DISTRIBUTION NETWORK FAULT SECTION ESTIMATION USING ANALYTICAL DATABASE APPROACH

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Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university, or institution of learning.

Abstract

A fault in a power system may cause interruption of supply. The fault needs to be detected, located and cleared as soon as possible. In a distribution network, it is difficult to determine where the fault occurs. This is because there is lack of information on the distribution network status except a trip feeder. Therefore, in order to improve the customer minute loss, the fault section should be estimated so that the faulty section can be isolated and the rest of the sections in the feeder can be quickly restored.

This thesis describes the development of a new fault section estimation algorithm in a distribution network. This is the main part of the research which investigates how the voltage sag can be used to estimate the fault section in the distribution network. The method is based on an analytical database approach which uses a power flow and fault analysis program to establish analytical voltage sag databases for a typical studied distribution network topology. The databases contain voltage sag magnitude and phase shift information for all nodes on the distribution network under different fault types and load conditions. When a fault occurs, the method only needs to measure the fault generated voltage sag waveform at the network primary substation. This measured waveform is then compared to the analytical databases. Database search and comparison algorithms were developed to identify the faulty section for the network. The proposed method was evaluated and tested on a typical distribution network by using voltage waveforms produced by PSCAD/EMTDC, a power system simulator.

Prior to the fault section estimation process, the fault type has first to be classified. This is because different types of fault may cause different values of voltage sag, which leads to having different databases for different types of fault. In this research, wavelet technique was adopted. The voltage signal was transformed to wavelets coefficients using the wavelet transform. Then the standard deviation of these coefficients was calculated, and an algorithm was developed to classify the fault type, using these standard deviation values.

In addition to the fault section estimation and fault type classification. this study also investigates how to transfer voltage waveforms efficiently from the substation to the central site. This is because a substation is usually situated far from the central site, and the waveform needs to be transferred to the central site so that the fault type classification and fault section estimation process can be done. The method proposed in this thesis is by data compression and reconstruction using wavelet transform.

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List of Abbreviations and Symbols

F_{fault}	Fuzzy set
R_i	Fuzzy set
$\mu(x)$	Membership grades
σ	Standard deviation
$\bar{x}$	Mean
ε_1, ε_2, ε_3, ε_4, ε	Threshold values
AM/FM/GIS	Automated mapping/Facilities management and Geographic information system
CR	Compression ratio
CWT	Continuous wavelet transform
D4	Daubechies-4
D20	Daubechies-20
DA	Decision algorithm
DLF	Double line fault
DLGF	Double line to ground fault
DWT	Discrete wavelet transform
GDN	Generic distribution network
GPS	Global positional system
HF	High frequency
I^0, I^1, I^2	Sequence current values
I_{Di}	Local load current
I_{Gi}	Generator current
I_i, I_j	Bus current
IP1, IP2, IP3, IP4	Fuzzy variables
IPSA	Interactive power system analysis
L	Inductor
LLLF	Three-phase fault
LTC	Load tap changer
MRA	Multiresolution analysis
n	Number of buses
n_G	Number of generator buses

NMSE	Normalised mean square error
P_{Di}	Local real load
P_{Gi}	Injecting real power
Q_{Di}	Local reactive load
Q_{Gi}	Injecting reactive power
R	Resistor
RBF	Radial basis function
RMS	Root mean square
rms	Root mean square
RTU	Remote terminal unit
S4	Symmlet-4
SCADA	Supervisory control and data acquisition system
S_{Di}	Local load
S_{Gi}	Injecting complex power
SLGF	Single line to ground fault
V_i, V_j	Bus voltage
V_{rms}	rms voltage
V_{sag}	Voltage sag
Y_{ij}	Bus admittance matrix of transmission line

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Chapter 1

Introduction

1.1 Fault section estimation on distribution network

One of the main tasks of a power utility is to deliver uninterrupted power supply to its customers. However, it is impossible to avoid faults that may be caused by extreme weather conditions or accidents. Faults may cause interruption of supply, which may cost the utility in terms of revenue and may also annoy customers because of the outage of supply. This may force customers in the manufacturing industry to stop production, and cause a significant loss of income. Therefore it is important for the utility to improve the service reliability. These objectives could be achieved by building new substations and circuits, or updating and installing protection relays at all nodes of a distribution network, which would allow the distribution networks to operate ring or meshed networks rather than radial ones. but they are expensive. Automatic fault management [1, 2] incorporating distribution automation [3, 4] could help reduce the outage times as measured in "customer minutes lost" and therefore improve the reliability and quality of service at a relatively low cost.

