Optimization of Water Distribution Network - A Review

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Abstract

With increasing population growth, decaying infrastructure in municipalities and industrial development, water flow rates and other hydraulic requirements associated with water distribution network have been estimated to increase both in national and in local scale. Water shortage will cause inconvenience to people's life and it will impact city function and industrial production. Hence to overcome this problem design and analysis of Water distribution network is necessary to get optimal discharge. A formulated model is developed which is based on the mathematical method. In this model not only cost criteria of network but also energy consumption is to be considered. This paper also includes reviews of various papers which describes the optimization of Water distribution network.

Keywords: Optimisation, Non-linear programming method, water distribution network design

I. INTRODUCTION

In India demand for water is continuously increasing due to population growth, industrial development, and improvements of econonomic conditions. Water distribution systems generally consist of a number of sources of supply from which water is pumped to storage reservoirs to meet demands at consumer nodes through interconnected pipeline networks. In many water distribution systems, due to large amounts of energy are required to pump, transport and apply water, improved management of pumps leading to a reduction in energy usage and operational cost . If we lack the rainfall for extended period of time ,we will face problem of water shortage. On one hand it needs to produce safe drinkable water. On the other hand, it needs to provide excellent service to user. If you have a water shortage, it will cause inconvenience to people's life and it will impact city function and industrial production. Design and analysis of pipe networks are important, not only because water is an important economic development parameter, but also because water is a deciding factor in the future of peace between states or between countries.

II. TYPES OF WATER DISTRIBUTION NETWORK

Water distribution network are classified according to their layout. They are described as,

1) Serial Networks: A serial network has no branches and loops. It is the simplest of all types of water distribution networks. Generally it has one source node, one sink and one or more intermediate nodes.
2) Branched Network: A branched network is a tree network and has no loops. It consists of several serial networks; usually it has one source node and has more than one sink.

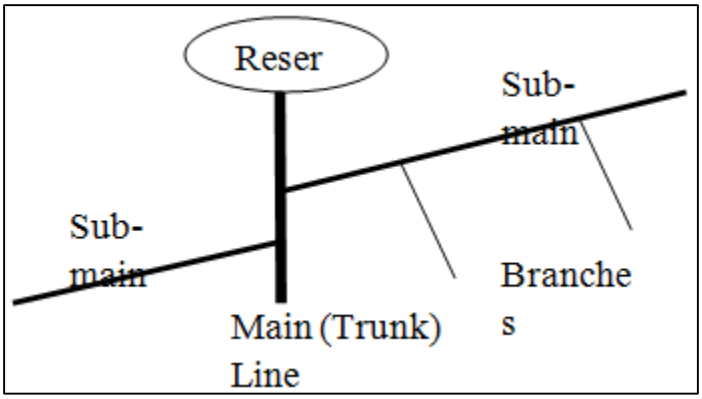

Fig. 1.1: Branch water distribution network

3) Looped Network: A looped network contains loops .It has one source node in a single source network, but has several source nodes in a multiple source network.

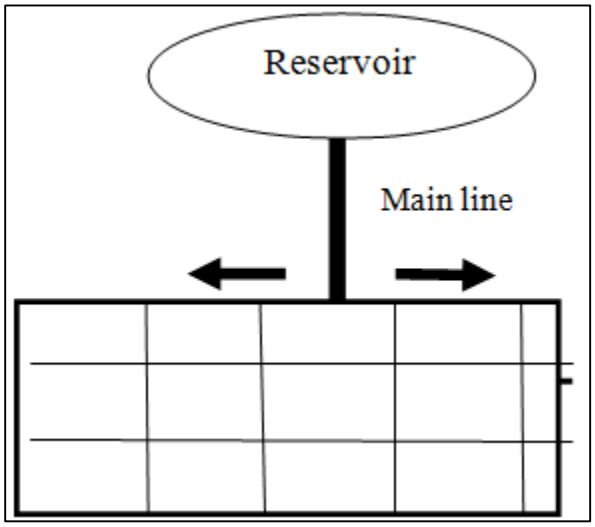

Fig. 1.2: Grid water distribution network

III. ITERATIVE PROCEDURE FOR NETWORK ANALYSIS

All formulated equation is non-linear and there is no direct method to solve the equation. Therefore, iterative procedure is used to carry out the solution. Four methods are commonly used in practice for the iterative solution of these equation .The methods are

1) Hardy Cross method: Hardy Cross was the first to suggest in 1936 a systematic iterative procedure for network analysis.It is based on the loop flow correction equation known as method of balancing head and nodal head correction equation known as method of balancing flow.

Merits:

- It is simple method and easy to apply.
- It is suitable for hand calculation.

Demerits:

- The number of iteration increases as the size of network increases.

2) Newton Raphson method: Martin and Peters were first to analysis water distribution network. It is a method which linearises the non-linear equation through Tayior series and partial differentiation.

Merits:

- Number of iteration required is less than Hardy Cross method.

Demerits:

- It takes more time for iteration than Hardy Cross method.
- It needs update for each iteration.

