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# Islanding detection method for DFIG wind turbines using artificial neural networks

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ABSTRACT

A new passive method of islanding detection is proposed for a wind farm power generation system using artificial neural network. The proposed method is based on the voltage and current measurements and processing of these signals with a Fourier transform to find the second harmonic. Then, the symmetrical components of the second harmonic of voltage and current signals measured at the wind farm side are used to feed an artificial neural network (ANN). The proposed artificial neural network is used through different environments of power quality to identify whether the abnormity at the point of common coupling (PCC) is a power quality disturbance or an actual islanding operation. The results show that the proposed islanding detection method is able to detect islanding operation very fast in an efficient way. Finally, Matlab/Simulink is employed for this purpose.

## 1. Introduction

Distributed generation (DG) is small-scale generation that can be installed near to a load with the ability to interact with the grid (buying or selling energy) [1]. Distributed generation includes wind farms, micro hydro turbines, photovoltaics (PV), and other generators that are supplied with biomass or geothermal energies [2]. DG has the ability to improve the power system efficiency, reliability, power quality and increases the system flexibility [2]. However, integrating DG into utility is a major concern. One problem that should be taken into account is the islanding condition. Islanding is defined as a condition in which a portion of utility system that contains both load and distributed generation remains energized while it is electrically isolated from the rest of the utility system [3].

Islanding is undesirable phenomenon because it results in safety hazards for personnel, power quality problems for customers load and may cause damage to power generation and power supply facilities as a result of unsynchronized re-closure [2–4]. Considering the severe consequences islanding can bring, IEEE STD 929-2000 and IEEE STD 1547-2003 agreed that islanding should be prevented [5]. The IEEE STD 1547-2003 specifies a maximum delay of 2 s for the detection of the islanding condition [6].

## 2. Current islanding detection techniques

Until now, various anti-islanding methods for detecting and preventing islanding operation of distributed generations (DGs) have been proposed. The present islanding detection techniques can briefly be classified into two categories, local detection methods, where the detection is based on the DG side, and remote detection methods, where the detection is based on the utility side [1–4].

Remote detection methods rely on external communication devices which link each DG to the utility side [1]. They are more reliable than the local techniques, but they are more expensive to implement [3]. Local detection methods can be divided into passive and active detection methods [1–5]. The performance of each type of detection scheme can be evaluated according to their non detection zone (NDZ). The NDZ represents the interval in which islanding detection scheme fails to detect islanding condition once islanding occurred [5].

Passive methods depend on available local measurements such as frequency, voltage, phase angle and harmonic distortion, measured on the DG site at the point of common coupling (PCC) with the grid to judge whether there is an islanding operation [2,5]. These parameters vary greatly when the system is islanded. The discrimination between a normal grid-connected condition and an islanding condition is based on the threshold setting of the system parameters. So if the measurements are outside the thresholds, the relay decides to disconnect the DG. Some important

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passive methods are under/over frequency or voltage [7], total harmonic distortions [1], rate of change of frequency [8], phase displacement monitoring [9], and the THD technique [10]. Several new passive methods that use intelligent techniques for detecting power islands have been recently proposed. Wavelet-transform-based techniques discussed in [11–16] attempt to detect power islands through the changes that occur in high-frequency components in the measured signals, such as voltages, currents, and frequency. Active methods are based on the injection of small periodic disturbances on the voltage or frequency of the system at the PCC [1–5]. Since the grid power system is a very stable reference supply, these small disturbances do not have a significant effect on the system voltage or frequency under normal conditions [17]. However, when an islanding operation occurs, the system loses its stable reference power supply [17], and these small disturbances result in a significant change in system parameters (voltage and frequency) and stability of the system even if the power generation and load consumption are balanced [5,17].

Some important active techniques are impedance measurement [1,7], frequency shift and active frequency drift [2,7], current injection [18], sandia frequency shift and sandia voltage shift [13], negative phase sequence current injection [19] and voltage phase angle [20]. Active methods can reduce, even eliminate, the NDZ and detect islanding accurately compared to passive methods [1–5]. In contrast to the passive detection methods, the active detection methods can degrade the system stabilization and power quality [3,5]. Moreover, the active detection methods require time to give an external disturbance and to detect voltage or frequency changes due to the external disturbance [21].