An automatic fault management system [1, 5] has mainly consists of four important tasks: (i) automatic fault section identification, (ii) fault section isolation, (iii) fault location on the isolated fault section, and (iv) fault section restoration. In a transmission network, task (i) may be done based on protection device and circuit breaker status information. Tasks (ii) and (iv) may be carried out by the network operator in the control centre through remote manual control switches, and task (iii) may be carried out by field engineers with pin-point fault locator and circuit reparation tools. However, task (i) on a distribution network with radial topology can not be done by using the techniques employed in a transmission network. This is because protection relays are often installed only at primary substations. The traditional way of managing the fault in a radial distribution network is to energise the faulted feeder step by step, using either remote control sectionalisers or autorecloser until the protection relay trips again [5]. Although fault indicators are used to divide the distribution feeders into several fault detection zones, trial and error switching is still required for each feeder.

1.2 Research motivation

Fault section estimation in a distribution network is difficult. This is because of lack of information on the distribution network compared to transmission lines. Therefore, the primary concern of this research is to investigate the possibility of estimating the distribution fault section using voltage sag magnitude and voltage phase shift at a particular location when a fault occur in the network. This could be done by using the database approach. This approach has been used in several applications of a power system, such as in disturbance recognition [6], power quality analysis [7], investigation of voltage sags [8], and industrial power system analysis [9]. The database in this research contains both fault-generated voltage sag magnitude and phase shift information for all nodes on the distribution network. When a fault occurs in the network, the method measures the fault-generated voltage sag waveform at the network substation. By comparing the measured voltage to the database, the fault section is estimated. The fact that this method needs only the voltage information and does not need any information, from the circuit breaker and relay, it is likely to be an effective way to estimate the fault section in distribution network.

1.3 Aim of research

The aim of this research is to develop a method of using an analytical database approach to estimate the fault section in a distribution network. This method will concentrate on an 11 kV radial feeder with a few branches along the feeder. The objective of the research is to investigate whether voltage sag at a particular node can be used to estimate the fault section in a distribution network. A database approach, together with search algorithm and decision algorithm, will be used in the investigation.

1.4 Programme of work

To achieve the aim of the research, there are three main tasks that have to be done.

Task 1 Develop algorithm to classify the fault type. Different types of fault will cause different voltage sag values. This will lead to having different databases for different types of faults. Therefore it is important in the database approach to classify the fault type so that the correct database is used in the fault section estimation process. It is very crucial to classify the fault type correctly, as wrong classification will lead to the algorithm in Task 2 and Task 3 using the wrong database, resulting in wrong estimation of the fault section.

Task 2 Develop algorithm for selecting all possible fault sections. As the feeder may have a few branches, there are a few sections that may have the same voltage information. All these sections must be first identified before estimating the fault section. Voltage measured at a particular node will be matched with the information in the database for these sections.

Task 3 Develop algorithm to select the most possible fault section from the list of selected possible fault sections in Task 2. Using the same voltage as in Task 2, together with the information in the database for the sections selected in Task 2, this algorithm will estimate the most possible fault section.

The power flow analysis and fault analysis will be used to establish the database. Power flow analysis will provide the pre-fault voltages magnitude and angles while fault analysis will provide those during-fault. From these, voltage sag magnitude and phase shift information can be established in the database.

The signal that will be used in the investigation is obtained from the simulation by the power system simulator, PSCAD/EMTDC, on the same test network that is used to establish the databases. This simulator will be used extensively to produce different voltage signals at a particular node when different fault types and locations of fault are occurring in the test network. The signals from the simulations will be used to test all the three algorithms.

1.5 Structure of thesis

This section gives a summary of all the chapters in this thesis for the work carried out, starting in January 2001.

Chapter 1: Introduction: Presents the introduction, motivation and objective of the research.

Chapter 2: Background and literature survey: Provides the background of the research and reviews the different methods and techniques of fault section estimation and fault type classification.

Chapter 3: Fundamentals of voltage sag: Generally presents the basic theory of voltage sag, which includes the cause of voltage sags and voltage sag characteristics.

Chapter 4: Development of fault type classification technique using wavelets: Presents the basic wavelet theory and the development of fault type classification and identifying faulted phase using wavelets. It also presents the application of wavelets to waveform compression and reconstruction.

Chapter 5: Development of database approach algorithm for fault section estimation: Presents the basic theory of power flow and establishing databases using power flow and fault analysis. It also describes the developing of the database search algorithm to obtain the possible fault sections. and of the decision algorithm to estimate the most possible fault section. It also presents the results for the test on the algorithm.

Chapter 6: Conclusions and future work: Presents a summary of the thesis, and the conclusions and suggestions for future research.