International Conference on Applied Energy
2019 Aug 12-15, 2019, Västerås, Sweden
Paper ID: 245

OPERATION SIMULATION WITH FLOWMASTER AND VISUALIZATION WITH MATLAB FOR DISTRICT HEATING SYSTEM

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ABSTRACT

Modeling of central heating system is an important basis for intelligent management of heating system. In this paper, eight heat exchanger stations in a branch of a pipe network were studied, PostgreSql was used to establish the information database of physical network and internet of things, and BP neural network was used to predict heat load. In the meanwhile, fluid simulation software Flowmaster was used to build simulation system, then coupled with the graphical user interface (GUI) in MATLAB to realize the dynamic visualization of operation conditions of the simulation system. The results show that the related coefficients R^2 of heat load forecasts of the eight heat exchanger stations are all greater than 0.85 and the relative errors of temperature and pressure of supply and return water in simulation system are less than 10%; in addition, the dynamic visualization of operation conditions of the simulation system is achieved. The work and results of this paper preliminarily prove that the combination of the basic functions commonly used in Flowmaster and the graphical user interface of Matlab can economically achieve the operation simulation of heating system and the dynamic visualization of hydraulic and heat conditions. It is of great significance to generate new levels of the heat-supply network's intelligence and realize the intelligent heating with functions of intelligent diagnosis, intelligent surveillance and multi-dimensional service push.

Keywords: Flowmaster,PostgreSql data base, BP neural network, Matlab GUI, Dynamic visualization interface

1. INTRODUCTION

As the intelligent management and computer automatic control of heating system are imminent, it is particularly important to accurately build model of the heating network[1]. The heat network simulation models can analyze the operation law of the heating system[2], guide the operation and regulation of the heating network[3], and support the intelligent upgrading of the heating system[4]. Due to the large time delay, nonlinearity, multiple variable tight coupling and other characteristics of the central heating system, the traditional method of establishing the model through structural mechanism and experimental identification is more complicated[5-8]. In recent years, the central heating system is divided into three parts — heat source, heat exchange station and heat user to build model based on Matlab/simulink, so as to realize the optimal control of the whole heating system[9-12]. Thermal companies mostly use professional software such as Termis, Flowra, CyberSim to build and simulate the model, and optimize the control of central heating system[13, 14]. The one-dimensional fluid software Flowmaster has the advantages of rapid construction of the model, good applicability and high reliability of the model, etc. It has a wide range of applications in automotive engine systems, aviation oil supply systems, urban water supply systems, and central heating systems[15-17].

In this paper, a one-dimensional fluid simulation software Flowmaster is adopted to build a central heating simulation system[17]. PostgreSQL is used to build an information database of physical network and internet of things for heat source, the eight heat exchanger stations and hot users. The heat load of eight heat exchanger stations is predicted based on BP neural network. Furthermore, through the co-simulation of

Flowmaster and Matlab GUI, the dynamic visualization of the operation conditions of the simulation system is achieved in this thesis. This paper combines the general version of Flowmaster and Matlab GUI, which can economically realize the operation simulation of heating system and the dynamic visualization of hydraulic and heat conditions. It achieves the function of using enterprise version of Flowmaster. On the basics of practicability and applicability, and around the advancement and demonstration, this paper further improves the level of heating network's intelligence, which has important practical significance for realize the intelligent heating with functions of intelligent diagnosis, intelligent surveillance and multi-dimensional service push.

2. OPERATION AND SIMULATION OF CENTRAL HEATING SYSTEM WITH FLOWMASTER

Flowmaster, a one-dimensional fluid simulation software, is used to build a simulation system with heat source, heat exchanger station and heat user[16]. Based on the actual investigation, PostgreSql is adopted to establish an information database of physical network and internet of things for the heat source, the eight heat exchanger stations, as well as heat users[17]. At the same time, BP neural network is used to predict heat load[18], and Flowmaster data editor is served to fit the indoor temperature curve of the heat users with the formula.

2.1 Modeling of heat source, heat exchanger station and heat user

On the basis of Flowmaster, this paper establishes a heating simulation system with one heat source, eight heat exchanger stations and eight heat users. The heat source model, the heat exchanger station and the heat user model are established as shown in Figure 1 and Figure 2.

