Offshore Island Energy Cycle System Based on Wind Turbine

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Abstract

The state has gradually attached importance to the development and utilization of islands, and the problem of island energy supply far from the mainland has become increasingly prominent. On the basis of the traditional single energy acquisition method, an island independent energy cycle system was established, which was mainly composed of highly reliable wind turbines and supplemented by tidal energy and photovoltaic power generation. The system integrated power generation, energy storage and seawater desalination. A solution was formed, which integrated the comprehensive utilization of multi-clean energy and energy complementarity.

It provided an effective solution to the needs of military, production, tourism and life on offshore islands. At the same time, combined with big data to discuss the intelligent operation of the integrated system.

Keywords

Wind power generation; Off-grid; Energy complementarity; Energy storage; Desalination; island.

1. Introduction

Building China into a maritime power has now become a major national strategy. The report of the 18th National Congress of the Communist Party of China proposed that China should "improve the capacity of exploiting marine resources, develop marine economy, protect the ecological environment, resolutely safeguard national marine rights and interests, and build a marine power." One of the important measures for building a maritime power is to vigorously develop the island economy, and the primary issue of island development is energy supply and security. [1] In 2016, the State issued the "Guiding Opinions on Promoting the 'Internet +' Smart Energy Development". It clearly states that the construction of smart energy systems such as off-grid energy or micro-grid networks in remote areas such as islands will solve the problem of local power supply guarantee. [2]

For a long time, the basic energy and electricity of remote islands have basically been transmitted by long-distance oil to generate electricity. This method is costly and susceptible to external factors, so it is the fundamental way to form an island-based independent power generation energy system.

Combined with the environmental conditions of the island, new energy sources such as wind power generation, tidal current, and photovoltaic can be used to provide basic electrical energy. However, these new energy sources are affected by factors such as season, climate and geographical location, and each power source has intermittent characteristics. However, it is possible to comprehensively analyze the characteristics of these three new energy sources, adapt to local conditions and complement each other, and exert their respective maximum functions to provide relatively stable power output. [3-4]

Climate conditions on islands are often severe. Therefore, even if a variety of new energy complementarity utilization methods are used to achieve relatively stable power output, there is no guarantee that such power output will be uninterrupted throughout the year. In extreme weather, the power generation unit is likely to be in a shutdown state, at which time the power supply is interrupted, and the island's production and life will be greatly affected. Therefore, an energy storage system needs to be established. According to the principle of multi-energy complementarity, islands should also make full use of various energy storage devices to complement each other, maximize energy storage efficiency, and reduce the risk of energy interruption [5-7].

In addition, islands lack freshwater resources due to geographical constraints. However, fresh water is an indispensable resource for the survival and production of islands, so the continuous desalination capacity is also an important part of the energy system. Desalination will cost a lot of energy, and it can only meet the needs of island desalination if it provides sufficient and stable power output in the form of multi-energy and multi-storage complementary utilization. [8-10]

To sum up, it is necessary to establish a systematic living energy system that integrates basic power, energy storage, and desalination, so that islands can be efficiently developed and used. The concept of big data analysis and unattended needs to be integrated into this system to make the system truly intelligent in order to realize the scientific development of the island economy.

2. Introduction to Various Kinds of Energy

2.1 Wind Power Generation

Offshore wind energy resources have the advantages of high wind speed and stable operation. The east and south coasts of China are vast. According to the "China Wind Power Generation Development Roadmap 2050" analysis and calculation of China's offshore 100m altitude wind energy resource technology development volume, China's offshore water depth of 5-50m, the potential development of wind energy resources reached 500GW.

Wind power generation is a very mature new energy generation method in the current industrial chain. In recent years, Wind power generation technology has become increasingly mature, and the availability of large-scale megawatt-scale units has reached 99.3%. Several units can fully meet the normal power demand of an island.

2.2 Power Generation with Tidal Current

Tidal energy is an emerging renewable energy source, which uses the tidal current characteristics of seawater to drive power generation units. Although its energy density is low, its total storage capacity is large, its changing law is stable, and it can be predicted in advance, and its energy is controllable.

The power generation units developed by the domestic United Power Technology Co., Ltd., Zhejiang University and other units have been successfully operated. In particular, the former has been operating stably for 13 months, and has the capacity for batch manufacturing and installation, which can effectively support the island off-grid power generation system.

2.3 Photovoltaic Power Generation

Photovoltaic power generation is a technology that directly converts light energy into electricity using the photovoltaic effect of the semiconductor interface. Its advantages are safety and reliability, no noise, no restrictions on the geographical distribution of resources, no need to consume fuel and erection of transmission lines to generate electricity locally. Its disadvantages are low energy distribution density and large equipment occupation area. Although the energy obtained is highly correlated with weather conditions such as four seasons, day and night, and overcast, but the southeast coastal area has good lighting conditions, which can make up for this disadvantage to a certain extent. The domestic photovoltaic industry started early, and its products have been running on a large scale, which can completely serve as the economic foundation of the island to support energy.

