Design Study of Urban-Rural Water Supply Integration Based on DMA Zoning

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Abstract. The current traditional urban-rural water supply integration planning scheme mainly relies on the management platform to realize, which leads to poor planning effect due to the lack of zoning treatment of water supply pipelines. In this regard, the design of urban-rural water supply integration scheme based on DMA zoning is proposed. The urban and rural water supply pipeline networks are zoned, and the water supply pipelines are coarsened and refined. And the hydraulic condition of the water supply pipe network is calculated and the planning model is constructed. In the experiments, the proposed method is verified for the hydraulic scheduling performance. The analysis of the experimental results shows that the proposed method is used to plan the urban and rural water supply, and the average daily flow of water supply changes smoothly and has a more ideal water dispatching performance.

Keywords: dma zoning · urban-rural water supply · integration · water pipelines

1 Introduction

Urban-rural integration refers to the integration of urban residents and rural villagers into an organic whole in terms of geographical distribution, production and life, overall coordination, systematic planning, through policy reform and institutional innovation, constantly promoting the integration of urban and rural areas in economic and social development, breaking the old economic structure, seeking industrial complementarity, implementing integrated consideration of urban residents and rural residents in terms of policy, and maximizing the realization of all aspects of national It will eliminate the urban-rural gap and promote the scientific and harmonious development of the whole society and eventually achieve common prosperity. The integration of urban and rural areas is an inherent requirement of socio-economic development, in which the development of rural areas has been a relatively weak link. Urban-rural integration is an adaptive development change between urban and rural areas to conform to the transformation of productivity, a new stage of urbanization development and a parallel path, in the process of evolutionary development, constantly adjusting to seek dynamic balance, with a view to achieving interdependence and interaction between urban and rural areas [1]. Obviously, enhancing rural development through the implementation of a series of system rural construction and livelihood project construction is an inevitable requirement for

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promoting urban-rural integration and a necessary condition for promoting urban-rural integration development. The integration of urban and rural water supply refers to taking the city and the countryside as a whole, extending the urban water supply network to the countryside, and transforming the independent, scattered and simple water supply mode in the countryside into a centralized, scientific and modernized water supply mode, so as to establish an integrated urban and rural water supply network, realize the purpose of sharing high-quality water resources between urban and rural residents, promote the coordinated development of urban and rural water supply and improve people's living standards [2, 3]. The core of urban-rural water supply integration is that rural residents can share the same quality of tap water and the same high-quality water supply services as urban users, and urban-rural water supply integration is more importantly effective. The most fundamental aspect of urban-rural water supply integration is the same policy, local governments should coordinate existing policies when implementing new policies to ensure that urban and rural water supply enjoy the same policies, as soon as possible to create a reciprocal policy system for urban and rural water supply, promote the integrated development of urban and rural areas, and break the dual structure of urban and rural areas. On the contrary, if the policy system and water quality standards of towns and villages are different, it is difficult for urban and rural residents to enjoy the same rights and services. This paper combines DMA zoning technology and proposes an urban-rural integration design method, aiming to improve the development of two-way urban-rural integration and the close integration between rural and urban areas.

2 Urban and Rural Water Supply Network DMA Zoning Treatment

The implementation of independent metering zoning (DMA) is an important tool to assist in the daily management and leak identification of the pipeline network. By analyzing the minimum nighttime flow within the DMA partition, it can narrow the scope of leak identification, combine with leak detection equipment, achieve regional active leak control, improve the speed of leak repair, and increase the speed of main equipment replacement and repair. In this paper, the DMA method is used to partition the urban and rural water supply network, and the specific implementation steps are shouwn as Fig. 1 [4].

