Research on Economic Benefit Calculation Method of Typical New Power Grid Project Under New Power System

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Abstract. Frequent natural disasters and extreme weather events have encouraged governments around the world to speed up efforts to promote low-carbon transformation in various sectors. Under the goal of "double carbon", the construction of new power system has been continuously promoted, and the following new investment related to power grid has also gradually increased. From the perspective of power grid companies, based on the overall study of the economic benefits of new investment in power grid under the new power system, this paper classifies and analyzes the relevant investment in power grid under the new power system based on the scenario analysis method, studies the cash inflow and outflow of various typical new investment in the new power system during the whole life cycle, and gives the relevant calculation scheme, which is the direction of new investment in power grid under the new power system Investment scale and investment income provide scientific basis for economic benefit measurement.

Keywords: Economic benefit · New power system · Economic benefit calculation

1 Introduction

Under the "double carbon" goal, it is imperative to build a new type of power system based on new energy. Under the new situation, power grid enterprises have also generated new demand for investment projects, it is necessary to analyze and measure the economic benefits of new investment projects of power grid by category.

Under the new power system, new energy consumption and distributed wide access are the key points of power grid investment [1]. The benefit of power grid investment mainly refers to the economic benefit analysis of the result of power grid investment, and the quantitative expression of the benefit generated within the depreciation period

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in the form of internal rate of return, rate of return on investment, net present value [2]. The literature [3] improved the TOPSIS method based on the benefit assessment index system and constructed a grid investment benefit index system suitable for the characteristics of the Chinese distribution grid. The literature [4] analyzed the benefit level of the grid under different planning schemes based on the whole life cycle input-output model. The literature [5] analysed the economic benefits of deploying energy storage in PV systems by studying the net present value, discounted reporting period, and benefit-cost ratio. The literature [6] considered the time value of money, whole life cycle cost and other factors, and established a grid input-output benefit evaluation model to analyse the economic benefits of grid investment. The literature [7] proposed an improved index system for evaluating the efficiency of grid investment projects, and evaluated the investment effectiveness as well as the efficiency of actual grid projects. The literature [8] considered the time-series characteristics of distributed power sources such as wind power and photovoltaic and electricity load, and carried out multi-objective optimization of the distribution grid investment strategy. The literature [9] constructs a two-level distribution grid project investment efficiency evaluation index system, which provides a scientific and reasonable evaluation of the distribution grid project investment efficiency. The literature [10] established a hierarchical and comprehensive evaluation index system to evaluate the investment benefits of county-level distribution networks.

In summary, this paper establishes a model for measuring the economic benefits of new investments in power grids and analyses the cash flows of various typical new investment projects in power grids over their whole life cycle to provide some reference for the investment measurement of actual power grid planning projects.

2 Economic Efficiency Model for New Investment in Typical Power Grids Under New Power Systems

Through the economic benefit measurement of power grid investment, we can understand the economic benefits of power grid investment projects, and provide certain theoretical support for future power grid investment decisions, so as to improve the rationality and scientificity of power grid planning and construction.

The economic benefit model of new investment in typical power grid under the construction of new power system is shown in Eq. 1:

$$B_{eco} = I_{all} - C_{all} \tag{1}$$

where, B_{eco} is the economic benefit of new investment in power grid, I_{all} is the present value of cash inflow in the whole life cycle, C_{all} is the present value of cash outflow in the whole life cycle.

The measurement of economic benefit can provide reference for investment decision by calculating internal rate of return and investment rate of return.

Internal rate of return refers to the discount rate when the total present value of capital inflows equals the total present value of capital outflows and the net present value equals zero. Its calculation equation is as follows:

$$\sum_{t=0}^{n} \left[(CI - CO)_t (1 + IRR)^{-t} \right] = 0 \tag{2}$$

where, t represents the year, $(CI - CO)_t$ represents the net cash flow in year t, IRR represents the internal rate of return.

Next, based on the summary of cash inflows and outflows in the whole life cycle, the two typical projects under the construction of new power system - distributed photovoltaic grid connection project and large-scale new energy grid connection project will be studied by scenario economic benefit model.

3 Economic Efficiency Model of New Investment Driven by Distributed Photovoltaic

In this paper, economic benefit analysis is conducted based on three grid connection modes of distributed photovoltaic [11], as shown in Fig. 1.

The main income and expenditure in the whole life cycle of distributed photovoltaic grid investment are as follows:

$$M_g = I_{ps}^1 + I_{sr} + I_{ia} + I_{rv} - (C_{invest} + C_{OM} + C_{retirement}) \tag{3}$$

where, C_{invest} is the cost of the investment stage of the project, C_{OM} is the operation and maintenance cost of the project, $C_{retirement}$ is the cost of the retirement and scrapping stage, I_{ps}^1 is the income from electricity sales, I_{ia} is the income from the network overcharge, I_{sr} is the income from the capacity reserve fee, and I_{rv} is the discounted value of the residual value of fixed assets.

