International Experience in Electricity Industry Regulation and Enlightenment for Domestic Policy

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Abstract. This paper provides an in-depth analysis of the international experience and trends in the regulation of the electricity industry, and offers the valuable insights for the development of domestic regulatory policies. The electricity industry is a crucial pillar of national development and a key component of social progress, with its monopolistic tendencies presenting significant challenges to current regulatory frameworks. The research discusses the role of deregulation in fostering competition, market efficiency, and innovation within mature electricity markets such as those in Europe, the United States, and the United Kingdom. It also emphasizes the necessity of systemic reform and innovation, as well as the integration of new energy sources, to address these challenges and ensure the industry's stable growth. And the quantitative analysis has been conducted on the reform of transmission and distribution electricity prices in Chongqing.

Keywords: Regulation; International Experience; Renewable Energy

1 Introduction

Electric power industry regulation is an important measure to ensure the normal operation of the power system and is the cornerstone of power system management. The electricity industry is an important pillar industry in our country and an essential component of social development, closely related to the nation's security and stability. Monopolistic behaviors in the electricity industry are diverse, complex, and covert, posing numerous challenges to the current regulation and legislative regulation of the electricity industry[1]. While ensuring the steady development of the electricity industry, it is also necessary to actively reform and innovate the system, and to strengthen the research and application of new energy sources, which is of great significance to the development and reform of the electricity industry[2]. The construction of the electricity industry regulatory system should be based on public efficiency and enterprise management with the goal of improving regulatory efficiency[3].

Nowadays, the global energy transition process is accelerating with emerging economies leading the growth in global energy consumption. Renewable energy has become a major measure for the world to address climate change, and the electricity sector is

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undergoing a significant transformation. Nuclear power is expected to become the most competitive decarbonized electricity source, the core status of coal is gradually decreasing, technological innovation breaks the constraints on renewable energy, and renewable energy will reshape the geopolitical landscape. Deregulation is considered to be a factor in promoting competition and improving market efficiency, and can also promote innovation[4]. Previous studies have investigated the latest developments and trends in countries which are mature and widely recognized electricity markets such as the United States, Australia, the United Kingdom, and France in this field[5]. Several researchers have revealed the logic of regulatory changes in other European countries, some researchers have analyzed the complexity of the relationship between the electricity sector and regulatory policies[6], and other researchers have pointed out the relationship between electricity industry regulation, economic efficiency, and social justice[7].This study will sort out the international experience and trends in the electricity industry and summarize the important experiences applicable to the construction of the domestic regulatory system.

2 International Experience and Trends in Electricity Industry Regulation

2.1 International Electricity Market Regulatory Adjustment Strategies

Table 1. Overview of International Adjustment Strategies

Countries and Regions	*Adjustment Strategies*
Europe	● Revise regulations and establish the Agency for the Cooperation of Energy Regulators (ACER). ● Amend the directive on the common rules for the internal market in electricity. ● Reestablish the regulatory framework for the internal electricity market. ● Implement incentive-based regulation for grid investments. ● Enhance information exchange and ensure data security.
United States	● The energy market shifts from centrally regulated command-and-control monopoly utilities to competitive markets. ● Allow energy storage to participate in the electricity market. ● Increasingly consider environmental benefits in regulation. ● Create suitable business models for electric companies. ● Maintain fairness in the energy ecosystem
UK	● In the future, as many small distributed power sources are integrated into the grid, the direction of power flow in low-voltage distribution networks will change, necessitating a reevaluation of the grid's structure and layout. ● The Office of Gas and Electricity Markets (Ofgem) in the UK has introduced a new model to ensure that consumers pay a fair price for new investments in the grid.

To better adapt to the energy transition, both domestic and international adjustments are beginning to be made in the regulation of electricity markets. From an international

perspective, major countries and regions such as Europe, the United States, and the United Kingdom have proposed a series of adjustment strategies, as shown in the Table 1.

2.2 Price Regulation

Price regulation includes two aspects: price level control and price structure control. Price level control refers to the regulation of prices in natural monopoly industries, while price structure control mainly involves setting different unit prices for the same product or service based on different consumer strata and varying demand elasticities.

