MICROCONTROLLER BASED CO-ORDINATED OVERCURRENT PROTECTION SYSTEM

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Abstract: With the rapid expansion of power system network, the issue of its protection has gained great importance nowadays. Proper clearing of fault in due time is necessary for any system to maintain stability and ensure safety. Conventional relays like electromagnetic or induction type relays can be used for this purpose. But they have slow performance and a single relay can perform only one task at a time. Though solid-state relays overcome some of the difficulties which are present in electromagnetic relays but solid-state analog relays are technically obsolete because they do not have a number of additional features which are on demand today. A numerical or microprocessor-based relay can have multiple relay functionality and faster operation. The aim of this work is to develop a microcontroller based coordinated over current protection system and apply the relay algorithm in this system using PIC16F676 microcontroller. An experimental setup of distribution feeder has been built and provided with coordinated over current protection. The performance of the system is tested and it is found satisfactory. This model can be modified further to use it in larger power system protection and application.

Keywords: Power System Protection, Over Current Protection System, Protective Relays, Microcontroller.

1. INTRODUCTION

Power system protection is the process of making the production, transmission and consumption of electrical energy as safe as possible from the effects of failures and events that place the power system at risk. The earliest protective system that evolved was protection against excess current. This basic principle helped to develop the graded over current protection system which is a selective fault protection. Over current protection is playing a significant role in power system protection since the beginning of last century [1]. It is necessary to co-ordinate the protection with neighboring over current protection for discrimination [2]. A reliable and redundant protection scheme can be ensured by relay co-ordination, while minimizing the disruption to customers [3]. In order to isolate the faulted section and to provide sufficient co-ordination margins without excessive time delays it is necessary to determine the sequence of relay operations for each possible fault location [4]. Relay coordination is necessary for protection systems where both primary protection and back-up protection are needed. The relays of such systems are sequenced to trip after specific time interval if primary protection fails to protect the system. Simplicity of operation and the economy of the over current protection make radial configuration predominant in distribution system. In such distribution systems, it is needed to sense the current only by the protection equipment, with no need to detect direction [5].

The major component of protection system is protective relays. In 1928 carrier current protection system was introduced for the protection of transmission lines which made the major break-through in the application of electronics in power system protection [2]. Transistor was invented in 1941 and after that in 1950's the development of static relays employing semiconductor devices was started [2]. The first generation of static relays was with

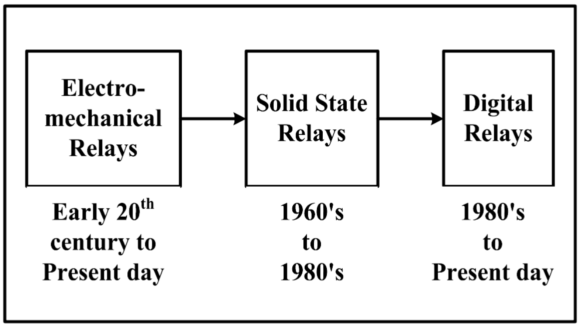

Fig. 1: Evolution of Protection relays.

discrete components fitted on printed circuit boards. Integrated circuits were used for the static relays of second generation. Before 1980's, the protective functions of relays were independent of control and monitoring functions [2]. Earlier generation of static relays (1970's) were with analog circuits [2]. Now digital circuits are preferred. Historically, the hardware evolution of protective relays experienced three technologies as shown in Fig. 1 [6]. Programmable multi-function systems were resulted from the development of digital electronics and microprocessor (1980's). In the 1990's microprocessor controlled relays have become popular [2]. By integrating many functions into a single unit, microcontroller based relays are available in compact design and lower cost.

In this paper an experimental model of distribution feeder has been developed and microcontroller based relays are used to provide the feeder with the necessary over current protection and co-ordination facility.

