APPLICATION AND EFFECT ANALYSIS OF HEATING SYSTEM BASED ON TRI-NETWORK JOINT REGULATION AND CONTROL TECHNOLOGY

Yanxi ZHANG*

Electrical Engineering, University of Western Australia, Perth WA 6009, Australia

**Yanxi ZHANG, E-mail: duoerxs@163.com*

In recent years, the state promotes intelligent heating and clean heating, which aims to achieve energy saving, emission reduction, cost reduction and efficiency, and improve the social and economic benefits of heating enterprises on the premise of ensuring the heat demand of the terminal heat users of the heating system. This paper first introduces the current situation of the heating system, analyzes the main problems and causes of the current heating system, and then analyzes the practical application and operation data of the three-network joint control technology of the heating system independently developed by Jilin Yuheng Industrial Electric Co., Ltd in Changchun Lianhuashan Thermal Power Co., Ltd., and finally comes to the conclusion that the application of this technology makes the heating system energy-saving effect is remarkable. It can adapt to all kinds of complex heating systems and has good market prospect and application value.

Key words: *joint control; temperature balance; supply and demand balance; hydraulic balance; energy saving and emission reduction*

1. Introduction

Central heating is the main heating mode in cold and severe cold areas in northern China. With the increase of population and the demand of economic development, the new residential buildings in China have gradually developed into high-rise buildings[1].

New thermal insulation materials are added to the external walls of new high-rise buildings, and the thermal insulation effect of new high-rise buildings is higher than that of old buildings [2], and the indoor temperature of buildings during heating period is affected by many uncertain and nonlinear factors [3]. The traditional indoor temperature control method uses temperature control valve, which can not consider the influence of many external factors on room heating temperature [4], especially the temperature between adjacent rooms, so it can not effectively control the indoor temperature of the building. The control systems of heat exchange stations equipped under residential buildings are mostly empirical control or semi-automatic control [5], which can not provide accurate heat supply according to the heat supply required by the superstructure, resulting in large heat supply and high indoor temperature. Many households use windows to dissipate heat to make the room temperature reach human comfort, resulting in a lot of waste of heating heat. The research shows that the heating energy consumption per unit area in China is 2 / 3 times higher than that in similar developed countries [6].

In recent years, the indoor temperature control system of central heating has made a lot of progress [7]. For example, for the robust control of the radiator heating system [8], a gain scheduling controller based on the current parameter variation model of radiation dynamics is proposed for the instability of

the constant temperature radiator valve [9]. In view of the lag of room temperature change in the control process, model predictive control uses mathematical models to predict and control the heat load of buildings to minimize heating energy consumption [10]. In the process of model prediction and control of indoor temperature, the need for weather measurement can be eliminated by accessing weather forecast data instead of measured values. In addition to the model predictive control, the artificial neural network (ANN) or the optimal control mechanism of the radiator can be used to realize the prediction and control of the indoor temperature [12].

At present, the regulation and control means of heating system in our country are simple, and the level of control technology is uneven [13]. Most of the heat sources, heat networks (heating stations) and heat users operate independently and are controlled separately, so they can not be adjusted effectively and uniformly. So that the phenomenon of the coexistence of low-temperature households and overheated households in the same building is very common. Due to the lack of necessary joint adjustment and control mechanism among heat source, heating network (heating station) and heat users, the heat loss of heating system is serious.

At present, the heating operation efficiency of heating enterprises in China is generally low, and the energy consumption per unit heating area is large, which is generally 2 ~ 3 times higher than that in developed countries at the same latitude. After the renovation of the warm house project in Jilin Province, it is found that the energy consumption and heat index of the building is basically between 20W/m2~30W/m2. In theory, the basic heating demand of the residential building is about 0.25GJ/m2, but now most of the heat supply of the heat source is 0.45GJ/m2-0.5GJ pump m2, and the heat utilization rate is about 50% of the output heat of the actual heat source. The national 13th five-year Plan requires the energy consumption of residential construction units to be reduced to 0.35GJ beat m2. In order to achieve this goal, thermal enterprises need to increase the heat utilization rate of the system by 40% through technological innovation on the basis of the existing heating operation technology. Therefore, the joint regulation and control mechanism of the heating system is undoubtedly one of the effective methods.

