Research on energy supply of intelligent energy system with energy storage

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Abstract. The coordinated intelligent energy supply should consider the characteristics of the energy supply equipment, load characteristics and user needs. As a special energy supply equipment, water energy storage system has two-way controllability, which can store and release energy. Using its energy supply characteristics, combined with the system characteristics such as peak valley electricity price difference, it is helpful to achieve peak load reduction, balance load and save energy supply cost of the system. In this paper, an enterprise park is taken as an example to study the energy supply of intelligent energy system with water energy storage. An energy supply strategy is proposed. An energy supply model is established. At last, the simulation verifies the advantages of intelligent energy system with water energy storage.

1. Introduction

with the development of industrial parks, the popularization of new energy generation and the upgrade of new investment mode, the new demands come out. Developing intelligent energy system and making full use of the advantages of various energy sources to achieve coordinated energy supply have become a focus. At the same time, intelligent energy is an important part of promoting the energy supply-side structural reform. As an advanced energy supply strategy, the coordination and optimization of integrated intelligent energy resources is also a key issue in the development of intelligent energy. The multiple energy sources can be utilized comprehensively through the coordination of various distributed energy supply units. Thus, it can effectively improve the full absorption of intermittent energy, the stability and economy of the system[1-3].

The coordinated intelligent energy supply should consider the characteristics of the energy supply equipment, load characteristics and user needs. As a special energy supply equipment, water energy storage system has two-way controllability, which can store and release energy. Using its energy supply characteristics, combined with the system characteristics such as peak valley electricity price difference, it is helpful to achieve peak load reduction, balance load and save energy supply cost of the system[4-6].

In this paper, an enterprise park is taken as an example. According to the existing intelligent energy configuration, the characteristic of the park's energy supply system is analyzed, and a multi-energy coordinated energy supply strategy is proposed. The impact of the water energy storage on the system is analyzed. Finally, the feasibility and superiority of these strategies are verified through simulation analysis.
2. System energy supply strategy
In this section, the system energy supply strategy will be proposed based on the analysis of supply side and demand side, combined with the characteristics of electricity price,

2.1 Supply, demand sides and electricity price analysis
An enterprise park is taken as an example for simulation verification and analysis. The basic information of the park is as follows:

(1) Supply side
1) at present, there is a substation in the superior power grid of the park, which is 110kV.
2) two 10kV medium voltage buses are used for power distribution, with interconnection switch set in the middle; and four transformers in operation in low-voltage distribution system, which is 10kV / 0.4kV.
3) CCHP system
A 635kw internal combustion engine and flue gas hot water LiBr unit matched, which the refrigerating capacity is 700kW and the heating capacity is 600kW.
4) distributed roof photovoltaic power generation system
The total installed capacity is 300kWp
5) energy storage system of water storage tank
There are three 200m3 energy storage tank.

(2) Demand side
There are three research buildings and one test plant in the park. This paper takes the research building as the main power consumption object.

The summer load of this park is taken as an example. The typical daily electrical load and cooling load are shown in the figures.

As shown in the figures, the load is concentrated in the daytime with fluctuation, and the peak value of electric load and cooling load is 2267kW and 6199kW respectively.

The electricity price adopts time-sharing price standard of Beijing commercial power consumption. The valley price is 0.3113 yuan / kWh, the flat price is 0.8110 yuan / kWh, the peak price is 1.3367 yuan / kWh, and the advanced peak price is 1.4660 yuan / kWh, as shown in the figure below.
2.2 System energy supply
According to the above characteristics of supply side and demand side, combined with the analysis of electricity price information, the optimal energy supply strategy is formulated.

(1) solar energy is the cleanest energy, and the installed capacity is small, so power generation is preferred. According to the load size and the predicted power generation size of photovoltaic, the maximum power can also be used for photovoltaic power generation when there is no energy storage in the system.

(2) in order to ensure the maximum efficiency of the gas generator, the cooling capacity made by the waste heat of the combined cooling heating and power (CCHP) system is preferred for the cooling load.

(3) for the insufficient part of CCHP supply, grid power supply shall be used.

(4) there are many peak price periods in the daytime and valley price in the early morning. In the peak price period, the system load demand is large, while in the valley price period, the system load demand is small. Using the peak valley difference of electricity price, we can refrigerate and store the cold in the valley price period and releases the cold in the peak price period. The CCHP system also participates in the coordination of energy supply in the peak price period.

