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Optimal neuro-fuzzy based islanding detection method for Distributed Generation

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ABSTRACT

Utilizing wavelet transform, in this paper an intelligent and optimum method is presented for islanding detection. The recommended relay is based on neuro-fuzzy system which is trained by using four different heuristic algorithms and finally among all of them, PSO with having the best results is elected for proposed relay. In this procedure, selection of mother wavelet and also proper input signals for islanding detection is done optimally. To do so, firstly, various islanding and switching in different loading conditions of network are simulated. Then, the eligible signals for islanding detection are sorted based on wavelet analysis and receiving operating characteristic (ROC) concept. Afterward, using four different algorithms, training of the designed relay is done by the sorted signals and the optimum condition of the fault detector is recognized. Reduction of non-detection zone approximately to zero, selection of optimum number of relay's input signal, fast detection, solving of threshold selection, appropriate signal selection and fast training via least information are the prominent features of the proposed method. Simulation results and comparison of them for different cases approve the efficiency of the proposed method.

1. Introduction

The importance of electrical generation based on renewable energies such as wind power, micro hydro, and solar photovoltaic and geothermal is increasing, due to their low emissions of greenhouse gases [1]. Also, energy efficiency and power quality of the distribution network are improved using Distributed Energy Resources (DERs) [2]. The generated power of main DERs is transferred to the grid through utility interfaced converters [3].However, the Distributed Generations (DGs) are creating many problems in power systems [4]. One of these problems is unwanted islanding. The islanding condition occurs when a portion of the utility system that contains both load and DG, remains energized while it is isolated from the rest of the utility system [5]. These conditions should be disconnected within 2 s after the formation [6].

Islanding detection techniques can be categorized into two main groups including local and remote techniques. Remote detection techniques are based on communication between the utility and the DGs. These schemes include power line signaling [7] and transfer trip [8].These techniques are expensive to implement and hence are uneconomical [9].The local methods are divided into active and passive techniques. In active techniques, the control circuit of interface system is designed in such a way that, when islanding is occurred, a certain system parameter is forced to instability [10].The salient feature of these methods is their relatively small Non Detection Zone (NDZ) and the main disadvantages of them are power quality problems and complexity of control circuit [11]. Also, in microgrids applications in which DERs should remain stable in autonomous operating mode, these techniques are not suitable [12].

Passive techniques depend on some specific parameters of system such as voltage, current, frequency. This concept makes it possible to detect islanding mode through data analyzing. The simplest methods of passive techniques to detect islanding are Over/Under Voltage (OV/UV) and Frequency (OF/UF) methods. The foible of this method is its failure when power generation and consumption are equal, because in this situation system's data changing is very small [5]. Other passive technique methods can be named as total harmonic distortions [13], rate of change of frequency [14], phase displacement monitoring, vector surge [15], rate of change of generator power output [14], rate of change of phase angle derivation [16], and reference signal generator with a multi-level inverter [6].

Recently, wavelet-based islanding detection techniques are commonly used to improve the performance of passive techniques. Outstanding features of these techniques such as stability, versatility, cost effectiveness and ease of properties' modification, motivated researchers to use them widely. A review of various wavelet-based islanding detection methods and their advantages are presented in Table 1.

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Table 1
Review of wavelet-based islanding detection methods.