2. Tri-networks Adjustment and Control Technology

2.1 Heat source control technology

2.1.1 Current status of heat source control technology

Due to the imperfect control technology, the control parameters of the operation process deviate from the design value, which leads to the decrease of the operation efficiency of the heat source boiler, which is quite different from the design efficiency. Although many technicians in the industry have carried out long-term research and exploration on how to improve the operation efficiency of heat source boilers and put forward a variety of different technical routes and strategies, they have little effect in practical application.

2.1.2 Realization of optimal Control Technology of Heat Source

The purpose of heat source optimization control is to improve boiler operation efficiency, reduce heat loss, save energy and reduce consumption. As the source of heat output, heat source is the basis for the realization of intelligent heating, and its optimal control results and operation efficiency play a

decisive role in the realization of joint control.[14]

The biggest losses affecting the operation efficiency of the boiler are the heat loss of exhaust gas (Q2) and the heat loss of mechanical incomplete combustion (Q4), which are closely related to each other and have a direct linear relationship with the ratio of air to coal. The excess air coefficient at the outlet of the boiler directly reflects the causal relationship between the ratio of air and coal, and also reflects the difference between the parameters in operation and the design parameters of the boiler. This is a breakthrough in the use of boilers to improve operating efficiency [15].

The optimal combustion control system of coal-fired boiler-optimal control 4.0 is referred to as "optimal control 4.0" (as shown in figure 1). The technical route and strategy of dynamic self-optimization of excess air coefficient and adjusting and controlling air-coal ratio are determined. The key point to improve the operation efficiency of the boiler is found, which is the technical core and innovation.

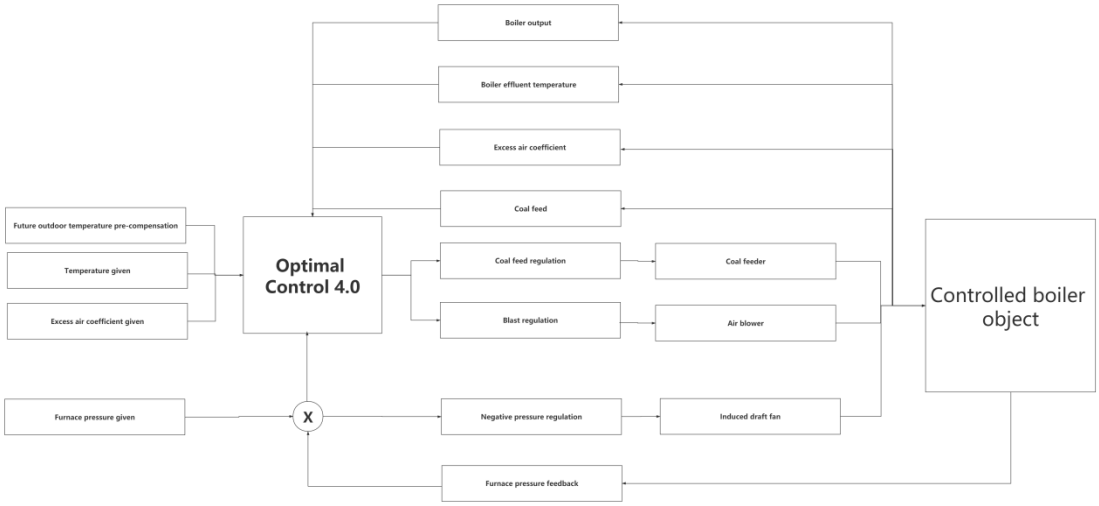

Figure 1 Control structure of optimal Combustion Control system for Coal-fired Boiler

2.2 Heating network control technology

The heat network (thermal power station) adjusts and converts the heat energy provided by the heat source and allocates heat to the heat user system.

The current situation in China is that the operation regulation of most thermal stations has basically realized the unattended remote control mode, but they have failed to establish an organic relationship with the heat source and terminal heat users, and are still in the stage of extensive management and control.

