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Research on Coupling Coordination Degree and Influencing Factors between Power Grid Development and Ecosystem

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Abstract

This paper establishes the coupling evaluation system of green development of power grid and ecosystem, and then quantitatively evaluates the coupling coordination degree between the two by using the coupling coordination degree model, identifies the key factors affecting the coupling coordination degree of the two based on the index backtracking, and proposes the improvement direction of green development of power grid.

Keywords: green development of power grid; ecosystem; coupling coordination degree; influencing factors

1. Introduction

President Xi Jinping has made a solemn commitment to the world to peak carbon and be carbon neutral.To achieve the goal of double carbon, energy is the main battlefield, and electricity is the main force. As a platform and hub of power supply and demand, the green development of power grid not only affects the transformation of energy and power system, but also profoundly affects the green and low-carbon economy and society. Therefore, it is urgent to study the coupling coordination relationship between the green development of power grid and the ecosystem under the new situation, and explore the key factors affecting the green development of power grid.

There have been many researches on the green development of electric power, but there are relatively few researches on the coordination analysis between the green development of power grid and the ecosystem and its influencing factors. Based on the background of the power industry facing environmental pressure, resource bottleneck, consumption and emission and many other problems, Li Ruobin et al. proposed that the power supply enterprises have the responsibility and obligation to carry the banner of industrial green transformation, take the consumption of clean energy as the starting point, build the green energy supply value chain as the means, and establish and perfect the electric power ecological civilization system that adapts to the requirements of ecological civilization construction[1]. Zheng Xinye et al. built a bottom-up energy system model containing power modules, introduced the power load curve, set the benchmark and low-carbon scenarios for future power development, and analyzed the low-carbon transformation of the power sector itself and its important role and contribution to China's mid-and long-term low-carbon development from the perspectives of supply and demand structure, technology demand, cost and

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investment[2]. Yang Chuntao et al. analyzed the bottlenecks faced by the current green development of electric power, designed specific systems for the supply side, the demand side and the power grid side from the aspect of perfecting the legal system of electric power, and provided policy guarantees[3].

First, this paper briefly analyzes the coupling mechanism of the green development of power grid and the ecosystem. Second, this paper establishes a coordination degree evaluation model. Third, this paper uses the coordination degree evaluation model to evaluate the coordination degree between the green development of the upstream power grid, the power grid itself and the downstream power grid and the ecosystem, and analyzes the important factors affecting the coordinated development respectively. Finally, according to the evaluation results, the paper puts forward some suggestions for the green development of power grid.

2. The coupling mechanism and research methods of green development power grid and ecosystem

2.1. The coupling mechanism

The coupling mechanism between power grid and ecosystem is reflected in three aspects.First, grid enterprises cooperate upstream power generation enterprises to promote clean energy development which does less harm to the ecosystem than traditional fossil energy. Specific indicators include clean energy generation proportion, new energy efficiency, trans-regional transmission capacity and scale of grid-side energy storage. Second, the construction, operation and equipment decommissioning of power grid have an impact on the ecological environment. Specific indicators include environment assessment rate for construction projects, environment acceptance rate of completed projects, sulfur hexafluoride recovery rate, comprehensive line loss rate, disposal rate of waste lead-acid batteries, general waste disposal rate, waste transformer oil disposal rate and annual monitoring coverage of electromagnetic noise in substations.Third, power grid enterprises should guide downstream to promote cleaner energy consumption. Specific indicators include electrical energy replacement, electricity consumption proportion and new electric vehicle charging piles.

2.2. The research methods

The entropy weight method was used to determine the development index of green development and ecosystem, and the coupling coordination degree was used to evaluate the coordination degree of green development and ecosystem. Coupling refers to the cooperative relationship in which two or more systems are related and influence each other, including coupling degree and coupling coordination degree [4]. The degree of coupling mainly reflects the degree of mutual influence and interaction between the system or internal elements, and the degree of coupling coordination mainly measures the degree of harmony between the system or internal elements in the development process.

