The Study of the Location Model and the Valve-closing Program of the Pipe-tube of the Water-supply

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Abstract. The city water supply pipe network is an important part of the rapid development of the city, so the safety and the reliability of the operation of the water supply pipe network are also paid more and more attention. When the water supply pipe network is in the explosion accident, a large amount of water loss is caused. So the explosion positioning model of the water supply pipe network is particularly important for the actual accident situation which is encountered in the real life. In combination with the SCADA system, the location of the explosion accident is determined, the optimal scheme of closing the valve is established by combining the topological structure of the pipe network, the waste of the water amount is reduced and the emergency repair time is saved.

1. Introduction

With the acceleration of urbanization, the reliability of urban water supply is directly related to the safety of water supply network operation and also closely related to the economic development of the city. In the current situation of pipe burst accidents, most water supply enterprises still rely on conventional leak detection methods, which will lead to a large amount of water waste, resulting in huge losses of enterprises and affecting water safety. Therefore, it is possible to establish and improve the safety system of urban water supply network by using SCADA system to monitor the urban water supply network in real time. By establishing the location model of pipe burst accident in water supply network, the optimal valve closing scheme is determined.

2. The idea of the establishment of the positioning model of the tube bursting of the water supply pipe network

From the hydraulic point of view, when the pipe burst accident occurs in the water supply network, it can be regarded as the sudden increase of the flow rate of a node in the water supply network, which leads to the change of the operation condition of the water supply network and the change of the dy
mic attributes in the pipe network. The SCADA system is the main basis of the modern city layout and monitoring point, and the real-time monitoring data is collected by the detection instrument installed at the pressure measuring point, and the monitoring data is fed back to the central control room. Then we can know the variation law of these variable parameters and analyze the change process of the variable parameters of the water supply network under normal working conditions. When the pipe burst accident occurs in the pipe network, the variable parameters of the water supply network under the accident condition can be monitored, and the location of the accident can be located by analyzing and calculating the purpose of shorting the accident handing time can be achieved[1-2].

The figure shows the distribution of all SCADA monitoring points in the Z-City High-tech Zone, through the analysis of the pressure change of each monitoring pressure measuring point in the state of the explosion accident of the pipe network, the approximate location of the burst accident is determined by finding the pressure measuring point with the greatest influence on the explosion accident. Then using the micro-algorithm to carry out careful calculation on the pipeline section near the pressure measuring point and finally determine the position of the explosion accident. The valve closing algorithm in the ArcGIS software is adopted to analyze the optimal valve closing scheme aiming at the position of the explosion tube. The pipe bursting positioning of the water supply pipe network is realized and the function of the explosion accident treatment scheme is developed.

Figure 1. All SCADA monitoring pressure distribution map of Z City High-tech Zone

3. Simulation of pipe burst accident in water supply network.

Once an accident occurs in the operation process of the pipe network, the pressure will change obviously, but it is difficult to describe the change law of the pressure in the pipe network, which requires the division of the water supply network according to the distribution of the pressure during the normal operation of the pipe network. As shown in the figure, the whole water supply network is divided into five areas according to the pressure gradient in the water supply network. The red curve in the figure is the dividing line of each pressure zone and the pressure gradient between each partition is 0.04Mpa. It is guaranteed that each pressure zone contains at least one monitoring pressure measuring point.
Figure 2. Distribution of water pressure and distribution of pressure monitoring points of Z City High-tech Zone

The hydraulic adjustment of the pipe network in each pressure zone is calculated by hydraulic modeling software, and the pressure distribution of the water supply network in different pressure zones is simulated, and the relative pressure drop at the pressure monitoring point in each pressure zone is calculated. The pressure drop is the difference between the water pressure under the normal working condition and the water pressure under the accident condition [4].

4. Using microscopic model to locate the accident point of tube explosion.

Because Z city high-tech zone is the newly planned urban area of Z city and there is no related pipe burst accident, it is impossible to establish the water supply pipe burst model from the historical pipe burst accident data, only through the custom pipe burst accident way to establish the water supply pipe burst location model. So the pipe explosion accident point can only be set up on the basis of the accurate hydraulic model in school, and then the hydraulic simulation calculation of the hydraulic model of the pipe explosion accident.

4.1 Location of pipe explosion accident

The simulated pressure value of each pressure monitoring point is calculated by applying the microscopic hydraulic model. Absolute error and relative error are usually used to judge the analog value and the true value. Each time an accident simulation is performed, a set of pressure monitoring points can be obtained. The average absolute error, average relative error and mean square error are three statistical indicators as shown in Table 1:

|                | Average absolute error | Average relative error | Mean variance |
|----------------|------------------------|------------------------|--------------|
| $A$            | $\sum_{i=1}^{n} |e_i| / n$                  | $R = 100 \sum_{i=1}^{n} \frac{|y_i - y'_i|}{y_i}$ | $S = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (y_i - y'_i)^2}$ |

It can be seen from Equations that the mean square error can better describe the degree of agreement between the simulated value and the true value.

