A Novel Islanding Detection Method for Photovoltaic Grid Connected System

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Abstract. It is very important to detect islanding effect timely and accurately in the case of power grid failure. Therefore, a new periodic perturbation positive feedback active frequency drift method is proposed in this paper. When the power grid fails, the inverter output voltage frequency always has obvious change under the different load of inverter, and the islanding effect can be detected quickly and accurately by this control method. Experimental results show that the proposed method can detect grid faults quickly and accurately under different load conditions.

1. Introduction

Due to the intensification of the crisis, photovoltaic power generation has attracted widespread attention due to its advantages of no pollution in the power generation process and long service life of photovoltaic devices. Among them, photovoltaic power generation mode because of its low initial capital investment, output power and stability, has become the fastest growing form of photovoltaic power generation using the. The so-called photovoltaic grid connected power generation refers to the output power of photovoltaic devices after the inverter, transported to the grid, become one of the sources of power grid energy. In the grid connected photovoltaic power generation system in power cut or due to human failure and stop the power supply to the load, the photovoltaic power generation system continues to power supply, so that the local grid load is still in power state, this phenomenon is known as the island effect (Islanding). Because the island effect will threaten the equipment and personal safety, so timely and accurately detect the islanding effect of [1] is a key problem in the design of photovoltaic power generation system.

In view of the shortcomings of the traditional AFD method [2], the positive feedback Active Frequency Drift periodic with Periodical Disturbance and Positive Feedback, referred to as AFDPDPF) islanding detection method, this method can quickly detect the islanding effect under various load conditions, improve the security and the reliability of photovoltaic power generation system.

2. AFD Working principle and existing problems

2.1. The working principle of AFD

AFD is a common islanding detection method for output frequency perturbation [3]. Fig. 1 shows its control principle. AFD working principle: the system by controlling the inverter so that the frequency

of f_{inv} the frequency of the output voltage f_{grid} and grid voltage error exists in certain Δf (Δf in grid connected standards within the allowable range); when the normal work of power grid, the PLL circuit correction function, Δf is always in a relatively small range; when the grid fault occurs, f_{inv} will change in inverter within a power cycle, the system will provide reference to f_{inv}, Δf frequency error and set to control the f_{inv}, resulting in a further increase in f_{inv}. The process is repeated until the f_{inv} exceeds the standard of the grid connection, thus triggering the islanding protection circuit action and cutting off the connection between the inverter and the power grid [4].

Fig. 1 shows the frequency perturbation waveform in the AFD method. The curve is a current waveform of the power frequency period and its disturbance control signal, and the longitudinal coordinate voltage in the figure is the standard value. In the AFD method, the period of zero current is t_z, and the ratio between the current and the fundamental voltage half cycle T_{grid} is the disturbance signal cf, and then there is $cf = t_z / T_{grid}$.

Control principle of islanding detection method in graph 1AFD

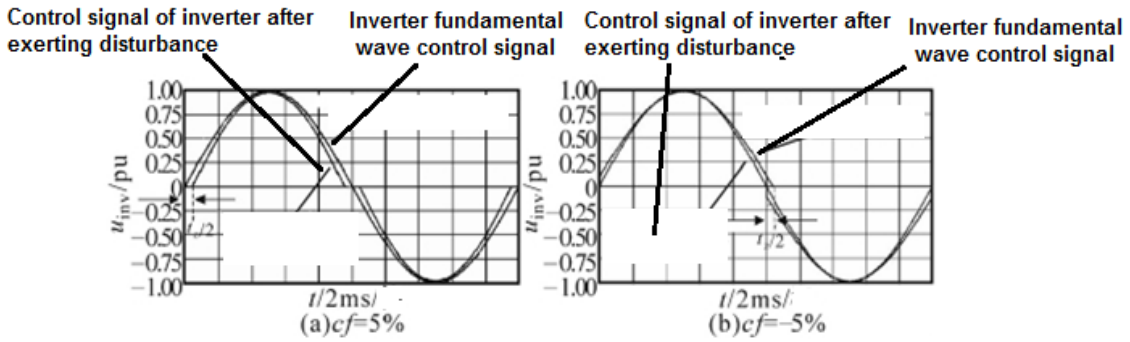

Figure 1. Output voltage waveform of inverter after disturbance of grid voltage

2.2. Effect of load properties on AFD method

Fig. 2 shows the power flow of the PV grid connected system in normal operation and islanding effect.

