

Research on coordination and optimization of power generation, loading and integrated storage, flexible condition system and response

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Abstract. The comprehensive energy system in the park is the effective ways of solving the problems of low efficiency of social energy utilization and difficulty in absorbing renewable and clean energy. Due to the inherent characteristics of thermal load, it will be utilized as adjustable load to take part in the system's ideal arrange. Therefore, a coordinated optimization the source load and storage model, of the park's comprehensive energy system, which takes into account the flexible load response, is proposed to enhance the consumption of new energy and decrease the operating expend.

1. Introduction

The park level comprehensive energy system will be the main bearing form and important evolution direction of the future energy system, which has been studied by many scholars and experts in recent years. In terms of power supply side, document1 proposes a two optimal allocation method of energy points in the comprehensive energy system of the park taking into account the energy supply network; Literature 2 considers the energy memory of the micro-pumped memory system and takes the time-shift electrical appliance as an energy resource to participate in the configuration optimization of the microgrid; In literature 3, in terms of demand, users are frequently guided to respond by incentive signals or power prices depending on load price elasticity, change the way of electricity consumption[4-5].

To sum up, the paper takes the igniting load of the park as the implementation object of the thermal demand response, which will be used as a adjustable load to attend in the system optimization and scheduling, and proposes a coordinated optimization model of the park comprehensive energy system that takes into account the flexible heat load response. The implementation effect of source-load-storage coordination optimization considering thermal load demand response is analyzed by simulation.

2. Optimal coordination model of source, load and storage of comprehensive energy system in the park considering heat load demand response

2.1 Operation structure of integrated power system in the park

The park mainly includes power subsystem and thermal subsystem. The power subsystem and thermal subsystem are mainly coupled by electrothermal coupling equipment, which improves the flexibility of the operation of the park's comprehensive energy system. The power subsystem mainly includes wind, photovoltaic, micro gas turbine, electric boiler, electric energy store and other equipment for power users to use at the load end, and is connected to the grid for electric energy exchange. The thermal subsystem consists of thermal energy storage system, gas boiler, micro gas turbine thermal output and thermal load.

2.2 Objective function

In a scheduled cycle, the response cost of electric heating demand is not considered, and the park's comprehensive energy system has the lowest overall operating cost. The optimization objective function of the comprehensive energy system is:

$$\text{Min } F = F^{\text{MT}} + F^{\text{WP}} + F^{\text{EX}} + F^{\text{ME}} + F^{\text{BL}} \quad (1)$$

The objective function of comprehensive energy optimization in the park includes five parts: The cost of the park's full power system is represented by F during the scheduling period, and the expend of natural gas consumed by micro gas turbines during the scheduled period is expressed by F^{MT} ; F^{WP} is the expend of new energy loss in the dispatching period; In the dispatching

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phase, F^{EX} represents the cost of purchasing power when engaging with a large external power grid; The gas-fired boiler's major energy cost in the dispatching period is represented by F^{BL} ; F^{ME} is the operation and maintenance expend of all equipment; The specific declaration is as follows:

$$F^{MT} = \sum_{t=1}^T C_{CH4} \frac{P_t^{MT}}{\eta_t^{MT} \times L_{MT}} \cdot \Delta t \quad (2)$$

$$F^{BL} = \sum_{t=1}^T C_{CH4} F_t^{BL} \Delta t \quad (3)$$

$$F^{wp} = \sum_{t=1}^T X^{wp} (P_t^{wp,forecast} - P_t^{wp}) \quad (4)$$

$$F^{EX} = \sum_{t=1}^T \left[\frac{C_{buy} + C_{sell}}{2} P_t^{ex} + \frac{C_{buy} - C_{sell}}{2} |P_t^{ex}| \right] \Delta t \quad (5)$$

$$F^{ME} = \sum_{t=1}^T \sum_{i=1}^{N_m} C_{mi} |P_t^i| \Delta t \quad (6)$$

Where, C_{CH4} represents the price of natural gas; P_t^{MT} and η_t^{MT} represent the electric energy and power generation efficiency of the micro gas turbine during the period; L_{MT} expresses the cheap calorific value of natural gas; Δt is the unit dispatching time; F_t^{BL} is the amount of natural gas consumed at any time; P_t^{ex} Interconnection line interaction power; $P_t^{wp,forecast}$ represents the new energy power of the previous dispatching cycle; P_t^{wp} represents the power of new energy in the dispatching period.

2.3 Constraint condition

(1) Maximum and minimum output thresholds for gas-fired boilers, photovoltaics, microgas turbines, and wind power;

$$P_i^{\min} \leq P_i^{chp} \leq P_i^{\max} \quad (7)$$

Where, P_i^{\min} and P_i^{\max} are the smallest and largest output of the *i*th micro-energy supply respectively.

(2) Storage limitations for thermal and electric energy;

$$E_{\min}^{EES} \leq E_t^{EES} \leq E_{\max}^{EES} \quad (8)$$

Where, E_{\min}^{EES} and E_{\max}^{EES} represent the smallest and largest capacity of thermal energy storage.

(3) Interaction of the park's comprehensive energy system with external energy grid tie lines' power limitations;

$$P_{\min}^{ex} \leq P_t^{ex} \leq P_{\max}^{ex} \quad (9)$$

In the formula, P_{\min}^{ex} and P_{\max}^{ex} are the smallest and largest values of interconnection line interaction energy.

(4) Climbing constraint of controllable unit;

$$-r_{di} \Delta t \leq P_{i,t}^g - P_{i,t-1}^g \leq r_{ui} \Delta t \quad (10)$$

In the formula, r_{di} and r_{ui} are the speed limits for the governable output unit *i* to decrease output and magnify power in the dispatching period *t*.

