Research on Dynamic Evaluation of Distributed Energy Supply Cost-Benefit for Integrated Energy Service in Campus

Shuo Yin1, Shiqian Wang1, Meng Yang1, Zhe Chai1, Jing Yan2, Qing Chang3, *

1 State Grid Henan Electric Power Company Economic and Technological Research Institute, Zhengzhou, China
2 State Grid Henan Electric Power Company Information and Communication Company, Zhengzhou, China
3 School of Business, Leeds University, Leeds, UK

*Corresponding author e-mail: yinshuo@ha.sgcc.com.cn

Abstract. Zones are natural test fields for integrated energy services. The main operating mode of distributed energy supply business is "energy equipment leasing", which means that users only have the right to use the equipment, and the power distribution company has the ownership of the equipment. Distributed energy supply business uses energy with lower cost and more environmentally friendly processes, in conjunction with related energy equipment, to provide users with daily required cold, heat, electricity, and gas energy for production and daily use. It not only effectively reduces the energy cost of users, but also achieves good environmental protection effect, and it can ensure that the distribution company can recover the initial investment and earn reasonable income. Therefore, this article analyses the cost-benefit structure of the distributed energy supply business based on the working characteristics.

Keywords: Zone; Integrated Energy Service, Distributed Energy Supply; Dynamic Assessment.

1. Cost structure of distributed energy supply business

According to the life cycle theory, the cost structure of distributed energy supply business mainly includes three parts: investment cost, operation and maintenance cost, and scrap recovery cost.

1.1. Investment cost

The investment cost of this business mainly includes: the design cost of the business implementation plan, the acquisition cost and installation cost of the related energy equipment, and the construction cost of the business implementation plant. It can be expressed by the following formula:

\[ C_{con}^j = C_{des}^j + \sum_{m=1}^{M} (C_{pur}^j + \sum_{m=1}^{M} C_{ins}^{j,m}) + C_c^j \]

In the formula: \( C_{con}^j \) is the investment cost of the distribution company in distributed energy supply business \( j \), ten thousand yuan; \( C_{des}^j \) is the design cost of the implementation plan of distributed energy
supply business \( j \), ten thousand yuan; \( C_{\text{pur}}^{j,m} \) and \( C_{\text{ins}}^{j,m} \) are the purchase cost and installation cost of the m-th energy equipment required by distributed power supply business \( j \), mainly determined by the installed capacity of each energy equipment, ten thousand yuan; \( M \) is the total amount of equipment, unit; \( C_{\text{om}}^{j} \) is the construction cost of the implementation of distributed energy supply business \( j \), ten thousand yuan.

1.2. Operation and maintenance cost

The operation and maintenance phase is the longest in the whole life cycle. In the operation and maintenance phase, it is necessary to formulate scientific and reasonable operation and maintenance plan to ensure the minimum cost of the whole life cycle. In the operation stage of cooling, heating and electric power supply of distributed power supply business, the involved energy equipment needs to be maintained at regular intervals, such as dust removal and overhaul, so a certain maintenance cost will be incurred, and the cost is in direct proportion to the installed capacity. At the same time, it is also necessary to consider the depreciation expense of energy equipment. The amount of depreciation is directly related to the initial investment cost, depreciation life and depreciation mode (average depreciation or accelerated depreciation), etc. Accelerated depreciation method will be adopted in this project. To sum up, the operation and maintenance costs of distributed energy supply business mainly include: operation and maintenance costs and depreciation costs. Operation and maintenance costs can be calculated by the following formula:

\[
C_{\text{om}}^{j} = \sum_{t=1}^{T} \left( \sum_{m=1}^{M} \left( C_{\text{pur}}^{j,m} + C_{\text{ins}}^{j,m} \right) \cdot \gamma_{t} + \sum_{m=1}^{M} C_{\text{par},t}^{j,m} \right) \frac{1}{(1 + r)^t}
\]

In the formula: \( C_{\text{om}}^{j} \) is the present value of the operation and maintenance cost invested by the distribution and sales company in the distributed energy supply business \( j \) in \( T \) years, ten thousand yuan; \( C_{\text{pur}}^{j,m} \) and \( C_{\text{ins}}^{j,m} \) are the purchase cost and installation cost of the m-th energy equipment required by the distributed energy supply business \( j \), the sum of the two is the total installed cost, ten thousand yuan; \( \gamma_{t} \) is the operation and maintenance rate in year \( t \), that is, the ratio of operation and maintenance costs to the installed cost; \( C_{\text{par},t}^{j,m} \) is the grid-connected cost of the m-th energy equipment required for distributed energy supply business \( j \) in year \( t \), this part of the cost mainly exists in the clean energy supporting business, and the related costs involved in the surplus electricity grid-connecting, ten thousand yuan; \( r \) is the discount rate; \( T \) is the life circle of the distributed energy supply business \( j \), year.

