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Application of Underwater Constant Pressure Compressed Air Energy Storage Technology in The Direction of Hydrogen Production

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Abstract: With the growing global demand for renewable energy to cope with climate change and energy security issues, underwater compressed air energy storage technology has gradually attracted attention. At the same time, hydrogen production process, as an important support for green energy transition, is becoming one of the key links to achieve clean energy generation and storage. This paper aims to explore the connection between underwater compressed air energy storage technology and hydrogen production process, and put forward a device combining underwater compressed air energy storage and hydrogen production, so as to solve the problems of low efficiency and serious pollution in the traditional hydrogen production industry. In the past, scholars focused on microcosmic research in the direction of hydrogen production, and tended to the direction of catalyst. Based on this, this paper will study the case of underwater compressed air energy storage device, and conceive a new hydrogen production device to promote the collaborative application of sustainable energy and improve the integration efficiency and reliability of energy system.

Keywords: Underwater compressed air energy storage, Hydrogen production, Renewable energy, Energy conversion, Environmental friendliness.

1. Research Background

1.1. Background and significance

Wind energy has unpredictable volatility and variability, and it is difficult to artificially interfere with the power output of wind farms.

Therefore, direct connection of large-scale wind power to the power grid may have a significant impact on power quality, such as the fluctuation of power grid frequency and voltage, and the adverse impact on harmonics. Compared with traditional compensation and adjustment devices, such as static reactive compensation devices and static synchronous compensators, energy storage technology has faster response ability. Traditional devices are usually characterized by reliable, stable and convenient maintenance, but energy storage technology can respond more quickly. To deal with the problem of wind power grid connection, we usually use traditional compensation adjustment devices and energy storage technology. Underwater compressed air energy storage technology is charged at load trough and discharged at peak.

The round-trip efficiency of the energy storage system under real and inevitable working conditions is 64.1 % and 87.9 % respectively. It provides a potential solution to solve the fluctuation of renewable energy and energy storage demand. The underwater compressed air energy storage system can realize the storage of high energy density in the Marine environment, and provides long-term energy supply, which is suitable for the balance of seasonal energy demand. However, how to better integrate the underwater compressed air energy storage system to meet the growing demand for clean energy still needs in-depth research. The role of hydrogen production technology in green energy transformation is becoming increasingly prominent. Hydrogen energy can be divided into three categories: gray hydrogen, blue hydrogen and green hydrogen.

Among them, ash hydrogen is produced by burning fossil fuels, and blue hydrogen is made by a series of natural gas reactions. Unlike this, green hydrogen comes from renewable energy sources, such as electrolytic water making hydrogen and solar pyrolysis water making hydrogen making, environmentally friendly. In these three types, gray hydrogen is not desirable, blue hydrogen is acceptable under certain circumstances, and green hydrogen is considered to be the optimal choice for the utilization of hydrogen energy, because it conforms to the direction of sustainable development. Using renewable energy to produce hydrogen not only produces green hydrogen, but also helps balance the energy system and improve energy utilization efficiency. The development of hydrogen production technology enables the excess energy of hydropower, solar and other energy sources to be converted into hydrogen for storage, and then supplied to the demand when the energy is insufficient. However, there are still some problems that need to be further studied how to organically combine hydrogen production technology with underwater compressed air energy storage technology to realize energy synergy.

1.2. Research objective and method

This study aims to explore the relationship between underwater compressed air energy storage technology and hydrogen production technology, focusing on the technical integration, environmental benefits, economic feasibility and practical application cases of the two.

This paper takes the knowledge network and nature database as the source of literature, and fully collects the corresponding literature data. It mainly involves the theory of proton exchange membrane (PEM) technology, the research status of hydrogen production of seawater, the combination of underwater constant pressure compression air energy storage

technology and the prospect of hydrogen production trend of seawater. The study and thinking of the above studies and references are the theoretical basis for the follow-up research and discussion of this paper. Under the condition of this theory, this paper puts forward a device combining underwater compressed air energy storage with hydrogen production to solve the traditional system.

2. Literature Review

2.1. Review of underwater constant pressure compressed air energy storage technology

Underwater Compressed Air Energy Storage (UW-CAES) technology, as an energy storage solution, has high efficiency energy density and long-term storage capacity, and has attracted wide attention in the energy field. UW-CAES system achieves energy conversion by compressing air from the surface and storing it underwater, and then releasing the gas to drive a turbine to generate electricity.