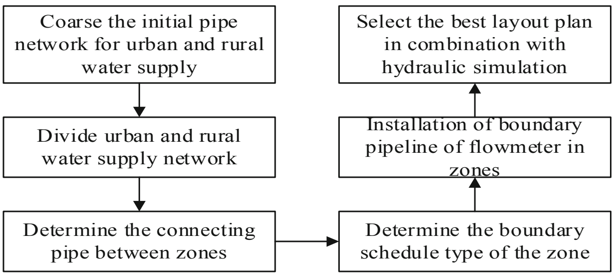

Fig. 1. Using DMA method to divide urban and rural water supply network flow

Suppose the initial pipe network of urban and rural water supply is $G_0 = (V_0, E_0)$, and after i times of coarsening, the new water supply pipe network $G_i = (V_i, E_i)$ is obtained, and the pipe network topology relationship can be represented by $G(V, E)$. Where V represents the set of pipe network nodes and E represents the set of pipelines. Each coarsening is a process of merging the nodes at both ends of the water supply pipeline and gradually reducing the number of nodes. The specific coarsening steps are as follows.

Considering the need of partitioning with reference to water demand in the partitioning process, the node weight is set to the node water demand; considering the need of protecting large diameter pipes in the refinement process, the pipe weight is set to the pipe diameter. Each time from G_i to G_{i+1}, the nodes of the pipe network are randomly traversed, and the unpaired nodes are matched with their neighbors in the traversal process. In order to protect large diameter pipes, priority can be given to matching neighboring nodes with high pipe weights between nodes. In order to avoid placing valves on the water transmission mains, nodes on the water transmission mains are not involved in node matching. At the end of each pairing at G_i, the paired nodes are merged according to three principles: the weights of the merged nodes are updated to the sum of the weights of the two nodes; the weights of the "overlapped" pipes are updated to the sum of the weights of the original pipes; and the pipes between the paired nodes are temporarily hidden.

The water transmission main usually separates the whole network roughly, and the network can be initially partitioned according to the simplified structure and the distribution of the water transmission main. The partitioning follows 5 principles: the small area separated by the water main is treated as a separate partition; try to choose the pipe with small weight as the boundary pipe between partitions; to reduce the number of large diameter boundary pipes in the partitioning process, part of the terminal water main can be included in the partitioning scope; consider the uniformity of partitioning, try to make the difference of water demand of each partition not big; consider the natural boundary formed by roads or watercourses, the influence of administrative zoning, etc. Administrative zoning and other practical factors [5].

The process of gradually reducing G_m to G_0 according to the reverse process of coarsening is called refinement. In the process of reducing to $G_i G_{i+1}$, , change the partition attribution of the pipe network nodes, place the meters (valves and flow meters) on the partition boundary pipes corresponding to the new partitioning scheme, after which the operation of each partitioning scheme is obtained using hydraulic simulation to select the optimal moving scheme at the moment. Move the node N times, corresponding to N partitioning schemes, and select the optimal partitioning scheme among them by the superior-inferior solution distance method, i.e., select the local optimal scheme under the current partitioning conditions, and then continue the refinement from to $G_{i-1} G_{i-2}$ until G_0. The detailed steps for refinement from G_i to G_{i-1} are as follows [6].

(1) After determining the connecting tubes between partitions, each boundary tube corresponds to two boundary node movement schemes, and the scheme that does not satisfy the movement conditions is dropped to obtain multiple new partition schemes. The node can be moved if it satisfies the following conditions: it is located at both ends of the boundary tube between two partitions; the sum of the weights of the

node's original partition is greater than 0 after moving the node; the nodes within the node's original partition are still connected to each other after moving the node.

(2) Determine the type of boundary pipe meter for the partition, after moving the node in step (1), it is necessary to determine the best water meter arrangement scheme corresponding to each new partition scheme for hydraulic simulation. The boundary pipe valve and flowmeter selection follows four principles: choose the main water transmission pipe or directly connected to the main water transmission pipe to install the flowmeter; install the flowmeter on the large diameter pipe; choose two boundary pipes in each partition to install the flowmeter; if the number of large diameter pipes in the boundary pipe of the partition is large, you can use Monte Carlo ideas, randomly select the pipe from the large diameter pipe, which will be used as the partition to install the flowmeter Boundary pipe, combined with hydraulic simulation for a number of attempts, and select the best hydraulic, water quality conditions from the scheme, as the best valve, flowmeter arrangement scheme under the partition.

