BIBLIOGRAPHY OF RELAY LITERATURE, 1994
IEEE COMMITTEE REPORT

Members of the Bibliography and Publicity Working Group of the IEEE Power System Relaying Committee are:
T.S. Sidhu, Chairman, M. Bajpai, A. Darlington, D. Finley, A.G. Folkman, M. Kezunovic, W. Marsh,
R. Ramaswami, M.S. Sachdev, J.E. Stephens, M.J. Swanson, S.S. Venkata, and P.B. Winston

ABSTRACT - The latest of a series of classified lists of power system relaying references, begun in 1927, is presented. This bibliography is in continuation to the bibliographies of relay literature which were published previously and are contained in the following volumes of the IEEE Transactions:

Bibliography for	**Particulars of the Transaction** Volume	No.	Year	Page# from	to
1927-1939	60		1941	1435	1447
1940-1943	63		1944	705	709
1944-1946	67	pt. I	1948	24	27
1947-1949	70	pt. I	1951	247	250
1950-1952	74	pt. III	1955	45	48
1953-1954	76	pt. III	1957	126	129
1955-1956	78	pt. III	1959	78	81
1957-1958	79	pt. III	1960	39	42
1959-1960	81	pt. III	1962	109	112
1961-1964	PAS-85	10	1966	1044	1053
1965-1966	PAS-88	3	1969	244	250
1967-1969	PAS-90	5	1971	1982	1988
1970-1971	PAS-92	3	1973	1132	1140
1972-1973	PAS-94	6	1975	2033	2041
1974-1975	PAS-97	3	1978	789	801
1976-1977	PAS-99	1	1980	99	107
1978-1979	PAS-100	5	1981	2407	2415
1980-1981	PAS-102	4	1983	1014	1024
1982-1983	PAS-104	5	1985	1189	1197
1984-1985	PWRD-2	2	1987	349	358
1986-1987	PWRD-4	3	1989	1649	1658
1988-1989	PWRD-6	4	1991	1409	1422
1990	PWRD-7	1	1992	173	181
1991	PWRD-8	3	1993	955	961
1992	PWRD-10	1	1995	142	152

1993 - Paper # 94 SM 436-6

95 SM 436-6 PWRD A paper recommended and approved by the IEEE Power System Relaying Committee of the IEEE Power Engineering Society for presentation at the 1995 IEEE/PES Summer Meeting, July 23-27, 1995, Portland, OR. Manuscript submitted April 7, 1995; made available for printing June 19, 1995.

The papers listed include references to the subjects of service restoration, testing and methods of calculation, as well as to the field of relaying. Only the more readily available foreign publications are included.

Each reference includes the title, author, publication information, and a very brief summary of the subject matter. The listing of the titles is subdivided into ten sections, depending upon the general substance of each article. The section titles are as follows:

3150 **RELAYING ALGORITHMS**
3151 **DISTRIBUTION AND NETWORK PROTECTION**
3151.1 Industrial and Power Station Auxiliaries
3151.2 Primary Distribution Systems
3152 **TRANSMISSION LINE PROTECTION**
3152.1 Distance and Ground Relaying
3152.2 Relay Communications
3152.3 Relay Systems
3153 **RELAY INPUT SOURCES**
3154 **ROTATING MACHINERY PROTECTION**
3155 **OTHER PROTECTION**
3155.1 Transformer and Reactor Protection
3155.2 Capacitor Bank and Static Var Protection
3155.3 Other Protection
3156 **FAULT AND SYSTEM CALCULATIONS**
3157 **MAINTENANCE, TESTING, ANALYSIS, AND MODELING**
3158 **STABILITY, OUT OF STEP, RESTORATION**
3159 **SURGE PHENOMENA**

The entries in each section are listed in alphabetical order by the name of the first author. Each title is listed in only one section even if it covers material that belongs to several sections. A list of the periodicals which have been cited and the addresses of their publishers follows the bibliography.

The abstracts of many articles reported in this paper are available in the Science Abstracts - Section B, the Engineering Index, and other digesting and/or indexing periodicals.

ADDITIONAL REFERENCES

Electrical & Electronics Abstracts, are published monthly by the Institution of Electrical Engineers (U.K.) and the Institute of Electrical and Electronics Engineers, Inc. (USA).

Papers and journals published in several countries are covered.

In addition to the papers published in Journals and Conference Proceedings, one book on the subject of power system relaying has come to the attention of the working group. A brief description of its contents is included here.

Protective Relaying Theory and Applications, W.A. Elmore(Editor), Marcel Dekker Inc., New York, 1994, 367 pp. The subjects covered include technical tools for relay engineers, basic relay units, instrument transformers, microprocessor relaying fundamentals, system grounding, and protection of transmission lines, transformers, reactors, station bus and rotating machinery. Relaying schemes, backup relaying, system stability, out-of-step relaying, reclosing, synchronizing, load shedding, and frequency relaying are also presented.

3150 RELAYING ALGORITHMS

Artificial Neural Networks for Real-Time Estimation of Basic Waveforms of Voltages and Currents, A. Cichocki, T. Lobos, IEEE Trans. on Power Systems, Vol. 9, No. 2, May 1994, p 612-8. Parallel algorithms for estimation of parameters of sinewave contaminated by noise are proposed. The implementation of algorithms by neural networks is also given. Computer simulation results are included.

A New Technique for High-Speed Evaluation of Power System Frequency, P.J. Moore, R.D. Garranza, A.T. Johns, IEE Proceedings - C, Vol. 141, No. 5, 1994, p 529-36. A numerical technique for evaluating power system frequency from either voltage or current signals is presented. The technique is tested for its capability to track frequency under dynamic power system conditions and for its immunity to harmonics.

Training an Artificial Neural Network to Discriminate Between Magnetizing Inrush and Internal Faults, L. G. Perez, A. J. Flechsiz, J. L. Meador, A. Obradovic, IEEE Trans. on Power Delivery, Vol. 9, No. l, Jan 1994, p 434-41. The paper describes the methodology used to train a feed forward neural network to make the distinction between the two currents using second harmonic detection. A methodology to apply neural network based algorithms to digital relays is given and problems for a practical application are discussed.

Fast Identification of Symmetrical Components by Use of a State Observer, E. Rosolowski, M. Michalik, IEE Proceedings - C, Vol. 141, No. 6, 1994, p 617-22. The application of a state observer to the estimation of symmetrical components is presented. The symmetrical component phasors are calculated from the orthogonal signal components which are the state variables of the recursive signal model.

Detecting Arcing Downed Wires Using Fault Current Flicker and Half-Cycle Asymmetry, A. F. Sultan, G. W. Swift, D. J. Fedirchuk, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 461-70. A high impedance arcing fault detection algorithm is described. Current peaks of each cycle are measured, and compared and summed for decision making. The algorithm performed well under test conditions except for arc welder load which requires additional measures to improve security.

Voltage Phasor and Local System Frequency Estimation Using Newton Type Algorithms, V.V. Terzija, M.B. Djuric, B.D. Kovacevic, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1368-74. This paper describes the design of a digital algorithm for estimating voltage phasor and local frequency. The estimation is considered as an unconstrained optimization problem and the algorithm is derived using Newton's iterative method.

