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Goertzel Algorithm Based Islanding Detection Method Based on Small Second Order Harmonic Component for Grid Integrated PV Systems

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In modern power system many challenges have beenoccur when the distribution generation (DG) integrating to the power grid. One of the major challenges is islanding phenomena, which occurs when the power grid disconnected from the distribution system and disconnected power line still supplied by the DG system. This unintentional phenomenon must be detected to prevent the damage to equipment and hazardous effects to the workers. Active methods have small non-detection zone (NDZ). This paper proposes a new islanding detection method (IDM) based on injecting the harmonic component and monitoring the changes in power system by reducing the islanding detection time and zero crossing effect of the system. A new algorithm is introduced to detect islanding condition. The advantage of using Goertzel Algorithm (GA) is reducing the total number of computational effort.The proposed islanding detection method is small detection time compared to the other techniques.This paper simulate by using the MATLAB/SIMULINK.

Keywords: Islanding detection, MPPT, Photovoltaic Systems, Goertzel algorithm, Discrete Fourier transforms

Introduction

Recently, there is an increasing for distribution generation with their low and medium voltage level of distribution networks. A new power plants have made DG systems an attractive choice to the existing system infrastructure. An energy source connected to the grid is formed as a DG system. DG systems are considered environmentally free, because they use renewable energy (RE)[1-4].RE become alternative energy source to the existing system to supply demanded energy consumption. Nowadays photovoltaic based DG systems are one of the major DG systems for their cost effective installation and low maintenance.Islanding is a critical technique in DG control. Majorly Anti-islanding detection methods are classified into two groups: local and remote methods. Local islanding detection methods again divided in passive and active methods. Communication based methods are comes under the remote methods.Passive methods are based on monitoring the some parameters like voltage, current, frequency and harmonic distortion at the point of common coupling (PCC).

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Passive methods

Passive methods such as over/under voltage protection, over/under frequency method, voltage-ripple based detection are normally detect islanding condition by exceed a threshold value. Main advantages of passive methods are easy implementation, speed of detecting and power quality. The major disadvantages of passive methods are they exhibit high non-detection zone. In general, passive methods use time domain analysis for detecting islanding condition. Active methods detect islanding by introducing small disturbance to the system and observe the changes in distribution system[5-7]. By injecting disturbance signal to system degrade the system power quality because it can cause variation in the output magnitude. Active methods have the advantage of small non-detection zone. Remote location islanding detection methods works on the basis of some type of communication between DG system and power grid.

Power line carrier communication and SCADA, Signal produced by disconnect wavelet transformation[8-9]. Using these methods no power quality degradation, effect of influenced by number of connected inverter is less, short operating time but high implementation cost. The proposed active method is based on injecting harmonic component to the system and monitoring effect to the utility system. The aim of this paper is to introducing harmonics and the algorithm is applied for analysis at the point of common coupling (PCC). By using this method reduces the detection time and power quality of PCC.

Islanding Phenomena

Islanding phenomena is a condition in DG system, which occurs when the power grid is disconnected from the DG source. When this phenomena occurs the DG system continue to supply to the utility system. Islanding phenomena is intentional or unintentional. Intentional islanding occurs whenever maintenance needs work at the transmission line or at the power grid. Unintentional islanding occurs by accidental, atmospheric effect, malfunctioning by human error and faults at the system.Power grid loses control over supply in islanding mode. Distribution networks used passive systems and they didn’t have any power sources injecting power to utility. Any fault occur in the network was deal with by grid protection technique on at basis. Another problem for occurring islanding phenomenon is safety issues for maintenance personnel and damage to the equipment.

