REVIEW OF MICROPROCESSOR BASED PROTECTIVE RELAYS

Er. Harpreet Kaur Channi*

ABSTRACT:

An electrical power system consists of generators, transformers, transmission and distribution lines. Short circuit and other abnormal conditions often occur on a power system. The heavy current associated with short circuits is likely to cause damage to the equipment if suitable protective relays and circuit breakers are not provided for the protection of each section of the power system. A protective system includes circuit breakers, transducers (CTs and VTs), and protective relays to isolate the faulty section of the power system from the healthy sections. The function of a protective relay is to detect and locate a fault and issue a command to the circuit breaker to disconnect the faulty element. The conventional protective relays are either of electromechanical or static type. The electromechanical relays suffer from several drawbacks such as high burden on instrument transformer, high operating time, contact problem etc. The static relays also suffer from a number of disadvantages such as inflexibility, inadaptability to changing system conditions and complexity. The functions of electromechanical protection systems are now being replaced by microprocessor-based digital protective relays, sometimes called "numeric relays". The increased growth of power system both in size and complexity has brought about the need for fast and reliable relays to protect major equipment and to maintain system stability. The concept of digital protection employing computers which shows much promise in providing improved performance has evolved during the past two decades. Digital computer can easily fulfil the protection requirements of modern power system without difficulties. With the development of economical, powerful and sophisticated microprocessor, there is a growing interest in developing microprocessor-based protective relays which are more flexible because of being programmable and are superior to conventional relays. The objective of this paper is to give a comparative review of microprocessor-based protective relays.

Keywords: Short circuit, abnormal conditions, conventional, inflexibility, inadaptability, complexity, numeric relays, digital, sophisticated.

* Assistant Professor (EEE Dept.), Chandigarh University, Gharuan, Mohali.

I. Introduction

Numerical relays or Digital relays are the latest development in the area of protective relays. The distinction between digital and numerical relay rests on points of fine technical detail, and is rarely found in areas other than protection. They can be viewed as natural developments of digital relays as a result of advances in technology. Typically, they use a specialized digital signal processor (DSP) as the computational hardware, together with the associated software tools. These relays acquire the sequential samples of the ac quantities in numeric (digital) data form through the data acquisition system and process the data numerically using an algorithm to calculate the fault discriminates and make trip decisions. The digital protective relay, or numeric relay, is a protective relay that uses a microprocessor to analyze power system voltages, currents or other process quantities for the purpose of detection of faults in an industrial process system. These convert voltage and currents to digital form and process the resulting measurements using a microprocessor. The digital relay can emulate functions of many discrete electromechanical relays in one device, simplifying protection design and maintenance. Each digital relay can run self-test routines to confirm its readiness and alarm if a fault is detected. Numeric relays can also provide functions such as communications (SCADA) interface, monitoring of contact inputs, metering, waveform analysis, and other useful features. Digital relays can, for example, store two sets of protection parameters, which allow the behaviour of the relay to be changed during maintenance of attached equipment. Digital relays also can provide protection strategies impossible to synthesize with electromechanical relays, and offer benefits in self-testing and communication to supervisory control systems. A microprocessor by itself cannot perform a given task, but must be programmed and connected to a set of additional system devices such as microprocessor which acts as CPU, memory and input/output devices interconnected for the purpose of performing some well-defined task called microcomputer or microprocessor-based system as shown in figure no.1[1]. The single chip microcomputer is called “microcontroller”. The interconnection of different components, which is a primary concern in the design of a microprocessor- based system, must take into account the nature and timing of the signals that appear at the interfaces between components. The overall task of connecting I/O devices and microprocessor is termed as “interfacing”.

