct current pulses. There are two types of full-wave single-phase rectifier circuits, namely center-tapped rectifiers and bridge rectifiers. Each type has different output voltage characteristics, where the rectifier with the midpoint produces a higher voltage at the diode compared to the bridge rectifier, which is -2Vm compared to -Vm in the dead diode condition (Widodo et al., 2017).

On a full-wave single-phase rectifier with a midpoint, two diodes (D1 and D2) will conduct current at two and a half different periods. Meanwhile, on the bridge rectifier, four diodes (D1, D2, D3, and D4) alternately flow direct current for two full cycles. The output voltage produced in these two types has different average direct voltage and effective voltage (Dewi et al., 2018).

The formula for calculating the output voltage of a full-wave rectifier is as follows:

DC output voltage (Vdc):

$$Vdc = \frac{2Vm}{\pi} \tag{1}$$

RMS Voltage (Vrms):

$$Vrms = \frac{Vm}{\sqrt{2}} \tag{2}$$

DC Output Current (I0):

$$I0 = \frac{Vdc}{R} \tag{3}$$

Where Vm is the peak voltage and R is the resistor load

2.1.2. Squirrel Cage Induction Motor

Squirrel cage induction motors are the most commonly used type of AC motors in the industry, mainly due to their ease of maintenance and relatively constant rotational stability. These motors consist of rotors that do not require the supply of external voltages, making them more efficient and simpler compared to wound rotor induction motors that require a connecting system to regulate speed and torque [5].

The speed regulation on the squirrel cage induction motor can be done by changing the frequency of the AC voltage source using an inverter. In this system, a 50 Hz source can be converted into a DC signal and then converted back into an AC signal with an adjustable frequency using a full wave rectifier circuit and a frequency regulator such as an unstable oscillator 【6】. The rotational speed of the motor can be calculated using the slip formula (s), which depends on the frequency of the source (f) and the number of poles of the motor (p)[7]:

$$n_m = (1 - s) \times \frac{f \times 60}{p} \tag{4}$$

2.1.3. Astable Oscillator

An astable oscillator is an electronic circuit that generates a box wave signal with a tunable frequency. This circuit is typically used in applications to generate trigger signals for the control of other devices, such as inverter controllers. The two transistors (Tr1 and Tr2) work alternately, setting the "on" and "off" times in turn, which are set by the values of the resistors and capacitors connected in the circuit. Thus, these oscillators are capable of generating waves of a certain frequency required to control the inverter and other components in the system [8].

2.1.4. Motor Universal

The inverter functions to convert direct current (DC) into alternating current (AC). One type of inverter that is widely used is an inverter with a thyristor as an electronic switch. Inverters with thyristors allow for more efficient voltage and frequency regulation. In this circuit, the thyristor will be controlled by a signal from an astable oscillator that works alternately, passing current through the transformer to generate an AC voltage on the secondary side【9】. The use of a thyristor allows the inverter to operate at higher power, but requires commutation to turn off the thyristor at low frequencies.

3. Results and discussion

In this study, the design of a single-phase AC motor rotation regulation system was carried out by utilizing PSIM simulation software. The system aims to optimize the speed regulation of AC motors through the simulation of a full-wave rectifier circuit, an astable oscillator, a thyristor inverter, a tap center transformer, and a squirrel cage single-phase induction motor. The purpose of this research is to create a practical solution in regulating the rotation of the motor efficiently and reliably using software simulation as a design aid.

3.1. Full Wave Rectifier Planning

The full-wave rectifier designed in this study uses four diodes arranged in a bridge configuration. This configuration allows the conversion of alternating current (AC) into direct current (DC), which will then be used as inputs to inverter circuits and oscillators. In this design, the components used include a diode, a 33 µF/450V capacitor, and 33KΩ and 220KΩ resistors. The simulation results on the PSIM software show that the voltage generated at points A and B has a peak voltage value of 220V, corresponding to the simulation on the PSIM oscilloscope that produces an AC waveform (Vs) with a voltage peak that can be accurately measured.

