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Considering the comprehensive optimization research of the hybrid energy storage control strategy based on the photovoltaic-storage-DC microgrid

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Abstract: *Considering the state of charge of the energy storage and the deviation of the DC bus reference voltage exceeding the limit, a multi-loop power control strategy is constructed in the front-stage structure, and the state of charge of the energy storage or the deviation of the reference voltage of the DC bus is fed back to the upper limit. In the photovoltaic power controller, the photovoltaic controller deviates from the maximum power operating point and adjusts the reference voltage of the photovoltaic output, thereby preventing the energy storage state of charge from exceeding the set upper limit or the DC bus voltage suddenly rising. On the contrary, the state of charge of the energy storage that exceeds the lower limit or the deviation of the DC bus reference voltage is fed back to the demand response side to send a command to cut off the DC load, to prevent the state of charge from exceeding the set lower limit and the DC bus voltage to drop suddenly, thus realizing the front stage of the system.*

Keywords: *Photovoltaic storage AC and DC microgrid; island operation; state of charge; power coordination control; master-slave control*

1. Introduction

At present, the independent photovoltaic power generation system has inevitable shortcomings such as volatility and randomness, which is also one of the reasons why the power grid cannot provide stable and reliable electricity demand to the user side [1]. At the same time, large-scale distributed photovoltaic power generation is connected to the power grid system, which has a great impact on the power grid.Cause serious impact, such as voltage increase, harmonic increase and power shock and other problems. In the island microgrid system, these problems also become more prominent with the increase of photovoltaic penetration. The microgrid system operating in the island mode usually uses battery energy storage as an energy buffer device to balance the excess or lack of power in the microgrid system. In order to ensure the continuous and stable operation of important loads in the microgrid, literature [2] proposes a dynamic islanding strategy for distribution networks considering the sustainable load-carrying capacity of optical storage to improve the reliability of the distribution network. Reference [3] combines diesel generators, supercapacitors and batteries to form a multi-component complementary coordination system to share the differential power to achieve long-term stable operation of the isolated microgrid. In terms of energy storage control, literature [4] proposes an energy management strategy for hybrid energy storage and a control strategy for bidirectional power converters, so that the microgrid energy storage elements in normal operation can be maintained within a reasonable state of charge range. Reference [5] adopts frequency coordination and considers the state of charge of energy storage to realize the output sharing of multiple energy storage units, so that the photovoltaic power generation system works in dispatch mode and photovoltaic stabilization mode. However, when the energy storage is connected to the microgrid, it is either directly converted into alternating current through the inverter, or converted into alternating current by connecting with other distributed power sources. The latter combination provides flexibility to the control of the system. In this structure, many researchers have introduced the upper-layer power management system to coordinate the operation of photovoltaic and energy storage units, so that the microgrid can meet the power balance in the system under different working conditions, such as literatures [6-8]. The upper-layer power management system often requires program algorithms to be implemented, which also adds complexity to the system to a certain extent. For example, an energy management and coordinated control strategy based on local information is proposed in [9], which combines constant voltage control and adopts open-loop pitch angle control method to solve the problems of DC bus voltage fluctuation and system instability in islanded microgrids . Similarly, in [10], a passive control-based power management strategy is proposed to control photovoltaics and energy storage. The method proposed in this document needs to add more communication to ensure the stable operation of the system, which will undoubtedly increase the cost input. The above-mentioned literature mainly controls the optical storage hybrid unit from the energy management layer, and the switching of the DC side load is not considered in the built model. For this reason, many scholars have studied the power management of island microgrids and the coordinated control of microgrids without the need for communication and energy management layers, such as literature [11-13]. Based on the above literature, this paper aims at the solar-storage AC-DC hybrid microgrid in the island mode, from the perspective of the bottom layer, considers the deviation of the energy storage state of charge and the DC bus reference voltage to form a multi-loop control strategy to manage photovoltaic and storage. The two capable DC/DC converters ensure that the system does not exceed the limit, and realizes the power balance of the optical-storage hybrid system while safely supplying power to the rear stage[14-16]. When the microgrid is in the island operation mode, because the support function of the external power grid is lost, a part of the power supply needs to provide voltage and frequency support, and this part is also called the main control unit[17-18]. In this paper, a virtual synchronous generator (VSG) control strategy is proposed for the main control unit. The load change is mainly followed by the distributed power supply as the main control unit, so its power output should be able to be within a certain range.

