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SWOT Analysis and Optimization Strategy Research of China Energy Internet Development in the Intelligent Era

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ABSTRACT

In the context of the ongoing wave of intelligence and urgent energy transformation, China faces the challenge of reducing carbon emissions and optimizing its energy structure. The existing energy system has issues with distribution, transmission, and efficiency, necessitating intelligent innovation. The Energy Internet emerges as a key solution but faces technical challenges, such as inadequate sensing, communication, and energy storage technologies, as well as system, regulatory, and coordination issues within the industry. This study applies SWOT analysis to examine the internal and external factors influencing the Energy Internet and proposes strategies and implementation plans. The research highlights the need for breakthroughs in technology, policy coordination, and business model innovation. By integrating various forces, this approach will help overcome current obstacles and is crucial for advancing energy transformation, improving energy efficiency, ensuring supply stability, and enhancing China's global energy influence.

KEYWORDS

SWOT analysis; Energy Internet; Intelligent era; Optimization strategy

1. INTRODUCTION

With the global acceleration of intelligence, the energy sector is undergoing significant changes, entering a new stage of development. The concept of the Energy Internet has gained attention from both academia and industry. In this wave of technological progress, the integration of big data, AI, IoT, and advanced power electronics is reshaping traditional energy systems, making them smarter, more efficient, and collaborative, aligning with the global trend of clean, low-carbon, and sustainable energy development.

The Energy Internet stems from the cross-integration of complex systems theory and energy system engineering. It aims to challenge the traditional energy model based on single energy sources by creating a cross-regional, cross-energy connectivity network. This network facilitates the coupling and optimization of electricity, heat, gas, and other energy forms across production, transmission, storage, and consumption stages, ensuring efficient resource allocation. It embodies the self-organizing and co-evolving nature of energy systems, moving towards more efficient operations.

China's energy structure is at a critical transformation point. The country faces rising energy demand and the need for deep structural adjustments, while also bearing responsibility for climate change mitigation and meeting global carbon reduction targets. The traditional energy system has longstanding issues such as mismatched energy production and consumption locations, high transmission losses, and poor coordination between different energy subsystems, which hinder the intelligent control of energy transformation.

Despite the opportunities the intelligent era brings for innovation, the development of the Energy Internet faces challenges. These include technical issues like the accuracy of intelligent sensing, real-time communication, energy storage efficiency, and cost control. Institutional barriers arise from the fragmented industry supervision and lack of coordination among energy sectors. Market rules fail to accommodate new business models, restricting industry integration. Additionally, the integration of ICT networks into the energy system raises security concerns, such as network attacks and data tampering, which threaten operational stability.

Given these challenges, researching the development of China's Energy Internet in the intelligent era is critical. Using the SWOT analysis framework, this study aims to identify internal and external advantages, disadvantages, opportunities, and threats, and propose optimized strategies based on system thinking. This research will contribute to the development path of the Energy Internet, support energy transformation, strengthen national energy security, and improve China's global energy influence, offering both theoretical and practical value for future development.

2. CHINA ENERGY INTERNET DEVELOPMENT SWOT ANALYSIS

2.1. Advantage Analysis

In terms of advantages, China energy Internet presents a significant development advantage. In terms of market size and investment, its market size has exceeded 300 billion yuan and has grown rapidly, and its investment activities continue to heat up, showing a strong impetus for development. According to relevant data, in 2024 alone, the total investment in power grid projects has reached 76.6 billion as of March, a year-on-year growth of 14.7%. State Grid expects that the total investment in power grid construction will exceed 500 billion yuan in 2024, such a large-scale investment has strongly promoted the construction of energy Internet infrastructure and technology upgrading. In terms of technological innovation, great achievements have been made. In key fields such as the innovation of the Internet of Things, smart grid and energy saving technology, the number of patent applications and grants has been increasing steadily, and the investment in scientific research is also increasing. In southern power grid Internet service co., LTD., for example, since the implementation of change action, has the number of invention patents from 1 to 201,131, three application for a patent for utility model, input and output ratio of scientific and technological achievements of 5.15, patent authorization, application number, comprehensive benefits, effectively promote the energy technology progress of the Internet industry. In terms of policy support, the Chinese government attaches great importance to it and has issued a series of policy documents to guide the development of the energy Internet clear direction has promoted the prosperity of the market. From 2014 to 2020, the state issued a total of 997 policies and regulations related to the energy Internet, of which 375 national policies were released in 2020. These policies cover all levels from macro planning to micro implementation, creating a good policy environment for the development of the energy Internet. In terms of resource base, China has a vast territory and is rich in renewable energy. Wind power and photovoltaic resources in northwest China and hydropower resources in southwest China provide solid support for the construction of energy Internet, laying a material foundation for the realization of sustainable energy supply and multi-energy complementarity (Zhang, Jin, et al. 2023).

