Research on Optimization of Regional Integrated Energy System Based on Thermal Inertia of Building Clusters

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Abstract. With the increase in the share of energy from new energy sources such as photovoltaics and wind power, the development and application of integrated energy systems are becoming more and more rapid. However, if energy is not coordinated and optimized, wind and solar abandonment may occur. This is to achieve a variety of energy sources. The integration, complementarity and flexible regulation of the company have brought great challenges. The fifth-generation district heating and cooling system, as a new direction of comprehensive energy development, can greatly improve the energy efficiency of sources and networks and the convenience of user-side energy consumption, but its adjustment potential for the user-side is insufficient. This paper explores the thermal inertia of the existing infrastructure in the system, that is, the user-side building cluster in the regional thermal system, and uses the thermal inertia of the building cluster to improve the overall potential flexibility of the regional-level integrated energy system and realize the optimized operation of the regional integrated energy system, then improve the flexibility and economy of system operation.

1. Introduction
In order to cope with the challenges of limited fossil fuel resources and global environmental issues, renewable energy power generation technologies have developed rapidly on a global scale. As a new generation energy system that is conducive to promoting the consumption of new energy, the integrated energy system has received more and more attention and its related research has been developing rapidly[1]. The integrated energy system refers to linking these different energy entities more closely with each other through coupling technology, in which the interaction is mainly carried out through the energy conversion devices between the different energy entities to provide services and manage each energy entity in the best way[2]. With the increasingly in-depth research on the integrated energy system, the park-level integrated energy system is developing rapidly on a global scale[3]. The park has the characteristics of high energy density, high load utilization hours, and diversified forms of energy production and use. It is the best entry point to promote the development of an integrated energy system.

The user's demand for secondary energy is mainly cold, heat, and electricity. The common cold, heat and electricity integrated energy system mainly considers the complementary characteristics of the source side to provide users with energy supplies of different attributes. The fifth-generation district heating and cooling system is a new energy supply system concept, which can better integrate various energy forms at the hub, and provide the cold and heat of the energy hub to the users through the low-temperature two-way pipe network. Therefore, it meets the needs of different users, realizes the upgrade
from the complementary utilization of energy to the integration of energy, and greatly reduces the network loss, and realizes the efficient and coordinated utilization of the source network[4].

Around 2017, Europe took the lead in proposing the concept of the fifth-generation district heating and cooling system (5GDHC)[5]. 5GDHC basic definition is: 5GDHC network is a brine or water as the carrier medium, the terminal sub-station network with energy supply source heat pump[6]. Its working temperature is very close to the ambient temperature, which is not suitable for direct heating and cooling. The low temperature heat/cold is supplied to the water source heat pump of the sub-station through the carrier medium to meet the cooling and heating needs of users. The low temperature of the carrier medium determines that it can directly use industrial and urban waste heat and renewable energy containing low-grade heat. The feature that the substations can supply energy in the reverse direction allows them to use the same pipeline to meet the heating and cooling needs of different buildings at the same time. Compared with the traditional heating and cooling network, 5GDHC technology has the advantages of efficient energy utilization, intensive space resources, user-friendly access, multi-energy interaction and coordination, and smart scheduling and operation. It can enhance the coupling of different networks such as heating and cooling in the integrated energy system, and greatly improve the efficiency of energy utilization. It is one of the hot research fields in recent years.

