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Design of water distribution network with pressure control and water leakage[1]

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Abstract. Optimal design of water distribution network is one of the major concerns of this century due to lack of water. In this study, pressure control valves designed to manage the water flow in networks and to reduce losses in pipes. This paper described an integrated model-based monitoring framework for leakage localization in district-metered areas of water distribution networks, which takes the advantage of the hydraulic model in the network. The leakage and losses reduction methodology based on the use of flow and pressure measurement and a limited number of pressure valves deployed inside the Network, was developed. The optimal simulation by considering the pressure control was conducted in the Epanet software for the network. The results showed that the proposed techniques were useful tool and are effective to design and location of water distribution network.

Key words. Pressure control, water distribution network, water leakage, Epanet.

1. Introduction

The issue of leakage in urban water supply systems from things that in the past two decades in many countries is taken into consideration with systematic planning and science, there has been a good experience. In general, non-revenue water loss and water production and distribution system is one of the main problems is water and wastewater companies. The amount of non-revenue water in developing countries and in developed countries more than 30 percent of the water produced less than 15 % of production. Water loss is actually divided into two general group's appearance. Water leakage of urban water supply networks is considered a real loss often due to the inability to control pressure occurs especially in older networks. One of the best and most cost-proposed procedures, management of pressure on the network that taps surging use of its tools is the most common. There are leaks in water distribution networks is inevitable. Today, reducing leakage by using

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hydraulic parameters such as pressure management in the projects is important. Intelligent control pressure, a suitable method for controlling leakage and reduce damage caused by excessive pressure on the network [1, 2]. Nasirian [3] in 2013 to evaluate the management of leaks in water distribution networks using genetic algorithms paid. Optimal positioning of valves installed surging in the network is as an optimization problem in the management of water distribution network definition. The proposed optimization models were developed to solve this problem [4, 5]. The pressure changes in a part of the water distribution network in Tehran EPANET2.0 model were simulated. For this purpose, the combination of neural network and fuzzy logic, neural networks and its results are compared with the results of Hydraulic Analysis and ability of neural network models to predict the pressure has been shown.

2. Materials and methods

A water distribution network includes pipelines (the intersection of pipes), pumps, valves and tank or reservoir, see Fig. 1. EPANET models flow of water in each pipe, pressure at each node, the height of water in each tank and the concentration of a substance within the distribution network during the simulation with several jumps in the track (Fig. 2). In addition, concentration of materials, water and trace the source of life can be simulated. The proposed program can simultaneously calculate a solution for both items. It can also calculate the hydraulic network.

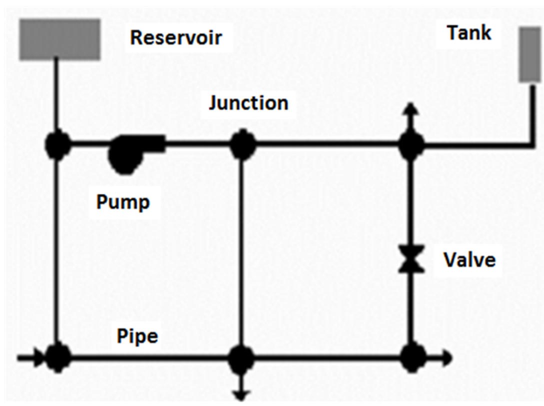

Fig. 1. Show piece - a network node

In this method, by measuring flow in a region overnight, the overall leakage network based on standards of the International Water Association (IWA) is determined as

$$Q_i = C_i P_i^N , \qquad (1)$$

where Q_i is the seepage, P_i is the pressure, and C_i is the coefficient of N pressure nodes (between 0.5–2.5). Germanopoulos' model for considering the relationship between pressure and leakage in the network assumes that a leak in the pipe length

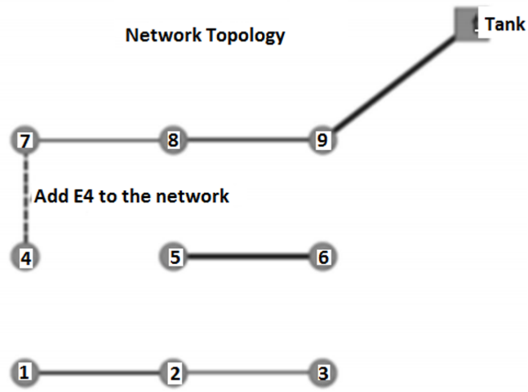

Fig. 2. Design procedure in Epanet

is unevenly distributed and the amount of leakage of each tube can be expressed as

$$Q_{\mathrm{L}i,j} = CL_{ij}(P_{ij}^{\mathrm{av}})^{1.18}\,, \tag{2}$$

$$Q_{\mathrm{L,MNF}} = C_{\mathrm{u}}\left[\sum_{i=1}^{\mathrm{NJ}} Nc_i P_i^N\right]. \tag{3}$$