## 3. Model description

The simulated system is a 9 Mw wind farm consisting of six 1.5 Mw wind turbines connected to a 25 kV distribution system. The wind farm exports power to a 25 kV grid through a distribution system and feeds a RLC loads. Fig. 1 shows the system used for simulation. Wind turbines using a doubly-fed induction generator (DFIG) consist of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 60 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The grid is a three-phase source with internal R–L impedance. The grid transformer ratings are 47MVA, 60 Hz, 120/25 KV and the wind farm transformer ratings are 10MVA, 60 Hz, 575 V/25 KV as shown in Fig. 1.

## 4. Symmetrical components and discrete Fourier transform

### 4.1. Symmetrical components

Symmetrical components are the key indicators which quantify the presence of any disturbances in the voltage or current signals measured at PCC. Thus, in this paper, symmetrical components of second harmonic voltage and current signals measured at PCC are considered for analysis towards effective detection of islanding and discrimination between the islanding and power quality disturbances. The positive, negative and zero sequence components of the voltage and current signals at PCC can be expressed by symmetrical component analysis as:

$$\begin{bmatrix} V_p \\ V_n \\ V_z \end{bmatrix} = (1/3) \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$$\begin{bmatrix} I_p \\ I_n \\ I_z \end{bmatrix} = (1/3) \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

where $V_a$, $V_b$, $V_c$, $I_a$, $I_b$ and $I_c$ are the three-phase voltages and currents measured at the PCC and $V_p$, $V_n$, $V_z$, $I_p$, $I_n$ and $I_z$ are the positive, negative and zero sequence voltages and currents, respectively, and $a = 1\angle 120^\circ$ is the complex operator.

### 4.2. Discrete Fourier transform (DFT)

DFT is very powerful tool for frequency analysis of discrete time signals. DFT is used for transforming discrete time sequence of finite length into discrete frequency sequence of finite length. Let $x(n)$ is a periodic discrete-time signal which is the source of the data. Let $N$ samples be denoted $x[0]$, $x[1]$, $x[2]$, $x[n]\ldots x[N-1]$.

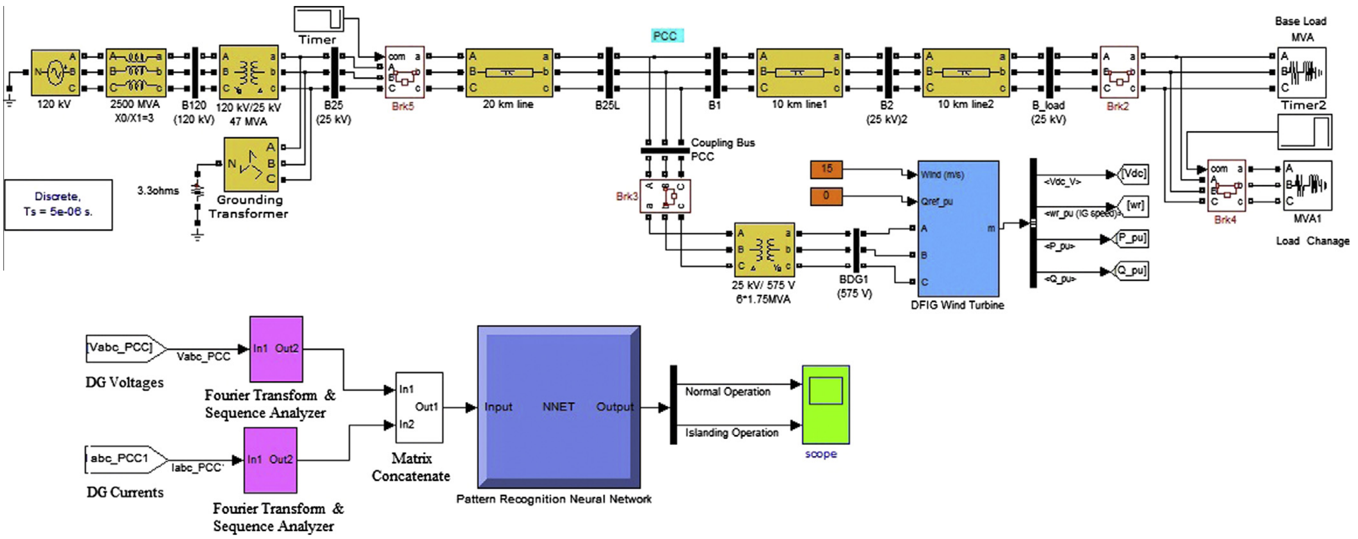

**Fig. 1.** The simulated model of the system.