

Research Article

Economic Analysis of Incremental Distribution Network Construction of Urban Industrial Park under the Background of Smart City

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The distribution system of urban industrial parks involves many relevant subjects, and there is an urgent need to effectively evaluate the technical and economic methods of distribution systems of urban industrial parks. This paper gives the architecture of a smart city and analyzes the characteristics of the incremental distribution network of the urban industrial park. The life cycle cost model of distribution network equipment is established, and the method for calculating the life cycle cost of distribution network equipment under multiple strategies is studied. The application of the economic evaluation of the urban distribution network is described in detail, and its evaluation indicators under the current power grid, the single plan of the planned grid, and the multiple plans of the planned grid are introduced. The results show that the evaluation method in this paper has the advantages of good versatility and strong operability for the economic evaluation of incremental distribution network construction.

1. Introduction

For a long time, electricity has been regarded as an important basic industry related to the national economy and people's livelihood, and it is an indispensable basic element for people's production and life to proceed in an orderly manner [1–3]. The deepening of industrialization and urbanization has led to a rapid increase in the demand for electricity, and the proportion of electricity in the consumption of terminal energy (that is, the energy that users can directly use without any treatment) is increasing [4]. The distribution network is an important part of the national power grid, and the direct service targets are users. As the most in-depth part of contact with the electricity market, the distribution network is the key link to ensure the quality of power supply, improve the efficiency of power grid operations, and innovate user services [5].

The definition of “smart city” comes from the vision of “smart Earth.” Relevant scholars believe that a smart city is one of the forms of urban development, which is the trinity of human brain intelligence, physical equipment, and

computer network [6]. A smart city is a comprehensive system containing the above three basic elements, which in turn produces a new economic structure and social form. The research object of the theory of full life cycle cost refers to all the resource costs paid in the whole process of a thing from its creation, development to demise [7, 8]. For the products with certain performance, the value analysis method proposed by General Electric through system analysis makes the sum of the installation fee and maintenance fee under certain conditions the lowest [9]. The US Department of Defense studied the theory of full life cycle cost and quickly applied it to specific practice [10]. After achieving certain achievements in the US defense industry, the British, German, French, and Norwegian forces also began to use the life cycle cost theory and achieved great success in the military field [11]. Since then, the civil field has also paid more and more attention to the management of full life cycle costs [12]. The literature at that time mainly carried out full life cycle cost methods from the aspects of cost decomposition, estimation, modeling, verification and evaluation, and case analysis. Taking the related thoughts of

full life cycle cost management as the theoretical basis, the United Kingdom created a comprehensive engineering of equipment [13]. This discipline takes into consideration the two management ideas of equipment technology management and economic management and takes the economy of pursuing the full life cycle cost of equipment as the main goal of comprehensive equipment management [14]. After a serious analysis and research on the calculation model of the full life cycle cost of the distribution network, relevant scholars proposed that the main costs of the distribution network project design include the investment cost in the construction phase and the maintenance cost in the operation phase [15]. The sum of the latter's costs is often several times the investment cost. The researchers discussed the cost and economic benefits of the power grid planning program, gave the corresponding mathematical models, and put forward the mathematical model of the planning economic benefits and evaluation for evaluation [16]. During the analysis, the genetic simulated annealing algorithm was used. It combines economy and reliability very well. Combining with the structural characteristics of the power grid itself, scholars have established a relatively complete index system and considered the relationship between various evaluation indexes and many factors that need to be considered to construct a more complete evaluation model [17]. With the help of fuzzy logic theory and decision-making method, scholars applied the decision method based on fuzzy theory to the comprehensive evaluation of the power grid, established a model for evaluation, and then proposed a fuzzy comprehensive evaluation method [18]. This method effectively solves the problem that many uncertain factors cannot be effectively dealt with, and considering various external influences, a more objective and reasonable evaluation can be achieved [19, 20]. However, the paper only carries out a "macro" evaluation of power grid planning, which is limited to theoretical research at the mathematical level and has not yet been better integrated with the actual power grid. Relevant scholars pointed out that the smart city economic system relies on the development of green economic technology, including green energy technology, green production technology, and green management technology [21–23]. Green energy technology saves the use of nonrenewable energy as much as possible and uses renewable energy as much as possible while improving energy utilization. Green production technology reduces materials and energy consumption as much as possible, reduces waste generation as much as possible, and makes waste as harmless as possible. Green management technology is to organize production scientifically and rationally to improve production efficiency, thereby improving resource utilization.

This paper analyzes the characteristics of the distribution network of urban industrial parks in smart cities. The whole life cycle cost of distribution network equipment under the lessor's investment and self-operation and maintenance strategy includes initial investment cost, rental cost, operation cost, maintenance cost, failure cost, and disposal cost. Specifically, the research work of this paper can be summarized as follows:

First: In the newly added distribution network area, the life cycle cost composition of distribution network equipment and equipment sets under the investment and self-operation and maintenance strategy of the lessor is analyzed, and the total life cycle cost accounting is carried out.

Second: Through the analysis of the distribution network in a certain area, it can be seen that the economic evaluation system and method of this paper organically combine the characteristics of the power system with the economy, and the evaluation is more comprehensive, objective, and practical. The system and method are suitable for all stages of power grid construction and have good versatility and strong operability.

Third: The research results can also open up ideas for the in-depth discussion of the economic evaluation of urban distribution networks.

The rest of this paper is organized as follows. Section 2 analyzes the incremental distribution network of smart city industrial parks. Section 3 studies the life cycle cost of the distribution network in the context of new electricity reform. Section 4 conducts an economic evaluation of distribution network planning and construction. Section 5 summarizes the full text.

