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OPERATION SIMULATION AND ANALYSIS ON ENERGY SAVING POTENTIAL OF A COMPREHESIVE BUILDINGS GROUP DISTRICT HEATING

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ABSTRACT

For the district central heating system, combined with the characteristics of user heating pattern, the energy consumption of building heating can be significantly reduced by adopting management and control in different time and areas. Taking the district heating system of a university comprehensive buildings group as the research object, this paper established the system model based on one-dimensional flow simulation software Flowmaster. Fully considering the different functions of buildings, taking a working day in heating season as an example, the energy saving potential of the heating system was analyzed by using management and control in different time and areas with working and non-working periods. The results show that based on the difference of functions and heating patterns of different buildings, the energy saving rate of the heating system is 21.14% by using the adjustment and control strategy in different time and areas and the controlling different indoor temperature values of users rooms. The results were compared by setting the dormitory buildings as 22 ℃, the teaching buildings as 22 ℃/13 ℃, the research buildings as 22 ℃/16 ℃ respectively and setting all of the indoor temperature control values of users as 22 ℃. Therefore, for comprehensive buildings group for multi-functional buildings, the management and control strategy in different time and areas based on the difference of heating patterns is of great significance to district heating energy saving.

Keywords: Comprehensive buildings group, Heating pattern, In different time and areas, Operation simulation with Flowmaster, Energy saving potential

NONMENCLATURE

V	Gas Quantity
Q	Heat Consumption
q	natural gas heat value

1. INTRODUCTION

Building energy consumption is an important part of energy consumption in our country. By 2020, building energy consumption will reach 108.9 billion tons of standard coals, accounting for about 30 % of the total energy consumption. Among them, building heating energy consumption accounts for more than 50 % of building energy consumption, and heating energy consumption in northern cities and towns accounts for about 40 % of building energy consumption, which is the largest part of building heating energy consumption and has huge energy saving potential [1,2]. For special buildings groups such as universities and scientific research institutes, the control strategy in different time and areas can reduce a large number of building heating energy consumption [3-5].

Wang Hongjun, Wang Shuo, et al. carried out adjustment and control in different time and areas for office buildings, apartment buildings and scientific research buildings in the comprehensive building group of the National Institute of Metrology of China. The theoretical formula analysis showed that the heating energy saving rate reached 31.19% [6]. Dong Yuping, Dong Yanlei, et al. carried out adjustment and control in different time and areas for scientific research area, office area and activity area in a scientific research buildings group of the National Institute of Metrology of China. The theoretical formula analysis showed that the energy saving rate of annual heating consumption is 55.2 % [7]. Dong Yanlei and Sun Tianbao used the adjustment and control strategy in different time and areas for Changping District buildings of the National Institute of Metrology of China. Compared with the data in the same period in 2016, the energy saving rate was about 17.62 % after the real-time energy saving reconstruction in 2017[8]. Wang Yafu et al. carried out intelligent heating adjustment in different time and areas at the early and last stage of heating in a Jilin heating company to reduce the power consumption of circulating water pumps. Among them, the first pipe network saved 64.1 % of the power consumption and the second pipe network saved 44.8 % of that [9]. Based on the households' energy consumption habits and normal routines, considering the different thermal demand of different rooms in different periods, Li Hongbo proposed a heating test in different time and areas for active solar energy heating system. The theoretical and experimental results show that the building heat loss is reduced by more than 10 % [10]. The above researches are basically based on theoretical formula and experimental analysis of energy saving rate of heating in different time and areas, without adopting simulation methods in analysis.

Flowmaster, a one-dimensional flow simulation software, can quickly build a simulation model of central heating system, which is fast, reliable and can be coupled with multiple software. It is widely used in aerospace engineering, engine air conditioning system, central heating system and other fields [11-13].