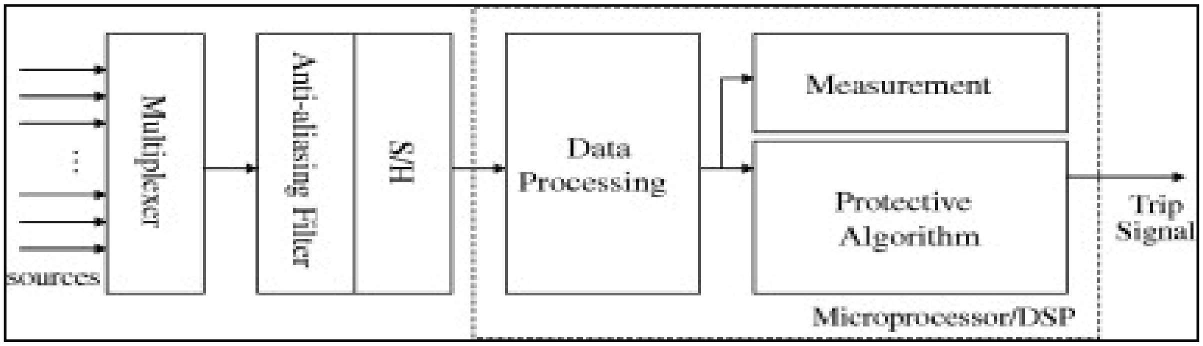

Fig.1 Block Diagram of Microprocessor Based relay

II. Related Work

Osorno, Bruno[2] provided a review of microprocessor based protective relay (MBPR) systems with emphasis on differential equation algorithms. The application of protection relaying in power systems, using MBPR systems, based on the differential equation algorithm are valued more than the protection relaying based on any other algorithms, because the algorithm has the advantages of accuracy and easy implementation. MBPR differential equation approach can tolerate some errors caused by power system abnormality such as DC offset. It is widely implemented in the protections for lines, transformers, buses, motor, and other equipment in power systems. However, the parameters for system description algorithms are obtained from power system current i(t) or voltage v(t), which are abnormal values under fault or distortion situations. So the error study for the algorithm is considered necessary.

M. Amin Zamani, Tarlochan S. Sidhu, Amirnaser Yazdani [3] explained that one of the major challenges associated with microgrid protection is to devise an appropriate protection strategy that is effective in the grid-connected as well as islanded mode of operation. They proposed a protection strategy based on microprocessor- based relays for low-voltage microgrids. Further, the structure of a new relay enabling the proposed protection strategy was presented. One of the salient feature of the developed protection scheme is that it does not require communications or adaptive protective devices. Moreover, it is to a large extent independent of the fault current magnitude and the mode of operation. Transient time-domain simulation studies are conducted to demonstrate the effectiveness of the proposed protection strategy and its enabling relay, using the PSCAD/EMTDC software package.

John J. Novak, Richard D. Kirby [4] explained that improvements in protection and control via communications methods used to exchange digital bits (DBs) among devices are common in progressive utilities in high-voltage substations. These improvements are now being incorporated into the process-sensitive electric power distribution systems of large industrial plants. Until now, new equipment purchases for new projects in industrial facilities using microprocessor (μP) multifunction protective relaying technology were typically done as a direct replacement of older technologies or as an updated equivalent. They described a recently commissioned electrical substation design philosophy, including implementation, construction, maintenance, and performance with μP-based protective relaying, metering, and control schemes. These schemes extensively utilize the interdevice DB exchange and programmable logic capabilities of time-synchronized μP technology.

Gary H. Fox[5] discussed the issues that can exist when applying multifunction microprocessor-based protective relays in switchgear that has alternating current (ac) control voltage rather than a direct current (dc)-battery-based control bus. He recommended several techniques for overcoming these issues.

