Clean energy consumption mechanism based on multi-energy transactions with electric heating

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Abstract. The comprehensive utilization of multi-energy is an important means to promote the high proportion of clean energy consumption in the region. This paper proposes a clean energy absorption mechanism based on electric heating to participate in multi-energy trading, which is applied to the transaction and operation optimization of energy terminals. In this paper, the scheduling framework of energy terminal is constructed first, and then the optimal scheduling model of energy terminal based on electric heating participating in multi-energy trading is established to promote clean energy consumption through collaborative optimization of multi-energy coupling equipment. The economic dispatch of energy terminal to all kinds of energy is realized. Finally, a test example is constructed to verify the operation economy and clean energy absorption rate of the energy terminal. The simulation shows that the proposed method can not only improve the clean energy absorption rate of the energy terminal, but also improve the operation economy of the system, and verify the effectiveness of the proposed method.

1 Introduction

Winter heating is the basic livelihood needs of residents in northern China. For a long time, coal-fired centralized heating has been mostly used, which has brought great impact to the environment [1-2]. Among many clean heating methods, electric heating has been strongly supported and promoted by governments and enterprises at all levels because of its advantages of clean environmental protection and strong controllability. On the other hand, with the rapid development of clean energy in recent years, the increasing permeability of clean energy, the volatility and randomness of clean energy consumption and utilization of energy terminals have brought difficulties. Combined with electric heating and other coupling equipment to promote clean energy consumption is of great significance.

At present, scholars at home and abroad have carried out a lot of research on clean energy absorption mechanism. Through the establishment of reasonable power market trading mechanism, the literature [4] put forward the problem of wind abandonment in order to solve the problem of high proportion renewable energy access to power system. Also, the power market trading mechanism can improve the competitiveness of wind power generation in the power market and ensure the complete absorption of wind power. By analyzing the electricity price elasticity of flexible power load [5] the paper establishes an operational model to optimize the period of peak and valley electricity division and the corresponding price level, which ensures the interests of

all participants. The peak-valley electricity price system with stronger resource allocation ability is obtained.[6] the literature, the benefit sharing model of cooperative innovation members is studied. The results show that the appropriate transformation mode can maximize the overall and individual benefits. Firstly [7] the typical characteristics of high proportion renewable energy are analyzed, and on this basis, the influence of high proportion renewable energy participation in power market on market mechanism is studied, which can provide reference experience for the construction of power market in China.

To sum up, at present, scholars at home and abroad have some research on promoting clean energy consumption, its research direction is mainly aimed at energy transmission, the optimization of consumption links, and less through the means of energy conversion to promote clean energy consumption. Therefore, it is necessary to use the means of trade to realize the conversion and utilization of electricity, gas and heat energy from the point of view of promoting clean energy consumption, and to improve the clean energy absorption rate of energy terminals.

This paper proposes a clean energy absorption mechanism based on electric heating to participate in multi-energy trading, which is applied to the transaction and operation optimization of energy terminals. Firstly, the scheduling framework of energy terminal is constructed, and then the optimal scheduling model of energy terminal based on electric heating is established. Finally, the simulation results are analyzed to verify the effectiveness of the proposed method.

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2 Energy flow structure of 1 energy source terminal

2.1 Energy terminal energy flow

The energy terminal energy flow constructed in this paper is shown in figure 1. The external energy sources of the system include END (electric distribution network) and GND (Gas distribution network). A terminal generator includes WT and PV. Coupling equipment include GB (Gas fired boiler), GT (Gas turbine); and EH (Electric heating).

Figure. 1. Energy Terminal Energy Flow

Energy transmission direction: energy terminal can buy electricity and natural gas from energy network. On the one hand, clean energy generation can supply terminal load demand, on the other hand, it can meet terminal heat load demand through electric heating equipment. The gas turbine and gas boiler inside the energy terminal can be used to meet the heat load and electric load demand of the terminal respectively.

2.2 Clean energy consumption mechanism

Based on the energy terminal energy flow structure shown in figure 1, a clean energy absorption mechanism based on electric heating to participate in multi-energy trading is constructed. Energy terminal clean energy output first supply terminal load demand. In the peak period of clean energy output, when clean energy output is larger than electricity load demand, electric heating supply heat load is operated to promote clean energy consumption.

3. Model description

3.1 Objective function

Taking the minimum cost of energy terminal as the objective function, the expression is as follows:

$$S = p_t \times (dzt_t + pp_t - de_t - p_{gt}) + pg \times (dag_t + qr_t + qd_t) \quad (1)$$

Where, p_t and pg are the prices of electricity and gas respectively. dzt_t , pp_t , de_t and p_{gt} are electric heating power consumption, electric load, clean energy supply and electricity generated by gas boiler, respectively.

dag_t , qr_t and qd_t are gas load, gas power consumption of GT and GB.

