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Interactive Multi-energy Complementary Island Microgrid Ecosystem

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ABSTRACT

Reliable and stable island power supply system is an important guarantee for the development of the island. Based on the island connected to the main network by cable, this paper proposes an interactive multi-energy complementary microgrid consisting of new energy generation, electric energy interaction, electric vehicle charging and discharging, home photovoltaic system, power distribution and emergency rescue. The electricity generated by the residents themselves can be used by themselves, and the excess can be sold back to the main network. This system makes full use of the characteristics of electric vehicles energy storage and mobility and participate in grid dispatching, which can improve the popularity of new energy power generation, balance the peaks and valleys of island electricity consumption and reduce the cost of electricity for residents.

Keywords: Interactive grid; New energy generation; Electricity cost; Hydropower.

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1. Introduction

China is a big maritime country with a large number of islands and a wide distribution. With the development of islands, reliable and stable power grid is the basis of the island's new energy system. At present, one of the major methods of island power supply is connecting the submarine cable to the mainland, which costs high construction but is easily damaged and difficult to repair. Otherwise, diesel power generation can be another method for islands to get its power supply. However, this method has high power generation cost and serious pollution, which is not conducive to the island to maintain a good environment[1]. Nowadays, the increasingly popular and mature new energy power generation technology has undoubtedly provided a new direction for island power supply.

At present, China's island power supply mainly depends on land. Due to the closed operation and low reliability of the operation of the island power grid, once the power supply fails, a large-scale power outage will occur, affecting the normal life of the residents. Therefore, it is urgent to construct a new type of power grid structure. On the one hand, it can achieve stable and reliable power supply. On the other hand, it can reduce investment as much as possible, adapting to the power supply of various islands.

The interactive multi-energy complementary island microgrid ecosystem is based on the traditional microgrid, which consists of home photovoltaic system, electric energy interaction system and island intelligent microgrid. The construction of an interactive multi-energy complementary island microgrid ecosystem can improve the utilization and popularity of renewable energy in island power grids[5]. At the same time, it will add electric vehicles, energy storage equipment and other units to reduce the power supply pressure during the peak period of the power grid and also to reduce the energy loss on the transmission line, which can not only can reduce the operating cost of the power system, but also the cost of electricity for users. In the meanwhile, it brings significant benefits in improving the quality of power supply during peak hours, reducing the cost of power grid construction, solving power supply difficulties in islands, and protecting the ecological environment.

2. System Composition

The system is mainly divided into six modules, including new energy generation, electric energy interaction, electric vehicle charging and discharging, home photovoltaic system, power distribution and emergency rescue (Fig. 1). The emergency rescue is mainly provided by the main network power supply and diesel generator.