2. BLOCK DIAGRAM DESCRIPTION OF THE PROTECTION SYSTEM

A block diagram of the coordinated over current protection system is shown in Fig. 2. Each block of the protection system is described below:

2.1. Signal Conditioning Subsystem

The function of this subsystem is to supply analog voltage signal to the microcontroller. For this purpose, it has a current transformer to sense the system current. The current transformer (CT) steps down the high current of the incoming supply. The CT primary is connected to the phase of the supply. For current to voltage conversion, a variable resistor is used across the

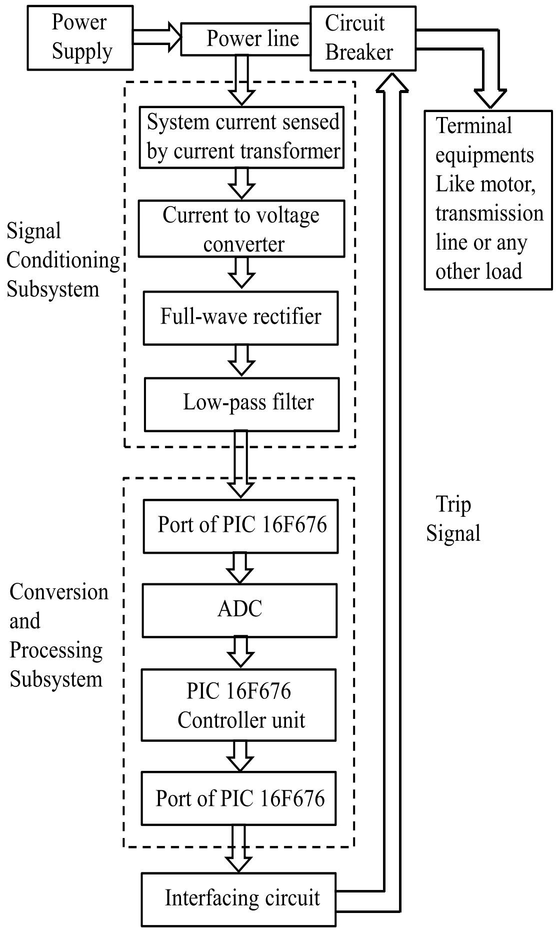

Fig. 2 Block diagram of the protection system.

secondary coil of the CT. The ac voltage across the resistor is fed to the full-wave rectifier unit. The output of the rectifier unit is a pulsating dc voltage, which is then passed through the low-pass filter section to obtain a ripple free dc voltage. This dc voltage corresponds to the line current of the CT primary and it is then fed to the Microcontroller.

2.2 Conversion and processing Subsystem

This section contains an analog to digital converter (ADC) to convert the input analog voltage signal to a digital signal. This ADC is inherent in the microcontroller (PIC16F676). The microcontroller unit gives the trip signal through its port when system current exceeds a predefined value. Interfacing circuit is required between port of micro controller and the circuit breaker. The trip signal operates the circuit breaker to isolate the faulty portion of the power system. Thus, electrical equipments are protected.

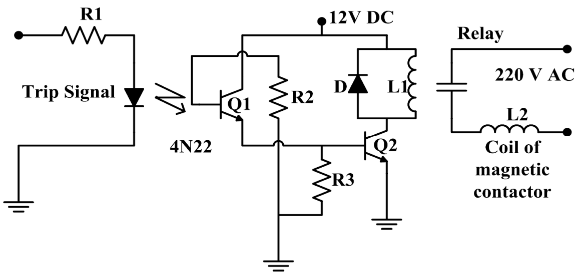

Fig. 3 Controlling circuit for the magnetic contactor.

2.3 Interfacing circuit

The interfacing circuit as shown in Fig. 3 receives the trip signal from the microcontroller port and operates the relays that work here as circuit breakers. The trip signal is fed to an opto-coupler through a 1KΩ resistor and an indicating LED. This resistor is used for current limiting because the maximum output current of the port pin is 20mA. The transistors work here as switches. When its base receives a trip signal, it goes to saturation region and its collector terminal and emitter terminal are nearly shorted. The relay coil is connected to the ground through these two terminals. So the relay operates and it closes the normally open contact on receiving a trip signal at the base of the transistor. The faulty portion of the power system is then isolated. There are three indicating LEDs to indicate the faults at different sections of the line.

