Research on Comprehensive Benefit Evaluation Model of Power Distribution Internet of Things Based on System Dynamics

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Abstract. Access of distributed energy to power distribution Internet of Things is of great significance to improving resource utilization and achieving emission reduction, and is an important means to improve the comprehensive benefits of distribution Internet of Things. Considering that the comprehensive evaluation of power distribution Internet of Things is a complex and dynamic process, this paper proposes a comprehensive evaluation model of power distribution Internet of Things based on system dynamics. Firstly, according to the principle of system dynamics, the system dynamics index is established from the two parts of economic benefit improvement and social benefit drive, and the corresponding system causality diagram is drawn. Secondly, regression analysis is used to determine the system dynamics equation of the comprehensive evaluation index. Finally, the comprehensive evaluation method of analytic hierarchy process is used to analyze the comprehensive benefits of a provincial power distribution Internet of Things. The results show that the system dynamics model considering the correlation of each index makes the evaluation result more objective and more valuable for application.
Keywords: Power Distribution Internet of Things, System Dynamics Model, Evaluation Model

1. Introduction

As an important part of the power grid, the distribution network directly faces power users and is closely related to production and life. It is an important infrastructure to ensure and improve people's livelihood, and it is also the most intuitive object for users to experience and experience power grid services. There are both opportunities and challenges to promote the evolution of traditional distribution networks to the energy Internet.

Many scholars have carried out a lot of research on traditional evaluation work of distribution network [1]. Literature constructs a distribution network investment evaluation index system from the two dimensions of economy and applicability, and uses data envelopment analysis to evaluate the effect of distribution network investment [2]. Literature considers four aspects of implementation process, effects and benefits, intelligent level, environment and sustainable development, and establishes a hierarchical multi-dimensional distribution network project post evaluation index system. Literature [3] builds a smart distribution network planning evaluation system based on risk assessment methods, and evaluates the benefits of smart technology applications from three aspects: the level of the distribution grid, the development risks of new business forms, and the effectiveness of smart technology applications. With the access of distributed energy, literature considered the distribution network of distributed energy system, proposed an improved comprehensive index evaluation system, and calculated the weight of the index through the analytic hierarchy process [4-5].

The comprehensive benefit evaluation of power distribution Internet of Things is a complex and dynamic system. The economic benefits and social benefits of the comprehensive benefits of power distribution Internet of Things influence each other and feedback each other [6]. This article conducts in-depth analysis and research on the provincial power distribution Internet of Things, determines the dynamic index system and correlation of comprehensive benefits through system dynamics theory, and draws a causal analysis diagram. Through regression analysis, the system dynamic equation of each index is given, and the comprehensive evaluation method is used to realize the comprehensive benefit evaluation of the distribution Internet of Things.

2. Evaluation process of power distribution Internet of Things

2.1. Construction of system dynamics index

Subsystem of economic benefit. Distributed power sources are connected to the distribution network on a large scale, and operating costs are rising. The economic benefits of the distribution network are directly reflected in the increase in electricity sales, the increase in load driven by investment, and the increase in installed capacity driven by the increase in assets. The feedback relationship in the economic subsystem is shown in Figure 1. The "+" in the figure represents a positive correlation, and the "-" represents a negative correlation. The main feedback relationships include:

1) Power distribution Internet of Things investment $\rightarrow +$ total power distribution Internet of Things assets $\rightarrow +$ new installed investment amount $\rightarrow +$ new installed capacity $\rightarrow +$ total regional GDP $\rightarrow +$
power sales → + power sales of power distribution Internet of Things unit assets → + distribution Economic Benefit Index of Electric Internet of Things.

2) Power distribution Internet of Things investment → + total power distribution Internet of Things assets → + new installed capacity investment → + regional electricity growth → + electricity sales → + regional electricity GDP.

3) Investment in distribution Internet of Things → + total assets of distribution Internet of Things → - power supply load per unit of assets.

4) Power distribution Internet of Things investment → + total power distribution Internet of Things assets → + new installed investment amount → + new installed capacity → + unit operation and maintenance costs → - power distribution Internet of Things economic benefit index.

Figure 1. Causal analysis of economic benefits of power distribution Internet of Things

Subsystem of social benefit. The population growth and GDP growth in a region will also affect the development of the distribution network. The construction of the power distribution Internet of Things requires a large amount of labor and knowledge personnel, which can increase the local employment rate. At the same time, the development of the power grid has a positive impact on reducing the population without electricity and reducing poverty. Therefore, the social benefits of power distribution Internet of Things mainly include new employment and reduction of the population without electricity. The feedback relationship in the social subsystem is shown in Figure 2. The main feedback relationships include:

1) Social benefit index → + power infrastructure investment → + new installed capacity (including new distributed energy equipment and new interactive energy equipment) → + new employment population → + social benefit index.
2) Social benefit index→+power infrastructure investment→+distributed energy investment→+government power public welfare fund→-population without electricity→-social benefit index.

3) Social benefit index→+power infrastructure investment→+new installed capacity (including new distributed energy equipment and new interactive energy equipment) →+ power generation→+electricity sales →+electricity income →+scientific research income→ +Social benefit index.