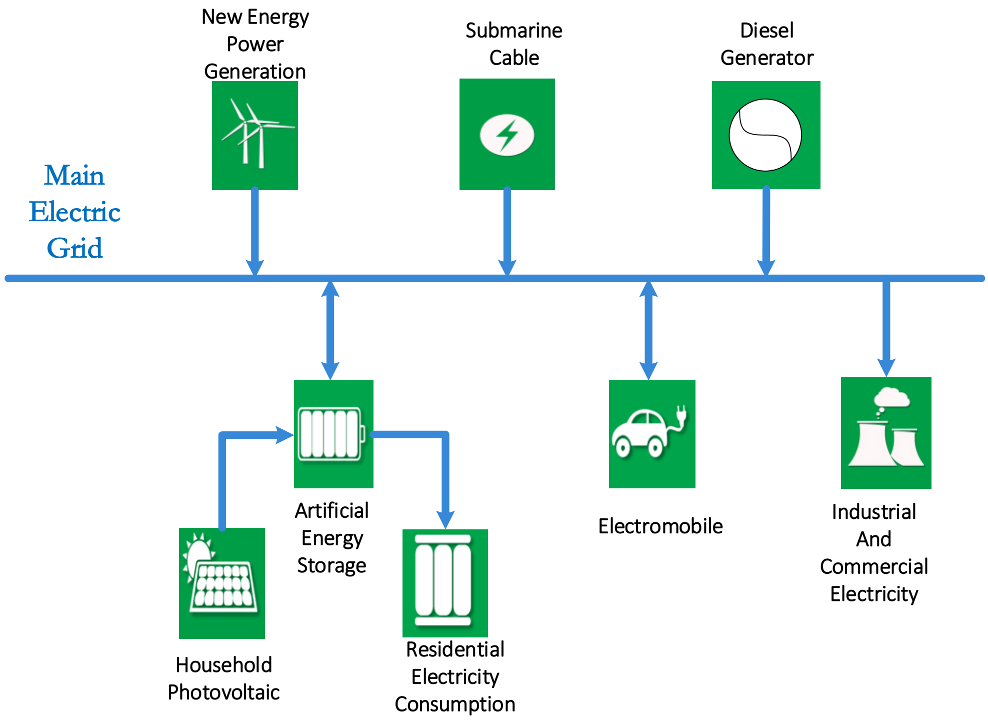

Fig. 1： The structure diagram of island microgrid ecosystem

2.1 Power Interaction System

The electric energy interaction system is based on the island electricity consumption graph and combines the time-of-use electricity price to provide the best solar battery and electric vehicle charging and discharging time scheme. The user can set the charging and discharging time of the energy storage unit accordingly. Under the premise of ensuring the demand for electricity, discharge when the electricity price is high, and charge when the electricity price is low, thereby reducing the electricity cost and maximizing the profit. The system also provides users with a large charge and discharge mode, and users can flexibly switch the system's charge and discharge status according to their own needs.

According to the daily electricity consumption map of the island (Fig. 2), we divide the daily time into several time periods: the peak period is 9:00-12:00, 17:00-22:00, and the flat time is 8:00-9:00. 12:00-17:00, 22:00-23:00, and trough period is from 23:00 to 8:00 the next day. During the low electricity period, the system load is low, and residents can selectively charge the household energy storage box. And during the flat period, if the illumination is sufficient, the photovoltaic power generation can store energy to the energy storage box or deliver it to the main network under the premise of satisfying the user's own use requirements. The energy storage box is used preferentially during the peak period of electricity consumption. If there is excess, it can be sold to the main network.

For electric vehicles, according to statistics, most electric vehicles are idle for more than 95% of the time, and this part of the power is wasted undoubtedly. So, we add the electric vehicle charging and discharging scheduling module to the system, with which the users can return power to the main network during the peak period of power consumption and then recharge when the electricity price is low to obtain the profit combining the electric vehicle battery condition and the use demand.

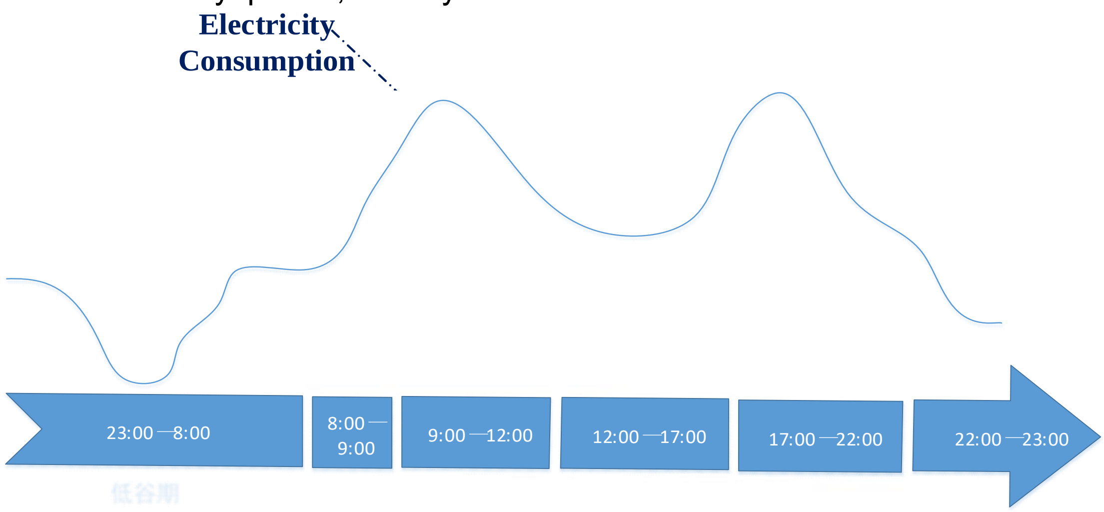

Figure 2: The island total electricity consumption at different times.