Therefore, in this paper, based on one-dimensional flow simulation software Flowmaster, a district heating simulation system is established for a university comprehensive buildings group with a building area of 232 161 square meters. Fully considering the different functions of buildings, taking a working day in heating season as an example, the energy saving potential of the heating system was analyzed by using management and control in different time and areas with working and non-working periods. The energy saving potential of the two conditions are compared and analyzed. One condition is that by using adjustment and control strategy in different time and areas, different temperature values in user room are set as 22 ℃ in dormitory building, 22 ℃/13 ℃ in teaching building and 22 ℃/16 ℃ in scientific research building respectively. And in contrast, the other is that the indoor temperature control values are all set to 22 ℃. Therefore, for comprehensive buildings group for multi-functional buildings, the management and control strategy in different time and areas based on the difference of heating patterns is of great significance to district heating energy saving.

2. THE CURRENT SITUATION OF HEATING IN A COMPREHENSIVE BUILDINGS GROUP

The heating area of a comprehensive building group in a university is 232 161 square meters, which is supplied directly by five gas-fired boilers in the B energy station. The energy consumption of the B energy station in the heating season from 2016 to 2019 is shown in Table 1. The annual heat consumption Q is calculated according to Formula 1-1, and natural gas heat value q is 35 590 KJ/m^3.

$$Q = q * V \qquad \text{(Formula 1-1)}$$

Tab. 1 The energy consumption of B energy station from 2016 to 2019

Year	Heating Time	Gas Quantity V（Ten thousand m³）	Unit Price of Gas（yuan）	Gas Bill（Ten thousand yuan）	Heat Consumption Q (GJ)
2016-2017	11.01-03.31	260.5291	2.37	617.454	92722.31
2017-2018	11.01-03.26	223.5014	2.51	560.989	79544.15
2018-2019	11.01-03.31	182.4367	2.72	496.2228	64929.22

Adjusted the system according to the experience of working personnel, energy saving in 2017 is 14.213 % compared with 2016, while energy saving in 2018 is 18.373 % compared with 2017, and the energy saving rate from 2017 to 2018 is 4.16 % higher than that from 2016 to 2017. With the increase of gas unit price, the demand for energy saving is imminent.

There are 15 buildings in the comprehensive buildings group of the B energy station heating pipe network. According to the difference of geographic location and user heating pattern of the 15 buildings, the 15 buildings are divided into six regions from A to F respectively. Area A to Area F are divided into three types of buildings, including dormitory building, teaching building and scientific research building. Area A and C are dormitory buildings, area B and D are teaching buildings, as well as area E and F are scientific research buildings. The relative geographical position of the area A-F is shown in Figure 1.

The information of the 15 buildings in the multi-functional comprehensive buildings group is shown in Table 2.

The area proportion of A-F areas in the comprehensive buildings group is shown in Figure 2, where the teaching buildings and scientific research buildings can be carried out by the control strategy in different time and areas. And the proportion of the area can be controlled in different time and areas is 57 %.

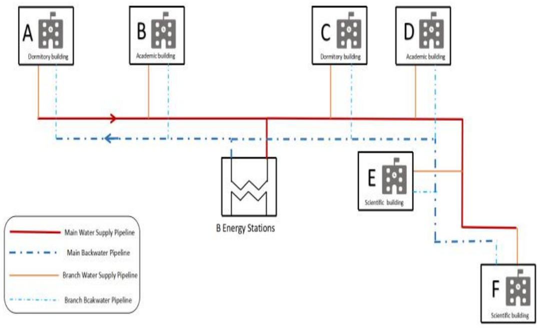

Fig 1 The relative geographical of the major area A-F

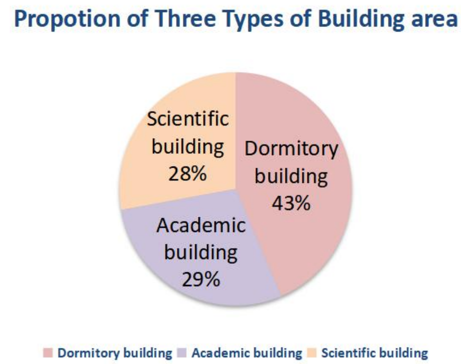

Fig 2 Area proportion of three Types of buildings in Area A-F

Tab. 2 The information of the 15 buildings in multi-functional comprehensive buildings group

