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Challenges of New Energy Power Systems

Jingxu Zuo

Shandong University of Science and Technology, Jinan 250031, China

ABSTRACT

At present, in the context of global energy transition, China is actively promoting the construction of a high-proportion renewable energy power system, but it faces multiple challenges. First of all, the increasing demand for new energy installed capacity and the challenge of power balancing ability make the system operation face complexity and uncertainty. Secondly, the reshaping of market mechanisms and business models, as well as complex challenges at the technical level, are also constraints. The key technologies involved include innovation and application in simulation analysis and mechanism cognition, system construction, energy frame and stability control.

KEYWORDS

Global Energy Transition; High-proportion Renewable Energy Power System; Market Mechanisms.

1. INTRODUCTION

In the context of the current global energy transition, China is actively promoting the implementation of a high proportion of new energy power systems.[1]

Energy security and electricity are gaining traction as a national strategy, and the Chinese government has accelerated the legislative process of the Energy Law since 2020 to put energy security at the core of its national security strategy. [2]

In order to support the development and utilization of large-scale new energy, China is actively promoting the construction of the energy Internet. The Energy Internet has the characteristics of decentralized collaboration, flat openness, and intelligent interaction, which enables it to effectively support the efficient use of clean energy and optimize the conversion and allocation of energy.

2. THE CHALLENGE

2.1. The Demand for New Energy Installed Capacity Has Increased

According to the forecast, the country's total renewable energy generation is expected to account for 16% in 2030 and 32% by 2050. [3]

Although this high proportion of renewable energy power scenario has the advantages of environmental friendliness and sustainable development, it also brings great challenges, especially in the case of low renewable energy utilization hours. This will not only require more investment and technical support, but also the innovation of existing market mechanisms and business models.

2.2. The Challenge of Power Balancing

The volatility and randomness of new energy resources make their intraday power fluctuations very significant.[4]

It is estimated that by 2050, the maximum daily power fluctuation of new energy nationwide will exceed 1 billion kilowatts, which is equivalent to the total installed capacity of conventional power sources in that year, as shown in Table 1.

This large fluctuation poses a huge challenge to the traditional conventional power regulation capability, which is difficult to effectively cope with by conventional power regulation alone.

Table 1. Forecast data of the largest daily fluctuation of new energy in China

	In 2019			In 2030		In 2050	
Installed type	Installed capacity	5min maximum fluctuation	15min maximum fluctuation	Installed capacity	Daily maximum fluctuation	Installed capacity	Daily maximum fluctuation
Wind power	16933	909	944	47750	10982	143840	33083
photovol taic	17703	3990	4062	57300	30942	215760	116510
New energy	34636	3966	3994	105050	32565.5	359600	111476

2.3. Reshaping of Market Mechanisms and Business Models

The promotion of a high proportion of renewable energy will inevitably promote the reshaping of market mechanisms, business models, and material, information and value chains. [5] This reshaping is not only a change at the technical level, but also a revolutionary challenge to the planning and design, production management and operation control of the entire power system. The establishment of new trading mechanisms and business models will be the key to the development of the electricity market in the future.

2.4. Security Challenges

The large-scale integration of new energy into the power grid brings many security challenges, mainly involving system inertia, frequency modulation ability, frequency over-limit and voltage stability. [6]

With the large-scale integration of new energy sources such as wind power and photovoltaic power into the power grid, the start-up space of conventional units is crowded, resulting in a decrease in the moment of inertia of the overall system and a decrease in frequency modulation ability.

As a result, the frequency response of the system in the face of load fluctuations becomes poor, and the frequency change accelerates and the fluctuation amplitude increases, which in turn increases the risk of frequency out-of-limit, as shown in Figure 1. The dynamic reactive power support capacity of new energy units is relatively weak, especially in terms of system voltage stability.

With the increase in the proportion of new energy, the dynamic reactive power reserve capacity of the system decreases sharply, which may lead to prominent voltage stability problems and even transient overvoltage, which endangers the safety of equipment and the stable operation of the power grid.