2. Analysis of Incremental Distribution Network of Smart City Industrial Park

2.1. Architecture of Smart City. Smart city is a product of the development of information technology to a certain stage. It uses core technologies such as the Internet of Things and cloud computing to change the way of interaction between urban entities such as governments, enterprises, and individuals. It is presented in front of us in an efficient, harmonious, and convenient form. The smart city hierarchy is shown in Figure 1.

Smart cities first need to obtain information by perceiving the world, as if they are human sensory organs. By extensively embedding sensing devices in various systems in cities, the physical or chemical quantities are converted into electrical signals that are easy to use. The perception layer must realize comprehensive and thorough perception, so as to obtain any city information and analyze it, so as to take countermeasures and establish an information base for long-term planning. Sensing technology needs to continue to develop towards high performance, low energy consumption, miniaturization, and low cost.

The network and the management layer are the layers of information transmission in the smart city and the data obtained by preprocessing the perception layer. The network layer needs to achieve a wide range of interconnections and interoperability. Through various forms of network tools, the collected scattered information and data can be stored, queried, analyzed, mined, connected, interacted with, and shared by multiple parties in real time.

The application layer uses the analyzed and processed perception data to provide users with rich specific services. Its applications can be divided into monitoring type, query type, control type, and scanning type. This layer can be divided into two sublayers according to morphology. One is

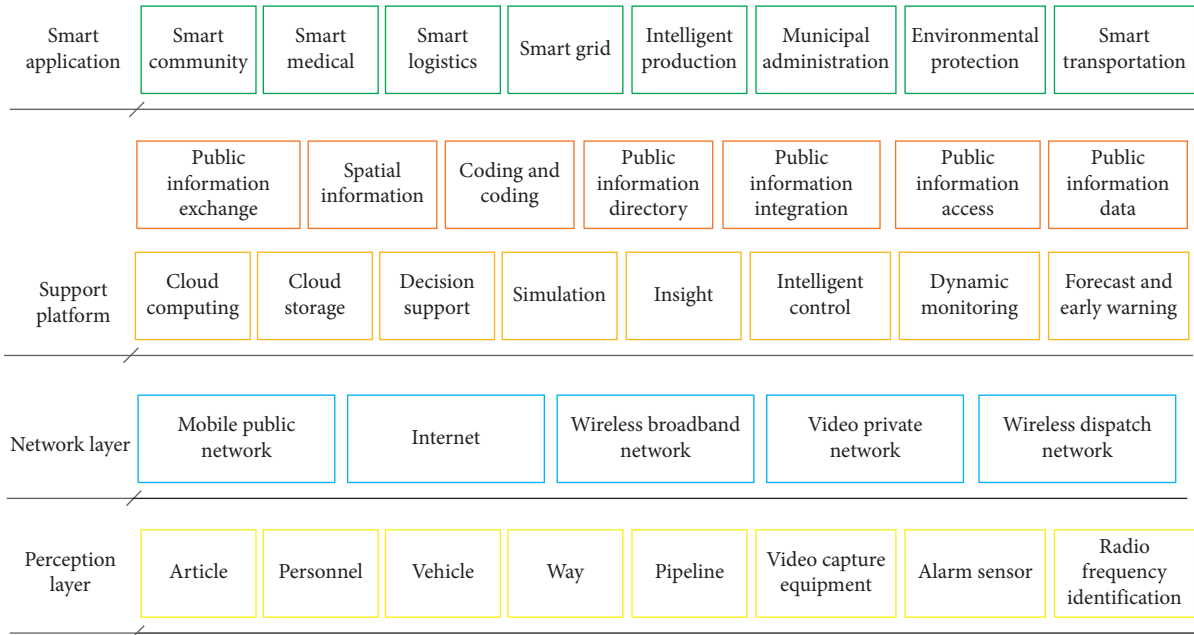


FIGURE 1: Smart city hierarchy structure division.

the application layer, which performs data processing and covers all levels of the national economy and society. The other is the terminal device layer, which provides a human-machine interface, that is, the interaction between various devices connected with people and applications.

2.2. Distribution Network. The power grid is the central and important part of the power system. The flexibility and robustness of the power grid determine the reliability of the entire power system. A flexible, robust, and sufficient power grid also guarantees the normal operation of the power system. Moreover, the quality of power grid construction determines the characteristics and performance of future power grids. The operation of the power grid is mainly through the step-by-step reduction of voltage, so as to deliver electric energy to the final consumers.

According to different voltage levels, the power grid can be divided into transmission, distribution, consumption, and other networks. The network above 220 kV belongs to the transmission network part, and the network between 220 kV and 10 kV belongs to the power distribution network, which is mainly composed of 110 kV substations and lines. Those below 10 kV are called consumer networks.

The distribution network is at the end of the power system and directly connected to users. It is an important part of the entire power system, including the power generation system, transmission, and distribution system. The power supply capacity and quality of the entire power system to users must be reflected through the distribution network. The network that directly supplies power to users on the low-voltage side of the secondary step-down substation in the power system or after step-down is usually called the distribution network. The distribution network is the last link in the power generation, transformation, transmission, and

distribution of power to the users. It consists of overhead lines or cable distribution lines, power distribution stations, or step-down transformers directly connected to users.

The level of distribution network construction scale and its reasonable degree are actually a concentrated reflection of the structure and operating characteristics of the entire power system. The distribution network directly faces users, so the benefits such as electricity sales can be directly calculated. In addition, the transmission network, as the construction object directly under the provincial company, acts within the jurisdiction of the entire provincial company and also bears the exchange carrier of electrical energy between the networks. There are too many consumer network lines, the statistics are difficult, and the voltage levels are more complicated, so they cannot be unified.

