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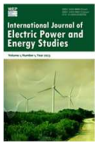

Study on the Sustainable Development of Electric Power Renewable Energy in the Context of Energy Transition

Yulai Wang

School of Management, Northeastern University, Shenyang, 110819, China

ABSTRACT

This study focuses on the sustainable development of electric power renewable energy against the backdrop of energy transition, systematically reviewing the three-stage evolution of China's renewable energy development and its policy support system, highlighting the pivotal role of electric power renewable energy in optimizing energy mix and environmental protection. Advancements in energy storage technologies, particularly lithium-ion batteries, have emerged as crucial factors in balancing the intermittency of renewable energy sources and enhancing the flexibility of power systems. Facing challenges such as technological barriers, economic considerations, and social acceptance, this study proposes that the government should clarify policy directions, strengthen tax incentives and R&D funding; while the power industry should actively introduce advanced energy storage technologies to improve system flexibility and deepen international cooperation to jointly advance the global green energy transition. This research not only enriches the relevant theoretical framework but also provides both theoretical and practical guidance for policy formulation and industry development.

KEYWORDS

Energy Transition; Electric Power Renewable Energy; Sustainable Development; Energy Storage Technology.

1. INTRODUCTION

Since 1986, China's renewable energy power generation has undergone three stages of development, from exploration to high-quality growth, achieving a leading position in the global renewable energy sector. The State Grid of China has become the largest grid integrated with renewable energy worldwide, reflecting the transformation of renewable energy from a supplementary source to a primary energy source. The implementation of the *Renewable Energy Law of the People's Republic of China*[1] has driven technological advancements and cost reductions, while refining the policy framework (as shown in Table 1). As a major energy consumer, China is actively adjusting its energy mix, reducing its reliance on coal, and developing renewable energy for power generation. However, the volatility and intermittency of renewable energy pose challenges to grid security, necessitating a balance between development and grid stability. Renewable energy for power generation is abundant, environmentally friendly, and crucial to the energy transition, with its competitiveness strengthening amidst technological advancements. This study delves into the current status and trends of renewable energy for power generation within the context of the energy transition, explores the application of energy storage technologies and their business models, aiming to provide theoretical and practical guidance for the sustainable development of renewable energy for power generation, enrich the theoretical framework of energy transition, and offer references for government and corporate decision-making.

Table 1. Evolution of China's renewable energy policy framework

Development Stage	Initial Exploration Phase	Rapid Development Phase	High-Quality Development Phase
Technical Standards	Primarily focusing on importing established foreign technologies.	Gradual improvement in the manufacturing capabilities of domestic turbine units.	Continuous increase in wind turbine capacity and photovoltaic conversion efficiency, coupled with the emergence of novel technologies.
Grid Integration and Consumption	None	Full guaranteed acquisition of renewable energy generation.	Establishment of investment monitoring and early warning systems for wind and solar power.
Feed-in Tariffs (FITs)	Primarily relying on approval-based pricing, with a fixed price model as the norm (fixed tariff system).	Transition to concession bidding and the setting of fixed benchmark tariffs based on resource zones, with bidding mechanisms becoming prominent.	Combination of fixed benchmark tariffs based on resource zones and feed-in at parity (both bidding and fixed tariffs).
Subsidy Policies	None	In addition to feed-in tariffs, the state provided additional subsidies.	Gradual phase-out of subsidies.

2. ENERGY TRANSITION AND ELECTRIC POWER NEW ENERGY DEVELOPMENT THEORY FOUNDATION

2.1. The Concept and Path of Energy Transition

Energy transition, as a key process of transition from traditional fossil fuels to a clean energy system, aims to increase the proportion of renewable energy and reduce carbon emissions in order to promote sustainable economic and social development[2]. This process involves fundamental changes in energy production, conversion and consumption patterns, and requires the synergistic promotion of technological innovation, policy guidance and social cognition. Globally, the path of energy transition is characterized by diversification, with Europe promoting renewable energy through policy incentives and market mechanisms, the United States relying on the advantages of technological innovation to gradually transition to clean energy, and Asian countries such as China and India accelerating the green transition through large-scale investment and technology introduction[3]. As a large energy producing and consuming country, China is actively implementing the strategy of energy production and consumption revolution, building a clean, low-carbon, safe and efficient modern energy system, with specific measures covering the vigorous development of renewable energy, promoting the clean and efficient use of coal, strengthening the construction of smart grids and the implementation of market mechanism innovations such as carbon emissions trading, especially in the field of wind power, photovoltaic has made remarkable achievements, and become an important driving force in the global energy transition (see Figure 1).