In this project, sum-of-the-years-digits method of accelerated depreciation method is selected to calculate the depreciation cost in distributed energy supply business. Since the time span of depreciation is also the full life cycle, the time value of capital also needs to be considered. The formula of depreciation for distributed energy supply business according to the summation of years is as follows:

\[
C_{\text{dep}}^{j} = \sum_{t=1}^{T} \left( \sum_{m=1}^{M} \left( C_{\text{pur}}^{j,m} + C_{\text{ins}}^{j,m} - C_{\text{res},t}^{j,m} \right)(T - t + 1) \right) \frac{T(T+1)(1+r)^t}{2}
\]

In the formula: \( C_{\text{dep}}^{j} \) is the present value of depreciation cost in distributed power supply business \( j \) of the power distribution company within \( T \) years, ten thousand yuan; \( C_{\text{res},t}^{j,m} \) is the salvage value of the m-th equipment in year \( t \), ten thousand yuan.
1.3. Scrap recovery cost

The cost of the scrap recovery phase mainly refers to the salvage value of the energy equipment. Different scrap recovery methods will produce different costs and benefits. The cost model of the scrap stage is relatively simple, while taking the time value of capital into account, the discount of the salvage value is:

\[ C_{scr}^{j} = \sum_{i=1}^{T} \sum_{m=1}^{M} C_{res,j}^{i,m} \left(1 + r\right)^{i} \]

In the formula: \( C_{scr}^{j} \) is the present value of the cost in the scrap stage of distributed power supply business \( j \) of the power distribution company, ten thousand yuan; \( C_{res,j}^{i,m} \) is the residual value in year \( t \) of the \( m \)-th energy equipment required for distributed power supply business \( j \).

2. Distributed power supply business benefit composition

2.1. Economic benefit

The economic benefits of distributed energy supply business mainly include four parts. On the one hand, power distribution companies can obtain certain benefits by charging users with corresponding equipment rental fees; on the other hand, the distributed energy supply business includes clean energy supporting services, therefore, distribution and sales companies will also have a portion of the revenue from the surplus electricity grid-connecting (the difference between the on-grid price and the price of electricity sold); at the same time, distributed power supply service also helps to eliminate bottlenecks in transmission and distribution power supply systems, delays in the construction of power generation/transmission/distribution systems, and help power distribution companies to reduce power purchase costs (including the depletion expenses of related lines and equipment). Therefore, while considering the time value of funds, the economic benefits of the distribution company can be calculated by the following formula:

\[ S_{f}^{j} = \sum_{i=1}^{T} \sum_{m=1}^{M} \sum_{Y=1}^{4} \left(Q_{Y,j}^{i,m} - q_{Y,t}^{i} \right) \left(P_{s,x,t}^{i} - P_{gri,t}^{i} \right) + C_{e,j}^{i} + C_{h,j}^{i} + P_{r,t}^{i} \left(1 + r\right)^{i} \]

In the formula: \( S_{f}^{j} \) is the present value of the economic benefits that the distribution and sale company can obtain from the distributed energy supply business \( j \) in \( T \) years, ten thousand yuan; \( Y=1,2,3,4 \), respectively representing cold, heat, electricity, and gas energy, in this model, \( Y \) is only equal to 3; \( Q_{Y,j}^{i,m} \) is the total supply of \( Y \) energy for the \( m \)-th device in year \( t \), kW·h; \( q_{Y,t}^{i} \) is the total \( Y \) energy required by user \( i \) in year \( t \), kW·h; \( P_{s,x,t}^{i} \) is the sales price of electricity in year \( t \), ten thousand yuan/kW·h; \( P_{gri,t}^{i} \) is the on-grid electricity price in year \( t \), ten thousand yuan/kW·h; \( C_{e,j}^{i} \) is the electricity purchasing cost reduction of power distribution companies that carry out energy conversion services \( j \) in year \( t \), ten thousand yuan; \( C_{h,j}^{i} \) is the cost saved by the distribution company in year \( t \) due to the delay in system construction, ten thousand yuan; \( C_{r,t}^{i} \) is the tariff for the distributed energy supply business \( j \) in year \( t \), that is, the leasing fee distribution company charges user \( i \) for the energy equipment, ten thousand yuan; \( r \) is the discount rate; \( T \) is the full life cycle of distributed energy supply business \( j \), year.
2.2. Environmental benefit