However, 5GDHC technology pays more attention to the integration of the source and the low temperature and high efficiency of the network, and there is not enough attention to how the user side participates in improving the overall energy efficiency. In practice, due to the time transmission delay of the heating pipe network, it is a high inertia system, and the user itself can be regarded as a heat storage equipment cluster. Literature[7] scheduling model to study the dynamic behavior cogeneration constraint model constraints and the heat storage device and heat pipe network meter. This model not only considers the economy of the system, but also improves the level of wind power consumption. However, the above research ignores the thermal inertia of the building clusters on the demand side, that is, due to the thermal insulation properties of the building clusters[8], the indoor temperature of the building clusters will not change drastically in a short time when the heat is absorbed, which allows the heating area located in the building cluster to act as a corresponding heat storage unit. In the literature[9], based on the heat storage capacity of the district heating system, the optimal dispatch model of the integrated energy system is studied. But how to take advantage of the thermal inertia of the district heating network and how to promote the integration of wind power in the electricity transmission network and not studied. In the literature [10-11], considering the thermal insulation characteristics of the building, according to the user comfort zone on the side of the cluster building, reduce the heat source output during the peak hours of wind power, and improve the peak shaving capacity of the cogeneration unit. In literature [12-13], In order to increase the flexibility of cogeneration units in promoting the integration of wind power, the heat storage characteristics of the central heating system are studied, and the output demand of cogeneration units is reduced when the heat load peaks. However, the detailed thermal model was not considered in the above research. Previous studies have carried out optimal scheduling based on the heat storage characteristics of the thermal system, but the building thermal inertia modeling is not detailed enough.

In this paper, a detailed model analysis based on the thermal inertia of the building cluster is carried out and applied to the 5GDHC system to establish a regional energy storage model based on the detailed building thermal inertia model, aiming at the optimal system operating cost, and comprehensively considering various equipment models in the 5GDHC and energy constraints, establish an optimal scheduling model, and realize regional-level energy coordination management. Taking a park as an example for simulation analysis, compared with the traditional optimization model, the user-side building response potential is further tapped, effectively reducing operating costs, verifying the effectiveness of the model, and improving the flexibility of the system.

2. Thermal inertia modelling of building clusters

The RC thermal network model of the building area is composed of thermal resistance with heat transfer capacity and heat capacity with heat storage capacity [28]. In the node method adopted, there are two
types of nodes, namely, room nodes and wall nodes, and each node in the building area is grounded through a heat capacity node and connected to each other through a thermal resistance. The RC thermal network model specifically describes a heating/cooling area, while the building model is a combination of multiple similar structural areas. The heating/cooling areas in each building are roughly similar to each other.

![Figure 1. RC thermal network model](image)

The specific mathematical model of the RC thermal network model in the heating/cold zone is described as follows:

\[ C_{wi} \frac{dT_{wi}}{dt} = \sum_{j \in N^w_i} \frac{T_{sj} - T_{wi}}{R_{wj}} + r_j \alpha_j A^w_j Q_{rad}^j \]  

(1)

\[ C_{zi} \frac{dT_{zi}}{dt} = \sum_{j \in N^w_i} \frac{T_{wj} - T_{zi}}{R_{wj}} + \pi_k \sum_{c \in N'^w_i} \frac{T_{cj} - T_{zi}}{R_{win}} + \hat{Q}^{int} + Q_{R,i} + \pi_k \tau_j A^w_j Q_{rad,win}^j \]  

(2)

Where \( T_{zi} \) is the temperature of the i-th room, \( C_{wi} \) is the heat capacity of the j-th wall, \( N^w_j \) is the set of all adjacent points of the j-th wall, \( T_{sj} \) is the value of all the adjacent nodes of the j-th wall temperature, \( T_{wj} \) is the temperature of the j-th wall, \( R_{wj} \) is the thermal resistance between the center line and the j-th wall. If the j-th wall is not exposed to sunlight, \( r_j = 0 \), otherwise, \( r_j = 1. \alpha_j \) is the absorption coefficient of the j-th wall, \( A^w_j \) is the area of the j-th wall, and \( Q_{rad}^j \) is the light intensity in the corresponding direction of the j-th wall.