4.2 Estimation of leakage and loss of water

The gold segmentation method has higher accuracy and precision, which can accurately determine
the water leakage when the accident occurs. The interval of the water loss is divided by the golden section method, and the amount of water lost by each division is taken as the accident water volume. Perform simulation calculation to obtain the mean square error of the pressure value of the monitoring point of the water supply pipe network and the pressure value of the pressure monitoring point under the actual accident condition until the accuracy of the mean square error meets the requirements.

The formula for calculating the golden point: first set an interval \((x_1, x_2)\), \(0 < x_1 < x_2\), and the golden point points \(x_3\) and \(x_4\) of the interval \((x_1, x_2)\) can be obtained by the formulas.

\[
x_3 = x_1 + 0.382(x_2 - x_1) \\
x_4 = x_1 + 0.618(x_2 - x_1)
\]

Within the set range, the mean variance shows a downward trend in a certain range. The fixed water loss interval, the golden point of the far left and right sides of the end point is used as the end point of the leaked water loss interval after expansion, as shown in the figure 3:

**Figure 3.** A schematic diagram of the principle of gold segmentation

\(x_3\) and \(x_4\) are the golden points of line segment \(x_1, x_2, x_5, x_6\) are line segment \(x_3\) and \(x_4\) golden point, \(x'_1, x'_3\) are line segment \(x_1\) and \(x_3\) golden point, \(S(x_3), S(x_4), S(x_5)\) and \(S(x_6)\) are the mean square error of the time leakage water loss \(x_3, x_4, x_5\) and \(x_6\), respectively. If \(S(x_5) > S(x_3) > S(x_6)\), then \((x'_1, x'_5)\) is the new range of water loss.

### 4.3 Case analysis

The data of the explosion accident of a high-tech zone in a city cannot be accurately collected, so the accuracy of the tube-bursting positioning model can only be checked by assuming the explosion accident. It is assumed that the position of the node-J-3606 in the fourth accident area at the time of 15:00 is the explosion accident, the leakage flow of the water is 22L/s, and the pressure monitoring point data at this time is used as the real data of the accident of the pipe network.

According to the water supply capacity under the normal working conditions of the water plant, the interval where the water loss can be estimated is \((0.01, 190)\) (unit L/s, the same below), and the golden section can be calculated from the golden section calculation formula (4), (5). The leakage water loss of the point is 72.586L/s and 117.424L/s, respectively, and then the average relative error, the average absolute error and the mean square error of the four conditions are compared by the formula (1), (2), (3). The results are as follows:

**Table 2.** Leakage interval \((0.01, 190)\) comparison table of leakage loss error

| Missing flow rate | Average relative error | Average absolute error | Mean variance |
|-------------------|------------------------|------------------------|--------------|
| 0.01L/s           | 1.181                  | 4.079                  | 1.193        |
| 72.586L/s         | 1.016                  | 3.782                  | 1.031        |
| 117.424L/s        | 2.469                  | 9.724                  | 2.483        |
| 190L/s            | 4.989                  | 21.894                 | 4.992        |

It can be seen from table 2 that when the leakage flow rate is 0.01L/s and 72.586L/s, the mean square error is relatively small, so let \((0.01, 72.586)\) be the new leakage interval, according to formulas (4), (5) Calculate the golden point: 27.734L/s and 44.862L/s, and compare the error of water loss again.
The results are shown in the following table:

**Table 3.** Leakage interval (0.01, 72.586) comparison table of leakage loss error

| Missing flow rate | Average relative error | Average absolute error | Mean variance |
|-------------------|------------------------|------------------------|--------------|
| 0.01L/s           | 1.181                  | 4.079                  | 1.193        |
| 27.734L/s         | 0.374                  | 1.342                  | 0.386        |
| 44.862L/s         | 0.157                  | 0.551                  | 0.205        |
| 72.586L/s         | 1.016                  | 3.782                  | 1.031        |

It can be seen from table 3 that the mean square error of water loss at 27.734L/s and 44.862L/s is relatively small, so the new leakage interval is (27.734, 44.862) and the new golden point is: 34.276L/s and 38.319L/s, the same mean square error comparison, the results are shown in the following table:

**Table 4.** Leakage interval (27.734, 44.862) comparison table of leakage loss error

| Missing flow rate | Average relative error | Average absolute error | Mean variance |
|-------------------|------------------------|------------------------|--------------|
| 27.734L/s         | 0.374                  | 1.342                  | 0.386        |
| 34.276L/s         | 0.213                  | 0.751                  | 0.214        |
| 38.319L/s         | 0.112                  | 0.387                  | 0.139        |
| 44.862L/s         | 0.157                  | 0.551                  | 0.205        |

It can be seen from table 4 that when the leakage flux is 38.319L/s and 44.862L/s, the mean square error is relatively small, the new leakage interval is (38.319, 44.862), and the new golden point is: 40.818L/s and 42.363L/s, also compare the mean square error, the comparison results are shown in the table:

**Table 5.** Leakage interval (38.32, 44.86) comparison table of leakage loss error

| Missing flow rate | Average relative error | Average absolute error | Mean variance |
|-------------------|------------------------|------------------------|--------------|
| 38.319L/s         | 0.112                  | 0.387                  | 0.154        |
| 40.818L/s         | 0.062                  | 0.214                  | 0.141        |
| 42.363L/s         | 0.084                  | 0.265                  | 0.157        |
| 44.862L/s         | 0.157                  | 0.551                  | 0.205        |

It can be seen from the table 5 that the corresponding mean square error is the smallest when the water loss is 40.818L/s, which indicates that the water leakage of the main pipe in the water supply system reaches 40.818L/s, which is the closest to the actual accident point. Due to the calculated water loss and there is a certain deviation in the amount of water leakage at the actual explosion accident point. It is necessary to add the missing water amount to the pressure monitoring point in the accident area, and then compare the mean square error to find the working point with the smallest mean square error. Close to the location of the actual accident occurrence point, and finally apply the golden section method to find a relatively accurate loss. By using the model to locate the occurrence point of the accident, the scope of the squib accident can be reduced, and the amount of water leakage in the event of a squib accident can be accurately determined by applying the golden section method.
5. Design and implementation of valve closing algorithm for pipe burst accident

5.1 Algorithm theory
   The general search procedure for breadth-first search is as follows: it is assumed that starting from a certain vertex i, and then sequentially accessing the points that are not accessed adjacent to i, and sequentially accessing points adjacent to these points from these points. In this process, it is ensured that the adjacent points of the vertices to be accessed are preferentially accessed at the adjacent points of the vertices that are accessed, until the accessed vertices are accessed with all of the adjacent points.

5.2 Valve closing algorithm
   The valve closing algorithm is mainly used for searching a valve needing to be closed, the process is mainly divided into two stages, and the first stage is to search out a valve needing to be closed when the quantity of the cut-off pipe sections is minimum as much as possible. The second stage is to reduce the number of closing valves as much as possible in the case that the valve closing measures are taken to prevent the pipeline from continuing to leak, so as to find the valve which is not obvious to the leakage effect of the pipeline, so as to reduce the workload of the emergency repair, and obtain the optimal valve closing scheme.

5.3 Case analysis
   Through the above, the pipe explosion accident in Z city high-tech zone has been simulated and located, and the leakage flow rate of the pipe explosion accident has been estimated. After determining the pipe explosion accident point, the valve closing scheme for the pipe explosion accident point can be analyzed through the breadth first search algorithm, and the continuous influence of the pipe explosion accident on the water supply state of the water supply network can be prevented by taking the valve closing measures for the pipe explosion accident.

Figure 4. Closing valve scheme for explosion accident
As shown in the figure 4, the red pentagonal star in the figure indicates the location of the pipe explosion accident point, and the green circle indicates the valves that need to be initially closed after the pipe explosion accident occurs. It can be seen from the figure that the closure of these valves can effectively prevent the impact of the pipe explosion accident on the surrounding pipe network and avoid the further expansion of the accident loss. It can be found that the number of valves that need to be closed is obviously reduced and the purpose of pipe explosion accident treatment is achieved, which meets the requirements of practical application.

6. Conclusions

(1) There is a certain rule in the change of node pressure in water supply network, and the change of node pressure shows regional differences in space. It is necessary to consider the spatial factors of water supply network when studying the operation parameters of pipe burst accident in water supply network.

(2) The change law of pressure detection point before and after pipe burst accident in water supply network can lock the occurrence area of the accident. The location of the accident point can be judged by establishing the microscopic model of the pipe network, the maximum water leakage interval can be determined, and the leakage water loss can be determined by gold partition method.

(3) Through the application of the breadth-first search algorithm, the tube-breaking accident is closed, the optimal valve closing scheme is determined, and the user who is affected by the explosion accident is obtained.

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