AL-MUKHTAR JOURNAL OF ENGINEERING RESEARCH ISSN online: 2519-6839 // ISSN Print 2519-6820
Available at : http://omu.edu.ly/engineering-journal/Volume1(1-9)2017.php Accepted 01-2016, Available online, Vol.1, No.1 (2017)

A PROTECTION AND FAULT LOCATION SCHEME FOR EHV LINE BASED ON SINGLE- ENDED TECHNIQUE

ASHRAF MOHAMED

Faculty of Engineering, Tobruk University

Abstract

Extra High voltage (EHV) transmission lines are designed to transfer large amount of power from one location to another. The transmission line protection relays, in the industry, are based on the fundamental frequency component of the voltages and currents. These relays need at least one fundamental frequency cycle for performing the protection operation.

Voltage and current traveling waves are generated when a fault occurs on the transmission line. The velocity of propagation of traveling waves is finite and the level of the waves decreases with increase in the distance traveled. Information about the fault can be obtained by analyzing the traveling waves. Single-ended technique, which use traveling waves for protecting EHV transmission lines, are proposed in this paper. The traveling waves are extracted from the modal voltages and currents at the terminals of the transmission line. The technique identify and locate the fault by using the information contained in the waves. A power system was modeled in the Electromagnetic Transient Direct Current Analysis (EMTDC) and several cases of faults and fault location were tested.

The performance of the digital techniques for protecting EHV transmission lines using traveling waves was confirmed to be satisfactory. The proposed technique provide protection at speed and discriminate well between internal and external faults.

Keywords: EHV Line, Traveling Waves, Fault Location, Single-ended technique Digital Relays.

1.INTRODUCTION

With the development in electronics, solid-state relay were developed. Small size, light weight and quiet operation are the advantages of solid-state relays over the electromechanical relays. Microprocessors technology made the relays even more compact, multifunctional and flexible.With the passage of time and increase in demand of electric energy, power systems have grown to large areas. The EHV transmission lines connect the generating sources and load points located at long distance. Due to the long lengths of EHV transmission lines and networking of the transmission systems, overcurrent relays cannot be used to protect EHV lines.

Distance relays are the most often used to protect transmission lines. Distance relays take voltages and currents as inputs from the power system and calculate impedance. If the calculated impedance lies in a pre-defined operating region on the impedance plane, distance relays operate to isolate the faulted part.

Digital relays, used in the transmission line protection, are based on the same protection logic as is used in analog relays but, the physical structure and operation of the digital relays are different.

Implementation of digital relaying was first proposed by G. D. Rockefeller in1969[1,3]. Efforts were made to predict the peak fault voltage and current. Fault impedance could be then calculated by taking a few samples at the initial stage of the fault as proposed by B. J.

Mann etc[2,11].

The bulk of recent literature on digital protection of transmission lines is devoted to utilize on-Line microcomputer to perform the protection, switching, monitoring and data collection functions of EHV/UHV transmission line by developing suitable algorithms.

The relaying schemes reported in the literature for EHV/UHV transmission line can be classified into two major categories[4,10]:-

1-Distance relaying schemes: in these schemes the aim is to extract the fundamental power frequency components of voltage and current signals from the complex post-fault waveforms using suitable filters. From the fundamental components the apparent impedance seen by the relay is calculated. Based upon the magnitude of this impedance, the relaying decision whether to trip or block is taken. A number of algorithms for digital protection which have been proposed by several authors can be grouped into four categories [5,14]:

A. Fourier analysis with a one-cycle data window proposed by Ramamoorthy.

B. Predictive calculation of peak values: This method based upon predicting the peak current and peak voltage. The impedance is then calculated by dividing the peak voltage by the peak current.

C. Solution of differential equation: The differential equation describing the transmission line is.

$$V = R_L i + L_L \frac{di}{dt} \tag{1}$$

A number of algorithm were proposed by several authors (ie. in1975, Rajbar and Cory, and in 1979 Smolinksi) to solve Eq(1) [12,13].

