# DESIGN OF PROTOTYPE NON DIRECTIONAL OVERCURRENT RELAY MICRO-CONTROLLER-BASED

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## *ABSTRACT*

*This paper presents a design of non-directional overcurrent relay micro-controller-based having the advantages of low cost, high performance and can be totally manufactured by local manufacturers. The proposed overcurrent relay can be employed to protect feeders of distribution systems for overcurrent and earth fault protection. Also, the proposed relay is considered a high speed overcurrent relay, thus it can be used for restricted earth fault applications. The main hardware platform is designed and tested with pickup accuracy not more than $0.001I_n$ and total scan cycle not more than 1ms which make this relay very accurate and adequate for fast tripping applications. . The relay has the capability to treat the incoming analogue signals of voltages and currents via the Discrete Fourier Transform (DFT) through the designed main hardware platform. In this way if the relay protects a distribution power transformer, it can detect the inrush conditions via the second harmonic detection. Also it can detect the over excitation via the fifth harmonic calculations to block the abnormal tripping for more reliable and secure distribution systems.*

## INTRODUCTION

Due to the large increase of power system network extension in Egypt at the past period and also due to the expected power network grow in future to match the large future demand; the need for overcurrent protection relays is essential. Since, the existing overcurrent relays in the Egyptian network are foreign brands and are very expensive, hence the need to create a local brand with low cost-high performance-based is very highly required in the Egyptian market. So that, this paper presents a design of non-directional overcurrent relay micro-controller based having the advantages of low cost, high performance and can be totally manufactured by local manufacturers. The proposed overcurrent relay can be employed to protect feeders of distribution systems for overcurrent and earth fault protection. Also, the proposed relay is considered a high speed overcurrent relay, thus it can be used for restricted earth fault applications. The main hardware platform is designed and tested with pickup accuracy not more than $0.001I_n$ and total scan cycle not more than 1µs which make this relay very accurate and adequate for fast tripping applications. The relay has the capability to treat the incoming analogue signals of voltages and currents via the Discrete Fourier Transform (DFT) through the designed main hardware platform. In this way if the relay protects a distribution power transformer, it can detect the inrush conditions via the second harmonic detection. Also it can detect the over excitation via the fifth harmonic calculations to block the abnormal tripping for more reliable and secure distribution systems. The proposed relay hardware platform is very compact and light weight in comparative with other competitive international manufacturers. Also, the total cost for developing a prototype unit is not more 800 Egyptian pound considering that it costs around 4600 Egyptian pound of other international manufacturers which encourages for the line production process to achieve lower production cost for the proposed hardware platform.

The design process is divided into several stages. The first stage is the DFT filter, the second stage is the design of the hardware platform, the third stage is the firmware implementation, and finally the fourth stage is the interfacing via the HMI and PC through a communication link. The above stages are described in details in the following paper sections.

## HARMONIC SPECTRUM ANALYSIS

For preventing the abnormal tripping due to different harmonic levels in the power system network, the power frequency component is very important to be used by the protection relay for the adequate tripping actions [2,5]. But, regarding the other harmonic orders, it is also important for other different protection applications [1,3,4]. The second harmonic order of the current is used for inrush current detection, which makes tripping inhibition during the inrush current period. Also, the fifth harmonic order of the current is used for over excitation detection for preventing from mal operation of the protection relay during that period.

According to the above reasons, the proposed relay is provided with the Discrete Fourier Transform (DFT) to make harmonic spectrum analysis to the input current for better enhancement and more relay reliability. The relay requires one power cycle for the harmonic spectrum analysis and only one scan cycle which is within 1µs.

Following are a testing cases simulated by Matlab M-files constructed by the authors for reliable tripping actions.

Case No.1: depicts a system current distorted with second and fifth harmonic. As per harmonic spectrum analysis shown in figure.2, the fundamental component of current is just below the pickup setting value which is 1 p.u. Thus, the relay is blocked to perform a tripping action as shown in figure.1.

Whereas, case No.2: depicts a system current distorted with second and fifth harmonic. But, the harmonic spectrum analysis shown in figure.4 depicts the fundamental component of current is just above the pickup setting value. So that, the relay starts to pick up and gives the tripping action after the adjusted delay time -which is 0.7s- plus the circuit breaker tripping time as shown in figure.3.

