

## *Retraction*

# **Retracted: Economic Evaluation Method of Incremental Distribution Network Project Based on Value Theory**

### **Security and Communication Networks**

Received 26 December 2023; Accepted 26 December 2023; Published 29 December 2023

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] W. Xie and L. Qiu, "Economic Evaluation Method of Incremental Distribution Network Project Based on Value Theory," *Security and Communication Networks*, vol. 2022, Article ID 1937177, 11 pages, 2022.

## Research Article

# Economic Evaluation Method of Incremental Distribution Network Project Based on Value Theory

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Received 3 November 2021; Revised 25 December 2021; Accepted 5 January 2022; Published 27 January 2022

Academic Editor: Jian Su

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In order to improve the weight calculation accuracy and overall evaluation accuracy of incremental distribution network project economic evaluation, a new incremental distribution network project economic evaluation method based on value theory is proposed in this paper. Firstly, based on the value theory, the economic characteristics of incremental distribution network are analyzed. Secondly, the economic benefits of the incremental distribution network project are calculated from the perspectives of DG owned operators and DG owned users. Finally, based on the calculation results of economic benefits, this paper constructs the evaluation index system, calculates the evaluation weight from both subjective and objective aspects, and finally completes the economic evaluation of incremental distribution network project. The experimental results show that compared with the traditional evaluation methods, this method can accurately calculate the evaluation weight, so as to obtain more accurate evaluation results.

## 1. Introduction

With China's economic development and the increasing expansion of power grid scale, whether the reliability of distribution network meets the requirements and whether the economy is reasonable has become a research hotspot [1]. Incremental distribution network liberalization is one of the key tasks of the power reform. Its main purpose is to realize the mixed ownership of infrastructure construction, promote economic growth by attracting investment, and improve the efficiency of power grid operation. The income model and investment activities of incremental distribution network are different from those of traditional power grid investment, mainly in the following two aspects. On the one hand, with the continuous development of transmission and distribution price reform, energy Internet, and comprehensive energy system, the income model of incremental distribution network is quite different from that of traditional power grid, and the investment of incremental

distribution network will not be limited to the investment of distribution and transformation equipment; it will also involve related investments such as integrated energy services, microgrid, and energy Internet [2, 3]. On the other hand, after the income of incremental distribution area is calculated independently, the characteristics of large initial investment and long investment payback period of power grid project will be further highlighted. In addition, there are many income influencing factors and high volatility, which makes it very meaningful to evaluate the economic value of incremental distribution network project [4].

Tian et al. [5] proposed a distribution network project economic evaluation method combining nonlinear mapping and cluster analysis. Firstly, the genetic algorithm and nonlinear mapping method are used to reduce the dimension of high-dimensional distribution network evaluation indexes into two-dimensional data, then K-means cluster analysis is carried out on the two-dimensional data, and simulated annealing algorithm is used to optimize the

clustering results. Finally, combined with the distribution network evaluation index system constructed by factor analysis method, the development status of distribution network is evaluated from the perspectives of economy, safety, and reliability. Sun et al. [6] put forward the economic evaluation method of distribution network project considering electricity price and electricity allocation. Based on the principle of return rate such as the value of different classified power grids and equipment assets and considering the influence of line loss and outage loss, the electricity price allocation formula for calculating the income of increased power supply of the project is deduced. Then, the calculation method of power supply capacity of multi-voltage distribution network is proposed, and based on the power supply capacity of the network before and after the project is put into operation, the power allocation formula for calculating the income of increased power supply of the project is given. Finally, the economic value of the project's increased power supply is calculated by using the project's increased power supply allocation and its electricity price allocation model. Zhao et al. [7] put forward the economic evaluation method of distribution network project under multi-type distributed generation access. According to the typical topology of low-voltage AC and DC distribution system with multi-type distributed generation access, a comparative evaluation model of AC and DC operation economy based on the whole link power loss of the system is established; taking the operation economy as the optimization objective, the distribution network operation strategy optimization model considering the charge and discharge states of energy storage is established.

According to the existing method, the weight calculation accuracy and overall evaluation accuracy of incremental distribution network project in economic evaluation cannot catch the actual demand. In order to evaluate the economic value of incremental distribution network project more accurately, based on value theory technology, an economic evaluation method of incremental distribution network project based on value theory is proposed in this paper.

According to the proposed method, it can be described as follows. Firstly, based on the value theory, the economic characteristics of incremental distribution network are analyzed. Secondly, the economic benefits of the incremental distribution network project are calculated from the perspectives of DG owned operators and DG owned users. Finally, based on the calculation results of economic benefits, this paper constructs the evaluation index system, calculates the evaluation weight from both subjective and objective aspects, and finally completes the economic evaluation of incremental distribution network project.

## 2. Analysis of Economic Characteristics of Incremental Distribution Network Based on Value Theory

Value theory points out the development direction of economic evaluation of incremental distribution network projects, and value management defines the basic task of

economic evaluation and the core goal of economic evaluation activities, that is, to maximize the economic value of incremental distribution network projects. The economic evaluation of incremental distribution network projects is no longer limited to the scale and function of expanding internal financial profits in the past, but centers on the central idea of value as the core and conducts business intentions in multiple dimensions of value creation and value sharing to enhance value creation. Promote the fundamental changes in the economic evaluation objectives, evaluation standards, evaluation methods, and evaluation mechanisms of incremental power distribution projects, and at the same time, promote the ability of the economic evaluation of incremental power distribution network projects to enter the era of value management [8–10].

Under the guidance of value theory, analyze the economic characteristics of incremental distribution network project.