Where \( C_{zi} \) is the heat capacity of the i-th room, \( T_{zi} \) is the temperature of the i-th wall, \( N^w_i \) is the set of all adjacent wall nodes in the i-th room, \( T_{cj} \) is the ambient temperature where the external node of the j-th wall with windows is located, \( Q_{R,i} \) is the heat/cold power consumed by the building group provided by the energy supply device. If there is no window in this room, \( \pi_k = 0 \), or \( \pi_k = 1. \tau_j \) is the transmittance of the window on the j-th wall, \( A^w_j \) is the total area of the window on the j-th wall, \( Q_{rad,win}^j \) is the light intensity corresponding to the direction of the window, and \( \hat{Q}^{int} \) is the i-th Heat source inside the room.

Taking into account the slow dynamic process of building heat dissipation/cooling and temperature changes, the building heat balance equation expressed by the differential equation is further differentiated, so as to achieve a simple and effective solution to the economic optimization problem of building clusters.

For the room in Fig.1, the model is established as follows:

\[ C_{w1} R_{w1} T_{w1}(t + 1) - (C_{w1} R_{w1} - 2) * T_{w1}(t + 1) \]

\[ = \Delta t * (T_{zi}(t) + T_{out}(t) + r_1 \alpha_1 A^w_1 Q_{rad}^1) * R_{w1} \]  

(3)

\[ C_{w2} R_{w2} T_{w2}(t + 1) - (C_{w2} R_{w2} - 2) * T_{w2}(t + 1) \]

\[ = \Delta t * (T_{zi}(t) + T_{out}(t) + r_2 \alpha_2 A^w_2 Q_{rad}^2) * R_{w2} \]  

(4)

\[ C_{w3} R_{w3} T_{w3}(t + 1) - (C_{w3} R_{w3} - 2) * T_{w3}(t + 1) \]

\[ = \Delta t * (T_{zi}(t) + T_{out}(t) + r_3 \alpha_3 A^w_3 Q_{rad}^3) * R_{w3} \]  

(5)
\[ C_w R_w T_w(t + 1) - (C_w R_w - 2) * T_w(t + 1) = \Delta t * (T_{z1}(t) + T_{out}(t)) + r_4 a_4 A_4^w Q_{rad}^f * R_{w4} \] (6)

\[ C_z1 * (T_{z1}(t + 1) - T_{z1}(t)) = \Delta t * \left( \sum_{j=1}^{N} \frac{T_{wj}(t) - T_{z1}(t)}{R_{wj}} + \frac{T_{out}(t) - T_{z1}(t)}{R_{win1}} + Q_{RI} + \dot{Q}_{int} \right) \] (7)

3. Modelling of the integrated energy system of the park

3.1. Objective function

The optimized operation of the integrated energy system in the park is aimed at economy, and the energy cost of the system is reduced by rationally arranging the unit's output plan and controllable load operation interval. Therefore, the objective function of the proposed optimal scheduling model is the lowest comprehensive operating cost of the park, which mainly includes three parts: power purchase cost, gas purchase cost, and operation and maintenance cost.

\[ \min \sum_{i=1}^{N_t} (C_{g,sum} + C_{gas,sum} + C_{e,sum}) \] (8)

\( N_t \) is the number of days before the optimization period.

(1) Power purchase cost. The electricity purchase cost in the park is obtained by multiplying the electricity purchased by the grid \( P_{grid,t} \) by the real-time electricity price \( \lambda^{TR}_t \).

\[ C_{g,sum} = \lambda^{TR}_t P_{grid,t} \] (9)

(2) Gas purchase cost. The cost of gas purchase in the park is obtained by multiplying the power \( P_{MT,t} \) of the combined heat and power by the coefficient \( \eta_{gas}^p \) of the combined heat and power, and then multiplying it by the converted natural gas price \( \lambda^{MT}_{gas} \).

\[ C_{gas,sum} = \lambda^{MT}_{gas} \eta_{gas}^p P_{MT,t} \] (10)

(3) Operation and maintenance costs of cold, heat and gas supply.

\[ C_{e,sum} = \sum_{i=1}^{N_M} C_{MT,i} + \sum_{i=1}^{N_S} C_{ES,i} + \sum_{i=1}^{N_B} C_{Br,i} + \sum_{i=1}^{N_A} C_{Ag,i} + \sum_{i=1}^{N_S} C_{Is,i} + \sum_{i=1}^{N_R} C_{Ar,i} + \sum_{i=1}^{N_pump} C_{pump,p} \] (11)