The energy conversion formulas for various coupling devices are as follows:

$$H_{gb} = \eta_{gb} P_{gb} \quad (2)$$

$$P_{gt} = \eta_{gt} P_{gt} \quad (3)$$

$$H_{EH} = \eta_{eh} P_{eh} \quad (4)$$

Where, H_{gb} , P_{gt} , H_{EH} are gas boiler heat generation power, gas turbine power generation, electric heating heat generation power respectively. η_{gb} , η_{gt} , η_{eh} are the respective conversion efficiency.

3.2 Constraints

(1) Power balance constraints of energy terminals:

$$md_t = dzt_t + pp_t - de_t - \eta_{gb} \times qd_t \quad (5)$$

Where, md_t is the purchasing power of energy terminal at time t .

(2) Balance constraints of natural gas at energy terminal:

$$mq_t = dag_t + qr_t + qd_t \quad (6)$$

Where, dag_t is the gas consumption of users at time t . qd_t , qr_t are the gas consumption of GT and GB. mq_t is the amount of natural gas purchased from the gas network at time t .

(3) Equilibrium constraints of heat

$$dah_t = \eta_{eh} \times (dzt_t + dh_t) + \eta_{gb} \times qr_t \quad (7)$$

Where, dah_t is the heat load at time t , dh_t is the amount of clean energy used for heating at time t .

(4) Balance constraints of clean energy power generation:

$$daw_t = de_t + dh_t + fq_t \quad (8)$$

Where, daw_t is the clean energy generation at time t . fq_t is the abandoned air volume at time t .

(5) Operational constraints of coupling equipment

The operation constraints of coupling equipment are conventional constraints. For details, please refer to [8].

4 Example analysis

4.1 Basic data

In order to verify the effectiveness of the proposed method, the simulation analysis is carried out based on the real data of an energy terminal. The energy terminal is directly connected to the power network and the natural gas network. The energy terminal consists of a wind turbine with a capacity of 100 kW and a photovoltaic generator with a capacity of 100 kW. The total output power curve of wind power and photovoltaic is shown in figure 2. The coupling equipment consists of a 150KW GB, a 100kW GT and a 150KW EH, with energy conversion efficiencies of 0.3, 0.5 and 0.9 respectively. The energy needs of users include electricity, gas and heat, The user's energy demand

power is shown in figure 2. The price of natural gas remains at 2.98 yuan/m³, and the electricity price information is shown in Figure 3.

Figure.2. Multi-energy load, clean energy output power

Figure.3. Electricity price curve

4.2 Result analysis

(1) Benefit comparison of energy terminal

Through the optimal operation of the proposed method, the purchase of electricity and gas from the main network of the system is shown in Fig.4, in which the total amount of electricity purchased is 1769.74 kwh, the total amount of gas purchased is 2259.44 m³. The total cost of purchasing energy is 2116.56 yuan. The amount of electricity purchased was 853 lower kWh, the volume of gas purchased was 326 m lower than before the optimization. The cost of energy purchase decreased by 1629.5 yuan. It can be seen that through the optimization of clean energy absorption mechanism based on multi-energy, it can effectively promote the transformation and utilization of internal resources of energy terminals and reduce energy purchase.

a. Energy purchase curve before optimization

b. Energy purchase curve after optimization

Figure.4. Energy Acquisition Curve of the System before and after Optimization

(2) Comparison of clean energy consumption rates

From figure 4, the curve of clean energy output and the electric load curve of users can be seen that during the peak period of clean energy output at 11-13, the demand for clean energy output will be greater than that of electricity load, and 340 kwh of wind power will be produced every day. Using the mechanism of clean energy absorption based on multi-energy trading proposed in this paper, the clean energy absorption rate is 100% through the conversion and utilization of coupling equipment between different energy sources. It is proved that the mechanism proposed in this paper is of great significance for the absorption of clean energy.

5 Conclusion

Based on multi-energy trading, this paper proposes a clean energy absorption mechanism based on electric heating to participate in multi-energy trading. Firstly, the scheduling framework of an energy terminal is established. Secondly, the optimal scheduling model of energy terminal based on electric heating to participate in multi-energy trading is established. The operating income of energy terminal is optimized. According to the example simulation, the operating economy and clean energy absorption rate of the proposed absorption mechanism are analyzed. The following conclusions can be obtained:

- To promote the conversion and utilization between electric and thermal energy sources by means of transaction, and to improve the economy of the system;
- By considering multi-energy trading and using electric energy with electric heating, it is helpful to clean energy consumption of energy terminal.
- On the basis of multi-energy trading, we will continue to study the impact of various coupling devices on the operation of energy terminals.

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