ISSN: 2688-9323

Establishing a Comprehensive Return Standard Evaluation Model for Customer-side Energy Storage Participating in Multi-energy Complementary Investment Business

Yunhu Wang [1,2,*],Yifeng Cao [1], Tongshui Xia [2]

[1]Shandong Institute of Standardizaiton, Jinan, Shandong 250014, China

[2]Shandong Normal University, Jinan, Shandong 250014, China

*yunhuwang@126.com

Abstract

At present, the cost-benefit model of energy storage system is not fully considered in the research on user-side energy storage. The cost-benefit model is aimed at multiple benefit subjects and does not subdivide users. Based on the cost-benefit analysis model of energy storage device, a two-level planning model is established in this paper. This paper analyzes the operation strategy and economy of energy storage devices for ordinary users under spot electricity price market, and analyzes the operation strategy and economy of energy storage devices for large and medium-sized power users under peak and valley time-of-use electricity price. The comprehensive return standard evaluation model for multi-energy complementary investment business proposed in this paper can be used for pre-evaluation and post-evaluation of energy system planning, providing basis for evaluation and decision-making of comprehensive energy system planning scheme, pricing of comprehensive energy services, and formulation of relevant policies.

Keywords

Multi-energy complementation, Operational strategy, User side, Energy storage device.

1. Introduction

The supply side corresponds to the demand side. The supply side is the one that provides the means of production and labor, while the demand side refers to investment, export and consumption. How to promote the transformation of energy structure, vigorously develop renewable energy and promote the use of clean energy has attracted the common attention of all countries in the world [1]. The multi-energy complementary integrated energy system with multi-energy coordination features can significantly improve the coordination capability of energy supply and demand through comprehensive planning, coordinated control, intelligent scheduling and multi-element interaction of multi-energy flows such as cold, heat and electricity. Judging from the current situation, most of the researches ignore the importance of pumped storage model, and pay too much attention to the simulation of system model in actual research work, resulting in many problems in energy storage mode [2]. The multi-energy complementary system couples the four energy sources of cold, heat, electricity and gas, integrates the advantages of various energy sources, and establishes an integrated energy supply system to provide users with various load requirements of cold, heat and electricity. In the future, urban distributed energy will be a model of "urban scale dispersion-regional scale multi-source concentration-individual energy consumption of end users" [3]. Under the general trend of smart grid, more effective use of electricity is strongly advocated by the State Grid Corporation, which is also the purpose of this paper.

The current research on user-side energy storage has the following problems: the cost-benefit model of the energy storage system is not fully considered, the cost-benefit model is aimed at multiple benefit subjects, users are not subdivided, and investment risks are not quantitatively analyzed [4]. Under different power policies and different types of users, the purpose of users' investment in installing and using energy storage devices will be different. Therefore, under different power policies and different types of users, the value of energy storage devices is different, their operation strategies are also different, and their economy is also different. From the point of view of life cycle theory, this paper uses the concept of two-tier planning to establish a standard evaluation model for the comprehensive benefits of energy storage devices, the optimal capacity allocation and the comprehensive return of multi-energy complementary investment services.

2. Model Building

The purpose of this model is to optimize the combination of available energy and technologies in the target area to build a multi-energy complementary energy system. After applying for a special transformer substation, large consumers of electricity, whether they use electricity or not, will pay the corresponding basic electricity charge per month according to the maximum applied capacity. The cost structure of all kinds of storage batteries is the same. Life cycle cost includes initial investment cost, operation and maintenance cost, replacement cost and decommissioning cost. Energy storage technology and power storage technology [5]. Energy storage technology is generally suitable for large energy input or output. The release time of electric energy is relatively long and the speed is relatively slow, which can generally last more than 10 minutes or several hours. The primary green distributed power source can realize zero pollution to the environment in the whole power generation process, save energy and protect the environment, but has strong volatility and poor power supply stability. A single index, such as coal consumption for power generation and coefficient of refrigeration performance, cannot comprehensively evaluate the performance of the system, and different energy media are coupled with each other. Determine the key links and equipment for energy conversion and multi-energy coupling in the system, and appropriately aggregate and simplify the energy facilities of the system.

In affine mathematics, a variable x^* with uncertain characteristics can be expressed as affine form [6]

$$x^* = x_0 + x_1\varepsilon_i + \cdots + x_n\varepsilon_n \tag{1}$$

Where: x_0 is the center value of the affine number x^*; $x_1, x_2, \cdots, x_n$ is each affine variable; ε_i is the noise element of the affine variable, which represents each independent uncertain source of the uncertain variable x^* and $\varepsilon_i \in [-1,1]$.

