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A survey on intelligent system application to fault diagnosis in electric power system transmission lines

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ABSTRACT

Fault analysis and diagnosis constitute a relevant problem in power systems, with important economic impacts for operators, maintenance agents and the power industry in general. This has motivated the research and development of new algorithms and methods to address this problem. Intelligent systems have been proposed in the literature to deal with this problem in a significant number of applications. In the context of fault diagnosis in electric power systems, this survey presents a review of intelligent systems application to fault diagnosis in electric power system transmission lines. A huge number of related works can be found in the literature, being the major contributions reported in international journals. Then, the works cited in the present survey are restricted to those reported in regular journals that present high adherence to the aforementioned subject. The classification of strategies employed and their relationships with classical techniques are presented and discussed, allowing the identification of the main trends and research areas related to transmission line intelligent fault diagnosis systems.

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1. Introduction

Fault diagnosis in power systems includes the detection of the time origin of failures with the identification and location of the event that occurred in these systems [1]. The proliferation of monitoring systems together with the exponential increase in computers processing data has stimulated the development of technologies dedicated to diagnosing electrical power system failures. These systems aim to assist decision-making both in real-time operation and in planning environments. Regulatory agencies in Brazil establish severe monetary penalties for agents in cases of transmission equipment unavailability and system restoration delays. Therefore, the restoration of faulty equipment must take place in a fast and efficient way, stimulating the research in fault diagnosis systems.

In the 1980s and 1990s there were a great number of electromechanical relays responsible for generating the tripping signals to the breakers that protect the equipment in transmission overhead lines. On the other hand, there were not systems capable of classifying the faults. This task was delegated to the human operators, resulting in considerable time consumption to its restoration. In recent years several expert systems were developed to automate this task, to aid operators in quickly restoring the power system to its normal operational state after a fault. The widespread use of digital protection relays started in the 1990s using the modules of detection, classification, and location presented by the fault diagnosis systems. Those systems were designed for local fault diagnosis and were implemented with this equipment for these purposes. However, the intelligent electronic devices may fail in their operation and are focused on power system protection equipment, with a secondary commitment to the diagnosis of and reporting to human machine interfaces. Fault diagnosis systems are still important in the identification of missing or incorrect faults and for multiple-fault events. In addition, in operation centers that receive data from several substations, fault diagnosis systems can be used to extract information for operators to make decisions in concise and objective ways. Those systems can focus on detailed information about faults and incorporate knowledge from simulations in the diagnoses, adding or correcting important information for the systems' operators.

The problem of fault analysis and diagnosis in power systems has been a constant subject of technical literature over the last 60 years. The present work is the result of intensive research in the scientific literature related to themes classified as power transmission fault detection, classification, and location. Over 2100 documents including journals, conference proceedings, and book chapters,

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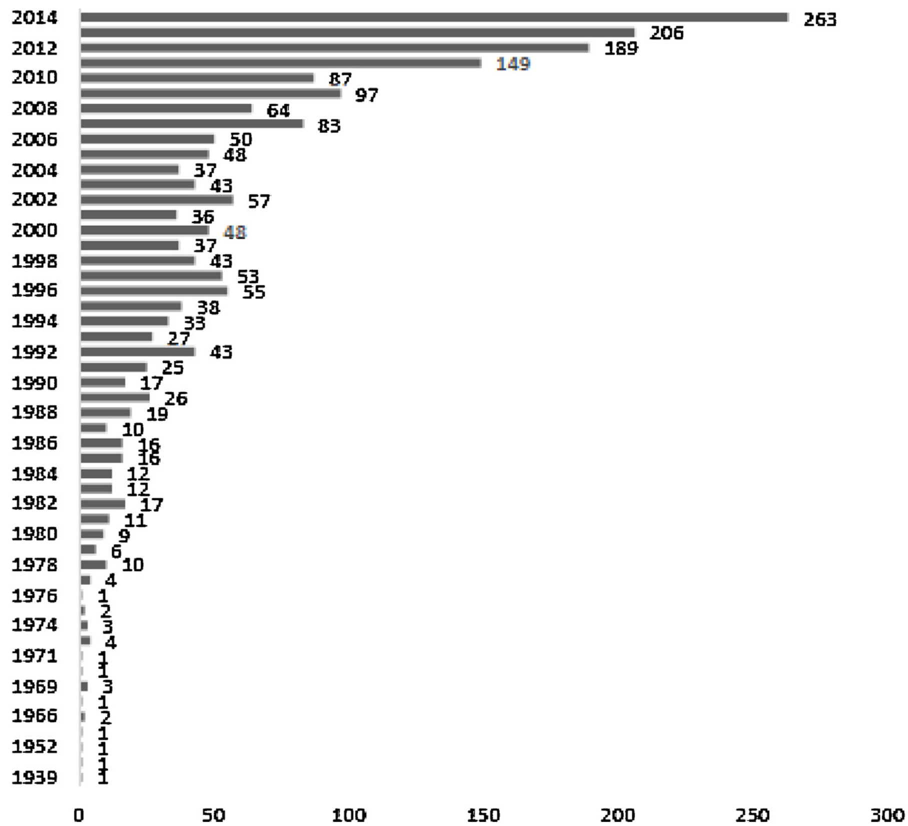