Compared with traditional compressed air energy storage systems, the underwater constant pressure compressed air energy storage technology has a higher energy density and a longer storage period. The static pressure characteristic of water is an excellent condition for realizing isobaric compression. The use of isobaric compression method to deal with gas can avoid the drawbacks of decreasing output power with the release of gas in the isobaric process, low efficiency of expansion machine, long-term working in non-rated conditions [1], and is suitable for the adjustment of seasonal energy fluctuations.

In addition, the existing scholars have studied the characteristics and performance factors of the system, providing strong support for further optimization of the technology [1].

2.2. Overview of hydrogen production process

As a key link of green hydrogen production, hydrogen production process has become the focus of renewable energy transformation. According to literature review [2], the use of electrolytic water, biological method, thermal chemical method and other methods of hydrogen production can convert excess renewable energy into hydrogen storage, so as to achieve sustainable energy utilization. There are three main ways of electrolytic water hydrogen production, which are alkaline water electrolyzer (AWE), PEM electrolytic water hydrogen production, and solid oxide electrolytic water hydrogen production (SOE)[3]. The seawater hydrogen production process can not only provide green hydrogen, but also help balance the power grid and increase the flexibility of the energy system when there is an energy surplus [4]. However, aspects such as the economy, energy efficiency and hydrogen storage technology of hydrogen production process still need to be further studied and improved.

2.3. Connection between underwater compressed air energy storage and hydrogen production process

Underwater compressed air energy storage technology and hydrogen production process are both areas of high attention, with their potential in energy storage and clean energy production, respectively. Unlike chemical and biological hydrogen production,this new energy hydrogen production technology can achieve zero emissions and produce hydrogen with high purity and almost no debris [5]. More striking, however, is the potential for profound technological integration between the two technologies. We can explore the relationship between underwater compressed air energy storage technology and hydrogen production process, revealing its synergies and future development prospects. The combination of underwater compressed air energy storage technology and hydrogen production process can realize the integration of multiple energy sources and improve the flexibility of the system. Underwater compressed air energy storage technology can convert electrical energy into gas energy when there is an oversupply of renewable energy [6], while the hydrogen production process can convert electrical energy into hydrogen for storage. This integration can balance the volatility of renewable energy while releasing stored energy at times of peak energy demand for a smooth supply of energy [7].

As another promising technology, underwater compressed air energy storage, combined with hydrogen production processes, offers broad prospects for the development of hydrogen energy.

Underwater compressed air energy storage can not only solve the problem of volatility of renewable energy, but also provide a stable power supply for the hydrogen production process. Such integration can not only improve energy efficiency, but also help reduce the cost of hydrogen production and promote the sustainable development of hydrogen energy.

3. Technology Integration and Optimization

3.1. System design: Integrated design scheme of underwater compressed air energy storage system and hydrogen production process

As shown in Figure 1, the operation process of this integration solution is as follows: Based on the principle of seawater hydrogen production, hydrogen and oxygen are produced by the electrolysis of seawater by the power supply, and the hydrogen is pressed into the compressor for storage. The oxygen generated by electrolysis is stored by the principle of underwater constant pressure compressed air energy storage, and then pressed into the turbine by the submarine pressure to generate electricity and current. At the same time, the off-current generated by the seaside wind power generation and the current generated by the turbine are input into the power supply together. Forming a semi-closed closed loop.

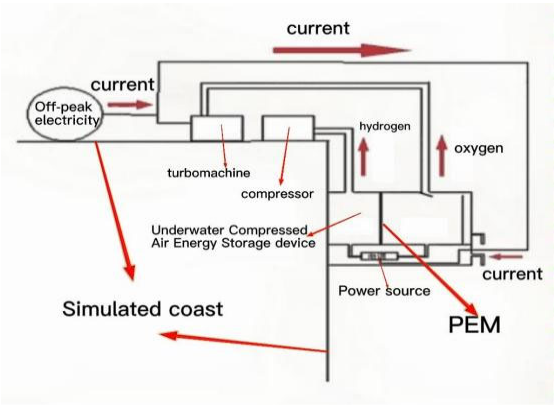

Figure 1.

3.2. Control strategy: Optimize the control method toachieve energy conversion and supply and demand matching.

Underwater compressed air energy storage technology has the potential to store and release energy in the power system [8,9].The advantages of this technology lie in its high energy density and long storage cycle. However, there are problems of energy loss and system efficiency in the energy storage process, which need to be solved by optimizing control strategies. On the other hand, seawater hydrogen production technology is able to use the water in seawater to decompose to produce hydrogen, providing a sustainable path for hydrogen energy supply. However, the energy consumption of hydrogen production from seawater electrolysis is closely related to the supply status of the power system and needs to be optimally controlled according to the availability of renewable energy sources.