![Diagram of social benefits of power distribution Internet of Things](image)

**Figure 2.** Causal analysis of social benefits of power distribution Internet of Things

2.2. *System dynamics regression model*

2.2.1. *Economic subsystem model.* The index composition system of the economic subsystem is shown in Figure 3.

![Diagram of economic subsystem](image)

**Figure 3.** Economic subsystem system

1) New installed capacity

\[
\Delta I = a_i + b_i \times DE + c_i \times TS + d_i \times TP
\]  

(1)
Where $\Delta L$ is the new installed capacity, $a_1$ is the constant that affects the new installed capacity, $b_1$ is the influence coefficient of distributed energy investment on the growth of new installed capacity, $c_1$ is the influence coefficient of the investment in substations on the growth of new installed capacity, $d_1$ is the investment in thermal power units the coefficient of influence on the newly installed capacity, $DE$ represents distributed energy investment, $TS$ represents substation investment and $TP$ represents thermal power unit investment.

2) Load increase

$$\Delta L = a_1 + b_1 \times EP$$  \hspace{1cm} (2)

Where $a_2$ is the constant that affects load growth, $b_2$ is the influence coefficient of power consumption elasticity coefficient on load growth and $EP$ is the power consumption elasticity coefficient.

3) Electricity sales

$$\Delta S = a_3 + b_3 \times \Delta Z + c_1 \times \Delta L + d_1 \times \Delta G$$  \hspace{1cm} (3)

Where $\Delta S$ is the growth of electricity sales, $a_3$ is the constant that affects the growth of electricity sales, $b_3$ is the influence coefficient of newly installed capacity on the growth of electricity sales, $c_3$ is the influence coefficient of load growth on the growth of electricity sales, $d_3$ is the growth of regional GDP growth on electricity sales the coefficient of influence, $\Delta Z$ is the newly installed capacity, $\Delta L$ is the increase in load and $\Delta G$ is the added value of regional GDP.

2.2.2. Social subsystem model. The index composition system of the social subsystem is shown in Figure 4.

![Figure 4. Social subsystem system](image)

1) New employment population
\[
\Delta P = \alpha_1 + \beta_1 \times \Delta I
\]  

(4)

Where \(\Delta P\) is the newly-added employment population, \(\alpha_1\) is the constant that affects the newly-added employment population, \(\beta_1\) is the influence coefficient of the newly-added installed capacity on the newly-added employment population and \(\Delta I\) is the newly-added installed capacity.

2) Decrease in population without electricity

\[
\Delta E = \alpha_2 + \beta_2 \times DE + \delta_2 \times GS
\]

(5)

Where \(\Delta E\) is the decrease in the population without electricity, \(\alpha_2\) is the constant that affects the population without electricity, \(\beta_2\) is the influence coefficient of the growth of distributed energy investment on the population without electricity, \(\delta_2\) is the influence coefficient of the government energy subsidy coefficient on the population without electricity and \(GS\) is the government Energy subsidy coefficient.

3) R&D investment growth

\[
\Delta R = \alpha_3 + \beta_3 \times \Delta S
\]

(6)

Where \(\Delta R\) is the increase in scientific research investment, \(\alpha_3\) is a constant that affects scientific research income, \(\beta_3\) is the coefficient of influence of electricity sales on scientific research income and \(\Delta S\) is the increase in electricity sales.

3. Empirical

For the evaluation model in Figure 5, the data of a provincial power distribution Internet of Things from 2014 to 2018 is selected, and the simulation data of each indicator from 2021 to 2025 is obtained by linear fitting, and the standardization result of the indicator is obtained by the maximum and minimum normalization method. The expert score determines the weight ratio of the economic and social benefits of the power distribution Internet of Things and the weight of each indicator of each indicator layer. SPSS regression analysis determines the constants and influence coefficients of the variable equations. The specific results are shown in equation (7).
Combined with the simulation data of various indicators from 2021 to 2025, the above model is used for comprehensive benefit evaluation[7,8]. The comprehensive evaluation results are shown in Table 1.

**Table 1. Comprehensive evaluation results**

| Year | Economic Benefit Index | Social Benefit Index | Comprehensive Benefit Index |
|------|-------------------------|----------------------|-----------------------------|
| 2021 | 0.56                    | 0.45                 | 0.527                       |
| 2022 | 0.67                    | 0.57                 | 0.640                       |
| 2023 | 0.66                    | 0.43                 | 0.591                       |
| 2024 | 0.74                    | 0.63                 | 0.707                       |
| 2025 | 0.76                    | 0.68                 | 0.736                       |

4. Conclusion

Aiming at the comprehensive benefit evaluation of the provincial power distribution Internet of Things, this article considers the new interactive power distribution Internet of Things for distributed energy. Starting from the two parts of economic benefit improvement and social benefit driving, the
comprehensive benefit evaluation model of distribution Internet of Things based on system dynamics is established. The results of the study found that the overall benefits of the Internet of Things of power distribution generally show an increasing trend year by year. Through system dynamics analysis, it can be seen that with the increase in distributed energy investment, the increase in power generation will meet the power supply load and produce economic benefits, while the increase in the power public welfare fund and the reduction of the population without electricity will also produce social benefits.

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