Electrical Power and Energy Systems 61 (2014) 380–385

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

A new procedure for determination of insulators contamination in electrical distribution networks

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ARTICLE INFO

Article history:
Received 13 December 2012
Received in revised form 9 December 2013
Accepted 20 March 2014
Available online 19 April 2014

Keywords:
Insulator's contamination
Power distribution faults
Packet Wavelet Transform
Principal component analysis

ABSTRACT

This paper presents a novel method for determination of insulator contamination (IC) level. ICs caused some problems in electric networks. Some faults occur in electric system due to ICs. These faults sometimes log to a sudden and serious damages to the systems. So ICs reduce power quality and reliability indexes. Usually insulator washing is a solution for this problem and its events. Insulators washing have a heavy cost and if a time table for their washing time can be planned, both time and cost will be saved. In this paper average insulators contamination calculated using line current. Leakage current on insulators surface are coming together with small arcs. These arcs have high frequency component. Proposed method extracts some features from these components using Discrete Wavelet Transform (DWT) and principal component analysis (PCA). Line current data gathered for six month on a 20 kV distribution feeder with 6.4 kHz sampling rate. Results show high accuracy of this method for determining of insulators contamination.

Introduction

Flashover of contaminated insulators in polluted areas has proven to be one of the most important factors influencing the operation of distribution lines and substations [1]. These are power-frequency flashovers on distribution lines without evidence of switching or lightning over voltages and usually take place in wet weather conditions such as dew, fog, drizzle or light rain. Near industrial, agricultural or coastal areas, airborne particles are deposited on insulators and the insulator contamination builds up gradually. When fog or light rain wets the polluted insulator, a conductive layer is formed on the contaminated insulator surface, which initiates leakage current [7,8,15,17]. The prediction of approaching flashover is important for utilities. Contamination-caused insulator flashovers result in expensive power outages. Utilities spend significant amounts of money on preventive maintenance, which includes insulator washing and cleaning [2]. This expensive operation is scheduled by the subjective judgment of line engineers, based on historical experience or total hours of service since last washing. Exact predictions of pollution build-up and identification of the time when the flashover is imminent has significant value to utilities [1].

Obviously, an accurate diagnostic criterion is needed to determine the condition of the insulator surface and to identify the possibility of flashover. So it is necessary to estimate insulator's contamination in order to prediction of approaching flashover [12]. Case studied feeder has approximately 84 poles and passes from desert aria around Yazd-Iran in 20 kV voltage level. Supplied loads by the 20 kV feeder are almost induction motor which are using for utilization in brick furnace. Fig. 1 shows the single line diagram of case studied feeder.

In 1996 Arlando et al. performed a laboratory and field test in order to investigate the pollution level in distribution networks. First they recorded the maximum current that passed from insulator's surface monthly, and then they measured the Equivalent Salt Deposit Density level in the laboratory. Then he correlated the results with the measurement of climatic condition and the amount of pollution on the insulators surface.

In 2005 Song et al. in Korea studied the aging of polymer insulator with using leakage current. This investigation has been executed on a single insulator by high frequency components of insulator leakage current. Song et al. neglect the low frequency components of leakage current and they examined the frequency spectra between 1.25 and 2.5 kHz [6].

In 2005 Zhao et al. in China could determine the insulator's pollution level with using Packet Wavelet Transform and also noise reduction method. They monitor the maximum value of insulator's leakage current passing from insulator's surface and then could predict the flashover by examining the pollution level.

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http://dx.doi.org/10.1016/j.ijepes.2014.03.034
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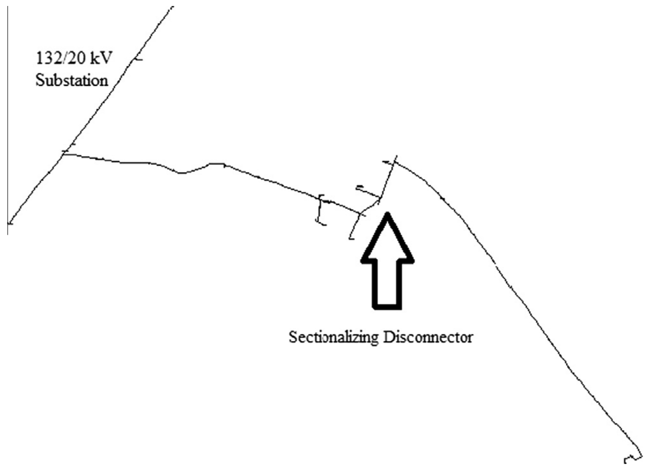

Fig. 1. Case study feeder single line diagram.

