Research on island detection method based on integrated impedance sequence component

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Abstract. Aiming at the large blind area of traditional passive island detection method, active island detection method has a certain impact on power quality. A new method of island detection based on integrated sequential impedance is proposed. In this method, the integrated impedance sequence component of the Inverter side union point is used to replace the sudden variable in the traditional impedance method. By detecting the change of the integrated impedance sequence component at the PCC point, the islanding phenomenon is determined when the value exceeds the limited range. The simulation of single-PV grid-connected inverter system verifies the correctness of the theoretical derivation and the effectiveness of the proposed islanding detection method.

key words: Photovoltaic power generation; island detection; integrated impedance; sequence component

1. Introduction

Photovoltaic power generation is a new type of power supply, which organically combines photovoltaic equipment, load, battery group and photovoltaic inverter to form a single controllable independent power supply system, which can supply electricity to local load separately and can be connected with the grid operation[1]. The energy collected by photovoltaic cells is transmitted to the power grid by a three-phase grid-connected inverter. In the process of energy transmission, not only the output current of the inverter, the voltage and frequency of the grid need to be detected. It is also necessary to take into account the isolated island state when the power supply is cut off. Islanding phenomenon means that when the power supply is interrupted due to electrical failure or natural factors, the PV grid-connected generation system still supplies power to the surrounding load, thus forming a self-contained power supply island beyond the control of the power company[2]. When the photovoltaic grid-connected power generation system is operating in an isolated island, serious consequences will occur. For example, the voltage and frequency in the isolated island cannot be controlled, which may cause damage to the user's equipment. The circuit in the isolated island is still live, which may endanger the personal safety of the maintenance personnel[3]. Therefore, it is of great practical significance to study the detection methods and protection measures of isolated islands in order to eliminate the harm caused by isolated islands.

Islanding detection methods are divided into passive detection and active detection. The passive islanding detection is to judge the island by detecting the change of the electrical parameters of the common point of the power grid. The common methods of the passive islanding detection include over-voltage or under-voltage, high-frequency or low-frequency detection, phase jump detection and voltage harmonic detection. This method is simple to realize, but the blind area is larger[4-6]. The active
detection method is to identify isolated islands by applying disturbance and accelerating the changes of electrical parameters when isolated islands are accelerated. The common methods are active frequency drift, slip mode frequency shift and output power disturbance detection methods\cite{7-9}. This method can reduce the detection blind area, but its implementation is more complex and affects the power quality.

2. Principle of islanding detection based on integrated impedance sequence component

The difficulty of islanding detection based on impedance measurement lies in the measurement of equivalent impedance of the common point\cite{10-13}. The traditional method uses the inverter to inject the non-characteristic harmonic current into the system, measures the non-characteristic harmonic voltage generated by the non-characteristic harmonic current, and then obtains the non-characteristic harmonic impedance. The main drawback of the traditional method is that two aspects: (1) the method need to inject harmonic current into the system, which affects the power quality during normal operation. (2) When the multi-inverter is running in parallel, the injected harmonics between the inverters will affect each other. These may cause an increase in blind areas or miscalculation. The traditional principle of impedance islanding detection is based on the change of amplitude abruptly. When the power provided by photovoltaic system and the power required by load are not matched well, this method fails.

A novel islanding detection method based on the integrated impedance sequence component is proposed in this paper. By detecting the voltage and current fluctuation at the common connection point, the three-phase current voltage is decomposed into sequence components by symmetric component method. The isolated islands are identified according to the variation characteristics of the integrated impedance sequence components of the 50Hz fundamental wave before and after the occurrence of the isolated islands. The integrated impedance sequence component is the ratio of the sudden change of voltage sequence component to the current sequence component when the fault occurs. This method does not need to inject harmonics, so it does not affect the power quality and the interaction between the inverters and other problems. The method can detect isolated islands in a very short time (2 cycles) after the occurrence of isolated islands, and has a higher detection efficiency.

It can be seen that when isolated islands occur, because the voltage and current at the PCC can not mutate, the current and voltage will fluctuate until the isolated island state runs stably, and the voltage and current will be decomposed by symmetric component method. The fundamental wave components of voltage and current sequence components are extracted by Fast Fourier Transform (FFT), and the occurrence of isolated islands can be detected quickly by means of sliding mode data window. Integrated impedance is defined as

\[
\Delta Z = \frac{U_{PCC} - U'_{PCC}}{I_{PCC} - I'_{PCC}}
\]

(1)

In (1), \(\Delta Z\) is integrated impedance, \(U_{PCC}, \: U_{PCC}'\) are the instantaneous voltage at the common point in the normal grid-connected state and the isolated island state, respectively; and \(I_{PCC}, \: I_{PCC}'\) are the instantaneous current at the common point in the normal grid-connected state and the isolated island state, respectively.

According to the definition of integrated impedance, the positive sequence component is

\[
\Delta Z_{(1)} = \frac{U_{PCC_{(1)}} - U'_{PCC_{(1)}}}{I_{PCC_{(1)}} - I'_{PCC_{(1)}}}
\]

(2)

In (2), \(\Delta Z_{(1)}\) is the positive sequence component of the integrated impedance, \(U_{PCC_{(1)}}, \: U_{PCC_{(1)}}'\) are the positive sequence component of the voltage at the common point in the normal grid-connected state and the isolated island state, respectively; and \(I_{PCC_{(1)}}, \: I_{PCC_{(1)}}'\) are the current positive sequence component...
component at the common point in the normal grid-connected state and the isolated island state, respectively.

