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Analysis of Energy Storage Technology Application Planning Under the "Dual Carbon" Goals—A Case Study of Nanchong City

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Abstract

For Nanchong City, this paper analyzes the application strategies of energy storage technologies and their comprehensive benefits, with a focus on the progress of energy storage technologies and their potential applications in the context of the "Dual Carbon" goals. Based on the current status of the Nanchong power grid, key issues such as the fluctuation of renewable energy, imbalance of supply and demand, and limitations in system flexibility are identified. To fully leverage the advantages of energy storage technology and promote the sustainable development of Nanchong's power system. Energy storage technology can enhance the flexibility and reliability of the power system by regulating the imbalance between electricity supply and demand. The aim is to optimize the grid structure, enhance the capacity for renewable energy consumption, reduce costs, and ensure the reliability of power supply. Ultimately, recommendations covering policy guidance, technological innovation, market mechanisms, and inter-departmental cooperation are proposed, aiming to guide all parties to work together to promote the upgrade of Nanchong's power system towards a low-carbon, efficient, and intelligent direction, effectively promote the transformation and upgrading of Nanchong's power system, facilitate large-scale utilization of renewable energy, reduce carbon emissions, and achieve a win-win situation for the economy and the environment, thus contributing to the realization of the national "Dual Carbon" goals.

Keywords

Dual carbon goals; energy storage technology; Nanchong power grid; application planning; benefit evaluation

1. Introduction to the Energy Transition in Nanchong City

The National Energy Administration and the National Development and Reform Commission issued the "14th Five-Year Plan Implementation Plan for New Energy Storage Development" on March 21, 2022. This plan proposes that by 2025, China's new energy storage will transition from its initial commercial stage into a phase of scaled development, ready for large-scale commercial applications. Among these, the performance of electrochemical energy storage technologies will be further improved, with system costs reduced by more than 30% [1, 2]. It is evident that new energy storage is a critical technology and fundamental equipment for building a new power system, an essential support for achieving the carbon peak and carbon neutrality goals, and an important area for fostering new domestic energy industries and gaining strategic advantages internationally.

Nanchong City, located in the northeastern part of the Sichuan Basin, is a key node in the Chengdu-Chongqing Economic Circle. It possesses abundant hydropower, biomass, and solar resources and has convenient transportation, making it an important hub for energy transmission. As a significant energy base in Sichuan Province, Nanchong is transitioning from fossil fuels to clean energy, strengthening grid construction, developing photovoltaic and wind power projects, and exploring efficient energy utilization. As a pilot project for the State Power Investment Corporation's integrated smart zero-carbon power plant, Nanchong is actively building a clean and low-carbon energy system, using technologies such as intelligent inspection to ensure stable power supply, and attracting investment through various policies to promote advancements in energy technology and structural adjustment.

From December 2021 to February 2024, the Sichuan Provincial Party Committee and the Nanchong Municipal Party Committee successively released decisions on promoting high-quality development of green and low-carbon industries and issued the "Nanchong City Carbon Peak Implementation Plan." Through multiple meetings and technical training sessions, Nanchong has advanced its efforts toward carbon peak, enhancing the understanding and implementation capabilities of grassroots units. The Nanchong Municipal Development and Reform Commission interpreted the "Nanchong City Carbon Peak Implementation Plan," clarifying its background and objectives to support high-quality economic and social development [3, 4]. These measures reflect Nanchong's active actions under the national "Dual Carbon" goals.

2. Research Progress and Applications of Energy Storage Technologies Domestically and Internationally Under the "Dual Carbon" Goals

Energy storage technologies are crucial for optimizing energy use and improving system efficiency, including batteries (such as lithium-ion batteries), mechanical systems (such as pumped hydro storage), electromagnetic storage (such as supercapacitors), thermal storage, and chemical storage [1]. Their importance lies in balancing supply and demand, integrating renewable energy, enhancing grid stability, reducing costs, and providing emergency backup. Energy storage technologies can also improve grid flexibility through functions like frequency regulation and voltage support. Research objectives include optimizing design, and system integration, exploring market mechanisms, providing policy recommendations, and promoting technological advancement to achieve reliable, economical, and sustainable power systems.