Let C represent the coupling degree[5-6], then the coupling model of the interaction between multiple systems can be expressed as:

$$C = \left\{ \frac{\prod (u_i, u_j, \cdots, u_n)}{\left[\frac{u_i + u_j + \cdots + u_n}{t} \right]} \right\}^{1/t} \tag{1}$$

In the formula, u is a system efficacy function for calculating the overall level of subsystems; t is the number of systems, which is 2; i and j represent the *i-th* and the *j-th* systems, respectively. It is assumed that $P(X)$ and $E(y)$ represent grid green development index and ecosystem index respectively. Let $P(X)=u_1$and $E(y)=u_2$, which are substituted into the comprehensive level of the grid green development subsystem and the comprehensive level of the ecological environment subsystem to build a two-dimensional coupling model:

$$C = \frac{2\sqrt[2]{P(X)\times E(Y)}}{P(X)+E(Y)} \tag{2}$$

let D indicate the coupling coordination degree[7].

$$D = \sqrt{C \times T} \tag{3}$$

$$T = \alpha u + \beta u = \alpha P(X) + \beta E(Y) \tag{4}$$

α and β is undetermined coefficient; $\alpha + \beta = 1$; and T is comprehensive evaluation index of two-dimensional system. This paper focuses on the green development of power grid, so set $\alpha = 0.6, \beta = 0.4$.

Table 1. Grade division of coupling coordination degree.

Type	Scope	Sub-type	Details	Meaning
Advanced development	$0.8 < D_1 \leq 1$	High symbiosis	P(X) > E(Y)	High symbiosis-E(y) hysteresis
			P(X) = E(Y)	High symbiosis-synchronous development
			E(Y) > P(X)	High symbiosis-P(x) hysteresis
Transitional development	$0.5 < D_1 \leq 0.8$	Coordinated development	P(X) > E(Y)	Coordinated development-E(y) hysteresis
			P(X) = E(Y)	Coordinated development-simultaneous development
			E(Y) > P(X)	Coordinated development-P(x) hysteresis
Primary development	$0.2 < D_1 \leq 0.5$	Running-in development	P(X) > E(Y)	Running-in development-E(y) hysteresis
			P(X) = E(Y)	Running-in development-synchronous development
			E(Y) > P(X)	Running-in development-P(x) hysteresis
	$0 < D_1 \leq 0.2$	Low symbiosis	P(X) > E(Y)	Low symbiosis-E(y) hysteresis
			P(X) = E(Y)	Low symbiosis-synchronous development
			E(Y) > P(X)	Low symbiosis-P(x) hysteresis

3. Analysis of coupling coordination degree

On the whole, the coupling coordination degree between the green development of power grid and the ecological environment is gradually increasing, the coupling coordination degree index is increased from 0.06 to 0.74, the coupling coordination relationship is developed from the low-level symbiosis stage to the coordinated development stage, and may reach the high symbiosis stage in the future. As shown in Figure 1. This shows that in the process of promoting energy transformation, power grid enterprises have effectively played the function of the platform for the optimal allocation of power grid energy resources, making the function and role of the power grid to promote green development more prominent, and clean substitution and energy substitution have made greater contributions to the improvement and upgrading of China's ecological environment.

Specifically, 2006 is a low-level symbiosis stage, the development level of both systems is low, the focus of power grid development in this stage is to achieve their own maximum economic benefits, ecological protection belongs to

the rigid constraints of power grid development. 2007-2011 is the running-in development stage. In this stage, the two systems gradually improved the level of development and the rate of development is equivalent. They restrict and promote each other in the stage.. The power grid system began to focus on promoting low-carbon energy supply and clean energy demand. The clean energy grid-connected scale gradually increased, and new energy utilization continues to improve. From 2012 to 2019, in order to coordinate the development stage, the green development of power grid and the ecological environment go hand in hand, and the green development level of power grid exceeds the ecological environment development level in 2015. The green development concept of this stage permeates the entire link of production, transmission and distribution of power grid, which promotes the green development level of power grid to be greatly improved, and the ecological environment protection has become the internal driving force for the development of the power grid. In the future, the green development of power grid will continue to play an active role in improving the ecological environment system, and the two are expected to reach a high level of symbiosis, and the green development of power grid at this stage not only focuses on the energy industry, but also uses the smart energy system as a carrier to promote the whole society's green industry, green transportation, green buildings and green life.

