

A New Approach to Islanding Detection of Distributed Generators

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Abstract: This paper proposes the categorization of DG islanding operational condition caused by interruption of main supply. In order to prevent the DG islanding problems, fast and reliable anti-islanding categorizer is v DG can provide in some cases a significant part of the load energy requirements. It is therefore important to consider the energy balance both locally, regionally and globally. Islanding operations of DG usually occur when the main utility supply is interrupted due to several contingencies (inrush currents, faults, etc) while the DG is still supplying power to the distribution networks. These conditions have negative impacts on the system protection, restoration, operation, and management. Therefore, it is necessary to detect the presence of this condition and switch off the DG from distribution network or isolate the DG with its load from the rest of the system. Conventional detection methods for islanding conditions are based on monitoring several parameters. These parameters include voltage magnitude, phase displacement, and frequency change. The conventional methods usually will not detect such an islanding condition. This paper utilizes the discrete wavelet transform to characterize the DG islanding contingency. The proposed methods were verified using a simple radial distribution system consists of a wind-Turbine induction DG, condensers, synchronous Condenser, and loads. The generated data were used to test the performance of the detection technique.

Key word: Anti-islanding, DG, harmonics, discrete wavelet transforms.

INTRODUCTION

Distributed Generation has the potential to play a major role as a complement or alternative to the electric power grid under certain conditions. DG can also improve a utility's ability to serve peak load on a feeder. A common case where DG is effective and economical occurs when it helps various parts of the power system to run as "islands" should they become electrically disconnected to supply load during contingencies until the utility can restore its delivery capacity. DG is fundamentally distinct from the traditional central plant model for power generation and delivery in that it can deliver energy close to loads within the power distribution network. DG can be utilized to improve the power quality, minimize peak loads, mitigate the voltage flicker, to displace the need to build new or upgrade existing local distribution lines, eliminate the need for high spinning reserve, and enhance the power system reliability and security. (Borbely and Kreider 2001: Jang and Kim, 2004: Marei *et al.*, 2005). Most DGs usually is connected in parallel and supply power into power grids as well as local loads. Therefore, DG must be operated in such an inherently safe manner that DG should supply the generated power to the network loads only if the utility power supply is present.

DG islanding operation usually occur when the main utility power supply is interrupted due to several contingencies (faults, inrush currents, etc) while the DG units is still supplying power to the distribution networks. This kind of condition has negative impact on the distribution systems protection, reconfiguration, operation, load management, and DG itself. This includes safety hazards to utility maintenance crews, power quality problems to the utility customers, and serious damages to the DG if utility power is wrongly restored (Jang and Kim, 2004). Therefore, during the contingencies and the restoration of the system main supply, the connected DG must detect the loss of utility power and disconnect itself from the power grid as soon as possible. Therefore, it is very essential to detect the islanding conditions and switch off the DG from distribution network while maintaining the system reliability. The convention detection methods are usually based on monitoring several parameters: voltage magnitude, phase displacement, and frequency change. These methods often have a non-detection zone, and also may cause false tripping of generating units. Also in case of small load changes for the DG (the contingency takes place close to the DG bus), the conventional methods have some difficulty in detecting such islanding condition. Also, the distribution system harmonics have a negative effect on the protection system performance. Hence a powerful classification method based on signal analysis should be used. Harmonics and discontinuities generated in power system can have a wide frequency bandwidth, from high-frequency transients and edges to slowly varying harmonic components. Hence, analysis only in the frequency or time domain alone is not sufficient to capture features that are spread within a wide bandwidth. Wavelet transform provides a local representation (in both time and frequency) of a signal. Therefore it is suitable for analyzing a signal where time and frequency resolution is needed, unlike FFT which gives a global presentation of the signal.

This paper investigates the detection of DG islanding contingency with the help of Wavelet transform (WT). This study provides us with an efficient way to classify different islanding conditions, and coordinate between different protective devices in the distribution system.