WT-based detection technique	Employed signals	Outstanding feature
Using Bi-orthogonal 1.5 and 5 decomposition levels for islanding detection [17]	Signal from a single PV system	• Reduction in number of sensors • Minimization of computational burden • Complexity reduction
Daubenchies mother wavelet based DWT used in [18]	Voltage and frequency variations	• Simplicity of programming • Enhancement of detection capability • Simultaneous observation of power quality profiles
Daubenchies db5-based DWT [19]	Voltage signal	• Fast detection • Complexity reduction
Daubenchies db4-based DWT [20]	Spectral changes in higher frequency components of voltage	• Very effective • Detect islanding conditions within 0.05 s
Localization and compactness property of the Dyadic wavelet transform [21]	Voltage and frequency variations	• Fast detection • Complexity reduction • Reduction of detection mistakes
Wavelet packet transform (WPT) of db10 [22]	Change rate of power index	• Fast detection • Reduction the influence of noise
Haar mother wavelet technique [23]	Current signal	• Least decomposition levels • Least detection time • Fast detection • Applicable for multi-DG enviroment
New feature extraction technique [24]	Variations of harmonic profiles	• Reduction in number of sensors • Minimization of computational burden • Complexity reduction
Wavelet transform-based multi resolution analysis [25]	Output voltage	• Successful in islanding detection under all operating conditions
Wavelet singular entropy (WSE) technique [26]	Three phase voltage signal and generates the detailed coefficients	• Perfectly matching the environment • Effective islanding detection within 10 ms

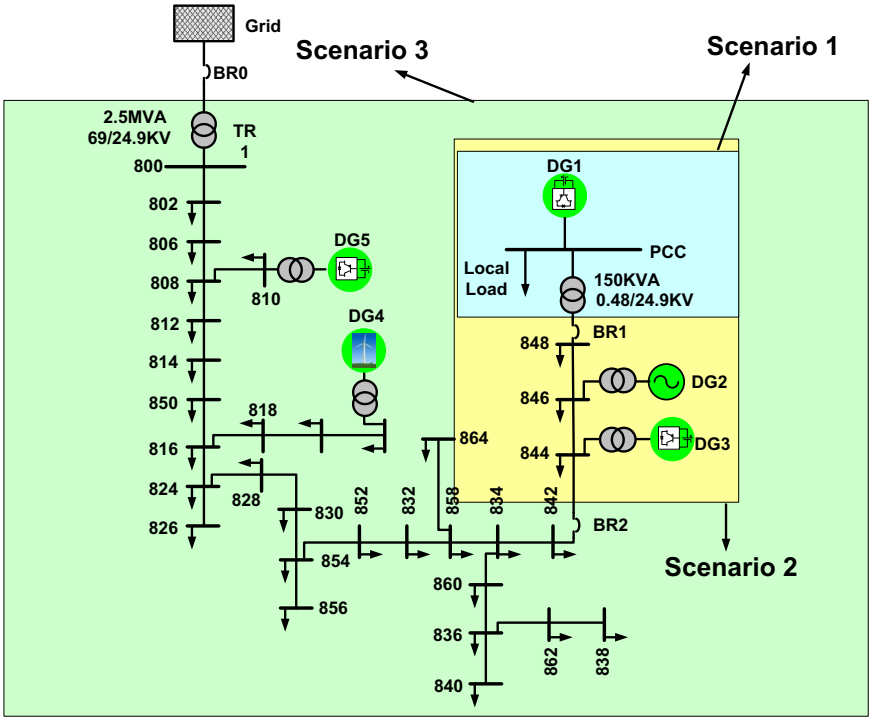

Fig. 1. Single line diagram of studying system.

As can be seen in Table 1, each of WT-based methods utilizes different signals and mother wavelet to do islanding detection. However, many of these techniques have not performed signal analysis and the reason for employed signals is not presented in them. Also, noise sensitivity is the disadvantage associated with these techniques [27]. To overcome the weaknesses of these methods, a new intelligent and optimum islanding detection approach based on ANFIS, heuristic algorithms and wavelet analysis is proposed in this paper. The proposed method has the principle features of the previous WT-based techniques. Along with these features, it can overcome noise sensitivity and reduce wrong detection by performing an optimal signal selection, optimum learning and energy analysis of signals.

In the proposed method detection signals are sorted based on a mathematical method and the optimum number of input signals is selected. First of all, different islanding and non-islanding cases under various loading conditions of network are simulated and total local signals are measured and recorded. Then using different mother wavelets with various decomposition levels, energy of time-frequency signals' are calculated. Criterions named as