In response to new changes in the energy industry, the UK has proposed an output-based model called "RIIO". The new output-based model RIIO aims to ensure that electricity consumers pay a fair and reasonable transmission fee, while addressing investment issues. RIIO stands for Revenue equals Incentives-Innovation-Outputs. This new model can ensure that grid costs do not increase too rapidly, and penalties will be imposed on grid companies that do not meet their output targets. Therefore, grid companies will have to achieve the planning goals they initially set with consumers and grid access customers. The Ofgem expects that the new model can ensure that the cost of achieving investment targets is lower than using the traditional RPI-X model. In the RIIO model, to provide more incentives for grid companies to achieve planning goals, an 8-year price control period is set, and a low-carbon grid fund is added to encourage the development of smart grids.

In the United States, the basic requirements for price regulation are to determine the total level of expenses and investment, to determine a reasonable rate of return, to allocate the total level of expenses among different types of consumers, and to set the price level to recover the total expenses. Different types of electricity consumers are classified based on their electricity usage characteristics. The classification of electricity consumers varies by state. General consumer types include residential, commercial, and industrial users. Some costs are allocated based on the number of customers, some based on their peak demand, some based on their total energy consumption, and others based on other aspects of usage. Regulatory agencies have very accurate knowledge of the number of customers and energy usage in each category, but sometimes they need to estimate peak demand.

In Europe, when conducting price regulation, regulatory agencies often establish a series of incentive-based regulatory mechanisms to reduce grid investment costs, improve grid operational efficiency, and promote the grid to achieve some development goals. Under the traditional regulatory framework in Europe, regulatory agencies define capital expenditure projects according to accounting procedures or specific regulatory methods, and grid companies can add any expenditures on these projects. Companies earn a rate of return on this expenditure over several years. Any expenditure that does not belong to capital expenditure projects is considered an operating expenditure without a rate of return. It can be observed that the traditional regulatory framework does not fully consider the grid's investment in research and development and innovative experiments, and the traditional form of incentive-based regulation has a fixed price regulation

cycle, which is currently conducted every three to five years. However, against the backdrop of energy transformation, the level of grid investment may need to span multiple regulatory cycles, posing a challenge to the traditional form of incentive regulation.

2.3 Electricity Universal Service Regulation

Considering the technical and economic characteristics of public utility companies, which have natural monopolistic attributes, it is necessary to regulate the principles that public utility companies must adhere to in order to protect the public interest. Electricity universal service regulation is the explanation and constraint of the principles that public utility companies need to uphold.

In Europe, for electricity universal service regulation, the following three principles have been proposed: Principle one is customer-centric, ensuring the interests of customers. Principle two is to maintain a neutral market position. Principle three is to consider the public interest, taking into account costs and benefits.

The United States has undergone electricity industry reform early on, forming an independent transmission segment and regulating it, while introducing market competition mechanisms in the generation and retail sectors. In 1992, the U.S. federal government passed the Energy Policy Act, which allowed electricity from non-utility companies to no longer be mandatorily purchased by utility companies and permitted them to enter the wholesale electricity market. Any electricity producer selling electricity on the wholesale market can require the utility company owning the transmission grid to provide transmission services at a fair and reasonable price. In 1999, the Federal Energy Regulatory Commission (FERC) required all utility companies owning transmission grids to join Regional Transmission Organizations (RTOs). RTOs control transmission facilities and independently operate and manage the transmission system. These organizations maintain the principle of neutrality and provide all entities with fair access to the grid and the use of transmission lines.

2.4 Scope of Business Regulation

For transmission networks, their main responsibilities include the safe operation, management, planning, and development of the transmission network. These businesses do not have the possibility of competition. Distribution networks are responsible for ensuring the safety of the distribution system's power supply and are also market service providers.

In the United States, since the 1980s, regulation of the electricity industry has been decreasing. It is believed that competition can bring sufficient benefits to consumers. This is particularly evident in New England, the Mid-Atlantic region, and Texas. However, some regulatory agencies are now undertaking significant reforms in the regulation of distribution public utility companies. In most states in the United States, franchise rights are used to prohibit entities other than public utility companies from providing electricity supply services to the public. Some public utility companies only provide dis-

tribution services. In states with restructured retail electricity markets, unregulated competitive companies provide power supply services, while regulated public utility companies still provide distribution services.

