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Forming district metered areas in a water distribution network using genetic algorithms

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Abstract

Dividing a water distribution network into District Metered Areas (DMAs) is the first vital step towards water loss management. It is a multivariate problem. Techniques based on Genetic Algorithms is a proven way to provide a very good solution to optimization problems. Basic requirement is that each problem must be well described by an objective function. The formation of the objective function is tested through Matlab's optimization tools. The results of the genetic algorithm are compared to the results of an algorithm (in C++ Language) developed in an earlier stage to provide optimal system pressure reduction by closing indicated pipes. The process for the formation of the objective function and a case study on a real network are presented.

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Keywords: genetic algorithms; DMAs; water loss

1. Introduction

In these last decades, one of the main concerns of the water system utilities' managers, has been the minimization of water losses that frequently reach values of 30% or even 40% of the System Input Volume (SIV). Nowadays, the problem of water losses in Water Distribution Systems (WDSs) and their reduction, is considered more and more

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important. This is due to the current trend to privilege the sustainability of consumptions and environmental protection. It is a subject of considerable media and politics visibility, mainly when occur periods of scarcity of water resources, or when the water supplying is not sufficient in areas with fast growth [1]. In Greece there are water utilities that lose more than 50% of the SIV of the network. As a result of the above, most of these water utilities started implementing pressure management policies in order to reduce bursts and leaks. Furthermore, Pressure Management (PM) has more upsides than mentioned before, such as demand control and asset management [2]. To implement and have an efficient PM, water distribution networks have to be divided into District Metered Areas (DMAs). DMAs are smaller segments of the network and their formation aims at a more accurate management and a better inspection of the network. For the optimal division of a network into DMAs, many parameters need to be taken into consideration, as well as more scenarios to be tested. Borders positioning of the DMAs has greater significance when other PM implementations are considered, such as PRVs installation on a later stage. The introduction of the concept of DMAs in water distribution networks (WDNs) dates back to the 1980s, when it was first proposed in the UK, with the aim of reducing leakage [3]. Many successful examples of DMAs implementation have taken place around the world in different WDSs [4,5,6,7], but is not an easy task to perform. DMAs implementation can be very challenging, especially in large networks where numerous variables exist. Topology of the network, demand allocation and pressure constraints along with, the required sensitivity to the service indicators of the network, are the main pillars of the problem's complexity. In the current study, two software tools have been used: a) Epanet to control and inspect the case study network's hydraulic model; and b) Matlab to develop the optimization algorithm and use one of its optimization tools. The inter-connection of Matlab and Epanet softwares unfolds numerous possibilities and help take the study of WDNs to whole other level, providing fast and well-aimed solutions to optimization problems [8].

2. Forming of the objective function

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems, which are based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. As described in the online Mathworks library, at each step, the genetic algorithm selects individuals at random, from the current population, to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" towards an optimal solution. The genetic algorithm can be used, to solve a variety of optimization problems, which are not well suited for standard optimization algorithms.

The use of Genetic Algorithms in optimization processes has one great requirement. An objective function (1) has to be formed, in a way that describes better the mathematical side of the problem. The objective function was developed so that it could take consideration of the pressure of a node, along with the allocated demand. The objective function follows:

$$MIN = \sum_{i=1}^{N} \left(\frac{D_{i,t}}{\Sigma D} * \left(\frac{P_{i,t} - P_{min}}{P_{min}} \right) \right) \Big|_{t=1}^{T} \tag{1}$$

where, i is a custom node of the network, $D_{i,t}$ is demand of node i for each time step t [lt/sec], $P_{i,t}$ is pressure of node i for each time step t [KPa], P_{min} is the minimum defined operating pressure [kPa]. Ratio $\frac{D_{I,t}}{\Sigma D}$ represents the weight of the demand of each node, multiplied by the pressure variation of each node.

3. The case study WDS

The case study network chosen, consists of one reservoir providing water to the whole network, two boosters providing the required hydraulic pressure, as well as a tank to store water and supply it back to the network, as depicted in Figure 1. The number of pipes of the studied network reaches one hundred. Size and complexity of this WDN is not of great figures, however is enough to demonstrate a real WDN of a small town, or a part of it. It has to be specified that the network is originated from Bentley's lessons library and is a verified and calibrated example of a real network.

The objective of the study is to divide the network into a proper number of DMAs, so that a maximum control of pressure is achieved. It is proven that most of the times DMAs implementation does not only offer better control of a