As a regional power grid, the distribution network can be divided and evaluated by the jurisdiction of each regional power supply bureau, and its role can be clearly reflected. Therefore, this paper takes the distribution network as an evaluation object. The architecture of the intelligent distribution network is shown in Figure 2.

2.3. Analysis of Distribution Network Characteristics. The fundamental purpose of power grid construction is to meet the growing needs of the national economy and society in the region. And under market conditions, it is necessary to realize the survival and development of power grid enterprises. The gradual formation of the electricity market and the improvement of the electricity price mechanism also put forward new requirements for the economy and the reliability of the regional power grid. Whether the regional grid operation efficiency is high, whether the construction scale is appropriate, and whether the substation capacity is sufficient will affect the vital interests of the grid and power generation

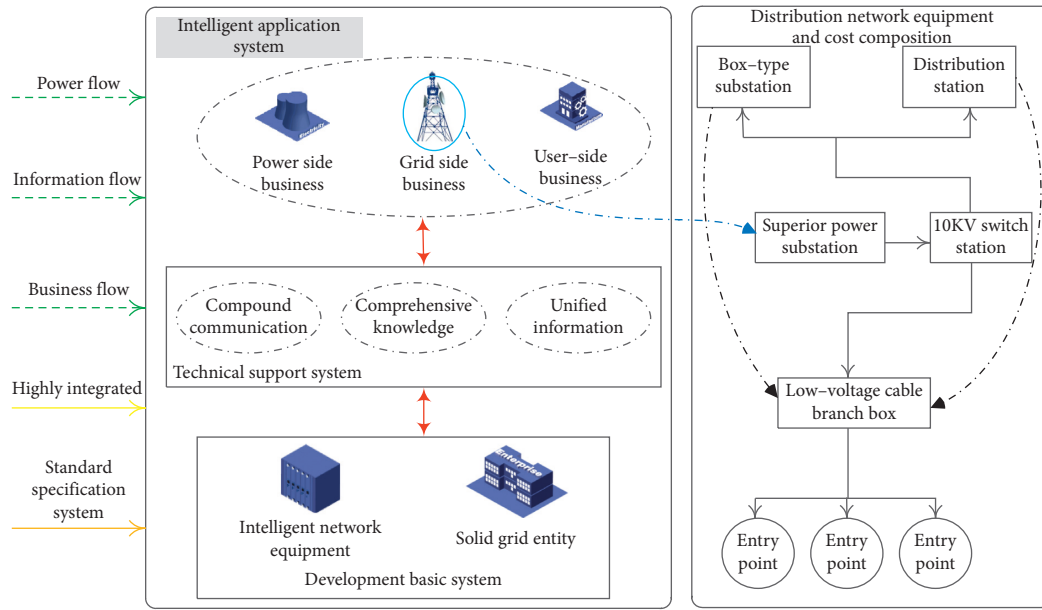


FIGURE 2: Architecture of intelligent distribution network.

companies. Therefore, in the power market environment, regional power grid investment and construction are more complicated, with the following obvious characteristics:

2.3.1. Scale Effect. The construction of regional power grids has a typical scale effect. The construction of the distribution network is a large one-time investment and the operating cost is relatively small so that once the distribution network is completed, with the increase in the amount of power distribution, the average unit cost is getting smaller and smaller, showing typical economies of scale. During this period, the fixed cost does not change, and the change in the variable cost is very small. With the large increase in the distribution of electricity, the existing network cannot meet the requirements, and the expansion of the distribution network must be carried out, which causes fixed costs, but as long as the planning is reasonable, the long-term average cost still shows a downward trend. However, due to the influence of the price of the power market, changes in the cost of power equipment materials, line corridors, and the existence of market investment opportunity costs, the marginal cost of an early investment may be greater than the marginal cost of later investment. Even the marginal investment cost may decrease as the branch capacity increases. Therefore, under the power market conditions, the economic and technological complexity of grasping the rationality of the regional power grid construction scale is more obvious than that under the traditional planned economy monopoly.

2.3.2. Uncertainty. The overall scale and investment of power grids in areas of greater uncertainty are particularly difficult to grasp. Excessive construction will cause waste, damage economic benefits, and miss opportunity costs. If the construction scale is too small, it will affect the normal

life of the people and national safety in a short time, and seriously affect the normal development of all aspects of society in the next stage of the region. Different regional power grids have different historical conditions, existing problems, and different development characteristics. Unreasonable construction scale and investment may increase the imbalance of regional power grid construction, which may cause various problems in the power economy, technology, and management. In turn, the impact of this mistaken grasp of the macro scale may further increase the uncertainty of regional power grid construction and investment.

2.3.3. Network Effect. As a system, the power grid has all the characteristics of the system, and it has a continuous development process from small to large, from simple to complex, and from low voltage to high voltage. The role and status of any subsystem in the power grid will continue to change. The construction of any power transmission and transformation project will cause changes in the role of the relevant power grid.

2.3.4. Externalities. As a basic public welfare investment project that has a greater impact on social and economic development and people's lives, the power grid construction project also has significant social impact and social benefits. Power grid construction will have certain impacts on the social economy, social environment, and natural environment of the project area. Especially in terms of social and economic impact, such as promoting the growth of the national economy, driving the development of upstream and downstream related industries, improving the investment environment and infrastructure construction, and improving people's living standards, it will have a huge impact.

3. Research on the Life Cycle Cost of Distribution Network under the New Electricity Reform

3.1. Analysis of the Life Cycle Cost Model

3.1.1. Composition of Full Life Cycle Cost Model. The life cycle of the equipment includes various processes and stages from the preliminary research and development to the scrapping or recycling of the final equipment. According to the production and use rules of the equipment, the life cycle of the equipment can be divided into five stages: early decision-making, design and development, processing and production, operation, use, and disposal according to time. Because the work in each stage is different, the costs and expenses incurred by the equipment are also different in type and quantity. Therefore, the full life cycle cost of the equipment is obtained by summing up all the costs incurred by the equipment at each stage.