Building Number	Heating Area (square meters)	Building Height (m)	Design heat load (KW)	Area
1	9720	16.65	581.2	A
2	9720	16.65	230.6	A
3	2012	16.65	81.1	A
4	10094	16.65	477	A
5	10094	16.65	477	A
6	38234	20.80	2421	B
7	8907.8	16.65	338	C
8	8907.8	16.65	299	C
9	8907.8	16.65	341	C
10	8907.8	16.65	301	C
11	8907.8	16.65	992.5	C
12	20664	24.40	1263	D
13	18452	20.80	1261	E
14	19700	16.80	1230	E
15	18795	20.80	1221	F

3. ENERGY SAVING RATE OF DAILY HEATING LOAD FOR COMPREHENSIVE BUILDINGS GROUP BASED ON FLOWMASTER SIMULATION

Based on one-dimensional flow simulation software Flowmaster, the heating pipe network system of the B energy station is simulated. Taking the working day as an example, the energy saving potential of the heating system is analyzed for three buildings with different functions by using the management and control strategy in different time and areas with working and non-working periods respectively. The energy saving potential of the condition that different temperature values in user room are set as 22 ℃ in dormitory building, 22 ℃/13 ℃ in teaching building and 22 ℃/16 ℃ in scientific research building by using adjustment and control in different time and areas compared with the situation of setting all users indoor temperature control values to 22 ℃ is analyzed. The simulation operation analysis result shows that the energy saving rate of the daily heating load in the B energy station is 22.14 %.

3.1 Building the district heating system simulation model based on Flowmaster

Based on the one-dimensional flow simulation software Flowmaster, the simulation model of district heating system is established. As shown in Figure 3, there is the B energy station and six major areas from A to F. The components in Flowmaster must satisfy four equations, including resistance equation, mass conservation equation, pressure loss equation and heat transfer equation.