3. Coupling of Power Generation Systems

The infrastructure of off-grid wind power generation units is relatively mature and the unit cost is relatively low. The single unit power is high, and the current single unit power of offshore units can reach 3000 ~ 6000kW, which can be used as the main support for integrated power generation systems. As a supplement, other power generation systems form a basic power generation system.

3.1 Coupling of Wind Power Generation Units and Tidal Current Units

Generally, the offshore wind power generation unit basic structure forms include gravity foundation, single makeup foundation, jacket foundation, negative pressure bucket foundation and floating structure support form. In order to ensure the reliability of the entire system after being combined with the tidal current unit, it is not recommended to choose a floating support structure. The basic characteristics of various offshore wind power generation units are shown in Table 1 [11-13].

Tab. 1 Characteristics of Various Offshore Wind Turbine Foundations

Basic Form	Structural Features	Advantages	Disadvantages	Cost	Applicable Water Depth	Installation
Gravity	With concrete gravity foundation and steel settlement foundation	Simple structure, resistance to wind and waves	Long construction period and inconvenient installation	Relatively low	<10m	Large cranes, etc.
Single makeup	Load on wind turbine by earth pressure	Easy installation, no sea floor preparation required	Large disturbance to soil, not suitable for rocky seabed	High	<30m	Hydraulic makeup hammer, drilling installation
Jacket	Structural welding of steel pipes	Suitable for various address conditions, convenient construction	High construction cost	High	>20m	Steam makeup hammer, hydraulic makeup hammer
Negative pressure bucket	Use the pressure difference between the inside and outside of the barrel to fix it in the sea floor	Material saving, fast construction, reusable	"Clogging" phenomenon, tilt correction	Low	<25m	Negative pressure sinks into place

There are two main types of tidal current unit fixing: makeup-type fixing and platform support. It can be installed on the underwater part of the Wind power generation unit by combining two energy characteristics. Take United Power Technology Co., Ltd.'s 300kW tidal current unit as an example, parallel installation of two units can be realized.

3.2 Coupling of Wind Power Generation Units and Photovoltaic Generators

Due to the low power density per unit area of photovoltaic power generation, it can be used as auxiliary energy for wind power generation units, such as maintaining the temperature and humidity in the cabin of the unit, thereby saving the unit's power consumption of the energy storage system and providing support for the normal operation of the unit.

One advantage of photovoltaic power generation is that installation is limited by geographical conditions, and can be erected on most buildings, such as roofs and walls, in addition to the ground. According to this, photovoltaic power generation equipment can be erected on the top of the wind power generation unit nacelle and on the side of the tower.

Table 2 lists the three coupling methods.

3.3 Coupling of Diesel Generators and New Energy Systems

Because wind power generation, tidal current energy, and photovoltaic power generation are easily constrained by environmental factors, the reliability of island power supply needs the support of oil power generation. The diesel generator needs to meet the active and reactive power requirements of the system, which can effectively suppress the power fluctuation of the system and ensure the stable operation of the system.

Tab. 2 Comparison of Different Energy Coupling Modes

Coupling Method	Advantages	Disadvantages
Cabin top	Easy maintenance	Small area and great influence by wind load
Tower	Large area can realize rotating alignment	Inconvenient maintenance
Ground installation	Largest layout area and most convenient maintenance	Large coverage

The literature studies the coordinated control and simulation of wind power generation systems (wind power generation, diesel power generation, and energy storage systems). Among them, in order to avoid frequent start and stop damage to the life of the diesel generator, this system requires the diesel generator to keep running as the main power source of the system. When the wind speed is small, the insufficient power supply is made up. When the wind speed is large, the wind power generation unit needs to run with limited power to prevent overloading of the wind power generation unit and the diesel generator.

However, in recent years, with the development of low wind speed Wind power generation units, high output can be guaranteed when the wind speed is low; at the same time, the tidal current generating unit is now equipped with variable pitch capability for output adjustment, so the diesel generator set can be used as a backup solution for the stable system. For most of the time, it can be in a shutdown state and only started when the climatic conditions affect wind energy, tidal energy and solar energy at the same time. This can reduce fuel consumption and reduce environmental pollution.

4. Complementary Energy Storage

Due to the intermittent characteristics of new energy sources such as wind, tide, and photovoltaic, off-grid new energy supporting energy storage technology has become an industry necessity. At present, related energy storage technologies are developing rapidly, and large-scale applications have basically formed. For example, the off-grid wind power generation-energy storage-hydrogen production project in Zhangbei region has been put into commercial operation.

4.1 Different Energy Storage Technologies

At this stage, energy storage technology is mainly divided into three categories: physical energy storage, chemical energy storage, and electromagnetic energy storage. The characteristics of various energy storage technologies are shown in Table 3.

