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Optimized Configuration of Distributed Energy Storage for Photovoltaic Driven New Energy

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Abstract: Photovoltaic power generation has the advantages of being renewable and widely distributed, becoming an important direction in the development of new energy (NE) at present. In this paper, a new type of power transmission system, solar photovoltaic energy storage battery, was used as the core device to study the optimal control strategy. Based on the characteristics of the battery pack, its output power, load rate, and efficiency were analyzed and calculated, and a mathematical model was established to achieve the optimal configuration capacity and optimal operating state. The simulation results showed that the charging times of distributed energy storage for NE optimized by photovoltaic drive range from 1643 to 1865. The controller has excellent performance indicators and steady-state stability, and can effectively convert solar radiation energy into electrical energy or other forms of energy for users to use.

1. Introduction

With the widespread use of fossil fuels, renewable energy has gradually become a topic of concern around the world. The NE distributed photovoltaic power generation system utilizes clean and pollution-free renewable resources such as solar energy and wind energy for energy conversion, storage, and transmission, and provides power supply. Currently, China has built many large-scale distributed photovoltaic power stations and distribution network projects for large-scale application nationwide, but due to its own shortcomings, the existing layout is inefficient, especially in remote areas where the power supply network is difficult to meet demand.

There are many studies on NE storage. Some scholars have analyzed and discussed the hybrid energy storage system based on wind-solar complementarity. They established an independent inverter model based on solar cell modules by combining solar cell modules with wind turbines. On the basis of this model, they proposed and applied the model to solve the power fluctuation problem in photovoltaic power generation systems. By calculating the optimal power capacity, they achieved maximum power output from distributed power sources [1-2]. Some scholars have optimized and modeled distributed energy storage devices based on energy conservation equations, and obtained a linear relationship between the power generation cost and battery consumption rate of a NE vehicle. Scholars have introduced design ideas for renewable energy and solar dedicated hybrid vehicles, pure electric vehicles, and fuel cell hybrid systems. After analyzing photovoltaic power generation systems, relevant researchers have proposed a NE vehicle based on a distributed solar energy distribution model, which can effectively solve the power consumption problem for remote users in remote areas [3-4]. Therefore, based on photovoltaic drive, this paper studied the optimal configuration of distributed energy storage for NE.

Photovoltaic power generation is the use of semiconductors and other devices that can convert electrical energy. Silicon based solar cells are the most commonly used among solar cells. With the development and progress of distributed power technology, it has become an important branch of NE applications. This paper studied the composition of energy storage system and power storage drive circuit based on a new type of high-efficiency, pollution-free, and green charging device, and analyzed its working principle. By optimizing the configuration structure and control strategy of photovoltaic power generation systems, the impact of output power fluctuations on solar energy was reduced, achieving optimal load effects and improving the stability and reliability of distributed power generation.

2. Discussion on Optimal Configuration of Distributed Energy Storage for Photovoltaic Driven NE

2.1 NE Distributed Energy Storage

The NE distributed energy storage system is composed of solar photovoltaic power generation units, battery modules, and inverters. By controlling power fluctuations, it achieves two-way energy flow and meets the needs of long-distance transmission and power supply. Changing the output voltage while the amount of solar radiation remains constant. When the length of the solar array increases to a certain extent, the output current would change. When the light intensity reaches the maximum value, the storage capacity would decrease until the charging is stopped, or the battery would be discharged or directly converted to direct current (DC) power by the inverter when the NE power generation system is restarted. Due to its high energy utilization rate, low noise pollution, and other advantages, it is known as a “four light” type semiconductor device. It can achieve the goal of improving system efficiency by controlling the inverter to regulate the illumination and frequency in the state of power storage, while also avoiding environmental problems caused by grid power supply to a certain extent. This is the so-called solar cell array power generation technology [5-6]. In the process of photovoltaic power generation in a NE distributed energy storage system, the solar panel receives the energy generated by solar radiation, and then converts the electrical energy into DC through an inverter for use by the load. Figure 1 shows the grid current output diagram.

