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Adapative Load Anti-islanding Method of Large Distributed Photovoltaic Power Grid

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Abstract

A large number of distributed photovoltaic power grid, islanding problems become more prominent. This paper first analyzes some existing anti-islanding scheme, and analyzes its advantages and disadvantages. Then, this paper proposes adaptive anti-islanding scheme by using the load, i.e. load automatic switching, changing the characteristics of the whole load, make the passive anti-islanding without dead-zone. Then using PSCAD simulation of the program, to verify the usefulness of the proposed scheme. To minimize the distributed photovoltaic power grid investment, saving the scheme relies on a new generation of distributed photovoltaic (pv) grid interface device. Then the paper introduces the overall structure and function of the device configuration, the device not only can solve the problem of area of backup protection, also save on investment, convenient for on-site equipment installation and maintenance, for the widespread promotion of distributed photovoltaic power grid to lay a solid foundation.

***Keywords**: Distributed photovoltaic grid-connected；Island detection； Adapt changes of load；grid-connected Interface & anti-islanding device*

1. Introduction

Distributed photovoltaic power generation, as a kind of clean and renewable energy, for it close to the load center, can reduce the transmission power of transmission-distribution network, reduce the construction and maintenance of transmission-distribution layout, also reduces the line loss of power grid, is an important part of China's new energy promotion [1,2]. But after a large number of distributed photovoltaic power grid connection, even if the overall permeability is low, but also have great influence on scheduling, maintenance, operations of the power grid. Especially after the grid-connected distributed photovoltaic power occurs island, bring a lot of harm: harm to power grid load or the personal safety, when conducting higher maintenance, the lower power supply system is uncertain; without the support of major network, the power supply quality of islanded power grid is difficult to meet the requirements; there tend to be large current impact caused by the phase out of sync at power grid recovery; out from the monitor of electric power administrative departments, it has uncontrollability [3].

The existing distributed photovoltaic (pv) grid are made clear in the specification, the interconnection of distributed photovoltaic, need at least one kind of active and passive island off-grid solutions[4, 5] . While in the actual operation, because of no mature and reliable solution, and the implementation of each link, each manufacturer is not unified, many grid situation does not conform to the specifications. Especially in the face of the future a lot of interconnection of distributed photovoltaic power supply, the problem become more prominent. This article puts forward a kind of anti-island method easy to be implemented, with both active and passive way, to solve the problem.

2. The Existing Distributed Photovoltaic Power Grid of Island Detection Methods and their Limitations

2.1. The Existing Island Detection Methods and their Limitations

The common island detection method can be divided into grid side (also called remote method), inverter side and grid-connected according to the installation position. And can also divided into passive, active and hybrid method according to the specific method category, each category can be divided into a variety of different ways[6][7]. Among these methods, the current discussed and more used are as following:

Remote method is based on the detection method of the grid side, the grid can be detected by means of the grid side own monitoring system failure or interruption of power supply, fault signal transmission to the grid inverter system. Its totally dependent on communication, when communication is not reliable, they will not work.

Active detection method on inverter side is through disturbance signal injection to the system, and by detecting relevant current and voltage parameters (amplitude, phase, impedance, frequency and harmonic content, etc.) or its variation beyond the threshold value, to determine the existence of the grid in order to detect the island. When a number of distributed power supply access to the same distribution transformer, because of its principles differed, and more often mutual interference, cause misjudgement on island or failed to detect island.

Passive detection method at grid-connected node, when distributed photovoltaic power island is running, there would be some changes on voltage amplitude, phase or frequency, power, harmonic parameters detected by grid-connected node. But in special cases theoretical detection blind area may also appeared.

And some increasing disturbance on superior busbar of grid-connected node, and carried out island detection method through waveform recognition at grid-connected node, without exception all can affect the power quality of power grid, and increases the potential security risk [8-10].

