RELIABILITY-BASED OPTIMAL DESIGN OF WATER DISTRIBUTION NETWORKS USING GENETIC ALGORITHM

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EXTENDED ABSTRACT

A water distribution network (WDN) is expected to supply desired quality of water in required quantities with sufficient pressure at desired locations throughout its design period. How well a network can satisfy this objective is indicated through its reliability. Reliability is better incorporated in design of WDNs using quantitative criterion. Several measures of reliability—*probability of pipe breakage*, *maximum node isolation probability*, *probability of no-node failure*, *system and nodal reliabilities* using minimum cut set, *hydraulic availability*, *the ratio of expected maximum flow to total system demand*, *total volume deficit*, *flow entropy*, *allowable shortage fraction*, *node, volume, and network reliability factors* using served demands, *capacity reliability*, *network resilience*)—have been suggested in the last two decades and approaches for their evaluation have been proposed (Bhave 2003).

Some of the reliability measures do not take into account network performance under failure conditions and therefore they are easy to calculate and incorporate in optimization model. On the other hand, reliability measures that take into account the network performance under failure conditions are better but their direct incorporation in the optimization model is difficult. Mostly reliability-based optimization models therefore involve two steps in which in the first step reliability is calculated for an initially selected or a designed network; and in the second step network is modified so as to improve its reliability. This two-step iterative method is terminated when the desired level of reliability is reached. Genetic Algorithm (GA) can handle such models more easily. Herein, and a method for reliability-based optimal design of WDNs using Genetic Algorithm is proposed.

The optimization model consists of minimization of cost function given by

$$\text{Min } C_T = \sum_{x=1}^{X} c_x L_x \qquad (1)$$

in which C_T = total cost of the network; c = unit cost of pipe x; L = length of pipe; x = subscript denoting link; and X = total number of links.

The constraints are usual node flow continuity constraints, loop head loss constraints, path head loss constraints and reliability constraints. Reliability is estimated through three parameters: (1) Node reliability parameters; (2) Volume reliability parameter; and (3)

Network reliability parameter (Gupta and Bhave 1994). Performance of the network under different conditions is obtained using node flow analysis (Gupta and Bhave 1996).

GA is used as an optimization tool to solve above optimization model. Different Steps involved in this are as follows:

(1). Generation of initial population; (2). Hydraulic analysis of each network; (3). Reliability analysis of each network; (4). Computation of network cost; (5). Computation of penalty cost; (6). Computation of total network cost; (7). Computation of the fitness; (8). Generation of a new population using the selection operator; (9). Partial exchange using crossover operator; (10). Mutation using mutation operator; and (11). Production of successive generations

Two networks taken from the literature are designed using proposed methodology for different levels of reliability. The relationship between the network reliability and the network cost, from the best solution for a specified reliability, is plotted as shown in the Fig. 1 for one of the network. It can be observed that as the network reliability increases the network cost also increases. Appropriate design considering available funds and meeting the reliability requirements can be adopted.

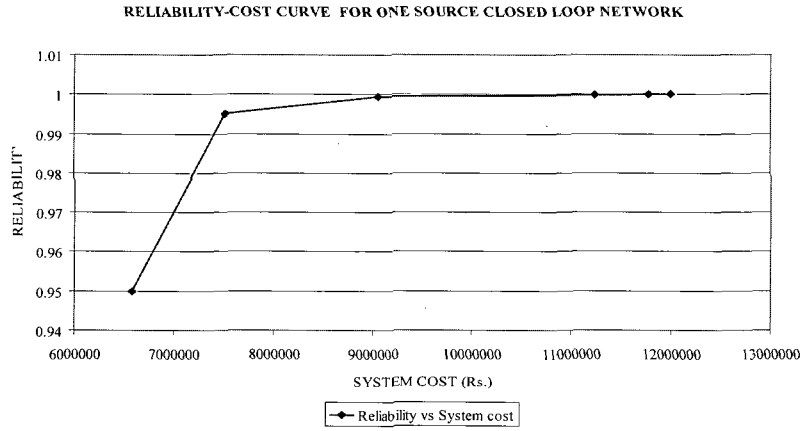

Fig.1 Reliability cost curve for one source network

Genetic algorithm is used as an optimization tool that provides minimum cost network design satisfying the reliability constraints along with other constraints.

Keywords: Design, Genetic Algorithm, Optimization, Pipe Network, Reliability, Reliability-based Design, Water Distribution Network

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