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MICROPROCESSOR - BASED DISTANCE RELAY SOLUTIONS

Dr - Ing. Mladen Kezunović,
Mr - Ing. Sead Kreso

Energoinvest
Institute for Control and Computer Science
Sarajevo, Yugoslavia

Introduction

Application of computers to perform protective relaying of Electric Power Lines has been investigated since the late 60-ties [1]. First solutions were mini-computer based and were not cost effective. Introduction of microprocessors enabled more attractive solutions which were developed since the mid 70-ties. A number of relays were developed so far, but there is no commercially available microprocessor-based distance relays on the world market. It is interesting to note that each of the approaches taken so for are unique and there is quite a variety of the characteristics obtained. A need to develope criteria to compare the solutions is evident and this paper is contribution to this issue. First, a classification of numerical algorithms for distance relaying is outlined. Then, a survey of microprocessor-based distance relay solutions is given. Finally, a discussion of the system characteristics of distance relay solutions is presented.

Classification of the Numerical Algorithms

Numerical Algorithms for Distance Relaying are used to determine the length of the line i.e. the short circuit impedance having taken measurements of voltage and current at the begining of the line. The basic equation that represents relation between voltages and currents on the power line is a partial differential equation. However, for the practical reasons, an assumption is made that the power line model can be approximated by the following differential equation:

$$\sum_k a_k \frac{d^k u(t)}{dt^k} = \sum_k b_k \frac{d^k i(t)}{dt^k} \qquad (1)$$

Classification of the numerical algorithms can be based on the methods for solving the equation (1), and it can be further based on the mathematical technique used to obtain the solution.

Numerical algorithms for Distance Relaying can be classified into two broad categories |2|:

- Differential equation parameter identification,
- Input/output equation parameter identification.

The first category includes methods which are aimed towards a numerical solution of the equation (1). Mathematical methods used to solve equation (1) are Fourrier analysis Correlation and Convolution techniques, Walsh analysis, Digital filtering and mathematical Regression techniques.

The second category takes into account shape of the voltage and current waveforms. In this case more apriori information is taken into consideration, which may improve the identification process. The mathematical methods used to provide the solution are classified as nonrecursive and recursive, with the Fourrier analysis technique suggested for the nonrecursive method and the Kalman filtering technique for the recursive method.

Survey of the Distance Relay Solutions

Microprocessor - Based Distance Relays have been mostly developed in Evrope, U.S.A. and Japan. A survey of the major characteristics of these developments is given in Table 1 and 2. Japanese developments are given in Table 3.

Table 1 gives basic information related to the Distance Relays developed so far. It can be noted that the published results are related to the developments done at the Universities and Utility companies while the resulsts of the developments performed by the manufactures are usually not available. It can be also noted that most of the Distance Relay solutions are complex relays beeing able to perform the complete protection of power transmission lines. Relay characteristics used are mostly the quadrulateral characteristics. Interesting to note is the variety of mathematical methods used for numerical parameter estimation. This area is stil under investigation and criteria for optimal selection of the mathematical methods are yet to be developed.

Diagnostic techniques available are specially important since the microprocessors technology enables major improvements in this area in comparison to the previous electromechanical and solid state technology. Finally, it is evident that most of the solutions are already laboratory tested and several Distance Relays are beeing now field tested. It is expected that first commercially available Microprocessor-- Based Distance Relay will appear on the world market in the mid 80-ties.

Table 2 represents hardware characteristic of the solutions. The major conclusion is that the 16-bit microprocessors are needed. Because of the high speed of calculations required, the bipolar technology is used if a monoprocessor solutions are implemented while the use of MOS technology requires the multiprocessor solutions. Major hardware variations are also in the analog input modul concepts and configurations.

Table 1. Distance Relay Developments

RESEARCH ORGANIZ.	RELAY FUNCTION		NUMERIC METHODS	DIAGNOSTIC TECHNIQUES	PHASE OF TESTING	
	PROTECTIVE FUNCTION	CHARACTERISTIC			LABORATORY	SUBSTATION
University of Washington, USA	Distance Relay	MHO	Walsh Analysis	- self testing - RAM check sum - watch dog timer - power supply check	Performed	Planned
AEP service corp, USA	Distance Relay	-	- symmetrical components - half-cycle Fourrier analysis	- remote operator communication	Performed	Started in 1979
University of New Brunswick CANADA	Single-phase distance with earth fault characteristics	Quadrilateral	Numerical solution of diff. equation	-	Performed	-
Hydroquebec IREQ CANADA	Distance overcurrent over voltage line check	Quadrilateral	Full cycle Fourrier analysis	- special processor for relay monitoring - autocalibration - remote operator communication	Performed	Planned
University of Bath ENGLAND	Distance relay	Quadrilateral	Fourrier analysis	-	-	-
UMIST ENGLAND	Distance directional overcurrent	Quadrilateral	Numerical solution of diff. equat.	-	Performed	-
Imperial College ENGLAND	Distance overcurrent earth-fault negative component	-	Numerical solution of diff. equation	- self checking of power supply and analog input circuit - general application	Performed	-
EdF FRANCE	Distance Relay	Quadrilateral	Least-square minimization technique	- watch dog - RAM check - CPU check - fail safe	Performed	Performed
AEG - Telefunken W. Germany	Distance Relay	-	-	- monitoring - logging - remote operator communication	Performed	-