According to the definition of integrated impedance, the negative sequence component is

\[ \Delta Z_{(2)} = \frac{|U'_{PCC(2)} - U''_{PCC(2)}|}{|I_{PCC(2)} - I''_{PCC(2)}|} \]  

(3)

In (3), \( \Delta Z_{(2)} \) is the negative sequence component of the integrated impedance, \( U'_{PCC(2)} \) and \( U''_{PCC(2)} \) are the negative sequence component of the voltage at the common point in the normal grid-connected and isolated island state, respectively; and \( I_{PCC(2)} \) and \( I''_{PCC(2)} \) are the negative sequence component of the current at the common point in the normal grid-connected state and the isolated island state, respectively.

The detection process of the new method is as follows: firstly, the method based on the power frequency integrated impedance sequence component measurement is used to detect, if the integrated impedance sequence component is less than the threshold value, then it is judged as a non-isolated island; If the integrated impedance sequence component is greater than or equal to the threshold value, the island is determined to occur.

3. Islanding fault setting and protection logic

In view of the above phenomena, the current and voltage sequence components can be monitored, the changes of the integrated impedance sequence components can be calculated and the corresponding setting values can be set up. When the changes of the integrated sequence impedance exceeds the threshold value, it can be considered as being in an island state at this time. Its setting rules are as follows

\[ |\Delta Z_{(1)}| > Z_{set1} = 0.5\Omega \]  

\[ |\Delta Z_{(2)}| > Z_{set2} = 0.5\Omega \]  

(4)  

(5)

In (4) and (5), \( |\Delta Z_{(1)}|, |\Delta Z_{(2)}| \) are the variation value of the positive and negative sequence fundamental wave component of the integrated impedance, and \( Z_{set1}, Z_{set2} \) are the setting value of the positive and negative sequence component of the integrated impedance.

According to the above analysis, the action logic diagram of the anti-islanding strategy of the island can be detected by using the integrated impedance sequence component in Figure 1.

4. Simulation analysis

The parameters are set in the detailed simulation model of grid-connected power generation system with unipolar photovoltaic inverter. The output voltage of photovoltaic array is 600V, the output line voltage of inverter side is 270V, the output current is 1000A, and the output power is 470kW. The RLC parallel circuit is used for the local load (the isolated island is in the most serious condition at this
time), the quality factor is 1, \( R=0.4673\Omega \), \( L=0.001487\text{H} \), \( C=6812\mu\text{F} \). The operating time of the system is 1.2s, and the isolated island occurs at the time of 1s. The sampling frequency is 16 kHz, the sampling interval is 62.5 \( \mu \text{s} \) and the data window is 0.98s-1.06s. The system running parameters are shown in Figure 2.

In Figure 2, the upper and lower block diagrams represent the output voltage and output current of photovoltaic grid-connected inverter respectively. From Figure 2, it can be seen that the operating parameters of the system have not changed during the normal grid-connected operation and the islanding operation, indicating that the isolated island is in the most serious state at this time. The power system simulation data from PSCAD is imported into Matlab for data processing. In this paper, voltage and current sequence signals are selected for calculation, and a new method of islanding detection is proposed for detection.

4.1. Identification of isolated Island faults of Integrated Impedance sequence components in case of Three-phase Breaking

The integrated sequence impedance waveform by using the islanding detection method proposed in this section is shown in Figure 3.

From Figure 3, it can be seen that the integrated impedance sequence component is basically 0 when the grid is connected, and when the isolated island fault occurs (the sampling point is 320), the composite sequence impedance fault component does not change, after a cycle (20 milliseconds, the sampling point is 640), the fault component of the integrated sequence impedance changes gradually, and the integrated sequence impedance of 50Hz is larger than the setting value, which is consistent with the setting conditions, and the islanding detection is successful.
4.2. Discrimination of isolated island fault with integrated impedance sequence component under single phase circuit breakage

The integrated sequence impedance waveform by using the islanding detection method proposed in this section is shown in Figure 4.

From Figure 4, it can be seen that the integrated impedance sequence component is basically 0 when the grid is connected, and when the isolated island fault occurs (the sampling point is 320), the composite sequence impedance fault component does not change, after a cycle (20 milliseconds, the sampling point is 640), the fault component of the integrated sequence impedance changes gradually, and the integrated sequence impedance of 50Hz is larger than the setting value, which is consistent with the setting conditions, and the islanding detection is successful.

4.3. Identification of isolated Island faults of Integrated Impedance sequence components in the case of Two-Phase Breaking

The integrated sequence impedance waveform by using the islanding detection method proposed in this section is shown in Figure 5.

From Figure 5, it can be seen that the integrated impedance sequence component is basically 0 when the grid is connected, and when the isolated island fault occurs (the sampling point is 320), the composite sequence impedance fault component does not change, after a cycle (20 milliseconds, the sampling point is 640), the fault component of the integrated sequence impedance changes gradually, and the integrated sequence impedance of 50Hz is larger than the setting value, which is consistent with the setting conditions, and the islanding detection is successful.
5. Conclusion
In this paper, a method of detecting islanding effect by using integrated impedance sequence component is proposed. By monitoring the difference of voltage and current signals of 50Hz in normal grid-connected operation and islanding operation, the value of integrated impedance sequence component is calculated. According to the difference of its value before and after the occurrence of isolated island state, the detection of isolated island fault can be realized. The islanding detection method can detect islanding faults quickly and effectively without affecting the power quality, and can still be distinguished when the grid-connected switch is single-phase or two-phase disconnected. The detection of isolated island fault without blind area can be realized. This method can effectively detect isolated islands, has the advantages of no blind spot detection, little influence on power quality, fast response speed, and so on.

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