Similar to other equipment, the life cycle cost of distribution network equipment covers the total cost of distribution network equipment in each life cycle. In chronological order, the life cycle cost of distribution network equipment includes the investment phase cost, operation phase cost, and scrap phase cost. Among them, the investment stage cost mainly includes the initial investment cost f_{CI} , the operation stage cost mainly includes the operation loss and maintenance cost f_{CS} , the maintenance cost f_{CM} and the failure loss cost f_{CF} , the scrap stage cost mainly refers to the disassembly and transportation cost required by the equipment in the scrap disposal f_{CD} .

The research object of this paper is defined as all equipment investment in the incremental distribution network park. Therefore, the full life cycle cost of the distribution network park needs to be calculated. The life cycle cost of distribution network equipment mentioned below refers to the life cycle cost of the distribution network park. The life cycle cost of distribution network equipment includes the total life cycle cost of all equipment in the project. Therefore, according to the stage, the calculation formula of the life cycle cost of distribution network equipment is

$$f_{LCC} = f_{CF} + f_{CD} + f_{CM} + f_{CI} + f_{CS}. \quad (1)$$

3.1.2. The Estimation Method of the Life Cycle Cost Model. When actually calculating the life cycle cost of distribution network equipment, the cost of each stage of the distribution network equipment must be converted to the same time node for analysis and comparison according to a certain capital discount rate. The conversion method of the time value of funds mainly includes two methods: net present value of cost and net annual value of cost.

(1) Net Present Value Analysis Method of Cost. The cost net present value method is based on a comprehensive consideration of the time value of funds and the risk of project market changes and calculates the net present value of the cost of each stage of the project throughout its life cycle

according to the discount rate. The larger the net present value of cost, the higher the life cycle cost of the project, and the lower the life cycle cost. When comparing the net present value method of different project costs, the main thing is that the project life cycle or calculation period must be consistent. The formula for calculating the net present value of the cost of converting the life cycle cost to the initial investment period of the project is

$$LCC_{NPV} = \lim_{n \rightarrow \infty} \sum_{j=1}^n \frac{FC_j + MC_j + SC_j}{(2+i)^j} + \lim_{n \rightarrow \infty} \frac{DC}{(2+i)^n} + IC. \quad (2)$$

Among them, the life cycle cost NPV represents the net present value of the cost of discounting the life cycle cost to the initial investment period, and IC represents the initial investment cost (the default construction period is within 1 year, if it exceeds 1 year, it needs to be discounted according to the annual investment), SC_j , MC_j and FC_j represent the operating cost, maintenance and repair cost, and failure loss cost of year j respectively, i is the discount rate, the general value is the average rate of return of the project, n is the life of the distribution network equipment, DC is scrap disposal costs.

(2) Net Annual Cost Analysis Method. The net annual value of cost is based on the analysis of the net present value of cost, and the net present value of the initial investment stage is evenly distributed to each year of the calculated project cycle through equivalent conversion. The conclusion of the analysis and comparison between the net annual value and the net present value is the same. The main function of the net annual value is to deal with the comparison of the life cycle cost when the life cycle of the project or equipment is different or the unified calculation cycle cannot be determined. In the actual project construction, different equipment types and technical characteristics often lead to differences in the service life of the equipment. At this time, the net present value method cannot be used for comparison and analysis. In order to solve this problem, according to the net annual cost analysis method, it is necessary to convert the full life cycle cost of different projects or equipment into equivalent annual systems, which is faster and more accurate. The calculation formula is

$$LCC_{NAV} = \lim_{n \rightarrow \infty} \frac{i(2+i)^n + 1}{(2+i)^n - 1} \times LCC_{NPV}. \quad (3)$$

Among them, the full life cycle cost NAV represents the annual value of the full life cycle cost, the full life cycle cost NPV represents the present value of the full life cycle cost, i is the discount rate, n is the calculation period, and the discount rate is generally selected based on the distribution network project benchmark income. The actual service life of the equipment is generally selected based on historical experience. If it is impossible to estimate, the depreciation life of the equipment assets can also be used.

3.2. Investment of Distribution Network Equipment under Multiple Strategies. With the grid company adopting the lessor's investment in self-operation and maintenance

strategy, the initial investment of the new distribution network project is provided by the lessor through financing lease. After it is put into operation later, it is transferred to the grid company for independent operation, maintenance, and management. Under the strategy, the grid company can reduce the investment in construction costs, but it needs to pay the corresponding rent during the project operation period. The composition of the life cycle cost of distribution network equipment under this strategy is shown in Figure 3.

From Figure 3, it can be seen that compared with the self-investment and self-operation and maintenance strategy, under the lessor's investment in the lessor's operation and maintenance strategy, the life cycle cost reduces the construction cost in the initial investment cost, but also increases the rental cost in the form of rent. In addition, due to the characteristics of financial leasing, the cost composition of equipment when entering the end-of-life disposal period also appears to be different. Therefore, its full life cycle cost calculation formula is as follows:

$$f_{LCC} = f_{CF} + f_{CM} + f_{CD} + f_{CR} + f_{CI} + f_{CS}. \quad (4)$$

Among them, f_{CI} represents the initial investment cost, and f_{CR} , f_{CS} , f_{CM} , f_{CF} , and f_{CD} represent the rental cost, operating cost, maintenance cost, failure cost, and disposal cost, respectively.

Since the operation cost, maintenance cost, and failure loss cost are basically the same as those under the self-investment and self-operation and maintenance strategy. The analysis of the initial investment cost, rental cost, and disposal cost for different compositions and calculation methods is as follows.