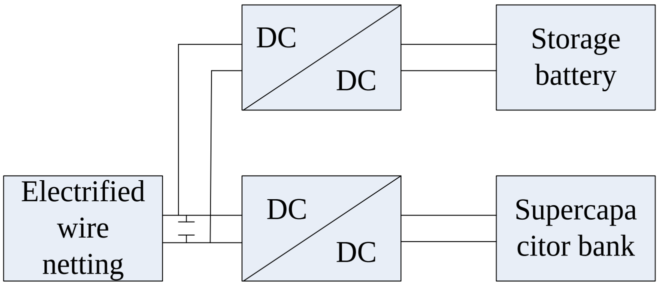

Figure 1: Power grid current output

When charging from an AC (Alternating Current) power source, a power storage device can be used for power supply. For example, constant voltage or amplitude modulation devices, alternators, and DC reactive power compensation devices can be used to achieve the conversion of output power and frequency. After generating electrical energy in the photovoltaic power generation process, it is transmitted to the power consumption terminal through the grid, thereby effectively utilizing the resources of the entire power system. The NE distributed energy storage system is composed of traditional photovoltaic power generation equipment and batteries. Its working principle is that the DC power generated by solar modules is converted into corresponding voltage values through an inverter, and the frequency matches the charging current, and can provide a certain amount of energy supply [7-8]. The NE distributed energy storage system utilizes the photovoltaic effect of solar energy to convert solar radiation energy into electrical energy and store it in a storage battery under the conditions of traditional photovoltaic power generation technology. It has the following characteristics: it can fully utilize solar energy, has no noise, occupies a small area, and does not pollute the environment. When the sun is abundant, solar panel arrays can be used to collect solar radiation energy. When the light is insufficient or the power control is inappropriate, photovoltaic arrays can be used to receive electrical energy generated by redundant equipment in the power grid to supply power to the load for use. At the same time, battery storage and discharge devices can be used to store the current and voltage required by the power supply system. [9-10].

