Renewable Energy 38 (2012) 94–106

Contents lists available at ScienceDirect

Renewable Energy

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

Wavelet transform method for islanding detection of wind turbines

H. Kazemi Karegar*, B. Sobhani [1]

Faculty of Electrical and Computer Engineering, Shahid Beheshti University, Evin Street, Tehran, Iran

ARTICLE INFO

Article history:
Received 26 January 2011
Accepted 2 July 2011
Available online 11 August 2011

Keywords:
Distributed generation
Islanding
Wavelet
Wind turbines
Wind turbine simulator

ABSTRACT

This paper presents a passive islanding detection method for wind turbines. The proposed method is based on voltage measurements and processing of this voltage with a discrete wavelet transform. This method detects the islanding conditions with the analysis of Daubiches wavelets. The studies reported in this paper are based on time-domain simulations using MATLAB, and the feasibility of the proposed method is evaluated with an experimental system. The experimental system parameters are the same as those of the simulated system. The results show that the proposed islanding detection method succeeds in detecting islanding both in the experimental and simulated systems.

1. Introduction

The increase of distributed resources in the electric utility systems is indicated due to recent and ongoing technological, social, economical and environmental aspects. Distributed Generation (DG) units have become more competitive against the conventional centralised system by successfully integrating new-generation technologies and power electronics. Hence, it attracts many customers from industrial, commercial, and residential sectors. DGs generally refer to Distributed Energy Resources (DERs), including photovoltaic, fuel cells, micro turbines, and small wind turbines, and additional equipment [1].

The total global installed wind capacity at the end of 2010 was 430 TWh annually, which is 2.5% of the total global demand. Based on the current growth rates, World Wide Energy Association (WWEA) predicts that, in 2015, a global capacity of 600 GW is possible. By the end of the year 2020, at least 1500 GW can be expected to be installed globally [2]. However, connecting wind turbines to distribution networks produces some problems, such as islanding.

Islanding occurs when a DG and its local load become electrically isolated from the utility; meanwhile, the DG produces electrical energy and supplies the local load [3]. Islanding creates many problems in power systems, and the existing standards thus do not permit DGs to be utilised in islanding mode [4]. Some of these reasons are the following [5,6]:

- safety hazards for personnel
- power quality problems for customers load
- overload conditions of DG
- out-of-phase recloser connections

Thus, islanding conditions should be detected within less than 2 s [5].

Originally, the methods of islanding detection were divided into two categories: communication and local. Local methods were classified as active and passive techniques, in which active techniques are based on direct interaction with the ongoing power system operation [4]. Some important active techniques are impedance measurement [7], frequency shift and active frequency drift [7], current injection [8], sandia frequency shift and sandia voltage shift [9], and negative phase sequence current injection [10]. Passive techniques are based on measurements and information at the local site. Some techniques are under/over frequency or voltage [7], total harmonic distortions [2], rate of change of frequency [11], non detection zone concept [12], vector surge and phase displacement monitoring [13], rate of change of generator power output [7], and the THD technique [14].

In this paper, a new method based on Discrete Wavelet Transform (DWT) is proposed for islanding detection of wind turbines. The proposed technique, which is suitable for asynchronous DGs, is explained in Section 3. Section 4 explains the simulation and experimental test system used to verify the effectiveness of the proposed technique. Section 5 explores the effectiveness of the proposed technique applied to the simulation and experimental test systems, and Section 6 concludes the paper. The simulation test systems were simulated in MATLAB/SIMULINK using *SimPowerSystemBlockSet*. The

* Corresponding author. Tel.: +98 21 29904170; fax: +98 21 22431804.
E-mail address: h_kazemi@sbu.ac.ir (H. K. Karegar).
[1] Tel.: +98 21 29904170; fax: +98 21 22431804.

