Study of a Fault Analysis System for a Heat Supply Network Based on GIS[1]

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Abstract: Conventional methods cannot satisfy the request of the layout and operation management in a heating system. The geographical information system (GIS) in a heat supply network can realize information conformity and information share roundly, which makes management of information improve to a new level in district heating. When fault of the heat supply network occurs, the traditional methods make fault reaction time long and the efficiency low, and enlarge the fault harm. The system of fault analysis in a heat supply network based on GIS mainly simulates and calculates according to various fault conditions. By selection of valve shut-off schemes in fault conditions and simulation of various fault conditions, the fault treatment scheme can be optimized. The results of simulation can be shown in the GIS graphics with the aid of advanced image display function of GIS. The application of this system brings great significance to heating system on the management enhancing, fault number-reducing, quick decision-making and influence area diminishing in case of fault.

Keywords: heat supply network, GIS, fault, emergency regime

1 INTRODUCTION

There are more and more types of heat supply network while city heat supply network's operation time becomes longer and the heat consumer's number becomes larger. Furthermore, it's rather difficult to know the pipeline situation, for the complex laying structure, the ceaseless changing of overground buildings and underground pineline. It's typical for china's city pipe network that the data are lack and the layouts of pipeline are complex. Because of these, it is difficult to operate and manage the heating system. Especially when pipes are broken or components of pipe network are damaged, a repair scheme is usually discussed and made by searching the drawings, which not only needs lots of work, lack of accuracy and rationality, but also enlarges fault's influence area due to the delay of time.

The geographical information system (GIS) is the organic assembly of geography data, users,

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computer hardware and software, which are used to search, storage, renew, deal with, analyze and display geography information effectively[1]. GIS is the omnidirectional data information system which is based on data, combines fittings and personnel to deal with data and estimates the result integratively.

Applying GIS to the operation and management of heat supply networks can take advantage of GIS to manage the network dynamically. Assembling fault analysis with GIS can solve problems of lots of work, low speed, lack of accuracy and rationality effectively.

More recently, several cities developed GIS, but most of them only paid attention to facility management and view display. The techniques of the analysis and decision-making of hydraulic calculation, fault analysis and dispatch are lack. So the application level of GIS is low. The heat supply system's GIS in Baotou Thermal Company has realized management of heating system well, but hasn't involved the hydraulic calculation module. The system has a few fault analysis functions including valve shut-off scheme in fault, display of fault pipes and customers[2]. The Fulong thermal GIS in Chifeng includes functions of hydraulic calculation and shut-off analysis , but doesn't consider hydraulic calculation of emergency regime [3].

The fault analysis system discussed in this paper has been applied in the heat supply network's GIS of Langfang Thermal Center. As a subsystem of it, the fault analysis system can realize functions of valve shut-off in fault, hydraulic simulation in emergency regime, dispatch in emergency regime. What's more, the system can supply the gist to operator by calculating and analyzing in emergency regime.

2 SYSTEM DESIGN

Today there are lots of popular GIS software platforms in domestic & overseas. This system has chose MAPGIS, one of domestic excellent GIS software, as basic platform. The basic data using in this system are all constructed in space databases and attribute databases provided by MAPGIS.

2.1 Valve shut-off schemes

In order to close off fault component, the pipe in which fault component is sited and values in interrelated pipe are needed to be searched and shut off. The function of this module is to determine shut-off scheme and display the customers in fault when the fault component is confirmed, in which the number of shut-off valves should be exact and smallest[4].

To planar network, there are three situations of shutting off the smallest number of valves[5]：

（1）the pipe having fault point has valves in both sides：choose this pipe's starting node as basic point, array fault point and this pipe's valves according to their distance from basic point, shut off the two valves nearest fault point.

(2) the pipe having fault point has valves in one side, not in the other side：first, array valves in the side of having valves according to their distances from fault point, determine the value nearest fault point and shut it off. Choose the node which is in the other no-value side of the pipe having fault point as starting point, then breadth-first ergodicity of pipe network should be done to search pipes interrelated with the no-valve side, stop searching until valves are found and shut off.

(3) the pipe having fault point doesn't have valve：choose a random point in this pipe as starting point, then breadth-first ergodicity of pipe network should be done, stop searching until valves are found and shut off.

In these valve shut-off processes above, valves should be omitted if they cann't be shut off because of their disrepair for long period of using or other reasons, go on searching until valves able to be closed are found and shut off.

When faults occur in valves or compensators, it can be turned into faults in these pipes. Then schemes above can be used for searching shut-off valves. To the valve faults in heat sources and heat customers, it can also be turned into faults in interrelated pipes.

Multi-heat source ring-shaped network is spatial network in emergency regime. The supply and return water pipes are generally symmetrical in normal regime. When fault occurs, the symmetry of the pipe network will not be damaged if shutting off valves symmetrically in supply and return water pipes. But

the symmetry of network will be damaged if only shut off valves in supply or return water pipe. The one-side valve shut-off scheme has small shut-off valve number, good system stability and ability to resist fault[6]. The one-side valve shut-off scheme is applied in this paper's fault analysis system.