Wavelet Theory:

The Wavelet transform is a time-frequency DSP technique, which decompose a signal in terms of oscillations (wavelets) localized in both time and frequency. As in Fourier analysis, the wavelet transform consists in decomposing a given function onto a set of “building blocks”. However, as opposed to the Fourier transformation (FT) in which the “building blocks” are the well-known complex exponentials, the wavelet transform uses the dilated and translated version of a “mother wavelet” which has convenient properties according to time/frequency localization.

The time-evolving effects of the frequency in nonstationary signals are not considered in FFT analysis. Despite the short time Fourier transform (STFT) can partly alleviate the problem, it has the limitation of fixed window width and this imposes limitations for the analysis of low-frequency and high-frequency no stationary signals at the same time. On the other hand, On the other hand, the WPT is localized in time and frequency yielding wavelet coefficients at different scales. This gives the wavelet transform much greater compact support for analysis of non stationary signals (Robertson *et al.*, 1996).

The main advantage of wavelet over the STFT is that it uses a variable-sized regions windowing technique. This feature allows wavelet to use long time intervals where we want more precise low-frequency information, and short regions where we want high-frequency information.

Multiresolution analysis:

The discrete wavelet transform (DWT) is computed by successive lowpass and highpass filtering of the discrete time-domain signal together with changes in sampling rates.

A signal can be successively approximated by DWT with different scales (multiresolution decomposition). Each step of the decomposition of the signal corresponds to a certain resolution. The decomposition process can be iterated, with successive approximations being decomposed in turn. Therefore one signal is broken down into many lower-resolution components. This is called the wavelet decomposition tree. For n-level decomposition, there are n+1 possible ways to decompose or encode the signal.

A multiresolution analysis of $L^2(\mathbb{R})$ is defined as a sequence of closed subspaces of V_j of $L^2(\mathbb{R})$, $j \in \mathbb{Z}$, with the following properties (String and Nguyen, 1996):

- $V_j \subset V_{j+1}$
- $v(x) \in V_j \Leftrightarrow v(2x) \in V_{j+1}$
- $v(x) \in V_0 \Leftrightarrow v(x+1) \in V_0$
- $\bigcup_{j=-\infty}^{+\infty} V_j$ is dense in $L^2(\mathbb{R})$ and $\bigcap_{j=-\infty}^{+\infty} V_j = \{0\}$
- A scaling function $\varphi \in V_0$, , with a non-vanishing integral, exists such that the collection $\{\varphi(x \Leftrightarrow l) | l \in \mathbb{Z}\}$, is a Riesz basis of V_0

The discrete wavelet transform (DWT) is computed by successive lowpass and highpass filtering of the discrete time-domain signal together with changes in sampling rates. Fig. 1 show a three level wavelet decomposition tree. Each of the wavelet levels correspond to a frequency band given by:

$$f = 2^{(n-m)} \left(\frac{f_s}{2^n} \right) \quad (1)$$

Where f is higher frequency limit of the frequency band represented by level m , f_s is the sampling frequency, 2^n Number of data points in the input signal

A seven level decomposition with db20 as the mother wavelet was selected to perform our study. Wavelet db20 is from Daubechies Family of Orthogonal Wavelets with compact support and highest number of vanishing moments. A sample rate of $f_s = 10$ kHz was selected for our study. Table 1 gives the frequency

band information for seven levels of wavelet analysis.

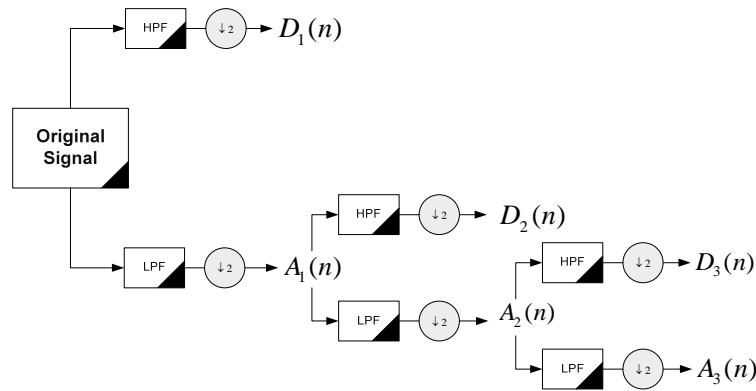


Fig. 1: Three level wavelet decomposition tree.

