DESIGN AND IMPLEMENTATION OF A PIC MICROCONTROLLER BASED FIRING CONTROLLER FOR A TRIPHASE THYRISTOR RECTIFIER

by

Sohail Anwar
sxa15@psu.edu
Division of Business & Engineering
Penn State University,
Altoona College

Patrick Favier
favier@iut-geii.univ-artois.fr
Department of Electrical Engineering
Institut Universitaire de Technologie
Unitersite d′ Artois
Bethune, France

Kalman Mikszath
Kando Kalman Faculty
Budapest, Hungary

Abstract: *This paper describes an undergraduate design project that involved the design, development, testing, and installation of a firing controller for a triphase thyristor rectifier. A PIC 16F877 microcontroller was chosen for this application. The microcontroller is used as the firing controller. This IC chip provides logical input and output, analog-to-digital conversion, timer for the delay counting, and various interrupt vectors for timing. The software algorithm consists of the detection of the zero crossing of the synchronization voltage to start the timing of a period. A special test is programmed to control the value of the firing angle. The firing angle is adjustable from 180° to zero.*

I. Introduction

Power electronics is one of the key topical areas within the electrical engineering discipline. Power electronics draws from a variety of topics, making it an appropriate vehicle for teaching design to undergraduate electrical engineering students. The interdisciplinary nature of power electronics presents a large variety of project possibilities [1]. The principal objective of a capstone design project is to require students to use skills and knowledge learned from a wide variety of courses, to solve an open-ended problem. In power electronics, one can find a large number of open-ended problems that are within the capabilities of undergraduate electrical engineering students. A capstone engineering design project based on power electronics is described in [2]. In this project, students designed and built a TMS320C30 DSP based controller for a power converter. The programming of this controller was accomplished using C language. Implementation of a microcontroller based three phase SCR power converter is described in [3].

This paper describes the design, development, testing, and installation of a PIC microcontroller based firing controller for a triphase thyristor rectifier. The block diagram of this rectifier is shown in Figure 1 below:

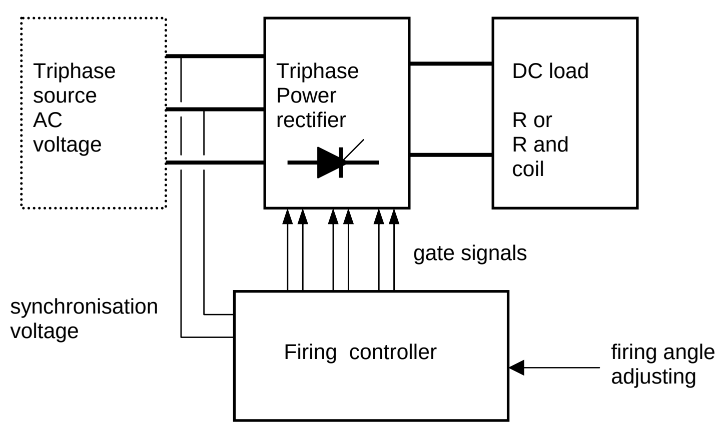

Fig #1: The Triphase Rectifier Block Diagram

The triphase rectifier uses a PIC 16F877 microcontroller as the firing controller. Three MOC3022 opto drivers are used to match the microcontroller to the triphase rectifier. The firing angle selection can be set by two potentiometers or by a voltage level. The hardware is shown in Figure 2 below:

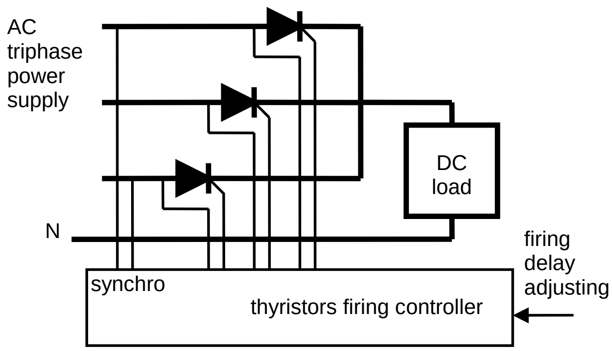

Fig #2: The Rectifier Hardware

II. Development of the System Design

Design and development of a firing controller for the three phase thyristor rectifier shown in Figure 1 is based on the following technical specifications:

