A Study on Controlling a Single-Phase PWM Inverter Using the M68HC11E Microcontroller with Accurate Precision

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Abstract

Because it provides various benefits and is a reliable technology to convert electrical energy into mechanical motion, induction motors are becoming more widely employed in a variety of industrial and commercial applications. Controlling the speed of an induction motor is desirable in several applications. Because of the physics of the induction motor, varying the frequency of the AC voltage driving the motor is the preferred technique of adjusting its speed. In recent years, it has been possible to use a microprocessor integrated into an appliance to provide variable frequency AC power to control the speed of an induction motor.

The variable frequency power inverter based on a microcontroller is the subject of this research. The microprocessor sends a variable frequency pulse width modulation (PWM) signal to the gate drive, which controls the applied voltage and produces the needed PWM frequency with fewer harmonics at the power inverter's output.

The completely controlled bridge voltage source inverter was built using semiconductor power devices isolated gate bipolar transistors (IGBTs), and the PWM approach was used to supply the motor with AC voltage.

Matlab/Simulink is used to simulate the proposed driving system for three and single phase power inverters. Different SPWM were used to get the Matlab

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Simulation Results for the proposed system. As a result, a stable variable frequency inverter with a large frequency range has been obtained, and a good agreement between the simulation and hardware of a microcontroller-based single phase inverter has been discovered.

Keywords: *AC Voltage Driving, PWM Frequency, Microcontroller, Convert Electrical Energy*

INTRODUCTION

Variable frequency inverters are widely utilised in a variety of applications, including three-phase induction motor drive traction and numerous high-power industrial applications including speed and torque control.

Due to the better availability of single phase power supply, single phase induction motors (SPIMs) are commonly used in home applications, such as dishwashers, fabric dryers, fans, pumps, and other domestic appliances. This system can also be utilised in other applications, such as electric vehicles, variable-speed equipment, and an AC variable-frequency power source in the laboratory, where many investigations necessitate the use of various AC sources in terms of voltage amplitude and frequency.

As a result, it's a great tool for evaluating appliances, products, and equipment in the lab. It could also be useful in an automated production process to check the Device Under Test (DUT) in a specific voltage and frequency operating range [1].

Various researches on the control of the variable frequency inverter have been presented as low-cost, high-performance, and development has been made in several areas, including microelectronics, which allows the use of software rather than hardware to solve complex control problems for an affordable price; power semiconductors technology, which provides powerful, fast, and easy to drive switches; and control algorithms, which control the inverter output and reduce harmonics. As a result of these efforts, AC motor drives have emerged as a viable alternative to DC motor-based systems.

A PWM inverter has been utilised as a vital element for a high-performance power conversion system for essential loads such as computers, medical

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equipment, and communication systems [2] due to the rising need for high-quality power sources and the elimination of harmonic distortion.

Many researchers developed software for the control system, which confirmed the high quality of the control based on microcontroller techniques [3] and to provide additional real-time processing throughput in an inverter operation, these features minimise the CPU's overhead in an interrupt intensive application [4]. Microcontrollers and digital signal processors (DSP) have been available in recent years; applications of advanced control techniques have been reported.

The Motorola MC68HC11 microcontroller was chosen for this solution because it is simple to programme, has a fast reaction time, is high-performance, high-speed, and low-power, and can run at up to 2MHz.

Because variable speed operation of a single phase induction motor traditionally suffers from big harmonics and restricted speed, the system was created utilising a voltage control approach using semiconductor power devices IGBT and PWM techniques to avoid huge harmonics.

Simulation of a single phase and three phase variable frequency inverter built in Matlab/Simulink to test its capacity to generate a chive sinusoidal waveform with variable frequency for usage as a single phase and three phase variable frequency power supply.

With varied PWM frequencies, the Matlab Simulation Results for the suggested system were accomplished. This system may be called a high power variable frequency voltage source inverter with less harmonics. As a consequence, a stable AC voltage with variable amplitude and variable frequency was achieved over a large range, and a good agreement between the simulation and hardware of a single phase inverter was discovered.

Ba- thunya et al [5] evaluated several converter topologies and found that the adjustable frequency PWM inverter is the best choice for single phase induction motor drives among the converter topologies.