Inverter-Based Distributed Generation Model

The PV array contains series and parallel combination of PV cells to supply desired output voltage. The single-crystalline silicon and the multi-crystalline silicon modules are most commonly used technologies. Generally PV cell prepare crystalline silicon material and each cell generates 0.6v. PV modules don’t have any moving parts and it requires little servicing or maintenance and have typical lifetime of about 20 years. In the field of solar photovoltaic system power electronics has a significance role. Power electronic based devices are used to enhance the efficiency of the solar system. By using these devices reduced the conversion efficiency and losses of system. The single-stage single phase grid connected PV system is as shown in fig. 1. The inverter is fed by a PV array. The maximum PV voltage and current is as follows: Vmax = 30.7v, Imax =8.06A. The I-V characteristics and P-V characteristics of the PV array are nonlinear, because the photovoltaic cell is used silicon semiconductor material. Solar irradiance and temperature affect the generated output voltage and current. As the irradiance increased the generated output voltage increased and hence the PV output power also increased. As the temperature increasing results in decrease the output voltage and slight increase in current. Power conditioning system broadly classified into two types i.e.., isolated and non-isolated systems. Isolated power conditioning system use low frequency and high frequency transformers to isolate between the PV array and the grid. This system involves increasing magnetic loss, low efficiency, complex control resonant problems and increase the

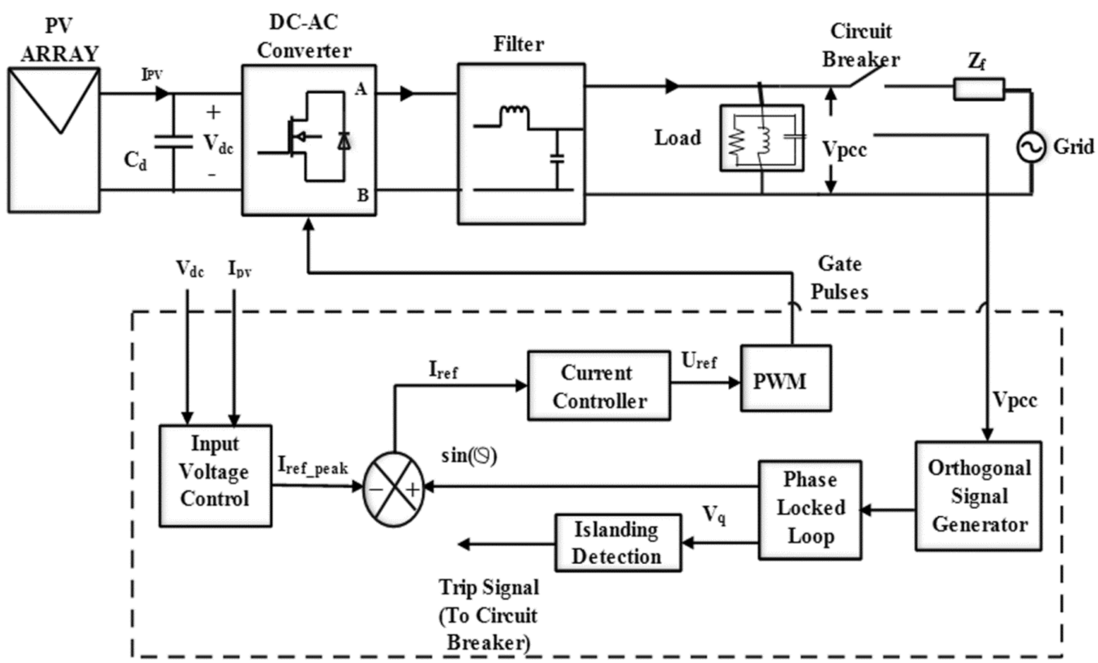

Fig. 1 — Control strategy for grid connected system

cost of the overall system. Non-isolated power conditioning system generally categorized into two type's i.e.., single-stage and multi-stage systems. Among these two systems single-stage systems are widely used in PV applications. Transformer-less inverter system has maximum efficiency and less weight. A voltage source H-bridge inverter is connected for the conversion of dc-ac with pulse width modulation[10-11], and a LCL filter. The development of inverter involves changes to the switching algorithm like pulse-width modulation (PWM), sinusoidal PWM and space vector PWM. The quality of output voltage after the inverter depends on the number of harmonics exists in the output voltage[12]. The control of the system starts from a MPP tracking (MPPT) executed by means of a P & O algorithm. The reference of the PV panel voltage is output of the MPPT i.e.., Vdc_ref. The output of the PI controller is the current loop reference Iref. A phase-locked loop is implemented for synchronization with fundamental component of the grid voltage with current by using synchronous reference frame techniques. The reference current is given as the input to the voltage controller. PCC voltage is given to the phase locked loop as an input[14]. Reference signal for PWM to generate pulses is produced by using current controller. By using orthogonal signal generator generates the stationary reference frame component for park transformation. The inverter current is synchronized with the grid voltage by means of a phase-locked loop (PLL).

