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Soft computing applications in high impedance fault detection in distribution systems

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Abstract

Two methods, one based on genetic algorithm (GA) and one based on neural networks (NN), are proposed for high impedance fault (HIF) detection in distribution systems. These methods are used to discriminate HIFs from isolator leakage current (ILC) and transients such as capacitor switching, load switching (high/low voltage), ground fault, inrush current and no load line switching. Wavelet transform is used for the decomposition of signals and feature extraction in both methods. In one method, GA is used for feature vector reduction and Bayes for classification. In the other method, principal component analysis (PCA) is applied for feature vector reduction and NN for classification. HIF and ILC data was acquired by experimental tests and the data for other faults was obtained by simulating a real network using EMTP. Results show that either of the proposed procedures can be used to identify HIF from other events efficiently.

Keywords: Bayes classifier; High impedance fault; Genetic algorithm; Neural network; Principal component analysis; Wavelet transform

1. Introduction

High impedance faults (HIFs) usually occur at primary network in electric distribution systems. Detection of HIFs generally is difficult by conventional over-current protection devices, because they have high impedance at the fault point and do not cause an excessive change of current in the affected line. These faults often occur when an overhead conductor breaks or touches a high impedance surface such as asphalt road, sand, cement or tree. When this type of fault occurs, energized high voltage conductor may fall within reach of personnel. In addition, as the arcing often accompanies these faults, it further poses a fire hazard. Therefore, from both public safety and operational reliability viewpoints, the detection of HIF is critically important. In the past two decades many techniques have been proposed to improve the detection of HIFs in power distribution systems [1]. Some of the methods and techniques are listed in Table 1.

In this paper two methods for HIF protection using soft computation techniques, Table 2 are proposed and compared.

In this research, HIF and ILC data was gathered by experiments on a 20 kV radial distribution feeder in a real network. Other transient data was produced by simulation of a real distribution network using EMTP. Experimental and simulation data gathering processes are explained in Section 2. Application of wavelet transform (WT) is presented in Section 3, and the two proposed approaches and results are given in Sections 4 and 5.

2. Data collection

In this work, HIF and isolator leakage current (ILC) data was gathered from tests on a real network. Due to some practical limitations, other transient data such as capacitor switching, load switching (high/low voltage), ground fault,

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Table 1
Some HIF detection methods

Methods	Description	Reference
Mechanical methods	In these methods some devices are used to provide low impedance by catching the fallen conductor	[2]
Electrical methods		
Time domain	Ratio ground relay	[3]
	Proportional relay algorithm	[4]
	A smart relay based on time domain feature extraction	[5]
	Arc detection method	[6]
Frequency domain	Several papers have been published based on harmonic component using Fourier transform	[7,8]
	Inter harmonic component	[9]
	High frequency spectra	[10]
	A method based on Kalman filtering	[11]
	A method based on fractal theory	[12]
Wavelet transform	Wavelet transform (WT) can be used to analyze the transient behavior of a signal in both time domain and frequency domain. Recently WT has been proposed to achieve a better solution for digital signal processing of HIF signals	[13]

Table 2
Computation techniques and their roles in the proposed methods

Method Number	Decomposition and feature extraction	Dimension reduction or feature selection	Classifier
1	WT	GA	Bayes
2	WT	PCA	NN

inrush current and no load line switching, was obtained by simulating the same feeder using EMTP.

For HIF data collection a radial 20 kV feeder in Qeshm Island, Iran was chosen for high impedance fault tests. Feeder length was 19.5 km and HIF locations were almost 8.5 km from the source end. The feeder was energized from another 20 kV feeder through two distribution transformers (20/0.4 kV, 100 kVA) connected back to back. The high and low voltage connections of transformers were Δ/Y, respectively. The high voltage sides of the transformers are connected to feeders and low voltage sides are connected together through the low voltage switch. For grounding in Δ side, a grounding transformer was used. Three phase voltages and currents are recorded using Hall effect current transformers (CT), resistive voltage divider (PT), power analyzer and computer. Sampling rate of recorded data was 24.670 kHz and total recorded time was 15 s for each test. A schematic of connections is shown in Fig. 1 and the site is shown in Fig. 2.

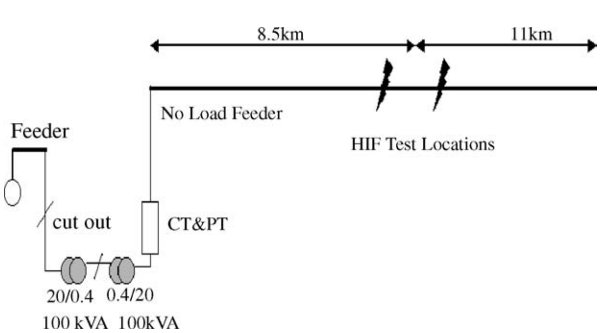

Fig. 1. Schematic of instrument connection.

Fig. 2. Experiment site.

For HIF tests a conductor connected to one phase of the feeder (Fig. 3) was dropped to the ground as shown in Fig. 4.

The fault tests were performed for seven types of surfaces (wet and dry asphalt, cement and soil, and dry tree) in two locations, approximately 8209 m and 8446 m from the source end. Three tests were conducted for each type of surface at each location for a total of 42 data sets. As a couple of data files were incorrect, a total of 40 test data files were used for processing.

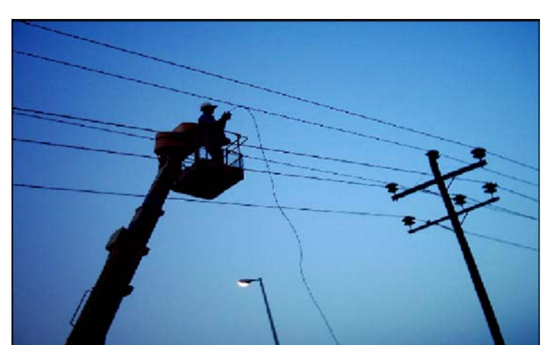

Fig. 3. Connection of a conductor to one phase.