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Minimum non detection zone for islanding detection using an optimal Artificial Neural Network algorithm based on PSO

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ABSTRACT

Islanding is one of the most important concerns of the grid connected distributed resources due to personnel and equipment safety. Many approaches have been proposed for islanding detection, which can be categorized into passive and active schemes. The main concern of the passive schemes is related to their large Non Detection Zone (NDZ), while the main problem of the active methods is related to their negative impact on power quality. This paper propose an efficient and intelligent islanding detection algorithm using combination of an optimal Artificial Neural Network (ANN) based on Particle Swarm Optimization (PSO) with a simple active method. The intelligent islanding detection method based on ANN, may have mal-detection in the case of change in the power network structure. In the proposed scheme, ANN is adapted with change in power network structure to reduce NDZ. Optimal parameters of the ANN such as weight coefficients and biases are derived using the PSO in order to minimize the technique NDZ. Also the performance of the various structures of ANN such as Multilayer Perceptron (MLP), Radial Basis Function (RBF) and Probabilistic Neural Network (PNN) in combination with PSO is compared for islanding detection purpose. The proposed method is simulated and tested in various operation conditions such as islanding conditions, motor starting, capacitor bank switching and nonlinear load switching. The test results showed that it correctly detects the islanding operation and does not mal-operate in the other situations and has a small NDZ.

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1. Introduction

Due to the rapid growth of energy consumption in the world, the conventional power systems are facing challenges such as environmental issues, high cost of establishing new power plants, the existing restrictions on building transmission lines and shortages of fossil fuels. Due to the increase in customers' demands, which should be serviced with high reliability, increased efficiency, postponing construction of new transmission lines, and reduction of congestion in distribution feeders and losses, a new concept known as Distributed Generation (DG) was proposed in the early 80's. DG refers to generating resources, rather than central generating stations that are placed close to load being served, usually at a customer site. In fact, many utilities have significant penetration of DGs in their system. It is expected that inverter-based DG technologies will be increasingly used in electrical power systems in the near future. One of the technical issues created by DG interconnection is inadvertent islanding [1–3]. Islanding refers to conditions in which one or more distributed energy resources in an island of loads are separated from the main network. Origin of the islanding may be related to Circuit Breakers (CB) operation in fault condition or main network maintenance. Islanding condition leads to some essential problems in power systems such as negative impacts on protection, management, and operation of distribution systems. Therefore, it is necessary to effectively detect the islanding conditions and swiftly disconnect DG from the network. Fig. 1 depicts a scenario of islanding, where the local loads are severed off from the grid but the system continues to operate because of the connected DG.

In the early decade, the standards have not allowed any kind of intentional or unintentional islanding (IEEE-925-1998). But nowadays, only unintentional islanding is not permitted (IEEE-1547-2003). According to IEEE 1547 standard, the islanding condition should be detected and the island section should be disconnected within 2s from the main grid [4]. Unintentional islanding results in unexpected consequences such as bad restoration (out of phase switching of re-closers leading to damage of the DG, neighboring loads, and utility equipment), degradation of the system voltage stability, and worst of all, an increased risk to related maintenance personnel. Therefore, during islanding condition, the connected DGs must detect the loss of main and disconnect themselves from the main grid as soon as possible.

Many techniques have been proposed for detection of an islanding condition. Before reviewing these methods, it is important to highlight two key features in order to understand the islanding phenomenon. The first is the so-called Non Detection Zone (NDZ) criterion. The NDZ can be defined as the power range (in terms of the power difference between the DG and the load), in which an islanding detection scheme under test fails to detect this condition [5]. The second is associated with the type of loads (inside the island) that can be modeled as a parallel RLC circuit. This circuit is primarily used for islanding analysis because it makes the worse condition for islanding detection by the relevant techniques. Generally, the islanding detection methods do not have significant problems with nonlinear loads that produce current harmonics or loads with constant power for islanding detection [6].

Usually, islanding detection methods are classified into remote and local methods. Local methods can be further classified into passive, active, and hybrid methods. Remote methods for islanding detection are based on communication between the utility and DGs. In the following some important remote methods will be briefly described:

a) Power Line Carrier Communication (PLCC) [7]. This scheme continuously broadcasts a signal from the utility substation to the downstream DGs. The scheme includes two devices Signal Generator (SG) connected to the substation bus and a Signal Detector (SD) at the terminal of a given DG and power line is used as a communication link. A DG is considered as islanded from the upstream system if the signal cannot be detected at the DG site.
b) Signal Produced by Disconnect (SPD) [8]. This method is similar to the PLCC, detecting islanding according to signal transmission between DG and utility substation. The only difference between them is that signal transmission is based on microwave, telephone line and others forms.
c) Supervisory Control And Data Acquisition (SCADA) systems [9]. The SCADA system is used to monitor the status of the CB and re-closers that could island a distribution system.
d) Inter-tripping [10,11]. The method detects the opening of a contact at the points of disconnection and transmits the signal to all generation sites that support the respective island zones.

These methods have zero NDZ, faster response time, zero impact on power quality, high reliability, and work effectively in multiple DG systems with different DG types. However, these methods are expensive to implement especially in small scale systems [7–11].

In compared with the remote methods, local techniques are fed by the gathered information at the DG site. Passive methods depend on measuring some certain system parameters such as voltage, frequency, harmonic distortion, and current on the DG site at the Point of Common Coupling (PCC) with the utility grid. If there are large changes in the DG loading after loss of the main, then islanding conditions are easily detected by monitoring several parameters such as: voltage magnitude, phase displacement, and frequency change. However, in case of small changes in DG loading, the conventional methods have some difficulties in the detection.

In the following some important passive techniques will be briefly addressed:

a) Under/Over Voltage Relay (UVR/OVR) and Under/Over Frequency Relay (UFR/OFR). These relays are the simplest and oldest passive methods used for islanding detection. However, change in frequency and voltage may be very small if the generation and load on the island region are closely matched and so the islanding situation cannot be detected. Thus, the weakness of the voltage and frequency relays is the large NDZ. Therefore, many investigations have being carried out to overcome the large NDZ of these techniques.
b) Rate of Change of Frequency (ROCOF) relay [12]. ROCOF relay is more sensitive than the voltage and frequency relays, and its detection speed is faster. The weaknesses of ROCOF are its sensitivity to load switching and fluctuation, which may lead to mal-detection and complexity in selection of the threshold. This method cannot distinguish whether the frequency change is caused by islanding or load changes.
c) The methods based on Rate of Change of Active Power (ROCOAP) and Rate of Change of Reactive Power (ROCORP) [13]. These methods are more effective than ROCOF relay to detect islanding in power imbalance but these methods still have considerable NDZ in the power balance condition.
d) Rate of Change of Frequency Over Power (ROCOFOP) [14]. This method is proposed for increasing detection accuracy and reduction of NDZ. Furthermore, test results have shown that for a small power mismatch between the DG and local loads, ROCOFOP criterion is more sensitive than ROCOF over time criterion.
e) The methods based on Phase Jump Detection (PJD) [15,16]. These methods are based on monitoring the phase jump between the voltage and current in terminal of the DG. Major