Proportional-Resonant (PR) controller based current control is used to achieve zero steady-state error by replacing the PI controller for single phase grid connected PV system[12-13]. The conventional PI controller has some drawbacks which are: inability to track a sinusoidal reference with steady state error zero and much reduced disturbance elimination capability. These drawbacks can be overcome by using the PR current controller. The drawback of the ideal PR controller is the gain of this controller is much less other than fundament frequency. The harmonics caused by the switching of the power converters are the main factor causing problems to equipment, where the filter an important consideration in the systems designs. Loading of the DG at the islanding condition, could affect the islanding detection method.

Passive Method of Islanding Detection

These islanding detection methods are based on monitoring system parameters like voltage, current, frequency, voltage-ripple based, phase angle and harmonic distortion. Voltage monitoring methods such as over voltage/under voltage and over frequency/under frequency detect islanding when the monitoring voltage and frequency exceeds the threshold value. In grid integrated mode the impedance of the grid is small, inverter current flows into the grid. When measured value is exactly matches the threshold value these techniquesfail to detect islanding condition.The advantage of this method, it is simple. The main drawbacks of passive islanding detection are presence of large amount of voltage harmonics and islanding detection time ishigh and non-detection zone of this method is large.

Conventional Active Islanding Method

Most of the passive IDMs are large NDZs and not enough accurate, thus affecting the output power quality of the grid integrated systems. Active IDMs are implemented for overcome the constraints of passive techniques.Active islanding detection methods implement by introducing disturbance to the system by some parameters like, voltage, current, power variations and frequency.A simple active islanding method is introducing for grid system. This method is introducing current phase angle as a feedback derived from the PLL.The current angle is distorted by a sinusoidal signal to a low magnitude and same frequency as one obtained from the PLL.Whenever grid disconnect from the DG system, the distortion through a loop positive or negative injection will continue to distort the reference angle pushing the signal from the inverter to cross boundary. This active method is based on modification of the angle to inverter current angle.Injected signal synchronized with the cycle is introducing to slightly change the inverter current angle.Extracting the feedback signal from the PCC as consequence of the injecting signal. The addition of injected signal to PLL angle has chosen over the addition of second-harmonic signal, hence not affecting the current reference amplitude. The injected signal has the two times the normal frequency and the amplitude is related grid impedance value. By using park transform extracted injected signal from the PCC voltage. After park transform frequency of the injected signal is half of the normal frequency. The algorithm for islanding detection method is monitoring feedback signal magnitude.First initializing the voltage feedback signal values. After initialization read the delta value from amplitude of the feedback signal with normal frequency.

Proposed Islanding Detection Method

Generation of the Disturbance

The disturbance is creating by the reform of the signal of the PLL. The injected current signal is according to expression (1). To generate the disturbance using the PLL is always proportional to the current. The inverter current angle is slightly changed by injecting the sinusoidal signal. The injected signal is defined as

$$\rho_{inj} = x * sin\theta pll \qquad \ldots (1)$$

For small values of x the adding of the inject signal is similar to the addition of harmonic component. The amplitude of the signal is slightly different of the amplitude of the signal in (2). The consequence of adding $xsin\theta_{pll}$ is seeing as a feedback in the voltage at the PCC, when the inverter supplies power to grid. The feedback signal is the twice the fundamental frequency. The signal frequency will become half of the frequency after the park transformation.
The N-point DFT is defined as,

$$H(x) = \sum_{n=0}^{N-1} h(n).e^{-j\left(\frac{2\pi}{K}\right).n.x} \qquad \ldots (2)$$

Where h(n)–current input signal sample; x-Discrete frequency index, N–Number of samples and k represents amount of the disturbance needed.