3151 DISTRIBUTION AND NETWORK PROTECTION

Protection of a Distribution Network: An Adaptive Approach, B. Chattopadhyay, M. S. Sachdev, T.S. Sidhu, Canadian Journal of Electrical and Computer Engineering, Vol. 19, No. 3, 1994, p 103-12. This paper describes a protection scheme designed for the distribution network of the City of Saskatoon. The scheme adapts to system changes in an on-line mode. The hardware, software, and implementation of the scheme in a laboratory are outlined. Sample results obtained from system studies are also included.

A New Approach to Digital Current Differential Protection for Low and Medium Voltage Feeder Circuits Using a Digital Voice-Frequency Grade Communications Channel, M.A. Redfern, A.A.W. Chiwaya, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1352-8. An approach to digital current differential protection, which provides the capabilities of conventional pilot wire differential protection while using the limited data transfer capabilities of a digital data voice-frequency grade communications channel, is described. The approach compares polyphase polarised current measurements taken at the feeder terminals and can trip in under two cycles.

How Distribution Automation and Protection Systems Can Complement Each Other, F. Soudi, J. Yee, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper discusses several distribution feeder topics. Included are the reconfiguration of protective devices automatically, the use of intelligent fault location methods, and high impedance fault detection methods. The importance of control and monitoring of protective devices and sensors out on the lines is emphasized.

An Adaptive High and Low Impedance Fault Detection Method, D.C. Yu, S.H. Khan, IEEE Trans. on Power Delivery, Vol. 9, No. 4, Oct 1994, p 1812-21. An integrated high impedance fault and low impedance fault detection method is proposed in this paper. The proposed technique is based on a number of characteristics of the HIF current and were identified by modeling the distribution feeders in EMTP.

3151.1 Industrial and Power Station Auxiliaries

Electronically Enhanced Low Voltage Motor Protection and Control, S.F. Farag, R.G. Bartheld, W.E. May, IEEE Trans. on Industry Applications, Vol. 30, N0. 3, May/Jun 1994, p 776-84. This paper emphasizes that the increasing processing speeds and communication capabilities of modern microcomputer chips allows designers to develop multi-function motor protection systems which can include control functions.

Design, Development and Application of Smart Fuses - Part I, R. Ranjan, E.W. Kalkstein, IEEE Trans. on Industry Applications, Vol. 30, No. 1, Jan/Feb 1994, p 164-9. Design and development of a Smart Fuse that simulates conventional current limiting characteristics during high current faults and has the inherent intelligence to self-monitor is reported. Application of the Smart Fuse in medium voltage distribution systems and equipment protective schemes is described.

3151.2 Primary Distribution Systems

Expert System for Integrated Protection Design with Configurable Distribution Circuits: Part I and Part II, R. P. Broadwater, J. C. Thompson, S. Rahman, A. Sargent, IEEE Trans. on Power Delivery, Vol. 9, No. 2, Apr 1994, p 1115-21 (Part I) p 1122-8 (Part II). Part I presents the expert system design and Coordination, Selection, and Placement rules processors. Examples of these rules are presented. The designer controls which rules are implemented. Part II presents an expert system design study involving the protection system for three interconnected distribution circuits. The expert system is able to fully integrate all pertinent data into the design. The expert system is a planning tool for the protection engineer - not a replacement for the engineer.

Distribution Protection Problems and Concerns and Their Solution Using Microprocessor Relays, R. E. Hart, R. S. Kochhar, I. G. Mohammed, J. A. Wilson, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. Presented in this paper is one utility's approach to using familiar methods for supervising the operation of backup overcurrent relays, trip saving, and fault location to improve distribution performance and overall reliability. One benefit discussed is the reduction of transformer exposure to high current line faults.

A Microprocessor-Based Digital Feeder Monitor with High Impedance Fault Detection, R. Patterson, W. Tyska, B. D. Russel, B. Aucoin, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper describes the functions and features of a digital feeder monitor. The procedures for assessment and application of the monitoring system are presented.

New Relay for Interconnected Distribution in the UK: Design and Field Experience, J. V. H. Sanderson, M. K. Kyriakides, W. An, A.J. Mackrell, H. R. Postlethwaite, W. J. S. Rogers, B. W. Swinnerton, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 453-60. The design and field experience of a new microprocessor protection relay for a U.K. 33kV interconnected network is described. The primary protection is based on measurement of the phase angle of an impedance obtained by dividing the positive sequence voltage by the incremental change in positive sequence current during the previous one cycle.

Application Experience With Microprocessor Distribution Relaying, D. Shroff, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. Discussed are some of the new capabilities and tools available in the newer microprocessor relays that can be used to enhance protection, simplify distribution system operations, and provide improved analysis aids. The metering and control functions of these relays are also discussed.

3152 TRANSMISSION LINE PROTECTION

Evaluating Line Relaying Schemes in Terms of Speed, Security and Dependability, G. E. Alexander, J. G. Andrichak, S. D. Rowe, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. Many different types of relaying schemes are available for the protection engineer to choose from. Each of these have advantages and disadvantages in terms of speed, security, and dependability relative to application to the power system. This paper presents a good tutorial on these issues with details provided in the appendix.

Present EHV Line Protection Choices - One Utility's Perspective, D. Angell, D. Arjona, D. Beaudreau, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper presents one approach to the problem of maximizing the investment in relay upgrades. A methodology is described where factors such as relay maintenance, installation, and operating costs were considered in the selection process.

Trends in Feeder Protection Relays, B.R.J. Caunce, A.D. Parker, S.M. Kidd, G.C. Weller, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-104. Advantages of designing a numerical relay using a floating-point digital processor (DSP) with separate processors for protection, communication, and non-protection functions are described.

Adaptive Distance Relay Characteristics, L. P. Cavero, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper reviews and evaluates adaptive distance relay characteristics which are found in commercially available distance relays and proposes new adaptive characteristics which may provide enhanced distance protection under changing power system conditions.

Existing 110-1150 kV Transmission Line Protection Performance Improvement Under Operating Conditions and Network Structure Changes, V. V. Ilyinichnin, V. I. Katunian, V.F. Lachugin, A.I. Leviush, V.T. Ujegov, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-202. This paper analyzes the misoperation of phase comparison and wave protection schemes.

Non-Unit Protection Technique for EHV Transmission Systems Based on Fault-Generated Noise, Part I: Signal Measurement, Part II: Signal Processing, A.T. Johns, R.K. Aggarwal, Z.Q. Bo, IEE Proceedings-C, Vol. 141, No. 2, 1994, p 133-40 (Part I), p 141-7 (Part II). Part I describes a protection technique for transmission lines which utilizes the high-frequency components of the fault-generated noise caused by arcing faults. Part II reports the signal processing techniques required for development and implementation of the proposed relay.

Numerical EHV Feeder Protection Concept and Realization, W. Matla, G. Ziegler, CIGRE, Paris, Aug. 28-Sep. 3, 1994, Paper No. 34-103. The paper discusses present German transmission network protection practices, numerical relay advantages, and protection of the new substation being installed to connect the Berlin transmission network to the West European interconnected grid.