*2.1. Phasing of Incremental Distribution Network Project Activities.* The construction of incremental distribution network is not achieved overnight, but a scientific construction activity made through long-term research. The incremental distribution network project can be divided into the following stages: feasibility study stage, construction period, and operation period. However, compared with the construction scale of incremental distribution network, the investment in the feasibility study stage is less. In the actual research process, the incremental distribution network construction stage is usually divided into construction period and operation period, and the cost of the feasibility study stage is included in the construction period. At the same time, incremental distribution networks are often constructed by stages, especially in areas with low existing load but rapid development in the future [11].

*2.2. Irreversibility of Incremental Distribution Network Construction.* The investment cost of incremental distribution network is large. Once it is constructed, it will be irrevocable and irreversible.

*2.3. Flexibility of Investment Decision in Incremental Distribution Network Construction.* Incremental distribution network construction investment has flexibility and diversity in investment time, investment scheme selection, investment strategy, and investment timing. Investors can choose the investment opportunity or specify their own investment scheme, control the investment process, and control the length of the construction period.

*2.4. Uncertainty of Incremental Distribution Network Construction Income.* The above uncertainties will affect the value of incremental distribution network. The change trend of economic value of incremental distribution network is uncertain, and its fluctuation is also uncertain. It is difficult to calculate the economic value of incremental distribution network through prediction and calculation.

### 3. Economic Benefit Calculation of Incremental Distribution Network Project

The income of incremental distribution network project operators mainly comes from restricted income, government subsidy income for DG, DG surplus power on grid income, and network fee income. The cost mainly includes investment cost, operation cost, network loss cost, and power purchase cost from superior transmission network. According to whether the construction of DG is considered and whether the owner of DG is the incremental distribution network operator or user, it is necessary to calculate the economic benefits of the incremental distribution network project from different angles. In order to simplify the calculation process, the calculation is carried out from the perspectives of DG home operator and DG home user [12].

*3.1. Economic Benefit Calculation considering the Ownership of DG Operator.* It is assumed that the operation calculation period of incremental distribution network is  $N$  years, in which the construction period is  $M$  years and the load growth period is  $R$  years. During the construction period, with the regional construction and the introduction of load, the incremental distribution network is constructed year by year, and the construction and operation coexist during the construction period. During the load growth period, it is necessary to consider whether subsequent construction is required as the load increases. After the regional load reaches saturation, there is no need for construction. The incremental distribution network considers the economic benefit structure of DG belonging to the operator, as shown in Figure 1.

According to this figure, we can see that the economic benefit structure of incremental distribution network operators contains comprehensive cost and comprehensive income. The comprehensive cost contains PV investment, construction, operation and maintenance cost, new line cost, and annual operating cost. The comprehensive income contains the revenue from electricity sales, PV subsidy income, and PV surplus power on grid revenue.

#### 3.1.1. Annual Comprehensive Cost

(1) *Construction Cost.* The construction investment cost of incremental distribution network operators in year  $y$  is

$$C_{\text{inv.}y} = C_{\text{line.}y} + C_{\text{DG.}y} + C_{\text{trans.}y} + C_{\text{sec.}y} + C_{\text{space.}y}, \quad (1)$$

where

$$\begin{cases} C_{\text{line.}y} = \lambda^{\text{line}} \sum_{l \in \Omega_{L,y}} d^l, \\ C_{\text{DG.}y} = \lambda^{fPV} \sum_{a \in \Omega_{PV,y}} G_a^{PV} + \lambda^{fWT} \sum_{b \in \Omega_{WT,y}} G_b^{WT}, \\ C_{\text{trans.}y} = \lambda^{\text{trans}} \sum_{c \in \text{trans}_y} S_c, \\ C_{\text{sec.}y} = \mu (C_{\text{line.}y} + C_{\text{DG.}y} + C_{\text{trans.}y}), \\ C_{\text{space.}y} = S_y \xi_1 \lambda^{\text{space}}, \end{cases} \quad (2)$$

where  $C_{\text{line.}y}$ ,  $C_{\text{DG.}y}$ ,  $C_{\text{trans.}y}$ ,  $C_{\text{sec.}y}$ , and  $C_{\text{space.}y}$ , respectively, represent the investment cost of line, DG, transformer, secondary system, and office space in year  $y$ ;  $\Omega_{L,y}$ ,  $\Omega_{PV,y}$ ,  $\Omega_{WT,y}$ , and  $\Omega_{\text{trans.}y}$ , respectively, represent the combination of lines, photovoltaic (PV), wind turbines (WTs), and transformers to be built or installed in year  $y$ ;  $\lambda^{\text{line}}$ ,  $\lambda^{fPV}$ ,  $\lambda^{fWT}$ , and  $\lambda^{\text{trans}}$  are the unit investment cost of line, PV, WT, and transformer, respectively;  $d^l$  represents the length of the  $l$ -th line;  $G_a^{PV}$  and  $G_b^{WT}$  represent the installed capacity of the  $a$  PV and the  $b$  WT, respectively;  $S_c$  represents the installed capacity of the  $c$ -th transformer;  $\mu$  represents the percentage of secondary system investment in primary system investment;  $S_y$  represents the power supply area of incremental distribution network in year  $y$ ;  $\xi_1$  represents the conversion coefficient between the power supply area and the floor area of the required office space; and  $\lambda^{\text{space}}$  represents the investment cost per unit area of office space in year  $y$  [13].

When the construction of DG is not considered,  $C_{\text{DG.}y} = 0$ .