2-Traveling waves relaying schemes: This scheme is proposed in this paper. In recent years, there has been on increasing awareness of the benefits of ultra fast clearance of faults. Attention is now focused on the development of ultra high speed (u. h. s) protective relays because of the recent development of u. h. s circuit breakers. This has been possible with the utilization of the concepts of the traveling wave phenomena. The continuous growth in the size and complexity of electric power system, has given arise to the need for extremely fast and highly reliable protection schemes. The utilization of traveling wave phenomena has enabled the realization of ultra high speed relaying scheme for the protection of EHV/UHV transmission lines.

The second part of this paper is the fault location. Fault location is one of much importance for safe and economical operation of power system. Several fault location algorithms based on one-terminal have been developed for this objective. They can be divided into two categories. One is the algorithm based on impedance, the other is the algorithm based on traveling wave which described in this thesis.

Algorithm based on impedance uses current and voltage sampling data to measure post-fault impedance. Based on the knowledge of line impedance per unit, the fault distance can be calculated. This method could not eliminate the effect of such factors as path resistance, system configuration, and series CT saturation; it could not possess high accuracy. Fault location algorithm based on traveling wave determines fault location with the time difference between initial wave and its reflection one’s arrival at the point of fault locator.

Traveling waves are usually sharply varying signals. Frequency domain based analysis, Such as Fourier transform, are not suitable for such transient signals, it can not describe the modulus and arrival time of the incident and reflection traveling wave at the measurement point. And the time domain analysis is easily influenced by noise. Therefore, how to develop the traveling wave based protection is still a challenging problem.

2-HARDWARE, SOFTWARE MODULE

The hardware and software used to implement the digital techniques for transmission line protection is described in this chapter. The hardware used to implement the techniques is a DSP module and a personal computer. A real time operating system was used to load the code on the processor.

A DSP module, generally, contains a microprocessor, an external memory and various peripheral devices. The main components of the DSP module, SMT335 [8,17], are shown in the block diagram in (Fig 1).

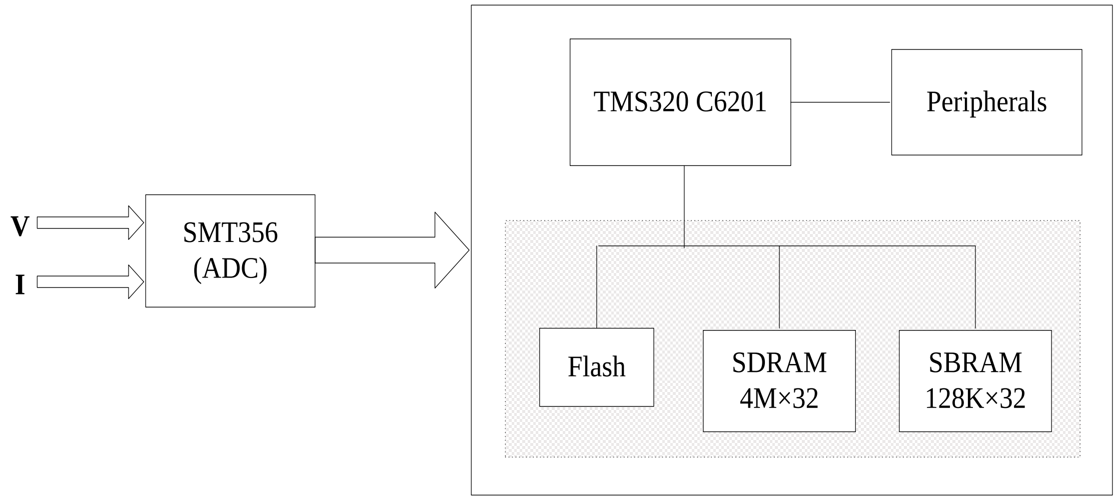


Fig. 1 Block Diagram of SMT335

The voltages and currents obtained from the power system are digitized by passing them through an analog to digital (A/D) converter unit, SMT356 [9,18], which consist of eight A/D converters (AD9240). The protection techniques were coded in C language and linear assembly language. These programs were loaded and executed on a microprocessor.