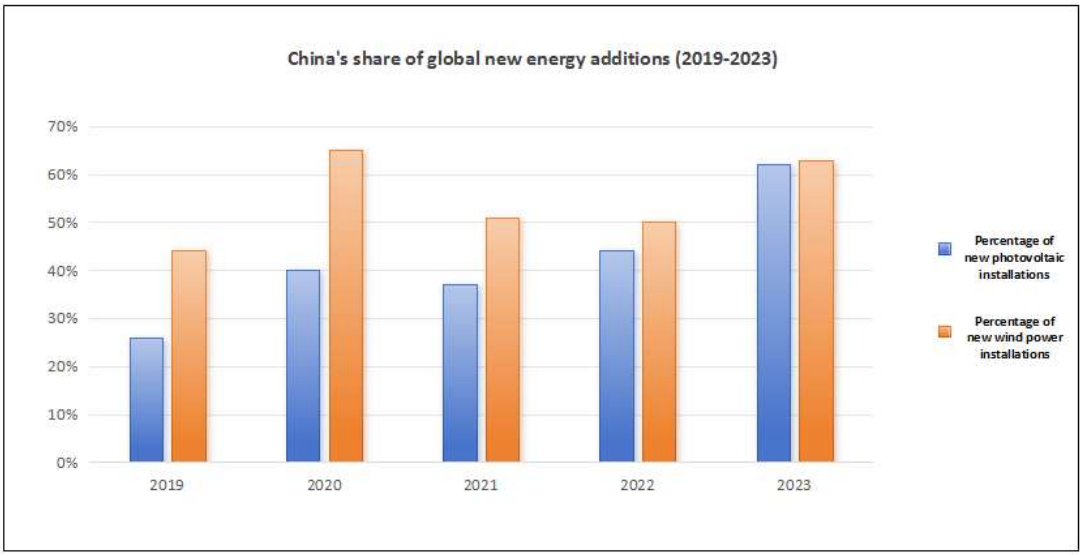

Figure 1. China's share of global new energy additions (2019-2023)

(Data source: https://www.nea.gov.cn/2024-08/29/c_1310785406.htm)