Due to the different floor locations of thermal users and the different room temperature among different thermal users, there is a large deviation in heat demand, which can not be reflected in the output regulation process of thermal power station. there is an urgent need to change from coarse regulation to fine regulation.

Therefore, in order to achieve the accurate regulation of the heating system, it is necessary to coordinate and control the heat source, heat network (heating station) and heat users.

2.3 Heat user temperature balance technology

In the past, due to the hydraulic imbalance in the building, the different floor positions of each heat user, and the heat transfer between households due to the existence of temperature difference, there was an imbalance between cold and heat in each room, and the indoor temperature difference between overheated households and low temperature households could reach 5 ℃ ~ 10 ℃. Due to the lack of effective regulation and control means for overheated households and low-temperature households, the heat loss is serious. According to the formula for calculating the annual heat consumption of heating at different indoor calculated temperatures in the relevant code [16]:

$$Q_a^h = 0.0864 * N * Q_h * (T_i - T_d)/(T_i - T_{al}) \quad (1)$$

In formula (1): Q_a^h is the annual heat consumption of heating (GJ); N is the number of days in the heating period (d); Q_h design heat load (kW); Ti is the indoor calculated temperature (℃); T_a is the average outdoor temperature during the heating period (℃); T_{ah} is the outdoor calculated temperature during the heating period).

Figure 2 is the structure diagram of the three-network joint control system. In the process of regulation and control of the heating system, because the temperature data come from the terminal thermal users, the regulation target is the most direct and real, and the regulation speed is fast, the period is short, and the efficiency is high. The joint regulation and control system also uses big data statistical analysis and processing technology to comprehensively and quantitatively analyze and deal with the actual heat demand of heat users, the parameters of the operation of the heating network and the heat supply of the heat source, so as to correct the operation deviation of the heating system in a timely manner. realize the temperature balance, hydraulic balance and heat balance of the heating system, while ensuring the heating quality, heating according to demand, saving energy and reducing consumption.

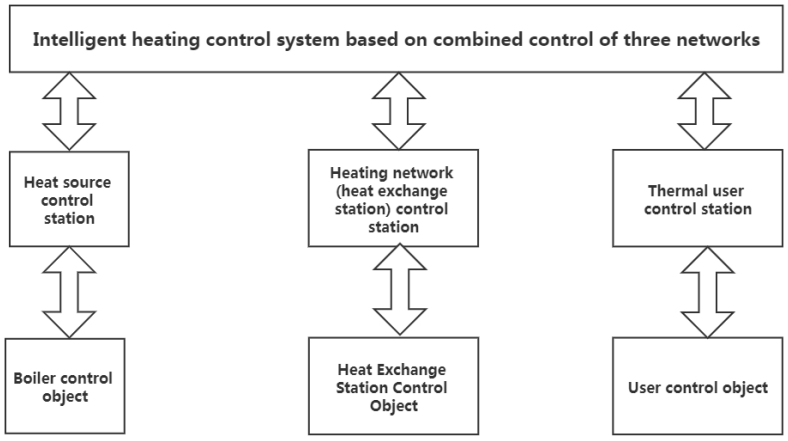

Figure 2 Three-network control system structure diagram

3. Technology Application and Effect Analysis

3.1 Technology Application

The triple-network adjustment and control technology was applied to Lianhua Yaju Community, Lianhuashan Eco-tourism Resort, Changchun City in 2018. There are 36 buildings in the community, all of which are energy-saving buildings and radiant floor heating. According to the height difference of

the building topography, the district heat exchange station has two circulation loops in the high and low areas.

In order to better realize the effect of system joint adjustment and control, Lianhuashan Thermal Power Co., Ltd. carried out system renovation before the heating season from 2018 to 2019. Figure 3 shows some pictures of on-site renovation. The specific renovation content is as follows.