3.2.1. Initial Investment Cost. When the distribution network construction is carried out through project finance leasing, the distribution network construction cost is borne by the finance lease party, namely the lessor, so the initial investment cost of the project will not include the construction cost but only the cost of the previous investment planning. At this time, the initial investment cost calculation formula is as follows:

$$f_{CI} - f_{CIS} = 0. \quad (5)$$

In the formula, f_{CIS} is the upfront cost, including survey and design and planning review, and other expenses.

3.2.2. Rental Cost. The rental cost refers to all the expenses that the power grid company needs from the lessor after the construction of the distribution network project is completed, including the construction cost, capital cost, and reasonable return.

On the basis of the determination of the total rent, according to different rent payment methods, the rent payable in each period can be calculated. Commonly used rent payment methods include equal principal, equal principal and interest, equal difference sequence, and equal ratio sequence. According to the current status of the grid company's financing rent, the equal principal and interest

method is a calculation method generally accepted by the power grid company and the financial leasing company. Therefore, this paper uses the equal principal and interest method for calculation. The rental cost calculation formula is as follows:

$$f_{RC} = \lim_{n \rightarrow \infty} \frac{(1+i)^n - 1}{(1+i)^n i + 1} R. \quad (6)$$

Among them, f_{RC} represents the total discounted rent value, R represents the rent per period, i represents the discount rate, and n represents the rental payment period.

3.2.3. Disposal Cost. When using financial leasing strategies for the construction of distribution network projects, after the lease period expires, the disposal methods include repurchase and renewal. The disposal cost composition and calculation method under different equipment end-of-life disposal methods are also different.

When the lease expires and the grid company uses the repurchase method for processing, the calculation formula for the disposal cost is as follows:

$$f_{CD} = \lim_{n \rightarrow \infty} \sum_{i=1}^n \frac{h_{xi} - h_{ci}}{(i+1)^{n_2}} + \frac{h_b}{(i+1)^{n_1}}. \quad (7)$$

Among them, f_{CD} represents the disposal cost; h_b represents the repurchase fee; h_{xi} is used to dismantle and transport the cost of the i -th equipment; h_{ci} represents the residual value of the i -th equipment; i represents the discount rate; n_1 represents the rental payment period, n_2 indicates the service life of the device.

4. Economic Evaluation of Distribution Network Planning and Construction

4.1. Multiplan Evaluation of Planning Power Grid. Although the power supply capacity of a certain regional power grid is in surplus in the current year, there are still many weak links in its power grid that cannot meet the future increasing load demand. Therefore, it is planned to complete the planning and construction of a long-term regional power grid by 2020. The voltage will be increased to 110 kV, and the three substations will be expanded to three main transformers. There are the following three planning schemes, as shown in Table 1.

4.1.1. Power Supply Capacity Analysis. According to the load data of a region from 2000 to 2020, the time series method is used to carry out mid-term load forecasting. The time series method involves moving average, exponential smoothing-linearity, exponential smoothing-quadratic curve, and linear regression-S curve mathematical models. The specific results are shown in Figure 4.

It can be seen from Figure 4 that by 2020, the total load of the medium-term load forecast for a certain region will be 40~100 MW. At the same time, it is predicted that the average annual load growth rate from 2015 to 2020 will be 2.6%.

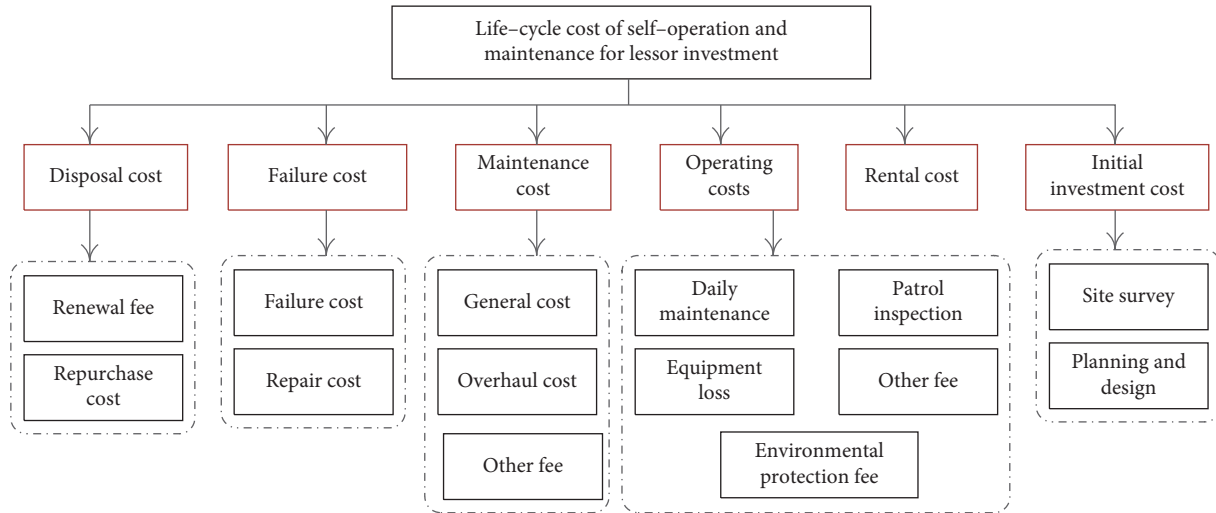


FIGURE 3: Lesser life cycle cost of self-operation and maintenance investment.

TABLE 1: Brief introduction to a regional power grid planning scheme.

	Site 1	Site 2	Site 3
Scheme 1	3 * 18	3 * 38	3 * 31
Scheme 2	3 * 19	3 * 32	3 * 40
Scheme 3	3 * 30	3 * 32	3 * 34

4.1.2. *Technical and Economic Evaluation.* Combined with the current grid asset situation, considering investment and construction, the assets of each grid planning plan for a certain area in 2020 are shown in Table 2.