Feeder Protection Practice in the Portuguese Transmission Network, J. M. Pombo Duarte, A. C. Reis Rodrigues, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-102. The paper discusses present transmission system relay practices, and application of numerical technology to adaptive protection, coordination, operation analysis, and open Energy Management Systems.

Directional Element Design and Evaluation, J. Roberts, A. Guzman, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper presents an overall look at the subject including identifying wherever mutual coupling is and is not a problem for various directional elements including zero sequence polarizing. Also discussed is the performance of a new negative-sequence directional element for an actual ground fault on a series-compensated 345 kV transmission line.

A Digital Algorithm for Differential Protection of Parallel Teed Transmission Lines, M.S. Sachdev, X. Liu, T.S. Sidhu, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. An algorithm for differential protection of parallel-teed transmission lines is presented in this paper. A synchronization technique that can be easily implemented is also proposed. Some test results are also included.

An Artificial Neural Network for Directional Comparison Protection of Transmission Lines, T.S. Sidhu, H. Singh, M.S. Sachdev, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper proposes the use of artificial neural networks to accomplish direction discrimination for protecting transmission lines. Design issues, such as network structure and selection of training data are discussed in the paper. Test results are also given.

Improved Protection Relays to Cope With Changes in Power Transmission Networks and Their Operating Conditions, T. Yanagihashi, S. Kumano, T. Nomura, T. Kubo, M. Hatata, E. Ibaragi, I. Mitani, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-201. The paper explains improvements of digital relays in providing improved backup protection on heavily loaded lines, overload protection, and reducing influence of waveform distortion due to EHV underground cable and ct saturation.

3152.1 Distance and Ground Relaying

Error Compensation in Digital Relays for Transmission Lines, B. Jeyasurya, M. A. Rahman, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper presents a method for improving the performance of digital distance relays by compensating for the error due to fault resistance. Simulation results and a discussion of implementation issues are included.

Adaptive Distance Protection of a Double-Circuit Line, A.G. Jongepier, L. van der Sluis, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1289-97. To achieve correct operation of the distance protection of a double-circuit line under SLG fault condition, relay should use the zero sequence current of the parallel circuit which requires extra measuring equipment. In this paper, another approach which uses a correction factor is introduced. The correction factor is set adaptively according to the power system state. Simulation results using the Dutch 400 kV power system are included.

New Approach to Distance Protection for Resistive Double-Phase to Earth Faults Using Adaptive Techniques, P.J. Moore, R.K. Aggarwal, H. Jiang, A.T. Johns, IEE Proceedings - C, Vol. 141, No. 4, 1994, p 369-76. The paper describes two adaptation techniques to improve distance protection performance. One is suitable for use with the earth elements and the other is for use with the phase elements.

Development and Field Experience with the WXB-41 Digital Distance Relay with Accelerated Trip for Faults in the Second Zone of a Transmission Line, L. Pei, C. Deshu, O. P. Malik, Electric Power Systems Research, Vol 28, 1994, 171-9. A digital protection system, type WXB-41, for a transmission line built with an Intel 8086 CPU is described in this paper.

Fault Impedance Estimation Algorithm for Digital Distance Relaying, D.L. Waikar, S. Elangovan, A.C. Liew, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1375-83. A fault distance estimation algorithm based on symmetrical components theory is developed in this paper. Test results demonstrating the performance of the algorithm are also included.

Advanced Numerical Distance Protection for EHV Lines, S. Wolf, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper describes the hardware and software structure and other features of a numerical distance protection relay.

Development and Implementation of a Variable-Window Algorithm for High-Speed and Accurate Digital Distance Protection, Y.Q. Xia, K.K. Li, IEE Proceedings - C, Vol. 141, No. 4, 1994, p 383-9. The paper describes a variable window algorithm which is designed to estimate the apparent impedance while the data window is increased to a desired size after fault occurrence. Results of real-time testing are shown.

High-Resistance Faults on a Multiterminal Line: Analysis, Simulated Studies, and Adaptive Distance Relaying Scheme, Y. Q. Xia, A. K. David, K. K. Li, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 492-500. The apparent impedance to high resistance faults on a three terminal line has been explored. Using the equivalent voltages of the three terminals and computer simulation, an adaptive relaying scheme which could follow the changing system conditions is proposed.

Adaptive Relay Setting for Stand-Alone Digital Distance Protection, Y. Q. Xia, K. K. Li, A. K. David, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 480-91. In this paper, an adaptive setting scheme is proposed for a microprocessor based distance relay to compensate for the effect of fault resistance and remote end infeed. A practical scheme was designed and computer simulation confirmed the validity of the concept.

3152.2 Relay Communications

Fiber Optic Communications: The Next Generation, M.G. Adamiak, T. Tobler, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. This paper addresses the fiber communication evolution to Synchronous Optical Network (SONET) and highlights this standard's features as related to application in relay communication systems.

Experiences of Current Differential Protections for Multi-Terminal Lines Using Multiplexed Data Transmission Systems, T. Einarsson, P. Wennerlund, L. Cederblad, S. Lindahl, S. Holst, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-203. The paper reports the use of current differential relaying on a three terminal line over multiplexed fiber optic and microwave channels.

Techniques for Integration of Substation Communications, P.J. Gregory, M.J. Dood, P.T. Carroll, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. While the revolution in electronic technology has had a significantly beneficial impact on the designs and functions of substations, utilities simultaneously are confronting a new set of communications challenges. This paper identifies some of these challenges and addresses some attempts to implement a strategy to solve them.

Installation of 930-960 Mhz Low Density Point-To-Point Radios and Solid State Relays for Primary Transmission Relay Protection on 69 kV Transmission Lines, J. K. Kahler, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. Presented in this paper is one utility's approach to improve system performance and reliability with the evaluation and installation of a new relaying scheme that provides instantaneous tripping on the protected line and directional overcurrent backup protection. The scheme proved to be simple to install, easy to maintain, and cost effective.

Interoperable Substation Data Communications, E.A. Udren, E.D. Price, R.E. Ray, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. This paper reviews the basic problem, some of the current technologies used with their shortcomings, and identifies the fundamental needs of utility and industrial users for open, interoperable data communications systems for the substation.

3152.3 Relay Systems

Field Experience With Charge Comparison Relaying of Transmission Lines, D. Bolam, E.G. Davidson, H.G. Farley, G.R. Hoffman, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-206. Field testing experiences of charge comparison pilot relaying installations are reported.

Current Differential and Phase Comparison Relaying Compared with Pilot Distance Schemes, W.A. Elmore, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. Current comparison and distance pilot schemes are, in most cases equally applicable to transmission line protection, but each type has its distinctive nuances that make it more suitable for particular applications. This paper attempts to describe the qualities of each of these systems and to point out where they excel.

Coordination of Microprocessor-Based Line Relays with Electromechanical Relays, M. Gaudi, S. Turner, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. Presented in this paper is one solution to the problem that exists when newer high speed technology is integrated into older schemes. The problem of communication coordination when different technologies are located at different ends of a blocking pilot system is discussed. One solution and supporting testing is presented.