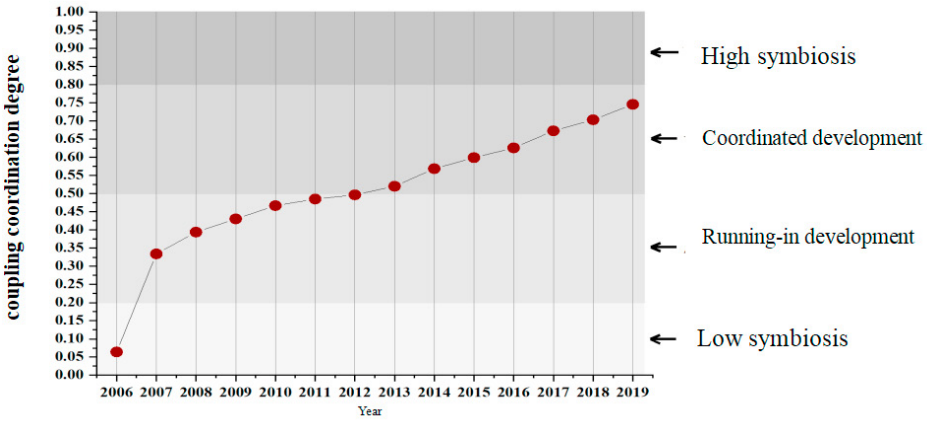


Fig. 1. The synergy degree between green development of power grid and ecological environment.

4. Backtracking of influencing factors

The factors influencing the coupling between green development of power grid and ecosystem are analyzed by using scatter plot, and the influence of each index on the coupling coordination between green development of power grid and ecosystem is analyzed.

4.1. Power grid coordinated upstream green development

In the process of grid coordinated upstream green development, the proportion of clean energy generation to total power generation, the utilization rate of new energy, the transmission capacity of cross-district lines and the energy storage at the grid side are all positive indicators. With the improvement of each indicator, the coupling coordination degree increases, indicating that the four indicators have a stable role in promoting the coupling coordination degree of the two systems.

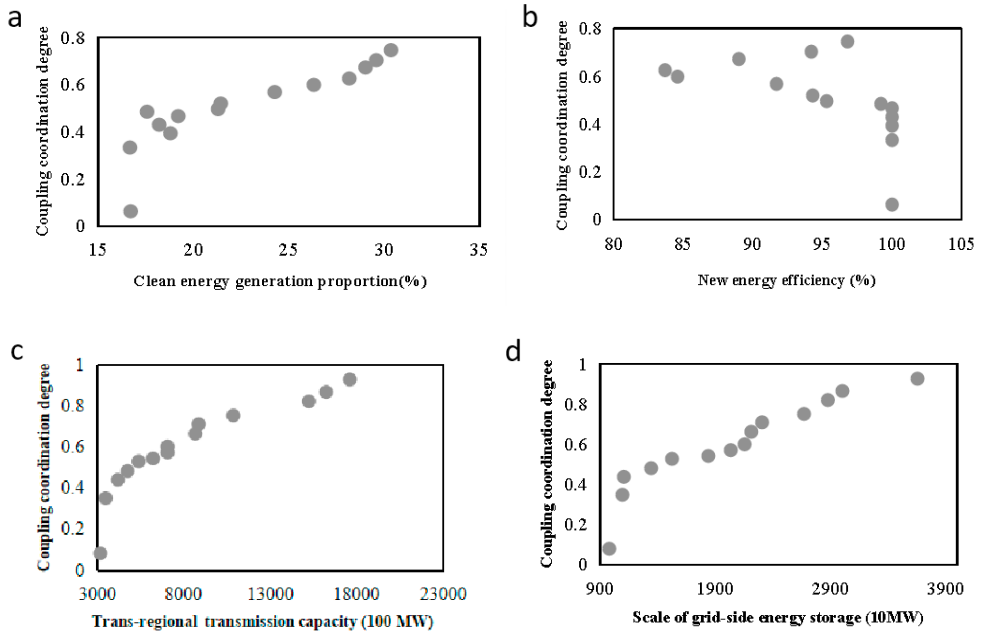
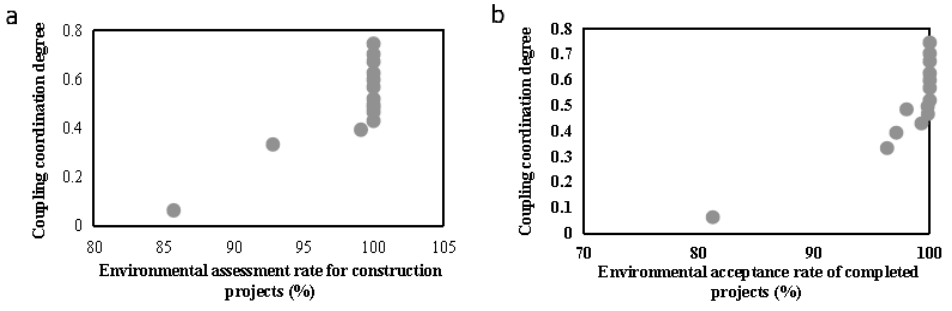


Fig. 2. The relationship between the indicators of the power grid upstream and the coupling coordination degree.