Interval numbers and affine numbers can be transformed into each other. Given an interval number $x^* = [x, \bar{x}]$, its corresponding affine form is as follows:

$$\begin{cases} x^* = x_0 + x_1\varepsilon_1 \\ x_0 = \dfrac{\bar{x} + x}{2} \\ x_1 = \dfrac{\bar{x} - x}{2} \end{cases} \tag{2}$$

Similarly, for any affine number $x^* = x_0 + x_1\varepsilon_1 + \cdots + x_n\varepsilon_n$, its interval expression is as follows

$$[\underline{x}, \overline{x}] = [x_0 - \sum_{i=1}^{n} | x_i |, x_0 + \sum_{i=1}^{n} | x_i |] \tag{3}$$

Due to the mutual coupling of transformers, compressed air conditioners, electric water heaters and other equipment providing cold, hot and electric energy output, there is some uncertainty in their output and their operating efficiency will also be affected by load fluctuation [7]. In the traditional geothermal heating system, the water source heat pump only uses low-temperature geothermal water for heating in winter, while the refrigeration function is not brought into play. In summer, the water source heat pump unit is in a deactivated state. According to local data, determine the types of energy and technologies that can be utilized, refer to load index or carry out load forecasting according to energy consumption simulation software. The configuration of energy storage system reduces the power consumption load of users at peak hours by cutting peaks and filling valleys, which is equivalent to the reactive power that can smoothly adjust the load, thus reducing the capacity required by the substation. Installing energy storage device in distribution network can realize peak cutting and valley filling of electric load, i.e. energy storage absorbs electric energy from power grid at low load level and releases stored electric energy to power grid at high load level. The residual value of the equipment is related to the initial investment cost and recovery coefficient and is negative. Environmental protection expenditure mainly refers to the cost of recovering batteries.

3. Cost-benefit Model Analysis of User-side Energy Storage Device

The annual operation and maintenance cost of the energy storage system includes the operation cost and maintenance cost of the energy storage system, mainly the daily and regular manual maintenance of the battery. The output power of the energy storage device is a variable, so the energy stored in the energy storage device can be calculated by the sum of the output power of the battery energy storage technology device [8]. Reasonable configuration of distributed small-scale power generation system through various conditions such as load and wind and light resources is an important method to reduce the power generation cost of distributed power generation and improve the reliability of distributed power generation system. When the cooling, heating and power load on the customer side is increasing, the energy saving generated by the multi-energy complementary system gradually decreases. The input/output and internal energy value of the system are usually expressed by the average value over the time span. Emergy table and emergy map jointly describe the emergy quantity and relationship of various input, output and intermediate links of the system. In the post-investment analysis stage, the model is used for post-investment assessment by comparing the actual performance of the business with the initial predicted value. The water head, flow rate, water volume, power and efficiency must meet the actual demand of power generation, and the reservoir water level under constraint conditions must be greater than or equal to the minimum water level and less than or equal to the maximum water level.

The application of energy storage device in distribution network can produce many benefits, but from the point of view of users, its value is mainly reflected in reducing the construction capacity of user distribution station, reducing the electricity charge in the electricity purchase cost of users, reducing the basic electricity charge of users under the capacity electricity price system and reducing the power outage loss cost of users. See Table 1 for the life cycle and operation and maintenance coefficient of various equipment.

Table 1. Life cycle and operation and maintenance coefficient of various equipment

Energy technology equipment	Operational maintenance factor	Life cycle/a
Heat pump	0.03	24
Cogeneration unit	0.27	24
wind power generation equipment	0.14	21
boiler	0.02	20

The initial investment cost of energy storage device is related to its power and capacity. The initial investment cost C capital can be expressed as [9]

$$C_{capital} = C_P P_N + C_W E_N \tag{4}$$

Where: C_P is the unit power cost of the energy storage device, 10,000 Yuan / MW; C_W is the unit capacity cost, 10,000 Yuan / MWh; P_N is the rated power of the energy storage device, MW.

The operation and maintenance cost of the energy storage device can be divided into operation cost and maintenance cost. For simplicity of calculation, the operation and maintenance cost $C_{OM,t}$ of the energy storage device in year t is expressed as

$$C_{OM,t} = C_{OMP,t} P_N \tag{5}$$

Where: $C_{OM,t}$ is the annual operation and maintenance cost per unit power of the energy storage device in a certain year, 10,000 Yuan / MW ·a.