Detection Algorithm

The Goertzel algorithm (GA) is used to work out the discrete Fourier transform (DFT) spectra. The advantages of using GA are reducing computatio nal effort and inherent simplicity. DFT taken over small time sections of the signal at a given frequency. GA is executed in a second-order IIR filter. The generation of individual co-efficient of the GA using simple recursive filter with incorporates digital resonator. Goertzel filters generate Fourier co-efficient at arbitrary frequencies rather than DFT frequencies expressed in (3a). Comparison number of operations for each type of Fourier transforms is[8]. The GA is a faster than a Fourier transforms method and a DFT.The expression representing the GA is given by a transfer function. The transfer function of filter and the magnitude (A_k) of the frequency component are

$$H(z) = \frac{1-e^{-j\left(\frac{2\pi k}{N}\right)}Z^{-1}}{1-2\cos\left(\frac{2\pi k}{N}\right)Z^{-1}+Z^{-2}} \qquad \ldots (3a)$$

$$|A_k(N)| = u^2(N-1) + u^2\,(N-2)\,u\,(N- 1u\,N-2\cos 2\pi kN \qquad \ldots (3b)$$

Extract the q-axis component from the voltage at the PCC after the transformation. To regulate the harmonic component magnitude, it is essential to discretize the voltage to implement the Goertzel algorithm. By using GA found magnitude and phase angle of the required frequency component. The magnitude of the required frequency component is low pass filtered with fundamental frequency yielding an averaged variable $A_k$is expressed in (3b). The magnitude is compared to the threshold value to determine islanding phenomena. The islanding detection algorithm is shown in figure2.

Simulation Results

The proposed islanding detection method performance is observed by using MATLAB/ Simulink. A conventional P&O MPPT algorithm is used to operate inverter in closed loop. In voltage control loop PI control is used to generate the reference current. The control circuit is included of a power control block with MPPT algorithm, a voltage

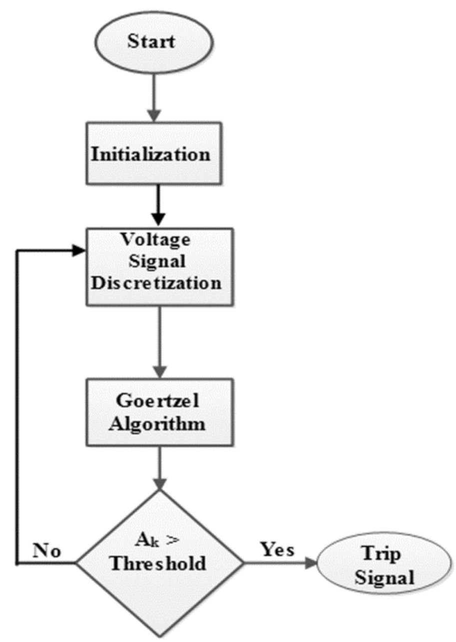

Fig. 2 — Algorithm for islanding detection

Table 1 — System Parameter Specifications

Parameters	Values
PV panel power	*1.2 kW*
DC Link capacitor	*220uF*
Output frequency	*50Hz*
Inverter inductance	*35mH*
Inverter output capacitor	*270nF*
Grid side inductor	*1.8mH*
Inverter switching Frequency	*20kHz*

Table 2 — Comparison of different islanding methods for different loads

S.No	Types of Load	Islanding Detection Methods	Detection Time(msec)
1.	Resistive load	Passive Method (Harmonic Component Detection)	4
		Active Method(Harmonic Component Injection)	20
		Proposed Method(Goertzel Algorithm)	10
2.	RLC Load	Passive Method(Harmonic Component Detection)	10
		Active Method(Harmonic Injection)	60
		Proposed Method(Goertzel Algorithm)	20