4.2. Green development of power grid

In the green development process of the power grid itself, except the comprehensive line loss rate is a negative indicator, the other indicators are positive. With the decrease of line loss rate and the increase of forward index, the coupling coordination degree increases. Among them, the environmental impact assessment rate of construction projects, the environmental protection acceptance rate of completed projects, the comprehensive line loss rate, the annual monitoring coverage rate of electromagnetic noise in substations and the general waste disposal rate have more significant effects on the coupling coordination degree than other indicators. This shows that it is necessary to deepen the environmental protection control of power grid construction projects, pay attention to the waste recycling management of the whole process of power grid construction, operation and retirement, and promote the reduction of line loss rate through technical means and management means.



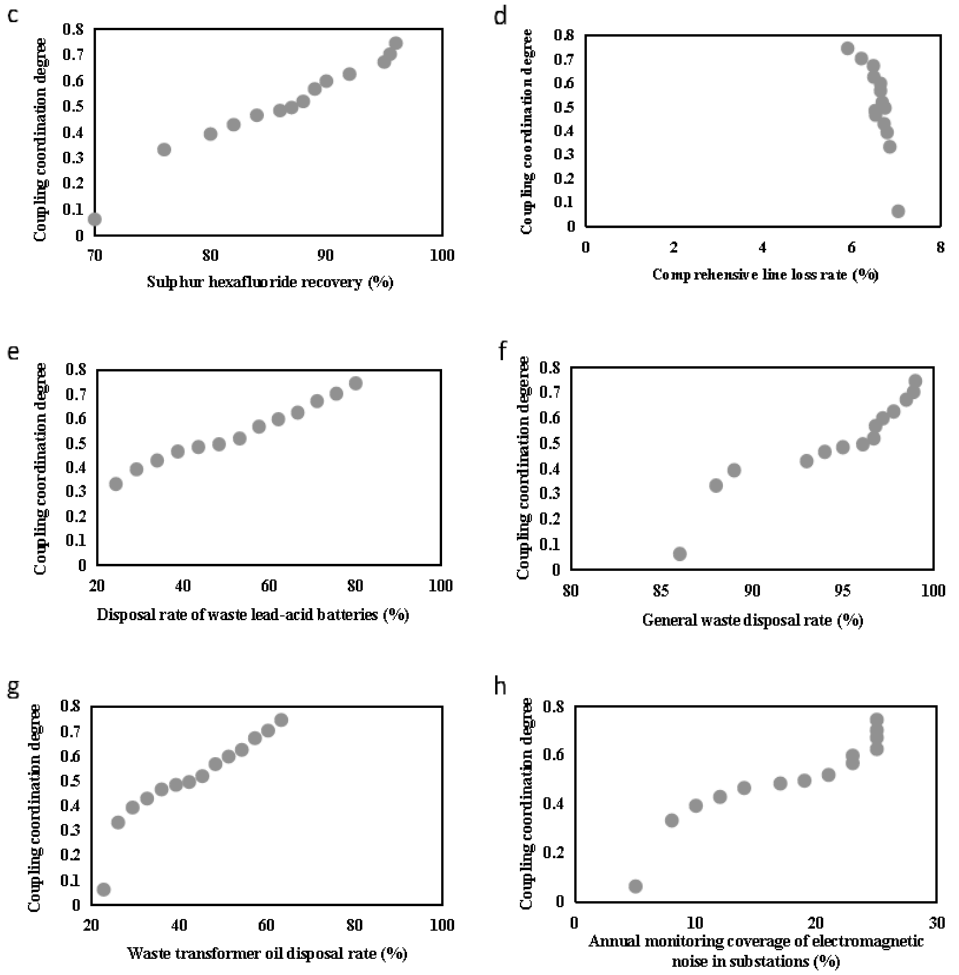


Fig. 3. The relationship between the indicators of the power grid itself and the coupling coordination degree.