2.2 Optimized Configuration of Energy Storage

The capacity of a photovoltaic power generation system increases as the load increases, so when the load is fixed, the energy storage configuration scheme should be determined based on the charging capacity of the battery. This method can be selected when the battery voltage is within a constant range or exceeds the normal operating current. If the capacity of the energy storage device is less than the set value, it can be controlled by switching the charging and discharging modes to achieve the optimal output power of the photovoltaic power generation system, thereby maximizing the utilization of solar energy resources, improving energy efficiency, and reducing costs. The output power of photovoltaic power generation systems can meet the grid load demand to a certain extent, so energy storage technology is an important means to improve the reliability and stability of distributed photovoltaic power supply [11-12]. Currently, it is commonly used to optimize the configuration of solar cell arrays based on photovoltaic drive algorithms. This method first determines the optimal working mode, charging mode, and voltage control strategy. Secondly, it estimates the battery capacity and calculates its remaining power to achieve the optimal distribution. Finally, it selects an appropriate charging and discharging potential based on the ratio of the maximum output power to the total power generated by the system load, in order to achieve the goal of improving the power supply efficiency and reliability of the entire photovoltaic power generation system. The core component of a photovoltaic power generation system is a distributed energy storage device, which can effectively convert solar energy into electrical energy and directly supply power to the load. In traditional distributed power generation, when power is needed, it must undergo a large current circulation. Large-scale power generation requires higher requirements, so optimizing the existing layout can not only reduce the operating costs of energy storage equipment, but also improve the transmission capacity and reliability of the power grid, as well as the stability and safety of the power system. At the same time, it also increases the capacity utilization rate and power supply quality of photovoltaic power stations. The output power of photovoltaic power generation systems is mainly affected by factors such as solar radiation intensity, illumination time, and batteries [13-14]. Therefore, energy storage is the most important part of distributed solar photovoltaic equipment. When installing a photovoltaic cell array, it is generally not necessary to consider the capacity issue. When the load is too large, it can lead to overload and excessive temperature of the solar panel. At the same time, when the load is small, it can reduce the power generation efficiency and even make it unusable. When the load is large, it can achieve the goal of energy conservation and emission reduction through improving the energy storage system. The core component of photovoltaic power generation systems is distributed energy storage devices, whose capacity has a significant impact on the reliability of the entire power transmission network and load power supply. Therefore, it is crucial to configure appropriate energy storage devices in distributed energy networks. Currently, the largest solar photovoltaic power stations have shortcomings such as insufficient charging piles and high construction costs. In large centralized power systems, there are a large number of components that need to be imported to solve storage problems, and they also face significant pressure. For small distributed power stations, due to their lack of large-scale storage capacity, they cannot meet the load requirements. In photovoltaic power generation systems, the working environment of battery modules is generally negative, positive, and dust. Under these factors, the energy storage unit would generate heat to varying degrees. In order to prevent excessive voltage fluctuations caused by uneven power distribution from affecting the safe operation of the power grid, and also to avoid damage to the battery caused by direct sunlight, it is necessary to reasonably configure the solar array and improve its energy density to achieve this goal. Based on the solar radiation situation, the optimal power generation method and control strategy have been determined, so that the entire system is in the optimal working state and maximizes the use of electrical energy generated by photovoltaic modules. In photovoltaic power generation systems, the capacity of solar panels is the maximum electrical power, but due to the small size of distributed power arrays, their output characteristics are not obvious [15-16]. Therefore, in order to improve the efficiency of the energy storage device, a “dual pressure device” can be used to achieve. The so-called “dual voltage transformer” is a closed cavity structure composed of two mutually independent and interconnected components, in which the first and second harmonics constitute the input terminals of the rectifier filter and circuit, and also generate voltage source signals connected to the DC side. Photovoltaic energy storage system is an efficient distributed power generation device with low investment and high efficiency. In solar cell modules, solar illumination intensity and photoelectric conversion rate are small. When there is no sunlight, the sun’s energy is almost zero. The illuminance changes continuously with the change of sunlight time, and the radiation power changes due to different temperatures. Therefore, the optimal configuration of the entire distributed power generation equipment can be achieved by adjusting the voltage of the photovoltaic energy storage system.

2.3 Photovoltaic Drive Technology

The development of photovoltaic power generation systems is to use semiconductor photoelectric effects to convert solar energy into electrical energy. Photovoltaic cells have the advantages of long working life, large power generation, safety and reliability. When the light intensity is high, it can convert solar radiation energy into DC. When the load is greater than the maximum power, an inverter can be used as the power supply. When the load is less than the minimum value or the power generation is unstable, wind turbines would be used for charging, or supercapacitors would be used to replace the power supply provided by the grid to supply power to the system, thereby meeting the requirements of load demand and solar resource scarcity. The photovoltaic cell module and controller are composed of semiconductor devices. In a photovoltaic power generation system, the solar panel generates electrical energy during operation, which is then converted and released. If the solar radiation intensity is high, resulting in its inability to function properly [17-18], or premature damage occurs, it would have a certain impact on the load. When the illumination is strong but the power is low, the output voltage is low, the frequency stability is not high, and the output current fluctuates greatly, it may cause the photovoltaic power generation system to malfunction or fail to work. Figure 2 shows the photovoltaic drive technology process.

