

Research on the Profit Model of Multi-Energy Interconnected Operation under New Power System Reform

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Abstract. With the large-scale development and utilization of clean energy, the advancement of new electric power system reform and the improvement of the energy marketization, multi-energy interconnected operation has become the main direction of energy development in the future, with the features that clean energy supplement, intelligent and efficient transmission and scientific terminal utilization. This paper focused on the profit model of multi-energy interconnected operation under new electric power system reform. Firstly, investment and construction model of multi-energy interconnection operation was proposed according to its construction characteristics. Secondly, the basic service models were analyzed for multi-energy interconnected operations from four aspects of electricity, thermal, information, and demand side management. Finally, the revenue approach of each basic service was studied, based on which, the profit model of multi-energy interconnected operation was proposed, to achieve economy and sustainable profit and meet the needs of residents, enterprises and society.

1. Introduction

Energy is the foundation of human survival and development and the lifeline of the national economy. However, the sustained development of the economy and society, the continuous growth of energy production and demand, and the overexploitation and utilization of traditional fossil energy resources have caused problems such as environmental pollution, climate warming, and depletion of fossil energy. And it is a major challenge for sustainable development and energy efficiency. At the same time, globalization and the Belt and Road have further strengthened international energy cooperation, which will bring more diverse energy cultures, technologies, and markets. Under this background, to absorb diversified energy cultures and technologies, improve the efficiency of various energy sources, strengthen the coordination and optimization of energy systems, and realize multi-energy complementarity are particularly important, therefore multi-energy interconnected operation systems emerged. [1, 2].

The multi-energy interconnected operation is to integrate various energy resources on both supply side and demand side into an integrated whole. Through efficient and economical utilization of energy resources on the supply side, and optimization of energy consumption on the demand side, under the premise of maintaining energy service levels, the entire energy supply and utilization can achieve optimal economic and resource environmental costs. As technology continues to mature, integrated energy systems in the future will have broad investment prospects [3]. However, there are still many problems in current multi-energy interconnected operation, such as the immature mode of investment and construction, and the unclear profit model. To this end, this paper first analyzed the advantages and disadvantages of different investment construction models, then the investment and construction model of multi-energy interconnection operation was proposed according to its construction characteristics. Secondly, the basic service models were analyzed for multi-energy

interconnected operations from four aspects of electricity, thermal, information, and demand side management. Finally, the revenue approach of each basic service was studied, based on which, the profit model of multi-energy interconnected operation was proposed, to achieve economy and sustainable profit and meet the needs of residents, enterprises and society.

2. Investment and Construction Mode of Multi-Energy Interconnected Operation

The multi-energy interconnected operation system can be invested and constructed by enterprises or users through various investment modes. This section will explore feasible investment and construction modes for multi-energy interconnection operation[4].

2.1 Investment and Construction Subject.

(1) Enterprise. At present, enterprises are subjects of investment and construction in China, including energy companies such as power grid companies and gas companies, as well as other social enterprises. However, in terms of technology, electricity and gas are the main types of energy supply, and the vast majority of energy use is still driven by electricity. Therefore, grid companies will occupy a dominant position to provide continuous, safe and reliable power support, which is crucial for multi-energy interconnection operations.

(2) Users. Users are both users and beneficiaries of multi-energy interconnected operating systems. They can also invest on their own and obtain relevant economic benefits. Since multi-energy interconnected operating systems are user-centric, the relevant equipment is close to the location where users use it. At the same time, the investment in its subsystem equipment is not large, so the user can also become the investment subject.

2.2 Investment and Construction Mode and Effect Analysis.

In the future, electricity will become the link for various types of energy interconnection. Therefore, grid companies occupy an important position in multi-energy interconnected operations. In addition, according to the analysis in Section 2.1, users is also an important investor. Therefore, this section mainly analyzes the investment model of multi-energy interconnected operation systems from the perspectives of grid companies and users.

(1) PFI mode for investment and operation of power grid companies

Under this model, the government is mainly responsible for organizing, and the grid company as a leader in the planning, investment, financing, construction, and operation of multi-energy interconnected operating systems. The company is both an investor and a system operator for scheduling and management.

