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Energy optimization of supplied flows from multiple pumping stations in water distributions networks

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Abstract

One of the most important concerns within the field of urban hydraulic engineers is the right management of water resources. When there is more than one water source, there is a question that must be answered: How much water should be provided by each water source according to the demand curve of the network? This work proposes a methodology that solves this question. It involves an energy analysis of the water network based on the concept of the setpoint curve. The setpoint curve gives, for every supplied flow, the minimum head needed to satisfy pressure requirements in the network. In this sense, the setpoint curve of every source relates two variables: supplied flow and minimum required head. Energy consumption in every source is evaluated by means of the product of these two variables. Then flow distribution among sources is optimized and minimum heads are obtained from the setpoint curve. The optimization process has been validated in two different ways. On one hand, a discrete method has been used, where a predefined combination of flow distributions are evaluated. On the other hand, the solution is found by means of Hooke-Jeeves and Nelder-Mead optimization algorithms. To apply these methods EPANET and its Toolkit has been applied to the mathematical model of the network. The optimization process can be applied to networks models with and without leakages. Finally, the methodology is applied to two cases, one academic network and real network where maximum flow limitations of every sources were also taken into account.

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Keywords: Energy; pumping; setpoint curve; optimization; pressure management

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1. Introduction

Pressure water distribution networks (urban, industrial, irrigation) always require new water sources supply as result of the demand increase, population growing, network extension, leakage rise, new service conditions and others. Water deliver requires energy to satisfy the network demands. In the case of distribution water networks are supplied by pumping, new sources represents an increase in energy consumption. In that context, any work related with water resource supply need to develop a feasibility study about the flow supplied by the source. At the same time an adjustment of nodal pressures to accomplish with the minimal pressure required can be developed. Moreover the nodal pressure adjustment can lead to an energetic optimization while network demands are accomplishing. To carry out the analysis it is necessary to answer the following questions: which are the optimal flow rates and head pressures to be supplied by each water source?, are the flow rates supplied effective to satisfy the network demand and keeping the minimum pressures?, how interact the different water sources and how important are they regard to the energetic consumption, what energetic implications represents a new water source?, how to get a lower energetic consumption?, and other similar questions.

Many works have been conducted to evaluate different strategies to get an optimal energetic consumption. For instance in arrangements of fixed speed pumps (FSP) one approach is the optimization of turns on and turns off of pumps by diminishing pumping cycles [1]. After this, variable speed pumps (VSP) were incorporated. These ones allow a better adjust between the pumping system curve and the resistant curve (system curve). That means that a reduction in the excess of energy consumption can be achieve to accomplish with the network minimal pressure requirements. VSP implementation can be complemented by fixing function restrictions to arise a pumping working at the maximum efficiency zones. [2]–[4]. When the system involves both FSP and VSP the energetic, optimization lies in a properly pumping selection as well as a suitable combination of them to aim a better adjustment with the system curve. Other works with multi-objective functions, search in addition cost optimization, therefore variables as network storage capacity and electric tariffs are included. In this way programming pumping groups to work at less energetic cost hours it is possible. This strategy is complemented with the control of the fill and empty levels of storage tanks [5]–[7]. On the other hand energetic consumption can be reduce with an appropriate pressure and leakage management. It can lead to a reduction on water demand as well as the need of energy. In irrigation systems a common strategy is grouping nodes that requires a high energy in hydrometric sectors. That allows to manage them efficiently [8]. Detection and manage of critical points on networks is also a measure adopted when exist the need of a reduction of the energetic consumption [9]. In irrigation systems the last two strategies can be combined with energetic tariffs and considers also more the one source of supply [10]. The aim is the cost reduction.

So far, many of the studies do not develop an explicit analyze of the interaction among the different water sources on a distribution network. Furthermore many of them only considers one water source supply. Besides and as was mention previously regulation of pumps is made taking as reference the system curve. Nevertheless in this work the use of the setpoint curve (SC) concept is proposed. The SC set point the pressure head and flow rate provided by each water source to accomplish with the minimal pressure required at the critical node or most representative node of the network [11], [12].

The present research propose a methodology where optimal flow rates and high pressures to keep the minimal pressure requirements can be founded by mean of the setpoint curve. Therefore optimal energetic consumption can be reached. This methodology can be addressed by two approaches. First one called the discrete method, refers to find the best solution after evaluate a set of possibilities previously defined. Second one or continuous method is based on the application of optimization algorithms. In this case Hooke and Jeeves [13] and Nelder Mead [14] were applied. The methodology has two levels: the first level corresponds to the optimization problem, and second level to the hydraulic model. Both are solved through EPANET software [15] and its TOOLKIT. Two study cases are studied. First one is an academic network "CT1" where consumptions are not pressure dependent. In the second one a real network is analyzed: the COPLACA network.