Chomat and Lipo [6] investigate a system linked to a single-phase supply and create a PWM output feeding one or both stator windings of a single-phase machine, with the output section of the converter consisting of two IGBT switches. The fact

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that both stator windings are supplied by the inverter distinguishes variable speed operation. An AC capacitor linked in series with the auxiliary winding maintains the phase shift between the currents in the main and auxiliary windings of the machine. A single-chip microcontroller controls the creation of triggering pulses for the solid-state switches as well as the condition of the output relay.

Jiangmin Yao [7] used the PIC17C756 microcontroller to regulate the speed of a single phase induction motor with a hardware setup and software application written in C language. This microcontroller's key feature was its peripherals, which were utilised to implement pulse width modulation in single phase motor control. Furthermore, the traditional complex circuit solution is replaced with a single chip and reprogrammable ROM.

He came to the conclusion that this resulted in low costs, a compact size, and the ability to update the control algorithm without having to replace the hardware. This microcontroller's fault was that it lacked a dead band register and only had three PWM outputs. As a result, extra logic analogue circuits were added to produce complement signals and generate dead time in order to avoid the upper and lower switches turning on at the same time.

The single phase variable frequency inverter was used in this project. The output power inverter's frequency has been varied using the microcontroller.

MATERIALS AND METHODS

The full bridge diode rectifier in a single phase variable frequency inverter is fed by a 110Vac power source, and the rectifier bridge is utilised to convert the AC supply voltage to a 155.56Vdc value.

The rectifier bridge's output voltage is smoothed by a capacitor, which helps to eliminate ripples. The constant DC voltage is then sent to a single bridge IGBT inverter, which receives the DC voltage and transforms it to variable frequency AC voltage to power the motor under control.

We can modify the frequency of the inverter by varying the frequency of the PWM signal that controls the frequency of the voltage applied at the gate drives, which has been programmed into the microcontroller.

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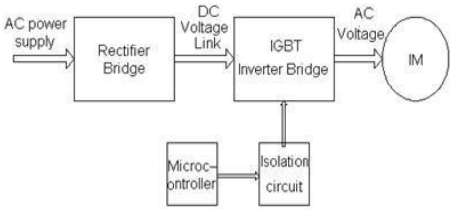


Fig. 1 Block diagram of the system

Three-phase variable frequency inverter: A three-phase full bridge diode rectifier converts the 110V three-phase power source to a fixed DC voltage. An LC filter removes the harmonics, resulting in a smooth DC voltage that is subsequently supplied to the inverter input.

The inverter is made up of six high-power IGBTs that convert the DC link voltage into a three-phase AC voltage that may be adjusted. The PWM control system modulates the on and off timings of power switches to regulate the inverter output voltage and frequency.

A. Simulation of the System

The circuit, which comprises of a complete bridge rectifier and an inverter circuit, was simulated using Matlab/Simulink software. Figure 1 depicts the entire system of a single phase inverter, whereas Figure 2 depicts the entire system of a three phase inverter.

The motor may be represented as an R-L lumped circuit in the steady state without losing accuracy. The stator and rotor core losses, as well as the winding inductance, are reflected in the resistance R. R and L were measured in an experiment, and the measured values were employed in a Matlab/Simulink simulation [3].