The main components of a DSP are shown in the block diagram in(Fig.2). The Central Processing Unit (CPU) performs all arithmetic and logic calculations. The memory on a microprocessor chip, called the on-chip memory, is used by the processor for temporary storage during execution of the program. CPU communicates with the internal memory and other peripheral devices via internal buses. The two types of buses are present in a processor. A control bus is used by the control unit of the CPU to control the flow of data among peripherals connected to the CPU. The other type of bus is a data bus, which transports data from memory to the CPU.The external memory and other peripherals can also communicate with the processor through various ports available on the processor. Peripherals consists of External Memory Interface (EMIF),Direct Memory Access (DMA),Host Port Interface (HPI)and two 32-bit general purpose timers.

Real time operating system, which gives high performance with simplified structure. It loads a program on the processor, and displays the results after the execution of the program.

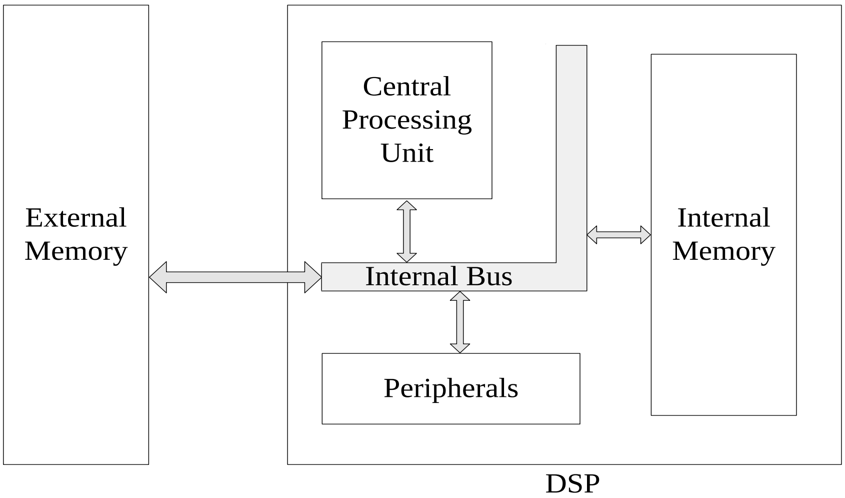


Fig. 2. Block Diagram of a Digital Signal Processor

3.FILTERING SCHEME

Traveling waves can be extracted from the modal voltage and current by using sequence filters [7]. A sequence filter, basically, is an algorithm that uses a sequence of samples to obtain information about the change in a signal.

Consider a three-sample sequence filter, which is based on the second differences of the voltage and current samples. The second differences of the voltage samples can be expressed as

$$\Delta V_n = V_{n+1} - 2V_n + V_{n-1} \tag{2}$$

Where, V_{n+1} is (n+1)th sample of the voltage,

V_n is nth sample of the voltage, and

V_{n-1} is (n-1)th sample of the voltage.

Taking z-transform of Eq. 2 provides,

$$H(Z) = Z^{+1} - 2Z^0 + Z^{-1} \tag{3}$$

Eq.3, in frequency domain, becomes

$$H(\omega) = e^{+j\omega\Delta T} - 2e^0 + e^{-j\omega\Delta T}$$

$$= 2(\cos(\omega\Delta T)\text{-}1) \tag{4}$$

The proposed techniques use modal voltages and currents as inputs to the sequence filters instead of the phase voltages and currents. The modal components simplify the logic for detecting the traveling waves.

4.PRGRAMMING

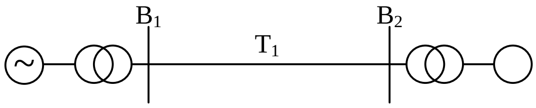
The code for the proposed technique was written in linear assembly language and C language. The logic of the proposed technique was implemented in a linear assembly program. Linear assembly language code [6,15] , used along with the assembly optimizer , efficiently generates the assembly language code without worrying about register usage, pipelining, functional units and delay slots. The C program was made to fetch data from the files stored on personal computer. The samples were scaled and stored in arrays and pointers to these arrays were passed to the assembly language program by the C program. C program also provided results to the real time operating system, which displays them on a graphical interface.