In Europe, in the traditional sense, distribution networks have been and will continue to be responsible for the safe operation and management of the distribution system, as well as its planning and development. According to the regulation of electricity universal service, the criterion for whether a distribution network can participate in a certain business is whether there is a possibility of developing a competitive business. If there is this possibility, distribution networks are generally not allowed to participate in this business. In the UK, multiple capital entries into the electricity industry are encouraged, and users can choose their electricity suppliers autonomously, which improves market allocation efficiency and enhances market vitality. The regulations on the core business areas of distribution networks in Europe include activities related to energy network infrastructure, activities related to system security (such as load shedding), technical data management, and management of network losses. The business areas that distribution networks cannot participate in include energy generation and energy supply.

2.5 Information Security Regulation

Traditional distribution networks are essentially passive grids, with the only interaction being with suppliers who are users of the distribution system and with transmission system operators. In some cases, distribution networks interact with electricity consumers due to safety or supply interruption reasons. With the emergence of new business models, the role of distribution networks has changed. Distribution networks no longer passively receive electricity from the transmission network but are gradually transforming from passive grids to active grid managers, with increasingly frequent information exchange with users and the transmission network. In this process, it is necessary to coordinate the exchange of information between the distribution network and the transmission network, and between the distribution network and users, to enhance security in information exchange and to improve the level of grid information security. The European Commission suggests strengthening the legislative framework for cooperation between distribution network system operators and transmission network system operators, requiring well-organized and smooth system information exchange mechanisms between distribution networks and transmission networks. This ensures that both transmission and distribution networks can obtain information as close as possible to the real-time operation of the system to ensure safe operation, while also ensuring that distributed resources on the distribution side can be coordinated and all necessary information and data can be shared.

2.6 Information Disclosure Regulation

Transmission and distribution networks, as public utilities, are obliged to provide necessary information to customers who use grid services. Customers can also request information disclosure from transmission and distribution network companies. As long as the items for information disclosure comply with regulations, grid companies must

proactively and in a manner that is convenient for the public to know, disclose relevant information to users. When providing information, no fees other than search, copying, mailing, and other cost fees shall be charged.

To promote energy transition and the development of distributed power sources, the European government is preparing to encourage active customers to produce, store, consume, and sell self-generated electricity in all organized markets. This approach can bring competitive dynamics to the retail electricity market. On the other hand, it is also necessary to protect passive consumers who do not have distributed power sources, especially in striking the right balance between protecting vulnerable consumers and encouraging active customers to participate in the market.

3 Enlightenment for Domestic Electricity Industry Regulation

Nowadays, the state and society are continuously raising their demands for energy conservation and emission reduction, as well as the reliability of power supply in the power system. Regulation is bound to trend towards legalization, modernization, and strictness. On one hand, the government will expedite the development of a robust regulatory legal framework, ensuring that there are laws to rely on for regulation. On the other hand, with the in-depth application of advanced technologies such as big data and cloud computing, regulation will become more modern, refined, and diverse, allowing it to fully adapt to the development of electricity marketization and corporate systemic reforms. Moreover, government regulation will be based on and strictly enforce the law, with a focus on areas such as promoting the consumption of clean energy and the low-carbon development of enterprises. Combining the above summary of foreign experiences, the following insights can be drawn for domestic electricity industry regulation.

3.1 Improving Market Design

International experience has shown that a scientifically sound and rational design of the electricity market is key to ensuring its healthy development. China can learn from the designs of other countries and regions, such as introducing competitive mechanisms and establishing wholesale and retail electricity markets. The rational design of spot electricity markets and ancillary service markets ensures the transparency, fairness, and effectiveness of market rules.

3.2 Enhancing Regulatory Capacity

Establish an independent and efficient regulatory agency responsible for the market supervision of the electricity industry, ensuring the consistency and continuity of policy implementation. Introduce performance assessment mechanisms to strengthen the performance evaluation of electric power companies and ensure service quality

3.3 Emphasizing Consumer Rights Protection

International electricity regulatory experience highlights the importance of protecting consumer rights. In China's electricity market reform, consumer protection mechanisms should also be strengthened to ensure that consumers can obtain reliable, high-quality, and fair electricity services. It includes ensuring the continuity of electricity supply, improving the stability and affordability of energy prices, and providing more contract options and direct access to renewable energy.

For instance, by referring to the EU's initiatives, protective structural measures are implemented to shield consumers and suppliers from the impact of price volatility, and to provide greater contract options and direct access to renewable energy sources.