Where \( C_{MT,i}, C_{ES,i}, C_{Br,i}, C_{Ag,i}, C_{Is,i}, C_{Ar,i}, C_{pump,p} \) is the equipment maintenance costs for micro gas turbine, accumulator, electric boiler, industrial air conditioning, ice storage device, absorption chiller and pump. The operation and maintenance cost of each equipment \( C_{gen} \) is the unit maintenance cost \( C_{gen,unit} \) multiplied by the equipment's operating power \( C_{gen,t} \).

\[ C_{gen} = C_{gen,unit} C_{gen,t} \] (12)

3.2. Energy supply equipment constraints

(1) Electric boiler

\[ H_{Br,t} = P_{Br,t} \eta_{COP}^{br} \] (13)

Where \( H_{Br,t} \) and \( P_{Br,t} \) are the heating power and power consumption of the electric boiler respectively, \( \eta_{COP}^{br} \) is heating efficiency of the electric boiler.

(2) Micro gas turbine

\[ P_{MT,t} = H_{MT,t} R_{MT} \] (14)

Where \( P_{MT,t} \) and \( H_{MT,t} \) are the electric power and heating power of the micro gas turbine, respectively, \( R_{MT} \) is the heat-to-electricity ratio of the micro gas turbine.
(3) Industrial air conditioners and absorption chillers

\[ Q_{Ag,t} = P_{Ag,t} \eta_{Ag}^{COP} \]  
\[ Q_{Ar,t} = H_{Ar,t} \eta_{Ar}^{COP} \]  

Where \( Q_{Ag,t} \) and \( P_{Ag,t} \) are the refrigeration power and power consumption of industrial air conditioners, respectively. \( \eta_{Ag}^{COP} \) is the refrigeration energy efficiency of industrial air conditioners. \( Q_{Ar,t} \) and \( H_{Ar,t} \) are the cooling power and heat consumption power of the absorption chiller, respectively. \( \eta_{Ar}^{COP} \) is the refrigeration energy efficiency ratio of the absorption chiller.

(4) Ice storage device

\[ Q_{is,t+1} = \left( \eta_{is}^s P_{is,t} - Q_{is,t} / \eta_{is}^m \right) \Delta t + (1 - \sigma_{is}) M_{is,t} \]  
\[ M_{is,t}^{\min} \leq M_{is,t} \leq M_{is,t}^{\max} \]  
\[ P_{is,t}^{\min} \leq P_{is,t} \leq P_{is,t}^{\max} \]  
\[ Q_{is,t}^{\min} \leq Q_{is,t} \leq Q_{is,t}^{\max} \]  

Where \( M_{is,t} \) is the capacity of the ice storage device. \( P_{is,t} \) and \( Q_{is,t} \) is the ice making power and melting power of the ice storage device, respectively. \( \eta_{is}^s \) and \( \eta_{is}^m \) is respectively the ice making and melting efficiency of the device during cold storage, \( \tau \) is the self-loss coefficient of the ice storage device. \( M_{is,t}^{\min} \) and \( M_{is,t}^{\max} \) is the upper and lower limits of the capacity of the ice storage device, \( P_{is,t}^{\min} \) and \( P_{is,t}^{\max} \) are respectively the upper and lower limits of ice making power, \( Q_{is,t}^{\min} \) and \( Q_{is,t}^{\max} \) is respectively the upper and lower limits of melting power.