(2) *Operating Costs.* The operating cost of incremental distribution network operators in year  $y$  is

$$C_{\text{ops.}y} = \eta (C_{\text{inv.}1} + \dots + C_{\text{inv.}y}) + S_y \xi_2 \lambda^{\text{salary.}y}, \quad (3)$$

where the first item on the right of the equal sign represents the transportation and maintenance expenses such as material expenses and repair expenses in year  $y$ , which shall be verified according to the proportion of accumulated fixed assets in that year; the second item is the employee salary in year  $y$ ;  $\eta$  represents the approved operation and maintenance rate, which is used to represent the relationship between the operation and maintenance expenses and the accumulated fixed assets formed in the current year;  $\xi_2$  represents the conversion coefficient between the power supply area and the required number of employees; and  $\lambda^{\text{salary.}y}$  represents the per capita basic wage in year  $y$ , increasing according to the discount rate [14, 15].

(3) *Power Purchase Cost.* The power purchase cost of incremental distribution network operators in year  $y$  is

$$C_{\text{buy.}y} = \sum_{d=1}^{365} \sum_{t=1}^{24} \lambda^{\text{buy}1} \max \left\{ 0, P_{y,d,t}^{\text{load}} - \sum_{a \in \Omega_{PV,\Sigma}} P_{a,d,t}^{PV} - \sum_{b \in \Omega_{WT,\Sigma}} P_{b,d,t}^{WT} \right\} + m \lambda^{\text{buy}2} S_{\text{trans}}, \quad (4)$$

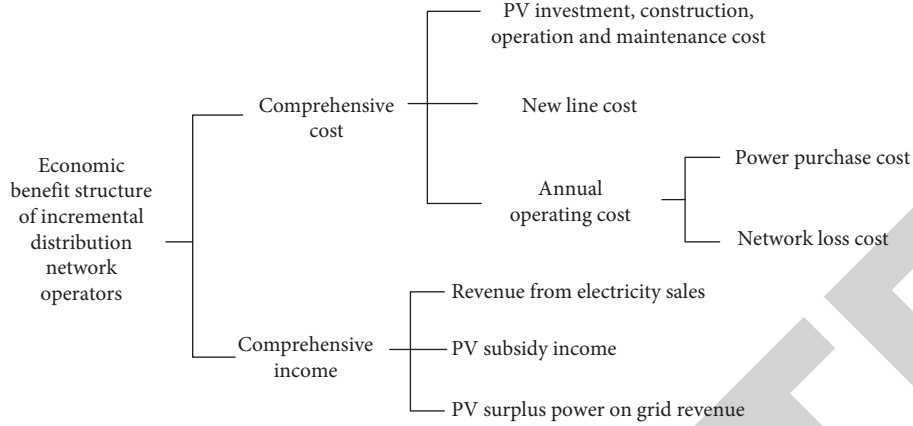


FIGURE 1: Economic benefit structure of incremental distribution network considering DG owned operators.

where the first item on the right of the equal sign is the on grid electricity price cost and transmission and distribution electricity price cost in the power plant construction cost of the operator in year  $y$  and the second item is the basic electricity price cost of transmission and distribution transformer capacity in the power purchase cost of the operator in year  $y$ ;  $\lambda^{\text{buy}1}$  and  $\lambda^{\text{buy}2}$ , respectively, represent the sum of on grid electricity price of power plant and transmission and distribution electricity price and the basic electricity price of transmission and distribution transformer capacity;  $P_{y,d,t}^{\text{load}}$  represents the total power consumption of all users in  $t$  period on day  $y$  of year  $y$ ;  $\Omega_{PV\Sigma}$ ,  $\Omega_{WT\Sigma}$ , and  $\Omega_{\text{trans}\Sigma}$  are PV, WT, and transformer sets put into operation in year  $y$ , respectively;  $P_{a,d,t}^{PV}$  and  $P_{b,d,t}^{WT}$  represent the active output of the  $a$  PV and the  $b$  WT at time  $t$  on day  $d$ , respectively;  $m$  represents the number of months in a year; and  $S_{\text{trans}}$  represents the capacity of transmission and distribution transformer.

When the wind power output is greater than the total load, the excess power of DG will be supplied back to the superior power grid, and  $C_{\text{buy},y} = 0$ . When the construction of DG is not considered,  $P_{a,d,t}^{PV} = P_{b,d,t}^{WT} = 0$ .

(4) *Network Loss Cost.* The network loss cost of incremental distribution network operators in year  $y$  is calculated as follows:

$$C_{\text{loss},y} = \sum_{d=1}^{365} \sum_{t=1}^{24} \lambda^{\text{loss}} P_{y,d,t}^{\text{loss}}, \quad (5)$$

where  $\lambda^{\text{loss}}$  represents the network loss electricity price in  $t$  period and  $P_{y,d,t}^{\text{loss}}$  represents the total active network loss of incremental distribution network in  $t$  period on day  $d$  of the  $y$  year.

### 3.1.2. Annual Comprehensive Income

(1) *Revenue from Electricity Sales.* The power sales revenue of incremental distribution network operators in year  $y$  is

$$I_{\text{sell},y} = \sum_{d=1}^{365} \sum_{t=1}^{24} \left( \lambda_t^I \sum_{i \in \Omega_{NIy}} P_{i,d,t}^I + \lambda_t^C \sum_{i \in \Omega_{NCy}} P_{j,d,t}^C + \lambda_t^R \sum_{i \in \Omega_{NRy}} P_{k,d,t}^R \right), \quad (6)$$

where  $\lambda_t^I$ ,  $\lambda_t^C$ , and  $\lambda_t^R$ , respectively, represent the electricity selling price of industrial, commercial, and residential users in  $t$  period;  $\Omega_{NIy}$ ,  $\Omega_{NCy}$ , and  $\Omega_{NRy}$  represent the collection of industrial, commercial, and residential users in the region in year  $y$ , respectively; and  $P_{i,d,t}^I$ ,  $P_{j,d,t}^C$ , and  $P_{k,d,t}^R$  represent the power consumption of industrial, commercial, and residential users in day  $d$  and period  $t$ , respectively.