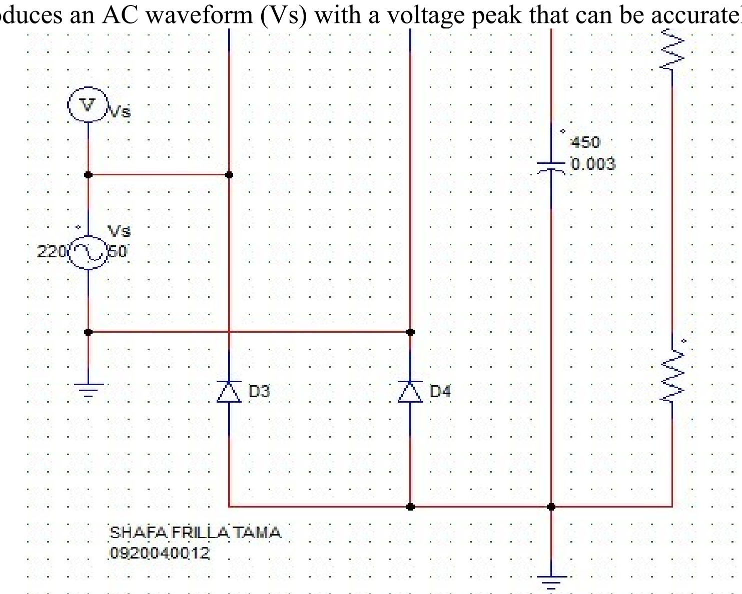

Figure 1. Full-Wave Rectifier Circuits Using Bridge Diodes on PSIM

The voltage measured at points A and B can be calculated using a formula that considers the value of the resistor, with the DC voltage (Vdc) generated by the rectifier having a full waveform with a voltage peak of 220V. The use of PSIM simulations allows for a clear visualization of these waveforms.

3.2. Multivibrator Design

In this simulation, a circuit of astable oscillators is used to generate the frequency generation signal required for inverter control. This series of astable multivibrators uses PNP transistor and diode components to prevent possible backflow due to induction from thyristors. This circuit functions to generate signals with a certain frequency which is then used to control the inverter in order to convert direct voltage (DC) into alternating voltage (AC).

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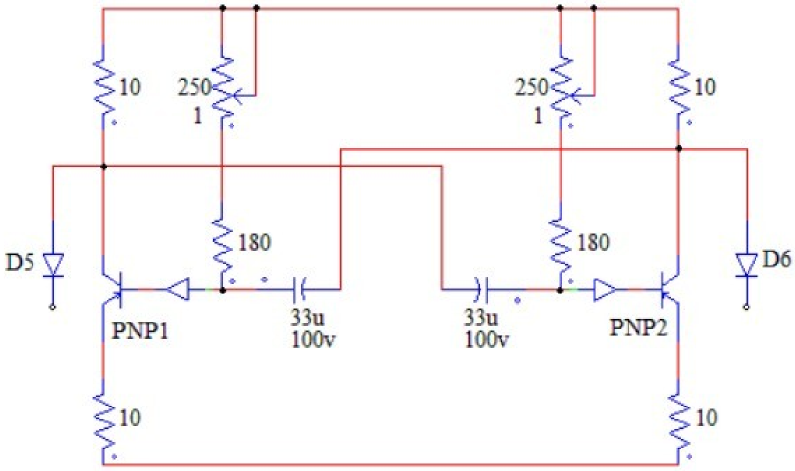

Figure 2. PNP Transistor Astable Oscillator Multivibrator Series

Simulations with PSIM show that the waveform generated by this astable oscillator has a peak voltage of 32V, with a frequency that can be adjusted according to the needs of the motor rotation setting.

3.3. Inverter Design

The inverter in this study is designed to convert DC voltage into AC voltage. The inverter circuit consists of a thyristor, a 4μF/400V capacitor, and a center tap transformer that is used to convert DC voltage into alternating voltage. The components work alternately, with the SCR being turned on and off to produce the desired waveform.

