Electrical Power and Energy Systems 45 (2013) 443–455

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

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

Islanding detection for inverter-based DG coupled with using an adaptive neuro-fuzzy inference system

Farid Hashemi [a,*], Noradin Ghadimi [b], Behrooz Sobhani [a]

[a] Department of Electrical Engineering, Ardabil Branch, Islamic Azad University, Ardabil, Iran
[b] Young Researchers Club, Ardabil Branch, Islamic Azad University, Ardabil, Iran

ARTICLE INFO

Article history:
Received 7 May 2012
Received in revised form 10 August 2012
Accepted 6 September 2012
Available online 7 November 2012

Keywords:
Distributed generation
Islanding detection
Non-detection zone
Adaptive neuro fuzzy inference system
Fuzzy subtractive clustering

ABSTRACT

This paper investigates a new integrated diagnostic system for islanding detection by means of a neuro-fuzzy approach for grid-connected inverter-based distributed generation. Islanding is one important concern for grid connected distributed resources due to personnel and equipment safety. Several methods based on passive and active detection scheme have been proposed. While passive schemes have a large non-detection zone (NDZ), concern has been raised on active method due to its degrading power quality effect. Reliably detecting this condition is regarded by many as an ongoing challenge as existing methods are not entirely satisfactory. The main emphasis of the proposed scheme is to reduce the NDZ to as close as possible and to keep the output power quality unchanged. In addition, this technique can also overcome the problem of setting the detection thresholds inherent in the existing techniques. In this study, we propose to use a hybrid intelligent system called ANFIS (the adaptive neuro fuzzy inference system) for islanding detection. The simulations results, carried out by MATLAB/Simulink, shows that the proposed method has a small non-detection zone. Also, this method is capable of detecting islanding accurately within the minimum standard time. Moreover, for those regions which are in need of a better visualization, the proposed approach would serve as an efficient aid such that the mains power disconnection can be better distinguished.

1. Introduction

It is expected that inverter-based distributed generation technologies will be increasingly used in electrical power systems in the near future. The increased expanding of distributed generation (DG) in utility systems has been mainly caused by the liberalization of the electricity markets. Recent advances in energy conversion systems and the environmental drive to promote green energy. These recent advances in energy conversion include the emergence of cheaper and more efficient power generation systems using renewable and hybrid power schemes. The attractions of 'green energy' have been and will continue to be a powerful force in the expansion of distributed generation. Distributed generation (DG) may be defined as generating resources, other than central generating stations, that is placed close to load being served, usually at a customer site. In fact, many utilities around the world already have significant penetration of DGs in their system. When the distributed generation systems are operated in parallel with utility power systems, especially with reverse power flow, the power quality problems become significant. Power quality problems include frequency deviation, voltage fluctuation, harmonics and reliability of the power system. In addition, one of the technical issues created by DG interconnection is inadvertent islanding [1–6]. Islanding condition causes abnormal operation in the power system and also causes negative impacts on protection, operation, and management 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 load of interest is severed off from the grid but the system continues to operate because of connected distributed generators.

Under this situation, a so-called island is formed, resulting in unexpected consequences that may include an increased complexity of orderly restoration (out of phase switching of re-closers leading to damage of the DG, neighboring loads, and utility equipment), a degraded stability of system voltage and worst of all, a raised risk to related maintenance personnel. In other words, under the scenario of islanding, line crew members may misjudge the load-side of the line as inactive where distributed generations are indeed feeding power to loads; hence jeopardizing the life of operators and meanwhile illuminating the importance of a reliable forewarning mechanism to such events. Therefore, during the interruptions of utility power, the connected DG must detect the loss of utility power and disconnect itself from the power grid as soon as possible [7].

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* Corresponding author. Tel.: +98 9126462477; fax: +98 4512235330.
E-mail addresses: f.hashemi@srbiau.ac.ir (F. Hashemi), noradin.ghadimi@gmail.com (N. Ghadimi), b.sobhani@gmail.com (B. Sobhani).

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http://dx.doi.org/10.1016/j.ijepes.2012.09.008

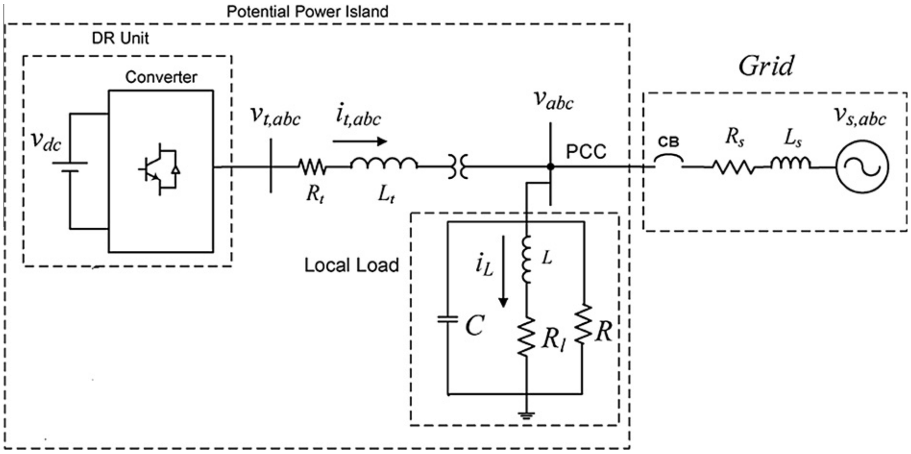

Fig. 1. Schematic diagram of a grid-interfaced DG unit.

