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The Research of an Automatic Phase Displacement Island Protection Method of Photovoltaic Power Generation System

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Abstract

This paper proposes a lonely island detection method based on automatic type phase displacement. Different form the traditional island detection methods, this method solve the problem of its some kind of detection under the condition of failure, improving active island detection technology of slip type automatic frequency quadratic displacement method. This method only need to change the output current of the initial angle without changing its frequency to detect whether the grid failure, compared with the traditional island detection methods, improve the accuracy of the grid fault detection.

Keywords: *island detection method, automatic phase displacement, distributed generation system*

1. Introduction

Phenomenon of "islands" refers to the grid photovoltaic power generation system in the case of grid suddenly loses power to a phenomenon of independent power supply, at this time, all independent operation of power systems and load form a sub-system, the subsystem with the grid other devices on the network have been isolated, but still have electricity generation, transmission and consumption, become "isolated island" in the power system [1-5]. Distributed generation system, including photovoltaic, isolated island phenomenon does exist, however, isolated island phenomenon will lead to damage to equipment, harm the personal safety and other adverse effects [6-12].

2. Solitary Island Detection Analysis and Design

2.1. Traditional Island Detection Method Analysis

Island phenomenon in traditional test methods can be divided into two major categories of active and passive. Passive detection method is condition monitoring of power grids, such as the voltage magnitude and frequency, and as a basis to determine whether a power grid failure. Using active detection method, grid inverter will take the initiative to interfere with the power grid, affected by observing whether the grid to determine whether the grid fault occurs. Has been widely applied in the active monitoring method, and is the frequency shift method, automatic frequency drift method, the sliding displacement of differential frequency method, etc., but through the analysis of these methods have different defects.

Frequency deviation method is to change the grid inverter output current frequency, make it to the grid voltage frequency is different, and in each grid voltage cycle should be starting point in current phase zero again, when the loss of power grid voltage, grid inverter frequency of the output voltage will vary with output current frequency, it can be used as the basis for detection of isolated island phenomenon. However, the size of the frequency offset will directly affect the size of the output current harmonic distortion, but considering the demand for power quality limits, the frequency offset cannot too big, it will greatly reduce the islands of the sensitivity of detection. In addition, this method of testing for some parallel resonant load will be completely out of action.

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Automatic frequency drift method is in view of the current type of photovoltaic (pv) grid inverter is proposed, the grid inverter as a source of alternating current. Due to the role of the internal phase lock loop, grid inverter can output and the output voltage and the frequency and phase of harmonic current. This method for some load still cannot successfully detect the grid fault, this is because there are possible when the frequency of the output current reaches a certain value, it has to do with the voltage phase difference is zero, the voltage frequency is within the scope of the normal power grid frequency, in this case, the grid inverter will continue to work, can produce island phenomenon.

Sliding displacement of differential frequency method and automatic frequency drift method is similar, just change the output current frequency at the same time, also change its initial Angle, the starting point of each voltage cycle is corresponding to each, the starting point of the current cycle, at the beginning of the output current of the phase Angle is decided by a voltage cycle frequency size before. Also, the sliding displacement of differential frequency method is similar to the automatic frequency drift method, when the output current of the initial Angle and load impedance Angle is zero, the sum of the grid inverter output current and voltage in a voltage cycle at the end of the phase difference is zero, at this point, the grid voltage and frequency is still in the normal frequency range, in this case, whether the method will not be able to successfully detect the grid fault occurs.

2.2. Improved Sliding Displacement of Differential Frequency Method

In order to solve the above problem, in this paper, the traditional sliding displacement differential frequency method was improved, the basic idea of improved method is only to change the output current of the initial Angle without changing its frequency, so as to avoid the frequency changes leading to changes in the load impedance Angle. make the first k at the beginning of a cycle of the output current voltage phase Angle theta [k] as:

$$\theta[k] = \frac{1}{\alpha} \cdot \frac{f[k-1] - 50\text{Hz}}{50\text{Hz}} \cdot 360° \tag{1}$$

Where, f (k - 1) is a voltage frequency, voltage cycle before alpha is an adjustable parameter. When voltage hysteresis current, a voltage cycle before the voltage frequency f (k - 1) is less than 50Hz, the current of the primary phase will be negative, which makes the voltage cycles, due to the constant output current frequency, phase difference between voltage and current can keep constant, won't appear the frequency of the output current reaches a stable value, the phase difference between voltage and current is zero.

But, at the starting point of each voltage cycle will force corresponding to the current waveform is also a cycle of the starting point, even if the output current is constant value for a given frequency, but in fact, current base wave frequency is still depends on the size of the voltage cycle. Before assuming a voltage cycle frequency f (k - 1) = 46 hz, alpha = 1.2, generation into the formula (1), getting the Kst voltage cycle of the beginning of a cycle of the output current phase $\theta[k]$.

$$\theta[k] = -24°$$

If the voltage cycle frequency of first k is 46 Hz, then the first k voltage cycle output current (I) (k) can be represented as:

$$I[k] = \sin(2\pi \cdot 50 \cdot t - 24°)\Big|_{t=0\sim\frac{1}{46\text{Hz}}} \tag{2}$$

Using Fourier decomposition, can find out the fundamental component I1 [k] as follows:

$$I_1[k] = sin(2\pi \cdot 46 \cdot t - 11.4°) \tag{3}$$

From formula (3) it can be seen that the output current of the fundamental wave frequency depends on the frequency, voltage and current of a given frequency is not the same, and initial phase Angle of fundamental wave current earlier than the actual current phase Angle

is small, as shown in Figure 1, which indicates that the effect of raising voltage cycle worse than expected.

