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Performance Evaluation of a Modern NPR for Over Current Protection with the Application of Microcontroller Technology in Power System

R.Gunasekari[1], Dr.D.Mary[2], Dr.P.C.Kishoreraja[3]
[1]*Research Scholar, Dept. of Electrical and Electronics Engineering, Saveetha University, Chennai*
[2]*Prof. & Head, Dept. of Control and Instrumentation Engineering, Government College of Technology, Coimbatore*
[3]*Prof. & Head, Dept. of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha University, Chennai*

Abstract:- Numerical Protective Relays (NPRs) are the result of the application of microcontroller technology in relay industry. NPRs have the ability to communicate with its peers, are economical and are easy to operate, adjust and repair. Over-current protection is a key part of the power system. Over-current relays are extensively used in power system protection. The relay operates when actuating current exceeds a specified limit. These relays have their application with wide range of power system components viz. sub-transmission and distribution network, generators, transformers etc. Design for implementation of an over-current relay as a System On Programmable Chip (SOPC) is presented. Microcontroller (µc) is used for the System On Chip (SOC) application to achieve a SOPC for the proposed design. The µc-based SOPC approach is faster and economical as compared to conventional SOC devices. The design is suitable for distribution or sub-transmission networks and can behave as extreme inverse or very inverse type of time over-current relay. The proposed relay follows standard inverse-time characteristics according to IEEE standard. Performance evaluation of the designed relay has been checked. The results from tests performed are also included.

Keywords:- Power System Protection, Numerical Protective Relaying (NPR), Over-current Numerical Relay Protection, Microcontroller

I. INTRODUCTION

The reliability and security electrical supply is an important factor in modern society. However, the increasing complexity of power systems makes it difficult for protection operation to achieve these objectives. Nevertheless, numerical relays embedded with digital signal processor (DSP) are able to improve the protection operation significantly. The relays are capable of performing complex processing faster and with higher accuracy since the processing using DSP are optimized for real-time signal processing. In this paper, an over-current relay is built and investigated using DSP. The over-current protection is chosen since it is used as a major protection in the distribution systems. The over-current relay is modeled in MATLAB/Simulink before it is implemented on the DSP. Comparison results between simulation and hardware execution based on two implementation methods are presented. The performance evaluation of the relay in terms of operation time, memory capacity usage, execution time and transient analysis is investigated [1].

Protective relays are used to detect any abnormalities in a power system and isolate the faulty part of the system in the shortest time. Protective relays are designed to maintain high degree of service continuity and limit equipment damage in the power systems. Severe disruption to the normal routine of modern society such as power outages is likely to increase the emphasis on reliability and security of supply electrical energy to consumers [2]. The expanding of power systems such as intense increase of transmission line capacity and increase of grids looping degree will increase the complexity of power system. This will cause the protection operation to become more difficult. The protective relays encounter several problems as revealed in [3]. The present protection technique used is unable to ensure selectivity and speedily operation for the faults appearing on the entire protected line. Numerical protective relays are able to improve the performance of the protection operation considerably. Numerical relay are embedded with microcontroller as the computational hardware.

II. NUMERICAL RELAY PROTECTION

A. Importance of Numerical Relay Protection

Modern civilization makes use of large amounts of energy to generate goods and services. From the industrial plants, the providers of public services to the ordinary man, all of them need energy to satisfy and create the well being of modern society. The purpose of electric power systems is to provide energy for human use in a secure, reliable and economic manner. Electric power systems are made up of facilities and equipment that generate, transmit and distribute electrical energy. Electric power systems are one of the largest and more complex systems man has ever built.

The importance of the services that power systems offer and the high amount of investments that represent the facilities and equipments, make the normal and constant operation of power systems critical and strategic for every society. Faults and failures normally occur in power systems. Due to the great amounts of energy involved, faults represent a threat to the operation and security of power systems if the faults are not promptly corrected. Power systems need an auxiliary system that must take corrective actions on the occurrence of a fault. This auxiliary system is known as protection system. The Protection systems are operated through protective devices like protective relays etc.

NPR systems are sets of equipments, schemes and policies dedicated to detect faults in the protected elements of the power systems, to disconnect the faulted element and to reestablish the service, if it was the case. Because power systems operate in different operating states, different fault scenarios may occur. Protective relay systems must provide different schemes and equipments to detect and to react to each and every one of these fault scenarios, from the most simple of them to the most complex and compelling.