2.2. Classification and Characteristics of New Power Energy

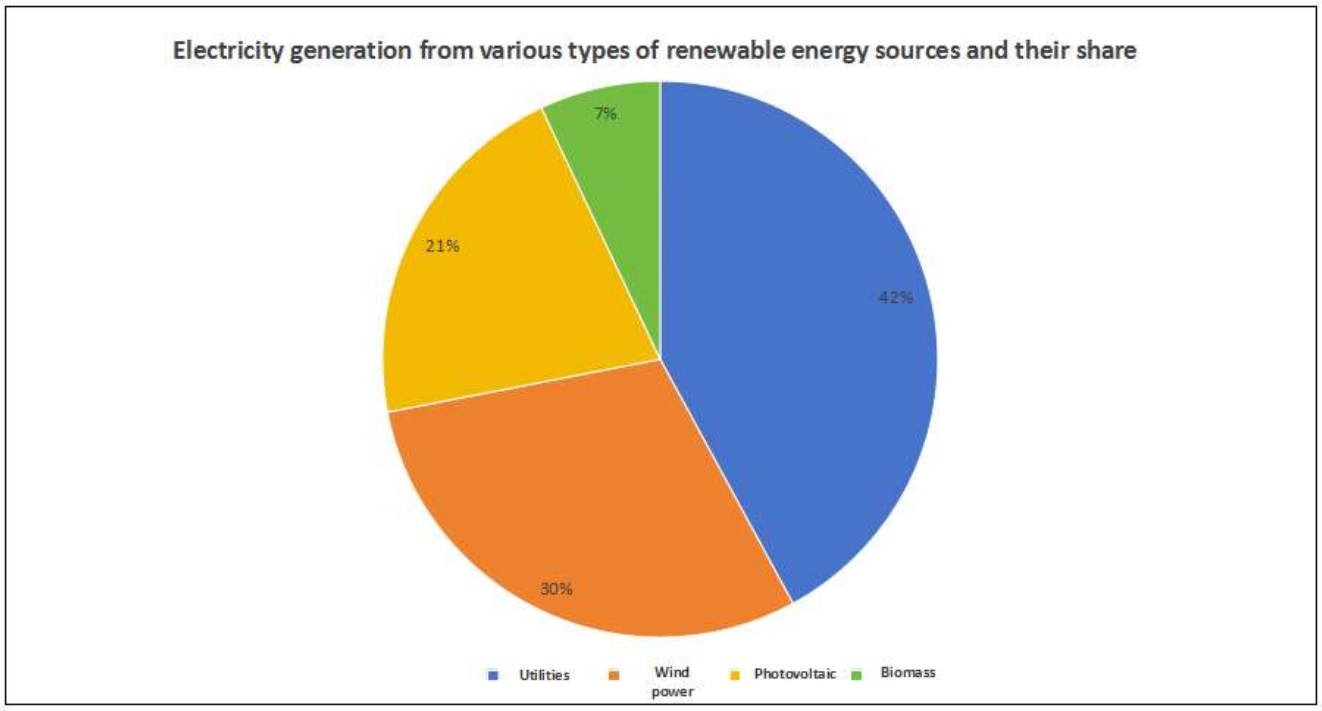

Figure 2. Electricity generation from various types of renewable energy sources and their shares

(Data source: https://www.gov.cn/lianbo/bumen/202311/content_6917855.)

As a core element of energy transformation, the classification and characteristics of new electric energy are of great significance to the optimization of energy structure. Wind power and photovoltaic as a representative of renewable energy, the former due to technological advances significantly improve the efficiency and economy, the development of offshore wind power is evidence; the latter through technological innovation to achieve cost reductions and the global wide application. 2023 January - October, the national renewable energy power generation accounted for 31.8%, of which hydroelectricity, wind power, photovoltaic and biomass energy occupy an important position

respectively (see Figure 2). Nuclear power and hydropower also play key roles in the clean energy sector, with nuclear safety increasing with technological advances and hydropower limited by geographic and ecological factors. Distributed energy and microgrids are known for their flexibility and reliability, and have become a major source of power supply, especially in remote areas and islands. Given the clean, renewable and widely distributed nature of new power sources, they play an important role in the energy transition. Based on the comprehensive consideration of technology, economy and environment, scientific development strategies and policies should be formulated to promote the sustainable utilization of new energy sources, and technological research and development and innovation should be strengthened to enhance its efficiency and economy, so as to lay a solid foundation for its wide application.

2.3. Energy Storage Technology and its Application in New Power Energy

Energy storage technology plays a crucial role in the field of new power energy, covering a variety of types such as physical energy storage, chemical energy storage and electromagnetic energy storage, etc., each of which is based on its own unique mechanism for storing and releasing energy to enhance the flexibility and reliability of the power system. Lithium-ion batteries play a key role in smoothing the output of intermittent energy sources such as wind and photovoltaic, as well as improving system stability due to their high energy density and long cycle life. Lithium-ion batteries can also provide emergency backup power in the event of a grid failure, ensuring continuity of power supply[4]. Although technological advances and large-scale production have reduced the cost of lithium-ion batteries, they are still relatively expensive compared to other energy storage options such as pumped storage, with the full lifecycle cost of kWh approximately 1.7 times that of pumped storage (see Figure 3).