3153 RELAY INPUT SOURCES

Poynting Vector Transducer for Transmission Line Monitoring and Protection, W. Z. Fam, IEEE Trans. on Power Delivery, Vol 9, No. 1, Jan 1994, p 378-83. A simple transducer unit containing current and voltage sensors is described. Signals from the two sensors are processed in a simple electronic circuit which brings them to a level suitable for metering and relaying purposes. It is free from saturation effects and has a very wide frequency response with a high degree of accuracy.

3154 ROTATING MACHINERY PROTECTION

Rotor Heating Effects from Geomagnetic Induced Currents, W. B. Gish, W. E. Feero, G. D. Rockefeller, IEEE Trans. on Power Delivery, Vol. 9, No. 2, Apr 1994, p 712-9. This paper addresses the possibility of damage to the generator rotor end ring structure from even harmonic currents which result from GIC in the associated transformer neutral. Generator current waveforms were created from recorded GIC monitoring, and applied to two types of negative sequence relays. One could be expected to alarm while the other is less likely to do so.

An Integrated Approach to Generator Protection, H. T. Yip, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper describes the specification and design principles of an integrated generator protection relay. The relay provides a number of common protection functions applicable to a wide range of generators.

3155 OTHER PROTECTION

Conventional Relays with Nonconventional Sources, A. Apostolov, S. Zocholl, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper presents one utility's experience in interfacing and low level testing of three relays and two types of meters with MOCT's on a 115kV line.

Real Time Fault Detection and Classification in Power Systems Using Microprocessors, J. Barros, J.M. Drake, IEE Proceedings - C, Vol. 141, No. 4, 1994, p 315-22. A method for real-time fault detection and classification is proposed. The algorithm is optimized to detect and correctly classify faults in less than 20 ms.

"Open" Systems Relaying, P. G. McLaren, G. W. Swift, A. Neufeld, Z. Zhang, E. Dirks, R. W. Haywood, IEEE Trans on Power Delivery, Vol 9, No. 3, Jul 1994, p 1316-24. This paper describes a development in relaying hardware and philosophy which has been made possible by DSPs and PCs. Details are given of a prototype design. Test results for the prototype relay are presented.

Open Systems Relaying, P. G. McLaren, E. Dirks, A. Neufeld, R. W. Haywood, G. W. Swift, Z. Zhang, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper describes a different approach to designing new relays. The approach suggests the use of off-the-shelf hardware and software which is designed to run on a standard operating system. Results for a prototype relay designed using this approach are presented.

A New Universal Protective Relay Architecture, its Philosophies, and Implementations, T. Newton, E. Lee, D. Rogers, D. Weinbach, B. Szczepanski, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. A new universal protective relay hardware and software architecture is described which exhibits certain advantages versus the conventional monolithic and application-specific architectures. These advantages could be of particular value where customization or high integration is desired.

Reduction of Substation Control Room Equipment and Cost, Through Integrated Control and Protection, R. Schultz, C. Adamson, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper is one utility's attempt to outline the benefits of totally replacing the existing control room equipment with a new system. The emphasis is on how a system will simplify and enhance the automation of a substation control room.

Present Day Substation Protection and Control Engineering Tools, K. Sridharan, G. Payne, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper discusses the approach and the tools for substation protection and control engineering. Data engineering tools for integrated protection and control are also illustrated.

3155.1 Transformer and Reactor Protection

Overcurrent Relays Versus Current Limiting Power Fuses for Transformer Primary Protection, J.C. Das, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. Presented is an analysis of the transformer protection in terms of electrical distribution system configuration, transformer impedances, winding connections, and the grounding arrangements. The necessity for additional protective devices for an effective through fault protection is demonstrated.

Integrated Digital Power Transformer Protection, B. Grcar, D. Dolinar, IEE Proceedings - C, Vol. 141, No. 4, 1994, p 323-8. This paper presents the hardware and software of a prototype integrated transformer protection system which provides protection against short-circuits, ground faults, and turn-to-turn faults. Results of laboratory and field testing are given.

Phase Angle Regulating Transformer Protection, M. A. Ibrahim, F. Stacom, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 394 - 404. The paper describes the protection of a 345kV, 450 MVA phase shifting transformer with a 32 step load tap changer. Complete protection requires a combination of differential, ground overcurrent, and sudden pressure relaying. The location and ratio of current transformers for differential relaying are discussed.

3155.2 Capacitor Bank and Static Var Protection

Fault Tolerable Programmable Controller for 500-KV Capacitor Protection and Control, R.D. Johnson, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. Described is one utility's approach to the protection and control of 500-KV capacitor banks which provided them with the necessary redundancy and fault tolerance.

HL&P 138-KV Capacitor Bank Relaying, D.R. Sevcik, C.W. Fromen, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. This paper discusses one utility's operating experience and protection philosophy concerning 138-KV capacitor bank installations.

3155.3 Other Protection

Intelligent Reclosing Functions for Microprocessor Distribution Protection Relays, A.P. Apostolov, I.S. Balinova, J.D. Bronfeld, M.W. Feltis, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. This paper describes one utility's use of a microprocessor distribution relay to design and implement an intelligent reclosing and tripping scheme in order to find a cost effective method of solving an overdutied breaker problem.

Power System Application of Phasor Measurement Units, R.O. Burnett, Jr., M.M. Bulls, P.S. Sterlina, IEEE Computer Applications in Power, Vol. 7, No. 1, Jan 1994, p 8-13. Synchronized sampling and high accuracy analog-to-digital converters form the basis of synchronised phasor measurement units that can measure the state of the power system at given instant. Applications for fault recording, disturbance recording, transmission and generation verification, and power system stabilization are outlined.

Application of Programmable Logic Controllers to Substation Control and Protection, J. G. Gilbert, G. R. Diehl, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 384-93. PLC requirements are discussed and the concept of "zones of control" is explained as applied to standard PP&L substation arrangements. The PLCs receive inputs from fault sensing relays, control switches, transducers, and aux. switch contacts. PLC outputs are now suitable for breaker tripping and other control functions. Details of a 1992 installation are presented, including experience acquired from power system faults.

Synchronized Sampling and Phasor Measurements for Relaying and Control, IEEE Power System Relaying Committee Report, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 442-52. This paper describes the concept of using time synchronized sampling over an entire power system to obtain phasor values of voltages and currents at particular instants of time. Various methods of providing synchronizing signals are examined. Possibilities for applications in protection and control tasks of the future are explained.

Static Power Converters of 500 kW or Less Serving as the Relay Interface Package for Non-Conventional Generators, IEEE Power System Relaying Committee Report, IEEE Trans on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1325-31. This paper presents the summary of the special publication whose purpose is to illustrate those Static Power Converter (SPC) characteristics that can obviate the need for the interface relay protection package normally required by a utility. A qualifying SPC can detect utility system disturbances that would require generator separation in addition to its normal function of protection and control of the dispersed storage and generation system.