(5) Power storage device

\[ S_{ES,t} = \left[ \eta_{ES}^s P_{ES,t}^s - P_{ES,t}^r / \eta_{ES}^m \right] \Delta t + (1 - \sigma_{ES}) S_{ES,t} \]  
\[ S_{ES,t}^{\min} \leq S_{ES,t} \leq S_{ES,t}^{\max} \]  
\[ P_{ES,t}^{\min} \leq P_{ES,t} \leq P_{ES,t}^{\max} \]  
\[ P_{ES,t}^{\min} \leq P_{ES,t}^r \leq P_{ES,t}^{\max} \]  
\[ P_{ES,t}^{\min} \leq P_{ES,t}^s \leq P_{ES,t}^{\max} \]  

Where \( S_{ES,t} \) is the battery energy storage capacity, \( P_{ES,t}^s \) and \( P_{ES,t}^r \) is the charging and discharging power of the storage device, \( \eta_{ES}^s \) and \( \eta_{ES}^m \) is the charging efficiency and discharging efficiency of the power storage device, \( \sigma_{ES} \) is the self-loss coefficient of the power storage device, \( S_{ES,t}^{\min} \) and \( S_{ES,t}^{\max} \) is the upper and lower limits of the energy storage capacity of the power storage device, \( P_{ES,t}^{\min} \) and \( P_{ES,t}^{\max} \) is the upper and lower limit of the charging power of the storage device, \( P_{ES,t}^{\min} \) and \( P_{ES,t}^{\max} \) is the upper and lower limits of the discharging power of the power storage device.

3.3. 5GDHC constraints

(1) Heat pump unit, HP

\[ P_{HP,i,t} \leq P_{HP,i}^{\text{capacity}} \]  
\[ COP_{HP,i} = \frac{Q_{ri}}{P_{HP,i,t}} \]  
\[ P_{HP,i,t} + H_{HP,in,i,t} = Q_{ri} \]  

Where \( P_{HP,i,t} \) is the heat pump power of the i-th room at time t, \( P_{HP,i}^{\text{capacity}} \) is rated power of the heat pump in the i-th room, \( H_{HP,in,i,t} \) is heat input from the system to the heat pump. \( COP_{HP,i} \) is the energy efficiency ratio of the heat pump in the i-th room.

(2) Pipeline constraints

\[ P_{pump,i,t} \eta_{pump} = H_{pump,in,i,t} * L * c_{pump} \]  
\[ \sum_i [P_{pump,i,t}] \leq P_{pump}^{\text{cap}} \]  

Where \( P_{pump,i,t} \) is pump power of the i-th room at time t, \( \eta_{pump} \), \( H_{pump,in,i,t} \), \( L \), \( c_{pump} \), \( P_{pump}^{\text{cap}} \) respectively represent the total efficiency of the pump, the heat flowing out of the energy supply pipe.
network, the distance from the pump to the room. According to Darcy's formula, the constant fitted according to the actual pipe diameter and temperature difference and the maximum installed pump power.

3.4. Multi-energy balance constraint

(1) Cooling balance

\[ \frac{Q_{ls, t}}{\eta_{ls}} + Q_{Ar, t} + Q_{Ag, t} + \sum_{i} P_{HP, i, t} = \sum_{i} Q_{R, i} \]  \hspace{1cm} (30)

Where \( N_c \) is the number of cooling rooms, \( \eta_{STD} \) is the heat exchange efficiency of storage device?

(2) Heating balance

\[ H_{MT, t} + H_{bt, t} + \sum_{i} P_{HP, i, t} = \sum_{i} H_{R, i} + H_{Ar, t} \]  \hspace{1cm} (31)

Where \( H_{R, i} \) is the heat load of the i-th room.

(3) Power supply balance

\[ P_{MT, t} + P_{WT, t} + P_{PV, t} + P_{ES, t} + P_{ES, T} - P_{ES, T} + P_{grid, t} = P_{HP, i, t} + P_{is, t} + P_{pump, i, t} + P_{Ag, t} + P_{br, t} + P_{load, t} \]  \hspace{1cm} (32)

Where \( P_{load, t} \) is the total electric load value required by the park.