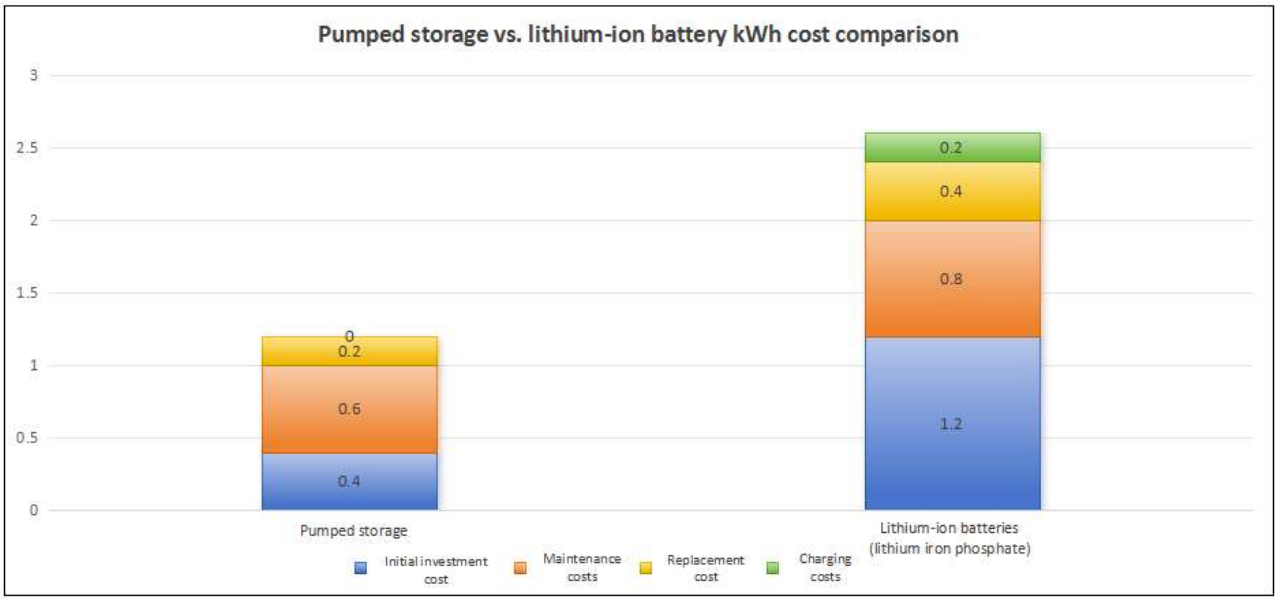

Figure 3. Comparison of pumped storage and lithium-ion battery kWh cost table

(Data source: https://www.qianzhan.com/analyst/detail/220/230705-8a3c371c.html)

At the same time, the safety and environmental friendliness of energy storage technologies also need to be improved, and lithium battery storage power stations have suffered frequent safety accidents, such as a number of accidents around the world in 2021, including the "April 16" Beijing Dahongmen incident triggered by an internal short circuit in a lithium battery (see Table 2). Focusing future

research and development on reducing the cost, improving the efficiency and safety of energy storage technologies is essential to promoting the sustainable development of new energy sources for electric power.

Table 2. Typical energy storage safety accidents and their causes

Typical Accidents	Accident time	Accident location	Type of energy storage	Cause of the accident
APS energy storage plant accident in the United States	April 19, 2019	United States of America	Electrochemical - Ternary Battery	Thermal runaway occurs in the battery pack, releasing explosive gases and causing an explosion
"April 16" Beijing Dahongmen Energy Storage Power Station Fire and Explosion Accident	April 16, 2021	China	Electrochemical-Lithium Iron Phosphate Battery	Internal short-circuit failure of lithium iron phosphate batteries, triggering thermal runaway and spreading fire of batteries and battery modules

3. ANALYSIS OF NEW POWER ENERGY SUSTAINABLE DEVELOPMENT MODE

3.1. Optimization of the Construction of New Power Energy System and Business Model

The construction and optimization of new power energy system is crucial to ensure its long-term stable operation, and its design must take into account high efficiency, environmental protection and economy, and comprehensively consider the availability of resources and technical feasibility[5]. By optimizing the grid structure and enhancing the scheduling capability, the flexibility and reliability of the system can be improved to effectively cope with the volatility and uncertainty of new energy generation. The complementary coordination of new energy sources and traditional energy sources is essential to guarantee the stability and economy of power supply, and the integrated utilization of wind energy and solar energy can enhance the overall efficiency of the energy system. In the field of new power energy, the application of energy storage technology and the diversification of its business model are crucial. User-side energy storage systems can create economic benefits through peak-valley spread arbitrage and demand response, while grid-side energy storage provides services such as frequency regulation and peak shifting through participation in the auxiliary service market. The exploration of shared energy storage models, such as the energy storage power station implemented in Qinghai, optimizes resource allocation and reduces costs by constructing an energy storage sharing platform, which promotes the commercialization of energy storage technology and market trading, and achieves the dual goals of stable auxiliary services and economic benefits.

3.2. Practice and Exploration

The sustainable development of new power energy has made significant progress in practice, with Denmark as a model, its wind power generation accounted for more than 40%, becoming the world's leading wind energy utilization. Denmark through the construction of smart grid, the realization of wind energy and conventional energy flexible scheduling, to ensure the stability of power supply, and is committed to the development of offshore wind power, the use of advanced technology to enhance the efficiency of wind energy and reduce power generation costs. In the field of energy storage technology, Tesla's Powerwall and Powerpack products are popular, not only for home energy storage,

but also for commercial and industrial users to provide effective energy solutions, helping users to reduce energy costs, improve utilization efficiency and reduce dependence on traditional energy sources. China's photovoltaic power generation industry has also made remarkable achievements. In Qinghai Province, for example, the province has made great efforts to develop photovoltaic power generation based on its abundant solar energy resources, and to optimize the allocation of energy through grid interconnection. Together, these practical examples demonstrate the broad prospects and huge potential for the sustainable development of new power sources.