3.1 Main Cash Outflows in the Whole Life Cycle

The cost in the investment stage is mainly divided into design planning cost, equipment purchase cost and construction and installation cost, as shown in Fig. 2.

The cost of the investment phase of the typical new investment project of the power grid under the new power system is calculated as follows:

$$C_{\text{invest}} = C_{\text{DS}} + C_{\text{EP}} + C_{\text{EI}} \tag{4}$$

where, C_{invest} is the investment stage cost of the project, C_{DS} is the design and planning cost of the project, C_{EP} is the equipment purchase cost of the project, and C_{EI} is the construction and installation engineering cost of the project.

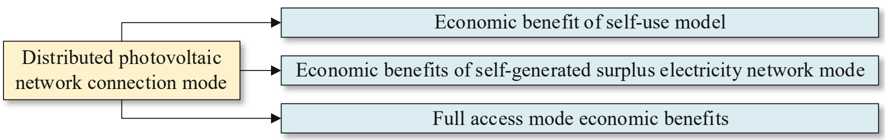

Fig. 1. Three modes of connection of distributed PV

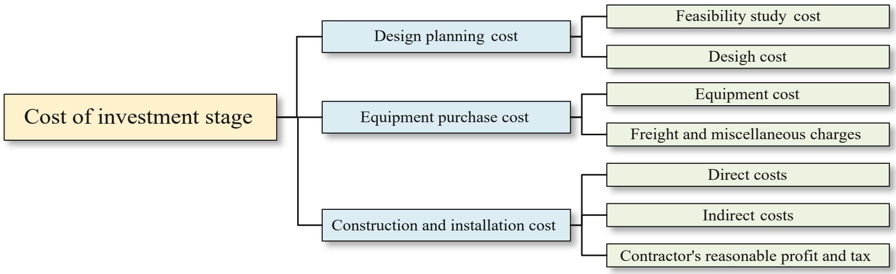

Fig. 2. Cost of power grid investment project in the investment period under the new power system

3.2 Main Cash Inflows in the Whole Life Cycle

The main cash inflows in the whole life cycle include electricity sales income, network fee income, etc.

$$I_{ps}^{1} = \sum_{t=1}^{n}\sum_{v=1}^{4}\sum_{u=1}^{4}[Q_{v,u}^{t} \times P_{v,u}^{t} \times (1 + i_c)^{-t}] \tag{5}$$

where, I_{ps}^{1} is the electricity sales revenue, $Q_{v,u}^{t}$ is the electricity sales volume of the second type of users in the voltage level in the first year, and the value of v is 1 ~ 4, representing the voltage levels respectively, and the value of u is 1 ~ 4, representing the categories of large industry, general industry and commerce, residential and agricultural users respectively. $P_{v,u}^{t}$ is the purchase price of electricity for class I users of the voltage level, and i_c is the benchmark rate of return.

The income from capacity reserve fee of distributed power users is as follows:

$$I_{sr} = \sum_{m=1}^{12}(S_m^t \times p_{sr}^t) \times (1 + i_c)^{-t} \tag{6}$$

$$I_{sr} = \sum_{v=1}^{5}(Q_v^t \times p_{sr,v}^t) \times (1 + i_c)^{-t} \tag{7}$$

When capacity pricing is adopted, the capacity reserve fee income is the standby capacity electricity price income, as shown in Eq. 10, where m is month, S_m^t is the transformer capacity or maximum demand of the user in month m of year t, and p_{sr}^t is the corresponding capacity reserve fee standard.

When pricing according to electricity quantity, the capacity reserve fee income is the price of reserve electricity, as shown in formula (9), where is the voltage level, the value of v is 1 to 5, representing the voltage levels respectively, and $p_{sr,v}^t$ is the capacity reserve charge standard of the user with voltage class v in year t, and Q_v^t is the power that can be supplied by the user's self-owned power plant and distributed power supply of the user with voltage class v in year t.

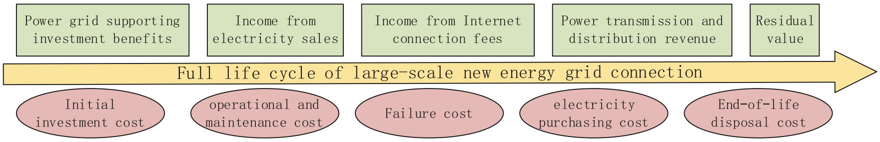

Fig. 3. The life-cycle costs and benefits of large-scale new energy grid-connection

4 Economic Efficiency Model of New Investment Under Gird Integration of Renewable Energy Generation

The main income and expenditure under the grid integration of renewable energy generation are as follows.

$$M_{ne} = I_{ps}^{1} + I_{td} + I_{\mathrm{inte}} + I_{rv} - (C_{invest} + C_{OM} + C_{F} + C_{retirement}) \tag{8}$$

where, C_F is the failure cost of the project, I_{td} is the income from transmission and distribution business, and I_{inte} is the income from large-scale renewable energy network connection fee.