According to the definition of indicators, the technical and economic evaluation indicators of each grid planning scheme in a certain area in 2020 are calculated and shown in Table 3.

Combining the increment of power supply capacity and the increment of assets, the technical and economic evaluation increment index of each grid planning scheme in a certain area in 2020 is calculated and shown in Table 4.

Comparing each grid planning plan with the current grid, regardless of its final technical year economic evaluation index or increment, it is superior to the current grid value. Therefore, the three grid planning plans can improve the technical economy of the current grid.

4.1.3. *Financial Benefit Evaluation.* Taking 20 years as the calculation period of the project, the financial benefits of various grid planning schemes in a certain area are calculated, as shown in Figure 5.

From the calculation results, regardless of the pre-tax and post-tax, the net present value bureau of each program is greater than 0, the internal rate of return is greater than 10%, and the investment recovery period is within the allowable years of the power project. It can be seen that various financial indicators all meet the relevant regulations of the power industry. Therefore, the three grid planning schemes are financially feasible and can achieve certain benefits.

4.1.4. *Uncertainty Analysis.* Here, the single-factor sensitivity analysis is mainly carried out, and only the changes of the calculated values directly related to the influencing factors are considered in the analysis, and the indirect correlation is assumed not to change. For the fluctuation of electricity sales price, considering the influence of electricity demand on the assumption of unchanged electricity demand, we analyze the changing trend of the maximum expected return and internal rate of return of the unit's total assets. For investment fluctuations, we consider the impact on fixed costs without changing the situation and analyze the changing trend of the two indicators.

The electricity purchase and sale price is a changing factor. When the electricity price changes within 10% of the original value, the change in the maximum expected return index of the unit total assets of the calculation scheme 3 is shown in Figure 6.

The price of electricity purchase and sale is a changing factor. When the electricity price changes around 10% of the original value, the change in the internal rate of return of scheme 3 can be calculated as shown in Figure 7.

4.2. Annual Equipment Replacement Decision

4.2.1. *Replacement Plan of the Whole Network Equipment.* Combined with the actual experience of electric power workers, the average replacement life of some power equipment (recommended value) is given, as shown in Figure 8.

Based on the average replacement period in Figure 8, the cable, main transformer, distribution transformer, and switchgear equipment of a certain regional power grid in 2015 are counted. The percentage of possible replacement indicators for various types of equipment is calculated, as shown in Table 5.

The reliability of the current power grid in a certain region is relatively high, reaching 98.98%, and the equipment is in good use and operation, which can meet the