2. System operation control strategy

In a solar-storage hybrid system, two configurations can be considered when combining energy storage with PV arrays. The first is to connect the energy storage and photovoltaic arrays to the inverter respectively, and then supply power to the rear stage after inversion[19-22]. This connection method is often not conducive to regulating the output of photovoltaics, and will bring certain safety hazards to the system; the other configuration is to connect the photovoltaic array and the energy storage device in parallel and then connect to the DC bus. This connection method allows the adjustment of the power balance of the system to have a certain flexibility. This paper also adopts the second connection method. The photovoltaic array is connected to the DC bus through a unidirectional boost converter, and Ppv is the power injected into the DC bus by the photovoltaic array. The energy storage is connected to the DC bus through a bidirectional DC/DC converter, and PB is the charging and discharging power of the energy storage. In the designed optical-storage hybrid system, the output terminals of the two converters are respectively connected with independent capacitors Cdc1 and Cdc2[23-24]. This combination of PV and energy storage not only ensures full control over charging and discharging of the energy storage, but also provides flexibility in choosing the rated voltage of the energy storage and the DC bus voltage level. When there is excess photovoltaic output power, the energy storage will store the excess photovoltaic power; when the photovoltaic output power is not enough to supply the load power demand, the energy storage will provide the load power shortage. The DC bus voltage is controlled by a bidirectional DC/DC converter connected to the energy storage. Under normal operating conditions, the perturbation observation method (P&O) is used to control the photovoltaic boost converter by adjusting the photovoltaic input terminal voltage Vpv to the maximum power point to achieve maximum power point tracking (MPPT) control. In the control strategy, the DC bus voltage Vdc, the energy storage real-time current iB, the photovoltaic input voltage Vpv and ipv are all passed through a first-order low-pass filter, which can reduce switching noise, measure noise and current ripple. In the photovoltaic controller, the difference between the voltage reference signals Vpvref and Vpv and the filtered photovoltaic output current ipv generate the control signal S1 through the voltage controller and PWM. In the energy storage bidirectional boost controller, the difference between the DC bus reference signal Vdcref and the filtered real-time voltage signal Vdc and the energy storage charging and discharging current iB generate the charging signal S2 (buck) and the discharging signal S3 through the voltage controller and PWM. The PV array output voltage reference value Vpvref is obtained by the PV power controller based on the battery and state of charge SOC, PV output maximum power, and load power. Based on these variables, the power flow in the system can be divided into: normal operation mode, state of charge over-limit regulation mode, DC bus voltage over-limit regulation mode.

