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The Digital Transformation of Power Grid under the Background of Artificial Intelligence

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Abstract

Artificial intelligence (AI) plays a crucial role in the intelligent development of China's power system. It is also an important part of the digital development of the power grid. The development of AI determines whether the digital transformation of China's power system can be successfully implemented. Therefore, this paper discusses the digital transformation of the power grid based on AI technologies. The author has established a digital evaluation index system to reflect the development of the power grid in one province. Both qualitative and quantitative methods have been adopted in the analysis, which delves into the economic effectiveness, quality, and coordination of power grid development in the province in a comprehensive way. Results show that, to meet the needs of the power grid's digital transformation, the correlation coefficient between the power grid's development and the province's overall coordination has been increasing in recent years.

Keywords

Artificial Intelligence, Digital Transformation of Power Grid, Index System, Smart Grid

1. Introduction

Everyday life cannot sustain itself without electricity. For power supply enterprises, satisfying people's demands for a stable and reliable power supply is their long-term mission. As good technical management can improve the safety and reliability of power supply, research on the digital transformation of the power grid attracts increasing attention from suppliers. Based on artificial intelligence (AI) technology, a smart power grid will help enterprises better adapt to the rapidly changing world.

Many scholars have studied the digital transformation of the power grid based on AI and significant progress has been made in the research. Some scholars believe that technological innovation should be included in the growth strategy of power enterprises. Considering the fierce competition in the domestic power industry, a smart distribution system is a feasible solution for enterprises [1]. As the operation of a smart distribution network is complicated, technical, and auxiliary tools are needed to operate and maintain the power grid [2]. Although power grid has begun to adopt AI technologies, the digital transformation in China is still at the experimental stage. Technological development of AI technology can accelerate the transformation [3].

The implementation plan and importance of the power grid's digital transition are outlined in this paper.

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The drawbacks of traditional power grid are examined, and solutions for its digital transformation are proposed. An AI-based indicator system is built to reflect the digital development of the power grid. The system includes the three indicators: economic benefits, good quality and overall coordination of digital transformation and development of the power grid. Four perspectives are used to assess the demand for the digital transformation of the power grid in our province.

2. Theories Related to the Digital Transformation of Power Grids

2.1 Implementation Strategies for Digital Transformation of Power Grid Companies

- **Improving data collection:** The improvement of digital acquisition ability relies on infrastructure [4]. To improve the digital acquisition ability of power grid enterprises, enterprises should increase infrastructure investment and cover all the digital facilities at all nodes of their power supply chain.
- **Enhancing data analysis:** Data analysis is important in digital transformation. Internally, data analysis supports business processes and decision-making. Externally, data analysis can better serve government and individual users, providing them with high-quality services and enhancing enterprises' reputation. In this way, a data analysis-driven smart grid is formed [5].
- **Improving management mechanism:** It is necessary to establish a system with clear team division, create a data research and development center and form a comprehensive digital team [6].

2.2 Development Indicators of Power Grid Digitalization

- **Economic effectiveness:** Whether the funds are sufficient will influence the standard of power grid enterprise's investment on a new digital transformation project [7]. It relates to the main problem of enterprises and becomes the primary indicator for the digital development of those power grid enterprises [8].
- **Quality:** As the medium for transmitting electricity, the quality of the power grid will influence the quality of the electricity supply. To establish a high-quality power supply system, it is necessary to improve the accuracy and density of power grid production and optimize the quality of power transmission. The improvement should come from the aspects of design, construction, operation, and maintenance. Power grid construction is important for the operation and development of power companies. It will influence the economic benefits and safety power supply [9].
- **Coordination:** Power grid development covers all aspects, including the integration and coexistence of the political, economic, and social environment, and ultimately comprehensive, sustainable, and coordinated development. The coordinated development of the power grid is critical to the sound development of power enterprises [10].

2.3 Significance of Grid Digital Transformation

- **Improving the construction of power grid projects:** Asset management is indispensable throughout the life cycle of power grid construction. To improve the construction of power grid projects, it is essential to first improve capital management. Digital transformation can provide comprehensive and

authentic data for the completion and takeover of power grid projects and minimize the conflicts caused by capital costs. Moreover, a smart data platform will ensure efficient and reliable capital management [11].

- **Improving operation efficiency of power grid:** To improve the operation of power enterprises, we must start from increasing the economic benefits generated by the power grid. When implementing power grid projects, economic interests are paramount at the early stage. Only when economic interests are secured can enterprises undertake some socially responsible projects [12,13].
- **Standardizing the budget management system to control cost:** Enhancing the benefit of power enterprises can increase the turnover of power grid enterprises and reduce their cost. Through scientific judgment, the budget management system can select an appropriate blueprint and estimate the total cost before the project starts [14,15]. For the digital transformation of the power grid, enhancing the access capabilities of distributed energy and promoting the coordinated development of power grid enterprises and the environment are both important.

