New Islanding Detection for Grid-connected PV Generation System Based on the Voltage Harmonic Sequence Components

Shu-Ping GAO¹, a, Wen-Hao LI¹, ², b, * and Bao-Ji YUN³

¹College of Electrical and Control Engineering, Xi’an University of Science and Technology, Xi’an 710054, China
²State Grid Hanzhong Electric Power Supply Company, Hanzhong 723099, China
³Xi’an Xirui Electrical Engineering Technology Limited Company, Xi’an 710018, China

¹067704076@qq.com, b544759558@qq.com

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Abstract. The islanding problem in grid-connected photovoltaics system and traditional islanding detecting method are studied in this paper. Based on the technology of passive islanding detection, a new method of islanding detection is proposed which is implemented by using the voltage harmonic sequence component. According to the principle that the power quality of inverter-side is unequal to power quality of the grid-side at PCC point, the characteristic harmonic frequency sequence components of voltage can be extracted by FFT at PCC when islanding state is occurring. Theoretically, non-detection zone can be thoroughly eliminated by the extraction and recognition of microscopic variables. Simulation model of grid-connected PV generation system is established in PSCAD/EMTDC, and algorithm is carried out by MTALB. The simulation results show that the method is effective and fast. The method proposed has high response speed and no influence on the power quality of the system.

Introduction

As a kind of clean and renewable resources, solar energy is increasing favored by countries all over the world, the global solar energy industry is booming [1].

Solar PV power generation has off-grid and grid-connected two kinds of works [2, 3]. Compared with off-grid PV generation system, grid-connected PV generation system has higher energy utilization rate. Besides that, grid-connected PV generation system has a special fault state, being called as an island state, which should also be considered.

A DG system is shown in Fig 1. In Fig 1, when the accident occurs due to a failure of power supply or power outage maintenance cause the tripping, each client DG system failed to detect the off state timely which will cut itself off the mains network, eventually a self-powered isolated power systems is formed by the DG system and its connected loads, which is called as an island state.

Figure 1. Islanding of distributed generation system scheme.
Currently, island detection method can be divided into two categories, namely local island detection method and the island detection method based on communication. The first detection method of Local Island is implemented by monitoring terminal voltage or current signal of the grid-connected power generation device.

Local island detection method can be further divided into passive and active two kinds. Passive method is only according to the abnormal of voltage or frequency at grid inverter side to judge the happening of the island. Passive methods usually exist relatively large detection blind area. And active way is carried out by injecting disturbance signal into the grid. The method judges the happening of the island by using the corresponding change of system voltage, frequency and impedance caused by the disturbance signal. This method can effectively reduce the detection blind area. However, it has certain influence on power quality.

The second category of island detection method detects island state by using communication. The method can reduce the detection blind area, but it has not been widely used because of the design of complex. In view of the island effect, many experts and scholars put forward the corresponding the islanding strategies [4-6]. This paper proposes a new method of islanding detecting, which is realized by using the voltage harmonic sequence components. The method proposed is simple and easy to be set. Moreover, it has low requirement to the sampling frequency and can be realized easily only using a specific frequency signal (100 Hz and 200 Hz) data.

The Islanding Strategy Based on Voltage Harmonic Sequence Component Detection Principle

For a complete power system, no matter what it is the running state, it can use sequence network as its equivalent circuit network. According to this, a new method of islanding detecting is proposed, which is implemented by using voltage harmonic sequence components at PCC.

When DG is connected to grid, grid can be thought of as an infinite power. Grid inverter produces harmonic current, which will flow into the low impedance of grid. The small grid harmonic current and low impedance of grid make the voltage output in the grid inverter contain only a small amount of harmonic voltage. That is to say, the voltage distortion rate closes to zero.

After the grid disconnection, harmonic current flows into the load impedance, which is much higher than the grid impedance, the larger voltage distortion will be produced at PCC. The islanding fault can be detected quickly and efficiently by fast Fourier transform to extract the specific frequency (100Hzand 200Hz) harmonic sequence components.

Practical application research shows that when the grid-connected PV generation system contains more than one grid inverter, the voltage harmonic detection method can cut off the failure within 0.5s time after islanding happens. Thus, voltage harmonic detection method can effectively prevent the formation of island. This method is high reliability, especially suitable for small grid photovoltaic power generation systems.

Failure Criterion and Setting

From the section 2, the content of voltage harmonic at PCC has changed when island happens. According to the above problem, specific harmonics (second-harmonic, fourth-harmonic) can be monitored, and every harmonic corresponding threshold values are set. When one or multiplex voltage is more than setting value, we can think the PV system is in the islanding state. Its setting rules are as follows:

\[ |\Delta U_{2}^{(n)}| > U_{set1} = 0.0012U_{1} \]  \hspace{1cm} (1)

\[ |\Delta U_{2}^{(n)}| > U_{set2} = 0.0012U_{1} \]  \hspace{1cm} (2)

\[ |\Delta U_{4}^{(n)}| > U_{set3} = 0.0006U_{1} \]  \hspace{1cm} (3)
\[ |\Delta U_4| \geq U_{set4} = 0.0006U_1 \]

In Equ.1-4, \( U_1 \) is the RMS value of the fundamental voltage; \( U_2^{(1)} \), \( U_2^{(2)} \) are the RMS value of the second-harmonic voltage positive sequence component, second-harmonic voltage negative sequence component, respectively. \( U_4^{(1)} \), \( U_4^{(2)} \) are the RMS value of the fourth-harmonic voltage positive sequence component, fourth-harmonic voltage negative sequence component, respectively. \( U_{set1}, U_{set2} \) are the second-harmonic voltage positive sequence and negative sequence component setting value, respectively. \( U_{set3}, U_{set4} \) are the fourth-harmonic voltage positive sequence and negative sequence component setting value, respectively.

