

Preface

Modern power systems involve large amount of investment. An electric power system comprises of generation, transmission, and distribution of electric energy. Growth of power systems has led to very complex networks extended across large areas. In such situations, the proper functioning of a modern power system is heavily dependent upon the healthy operation of the transmission lines within it. Transmission lines are used to transmit a huge amount of power over a long distance. But as these lines are located in the open atmosphere, they are highly affected by different types of abnormal conditions or faults. Therefore, they are very likely to be subjected to different types of electrical faults. If the faults are not detected and removed quickly then, in the worst case, they may create instability of the power system, resulting in the shut down of either the large parts of the network or the complete network. The causes and the consequences of faults can be minimized by operating the power system in a proper way and using sophisticated protective relays. Generally, numerical distance protection scheme is utilized to perform a task of providing adequate protection to the overhead transmission lines against such conditions. It is desirable that this protection system must be able to identify different types of faulty conditions within a minimum possible time delay. This book is devoted to the development of different types of protection schemes for different types of faults occurred in different configurations of transmission lines.

Looking to the above need, it is necessary to provide theoretical and practical education of protective devices to students as well as engineers working in industry and utility. The knowledge of protective devices is helpful to the power system engineers during design, erection, procurement, and maintenance of various power system components. Further, the study of relays also provides ample amount of knowledge to students and field engineers regarding the procedure of actual relay settings in the practical scenario.

About the Book

This book aims to give a comprehensive up-to-date presentation of the role of protection safety system and its advances in modern power system. This book begins with a state-of-the-art survey of theories and methods of transmission line protection. In continuation, it provides a theoretical summary along with examples of real-life engineering applications to a variety of technical problems. With this point of view, the book bridges the gap between the theoretical advances, experimental validations, and practical engineering in real life.

This book primarily targets undergraduate and postgraduate students as a text book and a reference book for researchers. This is equally important for power system engineers requiring information about the principles and choice of transmission line protection.

This is an academic book which is to be prepared to serve as a reference book in power system protection for undergraduate and postgraduate students of various technical universities. This book covers analytical techniques for transmission lines in easily comprehensible manner so that academicians and researchers will not find any difficulty. Further, the discussion of various digital relaying schemes for series compensated transmission line protection is one of the unique features of this book.

Content and Coverage

Chapter 1 deals with introduction of the problems, basic requirements of the protection systems and discusses the importance of primary and back-up relaying. This chapter provides the history of development of protective relays from the first generation electromechanical relays to the present digital/adaptive relays. It emphasizes on the research opportunities in the area of digital protection of single infeed and double infeed transmission lines for high resistance ground faults, protection of uncompensated/series compensated transmission lines for different types of simultaneous faults (earthed/unearthed inter-circuit faults, simultaneous open conductor and ground fault), and protection of series compensated lines for phase faults.

Chapter 2 addresses the problems encountered by the conventional digital distance relay used for the protection of transmission line fed from one end. In order to observe its behavior during a high resistance single line-to-ground fault, a laboratory prototype of three-phase transmission line, using equivalent power system components, has been developed. Afterwards, a new digital distance relaying algorithm is presented for the compensation of errors produced by the conventional digital distance relay during a high resistance single line-to-ground fault. Further, the proposed algorithm has been tested using MATLAB/SIMULINK software for a

single line-to-ground fault considering wide variations in fault resistance, fault location, power factor, and short-circuit capacity of source. Moreover, it has been demonstrated that the proposed algorithm provides effective discrimination between in-zone and out-zone fault occurred at the zone boundary of the transmission line.

Chapter 3 deals with the problems faced by the conventional ground distance relaying scheme for different types of high resistance ground faults (such as single line-to-ground, double line-to-ground, and simultaneous open conductor and ground), while protecting double infeed transmission lines. Further, a new digital distance relaying scheme is proposed, which compensates the errors produced by the conventional ground distance relaying scheme using local-end data only. Moreover, a detailed analysis of the apparent impedance as seen from the relaying point by the conventional ground distance relaying scheme and the proposed scheme during different types of ground faults is also presented in this chapter.

Chapter 4 presents a new digital distance relaying scheme that takes care of all the abnormalities of the conventional ground distance relays and measures the correct value of the fault impedance during phase-to-phase and phase-to-phase-to-ground inter-circuit faults. The impact of fault resistance and mutual coupling phenomena has been considered during such types of inter-circuit faults. To validate the proposed scheme, numerous computer simulations have been carried out on an existing 400 kV parallel transmission line network.

Chapter 5 deals with a new digital distance relaying scheme that takes care of simultaneous open conductor and ground fault occurring coincidentally on the same phase at the same point on a series compensated parallel transmission line. The effect of series compensation, mutual zero-sequence coupling, remote infeed/outfeed, and fault resistance on the relay reach has been considered by the proposed scheme. The proposed scheme is validated by carrying out numerous computer simulations on an existing 400 kV, 300 km long series compensated parallel transmission line. At the end, a comparative evaluation between the proposed scheme and the conventional scheme having a facility of series compensation is carried out.

Chapter 6 focuses on the issues related to the protection of series compensated parallel transmission line against the presence of various types of inter-circuit faults. In addition, this chapter also covers other unsolved problems, such as the effect of mutual coupling and fault resistance. Afterwards, a new digital distance relaying scheme is proposed, which takes care of all such abnormalities of the conventional ground distance relays for phase-to-phase and phase-to-phase-to-ground inter-circuit faults. Finally, the performance of the proposed scheme has been tested using MATLAB/SIMULINK software on an existing part of the Indian 400 kV, 300 km long series compensated parallel transmission line.

Chapter 7 addresses the problems encountered by the conventional non-pilot phase distance relay protecting double infeed series compensated transmission lines. Performance of conventional non-pilot phase distance relay is affected by series capacitor, remote infeed/outfeed, pre-fault system conditions, and arc

resistance. Based on the extensive computer simulations of the infeed/outfeed, arc resistance and effects of series capacitor on the relay characteristics, a new digital distance relaying scheme is proposed. At the end, the proposed scheme is validated by numerous computer simulations on a 400 kV, 300 km long series compensated transmission line.

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