Study of Business Models and Benefits of Integrated Energy System

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Abstract. Integrated energy systems plays an important role for improving Social Energy Efficiency and promoting the large-scale consumption of renewable energy and the Gradient utilization of energy. Integrated energy systems breaks through the technical, market and management barriers of traditional energy systems and provides unified planning and scheduling of various energy sources, such as electricity, gas, heat and cold, thereby accomplishing complementary and coordinated optimisation of multiple energy sources, which will certainly become the main form of future energy systems. However, Chinese integrated energy services started relatively late, the business models and the level of economic benefits of integrated energy systems are still at the stage of exploration and conception. Therefore, this paper refer to the design and cost-benefit analysis of regional integrated energy service business models.

Keywords: Integrated energy systems · Investment · Business Models · Integrated Energy Services · Target Users

1 Introduction

Integrated energy services have two meanings: one is integrated energy, covering a variety of energy, including electricity, gas, cold and heat, etc. Another one is integrated services, including engineering services, investment services and operation services [1]. Using interval number theory, Li Wei et al. [2] conducted a benefit analysis and sensitivity analysis of influencing factors for campus-based distributed integrated energy systems from both economic and environmental aspects, and it effectively reflected the economic advantages and emission reduction capacity of distributed integrated energy systems. Zhao Xiaodong, et al., [3] establish a physical and mathematical model of IES by analysing the cooling, heating and electrical load characteristics of this energy-using object. They carried out an economic evaluation of selected energy systems, using catalogue electricity prices and market-based traded electricity prices. Dong Ruibiao et al. [4] proposed a pricing method for energy Internet operators based on integrated

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energy system value analysis. Yang Mei, et al. [5] focuses on the dynamic optimal energy flow analysis of integrated energy systems, with the objective of analyzing the dynamic optimal tidal characteristics of source-grid load and storage in an economic and efficient manner. Gu Pengze, et al. [6] have developed an optimisation model for an integrated electricity and heat system, taking into account grid and heat network constraints, and have used the model to study the benefits of wind power consumption for heat supply. Gu establishes a directed graph model of a multi-energy flow system based on a graph-theoretic matrix in order to minimise daily operating costs. The multi-energy flow system is optimised in order to achieve an optimised energy structure, complementary multiple energy sources and improved renewable energy consumption rate. Ma Tengfei, et al. [7] minimise daily operating costs and develop a directed graph model of a multi-energy flow system based on graph theoretic matrices. The multi-energy flow system is optimised aiming to optimize energy structure and improved renewable energy consumption rate. Fang Tong, et al. [8] propose an integrated energy business operation method based on NSGA-II and the entropy method to address the cost and benefit issues in the operation of integrated energy systems containing hydrogen. Han Feng et al., [9] submit four integrated energy service models and five integrated energy service cooperation models. Through arithmetic examples, they showed that these integrated energy commercial service models achieve a graded use of energy and improve the comprehensive energy use efficiency. Wen Bo [10] believes that traditional electricity sales companies can explore their business value through customer data collection, build an intelligent platform for the integration of electricity purchase and sale, and provide more value-added services to customers in order to adapt to the development of the market.

Based on the existing researches, this paper proposes the overall design of the business model of integrated energy services from three aspects: the development potential of integrated energy services, the target customers and development strategy of integrated energy services, and the service content and profit model of integrated energy services. The integrated energy system business model is shown in the Fig. 1.