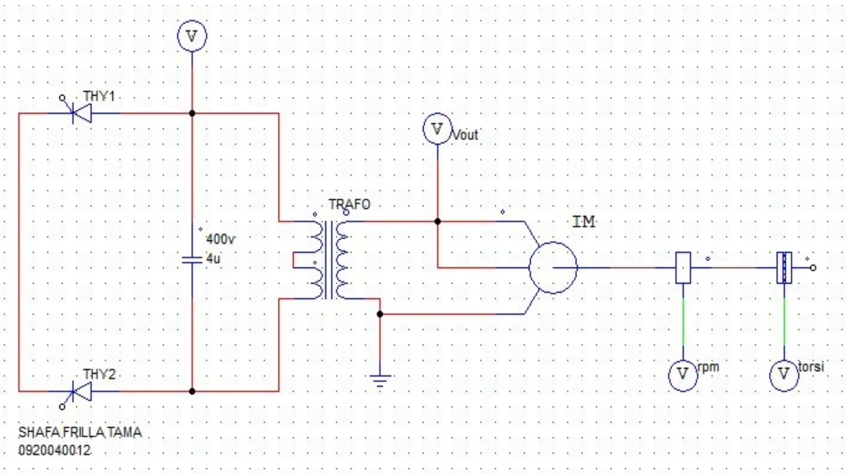

Figure 3. Inverter Series on PSIM

Simulations with PSIM show that the designed inverter generates a stable alternating voltage wave with the desired peak voltage. The generated waves can be monitored through an oscilloscope, which allows for further analysis of the performance of these inverter circuits.

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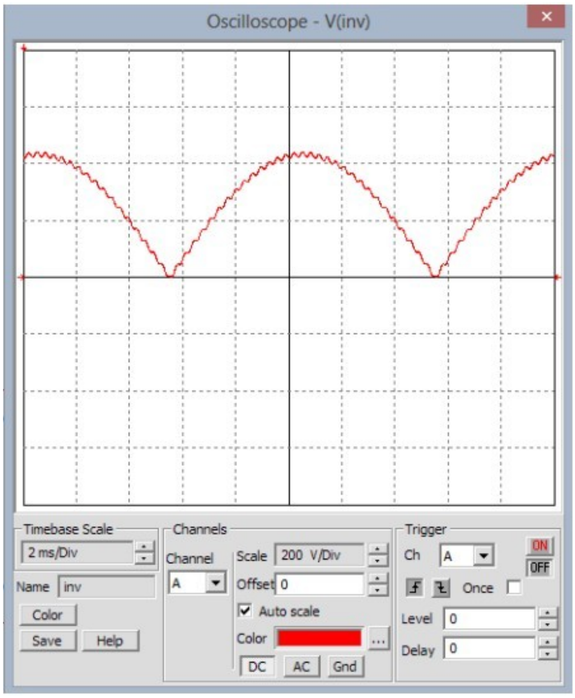

Figure 4. Waveform at Vinv Point by Oscilloscope at PSIM

This inverter circuit, once connected with other circuits, becomes an integral part of the single-phase motor speed regulation system. The motor rotation setting is done by changing the values of the two resistor variables connected to the inverter circuit.

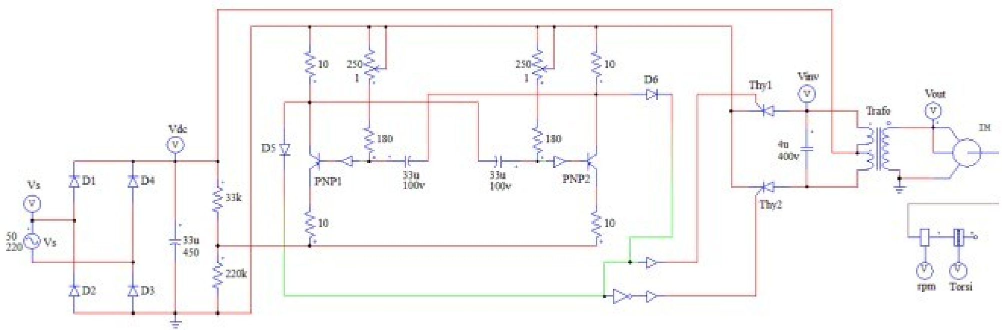

Figure 5. Single Phase Motor Rotation Regulation Network with Frequency Parameters

4. Conclusion

Based on the results of the design and simulation that has been carried out, the rotation regulation of a single-phase motor can be adjusted by changing the frequency through the variable resistor used in the circuit. This variable resistor functions to generate a trigger signal that regulates the thyristor work, allowing for effective control of the speed of the motor. The designed inverter successfully converts DC voltage into stable AC voltage, according to the operational needs of the motor. In addition, the astable oscillator multivibrator circuit shows optimal performance in generating signals with specific frequencies to support the inverter's function. The use of PSIM software in simulation provides the advantage of visualizing basic electronic circuits, such as full-wave rectifiers, unstable oscillators, and thyristor inverters, as well as enabling in-depth analysis of the performance of individual components without the risk of failure in real circuits. This simulation also proves that software-based methods can be a practical solution in the development of more efficient and reliable AC motor control systems.

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