Using Artificial Neural Networks for Load Shedding to Alleviate Overloaded Lines, D. Novosel, R. L. King, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 425-33. The paper discusses a system of neural networks to detect overloaded lines and make intelligent decisions on where and how much load should be dropped. The proposed system avoids unintentional separation of the system.

Protection Upgrading - A Utility Perspective, S. Reilly, J. Monaghan, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-204. Effects of system grounding on ground fault detection, and issues considered in replacement of remote backup with local breaker failure, pilot channel selection, bus protection, and transformer overfluxing are discussed.

Adaptive Protections Based on Interaction Between Protection and Control, B. Sander, S. Laderach, H. Ungrad, F. Ilar, I. De Mesmaecher, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-205. Examples of adaptive protection applications are given, followed by a discussion of requirements for integrating the new adaptive technologies into network and substation control systems.

3156 FAULT AND SYSTEM CALCULATIONS

Maximum Likelihood Estimation of Fault Location on Transmission Lines Using Traveling Waves, G. B. Ancell, N. C. Pahalawaththa, IEEE Trans. on Power Delivery, Vol. 9, No. 2, Apr 1994, p 680-9. This paper presents an improved method for fault location and examines its effectiveness for small fault angles and close-in faults. A matched filter (correlator) based on the initial surge to reach the relaying point is used to determine when the reflected surges return.

Analysis of Random Sequential Complicated Faults on a Balanced Power System, B. K. Bhat, Electric Power Systems Research, Vol. 28, 1994, p 201-10. This paper presents the most general method for analyzing faults. The method proposed imposes no restriction, either on the sequence in which the complicated fault develops or on the instants at which the individual faults develop.

A Parallel Processing Algorithm for Coordination of Directional Overcurrent Relays in Interconnected Power Systems, H.B. Elrefaie, M.R. Irving, S. Zitouni, IEE Proceedings - C, Vol. 141, No. 5, 1994, p 514-20. The paper proposes a parallel processing coordination algorithm which depends on the interaction balance principle of linear programming. Implementation of the algorithm and results showing comparison with the conventional linear programming algorithm and Benders algorithm are given.

Automatic Relay Coordination, W. English, C. Roger, IEEE Computer Applications in Power, Vol. 7, No. 3, Jul 1994, p 22-5. Consumer Power automated several steps in relay coordination checking process by using macros that access a comprehensive power system data base. The paper describes relay coordination concept, coordination program and, fuse and relay coordination.

An Improved Fault Analysis Algorithm for Unbalanced Multi-Phase Power Distribution Systems, S.M. Halpin, L.L. Grigsby, C.A. Gross, R.M. Neims, IEEE Trans. On Power Delivery, Vol. 9, No. 3, Jul 1994, p 1332-8. The results of an improved method for fault calculations in an unbalanced multi-phase power distribution systems containing non-utility generators and large induction motors are presented. The method uses a combined time- and frequency-domain analysis approach to produce results.

An Accurate Fault Location Algorithm using Synchronized Sampling, M. Kezunovic and J. Mrkic, Electric Power Systems Research, Vol. 29, 1994, p 161-9. This paper introduces new fault location algorithms based on synchronized sampling. Samples of voltages and currents at the ends of a transmission line are taken synchronously and used to calculate fault location.

An Overview of Digital Fault Location Algorithms for Power Transmission Lines Using Transient Waveforms, B. Lian and M. M. A. Salama, Electric Power Systems Research, Vol. 29, 1994, p 17-25. In this paper, the algorithms utilizing the differential equation and the traveling-wave approach are reviewed.

Optimal Fault Location for Transmission Systems, D. Novosel, D.G. Hart, M.M. Saha, S. Gress, ABB Review, No. 8, 1994, p 20-7. One-terminal data algorithms and two-terminal data algorithms for locating faults on transmission lines are discussed. These algorithms use current and voltage data. Some field results for both algorithms are included.

Fault Location in Radial Networks, W. Tenschert, Transmission and Distribution, Vol. 5, No. 3, 1994, p 54-6. A technique for locating faults on radial networks which is used by the Electricity Utility of Upper Austria is described in this paper. Operational experience and future developments are discussed.

3157 MAINTENANCE, TESTING, ANALYSIS, AND MODELING

Developing a Philosophy for Testing of Digital Protective Relaying Schemes, G. E. Alexander, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. Discussed is the history of relay testing and the need to develop a new methodology for the newer technologies being utilized today. The importance of thorough evaluation testing of new relays prior to use is discussed as well as the potential impact of software upgrades.

Transformer Model for Winding Fault Studies, P. Bastard, P. Bertrand, M. Meunier, IEEE Trans. for Power Delivery, Vol. 9, No. 2, Apr 1994, p 690-9. Modeling of the faulted transformer involves splitting the faulted winding into 2 or 3 sections . The paper describes a method to determine the 7x7 or 8x8 matrices representing the R & L impedances of the faulted transformer. Comparisons between experimental tests and corresponding simulations are described.

Time-Current Coordination Concepts, G. Benmouyal, S.E. Zocholl, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. This paper traces the origins of the shape of the well known induction characteristics in the electromechanical principle and the characteristics possible in microprocessor-based overcurrent designs. While drawing some conclusions, the paper recommends additional work in this area.

Justification and Basis for a North American Inverse Time Overcurrent Relays Standard, G. Benmouyal, S. E. Zocholl, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-101. Equations are derived for design of microprocessor time overcurrent relays based on induction disk relay principles.

Staged Fault Tests to Validate High Impedance Fault Detection Methods, J.S. Benton, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. Presented is one utility's approach to validate high impedance fault detection methods. The results of the staged faults which were monitored with digital recording instruments and played back through virtual instruments are discussed.

Protection System Representation in the Electromagnetic Transients Program, A. K. S. Choudhary, K.S. Tam, A. G. Phadke, IEEE Trans. on Power Delivery, Vol. 9, No. 2, Apr 1994, p 700-11. This paper concerns with the addition of models for current transformers and capacitor voltage transformers to the EMTP. The models represent the non-linearities of the instrument transformers and the presence of remanent flux in the core. Models of specific relays are also available.

The Influence of Third Harmonic Currents on the Operation of Single Phase Neutral Overcurrent Protection Relays, C.L. Coleman, J.B. Grant, D.E. Todd, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. The influence of the third harmonic currents on the operating time of selected relays is presented.

Developments in Dynamic Testing of Digital Motor Protection, J.M. Dunne, J.D. Gardell, H.J. King, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. Described is a methodology of testing digital motor protection using a process which combines static and environmental testing with full scale dynamic testing using a data base of actual faults and operating conditions.

Extensive Evaluation of High Performance Protection Relays for the Hydro-Quebec Series Compensated Network, C. Gagnon, P. Gravel, IEEE Trans. on Power Delivery, Vol. 9, No. 4, Oct 1994, p 1799-1811. Performance comparison of eight line protection systems on the Hydro-Quebec series compensated network are reported. The paper presents the evaluation of commissioning aspects and manufacturing quality of tested relays. The simulated network, the relay testing procedure, and laboratory test results are described.