B. Classification of NPRs Based on Technology

NPRs can be broadly classified into the following categories depending on the technology used for their construction and operation.

- Electromagnetic NPRs
- Static NPRs
- Microcontroller-based NPRs

C. Microcontroller - Based NPRs

Microcontroller-based NPRs are the latest development in this area. With the development in VLSI Technology, sophisticated and fast microcontrollers are coming up. Their applications to the problems of numerical protective relaying schemes are of current interests to power engineers. The inherit advantages of microcontroller-based NPRs over static NPRs with or a very limited range of applications, are attractive, flexibility due to their programmable approach. Microcontroller-based NPRs can provide protection at low cost and compete with conventional relays. The present downward trend in the cost of large-scale integrated circuit will encourage wide applications of microcontroller-based applications of microcontroller-based NPRs for the protection modern complex power network in the power system.

III. NPR FOR OVER CURRENT PROTECTION

A. An Introduction to Numerical Protective Over Current Relay

A numerical protective relay which operates when the current in any circuit exceeds a certain predetermined value is a numerical over current protective relay. The value of the predetermined current above which the numerical over current protective relay operates is known as its pick-up value Ipu. Numerical over current protective relays offer the cheapest and simplest form of protection. Numerical over current relay protection is widely used for the protection of distribution lines, motors, power equipment, industrial systems etc. It incorporates numerical over current protective relays for the protection of an element of the power system. The measured value of the current is compared with the pick-up value to decide whether there is a fault or not. If there is a fault in any element of the power system, the relay sends a trip command to circuit breaker for isolating the faulty element.

B. Overview of NPR for Over Current Protection

A protection which incorporates numerical over current protective relays for the protection of an element of the power system is known as a numerical over current relay protection. Numerical over current relay protection is a straightforward application of the numerical relay. A numerical over current protective relay acquires sequential samples of the current in numeric (digital) data from through the Data Acquisition

ystem (DAS), and processes the data numerically using a numerical relaying algorithm to extract the fundamental frequency component of the current and make trip decision. In order to make the trip decision, the relay compares the fundamental frequency component of the fault current (I) with the pick-up value (Ipu) setting and computes the plug setting multiplier (PSM), given by (I / Ipu) at which the relay has to operate. If the fundamental frequency component of the fault current exceeds the pick-up value (ie., PSM > 1), the relay issues a trip signal to the circuit breaker. The time delay required for the operation of the relay depends on the type of over current characteristic to be realized. In case of instantaneous over current relay there is no intentional relay. For definite time over current relay, the trip signal is issued after a predetermined time delay. In orders to obtain inverse time characteristics, the relay either computed the operating time corresponding to the fault current or selects the same from look-up table. For correct operation of the protection system, the design should take into account the following points:

- Continuous operation should not depend on one circuit only. Ensure that maintenance can be carried out without total de-energization of the plant.
- Make sure you can live with what happens when back-up protection operates. If not then the design of the electrical distribution system is not correct.
- Microprocessor multifunction relays from different manufacturers often have very different characteristics. Review all features when selecting a relay.
- Make use of other relays when present to enhance back-up protection. Adding extra components will often decrease reliability due to the difficulty of correctly designing and maintaining more complicated systems.
- Choose the maximum earth fault current carefully as it has an impact on both earth-fault and unit protection.
- When intertripping is performed, the relay should send the trip order directly to the other breaker and not through the related relay. This is more reliable for clearing faults. The one exception is for intertripping in the case of automatic transfer to prevent disastrous closing to a faulted bus.

