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A Single-Phase Transformerless Grid-Connected Inverter for Photovoltaic Applications Based on Switched Capacitors

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Abstract

This article studies the control strategy of photovoltaic power generation inverters, establishes a dual-loop control strategy for the stability of output power and builds the entire photovoltaic microgrid system model based on modeling and simulation. The stability of the inverter is studied with a double-loop strategy to maximize the output power of the photovoltaic power generation system through the inverter. Generally speaking, there are many kinds of photovoltaic inverter topologies, which can be roughly divided into unipolar and bipolar inverters. At present, the single-pole mid-interleaved flyback micro-inverter is generally selected, which has simple circuit, low cost and high efficiency, which is beneficial to the promotion of household photovoltaic power generation. The interleaved flyback inverter topology is mainly composed of dual flyback converters, power frequency polarity reversal bridges and filter circuits. The dual-circuit flyback converter is connected in parallel on the output side of the photovoltaic module to control its output voltage and realize the MPPT function. Parallel dual flyback converters can also increase the power level, reduce current ripple and improve power quality. The power frequency polarity reversal bridge has the function of inverter and is connected to the grid after the filter circuit. Through simulation experiments, the grid-connected current and voltage of the system can maintain the same frequency and phase stably, the output power of the solar photovoltaic power generation panel increases and the output power of the inverter is stable and controllable. We can verify the effectiveness of the dual-loop control strategy through verification.

Keywords: *Switched Capacitor, Photovoltaic, Inverter;*

1. Introduction

Photovoltaic power generation has the advantages of being clean, pollution-free and inexhaustible, so it has attracted more and more attention from all over the world and it is regarded as one of the most dynamic new energy sources in the 21st century. With the rapid development of power electronic technology, various power electronic devices, including photovoltaic power inverters, active power filters, etc., have gradually been widely used in modern power systems. Grid-connected inverter is the core equipment of photovoltaic power generation and it also plays an important role in improving the power quality management of distribution network. Therefore, photovoltaic inverter has become the main research object of many scholars[1]. For grid-connected inverters, pulse width modulation technology is currently used for grid-connected control and good control results have been achieved. However, due to the switching action of the inverter bridge of the inverter, high-frequency current components will be generated, which makes the output current extremely It is easy to cause current fluctuations and voltage surges; for this problem, LCL filters can be used to filter out the pulse voltage. The LCL filter is a third-order low-pass filter, which can achieve very effective switching harmonic attenuation while reducing inductance requirements and filter out the current harmonic content. We analyze and study it.

2. Overview of switched capacitors and inverters

2.1. Switched capacitor

Switched capacitors are the most commonly used capacitor devices in the current transmission network construction. They are connected to the circuit by switching, which can compensate for the inductive reactive power during circuit operation, effectively improve the power supply efficiency of the transmission network and reduce power transmission. Process consumption. In actual design, technicians should choose different switched capacitor devices according to different voltage levels of transmission lines to ensure that they can perform their design functions. Researchers need to optimize the substation according to the transformer capacity used in the substation, so as to realize the reactive power loss of the transformer and the reactive power compensation of the load equipment. In the actual operation process, if the capacity of the main transformer in the substation is above 40MVA, then two sets of capacitive reactive power compensation devices should be used in the design optimization process of the substation. In the process of determining the capacity of the reactive power compensation device, the technicians generally set it according to the capacity of the main transformer and in this process consider the minimum load of the grid operation and the reactive power compensation demand[2].

In practical applications, switched capacitor devices include switched capacitors, series reactors, discharge coils, lightning arresters, isolation switches and other equipment. In connection, technicians will use single star ungrounded wiring to connect to the grid. Among them, the main function of the series reactance equipment is to avoid the large inrush current of the capacitor in use and avoid damage to the equipment. Secondly, the series reactance can inhibit the harmonics generated during the operation of the transmission network from causing damage to the capacitor and ensure the normal safety of the equipmentuse[3]. The discharge coil can reduce the amount of charge in the capacitor when the capacitor is out of the grid, ensuring that there will be no problems such as inrush current when used again and ensuring safety in use. In addition, the discharge coil also provides unbalance protection for the capacitor during operation, which greatly improves the stability of the power grid and prolongs the service life of the capacitor. The photovoltaic applications system is in the figure below[3].

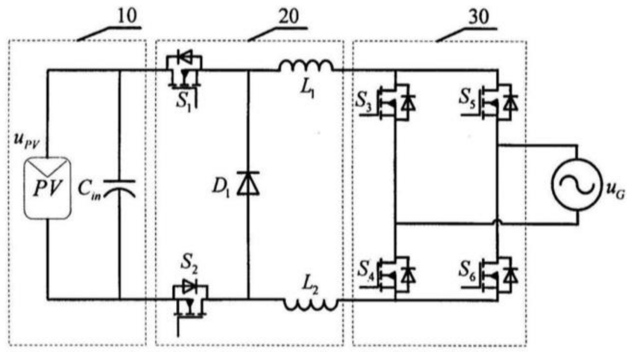

Figure1. Photovoltaic applications system.