Figure 3 Part of the site transformation diagram

(1)Install indoor temperature collectors indoors for terminal thermal users, install household heating medium on-off devices in pipeline wells, install temperature sensors on household water supply and return pipelines, install data collectors in units of buildings, and install base stations in communities One set adopts wireless communication technology and Internet technology to realize data collection and transmission; (2) The two circulation loops in the thermal power station are transformed from the original shared primary network variable frequency circulating pump to each circulating loop with a separate primary network variable frequency circulating pump. A heat meter is installed at the heating entrance of the heat exchange station, and the automatic control system in the heating station applies intelligent heating network control technology based on the average indoor temperature of the user; (3) Heat source plant: The heat source plant has applied the boiler optimization combustion control system in 2014, and the transformation process in 2018 The monitoring center of Zhongzai Heat Source Plant has built a three-network integrated debugging and integrated control platform.

3.2 Effectiveness Analysis

After the heating in 2018-2019, the average outdoor temperature in the Lianhuashan area of Changchun City was calculated to be 3.89°C throughout the heating season. Figure 4 shows the instantaneous average indoor temperature of a 24-hour heating user in the heating season. It can be seen from the figure that the average indoor temperature of the heating user has been between 22.5°C and 23.5°C throughout the heating season. Finally, the average indoor temperature of the heating user in the heating season is 22.87°C. This shows that the technical route, adjustment method and control strategy of the three-network control are feasible.

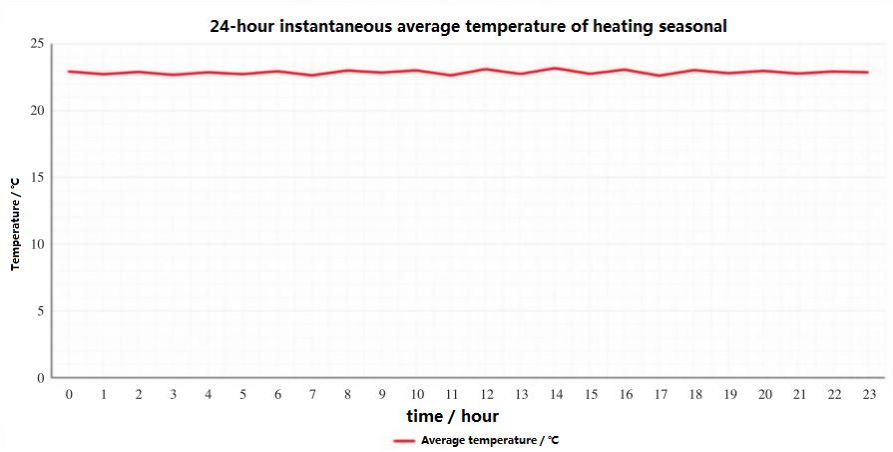

Figure 4 The instantaneous average indoor temperature of 24h hot users in heating season

It can be seen from Figure 5 that during the entire heating season, there were 1,268 thermal users with flow time in the range of 500h to 2500h, accounting for 72% of the total heating households. It can be seen from Figure 6 that the average instantaneous flow rate of thermal users in the entire heating season is less than 50%, but the instantaneous flow rate of thermal users does not have a relatively stable changing law. It is only in the cold heating period that the thermal users are instantaneous due to the low outdoor temperature. The flow rate is relatively high. According to detailed data calculations, the average flow time of heating users in the heating season is 1840.64h, accounting for 44.85% of the total heating time (4104h). The above data confirms that the traditional heating method generally has a serious problem of excessive heating, which is the root cause of ineffective heat supply and excessive consumption. The flow time and flow rate of heat users can reflect the problem of oversupply. In the part of the system, it is also reflected in the entire thermal system, which is difficult to solve without adopting the technical route of joint debugging and joint control.