4.3. Power grid coordinated downstream green development

In the process of power grid coordinated downstream green development, the ratio of electric energy to terminal energy consumption has a significant impact on the ecological environment, and the two indicators of electric energy substitution and new electric vehicle charging piles have a greater impact on the coupling coordination degree in the early stage of development, and later tend to be flat. This shows that in the process of power grid coordinated downstream green development, the implementation of electric energy substitution strategy and the improvement of the level of electrification of the whole society are the key measures for green development, so it is necessary to promote the replacement of electric energy in key areas, realize the transformation and upgrading of the terminal energy consumption structure, and give full play to the positive effect of power grid coordinated downstream on the ecological environment.

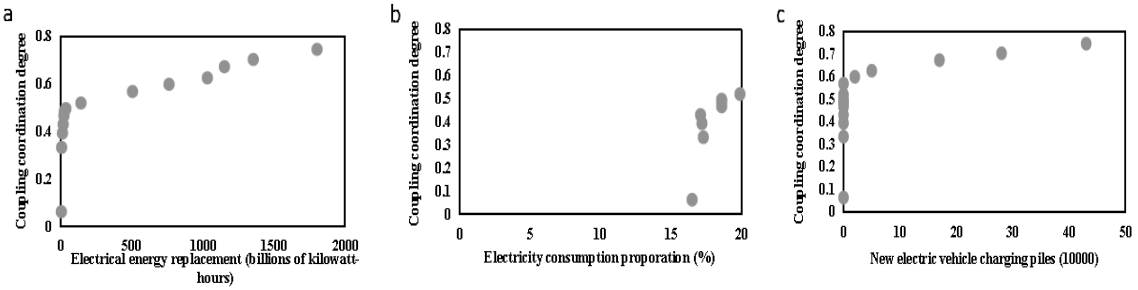


Fig. 4. The relationship between the indicators of the power grid downstream and the coupling coordination degree.

5. Conclusions and recommendations

From 2006 to 2019, the coupling relationship between the green development of power grid and the ecological environment had undergone low-level symbiosis, running-in development, and coordinated development. The promotion of green development of power grid to ecological environment is increasing, which shows that the implementation of electric energy substitution and clean substitution plays a key role in the coupling coordination of power grid and ecological environment system. Green development has changed from the constraint to the internal driving factor of the development of power grid. In the link of power grid coordinated upstream green development, the power grid should pay more attention to the improvement of trans-regional transmission capacity and improve the allocation and optimization of clean energy. In the green development link of the grid itself, corresponding management and technical measures should be further taken to reduce the comprehensive line loss rate, improve the annual monitoring coverage of electromagnetic noise in substations, and improve the timely disposal rate of transformer oil and waste lead-acid batteries. In the link of power grid coordinated downstream green development, electric energy substitution should be further promoted to increase the proportion of electric energy in the terminal energy consumption.

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References

[1] Li Ruobin, Zhang Baogang. (2017) *"*Building the value chain of green Energy Supply in power supply Enterprises*." The enterprise management,* **(S2)** : 153-154..

[2] Zheng Xinye, Wu You.(2018) "Innovation of Price Mechanism for Promoting Green Development of energy System." *Price theory and practice,* **(4)** : 12-16.

[3] Yang Chuntao. (2016) "The Dilemma and System Suggestion of Green and Low-carbon Electric Power Development." *Environmental protection,* **(24)** : 53-57.

[4] Xue Xiaoxiao. (2017) "Evolution characteristics of coupling relationship between economy and ecological environment in Zhejiang Province." *Contemporary Economy,* **(07)**: 82-85.

[5] Zhang Xinmu. (2017) "Study on Coupling Relationship between Land Use and Ecological Environment in Beijing." *Agricultural Science and Technology and Information*, **(08)**: 28-31.

[6]Liu Shuang, Zhang Xinlong, Hou Ying, Chang Wenqian, Zheng Yanan. (2018) "Study on Coupling Relationship between Urbanization and Ecological Environment in Beijing-Tianjin-Hebei Region." *China Market*, **(19)**: 33-34.

[7]Ma Yuefeng, Yuezhongchun. (2018) "Coupling analysis of mineral resources development and ecological environment protection in Huhhot-Baotou-Yinchuan Economic Region." *Ecological economy*, **34 (07)**: 196-200.