Voltage cycle continuously improve, in fact, if the frequency will be gradually reduced, the output current of the fundamental wave frequency will be reduced, this will lead to gradually reduce the load of equivalent current frequency, voltage and the fundamental current component of the phase difference gradually decreases, and finally is still likely to reach a stable state, it will lead to test failure.

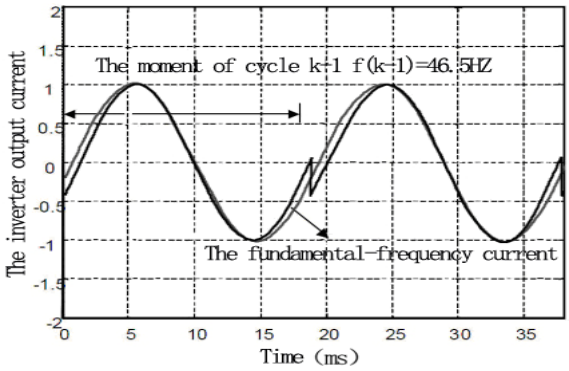


Figure 1. Output Current Plot of Improved Slip Frequency Displacement Method

2.3. Automatic Type Phase Displacement Method

This paper presents a automatic type phase displacement method is used to detect whether the grid failure, and prevent island phenomenon. Automatic type phase displacement method with automatic frequency drift method and slip displacement method, the frequency is in view of the current type of PV grid inverter is proposed, and the grid inverter as a controlled ac current source, power grid and the grid inverter is connected in the network load can be equivalent to the combination of resistance, inductance, and capacitance linear element, the nonlinear load, the method is not applicable.

Automatic type phase displacement method is trying to undermine the purpose of the possible steady state frequency points, the basic idea is similar to improve sliding displacement of differential frequency method, the only change at the beginning of the output current of the phase Angle without changing its frequency, just the first k at the beginning of a cycle of the output current voltage phase Angle theta '[k] as:

$$\theta'[k] = \frac{1}{\alpha} \cdot \frac{f[k-1] - 50\text{Hz}}{50\text{Hz}} \cdot 360° + \theta_0[k] \tag{4}$$

Where, the expressions of additional phase Angle theta is:

$$\theta_0[k] = \theta_0[k-1] + 3.6° \cdot \text{sgn}(\Delta f_{ss}) \tag{5}$$

θ[0] = 0, Δ FSS variation for steady state frequency of FSS, SGN (Δ FSS) is defined as:

$$\text{sgn}(\Delta f_{ss}) = \begin{cases} 1, & \Delta f_{ss} > 0 \\ 0, & \Delta f_{ss} = 0 \\ -1, & \Delta f_{ss} < 0 \end{cases} \tag{6}$$

By the formula (4) it can be seen that the output current of the initial Angle theta. '[k] in addition to a voltage cycle before the related frequency f (k - 1), but also with an additional phase Angle theta zero [k] is related to the size of the additional phase Angle theta 0 [k] is associated with the change of steady state frequency. If the steady state frequency of FSS is

reduced, theta zero will gradually increase, due to superimposition and vice will gradually decrease. This automatic type phase displacement island test flow chart as shown in figure 5, which determine whether for one cycle of the output voltage can by detecting the output voltage zero point, the starting point of the slope is positive.

Automatic type phase displacement method, the key lies in the fact that even if improved sliding displacement of differential frequency method makes the grid inverter output voltage in the first 1 k - voltage cycle reaches a steady state frequency point, due to the steady state frequency is not equal with the standard of power grid frequency 50 hz, so automatic phase displacement method will still according to the steady state frequency variation ΔF_{SS} of plus or minus to properly change the output current of the initial Angle, to detect whether the grid failure. If a fault has appeared, the test results will make the output voltage of the frequency adjustment value to another steady state frequency, automatic type at the beginning of phase displacement method will continue to change the output current of the phase Angle, under the action of the positive feedback, will force beyond normal steady state frequency grid frequency range, so as to detect a fault has been successful. If, on the other hand, the steady state frequency change is due to normal fluctuation in the power grid frequency, then the first k a voltage change at the beginning of the cycle of the output current phase Angle does not affect the power grid frequency, so the next cycle of voltage, output current of the initial Angle will be restored. If adopts the fundamental wave current instead of the actual current, its analysis process is similar to slip type frequency displacement method, when the initial phase Angle of fundamental wave current and load impedance Angle is zero voltage frequency is the sum of the steady state frequency of grid inverter, when the alpha = 2, according to the output current at the beginning of the expression of phase Angle (4) available grid inverter in the steady state frequency points, as shown in Figure 2. As you can see, the steady state voltage frequency and decreased with increment of voltage phase Angle at the beginning.