2.4 Dual Power Supply

For the over current protection system to operate, the input ac supply is first stepped down from 220V to 24V. It is then passed through full-wave rectifier, low-pass filter to get fixed +24Vdc. This +24Vdc supply is used for relay operation and to drive a +5Vdc voltage regulator. The output of +5Vdc regulator is used for power supply of microcontroller.

3. WORKING PRINCIPLE

The schematic diagram of the coordinated over current protection of a typical distribution system is shown in Fig. 4. The whole distribution system is divided into three sections. Each section represents a protection zone. Each zone has a relay, which acts as circuit breaker. Each zone has its associated CT,

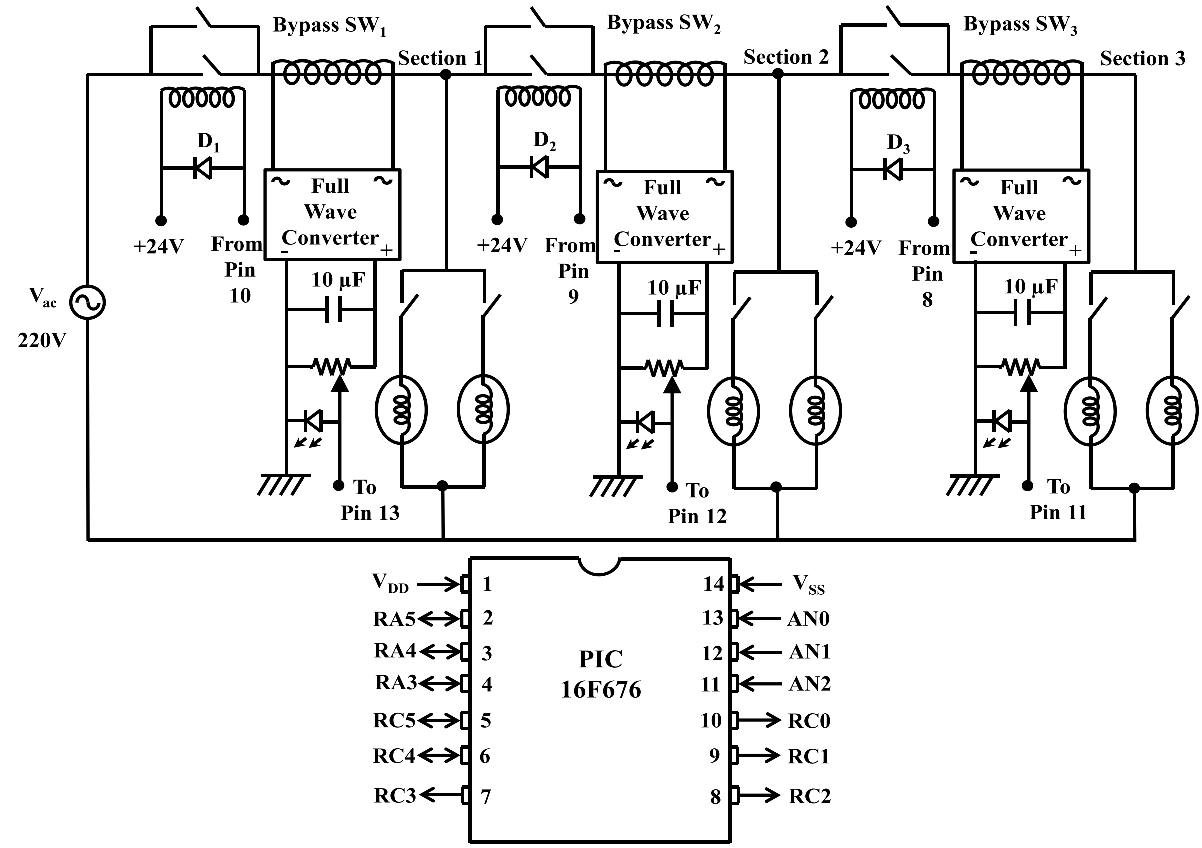

Fig. 4 Schematic diagram of coordinated over current protection system.