Montignies, Patrick, Jover, Bernard[6] explained that digital microprocessor based protective relays, installed in low voltage compartments of medium voltage switchgear and/or in control panels, become more and more exposed to EMC disturbances due to interferences that may affect the power quality of electrical networks. End-users sometimes report unexpected circuit breaker tripping and significant financial consequences due to process discontinuity. After analysis, it is quite easy to demonstrate that these incidents are caused either by a relay failure that went to a fall back position, incorrect operation or improper installation/cabling rules. Due to higher market requirements and more demanding applications, mainly in the Oil & Gas sector, digital protective relays have to integrate more powerful protection, control, monitoring and communication functionalities. Although these relays comply with the latest IEC 60255 and IEC 61000 standards and associated subsets, they have to be installed by switchboard manufacturers, whoever they are, in air insulated or Gas Insulated switchgear. Improper installation rules can sometimes result in unexpected tripping.

Tingfang, Yang ; Xin, Yang[7] proposed a generalizing modern microprocessor-based relay protection at the power transmission line and a design of relays based on ARM processor was put forward. This device used DSP made by TI to be the protective CPU, which mainly answered for controlling data acquisition, the sampled data processing, the protective function implementation, the human interface and peripheral serial interface and Ethernet communication, and used other devices to be assistant to control sampling/holding, multi-path option switch and the I/O switching value. The system is mainly composed of several modules such as A/D samples circuit, Fourier algorithm, fault analysis system. The test results show the design of the microprocessor-based protection has good performance.

III. Problem Formulation

Electrical Power System protection is required for protection of both user and the system equipment itself from fault, hence electrical power system is not allowed to operate without any protection devices installed. Power system fault is defined as undesirable condition that occurs in the power system. These undesirable conditions such as short circuit, current leakage, ground short, over current and over voltage. The functional security of the power grid depends upon the successful operation of thousands of relays that may be used in protective scheme for preventing the power system from cascading failures. The failure of one relay of the protective scheme to operate as intended may imbalance the stability of the entire power grid and hence it may lead the whole system to blackout. In fact, major power system failures during a transient disturbance are more likely to be caused by unnecessary protective relay tripping rather than by the failure of a relay to take action. In other words, the performance of protective relay or system is very important to be known especially in smart power grid. In other words, the performance of protection system is measured by several criteria including reliability, selectivity, speed of operation, etc. Reliability has two aspects: dependability and security. Dependability is known as the degree of certainty that a relay system will operate correctly when there is a fault on the system. Security is the degree of certainty that a relay will operate unnecessary even when there is no fault on the system.

Originally, electromechanical relays were used to protect power system. Most relays used either electromechanical attraction or electromechanical induction principle for their operation. These relays were classified as amplitude comparators or as phase comparators. When solid state technology was introduced, amplitude and phase comparison were implemented using discrete components including vaccum tubes. Solid state relays appeared as the technology poised to replace electromechanical relays. Devices using electron tubes were studied but never applied as commercial products, because of the limitatons of vacuum tube amplifiers. The advances in the in the Very Large Scale Integrated technology(VLSI) and software techniques led to the development of microprocessor based relays. Computer hardware technology has tremendously advanced since early 1970s and new generations of computers tend to make digital computer relaying a viable and better alternative to the traditional relaying systems. The additional features offered by microprocessor technologies encouraged the evolution of relays that introduced many changes to the industry. These multifunction relays reduced the product and installation cost drastically. This trend has continued until now and has converted microprocessor relays to powerful tools in modern substations.

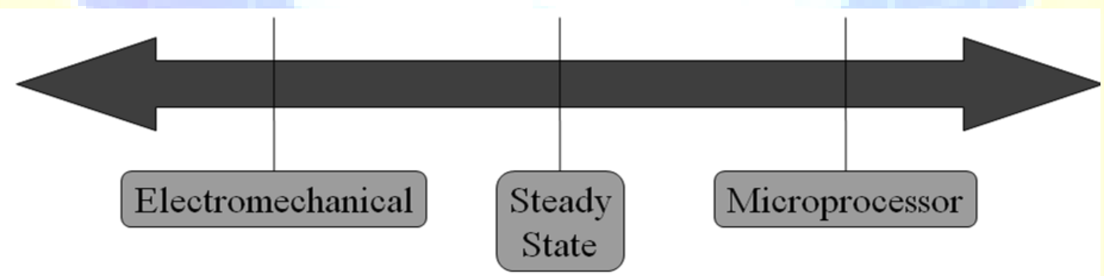

Fig 2. Evolution of Protection Devices

A. Objectives of the work

The objective of this paper is:

- To discuss the disadvantages of electromechanical and static type relays.
- To highlight the benefits of microprocessor based relays.
- To give an overview of basic principle of digital relays.