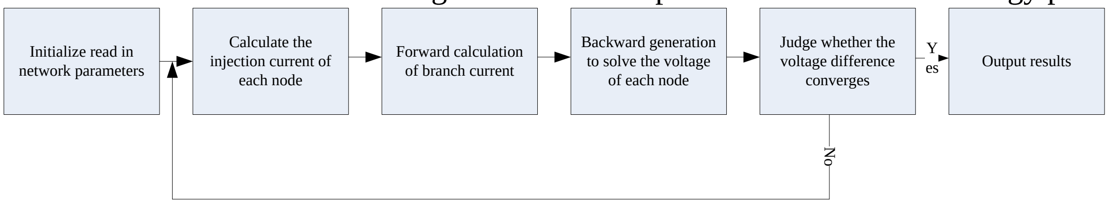

Figure 2: Photovoltaic drive technology process

In order to solve this problem, an array inverter is used to achieve complementary grid connection between solar and wind power generation. By controlling the power storage controller to change the maximum renewable energy distribution in the energy storage device for optimal configuration, photovoltaic modules are used to supply power to the load, with small changes in output current and no need for frequent switching. Therefore, it is necessary to consider the impedance matching problem between the battery module and the load to a certain extent. If this problem can be solved, functions such as voltage stability and frequency tracking near the power output point can be achieved by controlling the inverter. If this disadvantage can be overcome, it can achieve rapid switching of grid connection operation without changing the current size and phase distribution, thereby improving solar energy utilization and energy conversion efficiency in photovoltaic power generation systems. The working environment and load characteristics of a photovoltaic power generation system determine that it must have a certain power output capacity. Therefore, when conducting charge and discharge control on batteries, it is necessary to consider the mutual constraints between photovoltaic modules and solar energy. When the intensity of solar radiation is high, the intensity of sunlight is weak, or the temperature changes too much, it would cause a large current to be generated. If sunlight is directly irradiated on the battery panel, it can achieve maximum energy utilization and reduce system voltage fluctuations and load losses. If the solar irradiance is small and there is insufficient power output, it can be charged by controlling the inverter [19-20]. When solar panels generate voltage due to insufficient sunlight, excess electrical energy is stored in the circuit through the photovoltaic effect. The Pi calculation formula for normal power supply of NE power generation to distribution network nodes is:

$$p_i = p\left(p_D > \sum_{i=l}^{n} p_{l_i} \right) \tag{1}$$

The calculation formula for node power supply is:

$$P_i = 1 - \prod_{k-1}^{n} \prod_{j \in s_k} prob\left(p_j < p_{jl}, \middle| \in \Omega\right) \tag{2}$$

The probability C of obtaining NE power generation and supply can be obtained by Formula (3):

$$C(t) = C(t-1) - P_s(t)\Delta t \tag{3}$$

Among them, C is the event probability; P is the transmission power from the first load area node to node 1 in a NE supply path containing t. When the storage capacity is sufficient, it would be stored. If the load is less than the set value, the power supply would be stopped, and the maximum output power would be calculated. After that, the charging current and required capacity at the power storage and charging and discharging ends would be determined. Finally, based on the remaining energy of the energy storage pool, an estimate would be made and the results obtained, so as to obtain data such as the total power generation capacity of the battery panel, the system power generation capacity, and the number of photovoltaic modules [21].