2.2. New Island Detection Method

When a large number of distributed photovoltaic power grid-connecting, to timely detect the island, the optimal detection position is the grid-connected node, active and passive hybrid method is used to judge the island. The passive anti-island function: over/low voltage, over/low frequency, rate of frequency variation law, (fundamental wave, third-order harmonic, fifth harmonic) phase angle jump method, integrated passive criterion of active and reactive rate method for implementation. The active method is: when the electric parameters of grid-connected node are at the above passive criterion theory blind zone, its properties can be changed through input and remove the variable and controllable load.

In practical application, because the output of the photovoltaic (pv) is a real-time change, and the amplitude of variation is much bigger, while the load is relatively stable, so in most cases, the integrated passive criterion is enough to judge the island, so the probability of theory blind zone is very small. To foster strengths and circumvent weaknesses, on the basis of the organic combination of active and passive method, and basically without considering the anti-island method of inverter, the island can be detected rapidly and more reliably.

3. Adapt Load Island Detection Scheme

3.1. Implementation Scheme

The system mainly consists of two parts: one is the control device; second is the controllable once load. Controllable device is used for collecting voltage, current at distributed photovoltaic (pv) power outlet for calculating impedance Angle. Because photovoltaic inverter generally uses MPPT track algorithm, so basically no reactive power is produced, it can be concluded that, as long as the Angle is large enough, it will not fall into the non-detection zone. If island non-detection zone existing in detection, anti-island device automatically recognize input inductance and capacitance, change the overall load characteristics of distributed photovoltaic power, and break the balance of the output reactive power of inverter and reactive power of local, when island operation is occurring, anti- island device can rely on passive comprehensive criterion for island judgement.

3.2. Implementation Step

Before loading input, as shown in Figure 1.

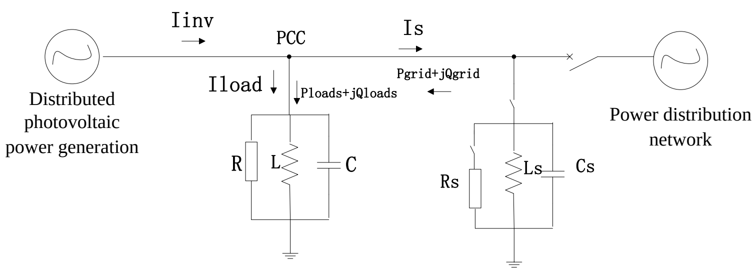

Figure 1. Controllable Load of Distributed Generation System Distributed Photovoltaic Power Generation, Power Distribution Network

In figure 1: PCC is the common coupling point; R L C is simulated photovoltaic power station in site load (R is resistance; L is inductance; C is capacitance). Iinv is output current of photovoltaic inverter; I_{load} is load current; Is is the load current of anti-island device after input controllable load. P_{loads} and Q_{loads} is active and reactive power of load in normal power grid, respectively; P_{grid} and Q_{grid} is the absorptive active and reactive power of photovoltaic power, respectively.

When the distributed photovoltaic is in the island operation, the total impedance of RLC load is represented as Z, assuming that the voltage is U, there are:

$$|Z| = \frac{1}{\sqrt{\frac{1}{R^2} + (\frac{1}{wL} - wC)}} \tag{1}$$

$$\varphi = \arctan[R(\frac{1}{wL} - wC)] \tag{2}$$

Z is the total impedance of distributed photovoltaic (pv) power supply, φ is impedance angle.