- To explain the construction/working of a simple microprocessor based overcurrent relay.

B. Basic principle of Digital Relays or Methodology used in Digital relays

In digital relays digital signals are used for data processing instead of analog signals. Analog signals are continuous signals and cannot be processed easily because of their several limitations as compared to digital signals. Digital signals are in form of coded square pulses which represents discrete elements of information (data). In digital system, the signals are in binary form i.e. only two discrete values referred to as binary coefficients 0 and 1 or logical values true and false. The number of binary digits needed to encode the various discrete elements of information (data) has a significant influence on the design of a digital system. The digital system generally operates on groups of 8 or 16 or 32 bits of information at once. The range of the digital system of encoding the information by a n bit group is 2^n. Hence digital systems with larger bit operating group can process a wider range of encoded information. The information to be processed may be textual, numerical and logical

IV. Microprocessor Based Overcurrent Relay

A. Components of a simple Microprocessor Based Relay

An overcurrent relay is the simplest form of protective relay which operates when the current in any circuit exceeds a certain predetermined value, i.e. the pick-up value. It is extensively used for the protection of distribution lines, industrial motors and equipment. Using a multiplexer, the microprocessor can sense the fault currents of a number of circuits. If the fault current in any circuit exceeds the pick-up value, the microprocessor sends a tripping signal to the circuit breaker of the faulty circuit. As the microprocessor 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 microprocessor accepts dc voltage proportional to load current. The schematic block diagram of the relay is shown in figure 2 [8]. The microprocessor accepts signal in digital form. Therefore analog signals must be converted into digital form before feeding them to the microprocessor for processing. Both voltage and current are analog quantities. As the microprocessor accepts only voltage signal in digital form, the current signal is first converted into proportional voltage signal and then the voltage signal is converted into digital form for applying to the microprocessor. An A/D converter is used to convert analog signals into digital forms. If more than one analog quantity is to be converted into digital form by using only one A/D converter, analog multiplexers are used to select any one analog quantity at a time for A/D conversion. The output of the rectifier is fed to the multiplexer. The microcomputer sends a command to switch on the desired channel of the multiplexer to obtain the rectified voltage proportional to the current in a particular circuit. The output of the multiplexer is fed to A/D converter to obtain the signal in digital form. The A/D converter ADC0800 has been used for this purpose. The microcomputer sends a signal to the ADC for starting the conversion. The microcomputer reads the end of conversion signal to examine whether the conversion is over or not. As soon as the conversion is over, the microcomputer reads the current signal in digital form and then compares it with the pick-up value. For time-varying voltages such as ac voltage, a sample and hold circuit is used to keep the desired instantaneous voltage constant during conversion period.