2.3 Supply strategy of water energy storage system
It can be seen from the above that in the system energy supply strategy, the characteristics of each energy supply unit and electricity price are fully utilized, among which the principle of water storage system is low price cold storage and peak price cold release. In the process of cooling release of water energy storage system, different cooling release strategies can achieve different results. For example, if the goal is to stabilize the load fluctuation, the water storage system will release the cooling when the load fluctuation is large; if the goal is to optimize the economy, the water storage system will release the cooling during the peak price. Such two different cooling release schedules will have different effects on the system.

3. System energy supply model
The system energy supply diagram is as shown in Figure 4.

From the diagram, it can be seen that the electric load of the system is supplied by the gas turbine generator set of the triple-generation system and the power grid. The cold and heat load is supplied by the lithium bromide unit of the triple-generation system, the water storage system and the conventional electric refrigerator. According to the need, the power external characteristic model and cost model of these energy supply units are established. And the cost of purchasing electricity and gas are considered in the cost model, while the cost of equipment maintenance, depreciation and other operating cost and the cost of pollutant discharge treatment are not considered.

![Figure 4 The system energy supply diagram](image-url)
3.1 Objective Function
Taken the minimum economic cost as the goal, considering the power and gas purchase cost, not considering the operation cost such as equipment maintenance, depreciation and pollutant emission treatment cost, objective function of the coordinated optimization energy supply is established as follow.

\[
\min \quad C_{\text{total}}(t) = C_{\text{grid}}(t) + C_{\text{gas}}(t)
\]

where,

\[
C_{\text{grid}}(t) = r_{\text{elc}}(t) \cdot E_{\text{grid}}(t)
\]

\[
C_{\text{gas}}(t) = r_{\text{gas}}(t) / n_{\text{gas}} \cdot F_{G}(t)
\]

\[
E_{\text{grid}}(t) = E_{\text{czl}}(t) + E_{\text{elc}}(t)
\]

In this formula, \(C_{\text{total}}(t)\) is the total cost. \(C_{\text{grid}}(t)\) is the purchasing electricity cost. \(C_{\text{gas}}(t)\) is the purchasing gas cost. \(r_{\text{elc}}(t)\) is the electricity price. \(E_{\text{elc}}(t)\) is the quantity of purchasing electricity. \(r_{\text{gas}}(t)\) is the gas price. \(n_{\text{gas}}\) is the gas heat value. \(F_{G}(t)\) is the gas consumption of gas turbine. \(E_{\text{czl}}(t)\) is electric energy required by conventional electric refrigerator. \(E_{\text{elc}}(t)\) is the electricity of electric load demand.

3.2 Constraint Condition
(1) Electric load balance
The electric power provided by the supply side of the system is balanced with the electric load power of the system, as follow.

\[
P_{G}(t) + P_{PV}(t) + P_{\text{grid}}(t) = P_{\text{elcload}}(t) + P_{\text{czl}}(t)
\]

In this formula, \(P_{G}(t)\) is the electrical power provided by the CCHP. \(P_{PV}(t)\) is the photovoltaic power. \(P_{\text{grid}}(t)\) is the electrical power provided by the grid. \(P_{\text{elcload}}(t)\) is the electrical load of the system. \(P_{\text{czl}}(t)\) is the input power of the conventional electric refrigerator.

(2) Cooling load balance
The cooling power provided by the supply side of the system is balanced with the cooling load of the system, as follow.

\[
P_{xzl}(t) + P_{\text{czl}}(t) + P_{xlg}(t) = P_{\text{load}}(t)
\]

In the formula, \(P_{xzl}(t)\) is the cooling power provided by the lithium bromide waste heat unit of CCHP. \(P_{\text{czl}}(t)\) is the cooling power provided by the conventional electric refrigerator. \(P_{xlg}(t)\) is the cooling power provided by the energy storage tank. \(P_{\text{load}}(t)\) is the cooling load of the system.

(3) Output restriction of each energy supply unit
1) gas generator
The generating power shall be greater than the minimum cut-off power and less than the rated power, as follow.

\[
P_{\text{Gmin}} \leq P_{G}(t) \leq P_{G0}
\]

Where, \(P_{\text{Gmin}}\) is the minimum cut-off power and \(P_{G0}\) is the rated power of gas generator.

2) Lithium Bromide Unit
The cooling power generated shall be less than the rated power.

\[
0 \leq P_{xzl}(t) \leq P_{xzl0}
\]

Where, \(P_{xzl0}\) is the rated power of lithium bromide waste heat unit.

