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Two level islanding detection method for distributed generators in distribution networks

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ABSTRACT

Use of distributed generators in distribution networks is proved highly reliable and economical. In utility practice at the present time, accidental islanding is an undesirable mode of operation as it can harm the personnel and other connected systems. Therefore, islanding must be detected and the islanded distributed generators must be disconnected from the rest of the system. This paper proposes a new islanding detection method which provides a reliable detection in two levels. At first level wavelet energy entropy is used as an indicator to suspect islanding and activate second level method. Second level method is an active frequency drift method with positive feedback and pulsating chopping fraction that vary the output voltage frequency of distributed generators to realize the anti islanding protections. The performance of the proposed method is simulated in MATLAB environment. The proposed algorithm provides fast islanding detection with least disturbance in inverter's grid connected operation.

1. Introduction

Islanding is a situation in which a distributed generator (DG) is disconnected from the main utility but remains energies and continues to supply local loads [1]. This condition can result in many potential hazards since supply is without control and/or supervision of utility. Therefore this condition needs to be detected and protected. Many detection methods are reported in the literature under different categories such as passive, active and remote techniques [1–3]. The basic protection schemes includes over current, over and under voltage and over and under frequency. Islanding is detected by observing and analyzing the change in these indicators. Such schemes are known as passive schemes [1]. The purpose of these schemes is to detect abnormal conditions and provide signal to switch off the DG. The detectable changes in above parameters occur when there is a considerable mismatch in the power generated by the DG and power required by the load. When the power mismatch is very less, the above schemes failed to detect the islanding scenario. This range of power mismatch is known as Non Detection Zone (NDZ) of the schemes. It has been found that effectiveness of passive schemes depends on threshold setting of the parameters and range of their NDZ [1,3]. If the threshold range is set too low, nuisance tripping could occur, and if it is high, undetectable islanding events could occur. Hence passive methods are not sufficient for islanding protection. To eliminate NDZ of passive methods, active methods are included in protection [1].

These schemes introduce perturbation to[1] the parameters of the system such as voltage, frequency or impedance. When the DG is grid connected these disturbance signals do not affect the performance of the system. When the DG is islanded, disturbance signal drift the parameter to detectable limits. This external disturbance degrades the output power quality [17]. Recently, some intelligent techniques are applied to get improved and rapid detection of islanding like; Artificial Immune System [4], Artificial Neural Network [5], Data Mining [6], Wavelet [10] and Fuzzy Logic [7]. Fuzzy logic based islanding detection techniques have registered efficient detection even under noise disturbances and different load generation profiles. The main advantage is the ability to consider more number of indicators and producing one result. But these methods are highly abstract and necessitate heuristic need for experts rule discovery. Fuzzy logic based systems also suffers from lack of self-organization and self-tuning which is necessary for islanding detection. Almost all the passive methods including intelligent methods suffer from threshold setting and dependability problems. In addition to this, intelligent methods are tough to implement and requires

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[1] DG-Distributed generator, NDZ-Non Detection Zone, DWT-discrete wavelet transform, WEE-Wavelet Energy Entropy, PCC-Point of common coupling, PWM-Pulse width modulation, AFDPFPC-active frequency drift with positive feedback and pulsating chopping fraction, *cf*-Chopping fraction.

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additional hardware and software support. Due to high level of complexity, it needs higher execution time. Performance of intelligent methods is also governed by the impact of system reconfiguration and appropriate data updates.

Hybrid methods are the best alternatives for the compensation of drawback in above mentioned methods. These methods involve two level of detecting procedure to overcome the shortcomings of both passive and active methods in order to achieve higher effectiveness. Hybrid methods are cost effective than communication based methods [8,9]. Main drawback of hybrid methods is their high detection time since their final response includes both passive and active method results. In response to above mentioned detection problems, a two level technique is proposed in this paper to build a robust anti islanding scheme. Firstly, in proposed islanding detection technique, wavelet transform based technique is used to improve dependability by reducing the NDZ to negligible level. Secondly, an active islanding detection technique is applied to confirm occurrence of islanding. In proposed system, active method initiates only for small period of time hence resolves the issue of power quality degradation. The time taken by this dual level approach is much shorter than other hybrid methods as response time of wavelet entropy indicator is less than one cycle, where as other passive methods require at least one time period to pronounce indication, and speed of active frequency drift can be improved by adjusting parameters without any restriction on power quality degradation.