**Islanding Protection Logic**

Based on the above analysis, we can construct an islanding protection logic scheme shown in Fig. 2.

**Simulation Verification**

**Establishment of a Grid-connected PV Generation System Model**

A 500kW grid-connected photovoltaic system sketch is shown in Fig. 3, which is established in PSCAD/EMTDC [7-9]. Inverter module is IGBT three-phase full bridge inverter circuit, the output voltage is 270V (line voltage), the output current is 1000A, the actual output power is 470kW. Local load using the delta connection in parallel RLC circuit simulation (the islanding is in the worst situation), quality factor is 1, \( R = 0.465 \Omega \), \( L = 0.000987 \text{H} \), \( C = 10268 \mu \text{F} \) [10-12]. Through two levels of step-up transformer, the voltage will rise to 110kV, which is connected to the grid. System operation time is 1.2s, islanding failure occurs at \( t = 1 \)s time, the islanding duration time is 0.1s. System operation parameters is shown in Fig. 4.

From Fig.4, it can be seen that there are no changes of running parameters in normal operation and island operation, which shows that the islanding is in the worst situation.
Simulation Verification

In this paper, simulation model is established in PACAD, and the method of islanding detection is implemented with Matlab. In simulation, the sampling frequency is 4.8kHz, the shifting data window length is 20 ms [13-15], the islanding failure is at t=1s moment and the duration time of islanding failure is 0.1s. Because the length of the paper is limited and positive and negative sequence component completely symmetrical, this paper only gives A phase positive and negative sequence fault component waveform.

Voltage Component Analysis When Three-Phase Circuit Breaker Tripping Occurs

When the three-phase circuit breaker tripping occurs, called as symmetrical failure, the voltage fault component waveform is shown in Fig.5-6. Fig.5 is the 100Hz voltage positive and negative sequence fault component waveform. Fig.6 is the 200Hz voltage positive and negative sequence fault component waveform.
From Fig.5-6, we can see that every harmonic voltage positive and negative sequence fault component close to zero in the normal operation state of grid. When islanding occurs (sampling points for 480), every harmonic positive and negative sequence fault component as not changed, after two cycle(40ms, sampling points for 672), 100Hz and 200Hz voltage positive and negative sequence fault component are greater than setting value. According to the setting logic, islanding testing is success.

**Voltage Component Analysis When Single-Phase Circuit Breaker Tripping Occurs**

When single-phase circuit breaker tripping occurs, the voltage fault component waveform is shown in Fig.7-8. Fig.7 is the 100Hz voltage positive and negative sequence fault component waveform. Fig.8 is the 200Hz voltage positive and negative sequence fault component waveform.
From Fig.7-8, we can see that every harmonic voltage positive and negative sequence fault component close to zero in the normal operation state of grid. When islanding occurs (sampling points for 480), every harmonic positive and negative sequence fault component has not changed, after two cycle(40ms, sampling points for 672), 100Hz and 200Hz voltage positive and negative sequence fault component are greater than setting value. According to the setting logic, islanding testing is success.

**Voltage Component Analysis When Two Phase Circuit Breaker Tripping Occurs**

When two phase circuit breaker tripping occurs, the voltage fault component waveform as shown in Fig.9-10.

Figure 9. 100Hz A phase voltage positive and negative sequence fault component waveform.

Figure 10. 200Hz A phase voltage positive and negative sequence fault component waveform.
Fig. 9 is the 100Hz voltage positive and negative sequence fault component waveform, Fig. 10 is the 200Hz voltage positive and negative sequence fault component waveform.

From Fig. 9-10, we can see that every harmonic voltage positive and negative sequence fault component close to zero in the normal operation state of grid. When islanding occurs (sampling points for 480), every harmonic positive and negative sequence fault component has not changed, after two cycle (40ms, sampling points for 672), 100Hz and 200Hz voltage positive and negative sequence fault component are greater than setting value. According to the setting logic, islanding testing is success.

Conclusions

In this paper, a new islanding detecting method is proposed, which uses the voltage harmonic sequence component to implement the islanding state identification according to the difference of the voltage harmonic component in the normal operation and islanding operation state. It takes 40ms to detect the island mode and activate the protection scheme. A great deal of simulation results show that the method proposed is effective.

The proposed method can detect islanding state effectively and quickly. It has no influence on power quality, and no island blind spot detection. The method is simple and has a wide application scope, need lower sampling frequency and can be implemented with hardware easily.

Reference