3) Linear Theory method: It is a method used to analysis water distribution network. It is a method which linearises the non-linear equation by merging a part of a non- linear term into pipe resistance constant.

Merits:

- It does not need balancing of node –flow continuity equation at each node.

Demerits:

- It consumes more time.
- The absolute value of correction obtained is larger than Newton Raphson Method.

4) Gradient method: It is a method used to analysis water distribution network. The pipe discharge and nodal heads are taken as the basic unknowns in formulating Q-H equations.

Merits:

- It does not need balancing of node –flow continuity equation at each node.

Demerits:

- It can be used to solve either the Q- equation or Q-H equation.

IV. USE OF COMPUTER MODEL

Widespread introduction of personal computers has enhanced hydraulic design of distribution networks. Commercial programmed available on the market, sometimes even free of charge, enable very precise and quick calculations, which make them equally suitable for the design of simple rural systems or large urban networks of a few thousand pipes. Accessibility of such software and PCs to the engineers of developing countries has been significantly improved since the mid-nineties. The

various models in terms of software are used in designing and analyze of the Water distribution network such as Ephanet , Water Gems ,Loop software, Branch software etc.

V. USE OF CONVENTIONAL TECHNIQUE

In the design and analysis of water distribution systems, the conventional procedure uses a trial-and-error approach. The performance depends upon the user's intuition, experience, skill, and knowledge. However, this approach is inefficient particularly in the design and analysis of large complex system. For example, to determine the least-cost water distribution network would require a selection of pipe sizes available in the market. Thus, a large number of repetitive simulations is required to arrive at a satisfactory network. Several optimization techniques, instead of the trial-and-error approach, have been used in the design of new as well as expansion of existing water distribution networks. The formulated model provides the optimized diameter which leads to least-cost water distribution network satisfying all hydraulic constraints. These traditional optimization techniques are:

1) Linear Programming: Alperovits and Shamir (1977) first presented a linear programming gradient (LPG) method in the optimal design of water distribution network. To apply LPG, they linearized the mathematical formulation. Segmental lengths of the pipe with different diameters were used as decision making variables. The objective function was to minimize the cost of the total pipe lengths.

Merits:

- It is favourable to use continuous length of pipe.

Demerit:

- Pipe arrangement causes bottleneck in the system when the flow direction changes.
- It is not desirable to have pipes that constantly change size along the network.

2) Non- Linear Programming method: A non-linear programming technique (NLP) was developed by Chiplunkar et al. (1986). Su et al. (1987); Lansey and Mays (1989); and Duan et al. (1990) applied NLP for the design optimization of water distribution systems.

Merits:

1) Compared to LP, NLP model can deal with multiple demand pattern and much higher number of design variables.

Demerits:

2) A looped network often becomes a tree network with several zero value in some pipe diameters.
3) Heuristic Optimization Techniques:

Gessler (1985) and Loubser and Gessler (1993) applied enumeration approach to the design and to the rehabilitation of water distribution network. In the enumeration technique, the modeler assigns search space by specifying a range of commercial diameters for each pipe in the network.

Merits:

3) The algorithms select the combination of pipes with the least cost.

Demerits:

4) The most important drawback is that extensive computational time is required to find even a suboptimal solution.

VI. SUMMARY OF SOME SELECTED PAPERS

The literature review is done, which exposed relevant research work carried out (till today) on various aspects of studies related to design and analysis of water distribution networks.

1) Ioan Sabro. Have carried out optimization of water distribution network supplied from one or more node sources, according to demand variation. In this study an improved linear model is developed, which has the advantage of using not only cost criteria, but also energy consumption, consumption of scarce resources, operating expenses etc. This shows the good performance of the new model. For different analyzed networks, saving of electrical energy, due to diminishing pressure losses and operation costs when applying the developed model, represents about 10-35%.
2) C. Bragalli et al. have considered the case of Modena, a city northwest of Bologna in the Emilia-Romagna region of Italy .The aim is to replace all the pipes using the same network topology at minimum cost to achieve pressure demands at junctions of the network. Mixed Integer Nonlinear Programming (MINLP) has been applied to optimize the diameter which ultimately leads to least cost design of network. The result shows that the programming method save the cost by 4.5 to 6% of the existing network.
3) Vinayak. V. Sadafule et al. have developed a model which is based on the method of linear programming. In this model not only cost criteria of network but also energy consumption is to be considered. Computer program is developed in visual basic for looped water distribution network using Hardy-cross method to minimize the time required for analysis and to make tedious work to easier. Result shows that software results were more accurate, time saving than manual results.
4) Maulik Joshi et al. have designed Water Distribution Network which was located at district Porbandar , State Gujarat, India. For the Level survey ,map was created and also elevation and length of pipe line required for the village was calculated.The node no. and pipe no. was denoted on map of villages .In this paper design was done by loop software and compared with manually result. It was found that software result were more accurate, save time and manpower than manual result.

VII. CONCLUSION

It has been concluded that software results are more accurate, save time and manpower than manual result. The conventional techniques were successful in providing the optimized diameter of water network resulting in minimum cost of network design satisfying all hydraulic constraints.

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