4. Example analysis

4.1. Basic data of the calculation example

This section takes an industrial park as an example to analyse the optimal scheduling model proposed in the previous section. In the industrial park, electric power is supplied by the grid company and the fans and photovoltaics in the park at the same time; and for heating, the park is equipped with a micro gas turbine with a rated power of 1200kW and an electric boiler with a rated heating power of 600kW. At the same time, the cooling system is equipped with an industrial air conditioner with a rated electrical power of 1,000 kW, an ice storage system with a rated electrical power of 500 kW, and an absorption chiller with a rated cooling power of 500 kW. On the user side, in addition to the energy demand of industrial users, 5GDHC also provides cold and heat supply for the surrounding 5 residential buildings. Each building has 5 floors, each floor is simplified into 4 heating and cooling areas, each area is 8m long, 8m wide, and 3m high.

In this case, a typical day in the cooling season is selected, and the operating parameters of each building and equipment are as follows:

| Parameter | Numerical value |
|-----------|----------------|
| Window area A\(^{win}\) /m\(^2\) | 4 |
| Wall heat capacity C\(_{wall}\) /(/J·K\(^{-1}\)) | 7.9*10\(^5\) |
| Wall thermal resistance R\(_{wall}\) /(/K·W\(^{-1}\)) | 0.06 |
| Window thermal resistance R\(_{win}\) /(/K·W\(^{-1}\)) | 0.02 |
| Heat capacity of side wall with window C\(_{wall(win)}\) /(/J·K\(^{-1}\)) | 2.6*10\(^7\) |
| Room heat capacity C\(_r\) /(/J·K\(^{-1}\)) | 2.5*10\(^5\) |
Table 2. Equipment economic parameters

| Parameter                          | Numerical value |
|------------------------------------|-----------------|
| Micro gas turbine C_{MT} [yd/(kW·h)] | 0.059           |
| Electric boiler C_{BE} [yd/(kW·h)]  | 0.026           |
| Industrial air conditioning C_{AG} [yd/(kW·h)] | 0.016           |
| Ice storage device C_{IS} [yd/(kW·h)] | 0.02            |
| Absorption chiller C_{AR} [yd/(kW·h)] | 0.018           |
| Battery device C_{ES} [yd/(kW·h)]   | 0.01            |

Figure 2. Real-time electricity price within a certain day
Figure 2 shows the real-time electricity price of the power company in a certain day. The price of natural gas is converted into 0.380 yuan/(kW·h) in this article. Photovoltaic, wind power system, outdoor temperature parameters are shown in Figure 3.

Figure 3. PV and wind power forecast output and outdoor temperature
Figure 4 shows the electricity, cooling, and heating load forecasts of the industrial park with the energy storage characteristics of the cooling area of the building. The equal load composition is a fixed predicted value, and the thermal load is smaller than the electric load.

![Electricity, heating and cooling load](image)

In the optimization model, due to the consideration of the storage characteristics of the cooling area of the building, it is affected by the outdoor ambient temperature, the cooling load is not fixed to take the predicted value, but the result of the optimization of the park scheduling model based on the temperature constraints in the plant, thus through the multi-energy complementary characteristics of the industrial park, the output of the relevant components of electricity, cooling, and heat in the integrated energy system is affected. It can be seen from figure 4 that when the outdoor ambient temperature is relatively high, the cooling load required is also more. The cooling load power starts to rise from 11:00 and drops around 15:00 to meet the environmental temperature changes in the park. In the early hours of the morning, based on the lower ambient temperature, the required cooling load is relatively low. At the same time, due to the certain energy storage characteristics of the building's cooling area, the cooling load power remains unchanged for a period of time, but it does not affect the temperature inside the park. Require. In addition, because the selected building parameters are literature data, they are not the actual building parameters of the cooling zone in the park. Therefore, the energy storage characteristics represented by thermal inertia are not fully utilized, resulting in inertia between the outdoor temperature and the load value provided by the actual park.