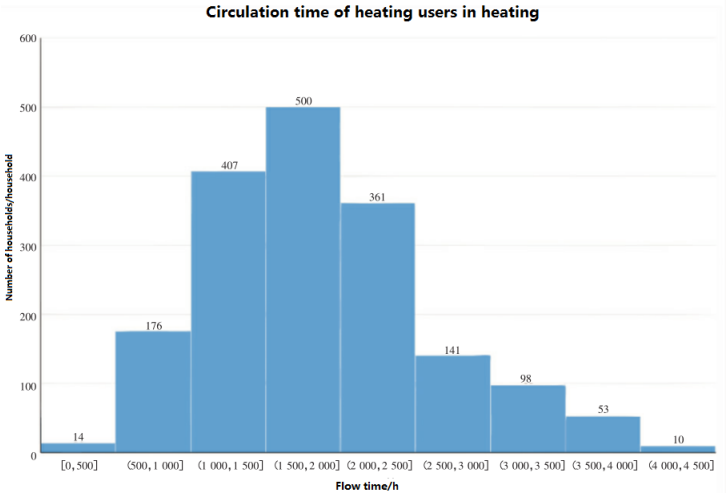

Figure 5 Passing time of heat users in heating season

Figure 7 to figure 8 are the heat consumption and coal consumption curves of the district in the heating season, respectively. According to the real-time monitoring heat meter data of the heating station, the total heat consumption of Lianhuayaju district is 36550GJ, and the heat consumption index of heating users in heating season is 0.2687GJ ~ 2, and the actual heating area heat index is 18.2W/m2.

From the above data, we can see that the seasonal heat consumption index of heating has achieved the goal that the unit heat consumption should be reduced to less than 0.35GJ/m2 at the end of the 13th five-year Plan under the condition of ensuring the room temperature required by heat users in the 13th five-year Plan. Because the boiler optimization combustion technology is adopted in the heat source, the combustion thermal efficiency of the boiler is greatly improved and the coal consumption of the system is reduced. Through the coal consumption statistics of the coal feeding system of the heat source plant, it is found that the total coal consumption of 4902kcal/kg in the whole heating season is 2228t, the standard coal equivalent to 7000kcal/kg is 1560t, the coal consumption index is 11.4kg m2, and the comprehensive combustion thermal efficiency of the boiler is 80%, which is also much higher than the average level of the heating industry.