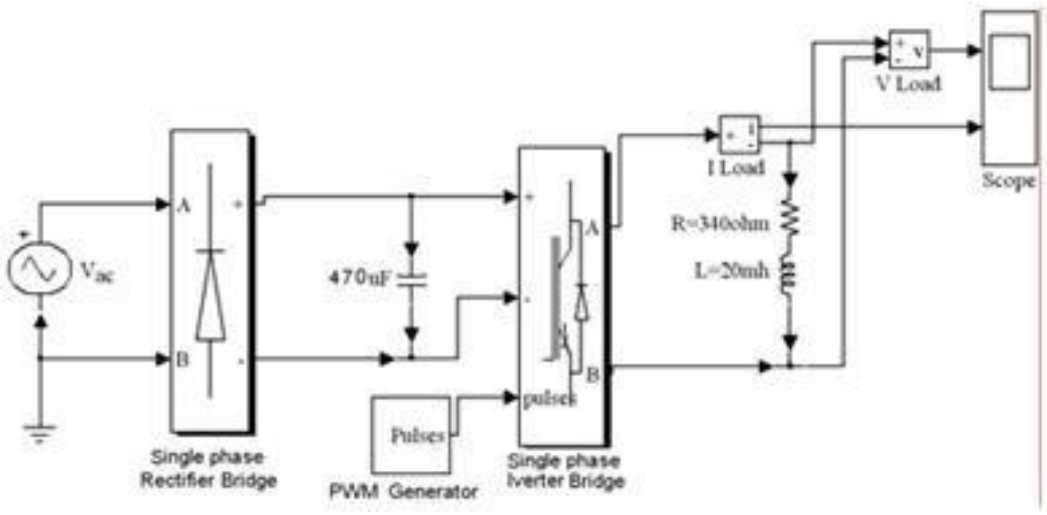


Fig. 2 Block diagram for single phase inverter simulation circuit

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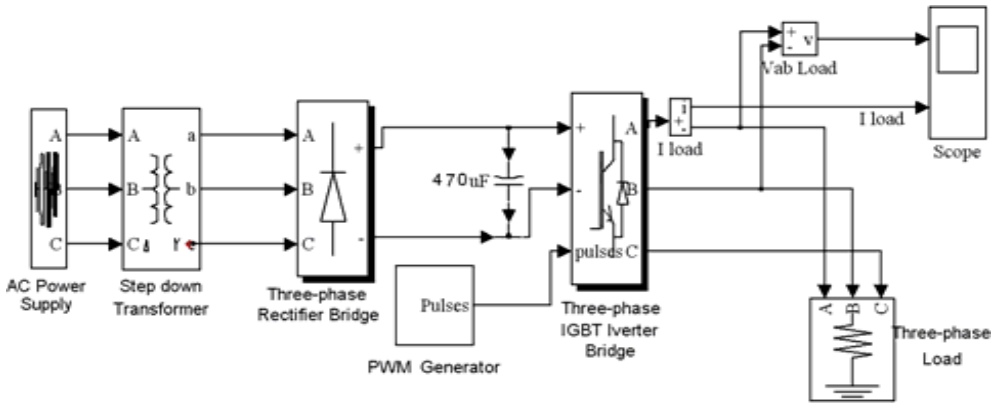


Fig. 3 Block diagram for three phase inverter simulation circuit

A. Experimental Setup

To convert the AC supply to a DC voltage, a complete bridge rectifier was employed in this experiment. A smoothing filter is made out of a capacitor and an inductor. The rectifier's output is sent into the inverter, which takes the smooth DC voltage and transforms it to AC power to produce a variable frequency power source.

The PWM signal that regulates the frequency of the power inverter has been designed to adjust the frequency of the microcontroller-based control system hardware.

The PWM module accepts two inputs: duty cycle and frequency. The frequency may be set between 20Hz and 2 KHz, and the duty cycle can be set between 0% and 100%. The frequency is transformed from Hz to counts using the following equation in order to use the output comparison function as a PWM generator.

$$FREQCNT = \frac{FREQHZ}{0.5\,\mu s} \quad (1)$$

where 0.5s is the microcontroller's one cycle period. Through gate drive, the MCU's PWM signals are applied to the IGBT's gate; the gate driver offers isolation, low impedance, and high current supply to drive the IGBT's. We can change the output frequency of the Microcontroller by controlling the input voltage to the ADC, since this input analogue voltage is converted to 8 bit digital signals with a resolution of 20mV/step.

The output of the power inverter was smooth when there was no load, and when this output voltage was delivered to the single phase induction motor, the motor began to spin and the drive system responded as predicted.

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SIMULATION & EXPERIMENTAL RESULT

1) Simulation Results: Figure 4 shows the Matlab Simulation Results for the single phase variable frequency at steady state, whereas Figure 5 shows the experiment outcome.