(2) PFI mode for investment and operation of users

Under this model, large-user enterprises take the lead in investment, financing, construction and operations. After the completion of the main internal business services. The advantages of such projects mainly lie in the convenience of raising funds, electricity and heat energy can be consumed on the spot, but the scale is relatively limited. The advantages and disadvantages of the two modes are shown in Table 1.

Table 1. Advantages and inadequacies of the four investment construction models

Model	Advantages	Disadvantages
PFI mode for investment and operation of power grid companies	Beneficial to control projects' construction and operating costs; easy to clarify the responsibilities and risks of each party; helpful to take technical advantages of the company.	Hard to balance interests and requirements of different stakeholders
PFI mode for investment and operation of users	Small investment, flexible installation; The market has a certain guarantee.	Limited size; low utilization rate.

Under the leading investment model of grid companies, despite direct energy saving, it also reduces the power grid company's power supply load, which plays a positive role in the balance of

power peaks and valleys and the protection of power grid security. This delays the expansion of power supply and substations and saves cost of power grid and generation construction.

The advantages of the user-led investment model are relatively obvious, the investment is small, the installation is flexible, and the market has a certain guarantee. However, its scale is relatively limited, and the utilization rate is also limited by the size of users.

Therefore, based on the above analysis, it can be seen that in the early stage of the market liberalization, the investment-building model of multi-energy interconnected networks dominated by the power grid is superior to other models. When the market is relatively complete, the user market can be opened up and appropriate investment space can be given to users. This can ensure the safe operation of multi-energy interconnection systems, increase the enthusiasm of users, and promote the rapid development of the system.

3. Basic Service Model of Multi-Energy Interconnected Operation

In the process of multi-energy interconnected operation, system operators need to provide users with diversified energy services, which mainly include electrical energy services, heating services, information services, and demand-side management services [5, 6].

3.1 Electricity Service.

The energy of multi-energy interconnected operation mainly comes from clean distributed energy. Distributed generation is connected to users as well as the large power grid through micro-grid. The system can be constructed by the model proposed in the previous section, equipped with energy storage facilities at the same time.

(1) Distributed Energy Development

Distributed energy sources is the main source of electricity in multi-energy interconnected operations. It includes distributed photovoltaic, small wind turbines, distributed gas cooling-heating-power cogeneration system, fuel cell power stations and energy storage equipment. Different distributed energy development strategies are different, and appropriate development strategies should be adopted for each type of distributed energy.

(2) Micro grid Operation

The development of micro-grid in multi-energy interconnection operations can realize high-reliability supply of multiple energy forms for loads. In the multi-energy interconnection operation, the grid structure should be strengthened, new grid lines should be laid, and advanced smart grid technologies should be added. To ensure that users and system operators build distributed power generation connected to the main network, so as to achieve electricity self-balance with spare to grid-connected.

In terms of trading mechanism: distributed power is mostly intermittent renewable energy generation whose output is fluctuant and unpredictable. For the characteristics of small power trading volume, large volatility of bidding output and intermittent strength, real-time trading model is recommended. While in terms of settlement mechanism: Considering various trading mechanisms comprehensively, it is recommended that settlement methods be adopted after the settlement of unified price settlements. That is, the system operators of the micro grid will trade the rich energy in the distributed energy supply system with the main network at the unified settlement price [7].

3.2 Heating Service.

There are three channels for multi-energy interconnected heating services. The first is the user-side heat pump technology [8]. It can be operated in the same way as a distributed power plant. The second is electric heating. By replacing the user's heating equipment with electric heating by means of electricity substitution coal and electricity generation, the related expenses can be calculated uniformly through electricity charges. The third is to connect the heating channels in the system to the unified heating network and still obtain heating services from the public heating channels. At present, the first method is the most environmentally friendly and economically.

3.3 Information Service.

With electricity market opened, information and data management will become one of the core competitiveness of the power industry. Corresponding monitoring equipment and cloud analysis and processing equipment will be constructed at energy supply and demand end, including information collection center, information processing center and information feedback center, to analyze the characteristics of the user's energy use behavior. This lays the foundation for providing users with more energy-efficient solutions such as accurate energy supply, power demand management, and low-carbon energy conservation.