4. CHALLENGES AND COUNTERMEASURES FOR THE DEVELOPMENT OF NEW POWER SOURCES IN THE CONTEXT OF ENERGY TRANSITION

4.1. Technical Challenges and Countermeasures

The main bottlenecks facing the field of energy storage technology include energy density, cycle life and cost issues. Although lithium-ion battery is the current mainstream technology, its performance improvement is close to the limit, and it is difficult to meet the demand for long-time energy storage[6]. To this end, the exploration of new energy storage technologies, such as liquid current batteries, solid state batteries, etc., has become an important breakthrough direction. Enhancing the level of intelligence of the energy storage system and realizing the coordination and optimization with new energy generation are also crucial for improving the efficiency of energy storage. New energy generation prediction and dispatch optimization is faced with the challenge of intermittency and uncertainty of renewable energy sources such as wind power. Constructing high-precision prediction models, combining historical data and real-time meteorological information, can improve prediction accuracy; and using advanced optimization algorithms for dynamic scheduling can realize the complementary coordination of new energy and conventional energy sources, and guarantee the stability of power supply. As the penetration rate of new energy increases, the dynamic characteristics of the power system become more and more complex. Strengthening monitoring and early warning capabilities, establishing an emergency response mechanism, as well as improving the flexibility and resilience of the power grid have become key measures to ensure the stable operation of the power system.

4.2. Economy and Policy Environment

The economic feasibility of energy storage and new energy projects is crucial to the promotion of new energy. In the evaluation process, the initial investment, operating costs and long-term benefits must be considered comprehensively. For example, although the initial investment in lithium-ion battery energy storage project is high, but can realize long-term profitability through the peak and valley spread arbitrage and reduce transmission and distribution losses[6]. The economic feasibility of new energy projects is also affected by multiple factors such as resource distribution, technology maturity and market demand. At the policy level, the government needs to design reasonable support and incentive mechanisms, such as financial subsidies, tax incentives and loan subsidies, to reduce the cost of new energy projects and enhance market competitiveness. The establishment of a green certificate trading mechanism can encourage new energy consumption and promote the healthy development of the industry. The improvement of the market mechanism and price system is also key, and it is necessary to build a level playing field, promote the reasonable competition between new energy and traditional energy, and improve the tariff mechanism, such as the implementation of peak and valley time-sharing tariffs and two-part tariffs, in order to guide the users to use energy rationally and improve the utilization rate of new energy. In short, in-depth analysis of economic feasibility, design policy support and incentives, improve the market mechanism and price system, is to promote the sustainable and healthy development of new energy industry is an effective way.

4.3. Social Acceptance and Environmental Impact Considerations

In the process of energy transition, social acceptance and environmental impact are key considerations in promoting the development of new energy sources for electricity. Social acceptance plays a crucial role in the widespread adoption of new energy technologies. The public's growing positive perception of low-carbon transportation, as revealed in "Toward Zero-Carbon Mobility - A Study of Urban Public Awareness, Behavior and Driving Factors", has significantly increased the market acceptance of new energy vehicles (see Figure 4), creating a favorable social atmosphere for the promotion of new energy for electricity. A favorable social atmosphere has been created for the promotion of new energy. Under the guidance of the global "dual-carbon" goal, reducing carbon emissions and protecting the ecological environment have become a universal pursuit, and the development of new power energy plays a positive role in reducing fossil energy dependence and reducing carbon footprint. However, the volatility of new energy generation, the limitations of energy storage technologies, and grid adaptability issues remain challenges that need to be urgently addressed, requiring concerted efforts of technological innovation and policy guidance. Governments need to formulate and implement effective policies to promote the research and development, application, and public education of new energy technologies to increase social acceptance, and to increase technological innovation to meet the challenges of new energy generation and energy storage technologies, to ensure that grid demand is effectively met, and to promote the sustainable development of new energy sources for electricity.