2.2 Home Photovoltaic System

The household photovoltaic energy storage system mainly includes solar photovoltaic panels, grid-connected inverters, household energy storage batteries (capacity 16kwh), and two-way energy meters.

The primary goal of home solar power generation is self-sufficiency, selling excess power under the condition of ensuring its own electricity demand. In order to maximize the benefits, the energy storage system is charged at the bottom of the valley, and the photovoltaic panels are used to generate electricity when the light is sufficient. In the case of normal power consumption, the main network power can no longer be used. Conversely, we can sell electricity to it. This not only reduces the cost of electricity, but also alleviates the power shortage during the peak period of island electricity consumption.

2.3 Electric Vehicle Charging and Discharging System

2.3.1 Electric Vehicle Scheduling Strategy

The portable battery and the performance comprehensive evaluation device are added to the electric vehicle, and the charging and discharging of the electric vehicle are scheduled by monitoring the state of the battery SOC (state of charge) and the real-time electricity price. During the trough period, the battery is charged, and during the peak period, the battery surplus is delivered back to the main network while ensuring that it is greater than SOC minimum value.

SOC State Analysis: The electricity cost of an electric vehicle includes the charging cost of the electric vehicle battery and the consumption cost of it, which are both related to the state of the electric vehicle battery at the next moment after charging and discharging. The state of charge in the state of charge and discharge of the electric vehicle is recorded by the battery performance evaluation device on the electric vehicle, and the state is defined as the following:

$$\begin{cases} SOC_d(j) = SOC_a(j-1) + \frac{t_c \times R}{Q_b} \times 100 \\ SOC_a(j) = SOC_d(j) - \frac{d}{E_f \times Q_b} \times 100 \end{cases}$$

d is the moment when the electric car leaves the charging pile. a is the moment when the electric car returns. t_c is the battery charging time. $SOC_d(j)$ is the charge state of the battery for the j th hour after the electric car leaves the charging pile. $SOC_a(j)$ is the state of charge of the battery when the electric car returned. $SOC_a(j-1)$ is the state of charge of the battery in the (j-1) hour after the electric vehicle returns to the charging pile. E_f is the charging efficiency of the battery. Q_b is the charging capacity of electric vehicle battery.

2.3.2 Analysis of Charge and Discharge Cost Based on Energy Storage Characteristics

$$C_{chg} = \frac{a_d^{\wedge} t_c Q_b (0.9 - SOC_m)}{\eta_E}$$

In the above formula, t_c is the storage period of the electric vehicle battery, and η_E is the charging efficiency of electric vehicles. Q_b is the charging capacity of electric vehicle battery and P_b is the charging efficiency of electric vehicles. V_{OC} is the open circuit voltage. SOC_m is the charge state corresponding to the open circuit voltage of each stage when charging the electric vehicle battery and its solution is as follows.

$$SOC_m = \frac{V_{OC} - \sqrt{V_{oc}^2 - 4P_b R_b}}{2Q_b R_b}$$

2.3.3 Analysis of Discharge Revenue of Battery

Assuming that the electric vehicle battery has sufficient power and long life. When the SOC state is greater than the SOC minimum value, the user can choose to supply the remaining battery power to the main network to obtain revenue. The revenue calculation formula is as follows.

$$g_{ev} = 30I(SOC_a(j) - 0.2)Q_b a_d^{\wedge}(\max)$$

In the above formula, I is the battery charging current and $a_d^{\wedge}(\max)$ is the peak hour price.

3. Conclusion and Outlook

This paper proposed an interactive multi-energy complementary island microgrid ecosystem, which can make full use of the island's abundant natural resources. While increasing the popularity of new energy power generation, it will reduce the user's electricity bills and the power supply voltage of the island's main network, cutting the peaks and filling the valleys. This method increases the utilization rate of the electric vehicle battery, thus challenges the performance of the electric vehicle battery. In the future, we can not only use this method for islands, but also spread to the mainland, forming micro-networks according to regional divisions, which will bring convenience to residents' electricity use and main network operation.

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