A multiple strategic evaluation for fault detection in electrical power system

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1. Introduction

An important objective of power system is to maintain uninterrupted 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 power systems is therefore very useful in the early detection of faults. The monitoring condition of power system does not deal with protection systems per say but with how to classify 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 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
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 in-
sight and usually do not allow a fault diagnosis, signal based meth-
ods 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 trans-
form 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 wave-
forms recorded by dedicated devices. Fiber Bragg grating (FBG)
sensors for real time fault detection deployed in [21]. In [30], prac-
tical approach based on Artificial Neural network (ANN) has been
introduced to fault location in power network. In [31], it is pre-
sented a statistical signal processing using Independent Compo-
ent Analysis (ICA) for fault detection and diagnosis of turbine.
An optimization technique used to analyze and process the infor-
mation 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 en-
ough 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 intelli-
gent 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 excel-
lent 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 com-
monly 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 cre-
ated 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 oper-
ation of an electrical power system is detected by means of signal-
ing alarms, circuit breakers and associated relays. This tool is
supplied with all useful information associated with occurrence,
in order to characterize the event more precisely. Thus, alarms re-
ceived 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 opti-
imization 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
\[ \dot{x} = f(x, v, T_m, t) \]  
(1)

where \( x \) represent state vector, \( T_m \) represents mechanical torque, \( t \)
presents time and vector \( v \) is a vector of voltages that includes \( v_b \),
\( v_q \), and \( v_s \). The objective here is to derive relation between \( v_b \),
\( v_q \), \( v_s \), \( i = 1, 2, \ldots, n \), and the state variables. It will be obtained in the
form of a relation between these voltages, the machine currents
\( i_b \) and \( i_q \), and the angles \( \theta_b \), \( i = 1, 2, \ldots, n \). 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 ma-
chine \( i \), it is define the phasors \( \nabla_i \) and \( \iota_i \) as
\[ \nabla_i = V_{qi} + jV_{di} \]  
(2)
\[ \iota_i = I_{qi} + jI_{di} \]  
(3)
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