(2) *DG Subsidy Income.* The DG subsidy income of incremental distribution network operators in year  $y$  is

$$I_{\text{sub},y} = \sum_{d=1}^{365} \sum_{t=1}^{24} \left( \lambda^{sPV} \sum_{a \in \Omega_{PV\Sigma}} P_{a,d,t}^{PV} + \lambda_t^{sWT} \sum_{b \in \Omega_{WT\Sigma}} P_{b,d,t}^{WT} \right), \quad (7)$$

where  $\lambda^{sPV}$  and  $\lambda_t^{sWT}$ , respectively, represent the subsidy cost of PV and WT unit power generation; when DG is not considered,  $I_{\text{sub},y} = 0$ .

(3) *DG Surplus Power on Grid Revenue.* In year  $y$ , the operator's DG surplus power on grid revenue is

$$I_{\text{over},y} = \lambda^{\text{over}} \sum_{d=1}^{365} \sum_{t=1}^{24} \max \left\{ 0, \sum_{a \in \Omega_{PV\Sigma}} P_{a,d,t}^{PV} + \sum_{b \in \Omega_{WT\Sigma}} P_{b,d,t}^{PV} - P_{y,d,t}^{\text{load}} \right\}, \quad (8)$$

where  $\lambda^{\text{over}}$  represents the on grid price of DG residual power.

When the wind power output is less than the total load, DG has no excess power, and  $I_{\text{over},y} = 0$ .

3.1.3. *Annual Net Income.* The net income of incremental distribution network operators in year  $y$  is

$$R_y = I_{\text{sell},y} + I_{\text{sub},y} + I_{\text{over},y} - C_{\text{inv},y} - C_{\text{ops},y} - C_{\text{buy},y} - C_{\text{loss},y}. \quad (9)$$

**3.2. Calculation of Economic Benefits of Incremental Distribution Network considering DG Attributable Users.** The economic benefit structure of DG owned users in incremental distribution network is shown in Figure 2. According to this figure, we can see that the user economic benefit structure of incremental distribution network contains comprehensive cost and comprehensive income.

**3.2.1. Annual Comprehensive Cost.** The investment cost and operation cost of the incremental distribution network operator considering that the DG belongs to the user are the same as those excluding the construction of DG contained in the above chapter, and the power purchase cost and network loss cost are the same as those considering the construction of DG by an operator as described in Section 3.1.

**3.2.2. Annual Comprehensive Income.** Compared with the annual comprehensive income when DG belongs to the operator as described in Section 3.1, it reduces the income of DG subsidy and the income of DG residual power online and increases the income of network fee.

(1) *Revenue from Electricity Sales.*

$$I_{\text{sell},y} = \sum_{d=1}^{365} \sum_{t=1}^{24} \left[ \lambda_t^I \left( \sum_{i \in \Omega_{NIy}} P_{i,d,t}^I - \sum_{a_i \in \Omega_{PV\Sigma_i}} P_{a_i,d,t}^{PV} - \sum_{b_i \in \Omega_{WT\Sigma_i}} P_{b_i,d,t}^{WT} \right) \right. \\ \left. \lambda_t^C \left( \sum_{j \in \Omega_{NCy}} P_{j,d,t}^C - \sum_{a_j \in \Omega_{PV\Sigma_j}} P_{a_j,d,t}^{PV} - \sum_{b_j \in \Omega_{WT\Sigma_j}} P_{b_j,d,t}^{WT} \right) + \right. \\ \left. \lambda_t^R \left( \sum_{k \in \Omega_{NCy}} P_{k,d,t}^R - \sum_{a_k \in \Omega_{PV\Sigma_k}} P_{a_k,d,t}^{PV} - \sum_{b_k \in \Omega_{WT\Sigma_k}} P_{b_k,d,t}^{WT} \right) \right], \quad (10)$$

where  $\Omega_{PV\Sigma_i}$  and  $\Omega_{WT\Sigma_i}$ , respectively, represent the PV and WT sets put into operation by industrial users in year  $y$ ;  $\Omega_{PV\Sigma_j}$  and  $\Omega_{WT\Sigma_j}$  represent the PV and WT sets put into operation by commercial users in year  $y$ ;  $\Omega_{PV\Sigma_k}$  and  $\Omega_{WT\Sigma_k}$ , respectively, represent the PV and WT set up by resident users in  $y$ ;  $P_{a_i,d,t}^{PV}$  and  $P_{b_i,d,t}^{WT}$  represent the active output power of industrial user-grade PV and typhoon;  $P_{a_j,d,t}^{PV}$  and  $P_{b_j,d,t}^{WT}$  represent enterprise user stage PV and typhoon active output; and  $P_{a_k,d,t}^{PV}$  and  $P_{b_k,d,t}^{WT}$  represent the effective output of stage PV and typhoon for residential users.