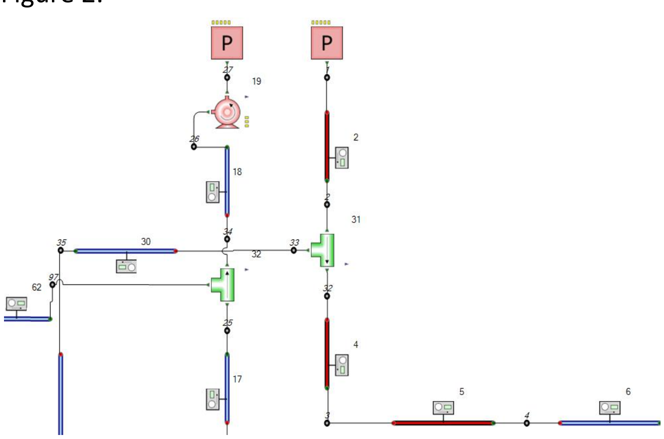

Fig 1 The heat source model

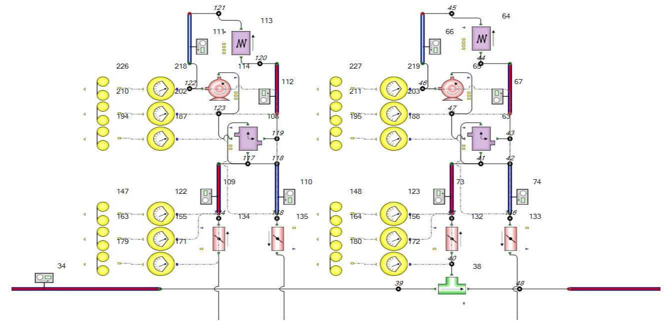

Fig 2 The heat exchanger station and the heat user model

Flowmaster software is able to quickly build the simulation model of central heating system[15]. The simulation model of integrated central heating system is shown in Figure 3.

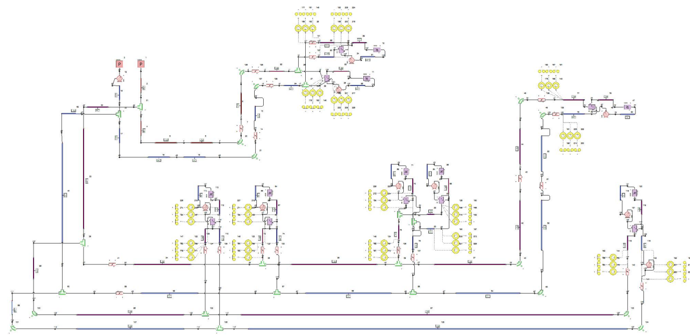

Fig 3 Central heating system simulation model based on Flowmaster

2.2 Establishment of information database of physical network and internet of things by PostgreSql

The basic model is built in Flowmaster, and the data of the heating physical network and Internet of Things of the eight heat exchanger stations in the branch of a pipe network are input into the model. The heating physical network and heating internet of things data of the heat source, the heat exchanger station and the heat users of the eight heat exchanger stations which in the branch of the pipe network from 2018 to 2019 are collected systematically, including 26 tables and two drawings. The collected data are entered into the PostgreSQL relational database at the outset, then the data is input by PgAdimin III graphical management tool to the system, furthermore, the data is loaded into the .sql file through PgAdimin III.

PgAdimin III can not only provide data support work for building model in Flowmaster, but also offer practical help for thermal companies to establish databases and inquire about heating information by one-key.

2.3 Prediction of heat load based on BP neural network

In this paper, the BP neural network structure of 10-12-1 layer is adopted and the BP neural network structure[19] is shown in Figure 4. Ten factors are considered in the input, including that whether it is a working day, the outdoor temperature of the day, the temperature of supply and return water of the primary network of the day, the temperature of supply and return water of the secondary network of the day, the pressure of the supply and return water of the primary network of the day and the historical heat load of the first two days. And the output is the historical heat load of the day[20-22]. The data for training BP neural network are thirty sets of data from December 1st to December 30th in 2018. And the data for testing network performance are ten sets of data from January 1st to January 10th in 2019.

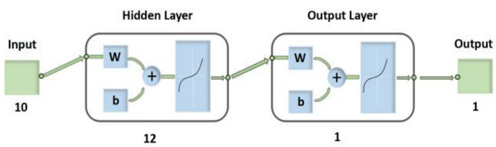

Fig 4 BP neural network structure of 10-12-1 layer

Among them, the predicted heat load and actual heat load at 10 test points at 1# heat exchanger station are shown in figure 5. The related coefficient R2 between the predicted heat load and the actual heat load is 0.85107. The related coefficient R2 of predicted heat load for the eight heat exchanger stations is shown in Table 1, and the correlation coefficients are all greater than 0.85[23-24].