2.1 Domestic and International Research Progress in Energy Storage Technologies

International advanced energy storage technologies include: Full-vanadium redox flow battery (VRFB) storage, which is mature, safe, flexible, and long-lasting, suitable for long-duration storage. Solid electrolyte technologies to improve safety and energy density, rapidly developing and nearing commercialization [5].

Sodium-ion battery storage, which is cost-effective and utilizes abundant resources, reduces dependence on lithium and offers large-scale storage potential.

Compressed air energy storage (CAES) uses underground caverns for compressed air storage, suitable for balancing grid supply and demand for large-scale and long-term storage.

Flywheel storage uses high-speed rotating flywheels to store kinetic energy, featuring high power density and rapid response characteristics.

Thermal energy storage involves phase change materials, high-temperature heat storage, and low-temperature cooling, applicable for industrial and building energy management.

China leads globally in research and application of full-vanadium redox flow batteries, conducting several large-scale energy storage projects for grid peak shaving and smoothing renewable energy output. China Nuclear Huapower has made breakthroughs in MW-level flywheel storage technology, demonstrating significant potential in power systems. Dr. Zhong Faping's research focuses on electrochemical hybrid storage technology, including battery safety diagnosis, life prediction management, and dynamic control of hybrid storage systems to reduce system safety risks. China is a global leader in lithium-ion battery production, widely used not only in electric vehicles but also in grid and residential storage.

2.2 Domestic and International Applications of Energy Storage Technologies Under the "Dual Carbon" Goals

Examples of energy storage applications include: The Moss Landing Energy Storage Project in California, USA, with an installed capacity of 400MW/1600MWh using lithium-ion batteries, stabilizing renewable energy fluctuations and enhancing grid stability.

The Remlingen salt cavern compressed air energy storage plant in Germany uses abandoned salt mines to store compressed air, generating electricity during peak hours to balance grid supply and demand, reducing carbon emissions [6].

The Hornsdale Power Reserve project in Australia, deployed by Tesla with a 150MW/194MWh lithium-ion battery system, improves grid reliability and promotes renewable energy integration.

The Greenock vanadium redox flow battery storage project in the UK stores large amounts of energy for extended periods, balancing loads and supporting renewable energy grid integration.

Japan's Tokyo Electric Power Company hydrogen storage system uses excess renewable energy to produce hydrogen via electrolysis, generating electricity through fuel cells for effective storage, aiding carbon neutrality [7].

In China: The Jin Tan Salt Cavern Compressed Air Energy Storage Plant in Jiangsu is the world's first non-firing project, with a capacity of 300MW/1500MWh, enhancing grid peak shaving and renewable energy integration, reducing carbon emissions.

Large-scale deployment of lithium-ion batteries in Guangdong's power grid enhances grid flexibility and stability, supporting renewable energy integration.

The Chongming Island distributed energy storage project combines sodium-sulfur and lithium-ion batteries, enabling microgrid-independent operation and seamless switching with the main grid, enhancing self-sufficiency.

The Zhangbei Wind-Solar-Storage Transmission Demonstration Project integrates wind, solar, storage, and smart transmission, smoothing renewable energy output and friendly grid integration.

The Hengqin New Area Multi-Energy Complementary Smart Microgrid Project in Zhuhai combines photovoltaics, wind, and storage with intelligent control, improving energy efficiency and reducing carbon emissions.

The Jiashan County Distributed Energy Storage Aggregation Platform in Zhejiang integrates 5G base stations with lithium-ion storage, supporting stable 5G network operation, promoting energy transition, and enhancing grid flexibility.

The "Photovoltaic-Storage-Charging" Integrated Charging Station in Haimen, Jiangsu combines photovoltaics, storage, and electric vehicle charging, enabling localized energy production and consumption, reducing carbon emissions, and enhancing sustainability.

Multiple lithium-ion battery storage plants deployed by the Guangdong Power Grid Company in Southern China enhance grid peak shaving capabilities, promoting renewable energy integration, and supporting the "Dual Carbon" goals [8, 9].

These examples demonstrate the role of energy storage technologies in achieving the "Dual Carbon" goals, including enhancing grid flexibility and stability, promoting renewable energy utilization, reducing carbon emissions, and optimizing energy structures. With technological advancements and cost reductions, energy storage will play a greater role in the energy transition [10].