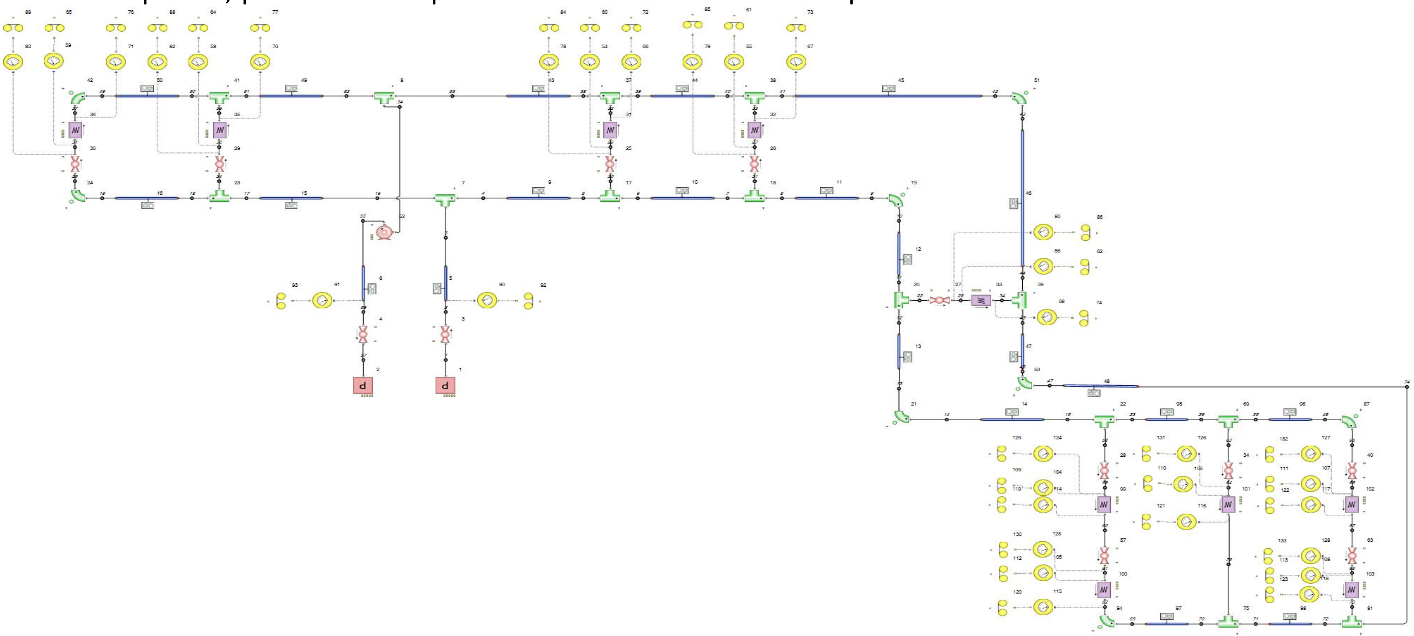

Fig 3 The district heating system based on the simulation with Flowmaster

Based on practical engineering cases, the information of heating physical network and heating Internet of things for comprehensive buildings group from 2018 to 2019 is collected systematically. Then, the actual heating physical network and heating Internet of Things data are input into the components of the simulation system of the B energy station. Among them, the component numbered 66-71 is a return water temperature meter in the building heating entry, measuring static-temperature-result.

The heat source selection of the B energy station is simulated on March 11, 2019. In the meanwhile, the temperature and pressure of the heat source supply and return water are 38 ℃/31 ℃ and 4.0 *Mpa*/3.8 *Mpa* respectively. Flowmaster default value is selected for loss coefficient and valve opening relationship of valve No. 3 and No. 4. The relationship between the loss coefficient and the valve opening is shown in Fig 4. The roughness of supply and return water pipeline is 0.025 mm.

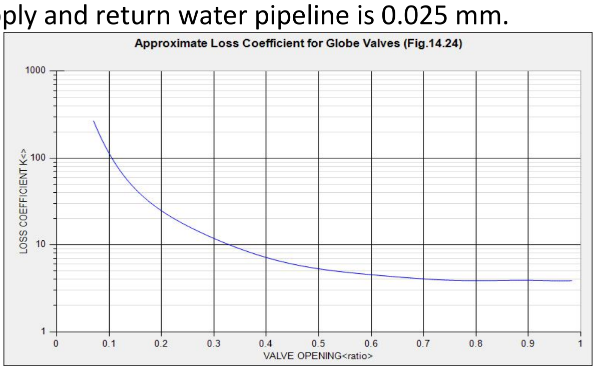

Fig 4 The relationship between the loss coefficient and the valve opening

Based on the actual case of the comprehensive buildings group, the design heat load is input into the Area A-F, which is used to the steady state simulation of the simulation model. The heat-transfer- steady-analysis is selected for simulation analysis, and the outdoor temperature is set to 0°. Among them, the measurement results of the return water temperature measuring element numbered 66-71 are shown in Figure 5.

From the Figure 5, it can be seen that the measurement results of the element numbered 66-71 for measuring return water temperature are between 13.2 839 ℃ and 27.5 773 ℃. The results conform to the normal value of return water temperature, which verifies the rationality of the model.

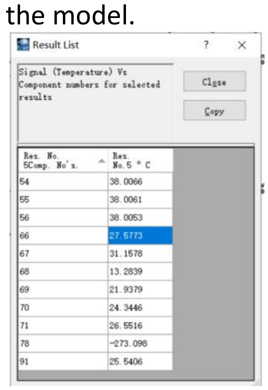

Fig 5 The measuring results of the return water temperature measuring meter

3.2 Analysis on energy saving rate of control heating in different time and areas of the B energy station

In view of the difference of heating patterns used by building users in the comprehensive buildings group of the B energy station, this paper takes the working day as an example and divides the working day into two periods. The working period I is from 6.00 a.m. to 23.00 p.m. and the non-working period II is from 23.00 p.m. to 6.00 p.m. Three different indoor temperature control schemes are simulated and operated for the multi-functional buildings in I and II periods respectively, and the energy saving potential of the B energy station is compared and analyzed.