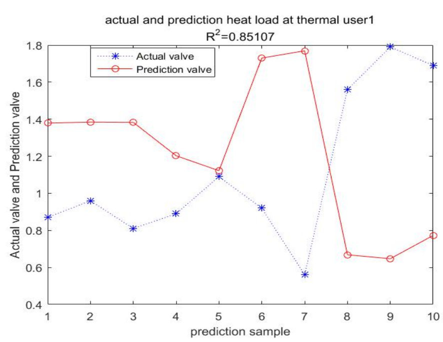

Fig 5 1# heat exchanger station prediction and actual value of heat load

Tab 1 BP neural network prediction results of eight heat exchanger stations

Sequence Number	Name of Heat Exchanger Station	Related Coefficient R^2
1#	A	0.85107
2#	B	0.85639
3#	C	0.95603
4#	D	0.85281
5#	E	0.98426
6#	F	0.89371
7#	G	0.87223
8#	H	0.88948

The predicted heat load value of 1 # heat exchanger station is calculated through the formula $Q = cm(t_1 - t_2)$, and the return water temperature of the heat user is also counted. The indoor temperature curve of 1 # heat user edited by Flowmaster editor is shown in Figure 6. According to this rule, thermal loading prediction is carried out for eight heat exchanger stations in turn.

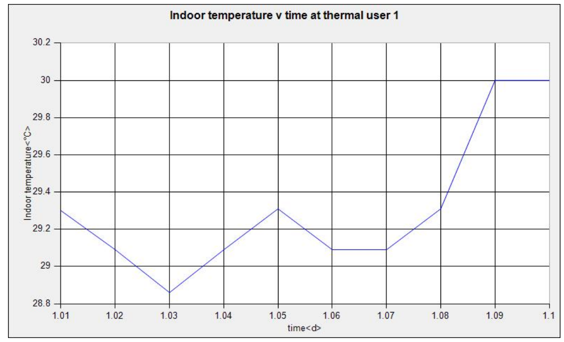

Fig 6 1# indoor temperature change curve of heat user

3. REALIZATION OF DYNAMIC VISUALIZATION OF SYSTEM OPERATING CONDITIONS COMBINED WITH MATLAB GUI

The accuracy of the model is verified by the relative errors of temperature and pressure of supply and return water in system simulation. Flowmaster combined with MATLAB GUI can realize the dynamic visualization of the operation conditions of the simulation system[25]. That is, the dynamic visualization of the supply and return water flow, pressure, temperature and heat load of the primary network of the eight heat exchanger stations from January 1 to January 10 in 2019 is achieved.

3.1 Verification of the model

The simulation model of central heating system through Flowmaster is built and the heat transfer transient condition is selected in analysis. The step length is set for 24 h, the starting time is 0 s, and the termination time is 240 h. The working conditions of ten days from January 1, 2019 to January 10, 2019 are simulated. Then, this paper compares the simulation operation value and the actual value of temperature and pressure of supply and return water in primary network of the eight heat exchanger stations, and chooses relative error to verify the accuracy of the model. The formula for calculating relative error is shown in Formula 3-1.

$$\delta = \frac{\nabla}{L} \times 100\ \% \qquad \text{(Eq. 3-1)}$$

Where, δ is the relative error, ∇ is the absolute error, and L is the truth value.

The average value of the relative errors of supply and return water parameters of eight heat exchanger stations in the ten days are calculated. The relative errors of supply and return water parameters are shown in Table 2.

Tab 2 Relative errors of temperature and pressure of supply water of primary network

Number of Heat Exchanger Station	Supply water pressure error	Supply water temperature error	Return water pressure error	Return water temperature error
1#	3.13%	4.84%	3.53%	4.12%
2#	3.26%	3.23%	2.09%	1.23%
3#	3.73%	2.59%	5.03%	5.23%
4#	3.56%	2.45%	2.23%	5.17%
5#	3.98%	2.36%	7.78%	5.49%
6#	4.51%	2.78%	5.46%	6.48%
7#	1.56%	2.49%	5.23%	0.02%
8#	5.46%	4.23%	2.96%	1.15%

It can be seen from the table that the relative errors of supply and return water parameters of the eight heat exchanger stations are all less than 10%.