Fig. 1. Number of papers related to fault analysis in power system transmission lines in journals.

have been found. Considering the huge amount of related work in the literature and due to the fact that major contributions to those themes are usually published in international journals, only articles published in regular journals with high adherence to the aforementioned subjects have been selected as references for the present survey. Fig. 1 shows the number of papers related to fault analysis in power system transmission lines that were published in periodicals from 1939 to 2014. The search was conducted through scientific repositories (Science Direct and IEEExplore) using the following keywords: "Fault Location," "Fault Diagnosis," "Fault Detection", "Fault Classification," and "Fault Analysis".

In the following sections, a synthesis of the major contributions found in the selected articles is presented and shows an overview of different methodologies applied to the problem of fault diagnosis in electrical power transmission systems.

This paper is organized as follows. Section 1 presents the introduction. The Electromagnetic Transients Simulation, along with the main simulation parameters that must be varied for fault database generation, are discussed in Section 2. The three modules that constitute a full fault diagnosis system (fault detection, fault location, and fault classification) are detailed in Section 3. The techniques presented in literature for tackling the three fault diagnosis tasks, focusing on intelligent system algorithms, are discussed in Section 4. Given the large number of proposals, Section 4 is divided into subsections aiming to give an overview of the main Computational Intelligence techniques that have been considered for fault diagnosis systems. The main conclusions and research trends are discussed in Section 5.

2. Simulation of electromagnetic transients in transmission lines

The state of the art on transmission lines dynamic analysis of programmed or untimely outages is the time domain digital simulations using software for electromagnetic transients [1]. These tools can be applied to generate scenarios that will be stored in databases. Once these databases are ready, they will be used to train or to design the intelligent fault diagnosis systems. This approach is particularly useful in transmission equipment with a small number of registered events and can provide feasible situations not covered by the historical database of the real system.

The most widely used software tools for simulating electromagnetic transients are the PSCAD®, developed from EMTDC® [3], and new tools derived from EMTP® [4]. PSCAD [3] is one of the most used pieces of commercial software for the study of electromagnetic transients. This software implements the power system modeling methodology proposed in [4], based on the first version of EMTP software that ran on mainframe computers. More recently, ATPDraw® was developed by [5] with a graphic interface that helped its dissemination throughout a large group of companies and universities. This platform can simplify the construction of input files to be used by the ATP® software, which was developed based on the EMTP®, for personal computer users. The SIMULINK-MATLAB® [6] software is also widely used, probably due to the diversity of useful libraries integrated into this software.

Nowadays, the modeling methodology developed by Dommel [4] has been largely disseminated throughout the academic society. It is presented in a large number of books about electromagnetic transients [7–10]. The main advantages of this method are its simplicity, computational efficiency, precision, and numeric robustness. This efficiency can be credited to the use of sparsity and ordering matrix techniques [11] similar to those implemented in power-flow software.

At the beginning of EMTP [4] development, transmission lines had been represented by lumped-parameter models using RLC circuits in cascade with resistive, inductive, and capacitive coupling between phases, or by using the traveling-wave model in lossless lines with the characteristics method [12]. In such cases, the losses

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