which is connected in parallel with a variable resistor, a full wave rectifier and a capacitor. Thus, we get the respective voltage across the resistor for current in the CT secondary, which is fed directly to the microcontroller. The microcontroller continuously monitors the current in each zone of the distribution system. The time setting for co-ordination of relays are previously programmed in the microcontroller. When current in any zone exceeds its predetermined value, the microcontroller sends a trip signal to the corresponding relay through interfacing circuit. Hence, the relay isolates the faulty section. If any relay doesn't work within a specified time its nearest relay provides backup protection. Usually the relays trip immediately if fault condition arises within their section.

4. PROGRAM FLOWCHART

The flowchart of the microcontroller based coordinated over current protection system is shown in Fig. 5. The pick-up current is set by the microcontroller for the relays of section 1, section 2 and section 3 (see Fig. 4) which are 2100 mA, 1440 mA and 700 mA respectively. For co-ordination purpose, specific time delays of tripping of relays of different sections for providing back-up protection are set by the microcontroller. If the relay in section 3 does not trip immediately when fault condition arises in section 3 then for the relay of section 2 the time delay of tripping is 3s and for the relay of section 1 it is 2s. If the relay in section 2 does not trip immediately during occurrence of fault

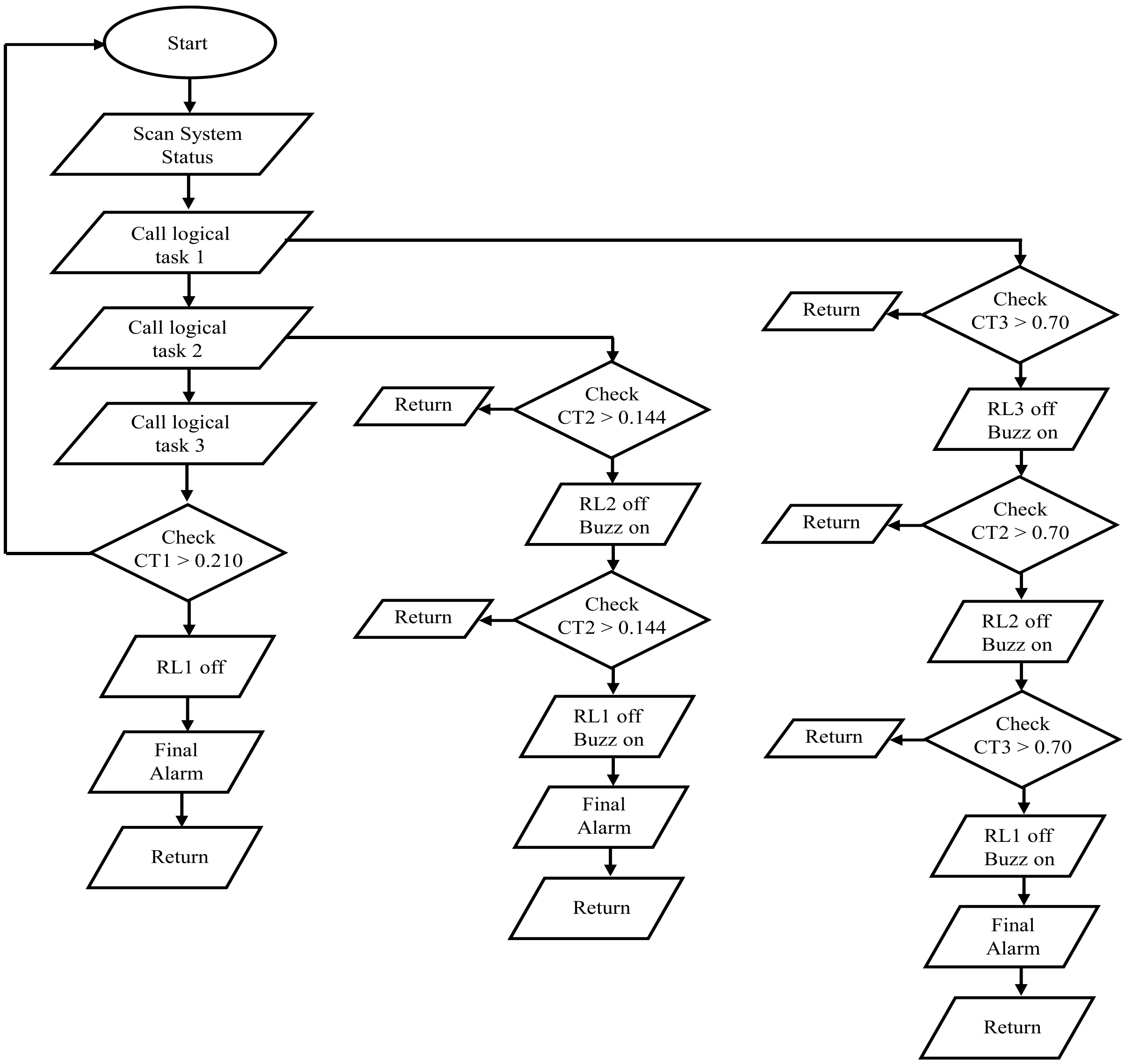

Fig. 5 Flowchart of relay algorithm.

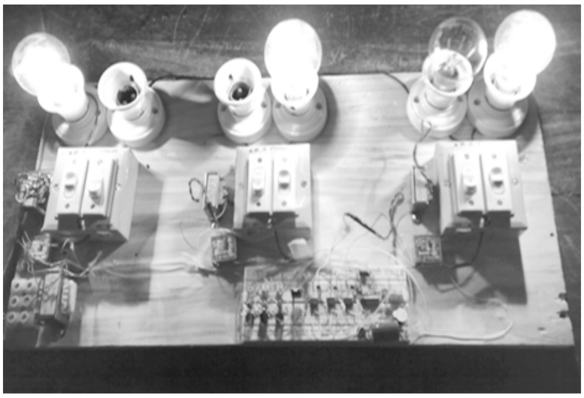

Fig. 6 Experimental setup of microcontroller based co-ordinated over-current protection system.

in section 2 then for the relay of section 1 the time delay of tripping is 2s.

5. EXPERIMENTAL RESULTS

