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A multiple strategic evaluation for fault detection in electrical power system

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ABSTRACT

A new combined formalism is described to detect faults in electrical power systems in this work. The aim of fault detection is to monitor and control the system which guarantees stable supply of electrical energy to consumers. To solve this problem, it has been proposed an integrated use between state space, optimization and analytical method by establishing a methodology for its completion. Initially, state space method performs through deviations signaled by its output, an analysis with relation to direction of fault in each component of power system. Though, state space is in possession of as much information as possible coming from output signals, can identify direction where disturbance has been occurred. Finally, the processing is done by optimization and analytical methods, which analyze the exact fault type and locations, using these signs, corrective action have been taken. By using proposed technique, the tasks of fault detection, classification, and location are accomplished. The common case of faults occurring in the electrical power system has been illustrated to verify the proposed methodology.

1. Introduction

An important objective of power system is to maintain uninterruptible services, and to minimize the outage time. When abnormal condition occur, it is practically impossible to avoid consequences a natural events, physical accidents, equipment failure or misoperation, which results in the loss of power supply and voltage dips in the system. When faults occur in the power system, they usually provide significant changes in system quantities like current, power, power factor, impedance, frequency and voltage. Power system protection is the art of applying and setting up relays or fuses or both, to provide maximum sensitivity to faults and abnormal conditions. So it is desirable that a correct decision be made by the protective device as to whether the trouble is an abnormal condition or just a transient which the system can absorb and return to normal steady state condition. Power system fault detection using Kalman filter algorithm is proposed in Ref. [1]. In Ref. [2], Knowledge based fault diagnosis is used for power system. State estimation for conventional power system was proposed in Ref. [3]. Model-based fault diagnosis scheme for nonlinear dynamic systems with parametric uncertainties is presented in Ref. [4]. In Ref. [5], measurement stations belonging to control loop chains consisting of controller, actuators, device under control and instruments are considered for study of fault detection and isolation in automatic processes using analytical redundancy. All of these principles are based on predetermined network configuration taking into account worst-case fault conditions. The settings determined by the classical approach have inherent limitations in classifying certain faults if the network actual configuration deviates from the anticipated one. In such instances, the existing relays may miss operate [6]. Consequently, a more dependable and secure relaying principle is needed for classifying the faults under a variety of time-varying network configurations and events.

A number of methods have been proposed in the literature for reliable and early detection of faults. The monitoring condition of power systems is therefore very useful in the early detection of component failure which would lead to better operational safety and economy. In Ref. [7] correlation analysis between transmitted and reflected waveform is performed, whereas in Ref. [8] peak detection on the reflected waveform is used to identify possible fault locations base on the delays estimated. A drawback of these methods is the necessity of measuring devices with a very high sampling rate. On the other hand, impedance based methods works on steady states values of currents and voltages during the fault to estimate an apparent impedance that is directly associated to a distance to the fault. The main drawback of impedance-based methods is the multi-estimation due to the existence of multiple possible faulty points at the same distance.

A software approach to fault detection and identification in the load frequency control loops of interconnected power systems has been presented in [9]. It has been shown that faults occurring in the loops and in the communication channels that carry signals from sensors to controllers. However, it can be noted that this paper does not deal with protection systems per say but with how to locate faults in real time using control and estimation theory. A literature survey reveals that the application of analytical model based fault detection techniques to power systems is presently at

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its infancy, although a few applications of neural networks to fault detection in power systems have been reported [10,11]. The fact that conventional dynamic models of power systems as reported in the literature [12,13] are not directly amenable to existing fault detection techniques may be the main reason behind the lack of any major contributions in this area. Rule-based expert systems have been investigated very intensively for fault detection and diagnosis problems such as [14–16]. Nevertheless, these systems need an extensive database of rules and the accuracy of diagnosis is dependent on the rules. The development of fault detection methods up to the respective times is summarized in the book [17]. The classical approaches are limit or trend checking of some measurable output variables. Because they do not give a deeper insight and usually do not allow a fault diagnosis, signal based methods of fault detection were developed by using input and output signals and applying dynamic process models. Transmission line boundary protection, traveling waves theory and wavelet transform are used [18]. Fault detection and identification algorithm, called the residual sensitive fault detection filter is presented [19]. These methods are based on parameter estimation, parity equations or state observers. To identify the exact fault location, some researchers utilize power angles, voltage, and current waveforms recorded by dedicated devices. Fiber Bragg grating (FBG) sensors for real time fault detection deployed in [21]. In [30], practical approach based on Artificial Neural network (ANN) has been introduced to fault location in power network. In [31], it is presented a statistical signal processing using Independent Component Analysis (ICA) for fault detection and diagnosis of turbine. An optimization technique used to analyze and process the information for obtaining the operating status of all the components in a power system. However, the approach is not practical for implementation in distribution systems because there is not enough information available from the protective devices which, tries to develop an analytic model by taking into account the incorrect or missing alarms as in [22]. The approach uses a combination of model data and alarm data to identify fault section, malfunctions of protective relays, and circuit breakers in power system.