2.2. Disadvantage Analysis

However, the development of energy Internet in China also has some disadvantages. Technical challenges still exist. Although phased progress has been made, key technical problems such as the accuracy of intelligent sensing, real-time communication, the efficiency and cost control of energy storage have not been effectively solved, which limits the improvement of the intelligence level of the system to a certain extent. For example, in terms of energy storage technology, the current energy storage equipment still has the problems of insufficient energy density, improved charge and

discharge efficiency and high cost, which restrict the large-scale access and effective utilization of distributed energy in the energy Internet (Gao, Peisheng, et al. 2023). In terms of system and mechanism, due to the long-term separate supervision and segmentation of the energy industry, the lack of overall planning and collaborative operation mechanism of cross-energy varieties prevents the existing market rules to adapt to the development of new business forms of energy Internet, which hinders the deep integration and innovation among industries. The lack of effective coordination mechanism between the planning, construction and operation of different energy varieties makes the overall efficiency of the energy Internet unable to be fully played (Lu, Gang, et al. 2023). In terms of security and reliability, with the deep integration of the information and communication network into the physical energy system, the potential information security risks such as network attacks and data tampering have significantly increased. At the same time, a large number of distributed energy access makes the power grid trend become complex and changeable for the system stable operation poses a serious threat and brings a huge lead to the security and stability of energy supply.

2.3. Opportunity Analysis

In terms of opportunities, the global intelligent trend has provided strong technical support for the development of the energy Internet. The deep integration of big data, artificial intelligence, the Internet of Things and other emerging technologies has created favorable conditions for the intelligent, efficient and coordinated operation of the energy system. The application of these technologies can realize real-time monitoring, optimized scheduling and precise control of energy production, transmission, storage and consumption, and improve the efficiency of energy utilization and the reliability of system operation. The international consensus on addressing climate change and realizing carbon emission reduction has prompted China to accelerate the pace of energy transformation. Therefore, as an important platform for the large-scale development, transmission and utilization of clean energy, the energy Internet is highly in line with this development demand and has a broad market space. With the sustainable development of economic and social, energy demand, people to the reliability of energy supply, economy and cleanliness put forward more stringent requirements, energy Internet with its intelligent, distributed, can better meet the demand of these diversified, effectively promote energy consumption upgrade, promote the coordinated development of energy and economic and social.

2.4. Threat Analysis

The threat factors are mainly reflected in the following aspects. The international competition is increasingly fierce, the rapid development of the global energy Internet makes the competition in the energy field increasingly intensified, China energy Internet enterprises are facing strong competition pressure from the international peers, need to constantly improve their core competitiveness, in order to occupy a place in the international market. The uncertainty of market demand is also a major threat. The energy market is affected by a variety of factors such as economic situation, policy adjustment, and technological breakthroughs, with obvious volatility and uncertainty in demand, which brings great risks to the investment and operation of energy Internet (Hua, Haochen, et al. 2023). For example, the change of macroeconomic situation will affect the energy consumption demand in industrial, commercial and other fields, and the breakthrough of new energy technologies may lead to the reshaping of the energy market pattern, which increases the difficulty of investment decision and operation management of energy Internet projects. In addition, the standard specification is also one of the restriction factors, imperfect energy Internet involves multiple fields and industries, the relevant standards is not sound, lead to compatibility and interoperability problems between different systems, affect the large-scale promotion and application of energy Internet, hindered the coordinated development of the Internet industry and integration construction.

3. OPTIMIZATION STRATEGY FOR CHINA ENERGY INTERNET DEVELOPMENT

3.1. Strengthen the Advantages

To strengthen advantages, it is essential to consolidate the market foundation and expand scale benefits. Given the current investment momentum and market growth, capital should be directed towards R&D in core energy Internet technologies, infrastructure enhancement, and emerging business models. A diversified investment pattern, supported by government funds and social capital, should encourage long-term strategic investments. For example, venture capital can support frontier energy storage research to overcome technical barriers, while robust debt financing can back mature smart grid projects, solidifying market scale and industry resilience (Guo, Honggang, et al. 2023).

Building a collaborative innovation ecosystem is key. By integrating industry, universities, research institutions, and energy enterprises, we can break down barriers and pool resources. For instance, power grid companies provide application scenarios, universities focus on theoretical breakthroughs, and research institutes address key technical challenges, accelerating the conversion of scientific research into practical technologies and services.

In terms of policy, existing frameworks should be refined to improve coordination across energy strategy, innovation, and regulation. A comprehensive, life-cycle policy support system should be created, offering guidance and incentives from project planning to market development. Special policies should be implemented for regions with abundant renewable energy to streamline approvals and enhance clean energy integration, converting resource advantages into industrial benefits.