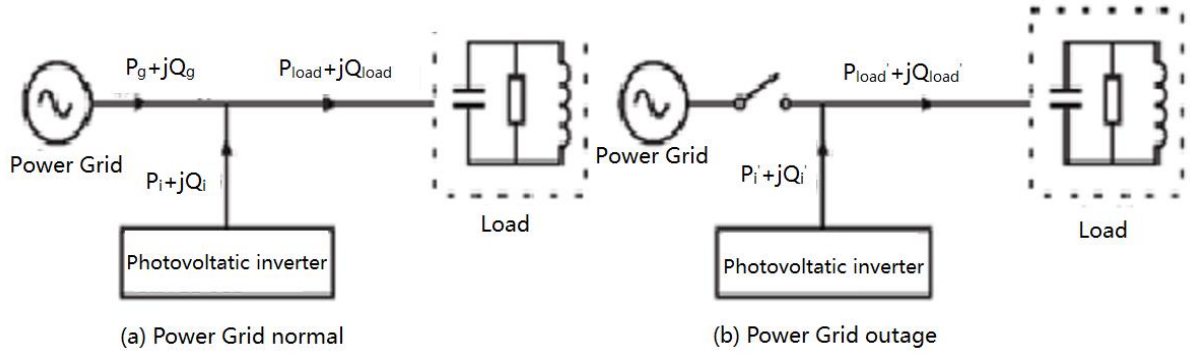

Figure 2. Power flow diagram of photovoltaic grid connected generation system

Active and reactive power output of P_i, Q_i photovoltaic grid connected generation system in Fig.2 P_g, Q_g is the active and reactive power on the load P_{load}, Q_{load} is the active power error between photovoltaic grid connected generation system and power grid ΔP is the reactive power error

between grid connected photovoltaic power generation system and power grid ΔQ is the angle frequency of the inverter and the frequency ω_i, ω_g of the grid work angle The load in the circuit is RLC parallel load, so when the island effect occurs, the reactance of the LC in the load is:

$$IM\left[Z_{LC}\right]=\frac{\omega_i L}{1-\omega_i^2 LC} \tag{1}$$

When the ω_i islanding effect occurs, the angular frequency of the output voltage of the inverter and the reactance of the LC can also be expressed by the output active power and reactive power of the inverter:

$$IM\left[Z_{LC}\right]=\frac{RP}{Q_i} \tag{2}$$

Combination type (1) and (2) available:

$$\omega_i^2-\frac{Q_i}{RCP_i}\omega_i-\frac{1}{LC}=0 \tag{3}$$

The quality factor q of parallel load is 0:

$$q=R\sqrt{\frac{C}{L}} \tag{4}$$

The frequency function of the output voltage of the inverter is obtained when the islanding effect is obtained by the formula (3):

$$\omega_i \approx \frac{1}{LC}\left(\frac{1}{2}\bullet\frac{Q_i}{qP_i}+1\right) \tag{5}$$

According to the formula (5), when the island phenomenon occurs, the ω_i is related to the properties of P_i, Q_i and load. If Q_i is negative, it shows that the load is capacitive load, and ω_i will decrease when islanding occurs, otherwise ω_i will rise [4].

The results show that when the islanding effect occurs, the nature of the inverter load has an impact on ω_i [5].

3. The working principle of. AFDPFPD method

In order to avoid the effect of AFD islanding detection due to the load property, a periodic perturbation positive feedback (AFDPFPD) islanding detection method is proposed on the basis of the original AFD method.

3.1. Working principle

The control principle block diagram of AFDPFPD islanding detection method is shown in figure 3.