Table 2. Distance Relays Hardware Characteristics

No.	RELAY PROCESSOR CHARACTERISTICS				ORGANIZ. OF ANALOG INPUT	SAMPLING RATE (SYST. FREQ)	FILTERING		NO.OF A/D	A/D RESOLUTION	DYNAMIC RANGE OF INPUT SIGNAL
	PROCESSOR TYPE	NO.OF PROCESS.	WORD LENGTH	TECHNOLOGY			TYPE	SPECIFICATION			
1.	MC6809	1	8	MOS	COMMON	4/CYCLE (60Hz)	ANAL.	TWO-POLE LOW PASS 85Hz CUT OFF	1, HYBRID	12 bit	PCA PROCESSOR CONTROLLED
2.	PLESSEY MIPROC-16	1	16	BIPOLAR	EACH CHANNEL COMMON	12/CYCLE (60Hz)	ANAL.	LOW PASS 360 Hz CUT OFF	16	8 bit	4 BIT ARE ADDED FOR 12 BIT
									1	12 bit	FIXED
3.	INTEL 8086	2	16	MOS	EACH CHANNEL	20/CYCLE (60Hz)	DIG.	3RD ORDER BUTTERWORTH 120 Hz CUT OFF	3	-	-
4.	-	8	16	MOS	EACH CHANNEL (TWO IDENTICAL SYSTEMS)	- (60Hz)	-	-	2x8	12 bit	PCA
5.	z80	3	8	MOS	-	40/CYCLE (50Hz)	-	-	-	-	-
6.	INTEL 3000	8	16	BIPOLAR	-	24/CYCLE (50Hz)	ANAL.	2 ND ORDER BESSELL	-	10	-
7.	INTEL 3000	8	16	BIPOLAR	-	8/CYCLE (50Hz)	ANAL.	2ND ORDER BUTTERWORTH LOW PASS 180Hz CUT OFF	1	10 bit	FIXED
							DIG.	BUTTERWORTH 120Hz CUT OFF			
8.	8086	4	16	MOS	EACH CHANNEL	24/CYCLE (50Hz)	ANAL.	3RD ORDER BUTTERWORTH 550 Hz CUT OFF	6 HYBRID	12 bit	-
9.	-	5	16	-	-	20/CYCLE (50Hz)	-	-	-	14 bit	-

Table 3. Microprocessor Relay Developments in Japan

No.	REFERENCE	PARTICIPATING PARTIES	RELAY FUNCTION	SYSTEM CHARACTERISTICS	SOLUTION CHARACTERISTICS
1.	[12]	- Toshiba - Tokyo electric	Digital current differential - carrier	Percentage Restraining Characteristic	16-bit bipolar microprocessor
2.	[13]	- Chubu electric - Hitachi - Toshiba - Mitsubishi - Meidensha - Fuji	Back up protection 275 kV	Quadrilateral	2 systems each consisting of 2 microprocessors (main and redundant system
3.	[14]		Main-selective relaying Back-up directional distance (64-154 kV)	- MHO - directional overcurrent - overvoltage	Integrated solution consisting of 2 systems (primary and back-up). Each system h has the main and auxilliary fault detectors
4.	[15]		Integrated control and protection	-	Integrated system consisting of several 24-bit protection processors and 8-bit control processors all configurated out of 4-bit bit slice micro processors
5.	[16]	- Mitsubishi - Kansai electric	Directional comparison carrier relaying (154 kV)	MHO	Consists of 4 microprocessor units
6.	[17]	- Mitsubishi	- Directional distance selective-main - Distance and directional-back up (77 kV)	MHO	16 bit microprocessor
			Overcurrent protection	MHO	8 bit microprocessor
7.	[18]	- Tokyo electric - Toshiba	Directional distance	MHO	System consists of 2 relays. One performs distance relaying, and the other one balance relaying of parallel lines. 16 bit microprocessors are used

Table 3 gives developments performed by the Japanese manufactures and utilities. Those solutions are given separately since it can be noted that selection of algorithms and philosophy of the system solution for protective relaying of Power Transmission Lines is quite different from the developments in Europe and the U.S.A. It can be also noted that development of Microprocessor-Based Relays in Japan was quite active and well organized as a mutual activity among several manufactures and utility companies.

System Characteristics Improvements

Application of microprocessors enabled a number of improvements in the system characteristics of distance relaying function as well as in the system characteristics of the microprocessor--based equipment.

Using microprocessors it is feasible to improve a number of functions which enhance the typical system characteristics of the distance relaying function. One of the latest solutions of Microprocessor-Based Distance Relay provides the folowing protective relaying characteristics |4|:

- Phase and ground distance protection,
- High speed relaying of 1/2 to 1 cycle
- Directional comparison carrier blocking scheme,
- Three-zone stepped distance for both carrier and time--delayed back-up,
- Local breaker failure protection,
- Automatic reclosing with synchronism check,
- Sequence of events recording,
- Fault classification,
- Single pole trip output,
- Memory voltage for three-phase bus fault,
- Directional inverse time delay back-up for ground faults using ground current.

System characteristics of the Microprocessor - Based Equipment are enhanced by providing several special features such as |6|:

- Start-up and parameter setting procedures,
- Local Remote monitoring of relay functioning and status,
- Communications with the remote operator,
- Display of the calculated values,
- Autosynchronization to the power line frequency,
- Autocalibration of the A/D interfaces.

Availability, Reliability and Security are improved by providing a number of self-checking procedures and application oriented calculation checks. Finally, several serial communication channel tests are provided as well as some redundancy checks of the tripping signal output using the hardware combination voteing circuit.

Conclusion

The folowing conclusions can be made from the given discussion:

- Eventhough there is no commercially available Microprocessor - Based Distance Relays on the world market, it is evident that number of the relays are already developed and are either tested or beeing tested in both laboratory and substation environments.
- Solution developed so far differ one from each other in the algorithm selection as well as in the hardware and software characteristics.
- Application of microprocessor technology enabled a number of improvements in both the system characteristics of the distance relaying function and the system characteristics of the microprocessor-based equipment.

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