Data collected by running simulated cases in EMTDC was stored in a personal computer. EMTDC[16] is an electromagnetic transient direct current analysis program, which simulates the practical power systems for analysis. In EMTDC, the power system components are defined by using FORTRAN code. PSCAD provides a user interface to the EMTDC. PSCAD also supports models written in C\C++ code. All the power system simulations in this paper were done in EMTDC.

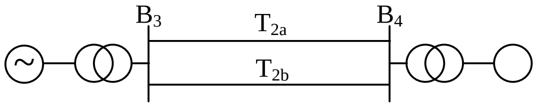
When the program was executed, the DSP accessed the data files stored on the personal computer. The program checked the data for the presence of traveling waves and detects the fault. It calculates the location of the fault on the transmission line. The linear assembly program saved the results in an array. The C program provides the results to the real time operating system. The results include; time of arrival of the traveling waves and distance of the fault. The real time operating system shows the results on the graphical user interface.

5.SIMULATION TEST

To test the single-ended technique, a system used for simulation is shown in (fig. 3).



(a) Single Circuit Transmission Line



(b) Double Circuit Transmission Line

Fig .3 Simulation Power System

In fig.4 B_1, B_2, B_3, and B_4 represent the buses. T_1 is 500KV transmission line with a length of 100km. T_{2a} and T_{2b} are 500KV transmission line with a length of 130km.Traveling wave digital relays are located at B_1 and , B_3 terminal of the line. These relays take input voltages and currents from the local terminal and calculates modal voltages and currents. The aerial modes of the voltages and currents are passed through the sequence filters.

When a fault occurs on the transmission line, the voltage and current traveling waves originate and propagate on the line away from the fault. One wave travels towards bus B_1 and the other wave travels towards bus B_2. The traveling waves, after a few microseconds, arrive at bus B_1 . When the traveling waves are detected by the relay, the timer is turned on. The spikes corresponding to the voltage and current incident waves are shown as V_{S1} and I_{S1} in the outputs of sequence filters, in (Fig.4). The opposite polarities of the voltage and current spikes confirm the occurrence of fault. B_1bus acts as a discontinuity in the path of the traveling waves. On reaching a bus, a part of the voltage wave and a part of the current traveling wave is reflected, and rest passes through. The reflected waves arrive at the fault, where a part of the voltage wave and a part of the current wave is reflected. These waves arrive at bus B_1, the second time. The arrival of the waves is detected by the relay.

The spikes, corresponding to these voltage and current waves are shown as V_{S2} and I_{S2}, in (Fig.4). The timer is stopped and the time is noted as T_a.

The distance traveled by the traveling waves is twice the distance of the fault from bus B_1.

therefore, the distance of the fault can be calculated as

$$D = \frac{T_a}{2} \times v \qquad (5)$$

Where, v is the velocity of propagation of the traveling waves.If the distance, D is less than the length of the protected transmission line, the relay sends trip signals to the circuit breakers to isolate the faulted line from the rest of the system. If the value of D is greater than the length of the protected line, the relay is reset and normal operation is resumed.