Here, $Q_{\mathrm{L}i,j}$ is leaving water leaks from any pipe, C is a coefficient that depends on the characteristics of networks and direct relationship with sex and age of the pipe, L_{ij} is the length of the pipe, P_{ij}^{av} denotes the average pressure in the pipe. Using the property geysers in EPANET hydraulic analysis software provided as equation (3), $Q_{\mathrm{L,MNF}}$ denotes the leakage current at the time of overnight, C_{u} is the leak rate of 1 m, Nc_i represents the number of branches in each node under pressure into nodes i and N is pressure. In this method, C_{u} is determined by trial and error.

3. The proposed method

Network management is certainly one of the most important concerns of leaks in water distribution networks. There are many methods have been proposed to manage the spill control. One of the best and most cost-effective procedures is management of pressure on the network. The obtained results are shown and compared with previous results in the proposed network topological design WDNs repair techniques for the efficient and effective tool. Identifying and controlling the leaks in irrigation and water distribution systems is of utmost importance. This paper proposes a new way to optimize the design of water distribution network (WDN). Techniques to repair the network name (NRT) is proposed to overcome difficulties in operating networks pipelines design. The obtained results were shown and compared. It has been shown that the proposed network and effective repair method is an efficient tool for topological design of the WDNs. A multi-objective design problem used in this work can be written as follows for hydraulic problem:

$$\min\{f_1, f_2\} \tag{4}$$

$$f_i(\boldsymbol{H}, \boldsymbol{D}) = 0; \quad i = 1, \dots, nn\,,$$

$$H_i \geq H_i^{\min}; \quad i = 1, \dots, nn\,. \tag{5}$$

Hydro restrictions $f_i(\boldsymbol{H}, \boldsymbol{D})$ can use the software EPANET functions as a calculation target:

$$f_1 = \sum_{i=1}^{np} \mathrm{Cost}(D_i, L_i)\,,$$

$$f_2 = \sum_{i=1}^{np} L_i h_i(D_i)\,. \tag{6}$$

In order to run the simulation, the structure of network is designed as shown in Figs. 3 and 4. The simulation is ran for i iteration until the optimal structure of network is achieved. The rate of convergence is suitable as a testing criterion for design problems with the smaller number of design variables. While when using indexes such as the flexibility and reliability as the objective functions, the convergence must be checked.

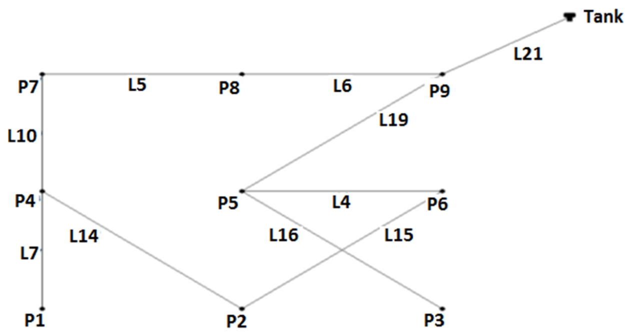

Fig. 3. Virtual network topology X_1

Figures 5 and 6 show the solution network designs which are obtained by a number of solutions. In addition, it can be observed from the above structures of network topology and branches that lower costs can be achieved. The rate of convergence for design problems is high for a smaller number of design variables.