0960-1481/$ – see front matter
doi:10.1016/j.renene.2011.07.002

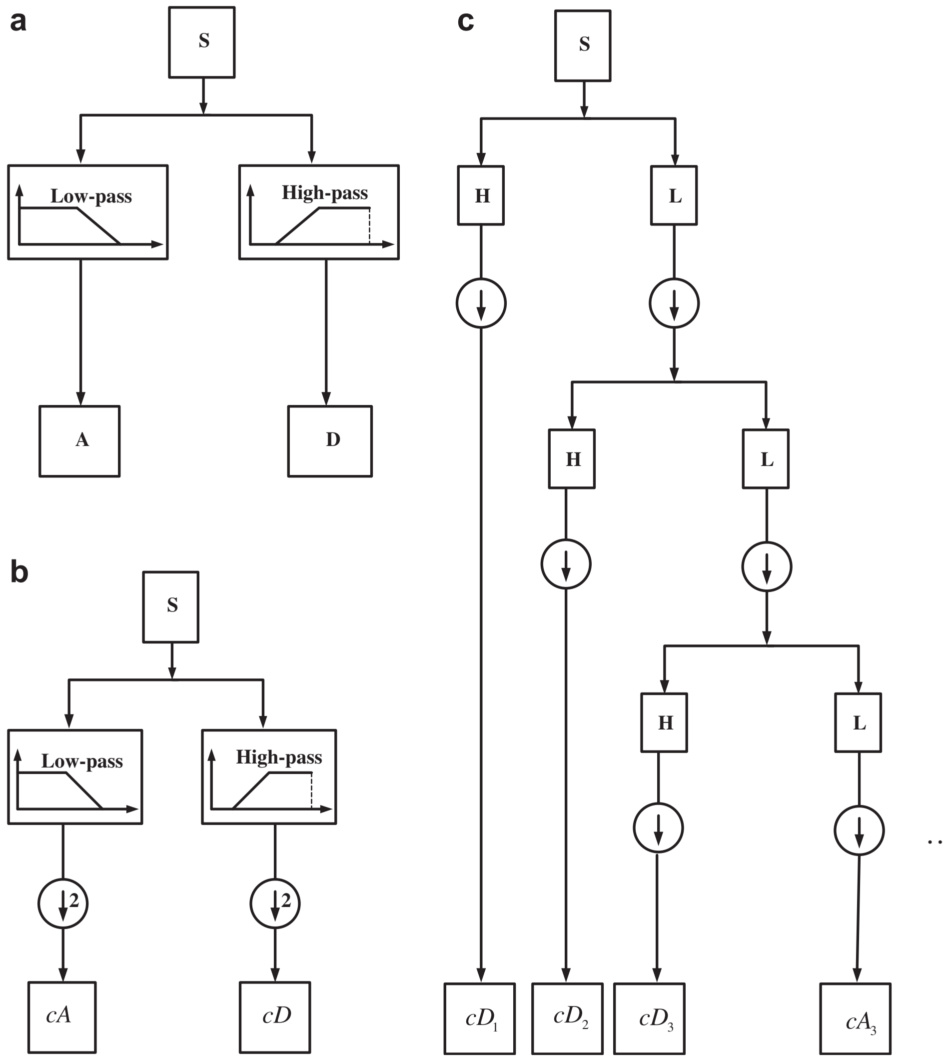

Fig. 1. (a) Filtering, (b) Filtering and Downsampling, (c) Decomposition.

simulation and experimental results show that the proposed islanding detection technique works well to discriminate between switching and islanding conditions.

2. Wavelet transform

The Wavelet Transform (WT) is a mathematical tool that is similar to a Fourier transform for signal analysis. Wavelet transform can be described with filter bank theory [15], where a wavelet and a scaling function are associated with a low and a high band-pass filter, respectively. Dyadic wavelet filters can be used for Multi Resolution Analysis (MRA) because it gives good time resolution and poor frequency resolution for high frequency components. It is worth noting that good frequency resolution and poor time resolution are normally used for low frequency components. For implementation, the input signal is divided into two components: low and high frequency. The low frequency component is further split into a low and a high frequency component [16].

The WT is more suitable than the Window Fourier Transform (WFT) or the Short Time Fourier Transform (STFT) because the WFT and STFT methods have permanent window widths. The disadvantage of STFT is the trade-off that has to be made between the length of the window and the frequency resolution. Therefore, any attempt to increase the window size to increase the frequency resolution leads to loss of time information and vice versa [17].

The DWT is “discrete” in terms of the scaling and shifting. The DWT is defined as [18]

$$C(j,k) = \sum_{n\in Z}\sum_{k\in Z} S(n)g_{j,k}(n), \quad g_{j,k}\in Z, j\in N, k\in Z \tag{1}$$

where, $g_{j,k}(n)$ is a time function with finite energy and fast decay called the mother wavelet.

$$g_{j,k}(n) = a_0^{-\frac{j}{2}} g\left(a_0^{-j}n - kb_0\right) \tag{2}$$

The selection of a_0 and b_0 is dependent on the family of scaled and shifted mother wavelets. To simply, choose $a_0 = 2$ and $b_0 = 1$, and a dyadic-orthonormal wavelet transform is obtained. $S(n)$ can be presented as

$$S(n) = \sum_{n\in Z}\sum_{k\in Z} d_{j,k}g_{j,k}(n) \tag{3}$$

The coefficients $d_{j,k}$ are generated by the DWT and called the ‘resemblance indexes’ between the signal and the wavelet. The similarity is strong if the index is large; otherwise, it is slight.