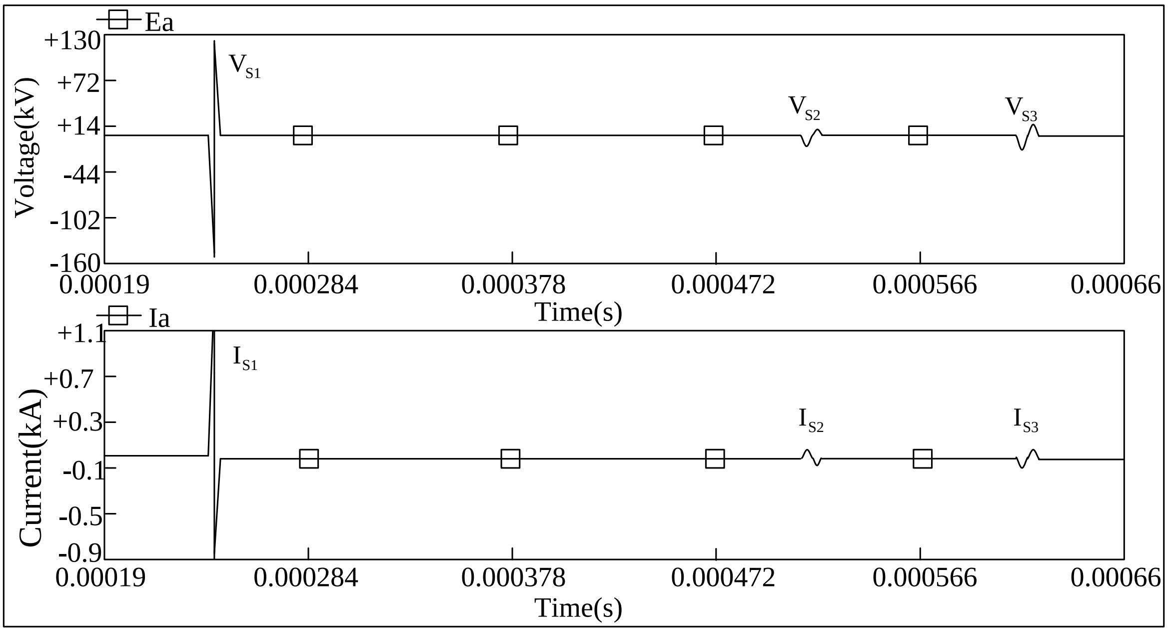


Fig.4 Sequence Filter Output at Relay B_1

In the case of double circuit transmission line, When a fault occurs on of the circuit 2 of the transmission line, the voltage and current traveling waves originate and propagate away from the fault. The traveling waves also exist on the healthy circuit due to magnetic induction. The voltage and current traveling waves, which arrive at bus B_3, are detected by the relays. The first set of spikes corresponding to the initial voltage and current traveling waves at relay are shown as V_{C21} and I_{C21} in(Fig.5). The polarity of the voltage spike is opposite than the polarity of the current spike, which indicates that the fault is on circuit 2. The timer in relay, is turned on.

The first set of spikes in voltage and current detected by the relay on circuit l are shown as V_{C11} and I_{C11} in(Fig.6). The polarities of these spikes are same; therefore, fault is not on circuit l. The bus B_3 reflects a part of the traveling waves, which travel back to the fault, where a part of the waves again gets reflected. The reflected voltage and current waves travel towards the bus B_3, where they are detected by the relays. The second set of voltage and current waves detected by relay on circuit 1 is represented as V_{C22} and I_{C22} in(Fig.5). The timer is stopped. If, the time recorded by the relay is T_a, the distance of the fault from bus B_3 can be calculated from Eq(5). Where, v is the velocity of propagation of the traveling waves. If the value of D is less than the length of the protected transmission line, the fault is on the line. Relay sends the trip signals to circuit breakers to isolate the faulted line. If the value of D is greater than the length of the protected line, the relays are reset and normal operation is resumed.