Table I: Frequency Band Information.

Wavelet level	Frequency band
1 (D1)	2500-5000 Hz
2 (D2)	1250-2500 Hz
3 (D3)	625-1250 Hz
4 (D4)	312-625 Hz
5 (D5)	156-312Hz
6 (D6)	39-78Hz
7 (A6)	20-39Hz

RESULTS AND DISCUSSION

The simple system in Fig. 2 consists of wind turbine driving a 480-V, 200-kVA induction generators with a customer load of 50 kW, a synchronous machine, and an equivalent circuit representing the main HV network. The synchronous machine is used as a synchronous condenser and its excitation system maintain the induction generator voltage at its nominal value. A standard three-phase Phase Locked Loop (PLL) system is used to measure the system frequency. A PLL is a nonlinear feedback system that can be used to detect and track changes in the frequency of input signal.

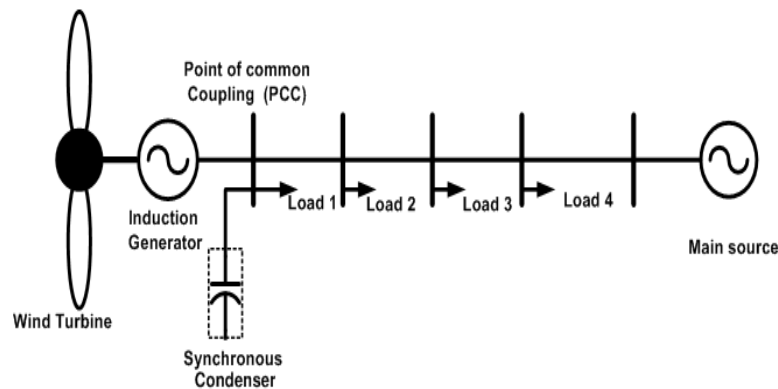


Fig.2: The system used for the study.

A study of the proposed method was conducted for different network conditions, normal network variation and islanding operational conditions of the DG.

Fig. 3 and Fig. 4 show the system frequency and current variation for normal network variation respectively. Fig. 5 and Fig. 6 show the system frequency and current variation for islanding operational conditions of the DG respectively.

Fig. 7 and Fig. 8 show the wind turbine output power for normal load change and islanding operation respectively. The contingency in both cases were created at $t=0.22$ sec.

Figure 9 shows the DWT coefficients for normal operation. As can be seen from figure 10, normal load change appears to be localized only in the D5-D7 detail coefficients. Since the load changes may create spikes in the current, any detection algorithm should be able to distinguish this condition from an Islanding condition.

Furthermore, Fig. 11 and Fig. 12 show that the DG islanding operational condition appears to be localized in D1-D7 detail coefficients. It can be seen that the DWT coefficients at the time of the islanding are much higher than their values beyond or before this time.

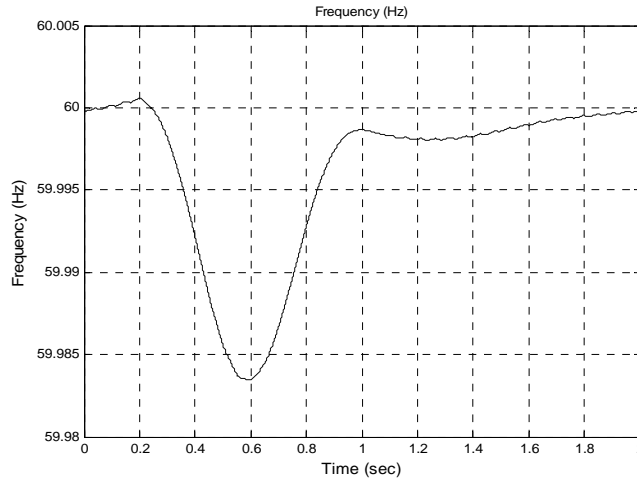


Fig. 3: The frequency variation for DG normal load change.