- The main printed circuit board used for this project measures 10 x 15 cm^2.
- The control panel must be provided with 5V DC in order to operate properly.
- A PIC16F877 microcontroller is used on the control panel and three MOC 3022 opto drivers are used to match the microcontroller to the triphase thyristor rectifier.
- The firing angle selection can be made by two potentiometers or by a voltage level.
- The firing angle selection is made as follows: if the input level is 0V, the firing angle must be 180°, if the input level is 3.6V, the firing angle must be 0°.
- A special test is programmed to check if the firing angle is set to 180°. This test has to be performed upon cold starting and restarting the firing angle control circuit.

III. System Hardware Description

A description of the firing angle controller is presented here. The principal components of system hardware are described as follows:

Power Supply:

The 24V DC is produced from a two-phase rectifier power supply and a smoothing capacitor as shown below in Figure 3. To suppress high-frequency interferences, a foil capacitor is used with the smoothing capacitor.

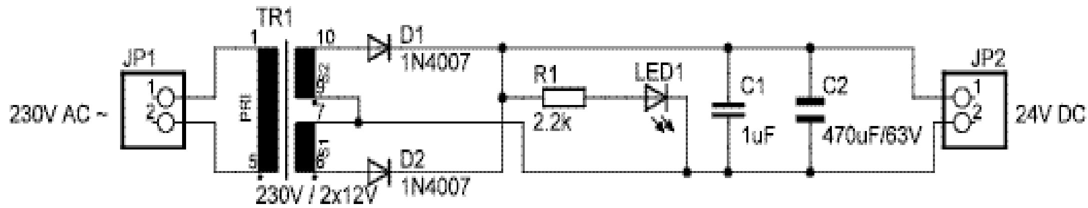

Fig #3: Power Supply Circuit

Main Printed Circuit Board Supply:

The required +5V is supplied by a 7805 voltage regulator as shown in Figure 4 below. C_{in} and C_{out} capacitors are required by the voltage regulator. Their respective values are shown in Figure 4.

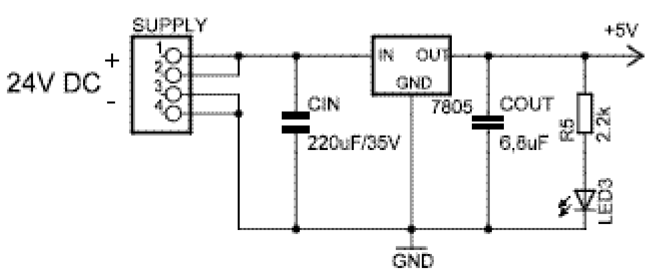

Fig #4: Main Printed Circuit Board (PCB) Supply Circuit

Logical Control:

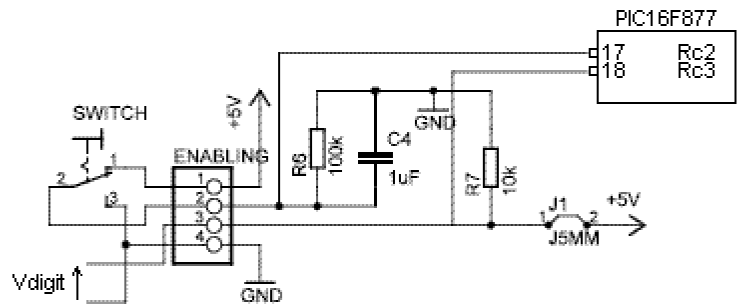

Fig #5: Logical Control Circuit

As shown in Figure 5 above, the firing control is enabled either by a switch or a voltage level. Two pins on PIC 16F877 microcontroller are configured as inputs. One of the pins is connected to the switch and the other one to the controlling voltage level. Control by voltage level can be disabled by jumper J1, so that in this situation only the switch enables the firing angle control circuit.