C. Block Schematic Diagram of proposed NPR for Over Current Protection

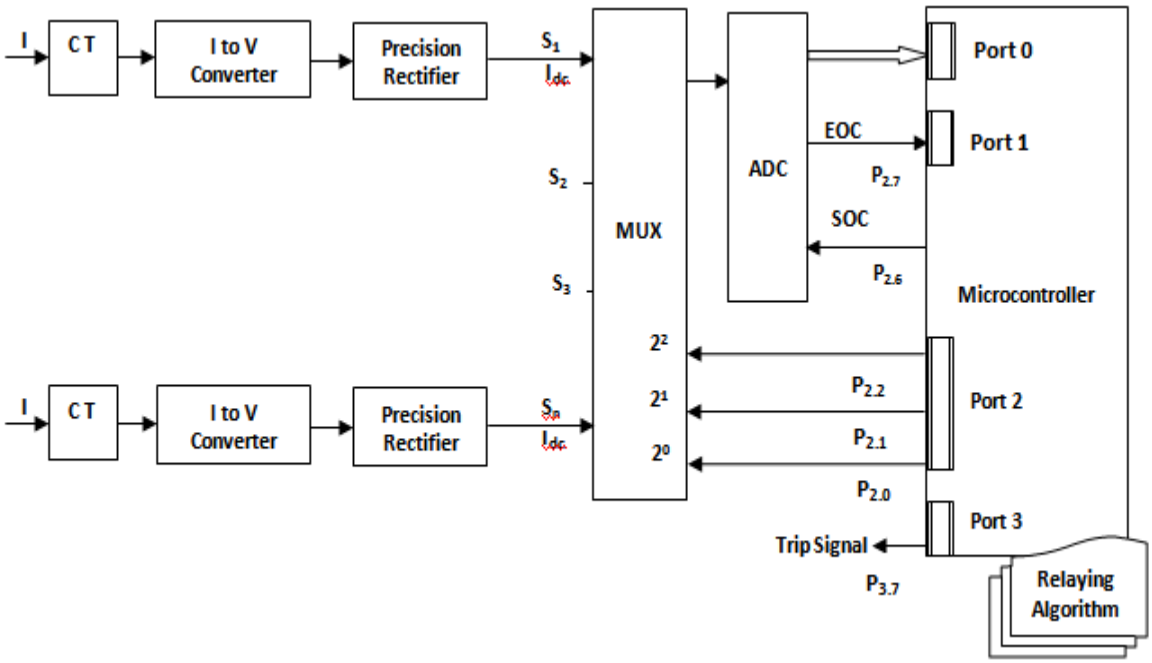

Fig.1: Block Schematic Diagram of proposed NPR for Over Current Protection

The block diagram of a NPR for over current protection is shown in fig.1. An over current numerical protective relay is the simplest form of numerical protective relay which operates when the current in any circuit exceeds a certain predetermined value, ie. pick-up value. It is extensively used for the protection of distribution lines, industrial motors and equipment. Using a multiplexer, the microcontroller can sense the fault currents of a number of circuits. If the fault current in any circuit exceeds the pick-up value, the microcontroller sends a tripping signal to the circuit breaker of the faulty circuit breaker of the faulty circuit. As the microcontroller

accepts signals in voltage form the current signal derived from the current transformer is converted into a proportional voltage signal using a current to voltage converter. The ac voltage proportional to the load current is converted into dc using a precision rectifier. Thus, the microcontroller accepts dc voltage proportional to load current.

IV. NPR ALGORITHM FOR OVER CURRENT PROTECTION

The numerical relaying algorithm first reads all the settings such as the type of characteristics to be implemented, the Ipu, the time multiplier setting in case of inverse time over current relay or the time delay in case of DTOC relay. In the case of a definite time over current relay, the microcontroller sends the tripping signal to the circuit breaker after a predetermined time delay if the fault current exceeds the pick-up value. In case of instantaneous over current relay there is no intentional time delay. In order to obtain inverse-time characteristics, the operating times for different values of currents are noted for a particular characteristic.

These values are stored in the memory in tabular form. The microcontroller first determines the magnitude of the fault current and then selects the corresponding time of operation from the look-up table. A delay subroutine is started and the trip signal is sent after the desired delay. Using the same program, any characteristic such as IDMT, very inverse or extremely inverse can be realized by simply changing the data of the look-up table according to the desired characteristic to be realized. The microcontroller continuously measures the current and moves in a loop and if the measured current exceeds .

The pick-up value, it compares the measured value of the current with the digital values of current give in the look-up table in order to select the corresponding count for a time delay. Then it goes in delay subroutine and sends a trip signal to the circuit breaker after the predetermined time delay. The flowchart is shown in Fig.2.

Table.1: Look – up Table

Digital Values of Current	Count for Delay in Register B	Delay Time in Sec
0C (COUNT)	-	-
7FH	03H	0.19
7AH	05H	0.32
6DH	09H	0.57
66H	00BH	0.70
60H	00DH	0.83
5AH	010H	1.00
53H	016H	1.40
4DH	01EH	1.90
46H	02DH	2.90
40H	050H	5.10
3AH	07DH	8.00
33H	0DBH	14.00

Table.2: Operation Time of the NPR for over-current protection execution on µc

Amplitude Input current (A)	According to IEC standard	Execution on µc
		Written ASM code
170	-	-
210	-	-
213	329.9419	324.6737
227	19.2614	19.34454
500	0.9948	0.994825