4.2 Influencing Factors of Multiple Storage Complementarity

There are a variety of energy storage methods. Different energy storage methods need to be combined according to the actual geographical conditions of the island to achieve complementary energy. The design of multi-storage complementary equipment should consider the following factors:

Reduce the amount of energy storage redundancy while meeting the total energy storage requirements;

Consider the difference in application purposes, such as different requirements for military and civilian response rates;

Consider regional environmental differences, such as multiple typhoon areas, far from the land and sea areas have different requirements for system reliability and easy maintenance.

5. Coupling of Energy Storage and Desalination

A complementary energy system for power generation energy storage has been established. In addition to meeting the daily production and living electricity consumption of islands, an important use of the system is to provide electricity to large energy-consuming units-“desalination devices”.

The desalination system consists of multiple desalination units and reservoirs. As a controllable load, desalination system can participate in the power regulation of island micro-grid system. When the renewable energy output of the system is insufficient, the desalination system gives priority to ensuring minimum freshwater demand; when the renewable energy output in the system is surplus, desalination system can absorb the surplus output in the system as much as possible. In response to this model, project research and development has been carried out by the academician Ni Weidou of Qingdao Fengsheng Desalination Research Institute Co., Ltd. The project plans to build 4 sets of desalination commercialization projects with a total capacity of 11700t / day. It is also planned to be used in the cultivation of Qingdao "sea rice" to provide desalinated seawater. In addition, Jiangsu Fenghai New Energy Desalination Seawater Development Co., Ltd. has realized the commercial engineering application of the container micro-grid desalination system.

Tab. 3 Characteristics of Different Energy Storage Forms

Classification	Energy storage form	Typical power	Energy power density / (W.h / kg)	Continuous discharge time	Energy self-dissipation rate /%	Suitable energy storage period	Conversion efficiency /%
Physical energy storage	Pumped storage	50∽1000MW	0.5∽1.5	4~10h	Very low	h∽month	70∽82
	Compressed air	5∽300MW	30∽60	6~20h	Low	h∽month	60∽70
	Flywheel energy storage	5∽250kW	10∽30	s ∽15min	59∽100	s ∽min	>90
	Low temperature energy storage	100kW∽300MW	150∽250	1~8h	0.5∽1.0	min∽day	<60
Chemical energy storage	Energy storage	0∽60MW	80∽200	1∽24h	0.05∽1.0	min∽month	<60
	Lead-acid batteries	0∽20MW	30∽50	s∽h	0.1∽0.3	min∽day	<80
	Ni-Cr battery	0∽40MW	50∽75	s∽h	0.2∽0.6	min∽day	^90
	Lithium Ion Battery	0~100kW	75∽200	min ∽h	0.1∽0.3	min~day	80∽85
Electromagnetic energy storage	Super capacitor	0∽300kW	2.5∽1.5	ms ∽60min	20∽40	s∽h	>95
	Superconducting magnetic energy storage	100kW∽10MW	0.5∽5	ms ∽8s	10∽15	min ∽h	^96

6. Intelligent Energy System

Because islands are far from land, it is difficult to maintain and maintain them in a timely manner. The energy cycle system must be able to operate intelligently, perform self-diagnosis, provide early warning, and provide guidance for early maintenance.

6.1 Intelligent Power Generation Equipment

For Wind power generation units, tidal current generator sets, and photovoltaic power generation equipment, they need to have their own intelligent operation control systems. The relevant requirements are as follows:

Unit equipment power prediction system;

The energy management system of power generation equipment needs to have big data analysis capabilities, as well as functions for component health assessment and life assessment;

The unit is designed with an automatic cleaning and filtering system.

6.2 System Energy Flow Optimization

This requires modeling research on energy flows. As a unified description of the multi-energy and multi-storage complementary system, hybrid modeling is the basis for integrated optimization and other key technologies.

This model establishes the corresponding coupling matrix for the power conversion relationship between different energy flow carriers and the entire energy control system. According to this model, collaborative optimization can be performed, energy flow can be controlled, and the optimal coupling matrix can be searched under system constraints to achieve the optimal output of equipment.

7. Conclusion

Various new energy power generation and energy storage technologies have developed rapidly in recent years, and have accumulated a lot of product experience and practical operation experience. This has laid the foundation for the construction of the island's smart energy system. Based on the traditional single energy acquisition, this paper studies the comprehensive utilization and complementarity of multiple clean energy sources. An island energy cycle survival system based on high-reliability Wind power generation units, supplemented by tidal current energy, photovoltaics, etc., integrating power generation, energy storage, and desalination is established. The hardware coupling of each power generation system was studied, and a mathematical model of a multi-energy multi-storage hybrid system was established, which established a theoretical basis for the intelligent direction of the integrated system.

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