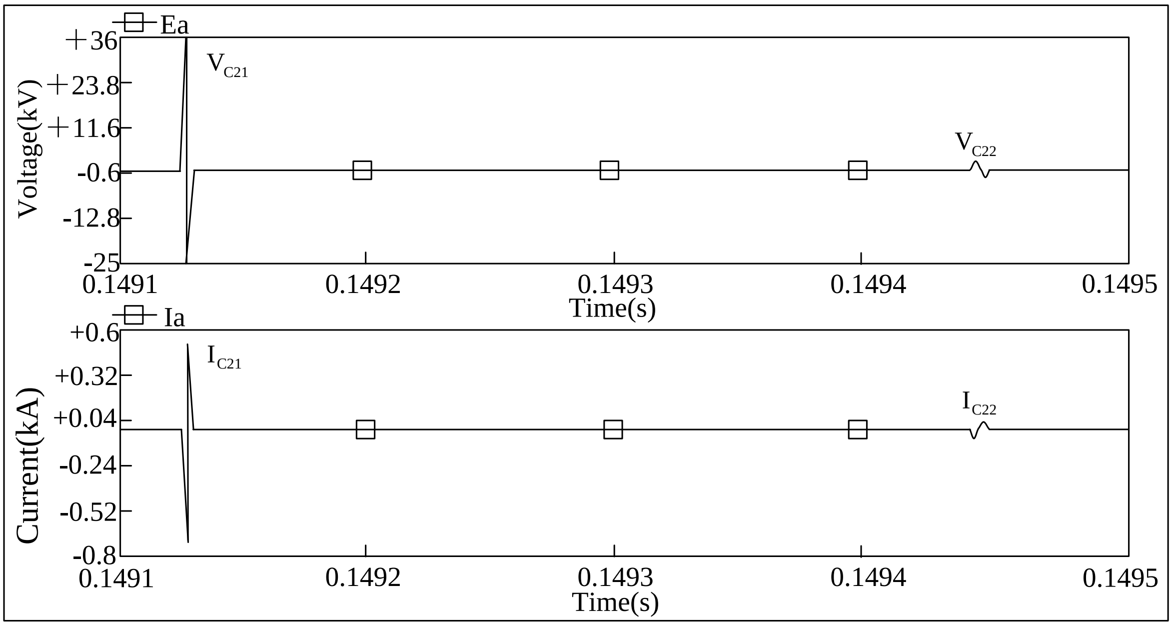


Fig.5 Voltage and Current sequence Filter outputs at the Relay on Circuit 2 at bus B_3

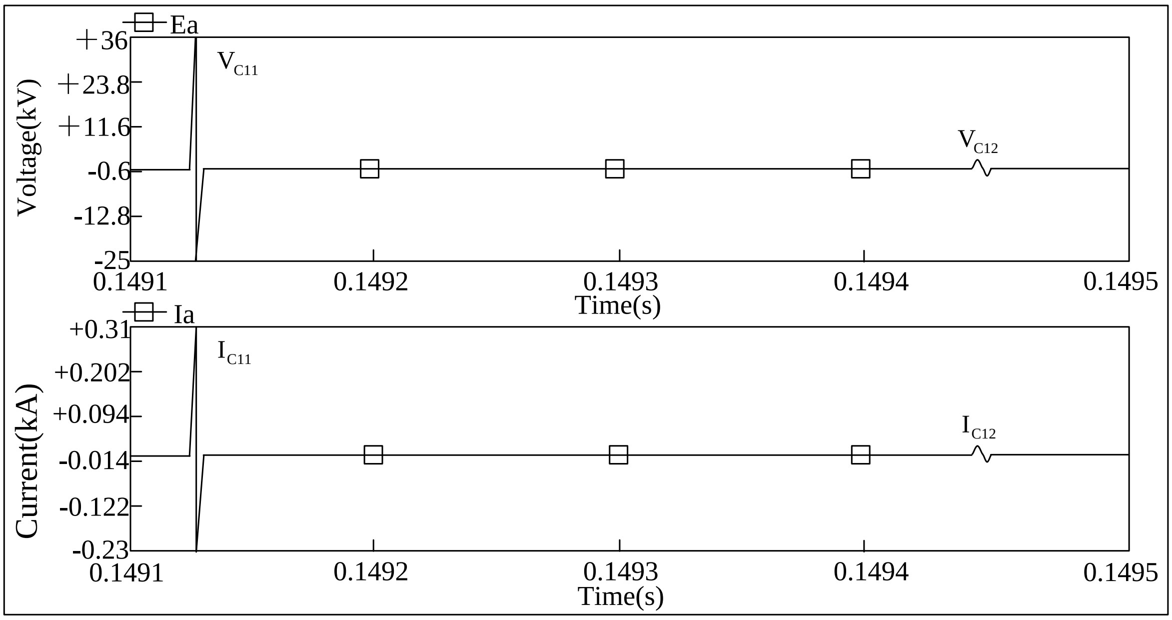


Fig.6 Voltage and Current Sequence Filter Outputs at the Relay on circuit 1 at bus B_3