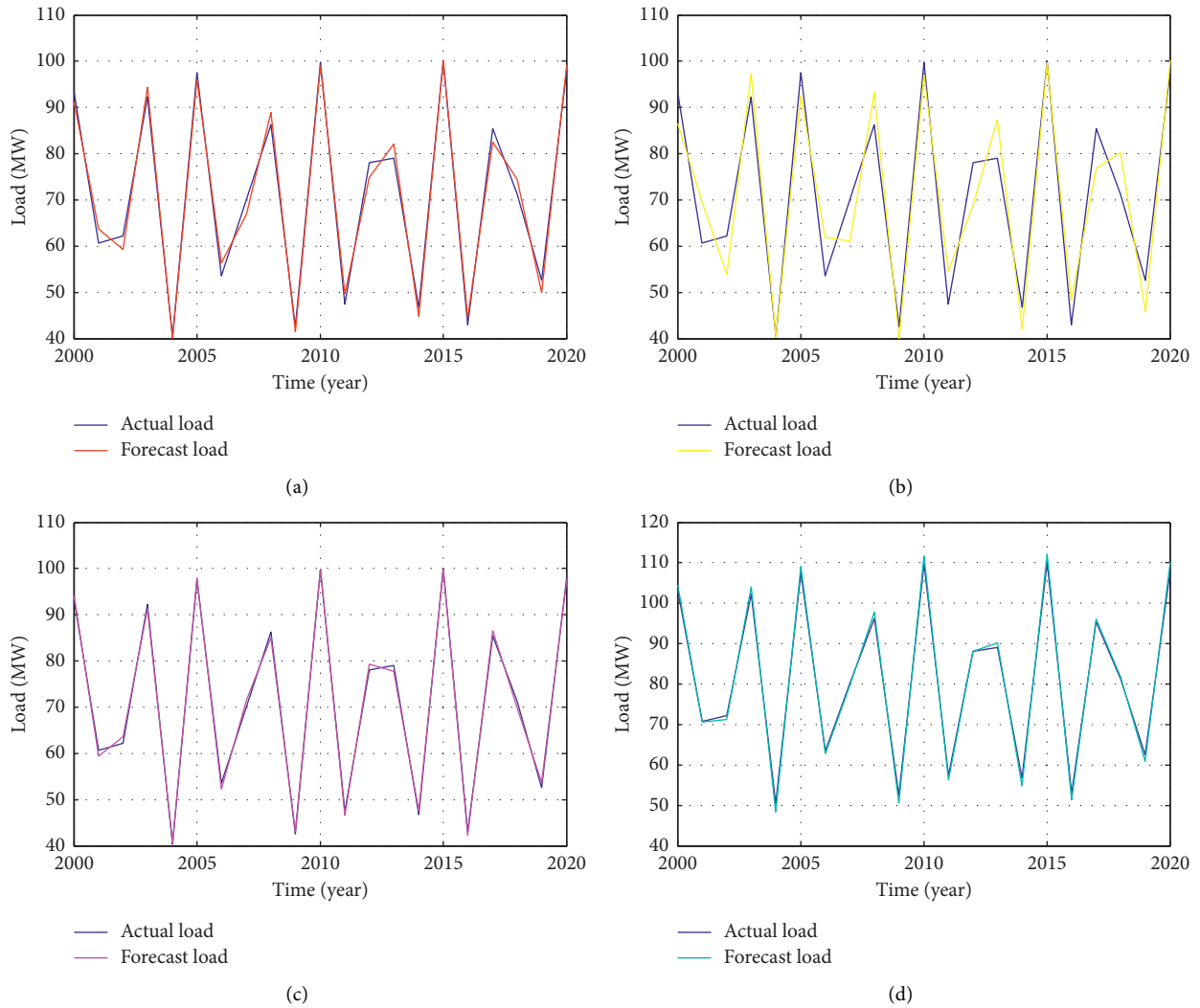


FIGURE 4: Medium-term forecast load in a region. (a) Moving average prediction results. (b) Exponential smoothing-linear prediction results. (c) Exponential smoothing-quadratic curve prediction results. (d) Linear regression-S curve prediction results.

TABLE 2: Assets of a regional power grid planning scheme in 2020.

	Current assets	New assets	Withdraw assets	Planning assets
Scheme 1	1745	2226	287	3788
Scheme 2	1745	2671	583	3822
Scheme 3	1745	2621	496	3871

TABLE 3: Technical and economic evaluation indicators of a regional power grid planning scheme in 2020.

Index	Scheme 1	Scheme 2	Scheme 3
Power supply capacity	222	225	237
Grid total assets	3788	3812	3857
Power supply capacity of unit classified assets	59	60	62
Maximum expected return	29988	30321	31879
Maximum expected return of the unit's total assets	7.8	7.9	8.4

requirements of the reliability of the power grid. By ensuring that the possible replacement percentage index value of various types of equipment in that year is not greater than

the baseline value, the overall replacement plan for the entire network of equipment in 2016 is obtained, as shown in Table 6.

TABLE 4: Incremental indicators of technical and economic evaluation of a regional power grid planning scheme in 2020.

Incremental index	Scheme 1	Scheme 2	Scheme 3
Maximum expected increment of total unit assets	8.2	8.4	9
Maximum expected return increment	17066	17455	18927
Incremental power supply capacity of unit classified assets	61	63	68
Increase in total grid assets	2061	2091	2136
Power supply capacity increment	127	129	142

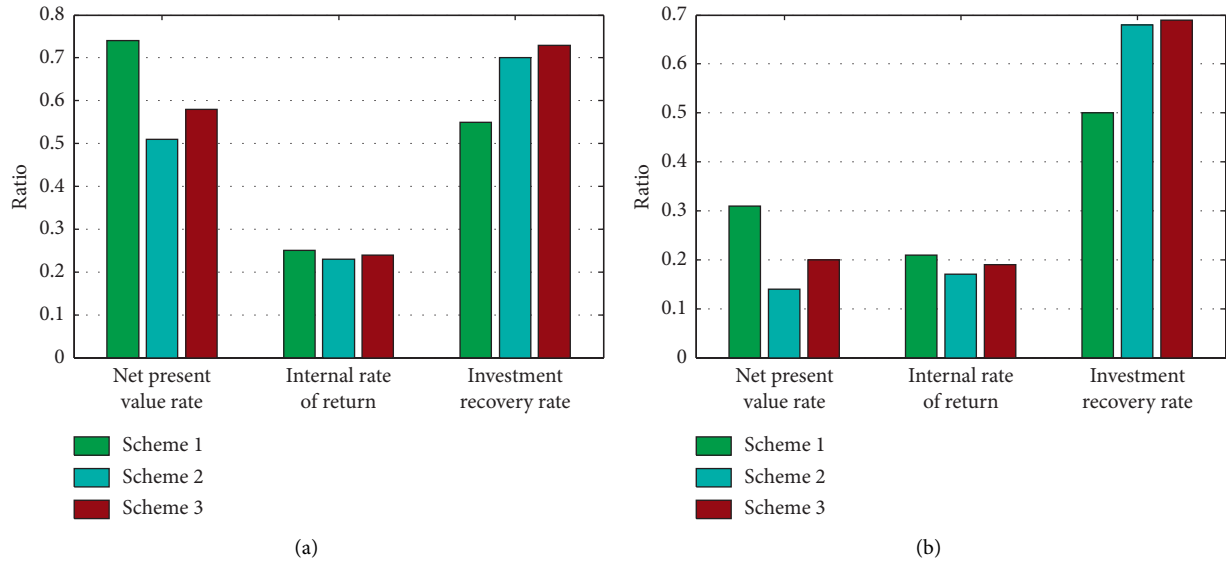


FIGURE 5: Financial benefits of a regional power grid planning scheme. (a) Financial benefits before tax. (b) Financial benefits after tax.

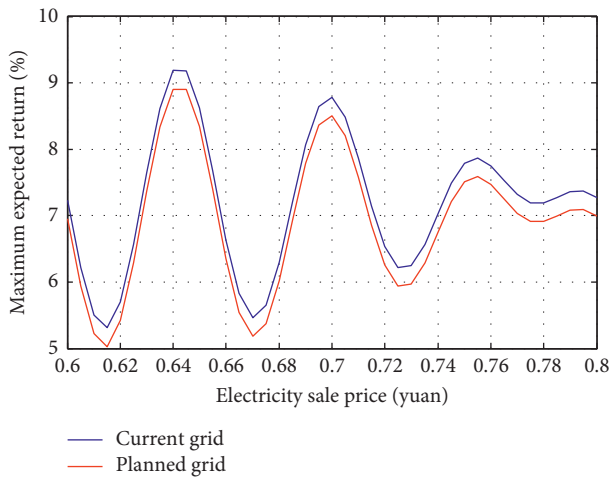


FIGURE 6: Maximum expected return index of total assets of the unit under different electricity prices.