controller, a single-phase PLL, a current controller and PWM generator. The gain k in the injected signal indicates the injection ratio. The gain k was set to 0.1 for the results shown below. A small magnitude signal was required to inject in order to detect islanding condition for high quality factor. In PLL circuit used park transformation to convert stationary components into d-q axis components. Inverter phase angle reference is not affected by the zero crossing under the normal operation and when the amplitude of the disturbance signal is ten times larger for the injected signal. The simulation results of grid voltage and current with RLC load with purely sinusoidal grid voltage as shown in figure3 (a). The magnitude of grid voltage and current are respectively 195v and 8.02A. The circuit breaker is opened at 0.6 sec when the trip signal is applied. At that time the grid will be disconnect from the distribution system. By using proposed algorithm the islanding condition detected at 0.622 sec.The grid voltage and the inverter current are in phase with each other, this can be achieved by the phase locked loop. When the grid is on condition grid voltage and inverter current are in synchronization up to the circuit break trip signal is in on state. Figure 3 (b) shows the PCC voltage, grid current, distortion magnitude and trip signal. When the grid is disconnected from the network a significant change in the harmonic content. The magnitude of distortion signal is indicating when the trip signal is occurred. The disconnection of DG network from the grid takes place whenever magnitude of the frequency component exceeds the threshold value. If the magnitude of frequency component is not more than the threshold value than normal grid connected operation takes place. The islanding detection time is 0.02sec, which is less than the conventional islanding detection method. The islanding detection time is defined by the standards IEEE 929-2000. The islanding detection takes place whenever tripping signal is sent to the circuit breaker. The proposed islanding detection has a small disconnection time.

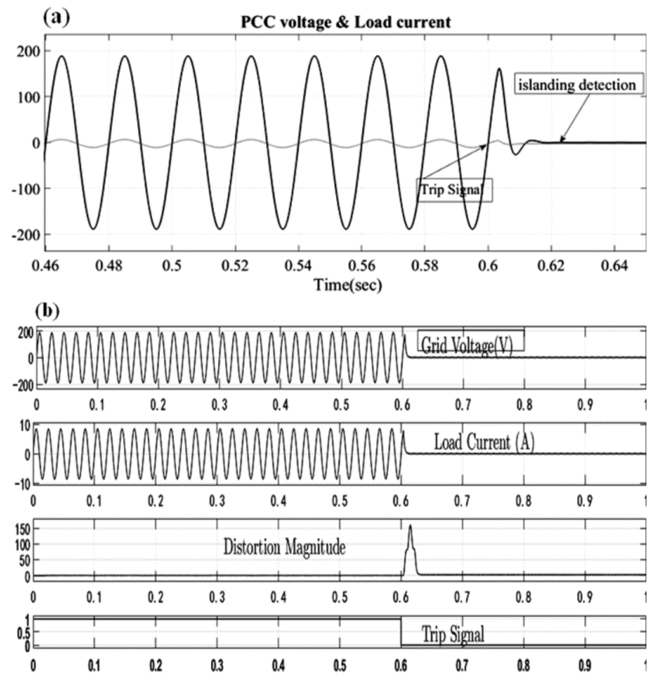

Fig. 3 — shows the simulation results of (a) Islanding Detection (b) pcc voltage and Load current in case of islanding detection for RLC load

Conclusion

In this paper proposed an anti-islanding detection method by introducing harmonic component as a feedback signal. The passive islanding detection method has large non-detection zone and detection time. The drawback of the passive islanding detection method is rectified by using proposed method. Active method is introducing to reduce the NDZ and detection time. The conventional active islanding detection method is introduced based on the injection of the harmonic component to the grid connected PV system. Active islanding detection method has detection time is large. To reduce the islanding detection time proposed an algorithm based active method for the DG system. The proposed active islanding method verified by using MATLAB/ SIMULINK. In proposed method Goertzel algorithm is introduced to generate signal to the breaker. The proposed method is based on introducing the harmonic component to the system. The island occurs when the magnitude of the signal is greater than the threshold value. The magnitude is generated by using the Goertzel algorithm. The proposed method is less detection time compared to the other technique. The future scope is to develop a prototype model for islanding detection using Goertzel algorithm.

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