3. Experimental Process of Optimal Configuration of Distributed Energy Storage for Photovoltaic Driven NE

3.1 Optimized Configuration Framework for Distributed Energy Storage of Ne Based on Photovoltaic Drive

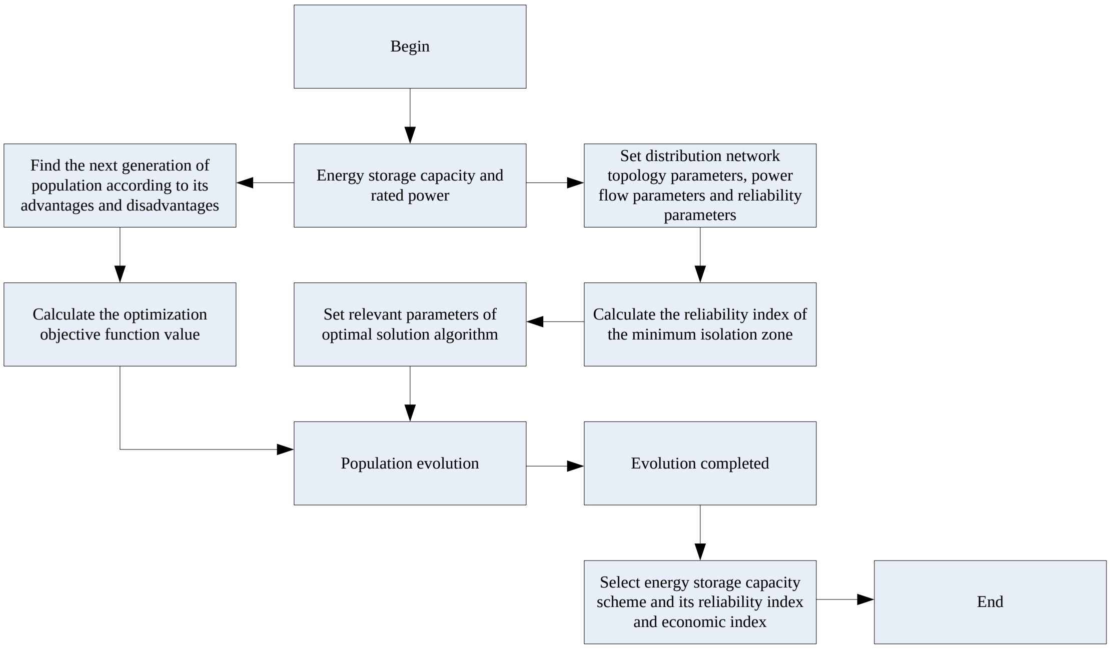

Figure 3: Optimized configuration framework of NE distributed energy storage based on photovoltaic drive

Figure 3 is an optimized configuration framework for distributed energy storage of NE based on photovoltaic drive. In photovoltaic power generation systems, batteries are the core components, which directly affect the energy conversion efficiency of the entire distributed energy system. NE sources such as solar and wind energy are considered to be complementary. Therefore, this article can use solar radiation intensity as a constraint to optimize the maximum power point required for charging electric vehicles driven by photovoltaic power. In order to improve the utilization of photovoltaic power generation systems during the power generation process, it is necessary to increase their output voltage or current, and achieve flexible voltage regulation to meet load requirements through feedback information from real-time monitoring systems. Photovoltaic power generation system is an important component of distributed energy storage technology, which has traceability and decentralized control, and uses solar panels to convert energy to the sun. The wind turbine generator is used as an energy conversion unit and outputs electrical energy through photovoltaic panels to meet the load demand. The battery pack provides a stable DC voltage source for the inverter to supply power to the load or store energy to achieve wind power complementation, thereby achieving the goal of reducing system costs.

3.2 Parameter Testing of Distributed Energy Storage Optimization Configuration for NE Based on Photovoltaic Drive

Based on the distributed energy storage optimization configuration parameter testing of photovoltaic power generation systems, this paper conducted simulation experiments on them, and combined them with traditional conventional power sources and renewable energy to form a NE box. Two solar load plates were installed on the photovoltaic battery array as charging controllers. By controlling the switch switching, it is possible to switch the power storage state at different voltage levels. In the event of a grid failure, the inverter can be manually disconnected to stop the power supply to the inverter circuit, or the AC supply can be disconnected directly to provide backup power to the system. At the same time, the output current is adjusted according to the load demand to ensure the normal operation and stable operation of the system. In practical applications, photovoltaic power generation systems generally require optimized configuration to ensure that they can meet power supply requirements. Through the above tests, it can be found that the optimal distribution mode of photovoltaic power generation systems under different operating conditions. According to practical needs and theoretical calculation results, the optimal layout scheme was determined. When the solar radiation intensity was low, the output power of the solar panel after receiving light was larger; while in sunlight (i.e. during the day), it did not generate enough power generation and cannot meet the load demand requirements, or when the load limit was large, it may lead to insufficient energy storage or even negative growth. At this time, the photovoltaic power generation system would choose to use inverters to improve the output power rate or convert electric energy into electricity for power supply. The battery voltage, output current and solar controller parameters were tested to determine whether the device met the requirements, and then the optimum charging method was determined based on the number of components required and the maximum power generated under different operating conditions. Finally, the calculation results were compared with the theoretical analysis. The optimum charging and discharging conditions and operating principle parameter values were then obtained, and a reasonable and feasible combination of solutions was put into practice.