The three schemes are as follows. The first scheme is that without considering the control in different time, the indoor temperature control values of dormitory building, scientific research building and teaching building are all 22 ℃ during I and II periods. The second scheme is that only the teaching building is considered the control in different time, and the indoor temperature of the teaching building in I period is 22 ℃ and the indoor temperature in II period is 13 ℃, and the indoor temperature of the dormitory building and the scientific research building is always 22 ℃. And the third scheme is that the control of teaching building and scientific research building in different time and areas is considered comprehensively. The indoor temperature of scientific research building is 22 ℃ in I period and 16 ℃ in II period. Three kinds of indoor temperature curves of the major six areas of A-F are shown in Figure 6 to Figure 8.

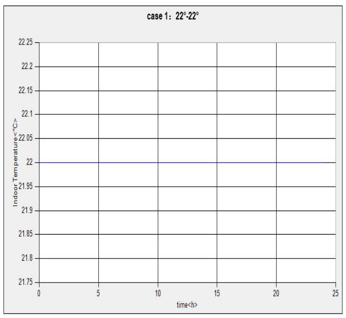

Fig 6 22℃ Indoor temperature control value

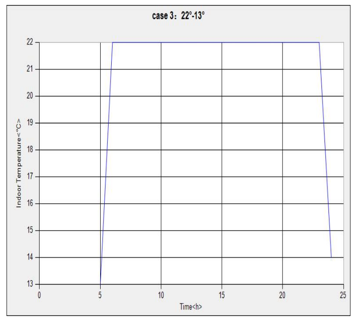

Fig 7 22℃/13℃ Indoor temperature control value

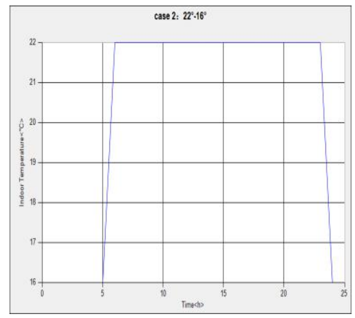

Fig 8 22℃/16℃ Indoor temperature control value

Based on Flowmaster, the transient heat transfer is selected for analysis. The simulation start time is 0, the termination time is 86 400 s, and the simulation step is 3 600 s. For the three schemes, the daily load of comprehensive buildings group is calculated respectively, and the energy saving rate of daily heating load of the comprehensive buildings group is compared.

The calculation results of the three schemes are shown in Figure 9 to Figure 11.

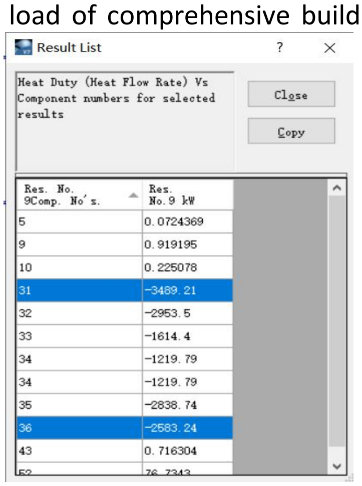

Fig 9 Operational results of scheme 1

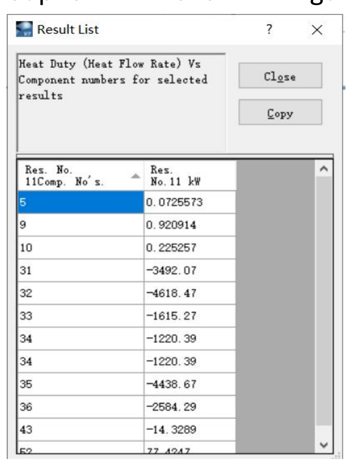

Fig 10 Operational results of scheme 2

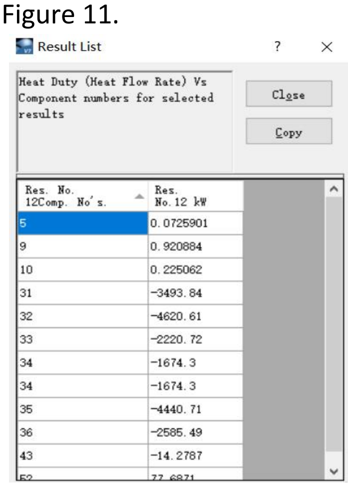

Fig 11 Operational results of scheme 3

The total daily load and energy saving potential of the three schemes are analyzed in Table 3.