A Computer Package for Teaching Relay Coordination and Loop Based Network Solution, S.K. Goswami, S.K. Basu, IEEE Trans. on Power Systems, Vol. 9, No. 2, May 1994, p 572-8. This paper reports the development of a relay coordination package specially designed as a teaching aid.

A Survey of Relay Test Practices, 1991 Results, IEEE Power System Relaying Committee Report, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1339-51. The results of a survey of North American Relay Engineers concerning their practices for testing protective and other relays as well as personnel requirements are presented.

Potential Applications of Expert Systems to Power System Protection, IEEE Power System Relaying Committee Report, IEEE Trans. on Power Delivery, Vol. 9, No. 2, Apr 1994, p 720-9. The paper contains descriptions of six protection problem areas where expert system methodology may be useful. Particularly the application and coordination of protective devices involve skill and experience where an expert system approach may be well suited.

Recommended Approach for Calculating Degraded Voltage Relay Setpoints for Nuclear Generating Stations, J.R. Jancauskas, IEEE Trans. on Energy Conversion, Vol. 9, No. 1, Mar 1994, p 173-8. This paper presents an approach for performing calculations to determine degraded voltage relay setpoints. The approach attempts to ensure that all relevant design issues are addressed.

Improved Techniques for Modelling Fault Arcs on Faulted EHV Transmission Systems, A.T. Johns, R.K. Aggarwal, Y.H. Song, IEE Proceedings - C, Vol. 141, No. 2, 1994, p 148-54. A time dependent dynamic resistance representation of the primary arc is proposed with emphasis on an empirical approach which is used to determine the parameters concerned.

Transients Computation for Relay Testing in Real-Time, M Kezunovic, M Aganagic, V. Skendzic, J. Domaszewicz, J.K. Bladow, D.M. Hamai, SM McKenna, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1298-1307. The paper discusses the characteristics of a digital simulator for protective relay testing. Design requirements, system architecture and real-time techniques used for transients computation related to network reconfiguring and simulating non-linear components are presented. Performance evaluation results are also given.

Experimental Evaluation of EMTP-Based Current Transformer Models for Protective Relay Transient Study, M. Kezunovic, L. Kojovic, A. Abur, C. W. Fromen, D. R. Sevcik, F. Phillips, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 405-13. The paper describes an EPRI study of three digital CT models for protective relay transient performance analysis. Two relaying CTs were tested to obtain comparison data. EMTP simulations of the same events were applied to the three models. The results are given and described.

New Digital Simulator Designs for Protective Relay Testing, M. Kezunovic, S.M. McKenna, B.A. Pickett, C.W. Fromen, M. Wilhelm, 47th Annual Texas A&M Conference for

Protective Relay Engineers, Mar 21-23, 1994. Results of several research and development activities related to digital simulators for relay testing are included in this paper. Each of the various configurations are described and their characteristics are presented.

Real-Time Digital Simulator for Protective Relay Testing, M. Kezunovic, S.M. McKenna, IEEE Computer Applications in Power, Vol. 7, No. 3, Jul 1994, p 30-5. This paper describes digital simulator design aimed at providing real-time operation while preserving accuracy and flexibility.

Assessing the Effectiveness of Self-Tests and Other Monitoring Means in Protective Relays, J. J. Kumm, E. O. Schweitzer, III, D. Hou, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper presents a scientific model for assessing the effectiveness of protective relay maintenance. Digital relay monitoring methods are presented which may extend the relay self-test. Statistical models quantify the benefits of relay self-tests and illustrate the usefulness of additional monitoring features.

An Efficient Method for Generation, Storage, and Retrieval of Data for the Coordination of Directional Relays, N. A. Laway and H. O. Gupta, Electric Power Systems Research, Vol. 29, 1994, p 147-52. An algorithm is developed to determine the backup/primary relay pairs for the coordination of directional protective relays of power transmission systems.

Satellite-Synchronized, End-to-End Testing on Transmission Line Protection Schemes Including Recent Field Experience, J. Littman, B. Ryan, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper discusses the application of public domain satellite timing signals to synchronize simultaneous tests at each end of transmission line protective relay schemes. Discussed are the principles and history. The need for such a test method and the details of a recent series of tests are included.

Real-Time EMTP-Based Transients Simulation, J.R. Marti, L.R. Linares, IEEE Trans. on Power Systems, Vol. 9, No. 3, Aug 1994, p 1309-17. A computer program that can achieve the required timings for relay testing in real-time is reported. The program accepts standard EMTP data cases and can be compiled and run in any computer platform with an ANSI C compiler.

Testing Modern Protective Relays, R. J. Martilla, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. Relay testing philosophy, experience, and capabilities developed at Ontario Hydro are described in this paper.

Relay Database Design, J. McClain, S. M. Chan, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper describes the relay database designs that are currently in use and presents a new design that is more flexible, easier to use, and utilizes computer memory more efficiently. The paper also covers the issue of database integrity and the IEEE database model.

On-Site Relay Transient Testing for a Series Compensation Upgrade, P.G. McLaren, R. Kuffel, J. Giesbrecht, W. Keerthipala, A. Castro, D. Fedirchuk, S. Innes, K. Mustaphi, K. Sletten, IEEE Trans. on Power Delivery, Vol. 9, No 3, Jul 1994, p 1308-15. This paper describes tests on the relays on a long 500 kV ac line carried out on site using the Real Time Digital Simulator. The purpose of the tests was to examine the relay behavior when series compensation is inserted in the line. New settings for the relays were found which will give adequate cover for all faults.

On-Site Transient Testing for a Series Compensation Upgrade, P.G. McLaren, R. Kuffel, J. Giesbrecht, W. Keerthipala, S. Innes, A. Castro, D. Fedirchuk, K. Mustaphi, K. Sletten, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. This paper describes tests on the relays on a long 500 kV line carried out on site using the Real Time Digital Simulator. The purpose of the tests was to examine the relay behavior when series compensation is inserted in the line.

A Refurbishment Scheme for Transmission Line Protection Relays, A. N. Molkov, G. Koch, Th. Liebach, CIGRE, Paris, Aug 28-Sep 3, 1994, Paper No. 34-105. Testing program and issues considered in selecting numerical relays for replacing existing analogue relays on the Ukraine Power's 750 kV transmission system are described.

Power System Disturbance Monitoring, R. J. Murphy, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. The ability to synchronously acquire power system measurements over large areas opens a new window on dynamics occurring within the power system. This paper describes a number of disturbances recorded throughout the US by GPS satellite-locked disturbance recorders.

Electromechanical Relay Technology Transfer to Operating and Maintenance Personnel, R.C. Patterson, J.E. Teague, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. Some of the challenges that face utilities as they struggle with the transition from electromechanical relay technology to the new generation relaying systems and communication networks are this paper's focus.

Modeling the Protective System for Power System Dynamic Analysis, L. G. Perez, A.J. Flechsig, V. Venkatasubramanian, IEEE Trans. on Power Systems, Vol. 9, No. 4, Nov 1994, p 1963-73. The paper describes procedures for modeling relays in power system dynamic studies. New concepts, such as, the notion of relay success regions are introduced and other problems of current interest are discussed.