This paper proposes a new method for development of intelligent alarms signal and fault section estimation, where problem is treated in two parts, one at system directional level, in equipment to identify the area or zone, and the other at system level aiming to identify the locations were affected by a particular contingency. The first stage is based on state space model where it is proposed a mathematical model to solve problem of alarm handling at equipment level in order to find a locally optimal solution of excellent quality. The second stage is based on a mathematical model that uses optimization and analytical model information from first stage and information that defines topology of system globally. The procedure of this scheme has been developed using a combined framework approach to accurately detect the faults those commonly occurs in electrical power systems.

2. Problem formulation

In this work a methodology where state space, optimization and analytical methods are complementary in order to solve a problem was developed. As the novel character of this work has been created with a functional tool for self-learning features that have the ease to adapt to new information, there is updating of database revels no need to change the parameter settings. Fig. 1 shows the working scheme of the proposed methodology. The proposed methodology is activated as soon as a condition of abnormal operation of an electrical power system is detected by means of signaling alarms, circuit breakers and associated relays. This tool is supplied with all useful information associated with occurrence,

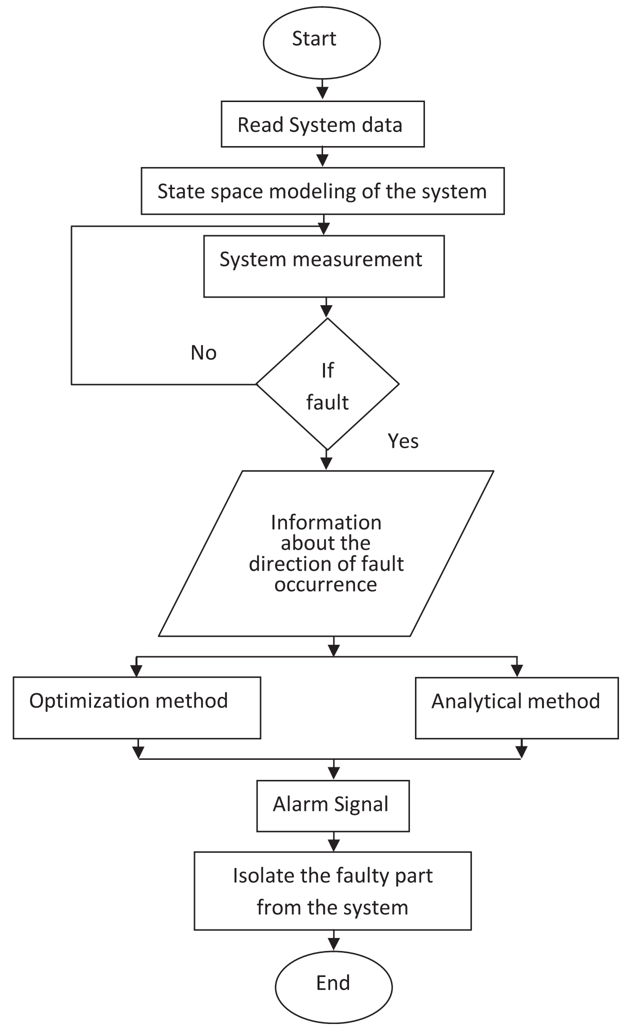

Fig. 1. Flow chart of the proposed method.

in order to characterize the event more precisely. Thus, alarms received from the system output provide information concerning the trip of relays and status of circuit breakers. The information about relays tripping is processed by state space, and circuit breakers information along with output of state space are handled by optimization and analytical hypothesis, which in turn provides the diagnosis for fault.

2.1. State space representation of the system

Each machine is described mathematically by a set of equations of the form

$$\dot{x} = f(x, v, T_m, t) \tag{1}$$

where x represent state vector, T_m represents mechanical torque, t presents time and vector v is a vector of voltages that includes v_d, v_q, and v_F. The objective here is to derive relation between v_{di} and v_{qi}, $i = 1, 2, \dots, n$, and the state variables. It will be obtained in the form of a relation between these voltages, the machine currents i_{di} and i_{di}, and the angles δ_i, $i = 1, 2, \dots, n$. In the case of flux linkage model the currents are linear combination of the flux linkages. For convenience it will use a complex notation defined as follow for machine i, it is define the phasors $\overline{V}_i$ and $\bar{I}_i$, as

$$\overline{V}_i = V_{qi} + jV_{di} \tag{2}$$

$$\bar{I}_i = I_{qi} + jI_{di} \tag{3}$$