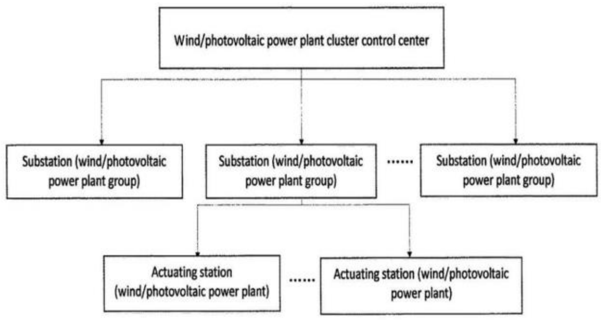

Figure2. Photovoltaic applications system.

2.2. Grid-connected inverter

According to the basic structure of the inverter system, the division of inverters can be carried out from different directions. According to the form of the main circuit of the inverter, it can be divided into single-ended inverter, push-pull inverter, half-bridge inverter and full-bridge inverter; according to whether there is a transformer, it can be divided into isolated type Inverter and non-isolated inverter; according to the different types of inverter main switching devices, it can be divided into thyristor inverter, transistor inverter, field effect tube inverter and insulated gate bipolar transistor (IGBT) Inverter: According to the inverter control mode, it

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can be divided into frequency modulation (PFM) inverter and pulse width modulation (PWM) inverter. We can divide photovoltaic inverters into centralized inverters, string inverters and modular inverters according to the difference of DC side photovoltaic components (different power) and introduce and analyze each type of inverter. The photovoltaic grid system is in the figure below.

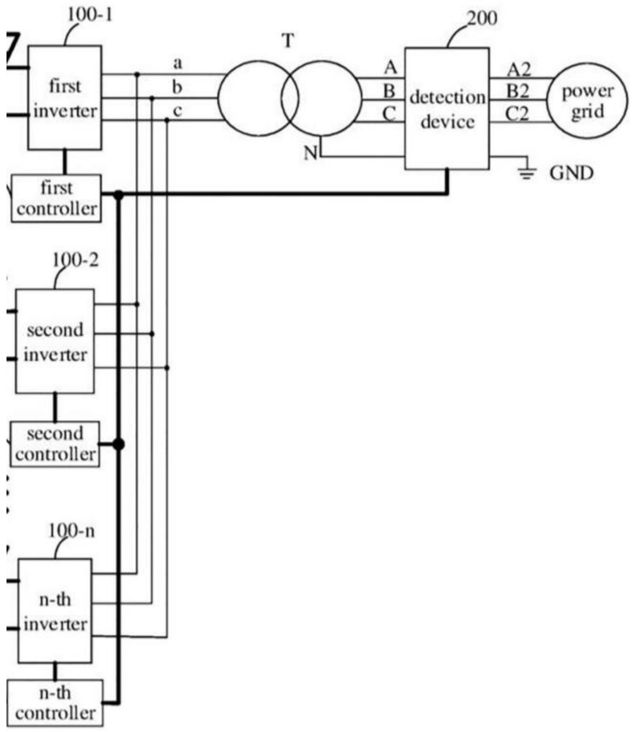

Figure3. Photovoltaic grid system.

3. Design of photovoltaic grid-connected inverter based on switched capacitor

3.1. Inverter composition

The basic structure of the photovoltaic inverter system includes: DC/AC inverter, controller, transformer, detection unit and DC/DC conversion circuit. The function of the photovoltaic inverter is to convert the direct current generated by photovoltaic components into alternating current and its core is the inverter power electronic switching circuit, namely the inverter[4]. The selection of main switching devices is also different under different power situations: three-phase IGBT power modules are used when the power is high; field effect transistors are used when the power is low. The on-off of power electronic switching devices (MOSFET, IGBT, etc.) needs a certain driving pulse to control, so the controller controls the inverter output by generating and adjusting pulses, so that the photovoltaic inverter output meets the grid-connected demand. The photovoltaic house system is in the figure below.

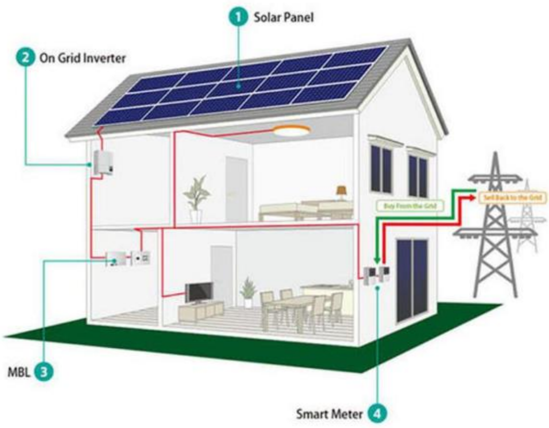

Figure4. Photovoltaic house system.