4. Results

In the simulation below the standard for a network, topology of the network is considered to be in the MATLAB simulation and an investigation followed to ensure the accuracy of water distribution network to be examined. According to the

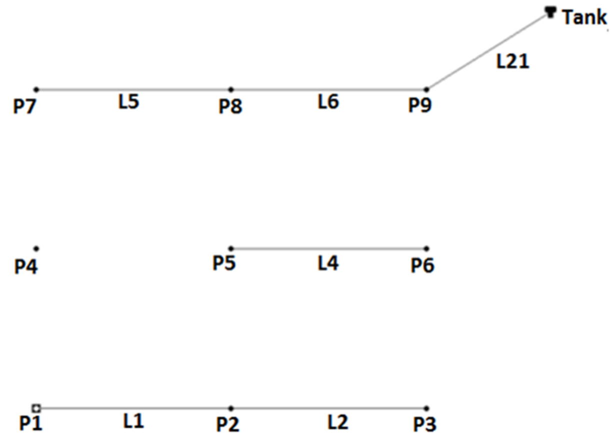

Fig. 4. Unauthorized network topology X_2

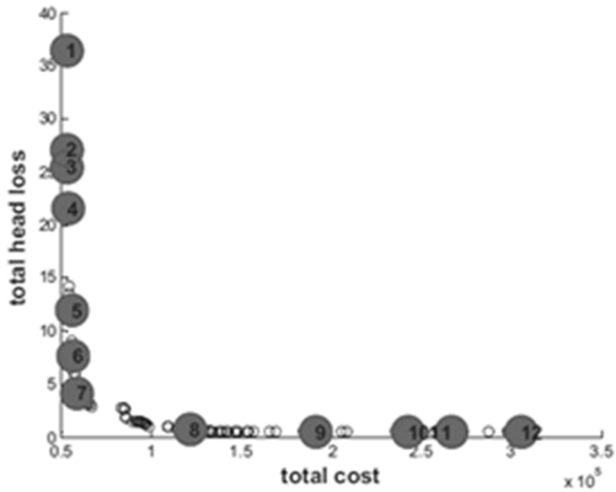

Fig. 5. Design procedure in Epanet

designed solution in the following figure, the network must be used and repaired. Water distribution network that is the repair process includes two main modes: the first phase of nodes that are not connected or separate nodes and the second stage of pipe non-connected groups. Using MATLAB algorithms in the software EPANET also some examples of network models and the two aims to minimize the economic costs and damages on the water distribution network is considered less likely to be the case. According to Net Applications arrangement for X to X is defined as

$$X_1 = \{1, 1, 1, 4, 2, 1, 1, 1, 1, 1, 1, 1, 2, 4, 2, 1, 1, 4, 1\}.$$

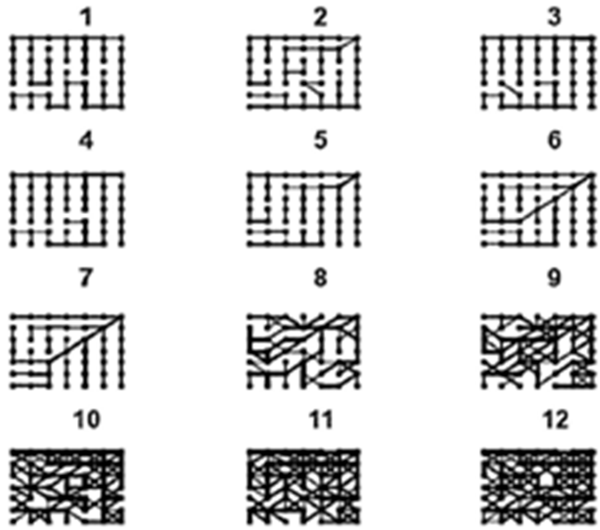

Fig. 6. Network of selected plot points

Tube elements are integer numbers in the group above. Also according to the thickness specified number of ground network now have been removed, because the rest of the elements are tubes with various thicknesses of expression

With this procedure, location of network can be reached. The problem occurs when the thicknesses are going to be zero such as

$$X_2 = \{1, 2, 1, 4, 2, 1, 1, 1, 1, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1\}.$$

The structure of pipe and nodes are independent for first design and a connection that does not have any link with each other. Such a network is said to be inactive since the EPANET network analysis can be performed. This is an unsuitable solution should be repaired to be applicable. Initially, the grid is created from predefined connections. The closest neighbor of each connection must be specified. The network connection shows 9 nodes from the previous section, and the elements of the neighboring ith pipe, the connections to the neighboring pipe elements are tolerated.

