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Developing an optimization algorithm to form district metered areas in a water distribution system

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Abstract

Exploiting the numerous possibilities that unfold from the inter-connection of Matlab and Epanet software, an algorithm is produced in C++ language. The algorithm reads all the significant data of the water distribution network from Epanet. Matlab calculates the optimized isolation valves allocation in terms of water losses reduction, considering vital limitations for the well-functioning of the network. The algorithm can be implemented in all water distribution networks. The outcome is a hierarchical list of closed pipes, causing the higher reduction in network's operating pressure. The closing of the pipes (or the installation of isolation valves) determines the optimal segmentation of the network in District Metered Areas. The process for the formation of the algorithm and a case study on a network' hydraulic model are presented.

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Keywords: optimization; DMAs; water loss

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1. Introduction

District Metered Areas (DMAs) implementation is widely recognized as one of the most successful and cost – effective methods for Water Distribution Networks (WDNs) optimization [1]. It is also the prerequisite for other water loss reduction techniques used and implemented by several water utilities around the globe. Sectorization of a network provides many significant benefits [2,3] such as increased system control and contributes to the mitigation of water losses. Implementation of DMAs can be carried out under several perspectives with different goals each time. Moreover, in real cases the achievement of the optimal design of DMAs may be very challenging because of the intrinsic complexity of the WDNs, as is presented in many examples of DMAs formation up to date [4,5,7]. Therefore, development of a methodology able to provide support to decision-making is required. In recent years, an increasing number of researches have addressed this problem, and different optimization approaches can be found in literature [8,9]. Some of the techniques developed so far suffer from limitations and drawbacks, which mainly are based on the limited number of design criteria and the dependence on the size of the network [6]. With the inter-connection of Matlab and Epanet [10], there is the possibility to produce an algorithm that collects data from the network and provides results as well as, algorithms that run tests on the network. Combination of these two software tools, forms an expert tool that can be used for the optimization of a network's segmentation in DMAs. Two algorithms in C++ language are produced in order to achieve two separate but relevant objectives. The first algorithm aims to collect data from the network, in order to be simulated by EPANET, and perform certain calculations. The second algorithm uses a preprogrammed tool named combinator, to produce all the different possible combinations of closed pipes. Afterwards, each combination is tested on the WDN's hydraulic model. Finally, data from each tested combination is collected and evaluated. Evaluation of data, determines whether a combination is an optimal solution or not. The algorithms take into account several rules that govern DMA's formation. In more detail, nodal pressure variation, fire flow requirements, water mains, population density, network's topology and minimum pressure requirements determine DMAs' borders. Optimization of the water distribution system's (WDS) segmentation into DMAs aims to reduce global nodal pressure as much as possible. A number of pipes are selected to close by installing isolation valves. Implementation of DMAs is tested on a case study network.

2. First algorithm (data collection)

An optimization process has to have a universal character and be able to be used on several WDNs. A short separate algorithm is written, in order to identify the studied network. This algorithm is written in C++ programming language and its purpose is to connect Matlab with EPANET as well as collect certain data from the network. Matlab is used for programming algorithms. On the other hand, Epanet performs hydraulic simulation of the studied WDS. Hourly nodal demand and pressure values are collected and equation (1) is calculated. As a result of Epanet's inability to perform pressure driven analysis, demand is volume dependent. This algorithm aims only to identify the network and does not perform any optimization process.

$$\mathbf{PD} = \sum_{\mathbf{i=1}}^{\mathbf{n}} (\mathbf{P_i} {}^{\mathbf{x}} \mathbf{D_i}) \quad (1)$$

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].

3. Second algorithm (test of combinations, optimal selection of closed pipes)

Optimization of implementing DMAs is based on the philosophy of exploiting every possible combination of closed pipes, in order to select which ones provide better pressure management. A second algorithm is written, for the purpose mentioned above, in C++ programming language. This algorithm uses a preprogrammed tool (named combinator) to produce every possible combination of closed pipes. After counting all WDS's pipes, the program closes one pipe and tests its pressure management effects. Each pipe is tested alone and the one that reduces mostly the "P*D" product is chosen as closed permanently. Then keeping the previous pipe closed, the algorithm tries out all the remaining pipes and closes the one that reduces the "P*D" product the most again. This hierarchical procedure is continued until the

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