(2) *Network Fee Income.*

$$I_{\text{pass},y} = \lambda^{\text{pass}} \sum_{d=1}^{365} \sum_{t=1}^{24} \left( \sum_{a \in \Omega_{PV\Sigma}} P_{a,d,t}^{PV} + \sum_{b \in \Omega_{WT\Sigma}} P_{b,d,t}^{WT} \right), \quad (11)$$

where  $\lambda^{\text{pass}}$  represents the network charge per unit of electricity.

**3.2.3. Annual Net Income.**

$$R_y = I_{\text{sell},y} + I_{\text{pass},y} - C_{\text{inv},y} - C_{\text{ops},y} - C_{\text{buy},y} - C_{\text{loss},y}. \quad (12)$$

## 4. Economic Evaluation of Incremental Distribution Network Project

This paper proposes a method which can help to calculate the weight by the association rules in data mining. Through a large number of historical economic data accumulated in the operation of incremental distribution network, this paper mines the confidence degree of loss caused by the change of each index to judge the importance of each index.

Because the association rule mining technology is based on a large number of historical economic data, it gets rid of the limitations of the advantages and disadvantages of the algorithm and can also overcome the problem of nonlinear relationship between various influencing factors. The weights obtained by this method are more in line with the actual situation of power grid operation, and there are no other problems that are inconsistent with the actual situation.

**4.1. Construction of Evaluation Index System.** The establishment of economic evaluation index system is essentially to determine the main influencing factors of incremental distribution network project economy. The economy of incremental distribution network can be improved by adjusting load, transforming grid structure, and replacing grid equipment. Therefore, whether the load under the current incremental distribution network structure is reasonable needs further verification. The evaluation index system shown in Table 1 is established from the three aspects of power grid structure and equipment economy under the current load, following the principles of systematicness, scientificity, objectivity, and practicability.

**4.2. Problem Description.** Given a set of items  $I = \{I_1, I_2, \dots, I_m\}$  and an economic database  $D = \{t_1, t_2, \dots, t_n\}$ , where  $t_i = \{I_{i1}, I_{i2}, \dots, I_{ik}\}$  and  $I_{ij} \in I$ , the association rule is an implication in the form of  $X \Rightarrow Y$ , where  $X, Y \subset I$  are two item sets, which are called item sets and  $X \cap Y = \Phi$ .

The support ( $s$ ) of association rule  $X \Rightarrow Y$  is the percentage of transactions containing  $X \cup Y$  in the database in all transactions in the database.

The confidence ( $c$ ) of association rule  $X \Rightarrow Y$  is the ratio of transaction data containing  $X \cup Y$  to transaction data containing  $X$ .

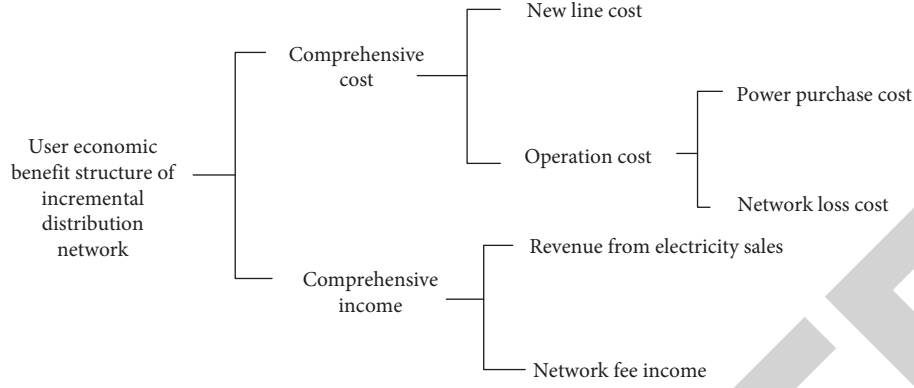


FIGURE 2: Economic benefit structure of incremental distribution network considering DG owned users.

TABLE 1: Evaluation index system.

Primary index	Secondary index
Load	Load rate Power factor Optimum load area
Distribution network equipment	High energy consumption transformer Conductor cross-sectional area Transformer capacity
Grid structure	Matching degree of conductor transformer Operation mode Capacitor switching Power supply reducing Capacity load ratio

If  $s(X \Rightarrow Y)$  is greater than or equal to the minimum support and  $c(X \Rightarrow Y)$  is greater than or equal to the minimum confidence, it is called an association rule.  $X \Rightarrow Y$  is a strong rule; otherwise, it is a weak rule. The minimum support and minimum confidence are usually specified according to the actual situation. Generally speaking, only association rules with high support and confidence can be useful association rules.

### 4.3. Weight Determination

**4.3.1. Objective Weight.** Classify a large number of historical data to find out the value of each index and loss. Calculate the change degree of each index value and loss, discretize the change degree by using the nearest neighbor clustering method, mine the relationship between the change degree of each index and the change degree of loss by using association rules, and find out the influence degree of each index on loss. Find meaningful rules with the greatest confidence from the mining rules and determine the weight according to their confidence:

$$\alpha_i = \frac{c_i}{\sum_i c_i}, \quad (13)$$

where  $N$  represents the number of indicators.

Because the change degree of each index is adopted, the work of dimensional processing is omitted.

In the case of maximum confidence, the index weight of load is shown in Table 2.

**4.3.2. Subjective Weight.** The objective weight determination method based on association rules finds out the importance of each index in operation from the actual operation data, but to build and transform the incremental distribution network and improve the economy of operation, other influencing factors other than economy should be considered. For example, the observable weight of power factor is higher than the load rate, but the power company believes that the cost of increasing the load rate is lower than that of increasing the power factor. It is possible to give priority to improving the economy of incremental distribution network operation from the load rate, which will give a greater weight to the load rate. Considering this situation, it is necessary to consider expert opinions and add subjective weight to the determination of weight.