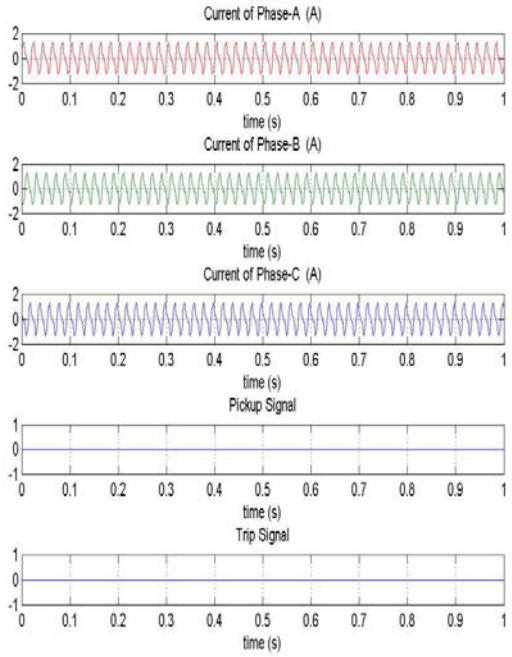


Figure.1: Wave form capture for non-tripped case due to harmonic inhibition

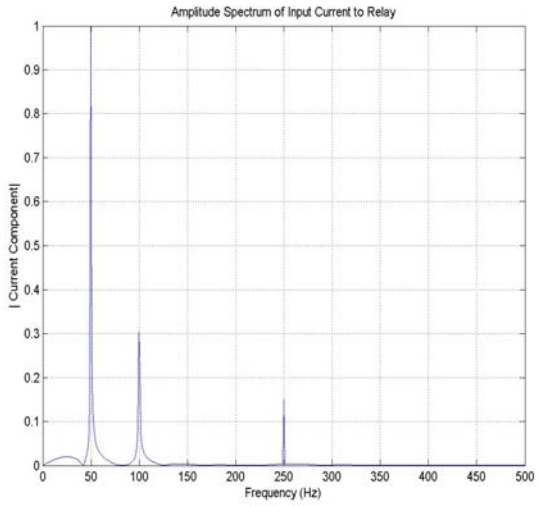


Figure.2: Harmonic spectrum for the non-tripped case

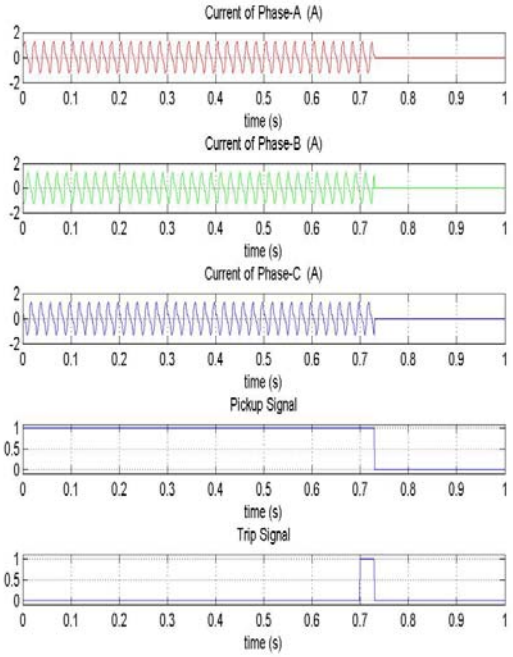


Figure.3: Wave form capture for tripped case

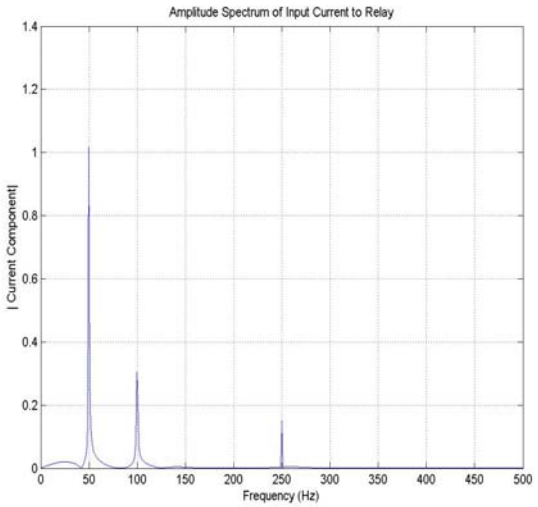


Figure.4: Harmonic spectrum for the tripped case

## HARDWARE PLATFORM

The main hardware platform comprises a current transducer, soft DFT filter for harmonic spectrum analysis, PIC micro-controller, input/output modules for signalling purposes, and also extended flash memory module for recording the Sequence-Of-Events (SOE) and waveform capture. Refer to figure.5 for graphical depiction.