(5) Thermal demand responds to heat supply balance constraints:

$$Q_t^{MT-h} + Q_t^{EB} - Q_t^{HS,in} + Q_t^{HS,dis} = \sigma Q_t^{load} \quad (11)$$

Where, $K_{pmin} \leq \frac{Q_t^{MT-h}}{P_t^{MT}} \leq K_{pmax}$ is the thermal load regulation coefficient.

(6) Thermal power ratio constraint of micro gas turbine;

$$K_{pmin} \leq \frac{Q_t^{MT-h}}{P_t^{MT}} \leq K_{pmax} \quad (12)$$

Where, K_{pmin} and K_{pmax} are the smallest and largest values of thermoelectric ratio of micro gas turbine.

3. Example simulation analysis

3.1 Simulation example scheme

In order to confirm the benefits of the comprehensive power system of the park in the sight of the comprehensive response of flexible heat load, The following situations will be compared. See Table 1 and Figure 1 below.

Mode 1: Demand response is not taken into account

Mode 2: consider the response of thermal demand side

Mode 3: taking into account the electric heating load's reaction to demand

Table1 Relevant operation handicap of comprehensive poewe system in the park

ID	type	P_{min}	P_{max}	C_m
1	Micro gas turbine	100	199	0.024
2	Gas boiler	29	299	0.025
3	Electric boiler	0	300	0.0165
4	Wind power	0	300	0.0196
5	Photovoltaic	0	300	0.0235
6	Grid	-100	300	/

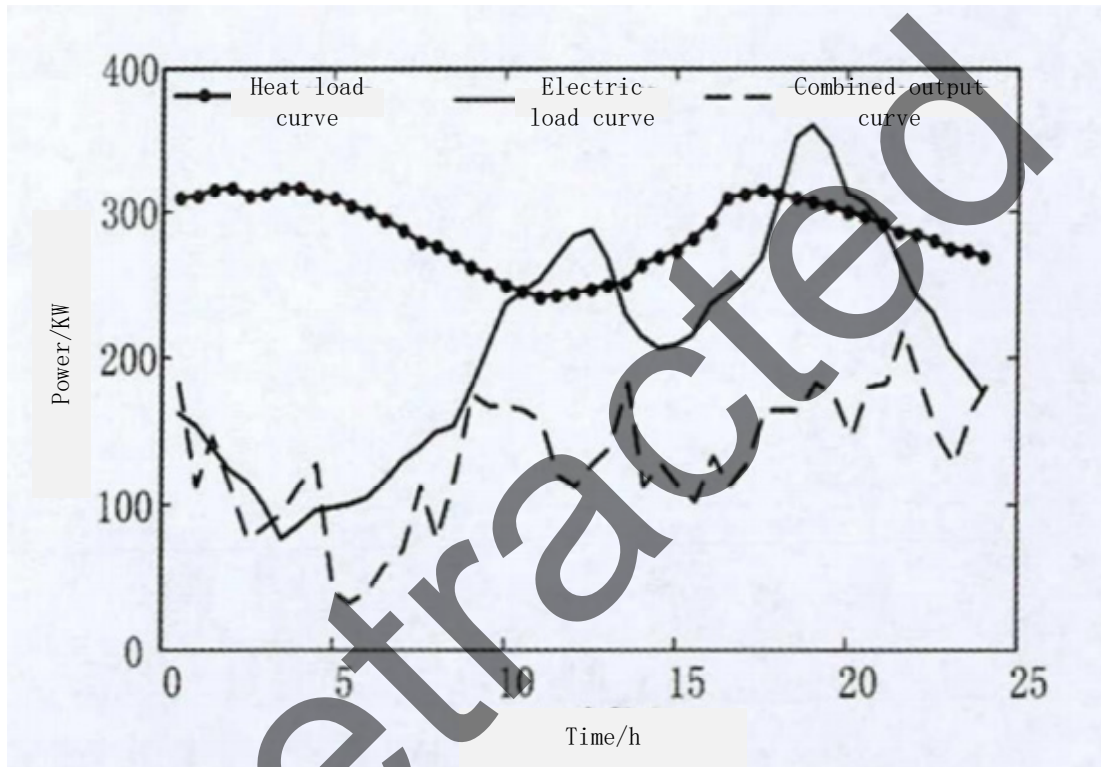


Figure1: Wind power and photovoltaic combined forecasting output and electric heating load forecasting curve

3.2 Analysis of different operation modes

Table2 System action expend and energy utilization competence under different operation modes

Operation mode	System operation cost (yuan)	Energy utilization efficiency (%)	New energy utilization rate (%)
Option 1	3660.41	80.54	65.4
Option 2	3400.01	85.21	74.4
Option 3	3121.21	89.65	90.8

As shown in Table 2, taking into account the full demand response of the electric heating load can significantly increase the efficiency of energy use. Through the coordinated operation of power supply, energy storage, electric heating coupling and electric heating load source, the operation expend of the whole system can be reduced,

the output stability of gas turbine units can be mainly improved, the flexibility of the system operation will be amended, and the absorption of new energy can be improved under the premise of ensuring the balance between supply and demand, Realize the effect of coordinated interaction among source, storage and load.

4 Conclusion

(1) There are few studies that consider the schedulability of multiple types of loads on the demand side. The thermal load also has its schedulability value in integrated energy management. According to the characteristics of thermal load delay in transmitting and heat users' softness in heating ease, thermal load can be used as an adjustable load to join in the best dispatching.

(2) When coordinating and optimizing the source, load and storage of the comprehensive energy system, taking into account the demand response of the electric igniting load can realize the complementary benefits between them.

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