The environmental benefits obtained by power distribution companies providing distributed energy supply services to users can be measured by distributing the benefits of “carbon emission trading” with users in a certain proportion. Power distribution companies provide users with distributed energy supply services to effectively help users reduce carbon emissions, allowing users to trade the emission rights with remaining emission allowances, thereby obtaining the benefits of reducing polluted gas emissions. In this process as a co-participant, power distribution companies can share the benefits of "carbon emission trading" with users. The environmental benefits of the distributed energy supply business provided by the power distribution companies can be determined by the carbon emissions reduced by the user when using the business. The specific calculation is as follows:

\[
S_g^j = \sum_{t=1}^{T} \frac{(Q_{c,t}^{i,j}, P_{c,t}^{j}) \xi_t}{(1 + r)^t}
\]

In the formula: \(S_g^j\) is the present value of environmental benefits that can be obtained from distributed power supply business \(j\) of the power distribution company in \(T\) years, ten thousand yuan; \(Q_{c,t}^{i,j}\) is the reduced carbon emission by user \(i\) from distributed energy supply business \(j\) in year \(t\), kW·h; \(P_{c,t}^{j}\) is the annual average trading price of carbon emission right in year \(t\), ten thousand yuan/kW·h; \(\xi_t\) is the proportion of environmental benefits that can be obtained from distributed power supply business \(j\) carried out by the power distribution company in year \(t\), and the proportion shall be determined by the power distribution company and users through consultation.

3. Conclusion

This paper focuses on analyzing the cost structure and business benefit structure of distributed energy supply business and relevant calculation model for the comprehensive energy service at the park level. Combined with the relevant operating modes of distributed energy supply business, the benefits of distributed energy supply business are calculated from the economic and environmental aspects. The economic benefits of distributed power supply business mainly include four parts. On the one hand, power distribution companies can obtain certain benefits by charging users corresponding equipment rental fees. On the other hand, as the distributed power supply business includes the clean energy supporting business, the power distribution company will also have a part of the electricity sales revenue brought by the surplus power grid-connecting. The environmental benefits of distributing power to users can be measured by sharing the proceeds of "carbon emission right trading" with users in a certain proportion. By providing distributed power supply services to users, power distribution companies effectively help users reduce carbon emissions and enable users to trade the remaining emission allowances, thus benefiting from the reduction of pollution gas emissions.

Acknowledgments

This work was financially supported by the State Grid Henan Electric Power Company Science and Technology Project (52170018000S).

References

[1] Fengkui Luan, Yanmei Tang, Lu Jin, Kecheng Li, Zhiyuan Liu, Comprehensive optimization model of park energy supply and consumption considering the dynamic changes of supply-demand control costs, J. China Electric Power. 2020,53(10):140-148.
[2] Qingyou Yan, Zhenhua Yu, Study on benefit distribution of park distributed integrated energy system based on Shapley value, J. Shandong Electric Power Technology. 2020,47(09):25-30.
[3] Lei Zou, Yiming Tang, Zhuping Liu, Zhengyong Wu, Chao Fang, Chaoqun Wang, Fushuan Wen, Optimal configuration of park-type integrated energy system considering phased planning and equipment replacement, J. China Electric Power. 1-10.
[4] Pengxiang Zhao, Ying Fan, Xichao Zhou, Yang Li, Fang Liu. The evaluation method for the integrated energy system of the park. J. Power Technology. 2020,44(09):1379-1382+1390.

[5] Yonglong Chen, Jinda Zhu, Dongmei Yang, Xinpeng Wang, Ming Gao. Research on economic optimization operation technology of park-level integrated energy system based on multi-party interest game. J. High Voltage Technology. 1-124.

[6] Yufeng Liao, Xiaotong Huang, Jibiao He, Yuquan Liu, Yajun Li. Optimization design of installed capacity and operation strategy of distributed energy supply system. J. Thermal Power Generation. 2019,48(05):89-96.

[7] Jing Liang, Jinghua Li, Yan Sun, Yu Han. Dynamic Evaluation and Analysis on the Economic Effects of China’s Energy Industry. J. China Strategic Emerging Industries. 2017(04):12-14.

[8] Xiping Wang, Xinghui Liu. Dynamic evaluation of distributed power investment benefits based on system dynamics. C. Intelligent Information Technology Application Society. 2013:6.

[9] Lei Zhang, Ruyang Lin, Wei Gao. Dynamic Evaluation of the Economic Effects of China’s Energy Industry. J. Industrial Technology & Economy. 2012,31(06):48-53.

[10] Baozhi Zang, Changlong Wu, Hongguang Zhu, Xin Wei, Jianhong Gao, Yi Sun. The economic operation technology of the park integrated energy system considering environmental protection and reliability costs. J. Distributed Energy. 2020,5(04):18-27.