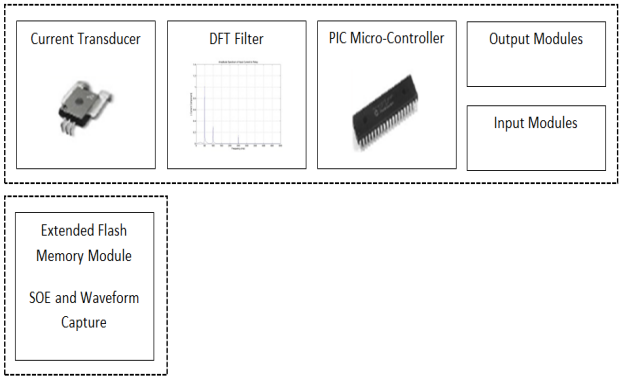


Figure.5: Schematic diagram for the main hardware platform

The current transducer function used in the relay is to measure the input current from the current transformer installed in the system.
The applied current flowing through a Copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage to be used as input analogue signal for the PIC micro-controller. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. The used type of current transducer can be used with CT type 5A and CT type 1A. So that, the relay current input module is a universal type which adds to its main advantages over other similar exiting types.

Regarding the used PIC Micro-controller [6,8,9,10,11,12], it's a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1640 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "Programmable Interface Controller", but shortly thereafter was renamed "Programmable Intelligent Computer".
The employed PIC has several advantages like Low cost, wide availability, free development tools, and serial programming and interfacing capability, power consumption compared to a design using a separate microprocessor, memory and input/output modules [10-12].

Also, the employed microcontroller offers cost efficient solutions for general purpose protection applications using a real-time operating system (RTOS) and requires a complex communication protocol stack such as TCP/IP, USB. Also, it provides flash memory modules with customized size according to the required protection application.

The main criteria of choosing a PIC micro-controller for the proposed relay depends on the following several factors:
Analogue input or output, digital input/output, memory size, interface (Serial interface, Ethernet interface-USB interface), internal clock. The PIC micro-controller hardware configuration with other hardware components is shown in figure.6.

Figure.6 depicts the main design of the hardware platform of the proposed non-directional overcurrent relay. Whereas, figure.7 shows the preliminary front view of the protection relay design.

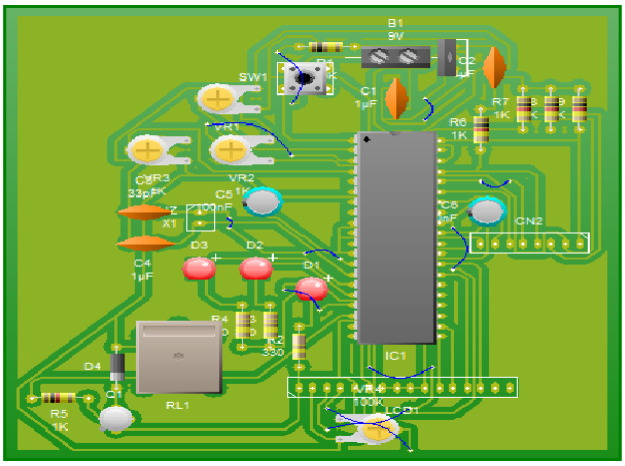


Figure.6: The main hardware platform


Figure.7: Preliminary front view of the proposed prototype sample

## FIRMWARE AND INTERFACING

The firmware design using MikroC is divided into three different layers. *The first layer* is for performing the hardware functionality. The first layer performs the HMI, keypad, ADC functions. Whereas, *the second and third layers* perform other functions as follow:
LEDs operation as per configured functionality, contact outputs for tripping and signaling purposes, read current values, interrupts for performing priority operations like pickup and tripping actions, display current values on the HMI for monitoring, calculating RMS value of current and DFT filter are for using the RMS value of the fundamental component of the relay input current into the relay algorithm for reliable tripping decision, pickup and trip commands.
Regarding the interfacing with PCs, the serial

communications RS232 is recommended for this type of relays as it is commonly used and widely available [7,8].

Serial ports contain important hardware called "Universal Asynchronous Receiver/Transmitter (UART) ". UART is small IC and it is responsible for converting from parallel connection from PC to serial connection for transmitting via wire.