Firing Angle Setting:

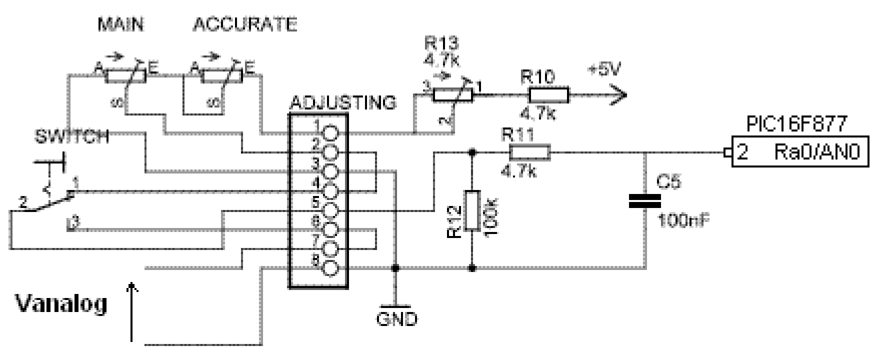

Fig #6: Firing Angle Selection

As shown in Figure 6, the firing angle selection is made by two potentiometers or by means of a voltage level. Selection of the control source is possible through use of a switch.

Zero Transversal Testing Circuit:

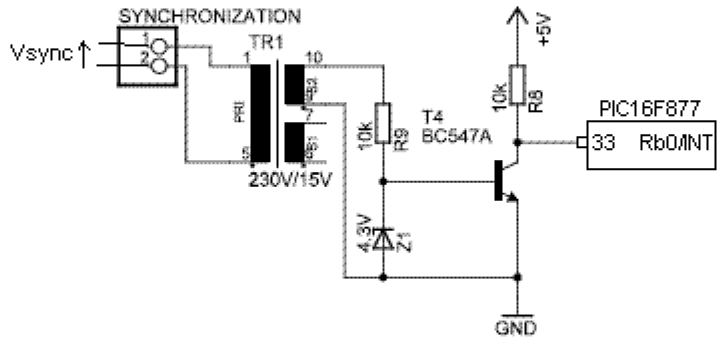

Fig #7: Zero Transversal Testing Circuit

A helpful feature of the PIC16F877 microcontroller has been used for zero transversal detection. As shown in Figure 7, this is accomplished through a PIC16F877 pin that generates an interrupt upon a change of the input value. The required signal is generated from a transformer connected to the mains power input so that the signal is galvanically decoupled from the mains. The voltage on the secondary side of the transformer is transformed into a square wave signal by a transistor circuit. The signal on the collector of the transistor is connected to pin 33 on the PIC microcontroller. Possible input voltages are 0 volt and 5 volts.

Logical Input and Output:

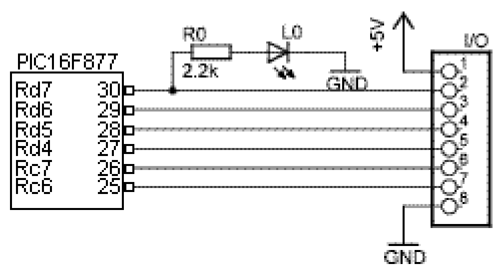

Fig #8: Logical Input and Output

This part of hardware is shown in Figure 8 above. It is reserved mainly for future development. However, one of its current functions is to provide safety control to the firing control circuitry. Upon starting the circuit, the firing control is disabled when a firing angle smaller than 180° is set. An LED is lit when the safety system disables the firing angle. If the firing angle is now set to 180°, the LED turns off and the firing is enabled.

IV. System software Description

The flowchart of the main program is shown in figure 9. Detailed flowchart is illustrated in Figure 10. Flowchart of the interrupt routine is shown in Figure 11.

When the user turns on the device, the program starts with a firing-angle test routine. The test routine checks if the firing angle is set to 180°. If it is not, then the program is suspended and a red LED is lit. The program remains suspended until the firing angle is set to 180°. At this point, LED is turned off and the program resumes. Afterwards, the firing angle can be adjusted arbitrarily. This subroutine is necessary for safety reasons.