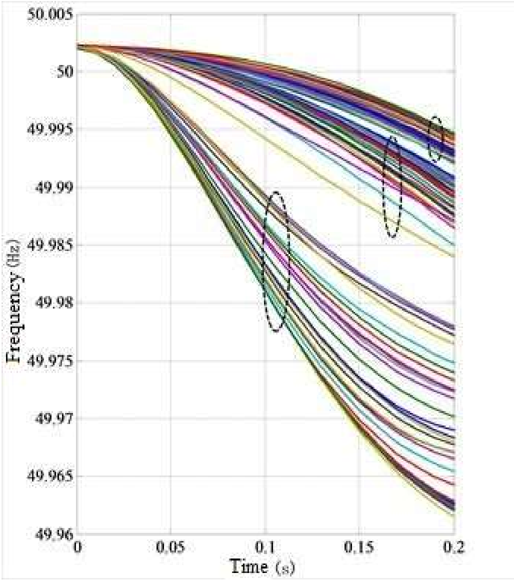

Figure 1. The frequency response of the system in the face of load fluctuations

2.5. Challenges of the Mechanism

The rapid development of renewable energy has brought multiple challenges to the power market mechanism and management mechanism, including grid parity, low marginal cost, short construction period and diversified development models.

As new energy enters the era of parity, its marginal cost is greatly reduced, and even negative electricity prices appear, which brings unprecedented challenges to the operation and market mechanism of the traditional electricity market, as shown in Figure 2.

The market mechanism needs to be redesigned to adapt to the characteristics of large-scale grid integration of new energy and ensure the fair and stable operation of the market. The construction period of new energy projects is shorter than that of traditional thermal power projects, and this rapid development model does not match the long cycle of grid planning and construction, which may lead to challenges in the carrying capacity and stability of the power grid.

In addition, new development models such as crowdfunding and Internet finance also bring risks of diversification and disorderly construction of market players, and it is necessary to strengthen market management and operation supervision.

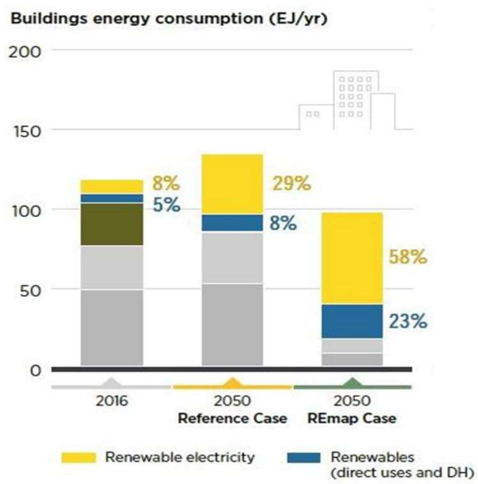

Figure 2. LCOE of renewable energy

3. KEY TECHNOLOGIES INVOLVED

3.1. System Building

The development of energy shelves is essential to achieve a high proportion of new energy systems. It involves the integrated utilization of energy and system optimization, especially in the study of multi-energy coexistence and energy conversion efficiency.

The construction of a power system with a high proportion of new energy needs to transform from simple grid connection to complex networking. This requires the new energy generator set to actively support the stability of the system in terms of frequency, voltage and inertia.

In addition, in order to achieve the effective operation and control of new energy equipment, it is necessary to establish a comprehensive standard system and technical conditions.

This kind of system construction is not only a technical issue, but also involves the challenges of architectural design and engineering implementation of future power systems, as shown in Table 2 for the comparison of domestic and foreign renewable energy grid integration requirements.

Table 2. Comparison of new energy grid integration requirements at home and abroad

ProjectStandard	GB/T 19963-2011 Technical Regulations	Technical requirements for foreign grid-connected guidelines	Technical requirements for conventional thermal power units
High voltage	1.1PU, normal operation	United States WECC: 1.2pu	1.3pu.0.5 seconds
Low voltage	0.2pu,625ms	AEMC Australia: 1.3pu.60ms	The voltage is allowed to be as low as 0 for a short period of time

3.2. Simulation Analysis and Mechanism Cognition

In the research of high proportion of renewable energy power systems, simulation analysis and mechanism cognition are crucial technical supports. Power system simulation needs to take into account the nonlinear characteristics and dynamic changes of new energy equipment, which are large in number and widely distributed, and it is difficult to simulate their cluster behavior simply and accurately. In particular, in the face of the challenges of interweaving multi-state variables and multi-time scales, researchers need to ensure the accuracy and effectiveness of system design and operation control through in-depth analysis of the dynamic characteristics of the system and the use of advanced simulation tools and algorithms.

4. CONCLUSION

In the process of achieving a high proportion of new energy power systems, we are facing many challenges, but we have also seen the rapid development of key technologies and the gradual improvement of coping strategies. Through comprehensive measures of technological innovation, optimization of market mechanisms and policy support, the high-proportion renewable energy power system will be able to support future power demand more stably and reliably, and make important contributions to sustainable energy development and national energy security.

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