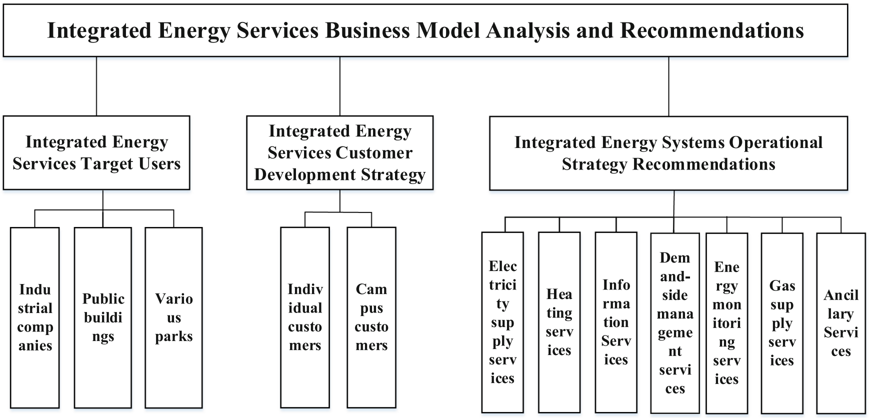

Fig. 1. Integrated energy system business model

2 Analysis of Target Customers and Development Strategies for Integrated Energy Services

2.1 Target Customers for Integrated Energy Services

When selecting target customers for integrated energy services, the urgency of reducing energy costs is one of the important factors in the selection process. In addition, the main body of integrated energy services should also consider the scale of customer energy use, demand stability, profit level, ability to pay and other factors in order to ensure a high service revenue. According to the above selection principles, the target customers of the integrated energy service main body to carry out integrated energy service business in the short term mainly include industrial enterprises, parks and large public buildings.

(1) Industrial enterprises

Industrial enterprises are characterized by a large scale of energy consumption, energy costs have a large proportion of production costs, high electricity prices for industrial use, and sensitivity to changes in energy costs. Carrying out integrated energy services for industrial enterprises is conducive to the main body of integrated energy services to strive for high-quality electricity sales customers and obtain better service revenue.

(2) Public buildings

Public buildings with high pedestrian flow and high quality demand for cold, heating and electricity, as well as high electricity prices, stable energy demand and strong payment ability, are also important targets for the company to promote integrated energy services. At present, energy service companies have accumulated rich experience in energy saving and electric energy substitution in the building field, and are familiar with the demand of energy service for this part customers.

(3) Various types of parks

Various parks often gather various large-scale industrial users, and the total energy consumption of the whole park is very significant. However, if industrial enterprises all adopt their own isolated and decentralized energy consumption mode, it will increase the initial investment pressure and operation and maintenance costs of the park. The main body of comprehensive energy service makes use of the park's unified…planning, unified construction, and integrated arrangement opportunities to develop regional energy station construction and comprehensive energy services. While improving energy utilization efficiency and reducing energy costs for customers, it can also get the direct economic benefits of managing quality customers in a large-scale and centralized manner.

2.2 Development Strategy for Integrated Energy Services

Expand the market in the order of risk from low to high and implementation difficulty from easy to difficult. Priority is given to production enterprises and office buildings in the system, and then gradually expand to social buildings, industrial enterprises and parks. In the process of social market development, regions with better policy environment, energy and economic structure, and customers with larger scale and demand and promising industry are preferred. A differentiated portfolio of services should be provided at different stages of development, taking into account customer needs and service acceptance.

(1) Individual customers

The development strategy for individual customers is mainly embodied in the implementation of the project and gradual progress. Initially, using the company's brand advantages and customer contacts, take the business of power operation and energy efficiency monitoring as the entry point to save operation and maintenance costs by providing professional operation and maintenance services for customers. By monitoring and analyzing customers' internal energy consumption data, centralized management of multi-customer power operation and maintenance information, and reduction the operation and maintenance costs of single households with scale development can be accomplished. In the medium term, through the analysis of customers' energy consumption data, we can provide customers with reasonable energy consumption suggestions and carry out energy saving and electric energy replacement technology transformation. Finally, on the basis of gaining the full trust of customers, energy hosting services to provide customers with total solutions for energy supply can be carried out.