The proposed scheme is basically designed for three phase inverter based distributed generators. The proposed two level method works on following paradigm:

- At first level, the ratio V_q/V_d of DG terminal voltage is analyzed using wavelet transform and then wavelet energy entropy is calculated. Whenever this wavelet energy entropy crosses predetermined threshold level, a signal is sent to initiate second level method.
- At second level, an active detection method named "active frequency drift with positive feedback and pulsating chopping fraction", (which already exists and proven) is being used to confirm the islanding event.

On getting the initiation signal from entropy based method the second level method changes frequency of DG supply up to frequency relay threshold limit, only if the system is islanded.

The paper is organized as follows: Section 2 gives the introduction of wavelet entropy indicator. Section 3 describes second level active frequency drift method including the selection of its key parameters. Section 4 presents the block diagram and algorithm of 'Two level detection method'. Implementation results and discussions are given in Section 5. Finally conclusions are presented in Section 6.

2. Wavelet entropy indicator for first level detection

Wavelet tool is used for analysis of transient, non-stationary, or time-varying phenomenon. The wavelet energy entropy is able to detect the unsteady signals and complexity of the system at time-frequency plane. Wavelet energy entropy has unique capabilities of picking-up features of transient signals.

2.1. Wavelet energy entropy

The entropy is closely associated to the concept of uncertainty embedded in a probability distribution. It appears as a measure of the degree of order/disorder of the signal, so it can provide useful information about the underlying dynamical process associated with the signal. A very ordered process can be a signal with a narrow band spectrum. It has been seen that entropy alone is not capable of dealing some abnormal signals, while wavelet can provide information on both its frequency content and on its time of occurrence [10]. In fact, if the principle of wavelet analysis is combined with the concept of entropy; one can make full use of localized feature at time frequency domain. The wavelet transform studies each component of the given signal using a resolution, for which it cuts the signal, operates or functions into various frequency components. The wavelet transform is a time frequency method to analyse a signal within different frequency ranges by means of dilating and translating the signal with a single function named mother wavelet [11]. The discrete wavelet transform (DWT) of the signal is computed through low pass $h(k)$ and high pass $g(k)$ filter bank. Results of these filter banks are called as approximate and detailed coefficients of DWT [12]. A time-varying signal can be represented in terms of its frequency components by resolving it in different frequency ranges using multi-resolution analysis features of discrete wavelet transform. In each level of resolution low pass filter output is the input signal of next stage and provides new approximation and detailed coefficients. This process is repeated applying the down sampled low pass filter output into another identical filter pair. This decomposes the signal into approximation $C(k)$ and detail $D(k)$ coefficient for various scales of resolutions. Combining wavelet analysis with entropy henceforward will be known as Wavelet Energy Entropy (WEE).

In WEE, the constituent wavelet analysis would deal with unsteady signal and the entropy and in particular the information entropy would derive the information of the signal. Hence wavelet entropy not only fulfils the purpose of information mergence, but also analyses the unsteady signals. A wavelet representation of such a signal will be resolved in one unique wavelet resolution level. All wavelet energies will be almost zero except for the wavelet resolution level that includes the representing signal frequency. A signal generated by a random process will represent a disordered behaviour. This signal will have significant contribution from all frequency bands. Consequently wavelet coefficient energy will be equal for all resolution levels and we will take their maximum value. The wavelet entropy principle has been used in different applications in power system such as fault diagnosis, optimal power flow, dynamic security assessment and load forecasting [13,14].

The wavelet energy entropy of the signal can now be mathematically represented using Shannon entropy [13]. The wavelet energy entropy at scale 'j' is given by;

$$WEE = -\sum_j P_j \log P \tag{1}$$

Here P_j is normalized signal energy and defined as ratio of energy of a layer at j level to total signal energy E corresponding to certain time window (window width is). Mathematically this normalized signal energy is given by a ratio $P = E_j/E$ and its summation is unity; as $\sum_j P_j = 1$.

The denominator of normalized signal energy P_j is total signal energy E, which using orthogonal wavelet transform is given by,

$$E = \sum_j E_j \tag{2}$$

where $E_1, E_2, \ldots, E_j, \ldots, E_m$ are wavelet energy spectra of signal $x(t)$ on 'm' scales and is represented as,

$$E_j = \sum_k E_{jk} \tag{3}$$

The E_{jk} in Eq. (3) is wavelet energy spectrum at scale 'j' and instant 'k' and calculated as sum of energy of all wavelet detailed coefficients at that particular scale as:

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