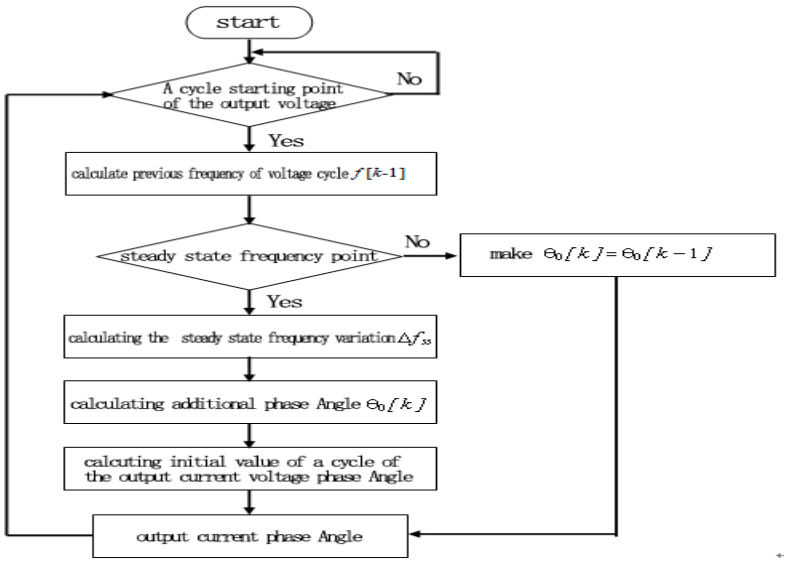
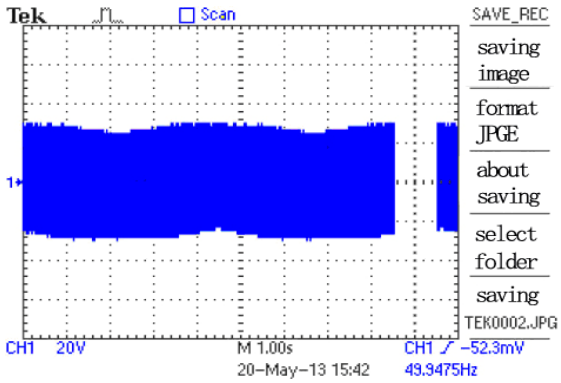


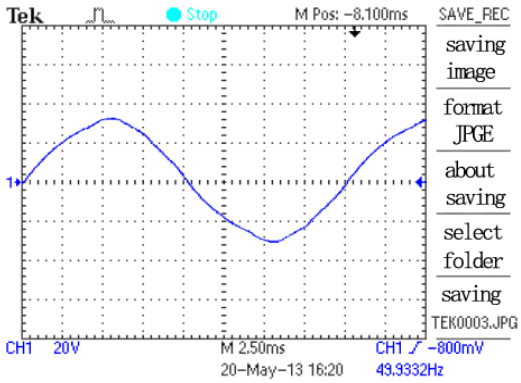
Figure 2. Flow Chart of Automatic Phase Shift Islanding Detection Method

3. Experimental Results

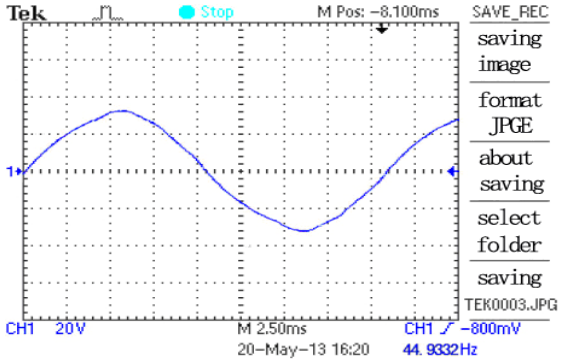
When the output voltage of PV grid inverter reaches grid conditions, it is connected to the electricity grid, when the frequency of the output voltage is always consistent with the power grid frequency is 50Hz. When power grid cut off, only the load is powered by photovoltaic power generation system, affected by the amount of disturbance, the output voltage of the inverter frequency will continue to drop, can judge the fault appeared accordingly. Figure 3 shows the grid fault occurs after PV grid inverter output voltage waveform and its partial enlarged waveform.



(A) Output Voltage Plot



(B) Local Amplification Plot as Frequency of Output Voltage is 50Hz



(C) Local amplification Plot as Frequency of Output Voltage is 45Hz

Figure 3. Output Voltage Plot and Its Local Amplification Plots of Photovoltaic Grid-connected Inverter (oscillograph probe decays ten times)

4. Conclusion

This paper analysises the causes and harm of the isolated island phenomenon, summarizes the advantages and disadvantages of the conventional island phenomenon detection method, and proposed based on automatic type island detection method. This method only needs to change the output current of initial angle without changing its frequency to detect whether the grid fault occurs. Compared with traditional active island detection methods, automatic type phase displacement method improves the accuracy of power grid failure detection.

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