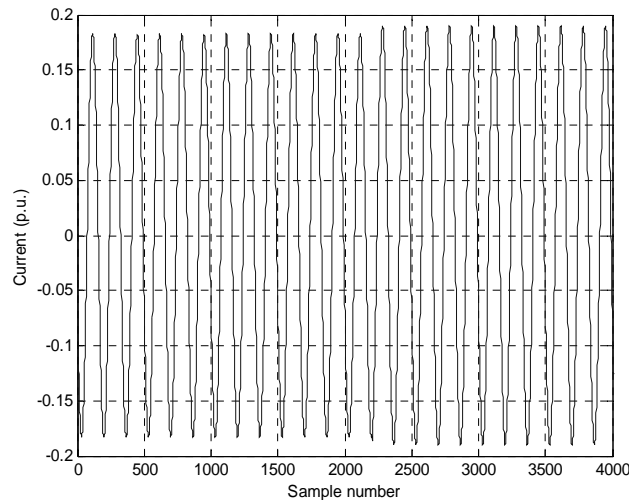


Fig. 3: The phase a current variation for DG normal load change.

Also, the first five scale detail signals (D1-D5), which includes the highest frequency components, shows a spikes at the time when the islanding occurs. The time duration of the spikes is short.

A hybrid detection system which monitors the DWT frequency bands change and the frequency of the system would be able to detect islanding. A detection algorithm that combines DWT as feature extractor with process decision trees (DTs) can be used for detecting the islanding operation.

The use of DWT as a feature extraction emphasizes the difference between normal load change and Islanding condition. More test cases need to be generated to evaluate the effect of system harmonics on the DWT based feature extraction algorithm

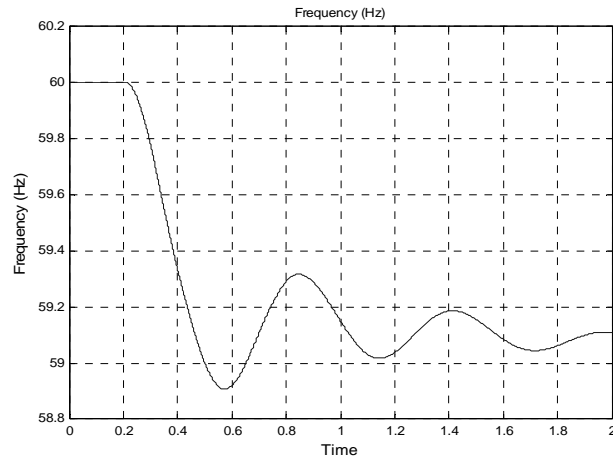


Fig. 5: The frequency for DG islanding operational conditions.

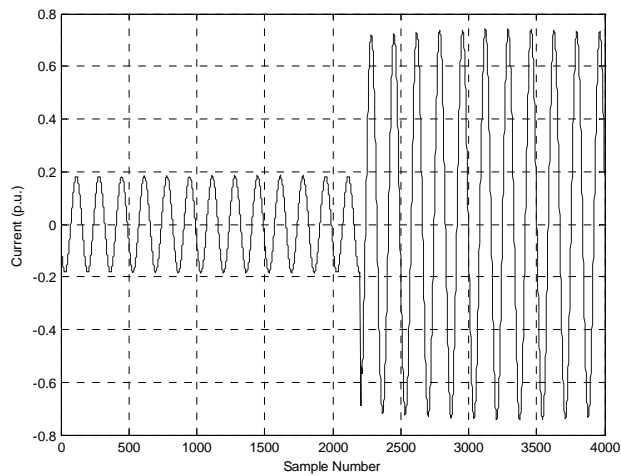


Fig. 6: The induction generator speed for DG islanding operational conditions.