The cost of new energy grid connection is basically the same as that of distributed photovoltaic promotion. The main cash inflows in the whole life cycle include the income from power transmission and distribution, the income from connection fees, the income from electricity sales, and the residual value of fixed assets. The power transmission and distribution income of market trading electricity includes the power transmission and distribution income of large industrial users and the power transmission and distribution income of general industrial, commercial and other users. The life-cycle costs and benefits of large-scale new energy grid-connection are shown in Fig. 3.

The grid charges for large-scale renewable energy are calculated as follows:

$$I_{\mathrm{inte}} = I_{ut} + \alpha_{hybrid} \times I_{rein} \times (1 + i_c)^{-t} \tag{9}$$

where, I_{inte} is the income of large-scale renewable energy connection fee; I_{ut} is the cost of the grid-connected line between the renewable power point and the public substation; α_{hybrid} is the connection fee coefficient; when α_{hybrid} is 0, the connection network is shallow; when $\alpha_{\mathrm{hybrid}} \in (0, 1)$, it is mixed; when α_{hybrid} is 1, it is deep;I_{rein} is the cost of grid enhancement for renewable power access.

5 Empirical Analysis

This paper makes an empirical analysis based on the investment situation of distributed photovoltaic and supporting power grids in Hunan in 2021. The total investment situation of distributed photovoltaic supporting power grids in Hunan in 2021 is shown in Table 1.

The economic benefit calculation results of the new investment are shown in Table 2 (Unit as above).

Table 1. Total investment in distributed photovoltaic and supporting power grids

Voltage Classes	35–110 kV	1–10(20) kV	Less than 1 kV
Grid Investment Cost (Unit: Ten thousand Yuan)	30126.15	38986.78	23923.70

Table 2. Economic benefit calculation results of distributed photovoltaic and supporting power grid

Voltage Classes	35–110 kV	1–10(20) kV	Less than 1 kV
Economic benefit of self-use model	5265.77	5359.30	2749.80
Economic benefits of self-generated surplus electricity network mode	44191.93	45753.75	23324.94
Full access mode economic benefits	54099.49	54099.49	27049.75

6 Conclusions and Suggestions

Based on the typical investment, this paper establishes the economic benefit model of the typical new investment in the power system in the whole life cycle, and based on the scenario analysis method, it makes a theoretical analysis of the two typical scenarios of distributed photovoltaic propulsion and large-scale new energy grid connection, providing a scientific basis for the economic benefit calculation of the new investment in the power system under the new power system.

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References

1. Shu Y, Chen G, He J, et al. (2021) Building a new electric power system based on new energy sources. Strategic Study of CAE, 23:61-69.
2. Xiao Y, Liu X, Wan Y, et al. (2022) Research on the optimization of power grid investment strategy under the supervision of transmission and distribution price——Based on the relationship between transmission and distribution price, power grid investment and socioeconomic benefits. Price: Theory & Practice, No.461:88–92.
3. Niu D, Song Z, Wang M, et al. (2017) Improved TOPSIS method for power distribution network investment decision-making based on benefit evaluation indicator system. International Journal of Energy Sector Management, 11: 595-608.
4. Zhang Q, Dai X, Han X, et al. (2018) An accurate investment method of power grid based on full life cycle unput-output benefit. Electric Power, 51:171-177.
5. Sardi J, Mithulananthan N, Gallagher M, et al. (2017) Multiple community energy storage planning in distribution networks using a cost-benefit analysis. Applied energy, 190: 453-463.

6. Liu Y, Ma Q, Niu W, et al. (2019) Research on Evaluation Method of Grid Investment Benefit. In: 4th International Conference on Advances in Energy Resources and Environment Engineering. Chengdu. p. 062024.
7. He Y, Liu W, Jiao J, et al. (2018) Evaluation method of benefits and efficiency of grid investment in China: A case study. The Engineering Economist, 63: 66-86.
8. Fan X, Wang R, Zhu X, et al. (2023) Multi-objective optimization of distribution network investment strategy considering the time series fluctuation of wind power generation, photovoltaic power generation and power load. Renewable Energy Resources, 41:268-276.
9. He C, Tan X, Zhou X, et al. (2022) Investment benefit evaluation of intelligent distribution network project based on game theory combination weighting. Journal of Electric Power Science and Technology, 37:161-167.
10. Li M, Liu W, Li P, et al. (2020) Method for allocation of country distribution network considering the investment benefit evaluation. Journal of Electric Power Science and Technology, 35:83-89.
11. Chaofan Wang, Yilan Wang, et al. (2023) Cognition process and influencing factors of rural residents' adoption willingness for solar PV poverty alleviation projects: Evidence from a mixed methodology in rural China, Energy, Volume 271, 2023, 127078.