6.CONCLUSION

The objective of this thesis was to propose a digital technique, based on traveling waves, for protecting EHV transmission lines.The techniques proposed in this paper and implemented with digital electronics technology, can identify a fault on a transmission line in less than 3 ms. The development of a single-ended technique has been presented in the third paper.

The technique was tested on data generated by running various cases in EMTDC. The code for the protection techniques was written in the linear assembly language and C language. The logic for detecting and locating a fault on the transmission line was coded in the linear assembly program. The C program was coded to fetch data from the files saved on the personal computer and provide the results to the real time operating system. The single-ended technique was tested for their performance by executing the programs on the microprocessor. The fault data, saved on a personal computer, was used by the programs; they implemented the proposed traveling wave techniques for the presence of faults and calculated the distances of the faults.The results, obtained from implementing the single-ended technique in hardware, are satisfactory. The techniques provide correct results for different types of faults, also it can distinguish between internal and external fault.

7-REFERENCES

1. Arun G. Phadke, James S. Thorp, “Computer Relaying for Power System”, Boldlck, Hertfordshire, England. 2000
2. Standly H. Horowitz, Arun G. Phadke, “Power System Relaying”, second edition, Baldock, Hertfordshire, England. 1995
3. P. M. Anderson, “Power System Protection”, institute of electrical and electronic engineers, New York. 1999
4. Harjinder Singh Sidhu “High Speed Digital Protection of EHV Transmission Lines Using Traveling Waves”, University of Saskatchewan, Canada. 2004
5. “Numerical Distance Protection principle and application”, Ziegler, Siemens, AG, Berlin and Munich. 1999
6. M. A. Redfern, M. M. El-kateb and E. P. Walker, GEC measurements limited, Stafford, UK, “An investigation into the effects of traveling wave phenomena on the Performance of a distance relay”, second int. Conf on development in power system protection. 1980
7. Jos Arrillaga, Nevillc R. Watson, “Power System Harmonics”, University of Canterbury, Christchurch, New Zeland 2003
8. L. P. Singh, “Protective Relaying from Electromechanical to Microprocessor”.New Delhi:Wiley Eastern Ltd,1994.
9. P. A. Crossely and P. G. Mclaren, “Distance Protection Based on Traveling Wave”, IEEE Trans on Power Apparatus and System. Vol 102, No9, Sep 1983
10. E. H. Shehab-Eldin and P. G. Mclaren,“ Traveling Wave Distance Protection Problem Areas and Solution”, IEEE Trans on Power Delivery, Vol3. No3 July 1988
11. A. T. Johns and S. K. Salman, “Digital Protection for Power System”, IEEE15, Peter Peregrinus Ltd 1995
12. Dong Xinzhou, Ge Yaozhong, Xu Bingyin, “A New Device for Fault Location of Transmission Line”, Power System Technology, Vol.22. No.l,pp17～21 ,Jan 1998, in Chinese.
13. Sant and Y. Paithankar, “Online Digital Fault Locator for Overhead Transmission Line”, IEEE Proceedings Vol 126 pp 1181～1185 November 1979
14. A. Burden and A. Mac Gregor, “Power Quality Initiatives at Schotish Power Transmission and Distribution World”,pp22-28 February 1998.
15. L. V. Bewley, “Traveling Waves on Transmission Systems”, Second edition , John Wiley & Sons. 1963.
16. 3L Limited, Diamond User’s Guide, Version 2.1.4, 2002.
17. Sundance Multiprocessor Technology Ltd, SMT335 SMT375, User Manual, Version 3.0, 2001.
18. Sundance Multiprocessor Technology Ltd, SMT356 User Manual, Version 3.0, 1999.