If detected photovoltaic inverter output power is matched load, then input sensitive, the capacitive load. After input capacitor, reactance in an anti-islanding device, we have:

$$\varphi_s = \arctan[R(\frac{1}{wL_\Sigma} - wC_\Sigma)] \tag{3}$$

The impedance angle changed to be:

$$\tan\varphi_s - \tan\varphi = R\left(\frac{1}{wL_\Sigma} - wC_\Sigma\right) - R\left(\frac{1}{wL} - wC\right) = R\left(\frac{1}{wL_S} - wC_S\right) \quad (4)$$

Z_Σ is the total impedance of distributed generation after input load in anti-islanding device, φ_S is the impedance angle of distributed generation after input load in anti-islanding device. Due to the input of capacitance and reactance, so the total impedance of distributed generation has some changes, and its impedance angle is also changed accordingly. Input appropriate L_S 、 C_S , impedance angle φ_S can jump out island non-detection zone $[-\varphi_{zd}, \varphi_{zd}]$。Specifically，combined equation（3）and equation（4）and obtained：

$$\varphi_s = \arctan\left[R\left(\frac{1}{\omega}\left(\frac{1}{L} + \frac{1}{L_S}\right)\right) - \omega(C + C_S)\right] \quad (5)$$

combined this formula, based on the relation between impedance angle φ_S and island non-detection zone $[-\varphi_{zd}, \varphi_{zd}]$，the input inductive load and /capacitive load can be determined then. In case of island running, anti-island device can adopts passive comprehensive criterion to identify the island phenomenon, when island occurring is determined, through the communication with inverter, send single to inverter stop working, and remove the island, if it is not exceeded the normal threshold setting, and the detection is continued then.

If you have already issued the island removal command, and found that the voltage has not been dropped below no-voltage condition, then it can be considered that the communication mode of inverter is failed, through input resistance load into anti-islanding device, make the inverter stop working via the low-voltage protection action, and remove the island. the equivalent model of distributed photovoltaic island system after input impedance low pressure in anti-islanding device is shown in Figure 2. Rs is load disturbance.

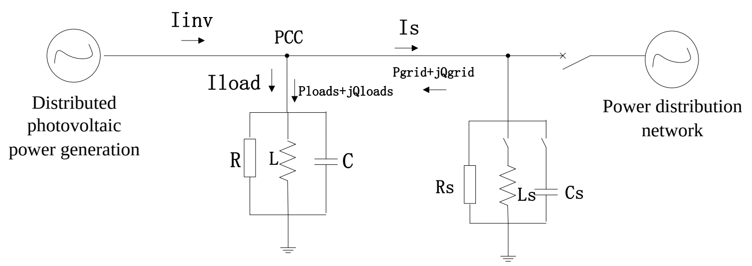

Figure 2. Resistance Load of Distributed Generation System

When the distributed photovoltaic (pv)is under island operation，Z represents total impedance of ＲLC load， after input impedance low voltage anti-island deviceＲs，the system voltage will drops，voltage drop（ $1+\frac{Z}{R_S}$ ）times. Therefore, to select appropriate disturbance load value，can make the distributed photovoltaic under-voltage protection. According to the requirement of the inverter voltage protection, input impedance low pressure anti-island device, the drop of voltage is usually as＜ 85% Un（where, Un is the nominal voltage of access distribution network system）。

The means of communication also serves as an alternative channel. In the case of anti-island device and scheduling communication, when conducting power maintenance on the upper level, and located in the grid-connected interface anti-island device receive scheduling command to direct remove local distributed photovoltaic (pv) power supply.

4. Simulation

4.1. Simulation Model

It is through the PSCAD simulation to test and verify the actual effect of this method. Its main wiring diagram as shown in the Figure 3 below. Three distributed photovoltaic power supplies are set in the system, DG1, DG2, and DG3, a total of 4 normal loads, as LOAD1, LOAD2, LOAD3, LOAD4, and a load controlled by anti-islanding device, LOAD5. S1 is the grid-connected node, and the control part of anti-islanding device is installed on here, and voltage and current are also collected here.