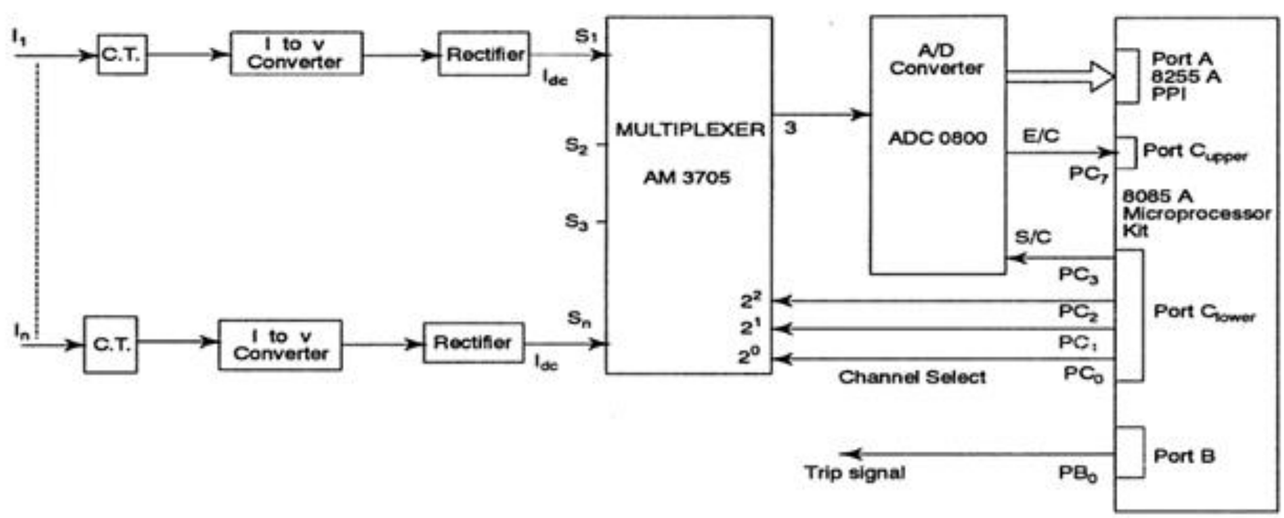

Fig .3 Block diagram of Overcurrent relay.

B. Flowchart for Overcurrent relay

The program flowchart is shown in figure 3 [8].The microcomputer first determines the magnitude of the fault current and then selects the corresponding time of operation. 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 realised by simply changing the data according to the desired characteristic to be realised. The microcomputer 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 the current 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.