Cooling, heating and power load, distributed energy output and operation efficiency are modeled based on interval theory, which makes the multi-energy complementary system become an organic whole, and the optimized operation result is transformed from static curve to interval curve. At the same time of using valley electricity to store heat, the heating capacity of a single well is expanded. At the same time, the cooling tower is added to the water source heat pump side for cooling in summer, giving full play to the cooling function of the water source heat pump. Under the current mechanism of industrial electricity price, the extra cost of peak load is transmitted to users in the form of demand/capacity electricity price. For ordinary household power users, the installation of energy storage device is mainly to consider charging when the electricity price is low at the low valley of power consumption, and to provide power for users when the power consumption peak or the mains supply is interrupted. The configuration of energy storage system greatly improves the reliability of single-loop and double-loop power supply modes, especially for single-loop power supply mode. In order to reduce the power transmission in the power grid during peak load, thus reducing the expansion of the distribution network. The difference in electricity tariffs between users at low load and peak load periods increases rapidly with the increase in peak-valley electricity tariffs, and cutting peaks and filling valleys can effectively reduce electricity tariffs [10].

4. Economic Benefit Analysis of Multi-energy Complementary Power Generation

Different applications have different energy supply capacities, and different user types correspond to different user requirements. Among them, the method of determining

ISSN: 2688-9323

electricity by heat is also called the heat following mode, i.e. during the operation of the system, the gas turbine and the auxiliary waste heat boiler preferentially meet the heat demand of the system while generating electric energy. Local power generation and purchased power are distributed to users through power distribution systems, and redundant power is sold to external power markets; Natural gas will be distributed to all distributed CCHP systems and gas boilers in the park. In terms of business dimension, any mobile value-added business in the same life cycle can be compared horizontally by using the investment evaluation model. Under normal circumstances, the staff should convert the surplus electric energy into water energy, which is not only convenient for storage, but also can reduce the loss of energy in storage. Stop charging when the battery state of charge reaches the maximum capacity of the battery, and stop discharging when the battery state of charge reaches 20% of the battery capacity. At the same time, its charge-discharge ratio should also be limited. Without gas peaking boilers, the residual heat cannot meet the heating demand of commercial buildings, and the configuration analysis of energy storage equipment should be carried out in combination with heating and cooling conditions.

Judging from the economic indicators described in Table 2. Although the annual benefit of vanadium redox battery is significantly higher than that of polysulfide-bromine battery, considering that vanadium redox battery also has a longer payback period, and the profit rate and internal rate of return on investment are significantly lower than that of polysulfide-bromine battery. Therefore polysulfide—bromine battery is a better investment scheme.

Table 2. Polysulfide-bronmine battery and vanadium redox battery technical and economic indicators

	polysulfide—bromine battery	vanadium redox battery
Payback period of investment (years)	18.3	49.93
Return on investment (%)	7.89	3.22
Internal rate of return (%)	5.51	3.10

The state of charge of the battery energy storage device, that is, the ratio of its remaining capacity to its fully charged capacity, ranges from 0 to 1. The loss of profits from less-produced products and the start-up costs for resuming production, etc. After the power failure lasts for a certain period of time, the loss of power failure is mainly the loss of profits from less-produced products. The charging and discharging power of the battery energy storage technology device and the storage capacity in the battery energy storage technology device should be smaller than the maximum transmission power and the maximum storage capacity of the battery energy storage technology device, so that the overload operation of the system can be avoided. If the electric energy cannot meet the demand, purchase electricity from the power grid; Electric heating mode is also called electric following mode. Its operation idea is opposite to that of electric heating mode. Gas turbine preferentially meets the demand of system electric load. When the thermal load of the system is large, the insufficient heat is provided by the natural gas burned by the peaking boiler. In this case, wind power and photovoltaic can be combined into a combined power generation system, and the waste heat of power generation equipment can be collected and heated by the recovery system. The system will have strong characteristics of day-night complementarity and seasonal complementarity, and the combined power supply system will be more stable and cost-effective.

Based on the maximum supply capacity constraint of the power grid, energy storage compensation or buffer of peak load is used to realize user demand side management, which can reduce part of the basic electricity price expenditure. At the same time, it charges at the low valley and discharges at the high peak. It uses the price difference between peak and valley to obtain arbitrage, thus realizing the economic operation of the energy storage system. Figure 1 below shows the electricity price and the load curve before and after adding energy storage.