4. Experiment on Optimal Configuration of Distributed Energy Storage for Photovoltaic Driven NE

Table 1: NE distributed energy storage performance parameters

Test times	Power density (W/kg)	Energy density (W/kg)	Peak efficiency (%)
1	343	231	95
2	452	242	93
3	356	212	92
4	321	204	95
5	362	214	90

Table 1 shows the performance parameters of NE distributed energy storage. The working principle of photovoltaic systems is to convert solar radiation energy into DC electricity through semiconductor materials. In this system, there is a certain physical interaction between the battery module and the load, which generates current output when the light intensity reaches a certain value. At this time, if the solar power generation device receives the electrical energy generated by the power source at the maximum power point and performs charging processing, it can directly supply power to the grid or provide power to the user by the battery. If the photovoltaic power station is unable to supplement the load, it can use the inverter to compensate for reactive power to achieve harmonious operation of the load and the system.

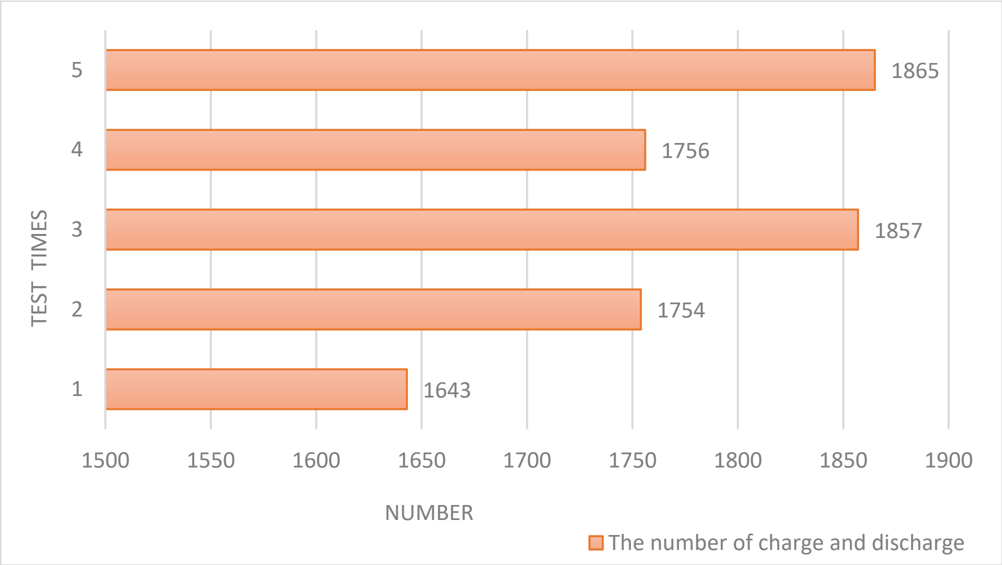

Figure 4: Charge and discharge times of NE sources

The key component of a photovoltaic power generation system is a battery, whose working principle mainly consists of a solar panel array and a battery. In the energy storage link, when sunlight shines on the module, it emits energy. When components receive sunlight, they generate electrical energy and transmit it to the load. Therefore, photovoltaic power generation systems can be used to convert solar energy into usable energy, or clean and pollution-free green and efficient power supplies can be used for power supply. For inverters, it is necessary to determine appropriate charging methods, control strategies, and other parameters based on the output voltage and power size to ensure their safe and stable operation. It can be seen from Figure 4 that the number of charges for distributed energy storage of NE optimized by photovoltaic driving ranged from 1643 to 1865.

5. Conclusions

Photovoltaic power generation is one of the important technologies that directly convert solar energy into electrical energy using semiconductor devices. It has the characteristics of high efficiency and low investment, and is widely used in the field of NE. Based on the principle of photovoltaic power generation and energy management and control strategies, a hybrid distributed power conversion topology model was constructed for distributed energy storage systems. The simulation software was used to perform numerical calculation and analysis to verify its effectiveness. After optimizing the device for the limitations of the operating characteristics of solar cell modules in the existing layout and the limited charging time, the performance was improved and the maximum output of electrical energy can be achieved.

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