The weight determined according to expert opinions cannot be based on the opinions of one expert. The opinions of multiple experts have more uncertain information and fuzziness. How to effectively synthesize the opinions of

TABLE 2: Weight of load indicators.

Optimum load area	Load rate	Power factor
0.418	0.212	0.370

various experts is often ignored. Evidential reasoning can better deal with the synthesis problem with fuzzy and uncertain information. Therefore, the Dempster–Shafer synthesis rule is used to comprehensively analyze the opinions of the group, so that the results can truly reflect the opinions of the group.

*Definition 1.* For a set  $A$ , set  $B = \{C|C \subseteq A\}$  is said to be a power set of set  $A$ , expressed as  $2^A$ . For a decision problem, set  $\Theta$  is used to represent all possible results that can be recognized, and this set  $\Theta$  is called recognition framework.

Generally, the propositions of interest correspond to a subset of  $\Theta$ , and the set composed of all subsets of  $\Theta$  is called the power of  $\Theta$  and expressed as  $2^\Theta$ .

*Definition 2.* Let  $\Theta$  be the identification framework, and if the set function  $m: 2^\Theta \rightarrow [0, 1]$  satisfies

$$\begin{cases} m(\phi) = 0, \\ \sum_{A \subseteq m} m(A) = 1, \end{cases} \quad (14)$$

then  $m$  is called the basic probability assignment function or basic reliability assignment of frame  $\Theta$ .  $m(A)$  is called the basic probability value BPN of  $A$ ; if  $m(A) > 0$ ,  $A$  is called the focus element.

*Definition 3.* Given an identification framework  $\Theta$ ,  $m: 2^\Theta \rightarrow [0, 1]$  is the basic probability assignment on  $\Theta$ , and the definition of the function is

$$\begin{aligned} \text{Bel}: 2^\Theta &\rightarrow [0, 1] \\ \text{Bel}(A) &\stackrel{\text{Bel}}{=} \sum_{B \subseteq A} m(B) \quad (\forall A \subseteq \Theta). \end{aligned} \quad (15)$$

Call this function a trust function on  $\Theta$ .

$\text{Bel}(A) = \sum_{B \subseteq A} m(B)$  represents the total trust of  $A$ , so we know that

$$\text{Bel}(\phi) = 0 \quad \text{Bel}(\Theta) = 1. \quad (16)$$

*Definition 4.* Given the recognition framework  $\Theta$ ,  $1 - \text{Bel}(\bar{A})$  is called the likelihood function of  $A$ , which is recorded as  $pl(A)$ , and  $pl(A) + pl(\bar{A}) \geq 1$ ,  $pl(A) \geq \text{Bel}(A)$ .

*Evidence Combination Rules.* Let  $\text{Bel}_1$  and  $\text{Bel}_2$  be the trust functions based on two independent evidences on the same identification framework  $\Theta$ , let  $m_1$  and  $m_2$  be their corresponding basic probability assignments, let the focus elements be  $A_1, \dots, A_I$  and  $B_1, \dots, B_L$ , respectively, and let

$$K = \sum_{\substack{i,j \\ A_i \cap B_j = \phi}} m_1(A_i)m_2(B_j) < 1, \quad (17)$$

where  $i = 1, \dots, I$ ;  $j = 1, \dots, L$ .

Then,

$$m(c) = \begin{cases} \frac{\sum_{A_i \cap B_j = \phi} m_1(A_i)m_2(B_j)}{1 - K}, \quad \forall c \subseteq \Theta, & c = \phi, \\ 0, & c = \phi. \end{cases} \quad (18)$$

In this study, the basic probability distribution function  $m(A)$  is regarded as the evaluation degree of the evaluation grade given by experts for the factor of a certain attribute.

The index importance determined by each expert is equivalent to an evidence body. The importance of indexes  $i$  and  $j$  is scored by using the 1–9 scale in analytic hierarchy process, and the expert opinions are synthesized by using Dempster–Shafer synthesis formula. Finally, the importance of index  $i$  and index  $j$  is obtained. Finally, according to the importance of each index, write the judgment matrix and calculate the weight.

According to the combined expert opinion of formula (18), the results are shown in Table 3.

*4.3.3. Combined Weight.* The multiplication synthesis method is used to weight the decision indicators, that is, firstly, the weight coefficients determined by the above subjective and objective weighting methods are multiplied correspondingly, and finally the product is normalized. The specific weighting calculation formula is

$$\omega_j = \frac{\alpha_j \times \beta_j}{\sum_{j=1}^n \alpha_j \times \beta_j}, \quad (19)$$

where  $\alpha_j$  represents the objective weight of the  $j$ -th index and  $\beta_j$  represents the subjective weight of the  $j$ -th index.

## 5. Experimental Verification

This study selects the incremental distribution network park located in an economic development zone in the province as the research object, which is hereinafter referred to as park A. The planned employment population of the park is about 150000, and the residential population is 80000. The planned urban construction land area is about 3228 hectares. There is one public transformer within the scope of park A, which is a 110 kV substation, located south of the park. The current situation of its transformation capacity is shown in Tables 4–7.

Then, the annual capacity demand of the park is calculated by referring to the distribution network planning standards.

The annual power consumption of the park is as follows.

The data of typical photovoltaic output and load curve of the park in four seasons are selected, as shown in Figure 3.

Based on the above data, the calculation accuracy and evaluation accuracy of evaluation weight are set as experimental comparison indexes. The economic evaluation method of distribution network project proposed in this paper and reference [5] combined with nonlinear mapping



TABLE 3: Expert opinions.