4.2. Comparative analysis

This article proposes two different schemes based on whether to consider the energy storage characteristics of the building cooling area:

1). The energy storage characteristics of the cooling area of the building are not considered. Assuming that without considering the energy storage characteristics of the building's cooling area, all loads in the park are fixed forecast values at each forecast moment, and there is no adjustable capacity.

2). Consider the energy storage characteristics of the building's cooling area. Assuming that considering the energy storage characteristics of the building's cooling area, the internal room temperature range of the building's cooling area in the park is set to 20-25°C, which has a certain demand response capability.

Figure 5 shows the comparison between the total operating cost of the industrial park and the power purchased if the energy storage characteristics of the cooling area of the building are taken into account. It can be seen from the figure 5 that in case 1, the park does not take into account the energy storage...
characteristics of the building cooling area because the cooling load is basically fixed, and the various types of resources in the park cannot be effectively adjusted during each time period, but the supply is provided according to the fixed forecast value. The total operating cost of the integrated energy system of electricity, cooling and heating in the park is relatively high, which is 85585.2 yuan.

After taking into account the energy storage characteristics of the building's cooling area, the goal is also to minimize the operating cost, and the energy supply equipment in the park at each time period is optimally dispatched according to the electricity price signal. Compared with case 1, in case 2, the power purchased in the industrial park has been significantly reduced during most of the time period, and the total operating cost in the park has dropped to 8,3749.7 yuan, making full use of the energy storage characteristics of the cooling area of the building, which can delay cooling. The loss time of cold energy produced by the equipment is reduced by reducing electricity purchases at relatively high electricity prices to effectively reduce operating costs.

Figure 5. The total operating cost and power purchase of the park in case 1 and 2

It can be seen from figure 5 that from some relatively low electricity prices, such as 16:00, the power purchase in case 2 has increased compared to case 1. It is mainly based on the environmental temperature of the park and the energy storage characteristics of the cooling area of the building to provide a certain response ability to maintain the indoor temperature of the industrial park plant within the required range.

Figure 6 shows the energy consumption of the related equipment in the park configuration in case 1 and case 2. It can be concluded from figure 6 that after considering the energy storage characteristics of the building's cooling area, the total power consumption of electric boilers, ice storage devices, and industrial air conditioners in case 2 is significantly lower than that in case 1 at most of the time. Similarly, in case 2, the cooling power of the building cooling area, that is, the cooling load, and the heat power of the absorption chiller are also reduced.

However, it can be seen from figure 6(b) and (c) that both the cooling power and the heat power consumption of case 2 will increase compared with case 1 for a period of time after 13:00. It is mainly caused by ensuring that the indoor temperature in the cooling area of the building does not exceed the upper limit under the condition of considering the outdoor temperature. Therefore, the power consumption of the corresponding equipment is increased at the same time, but it is mainly distributed at the time when the electricity price is relatively low. This fully demonstrates that by using the energy storage characteristics of the building's cooling area, the cooling power of the refrigeration equipment is flexibly reduced, and the relevant electrical and thermal energy equipment are affected while meeting the requirements of the park to improve the total operating cost.
(a) Power consumption of electric boilers, ice storage, industrial air conditioners

(b) Cooling power
5. Conclusion

This chapter first establishes the thermal inertia model of the building cluster, and fully considers the energy storage characteristics based on the detailed building thermal inertia model in the building cooling area to optimize the power purchase strategy of the industrial park. Then, component modeling is carried out for the energy supply and energy storage equipment of the industrial park. With the goal of minimizing the total operating cost of the park's integrated energy system, the components and energy storage models are integrated into the park's integrated energy system scheduling model, the scheduling framework is analyzed, and the optimal scheduling model is constructed. Finally, the validity of the model is verified through the analysis of a numerical example.

The main conclusions include: the energy storage characteristics of the cooling area of the building can help reduce the interaction power with the grid and the operating cost. Ambient temperature will affect the value of the cooling load and further affect the scheduling results; the thermal inertia model of the building cluster can provide additional operational flexibility for the integrated energy system of the park, and provide a direction for improving the economics and reliability of operation.

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