Next part of the program checks the logical control. The program checks if the control of the thyristors is enabled or not. A red LED is lit if the control is disabled. The LED turns off if the control is enabled. At that point, the program reruns the firing-angle test routine.

Two potentiometers can be used to adjust the angle value; the first one makes coarse adjustments, whereas the second one is used to fine tune the setting. With these two potentiometers, the firing angle can be set arbitrarily between 0° and 180° until either the device or the control is turned off.

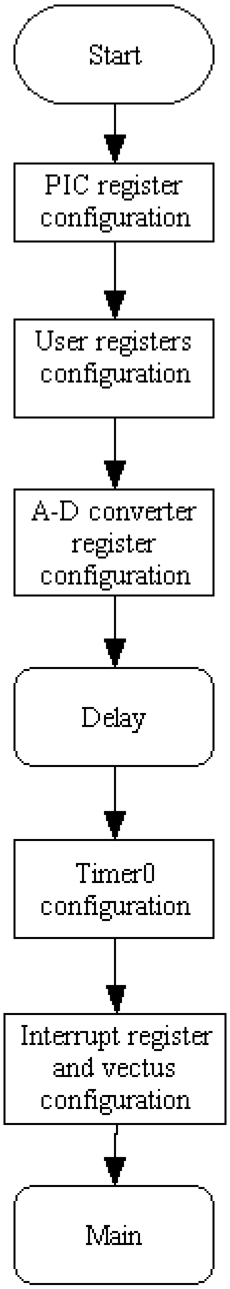

Fig #9: Flowchart of the Main Program

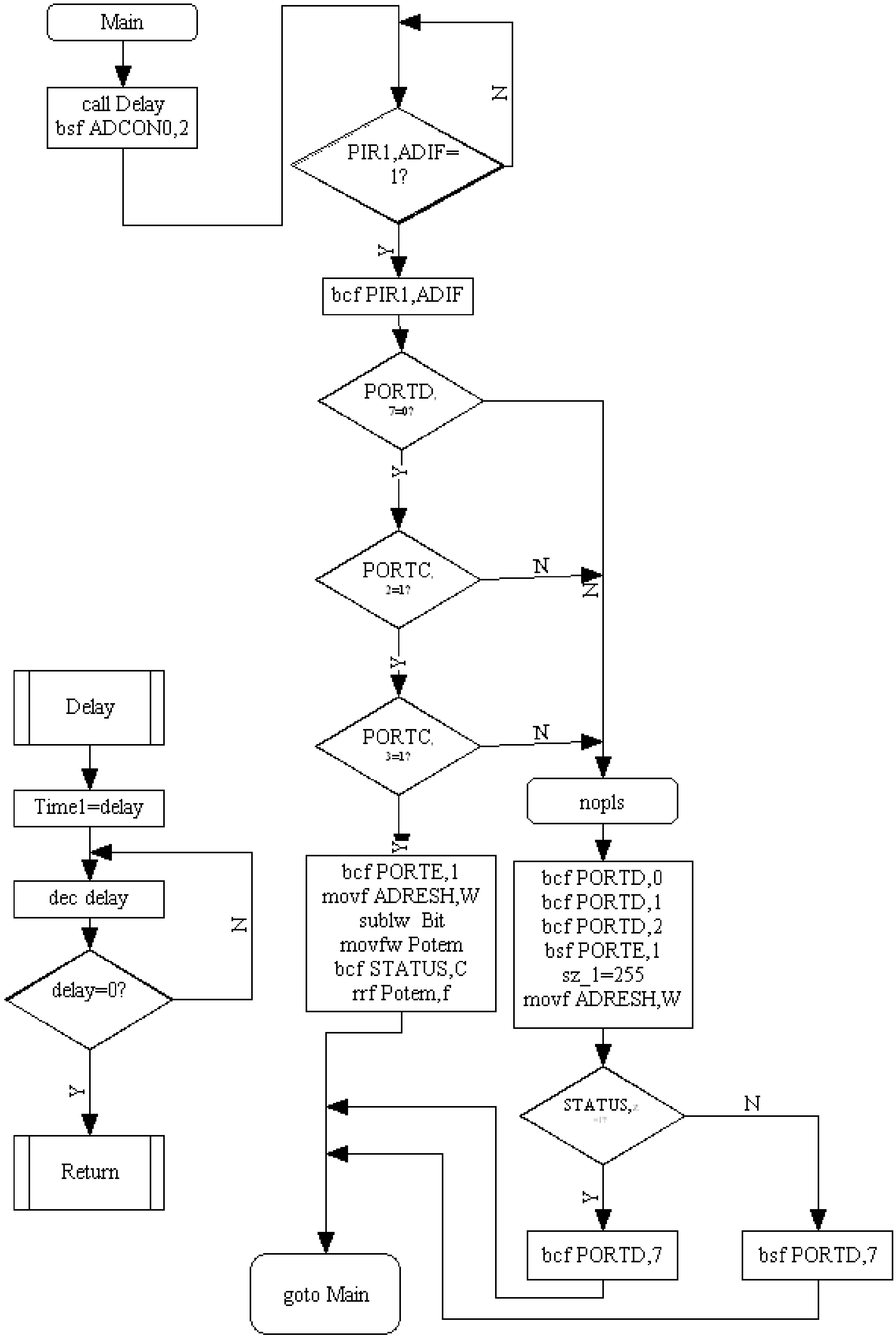

Fig #10: Detailed Flowchart

The flowchart of the interrupt:

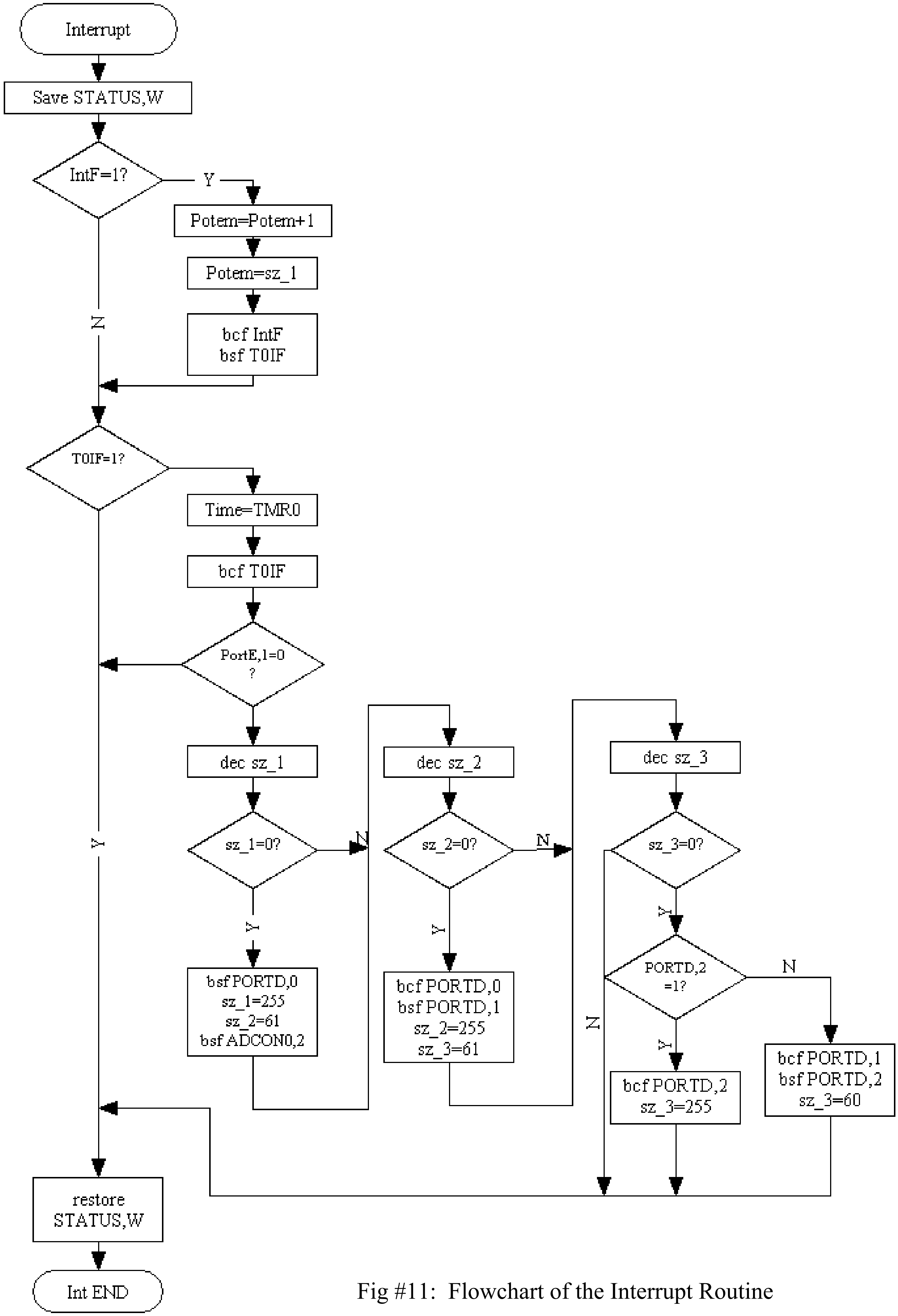

Fig #11: Flowchart of the Interrupt Routine

V. Measurements

Measurements were made to test the firing controller operation. The controller was tested on a triphase rectifier for the following conditions:

Triphase AC supply voltage = 130 V_{rms}
Load = Inductive
Firing angle = 45°
Load Current = 10 A

The inductive load used to test the controller had a resistive component to limit the average current. The value of resistive component to limit the average current. The value of resistive component was 10.7Ω. The inductive component of the load served to reduce the variation of the instantaneous current.