The communication technique employs Universal Asynchronous Receiver/Transmitter (UART) in software-based package instead of external hardware UART for more cost saving.

The data send/receive (Tx/Rx) process -via the typical baud rates are 4800, 9600, 19200, 38400- is simply depicted in figure.8 which shows a shift register has 1 byte and the port sends bit by bit till finishing byte and then the port asks the CPU a new byte through Interrupt ReQuest (IRQ). The CPU may not respond directly for the request. So that, the buffer used to solve the delay issue as bytes are stored in the buffer which will do IRQ process instead of the port. Then the port will not be delayed because there are ready bytes in the buffer.

As buffer becomes larger, IRQ process will be reduced and then increasing CPU responding for IRQ. Receiving process is performed using same procedure of sending process. The communication process is tested and simulated by Proteus simulator to check the validity of the Tx/Rx signaling from/to PIC micro-controller via the RS232 port.

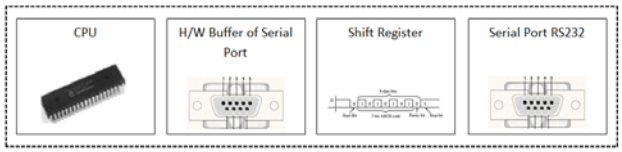


Figure.8: RS232 serial communication scheme

## CONCLUSIONS AND FUTURE WORK

Design and manufacturing of prototype non-directional overcurrent relay by the local manufacturers is produced as an alternative solution for power system protection. The paper presents low cost, high performance overcurrent relay that is used in several protection applications like, overcurrent, earth fault, restricted earth fault, second harmonic inhibition, and fifth harmonic inhibition.
The designed hardware platform can be used also for over/under voltage and load shedding protection with simple modification. Also, by adding voltage modules to the relay, it can be converted to a very powerful directional overcurrent relay with simple addition in the firmware package.
Also, as a future work, the communication with SCADA systems is under study now using the most commonly used MOD Bus and the new IEC 61850 protocol which is highly appreciated in the new communication standards and also by the specifications of Egyptian electricity companies.

## REFERENCES

[1] Dong-Gyu Lee, Sang-Hee Kang, Soon-Ryul Nam, “New Modified Fourier Algorithm to Eliminate the Effect of the DC offset on Phasor Estimation Using DFT”, 2008 IEEE PES Transmission and Distribution Conference and Exposition, April 2008.

[2] M. Sanaye-Pasand, B. Arya, Theoretical studies of an adaptive digital protection scheme immune to harmonic effects, Submitted to European conference on Power Energy Systems, Sept. 2003, Spain.

[3] Soon-Ryul Nam, Sang-Hee Kang and Jong-Keun Park, “An Analytic Method for Measuring Accurate Fundamental Frequency Components”, IEEE Trans. Power Delivery, vol. 17, no. 2, pp. 405-411, April 2002.

[4] Yong Guo, M. Kezunovic, and Deshu Chen, “Simplified algorithms for removal of the effect of exponentially decaying DC offset on the Fourier algorithm”, IEEE Trans. Power Delivery, vol. 18, no. 3, pp. 711–717, July 2003.

[5] IEEE Guide for Protective Relay applications to Transmission Lines, IEEE Standard C37.113-1999.

[6] A. Williams, Microcontroller projects with Basic Stamps. Lawrence, Kan.: R&D, 2000. Call No. TJ223 Pro.Wi.

[7] C. Hellebuyck, Programming PIC microcontrollers using PicBasic. Amsterdam: Newnes, 2003. Call No. TJ223 Pro.He.

[8] D. Ibrahim, PIC BASIC: programming and projects. Oxford: Newnes, 2001. Call No. TJ223 Pro.Ib.

[9] D. J. Pack and S. F. Barett, 68HC12 microcontroller: theory and applications. Upper Saddle River, N.J.: Prentice Hall, 2002. Call No. TJ223 Mic.Pa.

[10] D. V. Gadre, Programming and customizing the AVR microcontroller. New York: McGraw-Hill, 2001. Call No. TJ223 Pro.Ga.

[11] H. W. Huang, PIC microcontroller: an introduction to software and hardware interfacing. Clifton Park, N.Y.: Thomson/Delmar Learning, 2005.

[12] J. Iovine, PIC microcontroller project book: for PICBasic and PICBasic Pro compilers, 2nd ed., New York: McGraw-Hill, 2004.