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Application of decision tree and discrete wavelet transform for an optimized intelligent-based islanding detection method in distributed systems with distributed generations

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ABSTRACT

In this paper, a method for islanding detection based on analysis of transient state signals is provided. Decision tree (DT) is trained for classifying the transient events. The required features for classifying are extracted through discrete wavelet transform (DWT) of signals. The proposed method is then simulated on a medium voltage distribution system of CIGRE with two kinds of distributed generations (DGs) using DIgSILENT, MATLAB and WEKA softwares. By analysis performed on type of input signal, type of mother wavelet and required transform level, among 162 relay designs, an optimum relay is selected for distributed generations (DGs) based on accuracy, speed, simplicity and cost parameters. By evaluation, it is determined that using only one input (voltage) signal not only improves speed and simplicity and reduces costs, also makes accuracy of the proposed relay better than other intelligent and passive methods. The final selected relay for each DG is V-db4-D3 which has accuracy equal 98%.

Contents

1. Introduction

Recently, due to environmental pollution and the immanent exhaustion of fossil fuel, distributed generations (DGs) using renewable energy sources, including wind power, micro hydro, solar photovoltaic and landfill gas, have become one of the main power generations. Islanding detection is an important protection to consider when distributed generation (DG) is connected to distribution systems.

Islanding takes place when a part of the network becomes disconnected from the grid, and is powered by one or more DGs only. The system in Fig. 1 contains the utility system on the left and the DG fed distribution system on the right. There are various customer loads

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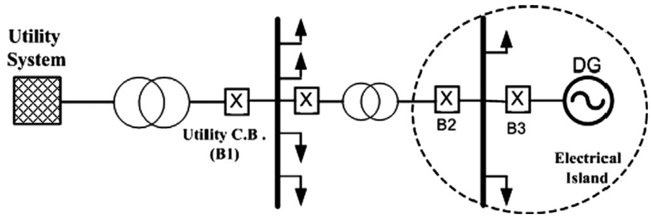

Fig. 1. A general view of electrical islanding.

between these two electrical power sources. The essential task of an islanding detection protection is to find accurately the time of islanding event and to disconnect the DG.

Islanding is an undesirable situation since it is a potentially dangerous condition for the maintenance personnel and may cause damage to the DG and loads in the case of unsynchronized reconnection of the grid due to phase difference between the grid and DG [1]. Therefore, it has become a mandatory feature specified in the IEEE Std. 1547.1, IEEE Std. 929-2000, and UL1741 standards.

Islanding detection techniques can be divided into remote and local ones, whereas the local techniques are divided into passive and active ones. Hybrid methods combine the effectiveness of passive and active approaches and can be applied as an alternative. Remote techniques such as power line communication (PLC) [2], supervisory control and data acquisition (SCADA) [3], transfer-trip [4] are based on communication between the grid and the DGs. They have better reliability than local techniques but are more expensive.

Active detection methods, deliberately introduce perturbations into the system. In the loss of grid situation, however, small deviations will be amplified by positive feedback and, hence, it becomes easy to detect the islanding condition. Some active islanding detection methods that have been proposed include active frequency drift (AFD) [5], slip-mode frequency shift [6], automatic phase shift [7], sandia frequency and voltage shift [8], reactive power export error detection [9], system fault level monitoring [10] and phase-locked loop (PLL) perturbation, system input impedance [11] methods. The main advantage of active methods is their relatively small NDZ. The main disadvantage, however, is power quality problems due to their direct influence on the power system.

Passive techniques rely on monitoring the power system's behavior by measuring system parameters. This is an advantage but many other non-islanding disturbances will produce transients that mimic very closely to those of an islanding event. For this reason, thresholds on measured parameters (for example, frequency or voltage) are set wide, but it results in large non-detection zone (NDZ) [12]. Passive techniques include over/under voltage and frequency (OVP/UVP and OFP/UFP) [13], rate of change of frequency with time (ROCOF) [14], rate of change of power with time [15], rate of change of frequency with power [16], and total harmonic distortion (THD) and voltage unbalance [17], phase jump detection [18], comparison of ROCOF (COROCOF) [19], inter-tripping [20], fault thrower and neutral voltage displacement (NVD) [20], rate of change of voltage and power factor [20], elliptical trajectory technique [20], rate of change of phase angle difference (ROCPAD) [21] and fuzzy rule [22].

Passive techniques do not have power quality problems and are generally quite cheap to install but they have large NDZs. However they cannot ensure guaranteed operation under all islanding situations [20].

Classification-based techniques have been recently proposed in the literature for islanding detection. An intelligence-based method is investigated in Ref. [23], which uses the decision-tree (DT) classifier, but with complex set of 11 features for classification, including total harmonic distortion of current/voltage, gradient of the product of voltage and power factor, etc. It has only 83.33% islanding detection accuracy. A hybrid islanding detection algorithm based on wavelet transform is discussed in Ref. [24], but it is specifically for single-phase photovoltaic (PV) DG systems. The method based on wavelet transform and DT classifier presented in Ref. [25] could obtain 96.43% accuracy by using fourth level of discrete wavelet transform (DWT) but with both two signals current and voltage. Accuracy of other passive methods that are summarized in Ref. [26] is lower than this value.

In some papers [27,28], the absolute value of certain wavelet coefficient of voltage or current or frequency, are compared against a threshold value; and if the relevant wavelet coefficient remains above this preset threshold for a certain time, an islanding condition is declared. These system specific threshold values are determined through trials based on the experience of utility engineers [28]. Some papers [29–32] without any reason or proof have used a certain signal (voltage or current or both) or specific mother wavelet or certain level of wavelet transform even with high levels 6th and 7th [31,32]. Some papers [25,26] have followed results which presented in Ref. [29]. In Ref. [29], a specific mother wavelet and certain level of wavelet transform have been proposed by analyzing only short circuit conditions on a simple system consisted of two generators and one distribution line. Whereas the real distribution system is more complex and its transient events are more varied. As a result it is necessary the mother wavelet and levels of DWT are selected with more precision and evaluation. In some other papers [29,30], few cases of transient scenarios were tested and comprehensive assessment has not been on the proposed algorithm.

In this paper, it is attempted through study and analysis of a real distribution system, an optimum algorithm with higher accuracy and speed (lower computation) than previous techniques is obtained. Instead of using (1) both voltage and current signals or (2) complex set of parameters, or (3) the threshold values determined through trial and error and (4) high level of DWT and (5) certain mother wavelet and DWT levels, it analyses different mother wavelet, DWT levels and input signals, uses lower DWT level and only one transient signal (voltage) generated during the disconnection of the grid. The method involves extraction of signal energies in different levels of DWT as features. It uses decision tree (DT) as a classifier in identifying the islanding condition.

The rest of the paper is organized as follows: Section 2 provides the theory of the DWT and DT. The case study is introduced in Section 3. Section 4 presents the proposed islanding detection method. Section 5 provides the simulation. The last section touches upon the conclusion.

2. DWT and DT

Voltage and current transient signals of a power system are believed to have unique characteristics that signify the cause of transient event. The method proposed here is based on this fact that transient state has certain characteristics which can be used to present a new method to distinguish the island occurrences from the other ones. Of course the features presented in transient signals are not directly diagnosed. So there should be a process to extract these features to speed up response in classifying. To this end, wavelet transform seems to be suitable.

Some important classification methods include support vector machines, neural network and decision tree. Although studies have been carried out to compare them [32], due to a number of factors and possibilities, we cannot definitely state which method