3.2 Dynamic Visualization of Hydraulic Regime in Central Heating System

For the central heating system model built in Flowmaster above, flowmeters and thermometers are installed on the primary network pipeline for data measurement. The flow and pressure measuring devices of supply and return water in one of the heat exchanger stations are shown in Figure 7. Among them, number 169 and 185 measured flow rate, number 153 and 200 measured static temperature result, number 28 and 126 measured static pressure result.

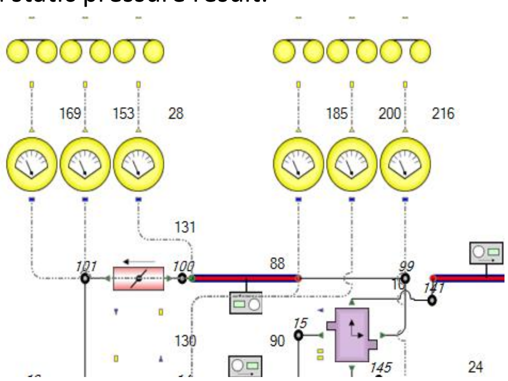

Fig 7 Pipeline flowmeter based on Flowmaster simulation

By running Flowmaster simulation model and jointing with MATLAB GUI, dynamic visualization of flow and pressure supply and return water in primary network pipeline of the eight heat exchanger stations during the ten days from January 1 to January 10 in 2019 is realized[26]. The design interface of primary network hydraulic condition is shown in Fig. 8. Dynamic visualization of supply and return water flow and pressure can be realized by the timer function of MATLAB GUI.

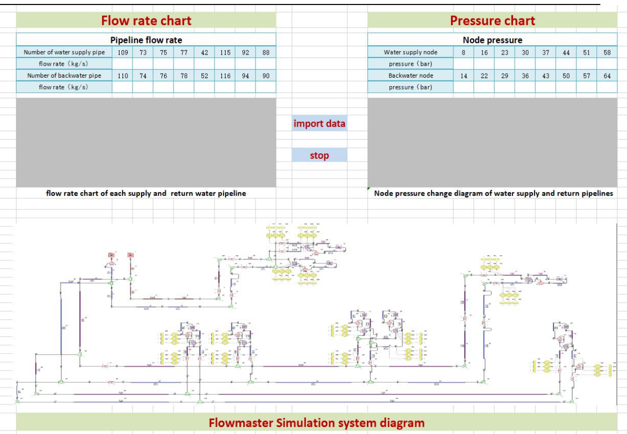

Fig 8 Design interface for dynamic hydraulic regime

Through the GUIDE function of Matlab, the. m file is generated, and then the corresponding callback function is written. By clicking on the option of importing data, the temperature and flow values can be refreshed every ten seconds to the next day. The visual operation interface of dynamic hydraulic regime is shown in Figure 9. In the interface, the flow rate and pressure of the heat exchanger station can be visualized intuitively and clearly, and the dynamic visualization of hydraulic conditions can be realized economically.

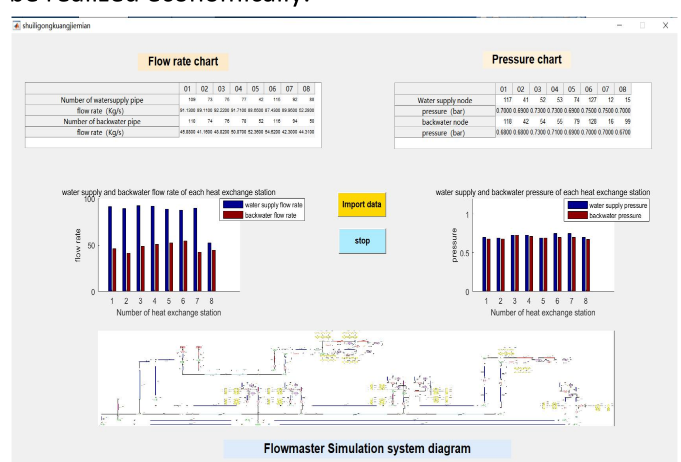

Fig 9 Visual operation interface of dynamic hydraulic regime

Combining Flowmaster and Matlab GUI, the visualization of flow and pressure of heat exchanger station can be realized economically. There is a great significance to further improve the intelligent level of the heat network and realize the intelligent diagnosis function of the heat network. Furthermore, it is of important practical significance for the development of multi-dimensional service push system for different managers of heat network system.