In 2006 Memaripour et al. examine the relationship between leakage current and insulator's pollution level in distribution ceramic insulator. They designed a fog chamber and simulated the condition which insulator treated in it. They executed the defined pollution on the insulator's surface and then placed the insulator in the fog chamber. They used the maximum, minimum and average of the leakage current which recorded by the oscilloscope in order to match the defined pollution level with the leakage current [14].

In this paper a different method from the mentioned methods has been proposed. The proposed method can determine feeder insulators contamination level by using the feeder end source current.

In the following and in the second section, basic concepts have been discussed. Data acquisition system identified in part 3 and data processing procedure in part 4 has been discussed. Obtained final curve for insulators contamination are defined in result part.

Basic concepts

Discrete Wavelet Transform (DWT)

Wavelets are classes of functions with properties suitable for the analysis of a wide spectrum of signals for engineering and bio-medical applications. The Wavelet transform (WT) was introduced by J. Morlet in 1985 and has attracted much interest in the fields of speech and image processing [3]. Applications of WT in power system are reported for

- Power system transient.
- Power quality assessment.
- Modeling of system components in the wavelet domain.
- Power system protection.

An introduction to Wavelet transform is presented. Wavelet transform is a mathematical tool, much like the Fourier transform in analyzing a stationary signal; this decomposes a signal into different scales with different levels of resolution. For efficient analysis, scales and shifts take discrete values based on powers of two (dyadic decomposition). A dyadic decomposition Wavelet analysis represents a signal as a weighted sum of shifted and scaled versions of the original wavelet, without any loss of information [4,5]. A three-level DWT frequency band is shown in Fig. 2. For implementation of DWT, quadrate mirror filters (QMF) are utilized for hierarchical signal decomposition, and a given signal is decomposed by a series of low- and high-pass filters followed by down-sampling at each stage as shown in Fig. 3.

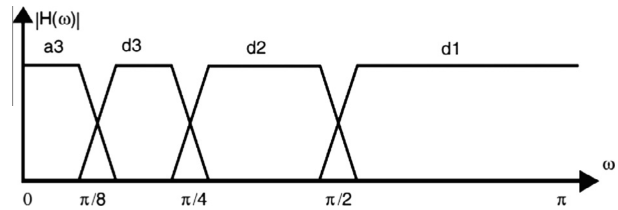

Fig. 2. Three-level DWT frequency band.

The particular structure of the filters is determined by the mother wavelet used for data analysis and by the conditions imposed for a perfect reconstruction of the original signal. The approximation is the output of the low-pass filter, while the detail is the output of the high-pass filter. In a dyadic multi-resolution analysis, the decomposition process is iterated such that the approximations are successively decomposed. The original signal can be reconstructed from its details and approximation at each stage [9–11].

A three-level decomposition signal is illustrated in Fig. 4. Decomposition proceeds until the individual details consist of a single sample. The nature of the process generates a set of vectors a3, d3, d2, and d1, containing the corresponding coefficients. These vectors are of different lengths, based on powers of two. These coefficients are the projection of the signal onto the wavelet at a given scale.

They contain signal information at different frequency bands (a3, d3, d2, and d1) determined by the filter bank frequency response. As expected, these bands are of unequal widths [16]. A variety of different wavelet families have been proposed in the literature. The choice of mother wavelet plays a significant role in time frequency analysis.

The wavelet packet method is a generalization of wavelet decomposition that offers a richer range of possibilities for signal analysis. In wavelet analysis, a signal is split into an approximation and a detail. The approximation is then itself split into a second-level

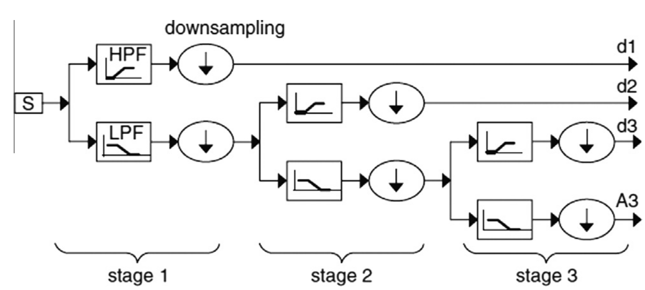

Fig. 3. Three-level DWT.

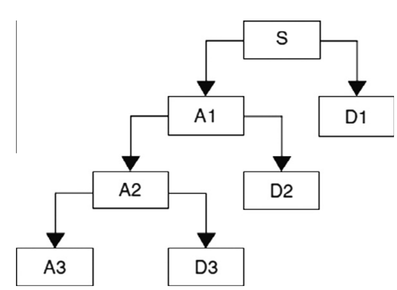

Fig. 4. Three-level decomposition signal in DWT, signal S can be written as S = A3 + D3 + D2 + D1.