(2) Campus customers

The development strategy for campus customers is mainly reflected in advance planning and overall layout. Cooperate with the park government to carry out regional energy planning at the initial stage, and fully consider factors such as energy configuration design and energy station location at the beginning of park development and construction, so as to lay a good foundation for regional energy supply. In the medium term, it can cooperate with the government, social capital and other stakeholders to establish a mixed ownership company to obtain local concessions and carry out the construction of energy stations, recommending the construction of distribution grids as an entry point and integrating distributed photovoltaic, energy storage, heat pumps, cold storage and other technologies to carry out comprehensive energy supply.In the late term, an energy consumption monitoring platform for customers can be built, providing monitoring and data analysis services to improve customer satisfaction, while recovering energy station construction costs and making profits.

3 Integrated Energy Services Content and Profit Model Analysis

3.1 Energy Supply Benefits

(1) Power supply revenue

The revenue from power supply mainly includes revenue from natural gas distributed power generation, revenue from peak-to-valley tariff difference of energy storage plants, revenue from distributed photovoltaic power sales, and revenue from fuel cell power supply.

1) Revenue from natural gas power generation

In the integrated energy system, the coupling link of electricity, heat, cold and gas is realized through the cold, heating and power trigeneration (CCHP) units. The CCHP system can convert and output electricity by feeding natural gas to generate revenue. Therefore, the total revenue B^E_{CCHP} from CCHP generation can be divided into revenue from electricity sales by customers $B^E_{1\ CCHP}$, revenue from electricity feed-in $B^E_{2\ CCHP}$, and revenue from market transactions $B^E_{3\,CCHP}$, as expressed in the following Formula.

$$B^E_{CCHP} = B^E_{1\ CCHP} + B^E_{2\ CCHP} + B^E_{3\ CCHP} \quad (1)$$

$$B^E_{1\ CCHP} = E^E_{1\ CCHP} \cdot p^E_{1\ CCHP} \quad (2)$$

$$B^E_{2\ CCHP} = E^E_{2\ CCHP} \cdot p^E_{2\ CCHP} \quad (3)$$

$$B^E_{3\ CCHP} = E^E_{3\ CCHP} \cdot p^E_{3\ CCHP} \quad (4)$$

where, $E^E_{1\ CCHP}$ denotes electricity consumption by customers; $p^E_{1\ CCHP}$ denotes the price of electricity sold to customers; $E^E_{2\ CCHP}$ denotes feed-in tariff; $p^E_{2\ CCHP}$ denotes feed-in tariff; $E^E_{3\ CCHP}$ denotes electricity traded in the market; $p^E_{3\ CCHP}$ denotes the transaction price of electricity trading.

2) Peak and valley tariff revenue from energy storage plants

Peak-valley tariff difference revenue refers to the revenue generated by energy storage devices charging at low load valley and low tariff, and discharging at peak load and high tariff, using time-sharing tariff difference arbitrage. When using energy storage power plants for peak-valley power differential arbitrage, energy storage system energy loss needs to be considered, and the current domestic mainstream converter one-way conversion efficiency k is about 95%. Therefore, the annual peak-valley tariff differential revenue B^E_{SV} can be expressed as Formula (5)

$$B^E_{SV} = E^E_{1\ SV} \cdot p^E_{1\ SV} \quad (5)$$

where, $E^E_{1\ SV}$ denotes the electricity storage capacity of the energy storage plant; $p^E_{1\ SV}$ denotes the electricity storage sales price.

3) Distributed photovoltaic power sales revenue.