1-9 scale	Power factor/load rate			Compliance area/load rate			Load area/power factor		
	2	3	4	3	4	5	1	2	3
$m_1$	0.6	0.3	0.1	0.6	0.3	0.1	0	0.6	0.4
$m_2$	0.5	0.5	0	0.7	0.3	0	0	0.5	0.5
$m_3$	0.7	0.2	0.1	0.1	0.4	0.5	0.1	0.3	0.6
$m_4$	0.4	0.6	0	0.4	0.5	0.1	0	0.8	0.2
$m_5$	0.9	0.1	0	0.7	0.3	0	0	0.9	0.1
$m_6$	0.9	0.1	0	0.9	0.1	0	0.1	0.5	0.3

TABLE 4: Current situation of substation in park A.

Substation name	Voltage class (kV)	Capacity composition (MVA)	Single-line single transformer
1# substation	110/10	50 + 50	No

TABLE 5: Overall load forecast of park A (MW).

Load (MW)	2017	2018	2019	2020	2021
Load forecast value	95.77	104.29	113.30	122.87	
Load (MW)	2022	2023	2024	2025	129.54
Load forecast value	136.33	143.83	152.16	160.62	

TABLE 6: Overall load forecast of park A (MVA).

Year	2016	2017	2018	2019	2020
Average annual capacity demand	89.46	104.39	120.14	136.81	154.52
Year	2021	2022	2023	2024	2025
Average annual capacity demand	166.86	179.43	193.31	208.71	224.37

TABLE 7: Annual power consumption of park A (10000 KWH).

Year	2017	2018	2019	2020	2021
Power consumption in the park	6.688.75	65708.15	71074.9	76839.45	
Year	2022	2023	2024	2025	81597.83
Power consumption in the park	86442.39	91787.11	97709.07	103729.5	

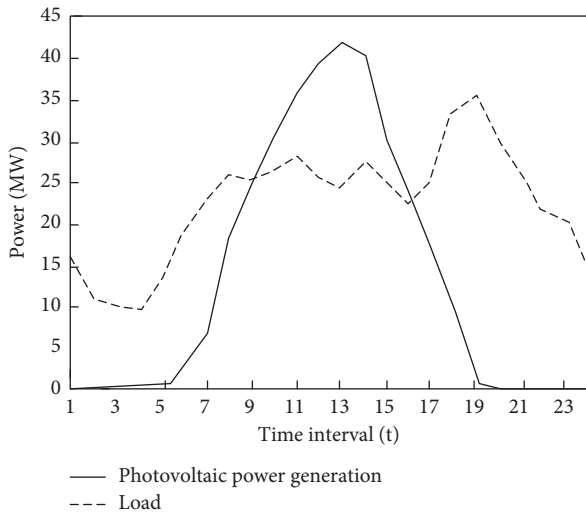
and cluster analysis and the economic evaluation method of distribution network project proposed in reference [6] considering electricity price and electricity sharing are compared and verified.

**5.1. Evaluation Weight Calculation Accuracy.** The comparison results of evaluation weight calculation accuracy of the three methods are shown in Figure 4. In this figure, the pink dotted line indicates the result of the method proposed in this paper. The green dotted line indicates the result of the method which combines the nonlinear mapping and cluster analysis. The solid red lines indicate the result of the method of electricity price and electricity allocation.

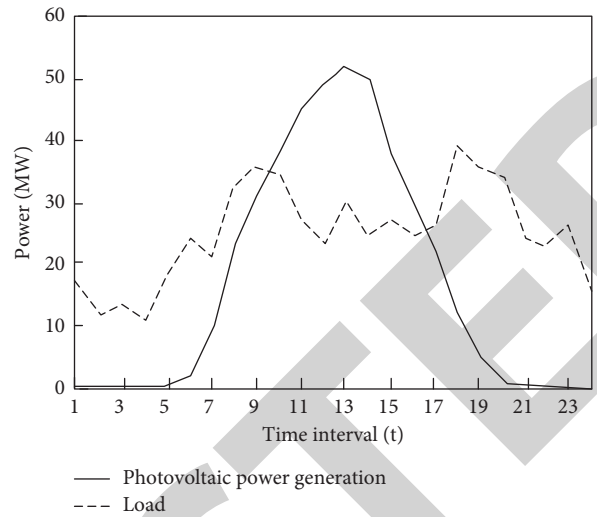
By analyzing the comparison results of the calculation accuracy of the evaluation weight shown in Figure 4, it can be seen that when the number of experiments continues to increase, compared with the two literature comparison methods, this method can calculate the evaluation weight more accurately, so as to obtain more accurate economic evaluation results.

**5.2. Comparison of Evaluation Accuracy.** The comparison results of the evaluation accuracy of the three methods are shown in Figure 5.