3.4 Establishing Effective Incentive Mechanisms

Incentives can be input-based or output-based. Regulatory agencies can devise incentives that reward utility companies for reasonable control over the prices of selected projects. Alternatively, regulators can set targets for service quality or minimum technical requirements, where power grid companies can receive financial rewards for meeting these targets, and financial penalties for failing to meet them.

By regulating the rate of return, utilities are encouraged to improve service quality. Reasonable regulatory rates of return can also be provided for renewable energy projects to encourage more investment in the clean power sector

3.5 Information Security

Electricity regulation should establish and improve a network security management system in terms of information security, implement a tiered protection system for cybersecurity, and focus on monitoring and protecting critical information infrastructure. It is also necessary to strengthen the protection of power monitoring systems, achieve network zoning and isolation, establish a network security monitoring and early warning system, respond promptly to cybersecurity incidents, and develop emergency plans. Additionally, data security should be ensured with effective backups, the security awareness of all staff should be raised, and investment in network security should be guaranteed. At the same time, supervision, management, and technical support should be strengthened to ensure the safe and stable operation of the power system.

4 Regulation of Electricity Prices

The core of electric power regulation lies in the regulation of electricity prices. The electricity price management agencies of some countries are shown in the Table 2 below.

Some Chinese researchers used the CEEEA/CGE model to simulate the reform of the electricity market and found that the reform can optimize the energy structure [8]. The reform of transmission and distribution electricity prices has limited the revenue of

power grid companies and increased operational pressure, therefore it is necessary to study how to regulate in order to achieve sustainable development of power grid enterprises[9]. Some Chinese researchers have studied how to set transmission and distribution electricity prices in regions with different natural resource distributions[10]. The allowed revenue(R) of power grid companies is calculated as follows,

$$R=C+E+T \tag{1}$$

where C represents the allowed cost, E represents the allowed earnings, and T represents the taxes.

The first regulatory cycle of transmission and distribution electricity prices in Chongqing was 0.393 yuan per kilowatt-hour (≤1kV), 0.373 yuan per kilowatt-hour (1-10kV), and 0.338 yuan per kilowatt-hour (35kV). In the second regulatory cycle, the prices were reduced to 0.2583 yuan per kilowatt-hour (≤1kV), 0.2383 yuan per kilowatt-hour (1-10kV), and 0.2183 yuan per kilowatt-hour (35kV). In the third regulatory cycle, they were further reduced to 0.2321 yuan per kilowatt-hour (≤1kV), 0.2121 yuan per kilowatt-hour (1-10kV), and 0.1922 yuan per kilowatt-hour (35kV). The reductions for the three voltage levels were 41% (≤1kV), 43% (1-10kV), and 43% (35kV), respectively.

For the two-part electricity pricing system, the capacity electricity price in the first regulatory cycle of transmission and distribution was 24 yuan per kilowatt-hour per month. It remained unchanged in the second regulatory cycle. In the third regulatory cycle, it was further refined and reduced to 22 yuan per kilowatt-hour per month for 1-10 and 35kV, or 20 yuan per kilowatt-hour per month for 110 and ≥220kV. The maximum decrease reached 17%. It can be seen that the reform of transmission and distribution electricity prices under the supervision of Chongqing has been very effective.

Table 2. The electricity price management agencies

Countries	***Agencies***
UK	Office of Gas and Electricity Market
United States	The Federal Energy Regulatory Committee, FERC
Denmark	The Danish Energy Regulatory Authority
Sweden	The Energy Agency
Spain	National Energy Commission
Russia	Federal Energy Commission of the Russian Federation
Finland	The Energy Market Authority
Norway	The Norwegian Water Resources and Energy Directorate

5 Conclusion

This research has provided a comprehensive analysis of the international experience and trends in electricity industry regulation, highlighting the importance of adapting regulatory frameworks to the evolving energy landscape. The study has emphasized the need for a robust legal framework, modernized regulatory practices, and strict enforcement to ensure market efficiency and fairness. It has also underscored the significance

of promoting competition, encouraging innovation, and ensuring environmental sustainability through regulatory adjustments. It has explored various aspects of electricity market regulation, including price control, universal service obligations, business scope, and information security. In conclusion, it suggests that domestic regulatory systems should adopt a strict, comprehensive, rational, and efficient approach to electricity industry regulation. By learning from international experiences and trends, domestic policies can be better equipped to navigate the challenges and opportunities of the global energy transition. It is concluded that the reform of transmission and distribution electricity prices under the supervision of Chongqing has been highly effective.

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