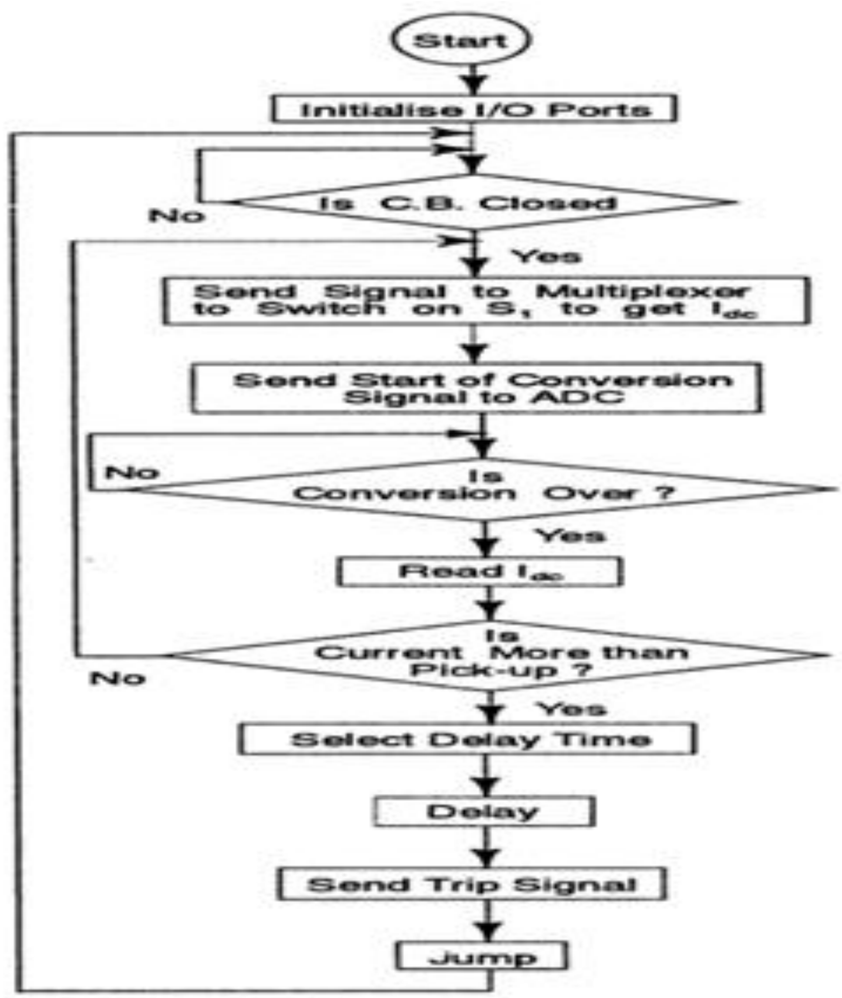

Fig .4 Flow Chart for Overcurrent Relay

V. Results and Discussions

The programmable microprocessor based relays have superior features which include the following:

1. Ability to combine a large number of protective and monitoring functions in a single relay unit.

2. Measured values of variables are processed digitally by microprocessor. The digital processing by microprocessor gives several abilities to the protective system such as combinational logic, use of on-line processing of variables, programmable features etc.

3. Digital relays are widely used because of their economy, compactness, flexibility, reliability, self-monitoring and self checking capability, multiple functions, low burden on instruments transformers and improved performance, high speed of operation over conventional relays of electromechanical and static types.

4. Microprocessor based digital relays can have interface with other relays, protected equipment and control and protection devices in the substation.

5. Microprocessor based relays are easy to apply, operate and use, yet highly capable. These relays are more accurate and can store large number of signals.

VI. Conclusions

The present downward trend in the cost of Very Large Scale Integrated (VLSI) circuits has encouraged wide application of numerical or digital relays for the protection of modern complex power system. Economical, powerful and sophisticated numerical devices (e.g., microprocessors, microcontrollers, digital signal processors (DSP), etc) are available today because of tremendous advancement in computer hardware technology. Various efficient and fast relaying algorithms which form a part of the software and are used to process the acquired information are also available today. Hence, there is a growing trend to develop and use numerical relays for the protection of various components of the modern complex power system. Numerical relaying has become a viable alternative to the traditional relaying systems employing electromechanical and static relays. Intelligent numerical relays using artificial Intelligence techniques such as Artificial Neural Networks (ANNs) and Fuzzy logic Systems are now available in the market and are still under further active research and development stage.

References

1. Jong Kang Park, Jong Tae Kim, Myong-Chul Shin, (2009) "A CORDIC-based digital protective relay and its architecture" Microelectronics Reliability Elsevier 49(4), pp 438–447.

2. Osorno, Bruno, "Industry Applications Society Annual Meeting", (2009). IAS 2009. IEEE California State Univ. Northridge, Northridge, CA, USA ,pp 1 - 8.

3. M. Amin Zamani, Tarlochan S. Sidhu, Amirnaser Yazdani, (2011) "A Protection Strategy and Microprocessor-Based Relay for Low-Voltage Microgrids" IEEE Transactions on power Delivery 26 (3), pp 1873-1883.

4. John J. Novak, Richard D. Kirby,(2010) "Better, Faster and More Economical Integrated Protective Relaying and Control Using Digital Bits and Logic" IEEE Transactions on Industry Applications, 46,(4), pp 1281-1294.

5. Gary H. Fox, (2005) "Applying Microprocessor-Based Protective Relays in Switchgear With AC Control Power" IEEE Transactions on Industry Applications, 41 (6), pp 1436-1443.

6. Montignies, Patrick, Jover, Bernard,(2008) "Electromagnetic compatibility of digital protective relays installed in medium voltage switchgear" Petroleum and Chemical Industry Conference Europe - Electrical and Instrumentation Applications, PCIC Europe, pp 1-11.

7. Tingfang, Yang ; Xin, Yang ,"Algorithm for microprocessor-based relay protection"2nd International Conference on Industrial Mechatronics and Automation (ICIMA), 30-31 May 2010 vol: 1 pp 56 – 59.

8. Rao S.S. ,(2007). Switchgear and Protection.13^{th} ed. Khanna Publishers, Delhi.