The spatial network method should be used to analyze hydraulic regime when topological structure of supply and return water pipes isn't symmetrical.

2.2 Simulation of no-limit emergency regime in heat supply network

When fault occurs, fault component should be closed off, the valves in pipes interrelated with fault component are needed to be shut off. Then heat customers are in the situation of emergency regime heating and topological structure of heat supply network has been changed. Limit heating can be achieved in emergency regime when there are automatic mechanism in network and controlling & adjusting measures in the entrances of customers, consequently heating system's energy consuming is reduced. The limit heating cannot be achieved without automatic mechanism in network. This module can simulate the redistributed situation of flow and press when fault occurs without controlling & adjusting measures in the entrances of customers, then customers not meeting requirement are found.

This module can also simulate one-side and both-sides shut-off schemes, the simulating results show that one-side shut-off is more available. This module is adapted to emergency regime's simulation of single and multi-heat source, branch-like and ring-shaped heat supply network. A hundred percent heating can be ensured for customers without breaking away from the branch-like network in emergency regime. Customers' heating requirement may not be met in emergency regime of multi-heat source ring-shaped network, then analysis and calculation are needed. Spatial network's theory is needed for analyzing multi-heat source ring-shaped network, because the network is no longer a planar network and the supply and return water network may be out of symmetry in emergency regime[6].

This module aims at establishing network's topological structure in emergency regime, calculating resistance losses, pipe flows and customer flows when resistance coefficients of pipes and characteristic curve of heat source's circulation pumps are known.

Algorithm flowchart can be seen in figure 1, where $\mathbf{A_k}$ is fundamental incidence matrix of spatial network in emergency regime; $\boldsymbol{B_k}$ is fundamental loop matrix of spatial network in emergency regime; $\boldsymbol{G_k}$ is pipe water flows' column vector of spatial network in emergency regime; $\boldsymbol{Q_k}$ is node input flows' column vector of spatial network in emergency regime; $\Delta\boldsymbol{H_k}$ is pipe press drops' column vector of spatial network in emergency regime; $\boldsymbol{S_k}$ is pipe resistant values' column vector; $\boldsymbol{H_{pk}}$ is pump heads' column vector of spatial network; $\boldsymbol{Z}$ is column vector of two nodes' potential energy difference of pipe.

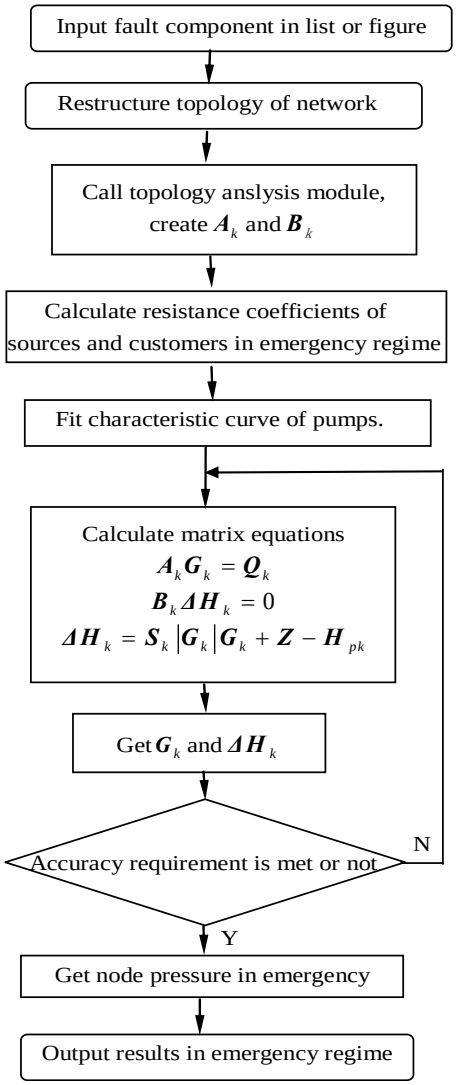

Fig.1 Simulation algorithm flowchart of no-limit emergency regime

2.3 Simulation of heat supply network's limit emergency regime

Limit heating can be achieved in emergency regime when there are automatic mechanism in network. Limit heating can make customer flows fall in a certain proportion, so customers far from heat source can be avoided of undersize flows. Limit heating coefficients can vary according to different customers. Limit heating coefficient can be 1 for important, special customers such as hospitals and beadhouses.

This module can simulate hydraulic regime of limit heating, check adaptive capacity of network's circulation pump in emergency regime, analyze necessity of setting pump for fault. It can also simulate hydraulic regime of one-side and both-sides valve shut-off scheme. The module is adapted to emergency regime simulation of single and multi-heat source ring-shaped heat supply network. It needs to point out that limit heating has no sense for branch-like source network because a hundred percent heating can be ensured for customers without breaking away from network in emergency regime. When there are automatic mechanisms in the entrances of customers, flowes can be limited to prevent customers from breaking away from excessive heating, which can reduce energy loss.