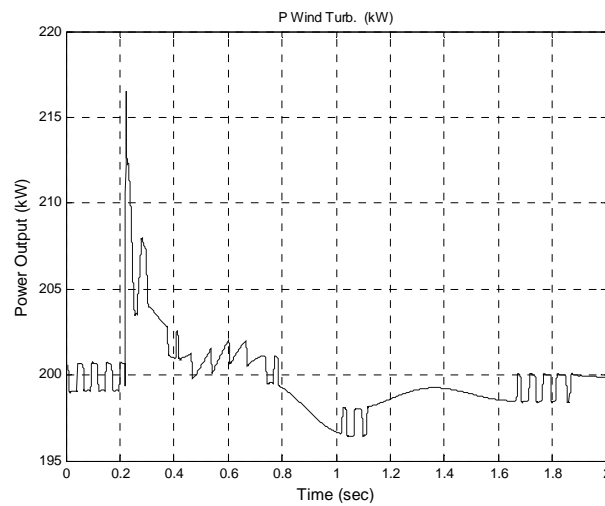


Fig. 7: The Wind Turbine output power (a) during DG normal load change and at bus 1.

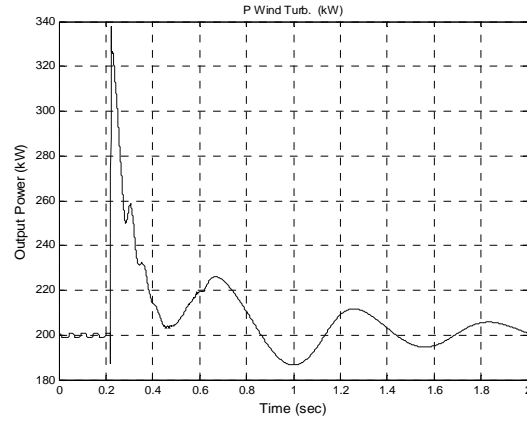


Fig. 8: The Wind Turbine output power during islanding operational conditions due to a fault at bus 1.

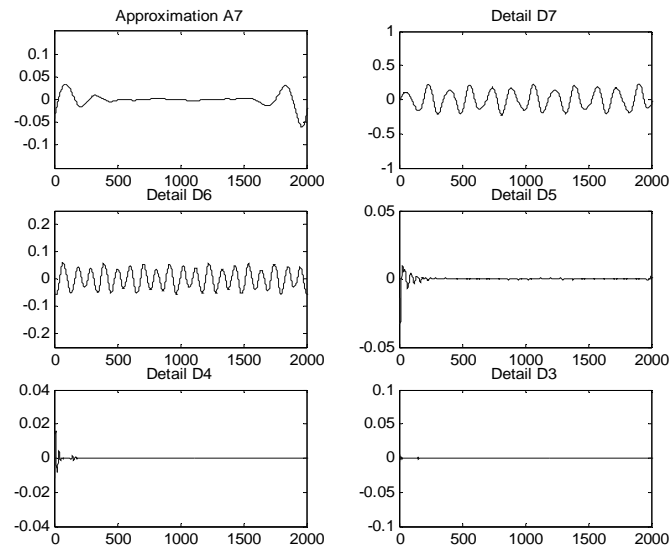


Fig. 9: DWT of the primary load currents for normal operating conditions.

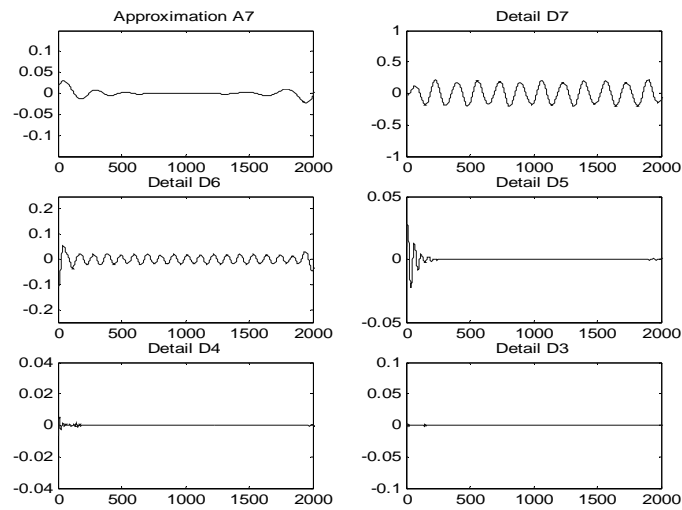


Fig. 10: DWT of the primary load currents for normal load change.