Fig. 6 shows the experimental model of the distribution feeder that was used for this research to verify the performance of the microcontroller based coordinated over current protection system. The distribution system consists of three sections representing three substations. Loads are supplied from each substation and are represented by incandescent light bulbs. The bulbs can be switched ON/OFF separately and are relay operated. The over current fault situation was created at each section by apposite arrangement of load. It was observed that the microcontroller based protection system can successfully handle the fault condition by sensing, analyzing and coordinating appropriate relay circuit. The program in microcontroller was written in assembly language based on which microcontroller does the function of monitoring, processing of input current signals, analyzing data and finally taking action after the predefined period of time.

6. CONCLUSION

Microcontroller based protection is a growing demand of modern power system. The ease of operation and complementary functions has made the microcontroller based relays more suitable than electromechanical and solid state relays. In this paper, a laboratory prototype of the distribution feeder with microcontroller based coordinated over current protection system has been developed and tested under sudden fault condition and was found to work satisfactorily as per requirements. The model can be suitably modified for transformer protection in addition with differential protection, for motor and generator protection, for protection of utility equipments such as furnaces, industrial installations, commercial and domestic equipments etc. Modification can also be made by changing the pick-up current of the relays, time sequence of waiting of the relays before tripping in case of co-ordination and observing the time-current characteristic of the relays. In future the microcontroller program can be upgraded to make the protection system more flexible and include more relay functionality. Instead of using miniature PCB relays IDMT relays can be employed in order to have better system performance and improve stability.

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