The resulting curves are shown in Figures 12 and 13 below.

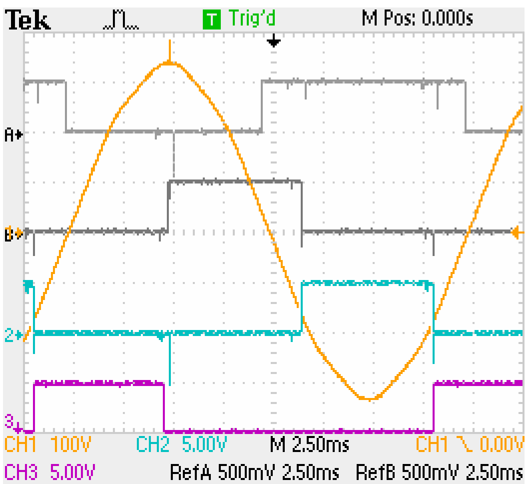

Fig #12: Reading of Internal Signals

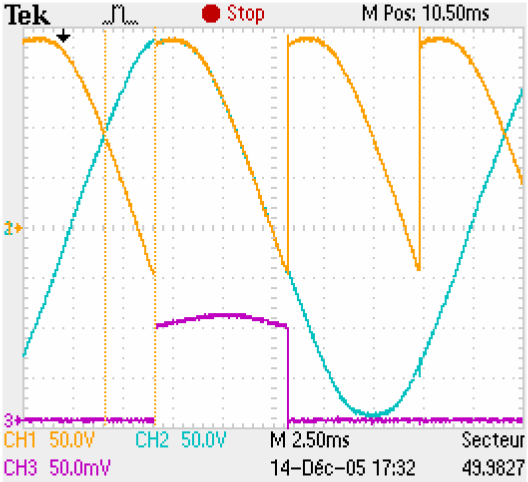

Fig #13: Reading on Power Rectifier

VI. Conclusions

The paper describes the design, development, testing, and installation of a PIC microcontroller based firing controller for a triphase thyristor rectifier. The tests conducted on the controller show that the three thyristors are correctly triggered and the firing angle is adjustable from 180º to 0º. As a result, the output DC voltage varies from 0 to a maximum value corresponding to the AC supply voltage.

References

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