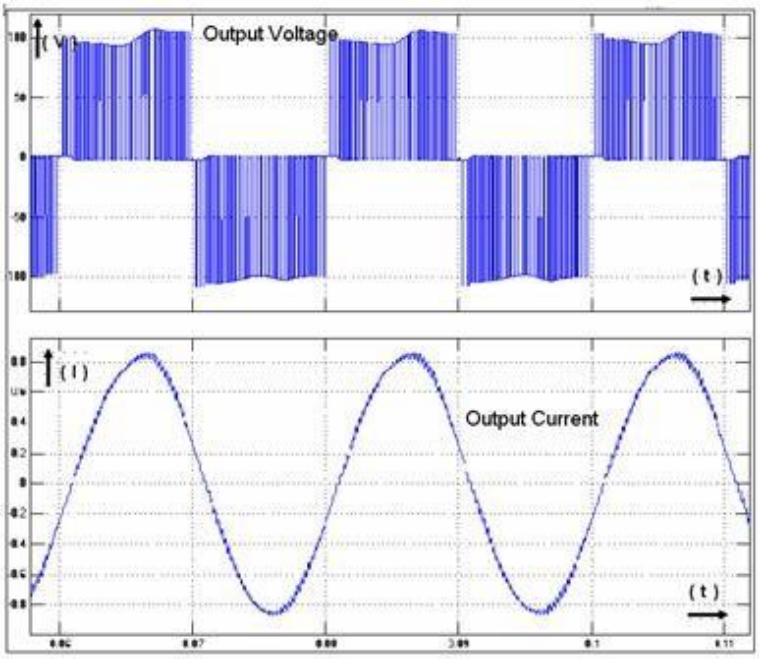


Fig. 4 Load voltage and current for single phase inverter during simulation

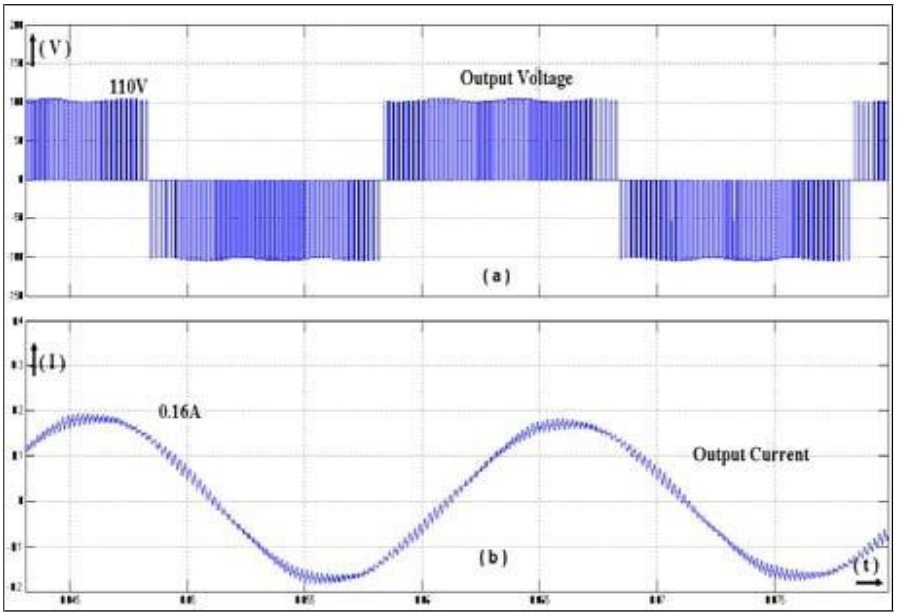


Fig. 5 Load voltage and current for three phase inverter during simulation

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2) Experimental results: A single phase variable inverter system based on a microcontroller has been implemented experimentally. The MCU's output PWM pulses, which have customizable pulse width and frequency, are shown in Figure 6. Figures 7 and 8 demonstrate the output voltage and current of a single phase system feeding an induction motor, respectively.