Figure 6 Instantaneous flow rate of heat users in heating season

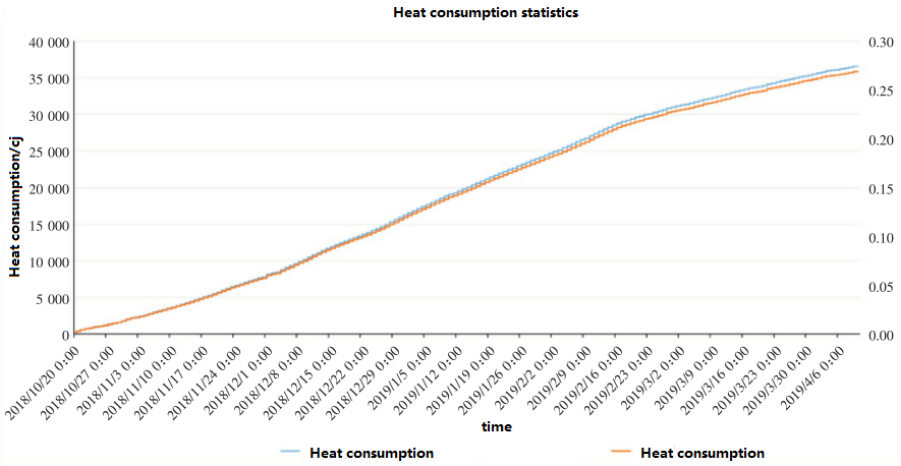

Figure 7 Heat consumption statistics for heating season

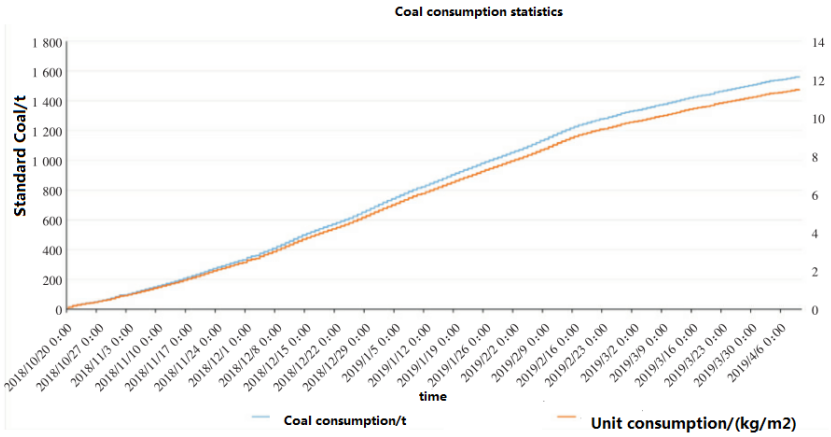

Figure 8 Coal consumption statistics for heating season

4. Conclusion

Through the practical application of the joint control technology of three networks in Lianhuashan Thermal Power Co., Ltd., an integrated regulation and control system of heating system including heat source, heat network and end users is established. the core of the whole technology is to take the average indoor temperature of the terminal heat user as the goal, and to reverse the heat energy allocation of the heat station and the heat supply of the heat source, which completely subverts the previous regulation and control mode. Practice has proved that this technology solves the persistent problems existing in the operation of the heating system for a long time, realizes the heat balance, hydraulic balance and temperature balance of the heating system, improves the heating quality and minimizes the heat consumption of the heating system at the same time. The economic and social benefits are remarkable, and it has a wide market prospect. The next step will promote the integration of the system with environmental collaborative control, customer service, dispatching and command systems, in order to further meet the needs of the construction of intelligent heating system.

References

[1] Wang, Z. *et al.*, Study on thermal adaptability of human body in severe cold areas (4): field study on thermal environment and thermal adaptation of different buildings. *HVAC*, 47 (2017), 08, pp. 103-108

[2] Wong, L. T. *et al.*, An open acceptance model for indoor environmental quality (IEQ). *Building and Environment*, 142(2018), 9, pp.371-378.

[3] Cadau, N. *et al.*, A Model-in-the-Loop application of a Predictive Controller to a District Heating system. *Energy Procedia*, 148 (2018), pp.352-359.

[4] Feng, H. *et al.*, Energy-saving analysis of central heating of existing non-energy-saving residential buildings in typical cities in northern China. *Journal of Shenyang Architectural University (Natural Science Edition)*, 34(2018), 02, pp. 323-332

[5] Li L. *et al.* Optimal control strategy and simulation of central heating secondary network. *Heating and Refrigeration*, 01(2019), pp. 23-26

[6] Yu, D. *et al.*, Application of energy efficiency evaluation system for heat exchange stations in cold areas. *Heating, ventilation and Air conditioning*, 49(2019), 3, pp. 78-79

[7] Han, F. *et al.*, Test and Analysis of Indoor Thermal Environment of Central heating Residential buildings in Qingdao. *Journal of Qingdao University of Technology*, 38(2017), 03, pp. 64-69

[8] Wang, Y. *et al.*, Accurate model reduction and control of radiator for performance enhancement of room heating system. *Energy and Buildings*, 138(2017), 3, pp.415-431.

[9] He, K. *et al.*, Dynamic simulation of steam-water heat exchanger station in heating network. Journal of Tsinghua University (Natural Science Edition), 43(2003), 12, pp. 1679-1683

[10] Samuel, P. *et al.*, Model predictive control of a building heating system: The first experience. *Energy & Buildings*, 43(2011), 2-3, pp.564-572.

[11] De, Dear, and Richard, J. A global database of thermal comfort field experiments." *ASHRAE transactions*, 104 (1998), pp. 1141.

[12] Hedegaard, R., *et al.*, Towards practical model predictive control of residential space heating: Eliminating the need for weather measurements." Energy and Buildings 170 (2018): 206-216.

[13] Li, B. *et al.*, Investigation and comprehensive evaluation of heating model in some rural areas of northern China. *HVAC*, 47 (2017),04, pp. 46-51

[14] Yu, X. Combustion optimization control system of chain furnace based on BCS technology. *Chlor-alkali industry*, (2015) 4, pp. 39-43.

[15] Han, X. Effect of excess air coefficient on thermal efficiency of boiler. *Journal of Shaanxi Institute of Technology*, 18 (2002), 4, pp. 56-58.

[16] CJJ34-2010 (2010 Edition), *Code for Design of Urban heating Network*. Beijing: China Construction Industry Press, 2010.