Adaptive Frequency Shift Islanding Detection Method Based on dq Transformation

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Abstract: The principle of adaptive frequency shift islanding detection method is analyzed. On this basis, adaptive frequency shift based on dq transformation which aim at three phase inverter grid-connecting system is presented, and the simulation by MATLAB is fulfilled. Verified by the simulation, this method can precisely detect the occurrence of islanding. At the same time, the superiority of the new method is verified.

1. INTRODUCTION

The island effect is that when the power grid interrupts power supply for some reason, the photovoltaic grid-connected power generation system still supplies power to the surrounding load, creating an isolated island of self-supply power that the power company cannot control. Photovoltaic grid-connected power generation system in the island operation state will have serious consequences. Therefore, it is of great practical significance to study the methods and protective measures of isolated island detection and eliminate the harm caused by isolated islands.

The common detection methods of anti-island effect are passive island detection and active island detection. Passive detection method is also known as passive detection method, which has the advantages of simple principle, easy realization and no effect on power quality. However, the non-detection zone is large when a passive isolated island detection method is used alone. There are mainly over-voltage/under-voltage, over-frequency/under-frequency, phase mutation, voltage harmonic detection and other detection methods. Active detection methods are mainly common methods such as active frequency offset (Active Frequency Drift, AFD), Sandia frequency shift method, Sandia voltage offset, active current disturbance method and adaptive frequency offset method. The non-detection zone of active detection method is small. [1-6]

Adaptive frequency offset method is based on the frequency offset island detection method, and can adaptively adjust the frequency of inverter output current, so that the island state can be quickly detected. Aiming at the grid-connected system of three-phase inverter, an adaptive frequency offset
island detection method based on DQ transform for three-phase grid-connected inverter isolated island
detection will be studied on the basis of adaptive frequency offset method.

2. ADAPTIVE FREQUENCY OFFSET ISLAND DETECTION ALGORITHM

The adaptive frequency offset method refers to changing the frequency of the inverter output current
in different ways at different common node voltage frequencies. Given a certain threshold range of the
voltage frequency of the public node, the frequency disturbance is carried out in the form of positive
feedback, in the range of the threshold, and when the threshold range is exceeded, the frequency
positive feedback is increased, thus accelerating the change of frequency to make the node voltage
frequency beyond the frequency protection threshold fast, so that the island state can be detected
quickly. The algorithm flowchart is shown in Figure 1. [7]

In formula (1), \( f_i \) is the output current frequency of the inverter, \( f_{up} \) is the frequency of the public
node voltage \( u_p \), \( K \) is the proportional coefficient, \( N_3 \) is the coefficient to increase the frequency
positive feedback, \( \delta_f \) is the frequency threshold to add periodic frequency disturbance and increase the
frequency disturbance.

When the frequency condition is satisfied, \( N_3 \) increases by 2 per cycle to increase the frequency
disturbance, so as to quickly exceed the frequency protection range of over-frequency/under-frequency
isolated island detection method and realize the rapid detection of the island State. And if the node
voltage frequency is found within the frequency threshold range, that is, \( |f_{up}-50| \leq \delta_f \), \( N_3 \) becomes 0,
which can prevent the abnormal action of the island protection caused by the fluctuation of the voltage
frequency of the power grid when the grid is connected, ensure the normal work of the grid-connected
system, and reduce the influence on the normal work of the grid-connected system.

The frequency of the public node voltage is detected each cycle, and when it is within a certain
threshold range, that is, \( |f_{up}-50| \leq \delta_f \), the periodic disturbance is given to the current frequency, the
meaning of \( N_A \) and \( N_B \) is the frequency disturbance continuous \( N_B \) cycle per \( N_A \) cycle. In this way,
currents being given frequency disturbances in some cycles, in most cycles currents track the grid
voltage. Compared to the AFD and other methods which give the frequency disturbance to the current
each cycle, the adaptive frequency offset island detection method reduces the harmonic pollution
introduced to the power grid.

There is also a certain regularity in adding frequency disturbances. When the frequency of the
public node voltage is greater than the normal frequency of the power grid voltage by 50Hz, the
frequency disturbance in the positive direction, that is, \( f_i = f_{up} + \Delta f \) is given to the current frequency, and
when the frequency of the public node voltage is less than the normal frequency of the power grid
voltage by 50Hz, the frequency disturbance in the positive direction, that is, \( f_i = f_{up} - \Delta f \) is given to the
current frequency.

In this way, the periodic disturbance of the current is also added to the current frequency in the
form of positive feedback.

\[
\begin{cases} 
  f_i = f_{up} + \Delta f & f_{up} - 50 \geq 0 \\
  f_i = f_{up} - \Delta f & f_{up} - 50 < 0
\end{cases}
\]
In formula (2), $\Delta f$ is the frequency disturbance amount. It is important to note that it is larger than $\delta f$.

When the grid-connected switch is closed, due to the clamping effect of the power grid frequency, the node voltage frequency follows the voltage frequency of the power grid. Although there is a disturbance of the current frequency in part of the period, the output current of the inverter is reset at 0 points of the power grid voltage every time, starting with another new sinusoidal. However, if when the grid-connected switch is disconnected, there is no clamping effect of the voltage frequency of the power grid, then the public node voltage will follow the change of the inverter output current. Because of the influence of the local load, it will cause the node voltage frequency to rise or fall, which exceeds the frequency protection threshold of the passive island detection method, thus detecting the isolated island.

3. THE MATLAB SIMULATION OF ADAPTIVE FREQUENCY OFFSET METHOD BASED ON DQ TRANSFORM

The adaptive frequency offset method simulation model based on DQ transform is constructed by using MATLAB's simulink module, as shown in Figure 3. In the s-function module, the frequency disturbance of the inverter output current is carried out by programming, and the fast and reliable detection of the island state is realized by combining the over/under-frequency protection passive isolated island detection method. In the simulation, the three-phase power grid voltage is 220V and the power grid frequency is 50Hz. Because the offset range $\delta f$ allowed by the power grid voltage frequency is 0.2 Hz (GB/T15945-1995), the selected frequency threshold range is 0.2. $\Delta f =0.5,N_1 =5,N_2 =3,K=5$ are selected during the simulation process. That is, a frequency disturbance of 3 consecutive cycles every 5 cycles. According to the simulation Figure 4, the adaptive frequency offset method based on DQ transform is applied to reduce the frequency to beyond the set protection.
threshold range when the grid is broken, that is, \( t = 2 \text{s} \). The occurrence of the island phenomenon is detected when \( t = 2.14 \text{s} \).

Figure 2. The structure block diagram of adaptive frequency offset method based on DQ transform

Figure 3. The simulation of adaptive frequency offset method based on DQ transform

(a) The inverter side voltage and current simulation waveforms

(b) The output current frequency

Figure 4. The simulation waveforms of adaptive frequency offset method based on DQ transform
4. CONCLUSIONS
Based on the analysis of the principle of adaptive frequency offset island detection method, an adaptive frequency offset island detection method based on DQ transform for three-phase grid-connected inverter is proposed in this paper. In this method, the feedback amount of three-phase grid-connected inverter realizes the data conversion by adopting DQ transform. As the frequency perturbation of the inverter output current in a single-phase grid-connected system, the angular frequency $\omega$ obtained by DQ transform is disturbed in the form of positive feedback in three-phase grid-connected system, thus the frequency perturbation of the three-phase inverter output current is carried out, and the island detection of the three-phase grid-connected inverter system is realized by adaptive frequency offset method. The correctness of this method is verified by MATLAB simulation.

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