The total revenue from distributed photovoltaic power generation B^E_{PV} can be divided into revenue from customer sales $B^E_{1\ PV}$, feed-in tariffs $B^E_{2\ PV}$ and market trading revenue $B^E_{3\ PV}$, as expressed in the following Formula.

$$B^E_{PV} = B^E_{1\ PV} + B^E_{2\ PV} + B^E_{3\ PV} \quad (6)$$

$$B_{1\ PV}^{E} = E_{1\ PV}^{E} \cdot p_{1\ PV}^{E} \tag{7}$$

$$B_{2\ PV}^{E} = E_{2\ PV}^{E} \cdot p_{2\ PV}^{E} \tag{8}$$

$$B_{3\ PV}^{E} = E_{3\ PV}^{E} \cdot p_{3\ PV}^{E} \tag{9}$$

where: $E_{1\ PV}^{E}$ denotes electricity consumption by customers; $p_{1\ PV}^{E}$ denotes the price of electricity sold to customers; $E_{2\ PV}^{E}$ denotes feed-in tariff; $p_{2\ PV}^{E}$ denotes feed-in tariff; $E_{3\ PV}^{E}$ denotes electricity traded in the market; $p_{3\ PV}^{E}$ denotes the transaction price of electricity trading.

(2) Heat supply revenue
1) Natural gas distributed heating revenue

CCHP systems can also convert and export heat for heating revenue through the input of natural gas. In an integrated district energy system, natural gas distributed heating revenues B_{CCHP}^{H} can be divided into heating revenues for commercial $B_{1\ CCHP}^{H}$ and residential customers and industrial heating revenues for industrial customers $B_{2\ CCHP}^{H}$ as shown in Formula (10) and Formula (11).

$$B_{1\ CCHP}^{H} = S_{CCHP}^{H} \cdot \Delta p_{1\ CCHP}^{H} \tag{10}$$

$$B_{2\ CCHP}^{H} = V_{CCHP}^{H} \cdot \Delta p_{2\ CCHP}^{H} \tag{11}$$

where, S_{CCHP}^{H} denotes the heating area of CCHP; $\Delta p_{1\ CCHP}^{H}$ denotes the heating price per unit area of CCHP; V_{CCHP}^{H} denotes the heating steam quantity of CCHP; $\Delta p_{2\ CCHP}^{H}$ denotes the heating steam price per unit of CCHP.

2) Heat storage system heating benefit

At present, there is a relatively large primary investment in thermal storage systems, and the operating costs of thermal storage systems are too large for the market promotion of thermal storage systems. The heating revenue from heat storage systems B_{SH}^{H} can also be divided into heating revenue for commercial, residential customers $B_{1\ SH}^{H}$ and industrial heating revenue for industrial customers $B_{2\ SH}^{H}$ as shown in Formula (12) and Formula (13).

$$B_{1\ SH}^{H} = S_{SH}^{H} \cdot \Delta p_{1\ SH}^{H} \tag{12}$$

$$B_{2\ SH}^{H} = V_{SH}^{H} \cdot \Delta p_{2\ SH}^{H} \tag{13}$$

where, S_{SH}^{H} denotes the heating area of the heat storage system; $\Delta p_{1\ SH}^{H}$ denotes the heating price per unit area of the heat storage system; V_{SH}^{H} denotes the heating steam quantity of the heat storage system; Δp_{2SH}^{H} denotes the heating steam price per unit of the heat storage system.

(3) Refrigeration revenue
1) Natural gas distributed cold revenue

The CCHP system can also convert and export cold gas by inputting natural gas to obtain cold revenue, as expressed in the following revenue expression.

$$B_{CCHP}^{C} = S_{CCHP}^{C} \Delta p_{CCHP}^{C} \tag{14}$$

where, B_{CCHP}^{C} denotes the revenue term of CCHP, S_{CCHP}^{C}, Δp_{CCHP}^{C} denotes the cold area of CCHP and the cold price per unit area.

(2) Ice storage cold revenue.

The ice storage air conditioning system plays an important role in balancing the grid load and shifting the peaks and valleys. The ice storage volume, cooling efficiency, cooling load and operation time are important parameters characterizing the physical characteristics of the ice storage air conditioning system. Currently, the revenue of the ice storage and cold air conditioning system can be divided into two ways: one is billed according to the ice storage and cold air conditioning supply time, and the other is billed according to the area of ice storage and cold air conditioning supply.