Tab.3 Analysis of heat consumption and energy saving potential of the three schemes

Scheme Number	Daily load of the B energy station（KW）	Proportion of load energy consumption	Heating energy saving rate
Scheme 1	19035.67	100%	0
Scheme 2	17909.16	94.08%	5.92%
Scheme 3	14953.88	78.56%	21.44%

As can be seen from the Table 3, the second scheme only considers the control in different time and areas of the teaching building, and the energy saving potential is 5.918 %. While the third scheme considers the control in different time and areas of the teaching building and the student scientific research office building, and the energy saving potential is 21.44 %. Therefore, for comprehensive buildings group for multi-functional buildings, the management and control strategy in different time and areas based on the difference of heating patterns is of great significance to district heating energy saving.

4. CONCLUSION

(1) The simulation system of district heating based on Flowmaster is built in this paper. Based on the difference of functions and heating patterns of different buildings, the energy saving rate of the heating system is 21.14% by using the adjustment and control strategy in different time and areas and the controlling different indoor temperature values of users rooms. The results were compared by setting the dormitory buildings as 22 ℃, the teaching buildings as 22 ℃/13 ℃, the research buildings as 22 ℃/16 ℃ respectively and setting all of the indoor temperature control values of users as 22 ℃.

(2) Compared with 21.14 % heating energy saving rate of the comprehensive buildings group, the gas consumption of the B energy station in 2018-2019 can be reduced by 385 671 m^3 and the gas cost can be reduced by 1 049 015 yuan, the energy saving potential is huge.

(3) For comprehensive buildings group for multi-functional buildings, the management and control strategy in different time and areas based on the difference of heating patterns is of great significance to district heating energy saving.

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REFERENCE

[1] Hou Enzhe. The issue of Annual Development Report of Building Energy Conservation in China 2018[J]. Building Energy Efficiency, 2018. 46(04): 133.

[2] Jiang Yi. Current building energy consumption in China and effective energy efficiency measures[J]. Heating Ventilating & Air Conditioning, 2005(05): 30-40.

[3] Ding Qi, Mu Lianbo, ZhanG Chunlei. Measurement and analysis of energy saving renovation project of district heating in different time and areas[J]. China Housing Facilities. 2017(07): 94-99.

[4] Zhang Zhizheng, Liu Yantao. Application of control system in different time and areas in heating[J]. China Plant Engineering. 2017(12): 109-111.

[5] Guan Yinjun, Shao Zongyi, Song Xiaochun, et al. Energy saving analysis of time-sharing district operation of heating system[J]. Heating Ventilating & Air Conditioning. 2016. 46(05): 119-122.

[6] Wang Hongjun, Wang Shuo, Dong Yanlei, et al. Energy-saving rate and cost saving evaluation of time-sharing district heating system of complex buildings in national institute of metrology[J]. Energy and Energy Conservation. 2018(12): 83-84+100.

[7] Wang Hongjun, Dong Yuping, Dong Yanlei. Energy saving rate evaluation of time-sharing district operation of heating system in research institutes[J]. Contamination Control & Air-Conditioning Technology. 2018(02): 19-20.

[8] Dong Yanlei. Application of control system in different time and areas in heating[C]. Symposium on Construction and High Efficiency Operation of Heating Engineering in 2018. China: Hangzhou; 2018.

[9] Wang Yafu. Study on intelligent heating regulation of heating network based on time division[D]. Changchun Institute of Technology. China: Changchun; 2019.

[10] Li Hongbo. Study on the indoor thermal environment of solar heating by Time and spatial partition heating strstegy[D]. LanZhou University of Technology. China: Lanzhou; 2018.

[11] Lan Jiang, Zhu Lei, Zhao Jingquan. Modeling and simulation of multi-nozzle ejector based on Flowmaster[J]. Journal of System Simulation, 2016. 28(02): 410-415.

[12] Wu Dongxue. Research on control and Simulink based PID Neural Network to district heating networks running[D]. Inner Mongolia University of Science and Technology. China: Baotou; 2014.

[13] Zhou Peng. Research of heating network system simulation and the primary network optimization control[D]. Inner Mongolia University of Science and Technology. China: Baotou; 2014.