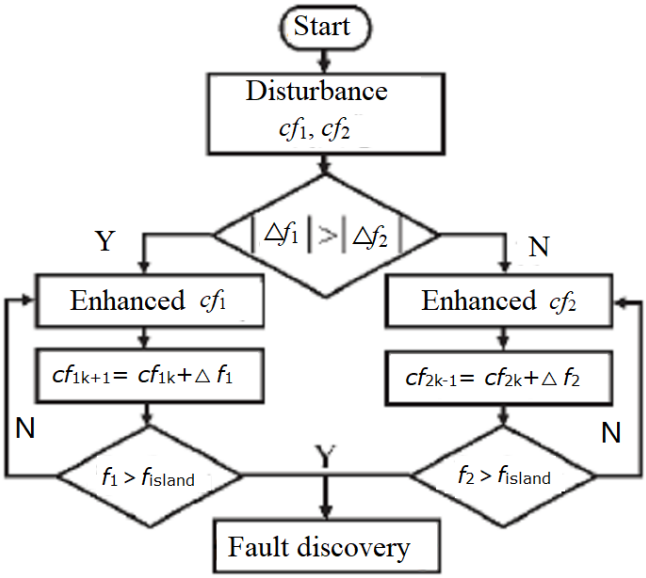

Figure 3. Periodic perturbation AFDPDPF islanding detection method

cf_1, cf In the graph -- two different directions of disturbance signals, cf_1=5%, cf_2=-5%.

3.2. Working process

In order to better understand the work process, the capacitive load as an example, the specific work process of the method is described, power grid blackout here if the normal work of the system: the initial disturbance signal cf_1 =5%: in cf_1 perturbations, the inverter output voltage of the f_{inv} frequency should be increased, but because of the capacitive load will reduce the f_{inv}, therefore the frequency change of Δf_1 inverter output voltage is lower than that of $|\Delta f_1| < |cf_1|$; the disturbance signal, the initial disturbance signal cf_2 =5%: the frequency of f_{inv} inverter output voltage signal interference effect should be reduced, due to the capacitive load from Δf_2 is greater than the disturbance signal, namely $|\Delta f_2| > |cf_2|$; the $|\Delta f_2| > |\Delta f_1|$ selection CF2 is the next step to strengthen the feedback signal to applying the perturbation of f_{inv}; the $f_{inv2} < f_{grid}$ system, judge the power failure, cut off the connection of inverter and.

4. experimental results

In order to verify the effectiveness of the proposed AFDPDPF islanding detection method, the experimental verification is carried out. The maximum output power of the photovoltaic device is 180W, the grid connected inverter is two level type structure, the first is a Boost circuit for boost and maximum power point tracking control, the second is the full bridge inverter circuit for DC output circuit DC/DC to grid and the same frequency and phase alternating current.

Figure 4 shows the topology of photovoltaic power generation system [5]. Due to the low output voltage of the photovoltaic device, a power frequency step-up transformer is connected between the inverter and the grid to meet the requirements of grid connected.

In order to verify the effectiveness of the proposed method, the topology of photovoltaic power generation system, is taken as the experimental platform, and the experiments are carried out under resistive load and inductive load respectively. Table 1 gives the direction of disturbance signal and islanding detection time. The experimental results show that, under the AFDPDPF control method, the

islanding detection time of the system for nonlinear load is shorter than the resistive load. Under different loads, the proposed method can detect the change of voltage frequency at the inverter end in the presence of islanding effect.

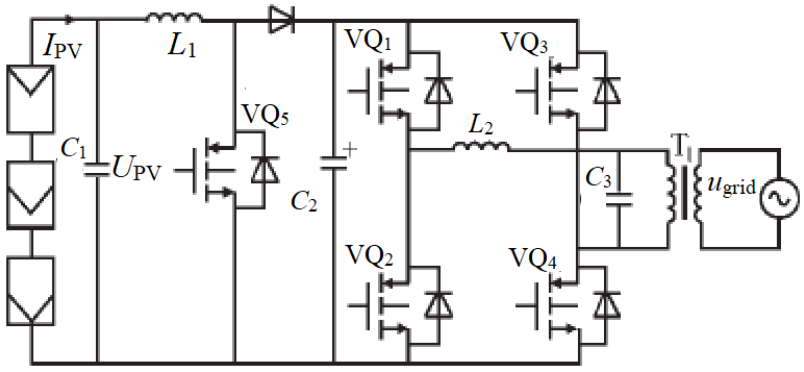

Figure 4. Shows the topological structure of photovoltaic power generation system

Table 1. Comparison of experimental results under different loads

Load property	Disturbance direction	Detection time/S
Q=0	+	0.56
ΔQ/ΔP=5%	+	0.48

5. Conclusion

Compared with the traditional AFD detection method, the AFDPDPF islanding detection method overcomes the load balancing effect on the disturbance signal, and enhances the frequency variation of the inverter output voltage due to the use of different directions of disturbance signals. On this basis, positive feedback control is applied to accelerate the detection speed of islanding effect, so as to achieve good detection results. The disadvantage of this method is that it requires higher frequency measurement and slightly increases the cost of hardware.

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