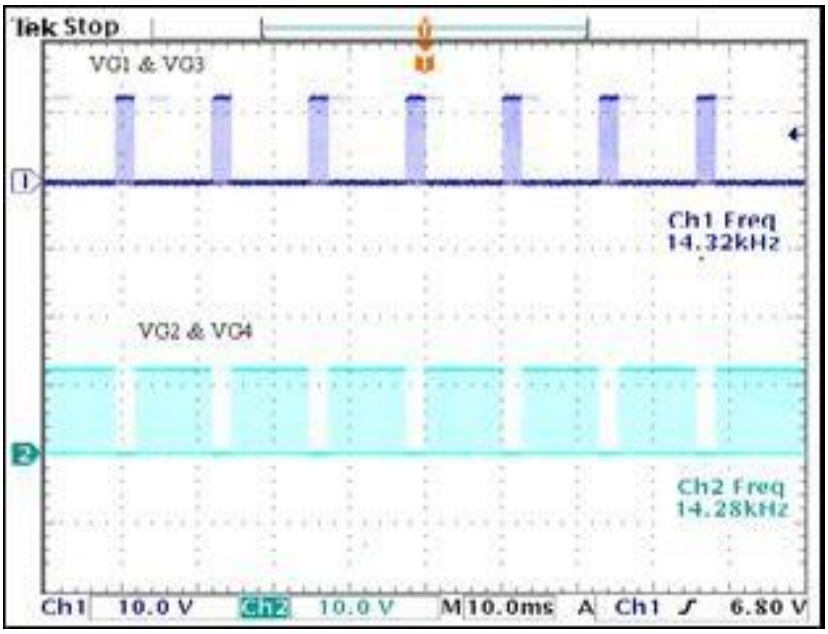


Fig. 6 firing signal for the single phase inverter

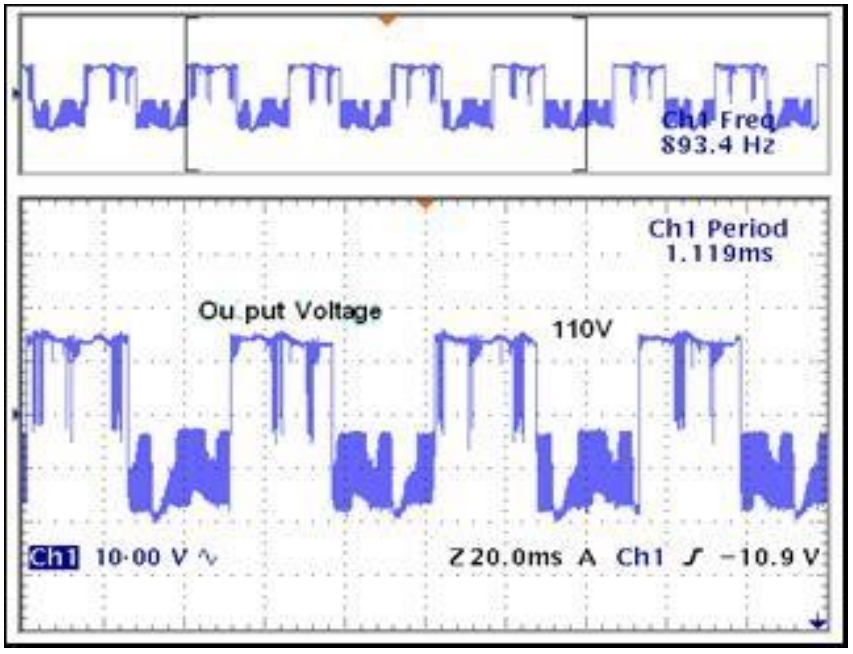


Fig. 7 Load voltage during experiment

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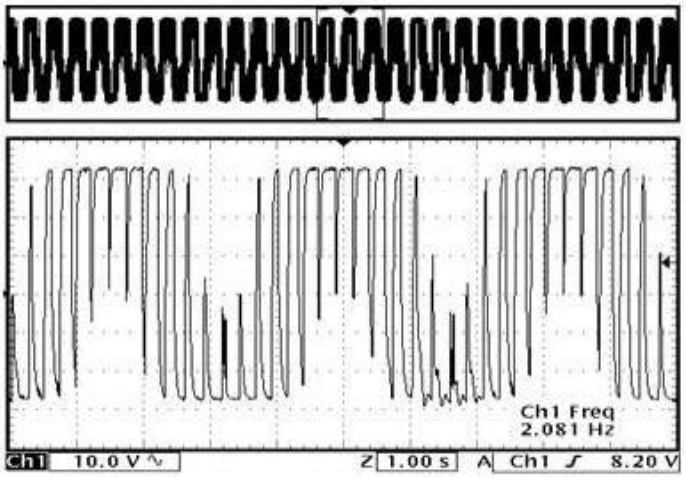


Fig. 8 Load Current during experiment

When comparing the output voltage and current waveforms of the simulation and experimental findings, we can see that the simulation and experimental results have a good agreement in terms of voltage and current waveform shape.

CONCLUSION

Matlab/Simulink software is used to model the single phase and three phase variable frequency inverters. It was possible to generate a steady AC power supply with variable amplitude and variable frequency across a large range.

The single phase variable frequency power inverter based on the M68HC11E-9 microcontroller has been introduced, and it can be effectively realised. The experiment findings were achieved for the microcontroller, which provides dependable and low-cost solutions for single phase variable frequency inverters, and the simulation and hardware results were found to be in excellent agreement.

The AC-DC-AC conversion was effective in general; nevertheless, considerable overshoot was discovered due to speculated factors such as the microcontroller's control algorithm and harmonic content at the inverter output. Good outcomes, on the other hand, validate the design's original goal.

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