

Abstract

The purpose of this project is to design a 5hp variable electric drive that converts an AC input signal to DC then to a variable AC output signal voltage that would vary the speed of an AC induction motor. To achieve the goals of this project, two three phase rectifiers are used to convert the AC input voltage to a DC voltage which in turn is inverted and its output amplitude and frequency varied using a pulse width modulation microcontroller. The inverter consists of six Insulated Gate Bipolar Transistors with gate drivers and a digital signal processor to generate the switching signals. The variation in AC output voltage allows the speed of the AC induction motor to be varied from zero to 1700 rpm. Although the load in this application is a 2 hp induction motor, the power system has been designed for a 5 hp unit. The main advantage of this system is its affordability and energy-efficiency. The cost of all components except that the motor has been estimated to be less than \$500, while similar products in the market cost at least ten times more. Low cost and energy efficient variable speed drives have numerous applications including appliances (fans, vacuums, etc.), industrial drives (robotics, centrifugal pumps, etc.) and automotive control (hybrid electric vehicles, electric trains, etc.)

Introduction

The field of power electronics is continuously growing, and its applications are endless. PWM systems are an emerging type of electric drive and are becoming more popular due to the availability of fast switching transistors such as IGBTs and their ability to reduce harmonics which create pulsations in the motor windings [1].

This project draws from the field of electronics, programming, and power electronics and requires the design of three subsystems:

1. An AC to DC converter
2. A Pulse Width Modulation generator
3. A DC to AC inverter with DC link

The block diagram shown in Figure 1 explains the different steps needed to achieve a variable amplitude and frequency AC output voltage.

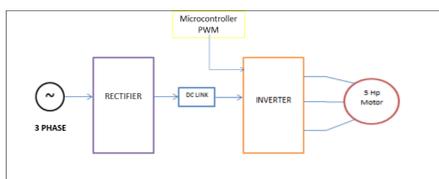


Figure 1: Block Diagram of a PWM System

The objective is to control the DC link voltage amplitude and frequency using the PWM signal generated by the controller.

A heat sink and forced cooled fan provide proper cooling for the inverter circuit to maintain the highest performance and efficiency.

Methodology

The three phase rectifier shown in Figure 2 converts the three phase input voltage to a single uncontrolled DC signal. The DC signal passes through the DC link capacitor which filters harmonics in the DC link (both rectifier and inverter sides). The DC link could be represented by any dc source such as a battery, in which case the rectifier would be eliminated from the system.

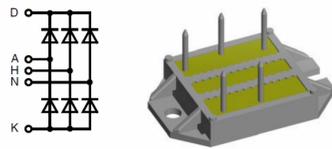


Figure 2: IXYS Three Phase Rectifier Bridge

The three phase rectifier shown in Figure 3 inverts the DC voltage to an AC output voltage that would drive the AC Induction Motor. The bridge circuit which includes six gate drivers is composed of six IGBTs and three legs transistors. Each leg is a single-phase inverter

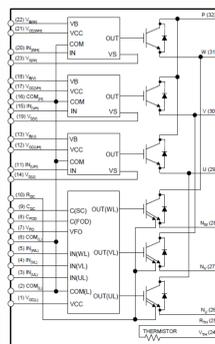


Figure 3: Fairchild Semiconductor Three Phase Inverter Bridge

The line to line voltages are defined in Equation 1, where m is the modulation index and V_{dc} is the input dc voltage to the inverter.

$$V_{LLrms} = \frac{m}{2} \times \frac{\sqrt{3}}{\sqrt{2}} V_{dc} \quad (\text{Eq. 1})$$

Pulse Width Modulation techniques reduce the output voltage distortion. There are several techniques including the classical Sinusoidal PWM used in this application and modern Space Vector PWM.

The principle of PWM is as follows: a reference signal also known as modulating signal and carrying the amplitude and frequency of the desired output voltage is compared with a triangular signal known as carrier which has a higher frequency than the modulating signal.

The technique of unipolar Sinusoidal PWM is used in this application. Each leg of the inverter is switched separately and the modulating signals are 120 deg in phase with respect to each other. The width of the pulses is determined by the amplitude and frequency of the modulating signal.

Using the modulation index in the PWM block, the output voltage and frequency can be varied.

The implementation of the PWM signals, is a fairly simple and inexpensive process:

The pulses can be generated using Matlab/Simulink and an Arduino board. Using the Arduino toolbox in Simulink, the C code for the two level PWM can be downloaded directly to the microprocessor with no programming skills necessary.

Results

The simulation of the PWM system using an input AC voltage of 220 Vrms in Matlab/Simulink is shown in Figure 4 and the steady state load torque and stator current, the rotor speed and line voltages are plotted in Figures 5 through 8 respectively.

The AC induction motor is modeled as a 5 hp - 460V – 60 Hz asynchronous machine.

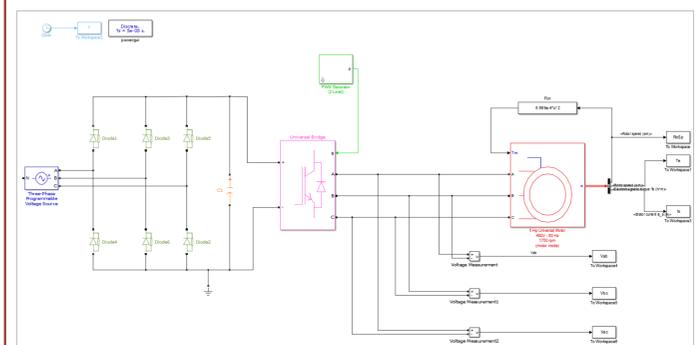


Figure 4: Simulink Model of AC-DC-AC PWM System

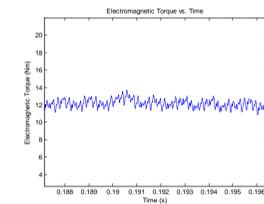


Figure 5: Electromagnetic Torque vs. Time

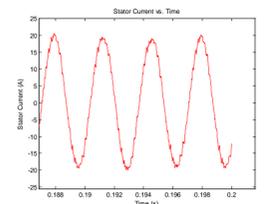


Figure 6: Stator Current vs. Time

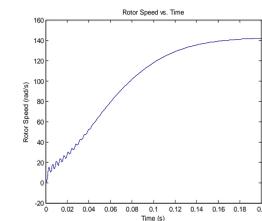


Figure 7: Rotor Speed vs. Time

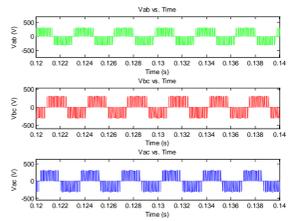


Figure 8: V_{ab}, V_{bc}, V_{ac} vs. Time

Current Status of Research

The next step in this research involves designing a control feedback circuit powered using Arduino and Matlab/Simulink to maintain a constant v/f and therefore operate the motor at full torque.

References

- [1] T. Wildi (2005). Electric Machines, Drives, and Power Systems. Upper Saddle River, New Jersey: Prentice Hall
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