2.4 Selection of Power Grid Voltage

As one of the important indicators of power quality, voltage affects the safety and profitability of the entire power grid.

When there is only one concentrated load at the end of the power line:

$$\Delta L\% = (M_R + N_X)^{10} L_C^2 \tag{1}$$

M and N are the active and reactive power of the concentrated load; R and X are the resistance and reactance of the power line; L_C is the voltage of the power grid.

Considering the rapid development of the national economy, the investment benefit cannot reflect its true effect in a static state. Therefore, calculations should adopt the annual fee formula of the least annual compound interest:

$$NF = H\left[\frac{r_1(1+r_1)^n}{(1+r_1)^n - 1}\right] + M \tag{2}$$

Among them, r_1 is the income ratio of unit investment; M is the total investment of dynamic lines (yuan); and H is the total annual operation cost of the lines (yuan).

3. AI-based Digital Transformation of Power Grids

This paper investigated the indicators of an electric power enterprise from 2016 to 2020. It included the voltage qualification rate, the power grid load rate, and the percentage of large container-type transformers to evaluate the digital transformation of the enterprise's power grid and offer helpful suggestions.

In addition, this survey adopts multi-angle research and multi-index evaluation. The approaches used in this work are challenging because of the variety of viewpoints and the complexity of the research.

3.1 Constructing an Indicator System for the Digital Development of Power Grids

AI can be used to build the digital development index system, and evaluate the economic benefits, quality, and coordination of digital development from natural and social attributes, technical features, and objective characteristics.

3.2 Research Methods

The new method adopts both qualitative and quantitative evaluation systems, and multi-angle evaluation. In this way, the evaluation will be more comprehensive and standardized. In this paper, the study of the digital transformation of power grids focuses on one province. The data indicators related to the economic factor of the power grid development in this province are qualitative indicators, while quality and coordination are quantitative indicators. Therefore, the statistical yearbook has collected data on quality and coordination. To understand the power grid's needs for digital transformation, the paper analyzes the development of the power grid by calculating indicator weights in this province.

4. Power Grid Digital Transformation

4.1 Quality Evaluation Analysis

Table 1 is the evaluation results of the quality of the power grid in a certain province. According to the voltage qualification rate index, the voltage qualification rate during 2016–2020 is on the rise, from 96.857% to 99.291%. The overall power supply quality of the grid keeps improving. According to the power supply reliability index, the index level is also rising annually, from 97.843% to 99.771%. Power supply reliability has improved significantly.

Table 1. Relevant indicators of power-grid quality in a province

	2016	2017	2018	2019	2020
Voltage qualification rate (%)	96.857	97.131	97.647	98.536	99.291
Power supply reliability rate (%)	97.843	98.679	98.920	99.357	99.771

Table 2. Evaluation results of the quality of the power grid

	2016	2017	2018	2019	2020
City average power cut time (hr)	12.55	18.40	14.16	10.69	8.75
Grid load rate level (%)	82.16	85.74	84.53	81.29	83.68
Proportion of multi-circuit transmission on the same tower (%)	3.52	3.69	4.82	5.63	6.35
Proportion of large container-type transformers (%)	16.38	17.50	19.86	23.55	25.22

According to Table 2, the average power cut time for urban users in 2017 was 18.40 hours. This is significantly higher than in other years. After 2017, the power cut time showed a significant downward trend. The analysis of digital transformation in the power grid should also consider the impact of a power cut on the reliability of the power grid. As can be seen from Table 2 of the power grid load rate, the power grid load from 2016 to 2020 first increased and then decreased. Due to its power structure, the power grid had the highest load rate in 2017, which was 85.74%. The proportion of multi-circuit transmission on the

same tower has been increasing since 2016. The technology of multi-circuit transmission on the same tower is fully developed and popular among power grid companies. The continuously improved transmission rate reflects the rapid development of power facilities. The trend of an increasing percentage of large container-type transformers reflects the continuous development of power grid technologies.

As shown in Table 3, the quality of power grids has improved significantly between 2016 and 2020. This trend will boost the demand for digital transformation.

Table 3. Calculation results of the weight of quality

	2016	2017	2018	2019	2020
Weight	0.254	0.363	0.327	0.512	0.646
Sort	5	3	4	2	1

4.2 Coordination Evaluation and Analysis

- **Coordination with resources:** Overall coordination refers to the correlation coefficient of the installed capacity of energy generating units. In general, the greater the correlation coefficient, the stronger the correlation will be. As shown in Fig. 1, the development of power grid is correlated with thermal power generation, but not correlated with hydropower generation. At the same time, the correlation between clean energy and power grid development has gradually increased since 2018. This indicates that more and more power enterprises are shifting towards green energy in their development of the power grid.