3.2. Overthe Disadvantages

To overcome technical challenges, interdisciplinary teams should be formed to address issues such as inaccurate intelligent sensing, delayed real-time communication, low energy storage efficiency, and high costs. A national research project should integrate material science, electronics, and energy engineering to break through limitations in sensing materials, chip design, and communication frequency interference. Innovations like quantum sensing for energy parameter monitoring, 6G communication for high-speed data transmission, and advancements in solid-state battery storage will lay the foundation for smart energy systems.

System and mechanism innovation is needed to address the fragmented energy industry regulations. A unified regulatory framework should be created to manage electricity, heat, gas, and other energy systems. Standardized market access and exit mechanisms should promote cross-energy collaboration. New market rules should be designed for distributed energy trading and energy service pricing, encouraging flexible market participation and resolving integration obstacles (Zheng, Mingbo, et al. 2024).

For security, an integrated information and energy security system should be developed, using AI algorithms for real-time monitoring, early warning of network attacks, and risk prevention. This system should also optimize energy trends and address the complexities of distributed energy access to ensure stable and secure energy supply.

3.3. Seize the Opportunities

In the process of seizing the opportunity, we will closely follow the global intelligent wave, actively carry out international scientific and technological cooperation and exchanges, and participate in the formulation of global energy Internet technology standards. With the international top scientific research team, enterprises to establish normalized cooperation mechanism, exchange experts, joint research and development, sharing results, accelerate the emerging technology in energy Internet

application, the China in transmission, energy big data application technology and foreign advanced Internet, artificial intelligence achievements, output China solution, promote international voice, relying on international cooperation platform to broaden the technology, capture the frontier trend, feedback domestic industrial upgrading (Fu, Shuke, et al. 2023). Comply with the trend of carbon emissions, to speed up the pace of energy transformation, set and national carbon peak carbon neutral target of energy Internet development road map, intensify the development of clean energy, optimize the energy transmission allocation network to adapt the new energy large-scale, distributed access characteristics, using energy Internet intelligent scheduling, can complementary function, improve clean energy in the terminal energy consumption proportion. Focusing on the demand of energy consumption upgrading, innovating the energy service mode, providing customized and comprehensive energy packages based on accurate analysis of user-side big data, covering multiple services such as power quality optimization, efficient thermal energy supply, distributed energy operation and maintenance, so as to improve user satisfaction degree and energy utilization comprehensive effect.

3.4. Responding to Threats

Responding to threats and challenges, facing international competition, Chinese energy Internet enterprises need to strengthen their core competitiveness. On the one hand, increase R & D investment and form a "moat" of independent intellectual property rights in key technologies and products, such as mastering core patents of high-performance power electronic devices and intelligent micro-grid control technology; on the other hand, expanding the overseas market should deeply study the energy policies, market demand and competition pattern of the target country, and integrate into the local industrial chain through localized operation, international mergers and acquisitions, and strategic alliance, and enhance the global market share and brand influence. In view of the uncertainty of market demand, build fine energy market forecast model, fusion of macroeconomic indicators, climate data, policy dynamics, multivariate factors, using big data analysis, machine learning algorithm accurate forecasting energy market short-term fluctuations and long-term trend, on the basis to optimize investment decisions, adjust the operation strategy, reduce market risk. Perfect standard system, led by the national standardization management organization, joint energy industry association, leading enterprises and scientific research institutes (Lyu, Yanwei, et al. 2023), combing energy Internet each link technical standards, interface specification, data protocol requirements, classification, step by step to formulate and improve the unified standard, regular revision update to match the industry development rhythm, strengthen the different systems, equipment. The intercompatibility and interoperability test and verification mechanism will ensure the large-scale and high-quality promotion and application of the energy Internet, and escort the orderly development of the industry.

4. CONCLUSION

China's Energy Internet has a unique development trajectory in the intelligent era, with significant advantages such as a market size exceeding 300 billion yuan, active investment, frequent scientific research and innovation achievements, growing patents, government support, and abundant renewable energy resources. These factors provide a solid foundation for its growth. However, challenges remain, including technical issues like intelligent sensing, communication, and energy storage, as well as regulatory fragmentation, outdated market rules, and security risks from network integration, all of which hinder progress.

Opportunities for growth lie in global technological advancements, with big data improving energy efficiency coordination, carbon emission reduction driving energy transformation, and increasing energy consumption spurring service optimization. The main threats include fierce international

competition, market demand fluctuations due to economic, policy, and technological factors, and imperfect standards hindering large-scale implementation.

To optimize strategy, China should strengthen its market position, improve innovation, implement supportive policies, and make good use of resources. Efforts should focus on overcoming technological challenges, innovating systems, ensuring security, and aligning with the global intelligence trend and energy transformation. Addressing these threats will enhance competitiveness, control the market, and improve standards.

In conclusion, with the right strategies, China's Energy Internet has the potential to overcome current challenges, contribute to national energy security and sustainable development, and play a significant role in the global energy sector.

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