This module's algorithm is similar to the algorithm of no-limit heating. The difference between two algorithms is that the flow of customer for limit heating is known.

2.4 Fault disposal and dispatch of heat supply network

The dispatch scheme should be given when fault occurs in heating system. This module can give the valves needed to be shut off and the shortest path between a random place and fault place by calling shut-off module. It can also give dispatch scheme in emergency regime, realize the filling, saving, accounting, searching, printing of fault dispatch requisition by simulating network's flow distribution and press situation through starting up or shutting off of heat sources, pumps and valves.

3 PRACTICAL EXAMPLES

There are has 2.7 million square meters heating area, five heating stations, 118 kilometres heating pipeline, 19 square kilometers heating covering area in Langfang Economic Development Area Thermal Center now. The establishment of this central heating system is complex. Many heat sources have different heat mediums and parameters. According to the different heat mediums and parameters, there are high or low temperature water network, steam network, condensate water network. So operation management of this heating system is complex.

The heating system's GIS of this thermal center mainly includes subsystems of pipe network engineering management, geography graphic library management, pipe network input editing, computing

data management, network design hydraulic calculation, operation regime analysis, fault regime analysis, heating system management, system setting and system help. Different function is realized by different subsystem.

The application of the fault analysis system reduces the time to make shut-off scheme and supplys the essential conditions to operator to get rid of faults in heat supply network duly. When fault occurs in network, engineers can know the affected areas and extent quickly with the help of the system. The system can supply decision-making for engineers and directors. It has achieved economical and social benefits since the system went into operation.

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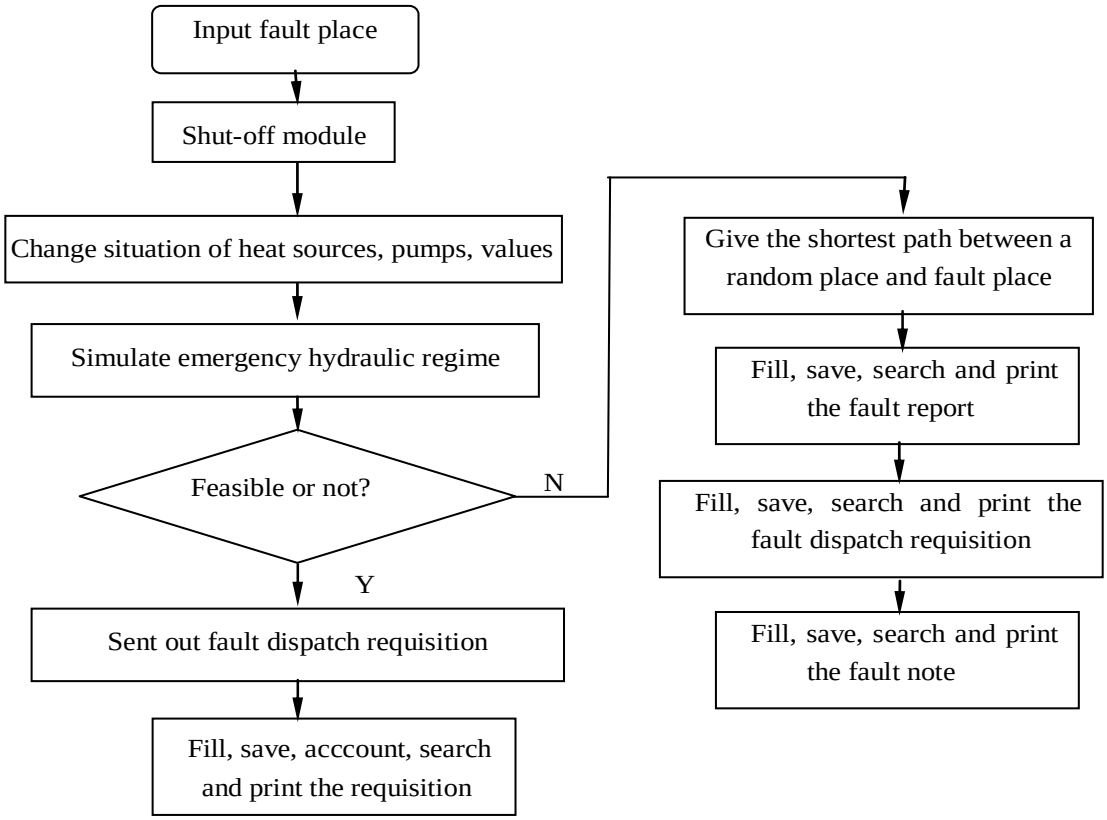

Fig.2 Flowchart of fault disposal and dispatch of heat supply network