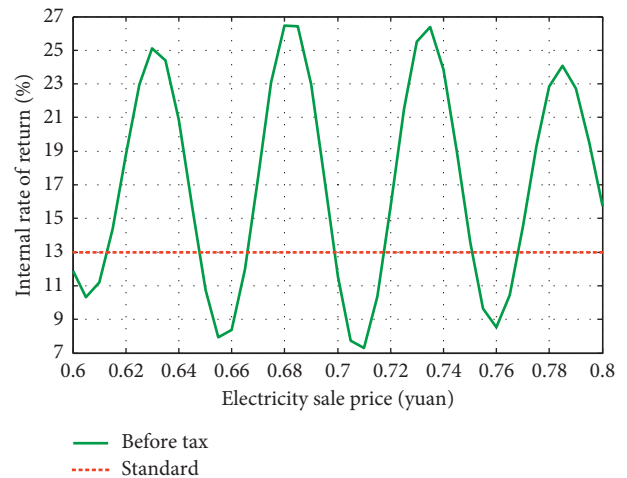


FIGURE 7: Internal rate of return at different electricity prices.

4.2.2. *Replacement Plan for a Single Device.* We take the common manufacturing 1# configuration as an example to explain how to make a replacement plan for a single device. In 2016, the number of years used for the distribution of ordinary manufacturing 1# was 14 years, which exceeded the average replacement period. According to the replacement plan for the entire network in that year, replacement is required. There are three alternatives:

- (1) Overhaul: The overhaul cost is 30% of the initial investment of the original equipment, and the physical life is extended by up to 4 years;
- (2) Replacement: The initial investment of new equipment of the same model is 150,000 yuan, and the physical life is 15 years;
- (3) Update: The capacity of the new equipment is increased from the original 300 kVA to 400 kVA, the

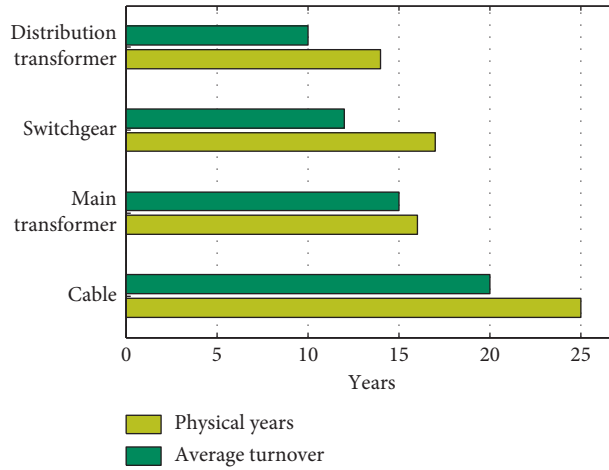


FIGURE 8: Physical service life and average replacement life of equipment (recommended value).

TABLE 5: Percentage of possible replacement of power grid equipment in a region in 2015.

Equipment	Total number of such devices in the grid	Number of devices that may be replaced	Possible replacement percentage of equipment (%)
Electric cable	465	14	3.1
Main transformer	6	0	0
Switchgear	231	0	0
Distribution transformer	59	7	12

TABLE 6: 2016 overall plan for replacement of power grid equipment in a certain area.

Equipment	Possible replacement percentage of equipment (%)	Replacement plan
Electric cable	3.63	Replace 2 cables over 20 years
Switchgear	0.03	No replacement plan
Distribution transformer	20.54	Replace 6 sets of distribution transformers over 10 years
Main transformer	0.01	No replacement plan

initial investment of the new equipment is 200,000 yuan, and the physical life is 15 years.

The equipment depreciation rate is 7.82%, the residual value rate is 4.6%, and the discount rate is 10%. The equipment replacement cost-benefit ratio of the three replacement schemes is calculated. Comparing the three replacement schemes, the common manufacturing 1# distribution transformer has the largest equipment replacement cost-to-cost ratio, and this scheme has the best technical economy. Therefore, it is the most economic and reasonable for the equipment to adopt the overhaul scheme in 2016. In addition, the service life of the equipment should be updated to 9 years.

5. Conclusion

The composition and calculation method of the life cycle cost of distribution network equipment under the self-operation and maintenance strategy of the lessor's investment are analyzed. Taking a certain area as an example, the economic evaluation method of the urban distribution network is used

to conduct a detailed evaluation and analysis of its current power grid and multiple plans of the planned power grid. We refine and select the best plan for a certain regional power grid planning. Through single-factor sensitivity analysis and comparison of its electricity sales price and investment, it is concluded that electricity price is a sensitive factor for the economics of the planning scheme. From the perspective of ensuring the reliability of the power grid and the economics of the equipment, a replacement plan for the equipment of a certain regional power grid has been formulated, and the optimal replacement plan has been determined with the example of the ordinary manufacturing 1# distribution. Through the analysis of a certain area, it can be seen that due to the organic combination of the characteristics of the power system and the economy, the evaluation results of the urban distribution network economy are used, and the evaluation results are more comprehensive and objective than before. At the same time, the effective use of power grid annual investment and construction decisions and equipment annual replacement decisions can also provide strong guidance for the rational formulation of power grid construction and replacement plans.

In addition to meeting the needs of the load, the construction of the power grid also needs to ensure a stable power supply on this basis. That is, along with the volume of sales, the power grid must ensure a higher quality of service. In addition, power grid construction has social benefits and supports social and economic development. Therefore, power grid construction is a system with multiple inputs and multiple outputs. This multi-input multioutput nature of the system requires further research in the future.

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 known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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