Tubes must be tied in such a way that all binding elements, have different neighbors, since separate nodes have been removed, the neighbor element 11 (elements) with mm 11 thickness added to the network, and a new entrance design solution changes to:

$$X_3 = \{3, 2, 1, 4, 2, 3, 111, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1\}.$$

The second repair is to connect all unconnected tubes to a group. According to the form at the beginning, the algorithm of the total group of tubes has been obtained. The first tube group is a group consisting of elements that are connected to the tank as shown in Fig. 1 (group 1). The group 2 is the closest group to the first group which was then removed and interconnected by adding tubular elements that are connected to the nearest nodes of the first group. By adding 1 element with a thickness of 11 mm to the grid, a new design is made as follows:

$$X_4 = \{3, 2, 2, 4, 2, 3, 111, 2, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1\}.$$

The solutions X_2, X_3, X_4 produce the same amount of application. In the process of optimization, connections, grid, and neighboring elements are prepared in the beginning. It is also suitable for making matrixes that are used to remove unconnected tubes.

Figure 5 shows the pressure distribution at the beginning. The horizontal axis and the vertical axis are the pressure and pressure loss in the water supply network. As indicated in Fig. 5, at low pressures to reduce energy, the pressure loss is approximately 6000 Pa but the high pressure in the water distribution in network causes that energy loss in transmission and distribution networks is increasing at high pressures. Figure 6 shows the pressure distribution versus the pressure loss after 12 hours.

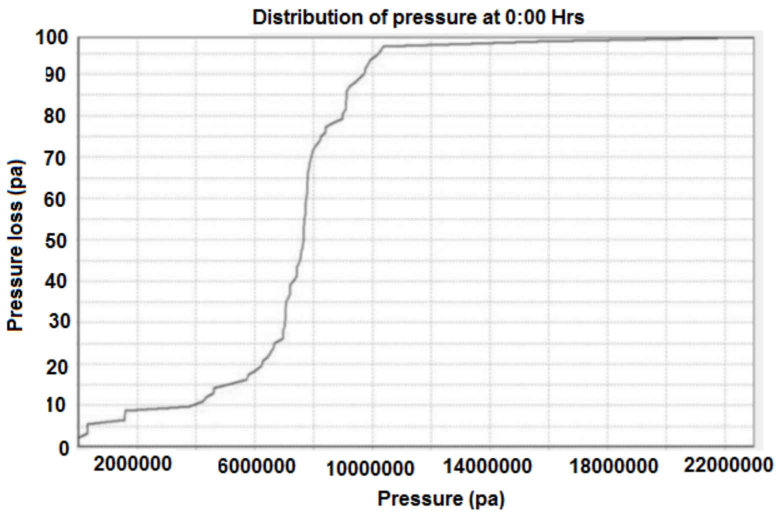

Fig. 7. Pressure distribution in Zero Hour

5. Conclusion

Detecting leaking pipes in water distribution networks in the network plays a significant role in managing the spill. In this study, a new model for calculating the components leaking water distribution networks is provided. By combining software and hydraulic analysis models to simulate and estimate of hydraulic parameters, leakages at each node calculated and the tube modeled and calibrated. The study also shows that the use of performance indicators by Epanet play a major role in managing the spill and setting priorities to prevent water loss and its components

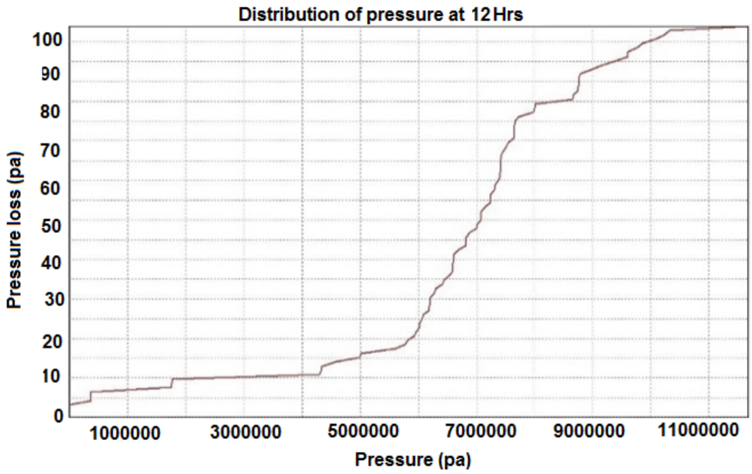

Fig. 8. Pressure distribution in twelve hours

and leads to save the costs in networks. On the other hand, simulation results demonstrated that controlling the pressure in network pipelines is the appropriate method reduce leakage in various times.

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