3.3 Dynamic Visualization of Thermal Condition in Central Heating System

On the basis of the simulation model of central heating system established above, the dynamic visualization of thermal conditions of the eight heat exchanger stations are achieved by combining with MATLAB GUI, such as supply and return water temperature of primary network, heat load prediction and actual heat load. The dynamic thermal condition design interface is shown in Fig. 10.

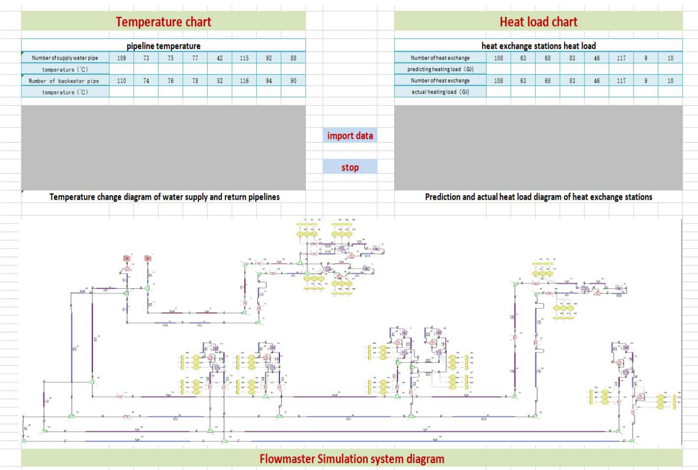

Fig 10 The dynamic thermal condition design interface

Through the GUIDE function of Matlab, the data can be refreshed every ten seconds by clicking the option of importing data, while the data can be stopped importing by clicking the stop option, thus realizing the visualization of dynamic thermal conditions. The visual operation interface of dynamic thermal conditions is shown in Figure 11. Combined with the basic functions of Flowmaster and MATLAB GUI, the dynamic visualization of supply and return water temperature, actual and predicted heat load can be realized economically, and the thermal conditions of the eight heat exchanger stations can be displayed in real time.

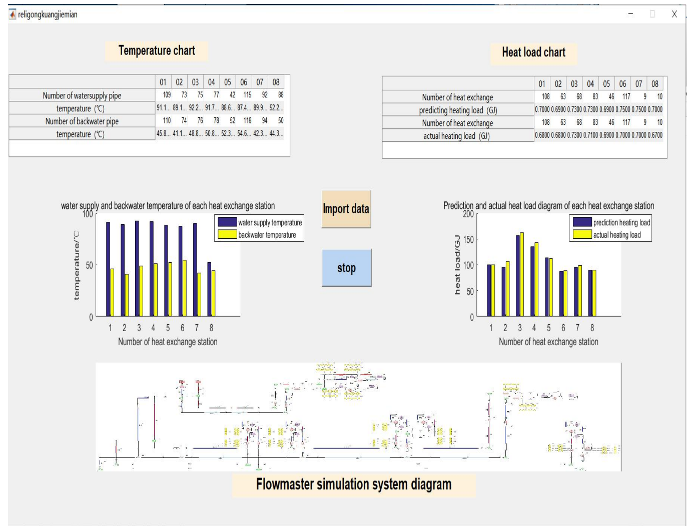

Fig 11 Visual operation interface for dynamic thermal conditions

The combination of Flowmaster and Matlab GUI is able to economically achieve the dynamic visualization of thermal conditions of heat exchanger station. There is a great significance to further improve the intelligent level of the heat network and realize the intelligent monitoring function of the heat network. Furthermore, it is of important practical significance for the development of multi-dimensional service push system for different managers of heat network system.

4. CONCLUSION

(1) Combined with the basic functions of Flowmaster and MATLAB GUI, the simulation and operation of the system and the dynamic visualization of the operation hydraulic and thermal conditions of the system from January 1, 2019 to January 10, 2019 are realized economically. It can provide convenient and intuitive operation interface for heat exchanger station.

(2) Through the combination with practical cases, this paper proves to some extent that the dynamic visualization of hydraulic and thermal conditions can be realized economically by combining the basic functions commonly used by Flowmaster and MATLAB GUI. It is of great significance to generate new levels of the heat-supply network's intelligence and realize the intelligent heating with functions of intelligent diagnosis, intelligent surveillance and multi-dimensional service push.

ACKNOWLEDGEMENT

This research was supported by the Research, Development and Demonstration of Key Technologies of Intelligent Heat Network Construction and Function Upgrading(2017GKF-0177).

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