3) Energy storage tank
The cooling capacity in the energy storage tank shall meet the following conditions

\[
Q_{\text{xlgmin}} \leq Q_{\text{xlg}}(t) \leq Q_{\text{xlgmax}}
\]
Where, $Q_{\text{slgmin}}$ is the minimum storage capacity of the energy storage tank, and $Q_{\text{slgmax}}$ is the maximum.

4) Photovoltaic

$$0 \leq P_{\text{PV}}(t) \leq P_{\text{PV0}}$$

Where, $P_{\text{PV}}(t)$ is the photovoltaic power, and $P_{\text{PV0}}$ is the rated power of photovoltaic power.

5) Conventional generator

$$0 \leq P_{\text{csl}}(t) \leq P_{\text{csl0}}$$

Where, $P_{\text{csl}}(t)$ is the cooling power provided by the conventional refrigerator, and $P_{\text{csl0}}$ is the rated power provided by the conventional refrigerator.

4. Simulation

In the MATLAB environment, the intelligent energy system with water energy storage system is simulated. The system operation under different cooling release strategies is simulated. The simulation results are as follows.

(a) electric load
(b) cooling load
Figure 5 Load diagram of system without water energy storage

(a) electric load
(b) cooling load
Figure 6 Load diagram of system with water energy storage under the first strategy*
Figure 7 Load diagram of system with water energy storage under the second strategy*

*In the first strategy, the water energy storage system is preferred to reduce the peak load. In the second strategy, the water energy storage system is preferred to save the cost.

The cost calculation results under different schemes are shown in the table below.

Table 1. Formatting sections, subsections and subsubsections.

| Scheme                                      | electricity cost (yuan) | gas cost (yuan) | total energy cost (yuan) | cost saving (yuan) |
|---------------------------------------------|-------------------------|-----------------|--------------------------|-------------------|
| intelligent energy system without water energy storage | 36127                   | 6406            | 42533                    | 0                 |
| intelligent energy system with water energy storage under the first strategy | 35149                   | 6406            | 41555                    | 978               |
| intelligent energy system with water energy storage under the second strategy | 34773                   | 6406            | 41179                    | 1354              |

It can be seen from the above charts that, first of all, in economy, no matter what cooling release strategy is adopted for the water storage system, the economy of the intelligent energy system with water storage is better than that without water storage.

Secondly, according to the strategy analysis above, the water storage system can achieve different results with different cooling release strategies. In order to reduce the peak load and stabilize the load fluctuation, the water storage system releases the cooling capacity when the load is large in the daytime, which can effectively eliminate the peak load and improve the system stability, as shown in the figure 6. In order to save the cost of purchasing energy and maximize the economy, the water storage system releases the cooling capacity at the peak price in the daytime, which can maximize the economic optimization and improve the system economy, as shown in the figure 7. Under the two modes, the water storage system can achieve the goal well.

5. Conclusion
Intelligent energy coordination and optimization need to make use of the characteristics of each energy supply unit in order to not only improve the full consumption of intermittent energy, but also improve the stability and economy of the system. As one of the special energy supply, water storage system can effectively achieve peak load reduction, balance load and save energy supply cost by using its two-way controllable characteristics, combined with peak valley price difference and other energy supply of the system.

References
[1] Wang Qinming. (2019) Exploration and application of industrial park smart energy management system. Power Demand Side Management, 21(1): 62-64,69.
[2] Shi Xin-lin Sun Shu-min Zhang Jiao. (2019) Construction and Application of Regional Smart Energy Integrated Service Platform. Electric Power System Equipment, 16: 201-202.
[3] Qing Huang. (2018) Developing intelligent energy is the way to conform to the energy trend. Energy of China, 40(12): 14-16.

[4] Yang Tao, Ren Hongbo, Xia Lin. (2019) Optimization of Combined Cooling Heating and Power System with Energy Storage. Journal of Shanghai University of Electric Power, 35(4): 367-372,378.

[5] Chang Lihong. (2016) Discuss the working principle of energy storage tank in energy storage system. China Science & Technology Panorama Magazine, 24: 100,103.

[6] Chen Jianyang, Cai Ye, Wang Heng. (2019) Optimization of operation strategy of energy storage tank based on distributed energy system of natural gas. Energy Conservation, 38(8): 55-56.