There are many proposed techniques for detection of an island [8–18]. Before defining these methods for islanding detection, it is important to highlight two key features in order to understand the islanding phenomenon. The first one is associated with the so-called "non-detection zone" (NDZ). The NDZ can be defined as the range (in terms of the power difference between the DG inverter and the load or load parameters) in which an islanding detection scheme under test fails to detect this condition [10]. The second feature is associated with the type of loads (potential loads inside island), which can be modeled as a parallel *RLC* circuit. This circuit is primarily used because it raises more difficulties for islanding detection techniques than others. Generally, nonlinear loads that produce current harmonics, or constant power loads, do not represent significant problems for islanding detection [11]. Most islanding detection methods suffer from large NDZs [19] and/or have a run-on time between half a second to two seconds [20], and thus cannot be used for uninterruptible autonomous operation of an island. These techniques can be broadly classified into remote and local techniques. Local techniques can be further classified into active and passive techniques. Remote techniques for detection of islands are based on communication between the utility and the DGs. Although these techniques may have better reliability than local techniques, they are expensive to implement and hence uneconomical. These schemes include power line signaling and transfer trip [21,22]. Local techniques rely on the information and data at the DG site. Passive methods depend on measuring certain system parameters and do not interfere with the DG operation. Over/under voltage and frequency is one of the simplest passive methods used in islanding detection. Unfortunately, if the load and the generation on the island are closely matched, the change in voltage and frequency might be very small and within the thresholds, thus leading to an undetected islanding situation. Other passive techniques have been proposed based on monitoring rate of change of frequency (ROCOF), phase angle displacement, rate of change of generator power output, impedance monitoring, the THD technique and the wavelet transform function [23]. These offer superior sensitivity as their settings allow detection to take place within statutory limits, but their settings must be carefully selected to avoid mal-operation during network faults. The trade-off between the two performance criteria is especially difficult for these methods. If the threshold for permissible disturbance in these quantities is set to a low value, then nuisance tripping becomes an issue, and if the threshold is set too high, islanding may not be detected. In active methods, the main theme exists in the design of control circuits such that the required variations can be produced at the outputs of distributed generators. Then, once the loss of grid takes place, this designated bias will accordingly enlarge sufficiently to trip the connected relays, notifying the occurrence of the event. On the contrary, when the utility supply is normally operated, the amount of variations will be insufficient to trip the relays, ensuring that there is no event misidentified. The main advantage of active techniques over passive techniques is their small NDZ. Some important active techniques are impedance measurement, frequency shift and active frequency drift, current injection, sandia frequency shift and sandia voltage shift, and negative phase sequence current injection. Under several circumstances, this active method has won the confirmation. However, the complicated control circuit for the generation of designated bias may offset its merits [24–26]. Generally, if there are large changes in loading for DG after loss of the main power supply, then islanding conditions are easily detected by monitoring several parameters: voltage magnitude, phase displacement, and frequency change. However, in case of small changes in loading for DG, the conventional methods have some difficulty in detecting such a particular islanding condition.

This paper introduces a new intelligent-based approach for islanding detecting that reduce the NDZ to as close as possible and to keep the output power quality unchanged. The proposed technique uses the adaptive neuro fuzzy inference system (ANFIS) as machine learning method to extract information from the data sets of these parameters after they are obtained via massive event analyses using network simulations. This approach measures the rate of change of active power at the target distributed generation location and feeds it to the ANFIS for intelligent islanding detection without determining any threshold.

This paper is organized as follows. Section 2 introduces the adaptive neuro-fuzzy inference system. Section 3 introduces the mathematical model of islanded system. The effect of the interface control on the NDZ of OVP/UVP and OFP/UFP is discussed in Section 4. Section 5 presents the methodology of the proposed Technique. Section 6 covers the architecture of the proposed algorithm. Section 7 explains the simulation results to verify the effectiveness of the proposed technique and in the last section of this paper the conclusion will be presented.

2. Adaptive neuro-fuzzy inference system (ANFIS)

Artificial intelligence, including neural network, fuzzy logic inference, genetic algorithm and expert systems, has been used to solve many nonlinear classification problems [27,28]. The main advantages of a fuzzy logic system (FLS) are the capability to express nonlinear input–output relationships by a set of qualitative if–then rules. The main advantage of an artificial neural network (ANN), on the other hand, is the inherent learning capability, which