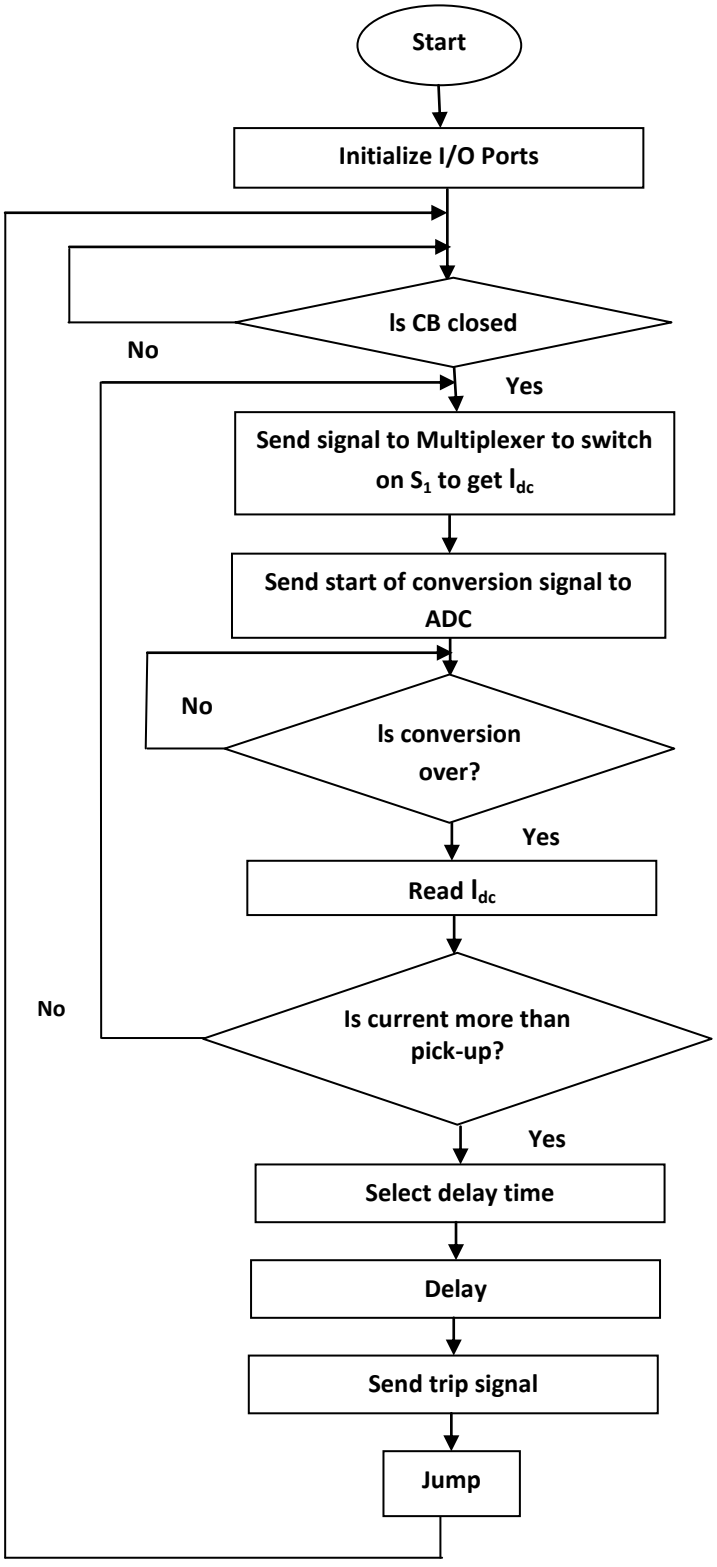

Fig.2: Flow Chart of NPR Algorithm for Over Current Protection

V. CONCLUSION

This paper describes the performance evaluation of modern NPR using the application of microcontroller technology for over current protection. Results clearly indicate that the operation time obtained for implementation method is similar to IEC standard. For transient analysis, the relay is proficient in detecting transient input. The µc based over current relay using implementation method is proven to provide adequate reliability and security with improved performance. The objectives of this research are:

- To design and fabricate over current protection relay using PIC microcontroller which can operate on the permissible conditions by setting the over current value.
- To test unwanted conditions (over current) and when such conditions arise to isolate the fault condition in the shortest time possible.
- To investigate IDMT curve characteristic. In future, the method selected to implement the over current relay will depend on the preference of memory usage or execution time of the protection algorithm.

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