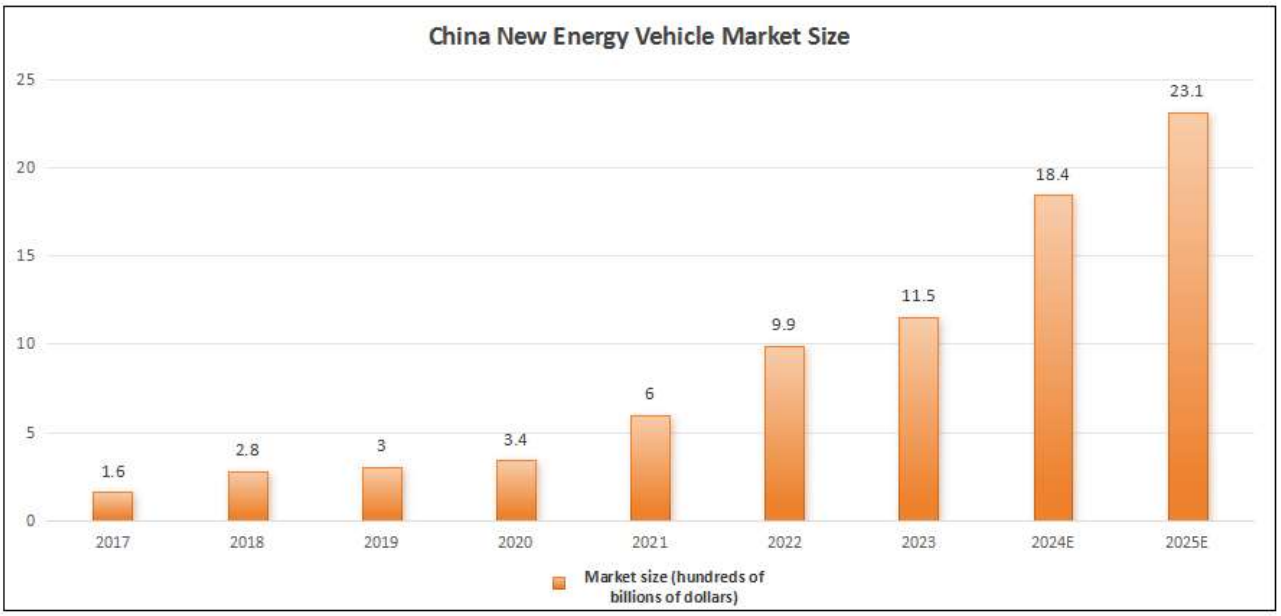

Figure 4. China's new energy vehicle market size

(Data source:https://www.iimedia.cn/c1061/99357.html)

5. CONCLUSION

The synergistic development of new power energy and energy storage technology is of great significance in promoting the transformation of energy structure and enhancing the flexibility and reliability of energy systems. The study points out that energy storage technology effectively balances the intermittency of new energy and is the key to energy transformation. The rapid progress of lithium battery technology and cost reduction for the popularization of new energy vehicles and grid energy storage applications provide strong support. In the future, new energy technology will focus on efficiency improvement and cost reduction, energy storage market has great potential, policy support

and market mechanism optimization will promote the global energy storage market size significant growth. It is recommended that the government clarify the policy direction, strengthen tax incentives and R&D subsidies; the power industry should adopt advanced energy storage technology to improve system flexibility, and strengthen international cooperation to jointly promote the global energy green transformation.

REFERENCES

[1] Information on: https://www.nea.gov.cn/2017-11/02/c_136722869.htm

[2] Ovsyannikov I ,Zhdaneev O .Forecast of innovative activity in key areas of energy transition technologies based on analysis of patent activity[J].International Journal of Hydrogen Energy,2024,871261-1276.

[3] Awolesi O ,Salter A C ,Reams M .A Systematic Review on the Path to Inclusive and Sustainable Energy Transitions[J].Energies,2024,17(14):3512-3512.

[4] Carne D G ,Maroufi M S ,Beiranvand H , et al.The role of energy storage systems for a secure energy supply: A comprehensive review of system needs and technology solutions[J].Electric Power Systems Research,2024, 236110963-110963.

[5] Bie Chaohong, Pan Chaoqiong, Chen Ye, et al. Probabilistic risk assessment of new energy power system under energy transition[J]. Journal of Xi'an Jiaotong University,2021,55(07):1-11.

[6] Long Yang. An overview of new energy transformation opportunities in China's power industry under low-carbon economy[J]. Business news,2019,(28):159+161.