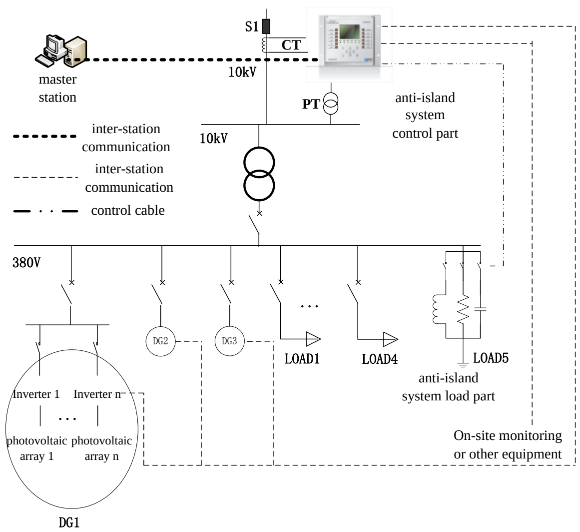

Figure 3. Main Diagram and Anti-Islanding System

4.2. Anti-Islanding Equipment Simulation

First of all, when the active and reactive power of load and the distributed power supply in the system achieved basic balance, and after island occurred, the voltage waveform as shown in Figure 4, it can be seen from the waveform, the voltage amplitude and frequency change are very small in such case, if the threshold of the variation is set to be very large, the island may not be detected; If the threshold value of variation is small, when there is nonlinear load stop up in the load, the island is easy to be misjudged. The ordinate in both Figures 4 and Figures 5 is the voltage standard unit value, while the abscissa is time, unit is second, island occurs at 1 second in the system.

Table 1. Initial Simulation Data

	active /kW	reactive/kVAR
DG1	11.5	2.8
DG2	11.0	2.6
DG3	6.2	1.8
LOAD1	5. 0	10.0
LOAD2	5.0	2.8
LOAD3	5.0	10.0
LOAD4	9.0	-20.0
LOAD5	0	0
electric power grid	0.3	0.2

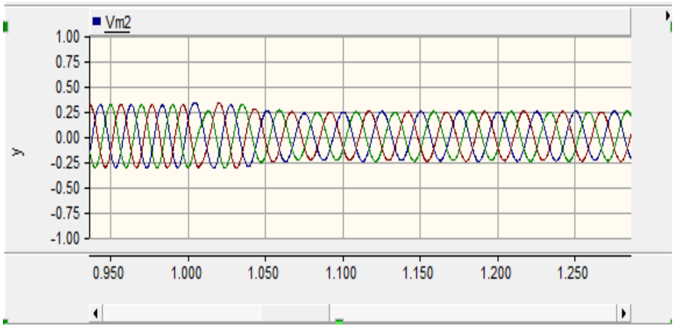

Figure 4. Three-Phase Voltage at the Time of Islanding

After using the anti-islanding equipment, if the detected current at grid-connected node is bigger, and no variable load input. As shown in Table 1, when the active and reactive power of distributed power supply and load are closed, and input corresponding load to change the character. If the condition the same as Table 1, input a set of capacitors, while the actual operation data the same as shown in Table 2. After the island occurring, the voltage waveform as shown in Figure 5, it can be seen from the figure, the voltage amplitude of variation is bigger, and island can be determined easily.