3 Urban and Rural Water Supply Pipe Network Hydraulic Calculation

Since the water supply network is under the road surface, the pipe network lines are complex and the pipe diameters vary in size. Therefore, in practice the network is simplified, usually leaving the main trunk pipes and omitting the secondary pipes and pipes with little impact on the hydraulic environment. There are six types of pipe network simplification: omission, merger, equivalence, parallel pipe section merging, decomposition, and appurtenance simplification. Specifically, the less affected by water conditions, pipe diameter is relatively small branch and distribution pipes omitted, the pipe diameter is relatively small, parallel and close to each other's pipeline merger, for different pipe and specification of the pipe section, equivalent into a pipe, equivalent before and after the head loss along the equal. Pipe diameter is smaller, closer to the parallel pipe sections can be merged into one, equivalent before and after the head loss is equal. Disconnect the water supply network sparse water supply area connected to the pipeline, 1 pipeline into 2 independent pipelines, they are separated into independent units calculated separately. Remove pipelines that can be streamlined, such as exhaust valves, drain valves, fire hydrants; two or more of the same equipment in the same place can be combined.

According to the demand for water in different areas and the convenience of maintenance, the pipeline should be laid along the road as much as possible to achieve the maximum water supply coverage with the least number of pipelines. Combined with the actual situation of rural housing in the city and rural planning, the minimum service head of the user take-over point in the planned water supply pipeline is 12 m. Calculate the flow rate along the pipe section based on the number of apportioned water users along each pipe section, and project the flow rate and pipe diameter of each pipe section from the end of the pipe network upstream; determine the most unfavorable nodal head point, and project the pressure head of each node from the most unfavorable point upstream to. Per capita water distribution equivalent q_0 Calculation formula is shown below.

$$q_0 = \frac{1000Q_0}{P} \tag{1}$$

where Q_0 represents the total design flow of the distribution network in the village and P represents the total number of designed water users. The formula for calculating hydraulic loss is shown below.

$$h = \frac{10.67q^2 l}{C^{1.85} D^{4.87}} \tag{2}$$

where, l represents the length of the pipe section, D represents the pipe diameter size, q represents the water supply flow rate, and C represents the water supply coefficient. The above steps can complete the calculation of the hydraulic condition of urban and rural water supply pipe network, and provide data support for the subsequent planning scheme of water supply integration.

4 Building an Integrated Planning Model for Urban and Rural Water Supply

In order to ensure the validity of the urban-rural water supply integration planning model, assessment indicators need to be set. According to the characteristics of evaluation indicators, they are divided into qualitative and quantitative evaluation indicators. The qualitative indicators are fuzzy and cannot be precisely expressed by specific data calculation, so they need to be quantified by fuzzy mathematical calculation methods. Considering the specificity of the model, an improved expert scoring method is used to judge them, and the specific calculation formula is shown as follows.

$$X_i = \frac{\sum \lambda_j E_j(c_i)}{\sum \lambda_j} \tag{3}$$

where, X_i represents the evaluation value of the expert group, λ_j represents the authority factor, and c_i represents the evaluation value of the individual evaluation index. The resulting planning model expressions are shown below.

$$\begin{cases} \min W_a = \min \sum_{i=1}^{M} \frac{t_i}{M} \cdot L \\ \min g_c = \min \left(\sum_{v=1}^{T_m} C_v + hC_m \right) q \end{cases} \tag{4}$$

where: M is the total number of nodes in the network in addition to the water source, t_i is the node water age of node i in the network, C_v is the price of the vth valve, M represents the number of volume flow meters installed, C_m represents the price of the mth volume flow meter, represents the network articulation matrix, q represents the column vector of volume flow rate of the pipe segment, Q represents the column vector of volume flow rate of the node, L represents the loop matrix of the network, h represents the column vector of head loss of the pipe segment.. The above steps can be used to construct the urban-rural water supply integration planning model, combined with the above hydraulic calculation and pipe segment partitioning related content, so that the design of urban-rural water supply integration planning scheme based on DMA partitioning is completed.