Stochastic Analysis in the Time Domain of Very High Speed Digital Distance Relays, Part 1: Theory, Part 2: Illustrations, J.L. Pinto de Sa, IEE Proceedings - C, Vol. 141, No. 3, 1994, p 161-8 (Part 1), p 169-76 (Part 2). A time-domain approach to the stochastic analysis of very high speed digital distance relays is introduced in Part 1. In Part 2, the theory developed in Part 1 is applied for evaluating impedance algorithms based on phasors estimated through Fourier transform and Kalman filters.

Real-Time Software Testing for Microprocessor-Based Protective Relays, N.I. Santoso, J.Y. Avins, IEEE Trans. on Power Delivery, Vol. 9, No. 3, Jul 1994, p 1359-67. This paper describes a new practical method, domain-partition boundary method with software probes, and test platform for testing real-time software embedded in protective relays. Implementation of the test scheme and test results from a motor control and overload protection device are presented.

Synchronous Generator Capability Curve Testing and Evaluation, N. E. Wilson, J. Mercurio, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 414-24. Changes in system characteristics led to MVAR capability range tests of all generators on the Ohio Edison System. Normal operation masked problems which were not discovered until the generator MVAR capability tests were performed.

Calculation and Harmonic Analysis of Transient Inrush Currents in Three-Phase Transformers, J. C. Yeh, C. E. Lin, C. L. Huang, C. L. Cheng, Electric Power Systems Research, Vol. 30, 1994, p 93-102. This paper proposes a simple method, extended from that for single-phase transformers, to investigate three-phase transformer inrush currents. Harmonic analysis of the inrush currents is carried out.

3158 STABILITY, OUT OF STEP, RESTORATION

Neural-Network Based Adaptive Single-Pole Autoreclosure Technique for EHV Transmission Systems, R.K. Aggarwal, A.T. Johns, Y.H. Song, R. W Dunn, D.S. Fitton, IEE Proceedings - C, Vol. 141, No. 2, 1994, p 155-60. In this paper, an adaptive single-pole autoreclosure technique is developed using artificial neural networks. Performance results are also included.

Comanche Peak Unit No. 2 100% Load Rejection Test-Underfrequency and System Phasors Measured Across TU Electric System, D. Faulk, R.J. Murphy, 47th Annual Texas A&M Conference for Protective Relay Engineers, Mar 21-23, 1994. This paper describes the procedure and devices used to document the system impact of a major load rejection test. It includes the results of the tests and provides insight into the system dynamics for this type of event.

Phasor Measurement Hardware and Application, R.J. Murphy, R.O. Burnett, 48th Annual Georgia Tech Protective Relaying Conference, May 4-6, 1994. Described is the implementation of a new technology which permits measurement and analysis of power system performance on a scale not previously possible.

A Microprocessor-Based Accelerating Power Level Detector, M. Nagpal, J.C. Albohert, W. Zaracki, CEA Engineering and Operating Div. Meetings, Mar 20-24, 1994. Hardware, software, and implementation of a microprocessor-based accelerating power level detector are described in this paper.

A Delta-Current Admittance Relay For Line Loadability Enhancement, G. Sweezy, G. Swift, R. Coish, 21st Annual Western Protective Relay Conference, Oct 18 - 20, 1994. This paper offers one solution for out-of-step distance protection where the normal load of a Minnesota- Manitoba Hydro series compensated 500-KV tie line is inside practical settings for out-of-step blinder relays. The problem is explained, conventional wisdom discussed, and a new concept set forward.

3159 SURGE PHENOMENA

Power Distribution System Equipment Overvoltage Protection, D. Paul, S.I. Venugopalan, IEEE Trans. on Industry Applications, Vol. 30, N0. 5, Sep/Oct 1994, p 290-7. Selection of surge protective devices should be based on the magnitude of surge overvoltage and the expected energy associated with the surge. This paper reviews the characteristics of surge arresters and discusses the MOV surge arrester selection parameters.

HEMP Environment for Protective Relays, D. E. Thomas, C. M. Wiggins, T. M. Salas, P. R. Barnes, IEEE Trans. on Power Delivery, Vol. 9, No. 1, Jan 1994, p 471-9. This paper examines the means of coupling a High altitude Electro Magnetic Pulse field to protective relays, and the effect on the relays and associated circuits. Measured impulse responses of one solid-state relay were compared with predicted HEMP stresses which are higher than the SWC tests allow.

LIST OF PERIODICALS

ABB Review
ABB Marketing Services Ltd., P.O. Box 58, Baden, CH-5401, SWITZERLAND

Canadian Electrical Association (CEA) - Engineering and Operating Div. Meetings
Suite 1600, 1 Westmount Square
Montreal, PQ H3Z 2P9, CANADA

Canadian Journal of Elec. & Comp. Eng.
Engineering Institute of Canada
Suite 700, 2050 Mansfield Street
Montreal, PQ H3A 1Z2, CANADA

CIGRE
3-5 rue de Metz, F75010, Paris, France

Electric Light and Power
Technical Publishing Co., 1301 South Grove Ave., Barrington, IL 60010
Electric Construction and Maintenance
McGraw Hill Publishing Co., 1221 Avenue of the Americas, New York, NY 10020
Electric Power System Research
Elsevier Sequoia S.A., P.O. Box 564, Lausanne, CH-1001, SWITZERLAND
Electrical Review
Reed Business Publishing, Central House, 27 Park Street, Croyden, CRO 1YD, U.K.
Electrical World
11 West 19th Street, New York, NY 10011
Georgia Tech Protective Relaying Conference
Georgia Institute of Technology, Atlanta, GA 30332
IEE Proceedings
Institute of Electrical Engineers, Michael Faraday House, Six Hills Way, Stevenage, Herts SG1 2AY, U.K.
IEEE Transactions, Journal and Conference Papers
IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331
Power
McGraw Hill Publishing Co., 1221 Avenue of the Americas, New York, NY, 10020
Texas A&M Protective Relaying Conference
Texas A&M University, College Station, TX, 77843
Transmission and Distribution
Intertec Publishing Inc., 5072 West Chester Pike, Edgemont, PA, 19028
Western Protective Relaying Conference
Washington State University, Pullman, WA, 99163

SUMMARY OF IEEE STANDARD C37.90.2-1995 "WITHSTAND CAPABILITY OF RELAY SYSTEMS TO RADIATED ELECTROMAGNETIC INTERFERENCE FROM TRANSCEIVERS"

Prepared by Working Group E2‡
High-Frequency Radiation Effects On Static Control and Protection Devices
of the
Relay Electrical Environment Subcommittee
of the
IEEE Power System Relaying Committee

Abstract

This paper describes the experience with the Trial Use Standard ANSI/IEEE C37.90.2-1987, the discussions in Working Group E2 of the Power System Relaying Committee, and the changes that have been made to the 1987 trial use standard before the 1995 standard was approved. The major change is a substantial increase in the required field strength, now 35 volts/meter vs. the previous 10-20 V/m.