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3. System control target

For the DC microgrid system composed of photovoltaic/supercapacitor/lithium battery, the coordinated control and reasonable distribution of energy among various microsources can be realized, and the advantages of the hybrid energy storage system can be better exerted and utilized. A power distribution method based on SOC fuzzy control of hybrid energy storage system is proposed, which uses fuzzy rules to reasonably distribute the output of hybrid energy storage, avoids battery overcharge and overdischarge, and optimizes the operating conditions of the system, but the quality of fuzzy control depends on When the rule is set and the application object is switched, the rule needs to be re-adjusted. In the photovoltaic grid-connected system, a power distribution strategy based on the SOC of the supercapacitor is designed, which limits the SOC of the supercapacitor to a reasonable range and reduces the number of charging and discharging of the battery, but ignores the limit of the SOC of the battery, and overcharge may occur. The voltage droop control is used to distribute the power of the hybrid energy storage, but the effect of suppressing the voltage fluctuation of the DC bus is not ideal. The energy management strategy (EMS) for the hybrid energy storage system is provided for different operating conditions. The proposed EMS has better performance in grid-connected and island modes, such as maximum power point tracking and voltage regulation. However, the mentioned EMS is very complex and difficult to implement, and also depends on various system parameters, and this control method is not universal. The hierarchical control of the hybrid DC power supply system is proposed, and the power distribution principle of the hybrid energy storage is formulated according to the photovoltaic output and load consumption power through the method of model prediction. The power command of the system is decomposed by the second-order low-pass filtering link, and considering the SOC of the hybrid energy storage unit, a limit management strategy is proposed to prevent the energy storage unit from overcharging and overdischarging, and prolong its service life. In summary, in order to eliminate the adverse effects of random fluctuations in photovoltaic output and sudden load changes on the safe and reliable operation of photovoltaic DC microgrid systems, this paper adds a hybrid energy storage system to the photovoltaic power generation unit, and decomposes the power command through a low-pass filter. , combined with the supercapacitor SOC to redistribute the hybrid energy storage power, and consider the photovoltaic output, load demand and the SOC of each energy storage unit in the hybrid energy storage system to divide the system into four different operating modes. A photovoltaic DC microgrid simulation model with hybrid energy storage system is built through PSCAD/EMTDC, which realizes the stable and reliable operation of the photovoltaic DC microgrid system, and optimizes the output between the micro-sources.The results verify the effectiveness and accuracy of the control strategy.

4. Simulation analysis

In order to cope with the severe challenges posed by the shortage of resources and environmental pollution to the development of the power system, distributed generation technology has received extensive attention from the power industry in various countries. However, the direct connection of a large number of distributed power sources (such as solar cells, fuel cells, wind turbines and small gas turbines) to the grid will have a significant impact on the peak regulation of the public power grid and the safe operation of the system. In order to give full play to the value and benefits of distributed power, distributed power is integrated into the main network in the form of micro-grid. The traditional power system belongs to the AC system, so most of the research on the microgrid focuses on the AC microgrid . In addition, due to the development of DC distributed power generation, the increase in the proportion of DC power loads, the increase in the use of energy storage devices, and the increase in the quality requirements of sensitive loads on the power supply, there is no phase synchronization, harmonics and reactive power losses in the DC system. Therefore, the DC microgrid composed of power supply, energy storage, load and monitoring devices in a DC way will become an important mode in the future electricity consumption field. The focus and difficulty of DC microgrid research lies in how to maintain the stability of the busbar voltage and ensure the system power balance during the operation of the DC microgrid system. Most of the renewable energy in the DC microgrid system is due to its energy.

It is inherently non-uniform and uncontrollable, and the output power may change at any time. When the external light, temperature, wind, etc. change, the corresponding output energy of the micro-source will change, which will cause the power imbalance in the system, and then cause the DC bus voltage to fluctuate in a wide range. In order to smooth the voltage fluctuation of the busbar, solve the fluctuation of energy supply, and improve the reliability of the system, it is usually necessary to increase the energy storage device in the DC microgrid system. Therefore, the control method of the charging and discharging of the energy storage system in the DC microgrid system has become one of the research hotspots . The control of the converter is the most basic and important control of the DC microgrid. At present, the commonly used power distribution methods include master-slave control, average current control and droop control, and droop control, as a traditional control method of DC microgrid, does not rely on communication algorithms, has simple control, and can better balance the output power , which is more suitable for use in DC microgrids. In this paper, according to the system structure of a typical DC microgrid, a simulation model of the DC microgrid is established based on the PSCAD simulation platform. According to the converter ripple coefficient of the energy storage system, the reasonable parameters of the filtering link are determined.The numerical value and the simulation analysis of the influence of the sag coefficient on the system are carried out.

5. Conclusion

Raditional droop control as the research object, this paper focuses on the structure of DC microgrid and the principle of droop control, and builds related models to analyze the influence of different droop coefficients on DC microgrids. The following conclusions are drawn: 1) The power distribution is based on the droop coefficient. 2) The bus voltage deviation is affected by the size of the droop coefficient, and the larger the droop coefficient, the more the bus voltage deviates from the set value; 3) The load power is affected by the size of the droop coefficient as the droop coefficient increases , the load power is reduced. The smaller the load resistance, the more pronounced this effect is.

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