3. Overview of the Nanchong Power Grid and Challenges Faced

The power load in Nanchong City varies seasonally, hourly, and based on weather conditions, with summer and winter being peak periods, especially during summer heat waves when air conditioning usage surges.

The power source structure is dominated by thermal power, supplemented by hydropower and small amounts of renewable energy. Although Sichuan Province has abundant hydropower resources, local hydropower capacity in Nanchong is limited, relying primarily on thermal power with grid interconnection for resource allocation. In recent years, Nanchong has actively developed wind and solar energy, optimizing its power source structure and reducing dependence on fossil fuels.

The grid layout has evolved over many years. Since 2012, multiple substations of 35kV and above have been built, including the 110kV Huohua and Nanmenba substations, and the 220kV Peng'an substation, enhancing power supply capabilities and stability. In 2021, the construction of the Langzhong Changqing 110kV transmission and transformation project optimized 35kV transformers, addressing heavy-load supply issues, and enhancing grid capacity. The commissioning of the southern 500kV transmission and transformation project established a "hand-in-hand" power supply pattern, improving the structure of the northeastern Sichuan grid, and enhancing the capacity for hydropower consumption and power transmission.

However, the Nanchong power grid still faces challenges in integrating renewable energy. For example, wind and solar generation are affected by weather, causing intermittency and unpredictability, requiring greater grid flexibility. Power electronics converters lead to harmonic currents, affecting power quality and requiring strict technical standards to ensure safe and stable grid operations. Balancing power supply and demand is also challenging, particularly during peak hours, as seen in July 2021 when high temperatures increased power demand significantly. Hydropower generation capacity is influenced by river water levels, impacting power supply reliability.

4. Application Planning of Energy Storage Technologies in Nanchong City

Mountainous and hilly areas around Nanchong City may be suitable for constructing small pumped hydro storage plants for storing power during off-peak nighttime hours and releasing it during peak daytime hours.

Compressed air energy storage can provide large-scale storage suitable for long-term power storage. Abandoned mines or salt caverns can be used as storage chambers, reducing the need for surface space. However, there are thermodynamic efficiency losses during energy conversion, and suitable geological structures are required for the safe storage of high-pressure air. If there are suitable geological formations nearby, compressed air energy storage can serve as a solution for large-scale and long-term storage, helping to balance grid loads.

Flywheel energy storage systems can provide immediate power, suitable for rapid-response grid services, with minimal physical wear and theoretically unlimited charge-discharge cycles. However, the system is relatively costly, and its energy density is lower than that of chemical batteries, making it suitable for short-term high-power applications but not for long-term large-capacity storage. Flywheel storage can be used for high-frequency regulation services in the Nanchong grid, enhancing dynamic response capabilities.

Vanadium redox flow battery storage allows the independent design of energy storage and power output, suitable for long-term storage applications, and is relatively safe under overcharging or over-discharging conditions without risk of thermal runaway. However, the energy density of vanadium redox flow batteries is lower than that of lithium-ion batteries, requiring more space and higher costs compared to traditional battery technologies. Vanadium redox flow batteries are suitable for scenarios requiring long-term storage, such as backup power for industrial parks or commercial centers, and can also serve as a means for grid peak shaving.

5. Conclusion

The Nanchong power grid should comprehensively consider the characteristics of various energy storage technologies and choose the most suitable solutions based on its needs and geographical conditions. For example, lithium-ion batteries are suitable for rapid-response frequency regulation and distributed storage; pumped hydro storage and compressed air energy storage are suitable for large-scale and long-term power storage; flywheel storage and vanadium redox flow batteries are suitable for high-frequency regulation and long-term storage applications [11, 12]. Through reasonable planning and deployment, energy storage technologies can significantly enhance the flexibility and stability of the Nanchong power grid, promoting the efficient utilization of renewable energy.

The development of the Nanchong power grid requires comprehensive policy support, technological research and development, and improvements in market mechanisms to promote the application of energy storage technologies and the construction of smart grids. These measures can enhance the flexibility and reliability of the power system, promote the integration of renewable energy, and provide strong support for Nanchong's economic development and energy transition.

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