The revenue model based on cold time can be expressed in Formula (15).

$$B_{IS} = T_I \times \Delta p_I^T \tag{15}$$

where, B_{IS} denotes the revenue term of ice storage air conditioner, T_I denotes the working time of ice storage air conditioner, and Δp_I^T denotes the price per unit time of ice storage air conditioner.

The model for billing according to the area cooled by ice storage air conditioners can be expressed as Formula (16).

$$B_{IS} = S_I \times \Delta p_I^S \tag{16}$$

where, B_{IS} denotes the revenue term of ice storage air conditioner, S_I denotes the cold area of ice storage air conditioner, and Δp_I^S denotes the cold price per unit area of ice storage air conditioner.

3.2 Ancillary services revenue

1) Energy storage plant backup revenue

Energy storage power plants store electricity in the low valley or abandoned wind and light hours, and release electricity in the time of need to provide standby capacity, peak and frequency regulation and other auxiliary service transactions. Energy storage power plant can participate in auxiliary services as an independent entity or in combination with thermal power, thermoelectric power, new energy sources, etc. to participate in standby capacity auxiliary services. Therefore, the backup revenue of energy storage power plant B_{BY}^{S} can be expressed as Formula (17).

$$B_{BY}^{S} = E_{BY}^{S} \times b_{BY}^{S} \tag{17}$$

where, B_{BY}^{S} denotes the standby capacity revenue term of the energy storage plant, E_{BY}^{S} denotes the standby power of the energy storage plant, and b_{BY}^{S} denotes the standby compensation standard per unit capacity.

(2) Energy storage power plant peak and frequency regulation revenue

The peak-to-frequency revenue of the energy storage plant B_{PK}^{S} can be expressed as:

$$B_{PK}^{S} = E_{PK}^{S} \times b_{PK}^{S} \tag{18}$$

where, B_{PK}^{S} denotes the energy storage plant peaking and frequency regulation revenue term, E_{PK}^{S} denotes the energy storage plant peaking power, and b_{PK}^{S} denotes the power compensation standard.

3.3 Value-Added Services

(1) Information services

The system operator should provide energy information services to users so that they can access their energy use information anytime and anywhere, and be able to compare energy use between multiple customers. Therefore, the system operator's data mining and analysis capabilities are crucial, which means that the operator needs to architect corresponding monitoring equipment and cloud-based analysis and processing equipment at the user side and energy supply side to characterize the user's energy use behaviour, thus laying the foundation for richer energy use solutions such as accurate energy supply, power demand-side management, and low-carbon energy conservation.

(2) Demand-side management services

The demand-side management service of the regional integrated energy system is closely linked to the information service. Specifically, through the collection and sorting of customers' electricity consumption data, it summarises information on peak and valley electricity consumption, self-generation and mains electricity purchases, as well as electricity tariffs and average electricity prices, and uses technical tools such as curve graphs to analyse customers' electricity consumption, average electricity prices and electricity consumption structure, and provides customers with an optimised energy consumption plan at the end of each day, so that customers can use more distributed clean electricity. This will enable customers to increase their use of distributed clean electricity and reduce their own electricity costs.

(3) Energy monitoring services

Energy monitoring is to ensure the smooth and safe operation of the region by monitoring the production and operation of each energy subsystem and distribution network such as electricity, cooling, heat, steam and water, the environment, the running and leaking of the pipe network, and the energy consumption of each end-user in the region. It is mainly divided into modules such as overall energy consumption monitoring, energy system monitoring, equipment monitoring, integrated pipeline corridor monitoring and fault alarm.

4 Conclusion

This paper first analyses the target users of integrated energy services and formulates the corresponding development strategies, then analyses the benefits of various types of equipment of integrated energy systems, including energy supply benefits, service benefits and value-added service benefits, and finally concludes that integrated energy systems have good economic and social benefits.

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