Table 2. simulation Data After the Capacitive Equipment

	active /kW	reactive/kVAR
LOAD5	0	2.0
electric power grid	0.3	2.2

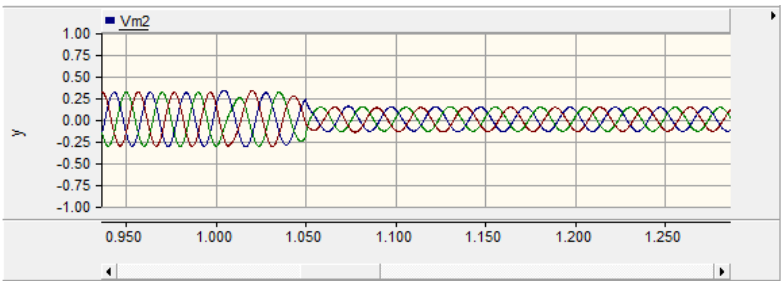

Figure 5. Three-Phase Voltage At The Time Of Islanding

5. Based On the Photovoltaic (Pv) Grid Interface Device To Realize The Structure of Anti-Islanding System

According to SGCC regulations, dispatching automation information of 10kV access of distributed power project must be accessed, upload real-time information of grid-connected equipment status, grid-connected node voltage, current, active power, reactive power, generated capacity and so on. If referring to the design of conventional power station, the cost of the investment in the construction of distributed photovoltaic power station is certainly raised. Second, numerous secondary equipment may bring many inconvenience to on-site installation and operation maintenance in the future. Therefore, according to SGCC relevant policies and technical standards, it has developed a new generation of distributed generation grid-connected interface and anti-islanding device, the device combined protection, measurement and control, power quality monitoring, code conversion, remote function, information encryption, looped network interchange, GPRS communication as well as anti-islanding function. The device not only meets the related specifications, but also greatly reduces the investment cost of grid-connected secondary equipment of distributed photovoltaic power, and with the small installation size, it can be easily installed on the switch cabinet, has brought great convenience for the design, installation and maintenance of distributed photovoltaic power station[1][11].

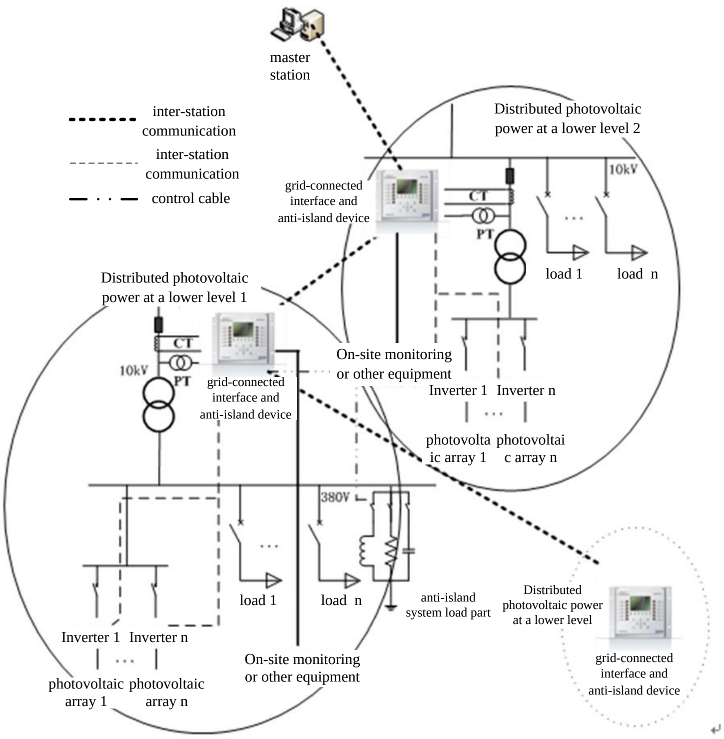

Figure 6. Photovoltaic Power Interface Device Application of Schematic Diagram

6. Conclusion

For some disadvantages of traditional island detection method, this paper presents an adapt changes of load method, the biggest characteristic of this method is that it implements anti-islanding from the grid-connected interface, at the same time adopts active and passive way to meet the specification requirements. Later in this paper, the effectiveness of the method is verified by simulation. In addition, this scheme relies on the new generation of distributed photovoltaic (PV) grid-connected interface device to realize local engineering application, saving investment, also convenient for on-site equipment installation and maintenance, thus bring convenience to operational maintenance. The promotion of the reverse island system also brings great promotion on grid-connected operation of distributed photovoltaic power.

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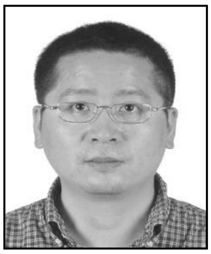

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