(1) Information Collection Center

The information collection center is equivalent to the system's receiving module. Its main function is to comprehensively collect the user's energy consumption data. According to a certain measurement and analysis model, the information collection center separately processes each data differently, and finally obtains the basic data required by the information processing center.

(2) Information Processing Center

The information processing center is the hub of the entire system, user energy data collected and consolidated by the information collection center can be transformed into the optimal energy use optimization solution through in-depth processing by the information processing center. Its main function is to display the user's daily energy consumption and expenses, and provide users with energy consumption optimization services. The end user's power load curve can be smoothed, and both sides of the energy supply and demand random interaction will be guided.

(3) Information Feedback Center

The information feedback center is the final module of the information system, and it is an information exchange section that implements fixed feedback in conjunction with the optimization plan formulated by the information processing center. Its main function is to provide users with a daily energy bill at the end of each working day to indicate the user's daily energy costs and energy usage structure.

3.4 Demand Side Management Service.

In the competitive market environment, both the power supply side and demand side are characterized by random fluctuations. In order to adapt to this new situation, the demand side needs to implement the service model of demand side management. And the demand side management services of multi-energy interconnected operations are closely linked with information services. In multi-energy interconnected operation, demand-side management services can be implemented from the following four aspects.

Energy-saving services and energy performance contracting

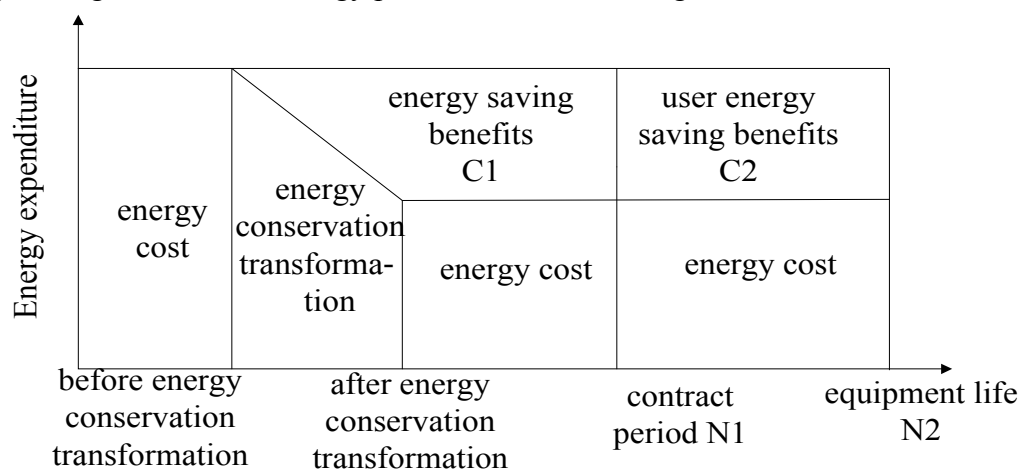


Figure 1. Distribution of benefits for contract energy management projects

(1) Energy performance contracting is a market-based energy-saving mechanism. It is based on the future energy-saving benefits as the current cost of energy-saving technology transformation, upgrading, and replacement, so as to gradually reduce the cost of energy costs to save energy and improve energy efficiency. The income distribution method is shown in Figure 1.

(2) Optimize power plan service

The company should make full use of the demand side management resources under the multi-energy interconnection operation. Specifically, by installing a smart meter on the user side, the daily load curve, the type of electricity used per hour, and the electricity price of each type of electrical appliances among residential users can be obtained. Moreover, establishing a reasonable power-supply optimization scheme based on price-responsive to minimize the user's power consumption cost, effectively improve the quality of service.

(3) Electrical diagnostic service

The electricity diagnosis service is aimed at the phenomenon of large power consumption but low efficiency or unreasonable distribution of peak power and valley power, etc., and then provides comprehensive analysis of power consumption and puts forward corresponding professional suggestions for users.