Therefore, during periods of oversupply of electricity, excess electrical energy can be used for electrolysis of seawater for hydrogen production to convert electrical energy into hydrogen energy. This can increase the utilization rate of renewable energy and lay the foundation for a future hydrogen energy economy. Through a comprehensive control strategy, the collaborative operation of electrolytic hydrogen production and compressed energy storage can be achieved. According to the power demand of this system, the operation of the two technologies is dynamically adjusted [10] to achieve the optimal distribution of energy.

The combined application of underwater compressed air energy storage technology and seawater hydrogen production technology has the potential to bring innovative solutions to the clean energy sector. By optimizing control strategies, achieving energy conversion and matching supply and demand, energy utilization efficiency and sustainability can be improved.

3.3. Energy matching: Study how the underwater compressed air energy storage system and hydrogen production process complement each other to cope with different energy fluctuations.

The challenge of energy transition requires us to seek innovative ways to deal with the volatility of different energy sources to achieve efficient conversion and storage of energy. Underwater compressed air energy storage and seawater hydrogen production technologies, as two important clean energy solutions, can complement each other to achieve a balanced energy match [11-13]. With the development of intelligent control and big data technology, underwater compressed air energy storage and seawater hydrogen production technology can be more closely integrated with the power system. This will help predict energy demand and supply more precisely, enabling more efficient energy matching. This integration not only creates new possibilities at the technical level [14,15], but also provides new directions for the sustainable development of energy systems in the future.

4. Technological Innovation

4.1. Technological innovation direction

technical innovation can focus on improving the reliability and stability of energy storage system, and realize long-term energy storage and release through more advanced control strategies and material technology. Innovation and improvement of gas storage storage design, material innovation and system engineering, improve energy storage density and compression ratio, integrate it with hydrogen energy, improve electrolytic efficiency, and reduce hydrogen production energy consumption. The research and development of efficient electrolytic equipment, electrolytic catalyst and optimization process will help improve hydrogen production efficiency and reduce production cost. Building an intelligent energy system can achieve the balance of energy supply and demand, and will help the sustainable development of the integration scheme.

4.2. Intelligent application:

Real-time monitoring and adjustment of the electrolytic process of hydrogen production in seawater by using intelligent control system to optimize the electrolytic efficiency, improve the hydrogen production, and achieve the best energy utilization. Intelligent control can adjust the time and yield of hydrogen production according to energy supply and grid demand, and realize flexible production plan. Combined with big data analysis and prediction algorithm, accurate prediction of hydrogen production process and energy supply can be realized, so as to make more accurate operational decisions.

Through data analysis, production plans can be optimized, production efficiency can be improved, and energy waste can be reduced. The application of automation technology to Marine hydrogen production equipment can realize the automatic control and monitoring of production process, reduce human intervention, improve production efficiency and stability. In addition, the intelligent maintenance system can monitor the state of the equipment in real time, predict the fault and carry out timely maintenance, and reduce the downtime. Intelligent prediction, optimization and control of hydrogen production process can be realized by using artificial intelligence technology.

Through machine learning and deep learning algorithm, the complex reaction mechanism of hydrogen production in seawater can be analyzed, and the operation parameters can be optimized, so as to improve the production efficiency and hydrogen production quality.

4.3. Energy market participation:

From the perspective of theoretical significance, research on the promotion of underwater compressed air energy storage technology in the hydrogen production market will provide a beneficial supplement for the traditional energy utilization mode and the theoretical system of the development of the existing new energy production industry.

In theory, the enrichment and expansion will provide the government, industry and enterprises with the key planning of new energy hydrogen production projects, the integration and cooperation development of new energy hydrogen production industry with other energy fields, and the formulation of new energy hydrogen production policy. In practical significance, with the accumulation of demonstration experience of new energy hydrogen production projects in China, the promotion of these projects has become an inevitable trend.

Under the background of energy transformation, how to maximize the competitive advantages of new energy

hydrogen production projects to meet the green development needs of the energy industry and optimize the energy structure, In addition, finding appropriate strategies in the fields of new energy hydrogen production and related policies will help improve the comprehensive competitiveness of the new energy hydrogen production industry, promote the development requirements of its internal and external environment, and accelerate the promotion of hydrogen production in underwater compressed air energy storage. Ensure the green transformation and upgrading of hydrogen production industry.

5. Conclusion

Hydrogen production using underwater compressed air energy storage is a potential technology that can promote the large-scale application of renewable energy and energy transformation. Therefore, the connection between underwater compressed air energy storage technology and hydrogen production process is of great significance for promoting the integration and application of renewable energy. A new type of device proposed in this study explores this connection in depth, providing a new perspective and method for clean energy generation and storage.

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