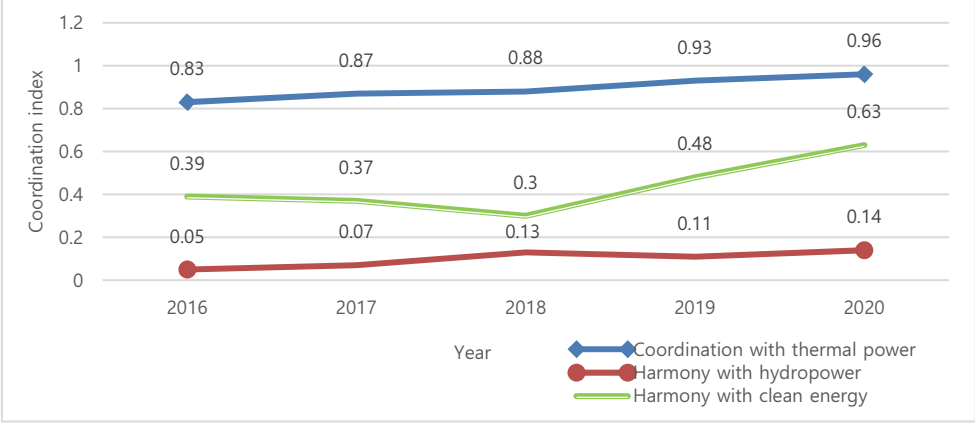

Fig. 1. Evaluation results of coordination with resources.

- **Coordination with consumption:** According to practical experience, the elasticity of electricity consumption should better not be more than 5% higher than the national economic growth rate. As shown in Fig. 2, the elasticity index showed a slow downward trend from 2016 to 2020. The overall coordination with gross domestic product (GDP) refers to the correlation between GDP and the transmission and distribution capacity of the power grid. The greater the correlation, the higher the coordination level will be. As shown in Fig. 2, the correlation coefficients are above 0.934, indicating that the correlation between the power grid of the province and GDP is significant. It also indicates that the transformation and development of the power grid in this province have a very high level of coordination.

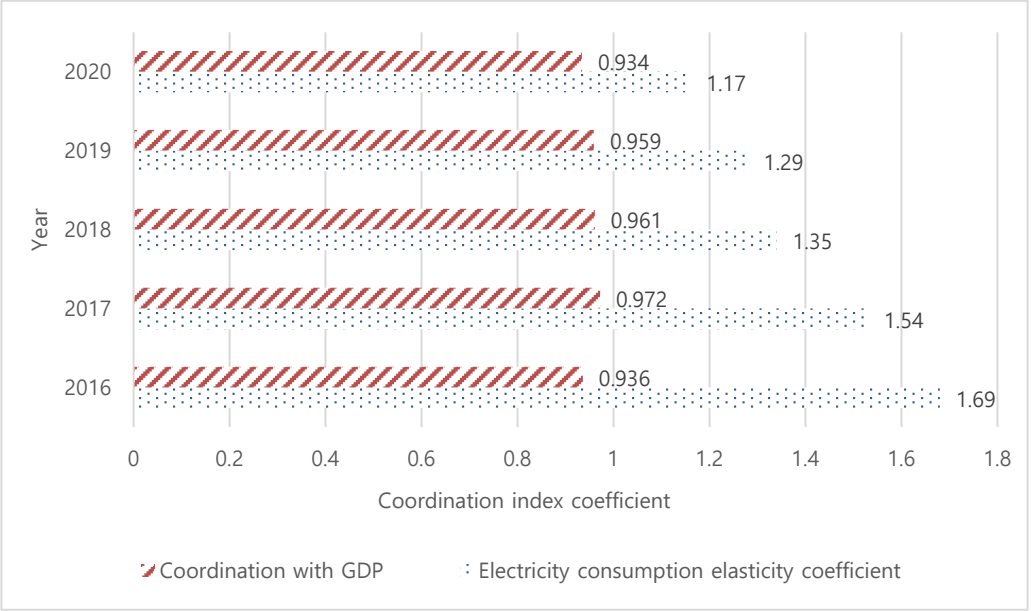

Fig. 2. Evaluation results of coordination with consumption.

4.3 Overall Evaluation and Analysis

As shown in Table 4, the weights of the three indicators of economic effectiveness, quality and coordination of the power grid are calculated. This province's power grid development had a low weight in 2017, which might be explained by the investment in social benefits. The findings of the weight calculation show that quality, and coordination are the two important factors in development of the power grid in this province. Therefore, the digital transformation of the power grid should focus on the quality and coordination level of the power supply.

Table 4. Weight of the three performance indicators

	2016	2017	2018	2019	2020
Weight	0.467	0.129	0.59	0.643	0.714
Sort	4	5	3	2	1

5. Conclusion

The strategy to promote the digital transformation of the power grid is to further help power enterprises adopt cutting-edge AI technologies. The most important thing is to guarantee the power grid's safety and provide high-quality services. However, when carrying out digital transformation strategies, power grid enterprises should also pay attention to the following three aspects: improving data perception, strengthening data analysis and application, and enhancing the management mechanism. In the future, corresponding support should be improved to lay a foundation for smart development, especially in talent, funds, infrastructure, and culture.

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