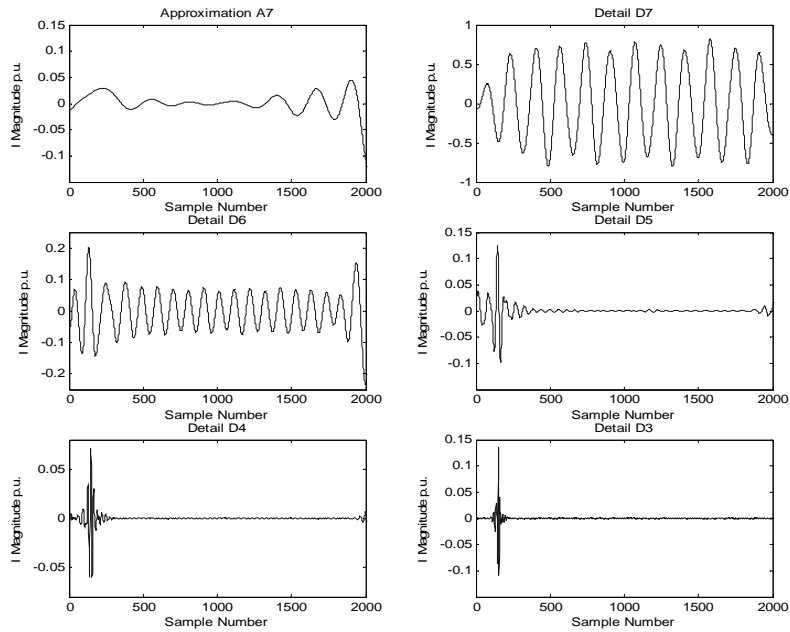


Fig. 11: DWT of the primary load currents DG islanding operational conditions due to a fault at bus 1.

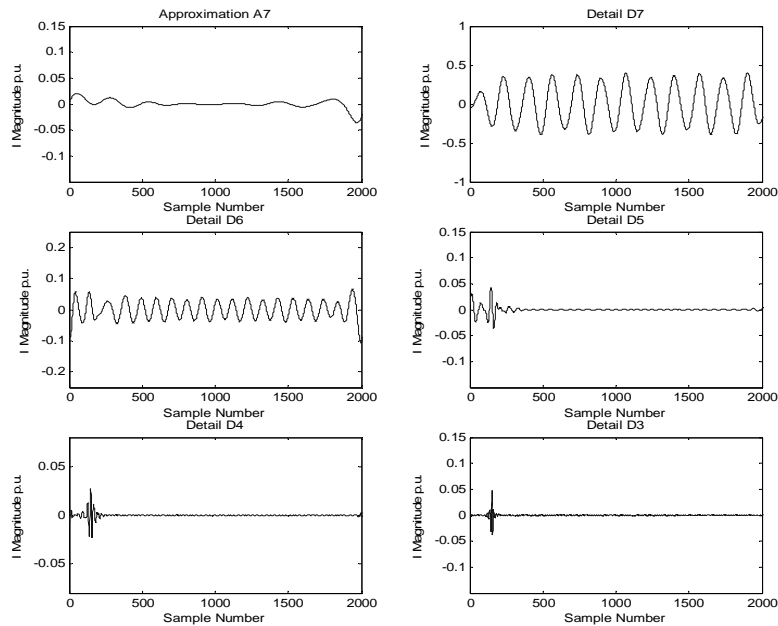


Fig. 12: DWT of the primary load currents for DG islanding operational conditions due to a fault at bus 3.

Conclusion:

The paper discussed efforts to classify DG islanding operational condition, resulting from main supply interruption. To prevent the possible problems caused by DG islanding, fast and reliable anti-islanding classifier is needed. DWT used in analyzing power system transients provide valuable information for use in feature detection systems. Data obtained from the simulations were analyzed using DWTs. The characteristics of the cases and difference between cases signatures were presented. The results of the DWT analysis show an ability to quantify different types of disturbances. It also shows high ability of wavelets to extract the different harmonic components disregarding the length of their occurrence in time.

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