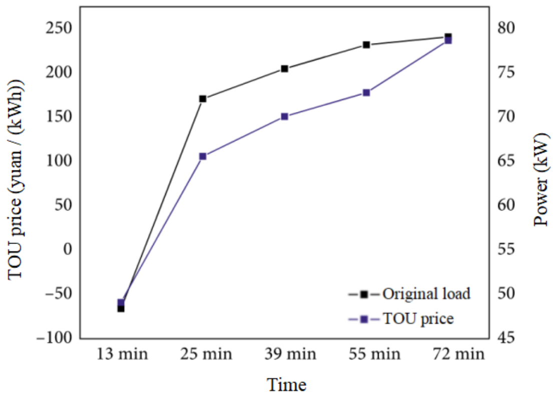

Figure 1. Electricity price and load curve before and after adding energy storage

The operation strategy of pumped storage in multi-energy complementary power generation system is based on the system model. The main advantage of the reversible pump turbine used in the system model is that it can maintain an effective operation state according to the given output. When the same noise source appears, it can be deleted directly, thus improving the problem that the simple interval number operation is too conservative. Therefore, the economy of the user's investment in the energy storage device is evaluated by the investment payback period and the investment profit rate. However, these two indexes are static technical indexes, which do not consider the time value and cannot accurately determine the effectiveness of the investment. The state of charge and the depth of discharge of the battery energy storage device are the two states of the battery. The sum of the capacities in the two states is the total capacity of the battery. The complementary relationship can closely connect the upper and lower models. According to the user energy consumption mode and the characteristics of distributed energy, the corresponding distributed energy is matched. The construction of wind power, photovoltaic, biomass power generation, combined cooling, heating and power supply devices, etc., and the allocation of corresponding energy storage devices according to the electricity load will play a supporting role in the construction of a new city in the future.

5. Summary

Considering the fluctuation of energy output and the uncertainty of load, this paper applies interval theory to establish interval linear programming based on affine operation to realize optimal operation of multi-energy complementary system. The scheme configuration and design analysis are carried out for multi-energy complementary geothermal energy utilization system and energy storage geothermal energy utilization system. The economic benefits brought by installing energy storage system on the customer side and establishing corresponding economic models are different. The models of pumping units in multi-energy complementary power generation systems are established in different ways under different working conditions. Under the market value evaluation method, the multi-function complementary scheme has large investment and low return on investment, which fails to

ISSN: 2688-9323

reflect the potential value of multi-function complementary. In the future, with the improvement of the electricity market, the widening of the peak-to-valley difference of electricity price, and the diversification of electricity price systems, the benefits of installing energy storage devices on the customer side will become increasingly significant.

References

[1] Chen Houhe, Li Wenming, Zhang Rufeng, et al. A day-to-day optimal dispatch model of an integrated energy system in an industrial park considering the energy storage characteristics of a building cooling area [J]. Electric Power Construction, 2019, 40 (8): 43-50.

[2] Sun Zhenyu, Shen Mingzhong. Application of multi-energy complementary system based on industrial plant in micro-energy network [J]. Huadian Technology, 2019 (11): 46-48.

[3] Li Hongzhong, Fang Yujiao, Xiao Baohui. Research on optimization operation of regional comprehensive energy system considering generalized energy storage [J]. Power System Technology, 2019 (9): 3130-3138.

[4] Liu Liu, Wang Dan, Jia Hongjie, et al. Comprehensive modeling and energy optimization analysis of generalized multi-source energy storage system [J]. Electric Power Construction, 2017, 38 (12): 2-11.

[5] Liu Jian, Fan Jiawen, Yao Xilong, et al. Research on development problems and countermeasures of multi-energy complementary system in Shanxi Province [J]. Coal Economic Research, 2019, 39 (10): 58-63.

[6] Li Ke. Research on key technologies of energy storage combined renewable energy distributed grid-connected power generation [J]. Science and Technology Shangpin, 2016 (7): 216-217.

[7] Zhu Ye, Lan Zhenbo, Kui Zhen, et al. Research on optimal operation of wind-solar energy storage multi-energy complementary system considering carbon emission cost [J]. Power System Protection and Control, 2019 (10): 127-133.

[8] Hu Wei, Shi Ruijing, Xie Xiaoguang, et al. Research on wind-solar hybrid, hydrogen energy storage coupled coal chemical multi-energy system in Hami region of Xinjiang [J]. Applied Energy Technology, 2017 (3): 11-14.

[9] Jiang Xianjin, Jiang Huaishen, Zhang Jiao. Brief introduction of energy storage type tram supercapacitor complete charging device [J]. 2015, 04 (3): 39-46.

[10] Zhou Yuhao, Zhang Haizhen, Song Shengnan. Research on key technologies of multi-energy complementary distributed energy experiment platform system [J]. Power Generation and Air Conditioning, 2017 (6): 5-9.