5 Testing and Analysis

5.1 Test Preparation

5.1.1 Testing Environment

To prove that the urban-rural water supply integration planning scheme based on DMA zoning proposed in this paper is better than the conventional urban-rural water supply integration planning method in terms of planning effect, an experimental test session is constructed to verify the actual planning effect of this urban-rural water supply integration planning method after the theoretical part of the design is completed. In order to ensure the reliability of the data results, this experiment was conducted in a comparative experiment, and two conventional urban-rural water supply integration planning methods were selected as the experimental control group, namely, the urban-rural water supply integration planning method based on ant colony algorithm and the urban-rural water supply integration planning method based on deep learning.

5.1.2 Test Data Set and Test Platform

This experiment selected an urban and rural water supply planning project in a province, which utilizes the rich water supply capacity of the water supply plant and jointly uses existing and new water supply facilities for water supply, with a maximum daily water supply capacity of 3. 97 x 104 m^3. The water supply area of the project covers the coincident towns under Qingfeng County that still use groundwater as the source of drinking water, with a service area of 778.7 km^2 and a service population of 640,000 people, realizing the urban and rural water supply for the whole area of Qingfeng County The goal of integration of urban and rural water supply in Qingfeng County. The project has laid 256 km of new water transmission and distribution pipes, built 3 new water supply plants, 1 booster pump station, and replaced 184,100 IC card water meters.

Take the above experimental data as the data set. MATLAB software was used to model the parameters related to the above experimental project, and three water supply planning schemes were used to plan the water supply project for the components and compare the planning results. Take the change of average water supply flow as the evaluation index. The water flow changes steadily on a monthly basis, and the higher the flow, the better the planning effect of the official water network.

5.2 Analysis of Test Results

The evaluation index chosen in this paper is the actual planning performance of the water supply integration planning scheme, specifically measuring the change in the daily average value of urban and rural water after the completion of the planning, the smoother the change in the value represents the higher the actual planning performance of the planning method, the specific experimental results are shown below.

Analysis of Fig. 2 shows that the integrated urban-rural water supply planning scheme proposed in this paper is better than the two conventional planning methods in terms of water dispatching capacity, and the average daily water supply flow changes more

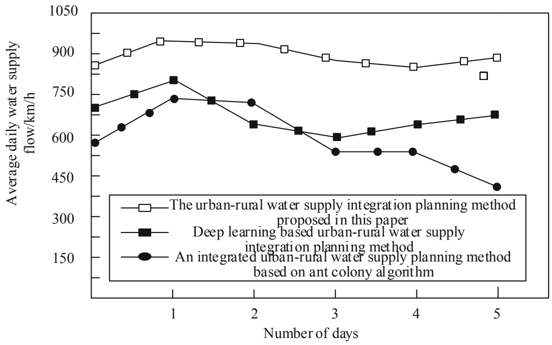

Fig. 2. Changes in average daily water supply flow

smoothly and has higher values, thus proving the effectiveness of the planning scheme proposed in this paper.

6 Conclusion

In order to improve the zoning planning effect of urban and rural water supply pipelines, this paper designs a comprehensive planning method of urban and rural water supply based on DMA zoning. Using DMA technology to partition the water supply pipe can effectively improve the planning efficiency. The hydraulic conditions of the water supply network are calculated and the planning model is established. So as to improve the water dispatching performance of the water supply pipeline. From the test results, it can be seen that the urban and rural water supply flow after planning using the method in this paper is more stable, and the water dispatching is stronger. This method can provide reference for similar planning and design schemes.

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