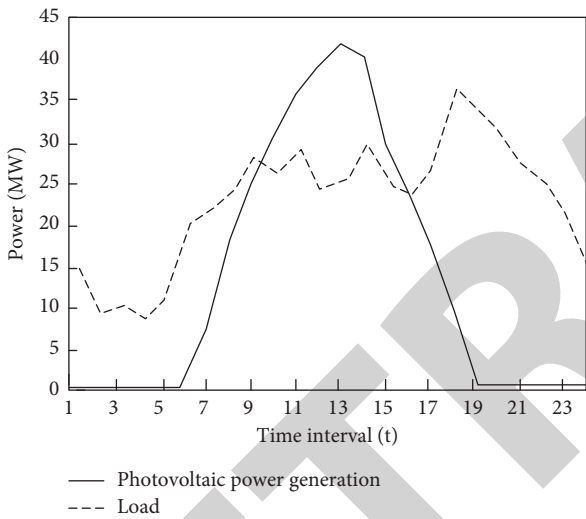
From the comparison results of evaluation accuracy shown in Figure 5, it can be seen that this method can more



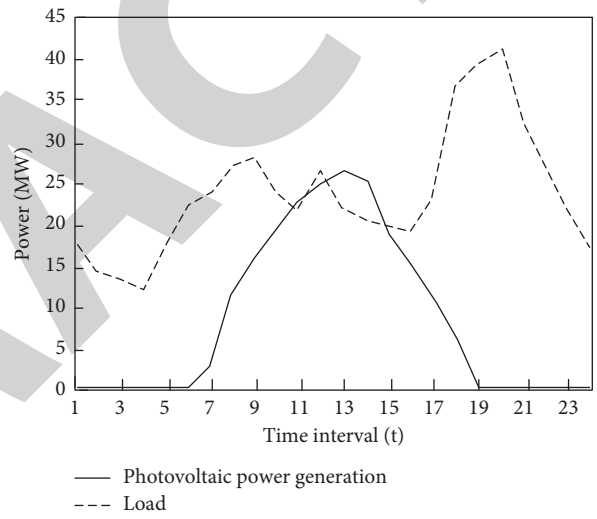
(a)



(b)



(c)



(d)

FIGURE 3: Typical photovoltaic treatment and load curve in four seasons. (a) Spring. (b) Summer. (c) Autumn. (d) Winter.

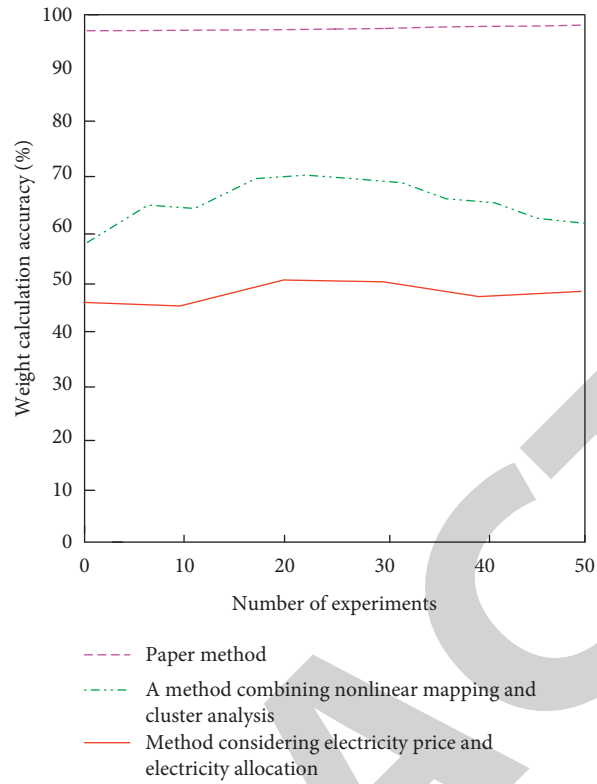


FIGURE 4: Comparison results of evaluation weight calculation accuracy.

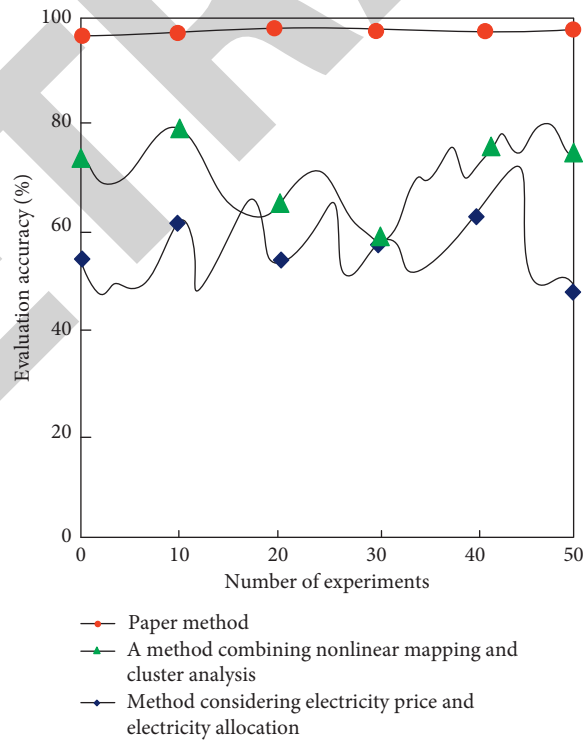


FIGURE 5: Comparison results of evaluation accuracy.

accurately evaluate the economy of incremental distribution network project, so as to improve the economic value of incremental distribution network project construction and promote the coordinated development of incremental distribution network economy.

## 6. Conclusion

In order to improve the effectiveness of incremental distribution network project economic evaluation, an incremental distribution network project economic evaluation method based on value theory is proposed in this paper. The performance of the method is verified from both theory and experiment. This method has high weight calculation accuracy and evaluation accuracy in the economic evaluation of incremental distribution network projects. Specifically, compared with the method combining nonlinear mapping and cluster analysis, the weight calculation accuracy is effectively improved. Compared with the method considering electricity price and electricity allocation, the evaluation accuracy is significantly improved. Therefore, it fully shows that the proposed evaluation method based on value theory can better meet the requirements of economic evaluation of incremental distribution network projects.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

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