3.2. Grid-connected operation mode of inverter

There *are* two ways to connect generators to the grid: quasi-synchronous and self-synchronous. The quasi-synchronous parallel method is that the frequency, voltage, phase sequence and phase of the generator are completely consistent with the system grid. The outlet short-circuit device of the generator is connected to the grid; the method of parallel synchronization is that the generator is not added first. Excitation, when the frequency of the generator is the same as the frequency of the system grid, close the generator outlet circuit breaker to connect to the system and then gradually increase the generator excitation current boost and the system will drag the generator into a synchronous operation mode[5]. The grid-connected method will absorb a large amount of reactive power from the system when it is connected to the grid, which will cause the system voltage to drop and the inrush current is relatively large at the moment the circuit breaker is closed. It is used. At present, the method of automatic quasi-synchronization is widely used. This method is

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determined by the computer to automatically signal the circuit breaker to close and connect to the grid.

4. Application mode of photovoltaic grid-connected inverter based on switched capacitor

4.1. Improve the prevention plan

Judging from the current situation, the fault prevention of switched capacitors requires a good response to and resolution of different influencing factors. In the future development, there will be many challenges to be solved. Therefore, the failure prevention program of switched capacitors must be continuously improved. First, the daily prevention and control of the failure of switched capacitors requires a good check on the relevant data and information of the switched capacitor and observe whether the development of the work can be carried out as expected and whether it can be maintained in a variety of work arrangements. High rationality, even if there is a small deficiency, it must be quickly compensated, thereby promoting the continuous reduction of the probability of switching capacitor failure. Second, the failure prevention of switched capacitors should be carried out continuously and no interruption should be shown, otherwise it is easy to cause later work to fall into a larger dilemma. The photovoltaic prevention system is in the figure below.

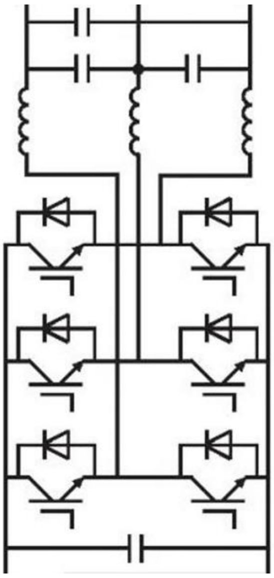

Figure5. Photovoltaic prevention system.

4.2. Enhanced configuration installation

As far as the switched capacitor itself is concerned, during the failure prevention process, the installation strength of the configuration should be continuously improved. The work in this area will have a particularly large impact. If you continue to follow the rigid route during the control process , You can't get good achievements.

Reasonable configuration and installation include: a) Star connection is used as the primary main wiring form of the high-voltage capacitor; b) The discharge coil cannot be connected to the neutral point and the three-phase transformation ratio must be consistent; c) Unbalance protection should strictly follow the design Standardize the setting and ensure good coordination with other protections; d) When selecting the reactance rate of series reactors, the background harmonic conditions must be considered first[6]. Usually follow the suppression of 5th and above harmonics with 5% series reactance rate and 3rd and above. 12% cross-resistance rate. From this point of view, the effective installation of the configuration can continuously improve the self-system of the switched capacitor and at the same time, the probability of failure can also be reduced. The photovoltaic management system is in the figure below.

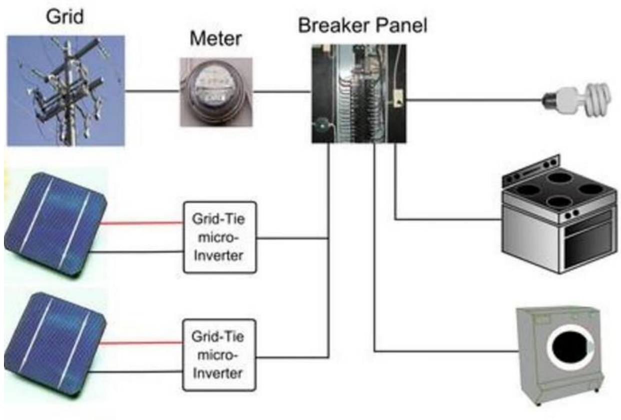

Figure6. Photovoltaic applications management system

4.3. Strengthen patrol inspection

Nowadays, the electric power work must be

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continuously improved in the degree of prudence. The inspection work has become a necessary part. If we are not able to continuously change the details in the process of work, it is very likely As a result, the internal vulnerabilities of switched capacitors are constantly increasing, which requires a high degree of attention in future work. Operation and maintenance personnel should do daily inspections and regular power-off inspection tasks and make relevant records to ensure that the capacitors operate within the scope of the various work indicators specified by the manufacturer. The patrol inspection includes: the cabinet should be clean, free of deformation and free of oil leakage; the surface of the insulating sleeve and insulator should be free of dirt, damage and discharge traces. In addition to the daily inspection tasks, the tightness and contact of the parts must be checked; the internal dust should be cleaned to avoid reducing the insulation level.

5. Conclusion

The grid-connected operation mode has been adopted by many self-provided photovoltaic power plants. However, regardless of the grid-connected operation mode or the isolated grid operation mode, the monitoring and adjustment of the units must be strengthened during operation, especially the isolated grid operation. Improving the accident handling ability of operators is the key to determining whether the unit can operate safely. Although there are many hidden safety hazards in isolated grid operation, as long as the unit operation management is done well, it can not only provide enterprises with low-cost electric power, but also improve Enterprise market competitiveness.

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