Introduction

Twenty years ago, a static transformer differential relay false tripped when a walkie-talkie was keyed in close proximity to the relay. This incident, and numerous others, led the industry to establish trial use standard ANSI/IEEE C37.90.2-1987 [Ref.1]. In addition, a summary paper 90 SM 304-6 [Ref. 2] was prepared which provided background information on the need for the standard, a thorough overview of misoperations experienced, the effects of RFI on static relay circuitry, and on the failure modes due to RF. It included a description of the RFI test and the test parameters, and defined "what the test does not do". Based on three years' experience, included were suggestions for improvement to the standard.

That summary paper is a valuable reference to those seeking to understand the background of the RFI standards for protective relays, and should be in the library of any one responsible for the design of relays to achieve the prescribed level of RF immunity, for RF proof testing of new designs, and most importantly, those who operate walkie-talkies in the vicinity of static devices.

The 1987 Working Group requested feedback from those testing relays per the trial-use standard. In the Foreward to that document, comments were requested in the following areas:

(1) Is the test relatively straightforward to perform? Describe problem(s) encountered.

(2) Were the test procedures and test results easy to interpret?

(3) Are the test results repeatable?

(4) Does amplitude modulation or the keying test produce malfunctions not detected by the continuous wave test?

Based on the comments received on these matters, and on the fundamental issue of RF test level, there was a clear need to revise and update the 1987 Standard.

Utility Experience With The 1987 Trial Use Standard

When the 1987 standard was being considered, an attempt was made to seek a reasonable balance between operating practices and design requirements. At that time, there was a concensus for the requirement that portable transceivers (walkie-talkies) not be keyed when closer than one meter from a relay. Measurements made on typical utility transceivers showed that the signal level at one meter was in the range of 10 to 20 V/m. This then led to the specification of a test signal level of 10-20 volts/meter, which was consistent with Standard PMC 33.1, 1978 of SAMA (Scientific Apparatus Manufacturers Association) "Electromagnetic Susceptibility of Process Control Instrumentation". That standard had three classes of field strength; Class 1 = 3 V/m, Class 2 = 10 V/m, and Class 3 = 30 V/m. Class 2 was defined as "moderate electromagnetic radiation

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‡ D.C.Dawson, *Chairman,* J.T.Tengdin, *Vice Chairman,* J.Andrichak, J.F.Banting, T.R.Beckwith, J.Burnworth, H.J.Calhoun, C.L.Downs, K.J.Fodero, J.G.Gilbert, W.C.Kotheimer, M.S.Simon, J.Teague

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environments, e.g. portable transceivers and mobile transceivers that can be relatively close to the equipment, *but not closer than one meter.*" (emphasis added)

During the Working Group discussions of the trial use standard with utility engineers, it became clear that the electric utilities had no practical means of enforcing a one meter separation between a static relay and a portable transceiver. And if the one meter separation was unrealistic, then the entire RF test level had no validity. Further, the Working Group received reports of relays which passed the manufacturer's test were failing the utilities' empirical tests with walkie-talkies.

Working Group Response

The immediate question was "What RF levels are generated by typical portable transceivers?" The following is quoted verbatim from the Annex to the 1995 Standard:

"Transceiver Field Strength Test Data
During the development of this Standard, two members of the Working Group contributed test data on the measured field strength of 5 watt, 150 and 450 MHz walkie-talkies at various distances from the measuring point. The maximum values are listed below for information.

Distance (cm)	*Field Strength (V/m)*
7.5	100
10	60
15	35
22	20
100	5

(end of quotation)

Based on these tests and numerous other factors, the Working Group concluded that requiring a 15 cm (6") separation between an operating relay and a portable transceiver was reasonable and practical. Thus, the new standard requires a 35 V/m field strength, which corresponds to the 15 cm separation.

Manufacturers Experience With The 1987 Standard

The 1987 standard defines a substitution method of determining field strength at the face of a relay. The relay or equipment to be tested was removed from the test chamber and replaced with a field strength receiving antenna. The test transmitter was then adjusted to achieve the required field strength. The equipment was then re-installed for the test. However, as the test frequency was swept through the required range, reflections from the relay or equipment under test could cause changes in the signal strength. So the test specimen had to be removed and replaced by the receiving antenna for calibration. In addition, some RF test chambers were designed for stepped frequency tests rather than the required swept frequency test.

The standard also required a 1000 Hz sine wave modulation test below 50 MHz, and a 10 kHz square wave modulation test for digital equipment. Neither of these tests proved to yield additional information.

Working Group Response

The new standard requires a field strength receiving antenna to be mounted at 5 cm from the face of the relay under test. From this antenna, a feedback signal is provided so that the test transmitter may be adjusted to maintain the prescribed signal level.

Stepped frequency tests are now allowed, but the step size is a maximum of 1 MHz. This requirement was established as one manufacturer reported frequency sensitivities 2 MHz apart with a null between.

The 1000 Hz modulation test and the 10 kHz square wave tests have been eliminated.

Other Changes In The 1995 Standard

The standard now explicitly requires that the tests be performed with access doors closed and covers in place. The tests are now performed on four sides of a relay or equipment (excluding top and bottom, which were previously required on relays). Wires connected to the relay under test must now be unshielded (previously shielded was required) unless the manufacturer requires the relay normally be installed with shielded wires.

A new section has been added, replacing the "General Conditions" section, to define the in-service conditions of the relay under test. It reads as follows:
"5.2 In-Service Conditions. It is the intent of this test to duplicate as nearly as possible in-service conditions with the relay in its normal non-transitional state. Where appropriate, the relay shall be energized with rated voltage and current equal to 75% of the nominal CT rating. The relay settings should be chosen such that the relay is as close as possible to its transitional state, but not closer than the recommended margins for its application. Input voltage to the power supply circuit must be within specified limits."

This new section is identical to the requirements of C37.90.1, the SWC test.

The last sentence of Section 6.0 Acceptance Criteria has been changed. The section now reads: "A test is successful when no erroneous output is present, no component failure occurs, and there is no change in calibration exceeding normal tolerance. An erroneous output is one that presents false information, such as targets or trip outputs." The previous reference to "missing bits, unwanted bits, and synchronization errors" have been eliminated.

The following bold faced CAUTION has been added at the end of the new standard:

CAUTION

Successful completion of this test demonstrates that the relay has a practical level of withstand capability to electromagnetic interference. It does not guarantee that the relay is immune to false operation from incautious use of walkie-talkies in close proximity to the relay."

NOTE THAT THE STANDARD DOES NOT COVER THE OPERATION OF WALKIE-TALKIES CLOSER THAN 15 cm (6") TO A RELAY.

References

[1] ANSI/IEEE C37.90.2-1987
Draft American National Standard
IEEE Trial-Use Standard
"Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Tranceivers"

[2] "Summary of 'Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers' (ANSI/IEEE C37.90.2-1987)" by J.F.Banting, T.Beckwith, J.Burnworth, H.J.Calhoun, D.C.Dawson (C), C.L.Downs, A.T.Giuliante, W.C.Kotheimer, L.Scharf, J.Tengdin IEEE Transactions on Power Delivery, January 1991, Volume 6, Number 1, pp. 103-108.

Figure 1

SHIELDED ENCLOSURE FOR TESTS (FROM C37.90.2)