(4) App Self Service

Combining the construction of information systems in multi-energy interconnection operations, system operators can develop mobile phone software on electricity usage. This enables users to track and analyze electricity at any time and provides support for several other demand-side management services.

4. Multi-Energy Interconnection Operating Profit Model

Multi-energy interconnection operators not only need to be responsible for system operations, but also participate in the construction and investment of some infrastructure within the system. Its main profit-making channels include electricity revenue, heating revenue, information service revenue and negative watt return.

4.1 Electricity Revenue.

The system operation business develops distributed power stations within the multi-energy interconnection operation system, provides users with power supply and charges for electricity. In addition, system operators also need to build a micro grid between distributed energy and large grids, between distributed energy sources and users. This part of the cost should be included in the electricity cost of per KW h, in a similar way to the transmission and distribution electricity price. Moreover, distributed generation follows the model of self-use, surplus online. When distributed generation generates excess electricity, system operators can purchase this portion of electricity from users and sell it to the grid to earn some of the price difference.

Therefore, electricity revenue can be calculated as follows:

$$R_e = R_{DG} + R_m + R_p \quad (0)$$

Where the R_e is electricity revenue, R_{DG} is distributed generation tariff, R_m is micro-grid cost and R_p is distributed margin electricity price difference.

$$R_{DG} = I \times A / C_e + P \quad (2)$$

I Is distributed generation investment, A is equivalent paid-up capital recovery factor, C_e is annual electricity consumption and P is reasonable return.

$$R_m = [(C_u + C_i) \times A + C_o] / C_e + P \quad (3)$$

C_u Is grid upgrade cost, C_i is new grid investment cost and C_o is system operating cost.

4.2 Heating Revenue.

System operators should build distributed heat pump heating on a user-by-user basis or actively explore other distributed heating modes. The user's charging method is the same as the electricity charge. The formula is:

$$R_h = \sum (I_p \times A / d + P) \quad (4)$$

Where R_h is heating service fee, I_p is heat pump investment of per user, A is equivalent paid-up capital recovery factor, d is annual heating days and P is reasonable return.

If the multi-energy interconnection operation in the area uses electric heating, the electricity revenue will cover the heating benefits; if the area still receives heat from the public heating network, this part of heating revenue belongs to the heating company.

4.3 Information Service Revenue.

This part of the fee follows the user-defined principle and charges according to the user's customized energy information service. This part of the information costs should be less than the user's savings in electricity expenses, otherwise the user will not be able to obtain the benefits of this service, and will lose motivation to use the service.

4.4 Negative Watt Revenue.

The negative watt revenue is closely linked to the revenue of information services. Because system operators have a large number of monitoring devices at the user end and energy supply end, they can meticulously characterize and analyze users' energy use behavior and provide optimized energy use solutions. Therefore, the user can also reduce the load or transfer part of the load at a specific time. This part of the load we call "negative watts." For grid companies, this part of the negative tile can shift the peak load to the base load, so the system operator can sell this part of the negative watt to the grid companies for profit.

In summary, the revenue of the multi-energy interconnections operation system can be calculated as follows:

$$R_s = R_e + R_h + R_i + R_w \quad (5)$$

Where the R_s is revenue of the multi-energy interconnections operation system, R_e is electricity revenue, R_h is heating income, R_i is information service revenue and R_w is negative tile gain.

5. Conclusion

During the 13th five-year plan period, great changes have taken place in the characteristics of the energy market and the environment of market operation. Realizing multi-energy interconnected operation is important to the development of energy companies. In current situation, the investment and construction model of multi-energy interconnected systems led by power grid enterprise has a higher superiority and better development prospects. When energy market become mature, it is possible to open user market to achieve a win-win result among the government, enterprises, and users. In addition, the current study of the service model and profit model of multi-energy interconnection operation in this paper is confined only to the economic benefits, while the system emphasizes more on low-carbon benefits and circular economy. Some economic benefits will actually transform into social benefits, so the social benefits of multi-energy interconnected operation system will be considered and quantized in the future research and practice, thus comprehensively measure its value and contribution.

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