Multiobjective Water Pinch Analysis of the Cuernavaca City Water Distribution Network

Carlos E. Mariano-Romero[1], Víctor Alcocer-Yamanaka[1], and Eduardo F. Morales[2]

[1] Mexican Instite of Water Technology, Paseo Cuauhnáhuac 8532, Jiutepec, Mor, 62550, Mexico
cmariano@tlaloc.imta.mx
http://www.imta.mx/
[2] ITESM Campus Cuernavaca, Paseo de la Reforma 182-A, Temixco, Mor, 62589, Mexico

Abstract. Water systems often allow efficient water uses via water reuse and/or recirculation. Defining the network layout connecting water-using processes is a complex problem which involves several criteria to optimize, frequently accomplished using Water Pinch technology, optimizing freshwater flowrates entering the system. In this paper, a multiobjective optimization model considering two criteria is presented: (i)the minimization of freshwater consumption, and (ii) the minimization of the cost of the infrastructure required to build the network that make possible the reduction of freshwater consumption. The optimization model considers water reuse between operations and wastewater treatment as the main optimization mechanism. The operation of the Cuernavaca city water distribution system was analyzed under two different operation strategies considering: leak reduction, operation of wastewater treatment plants as they currently operate, operation of wastewater treatment plants at design capacity, and construction of new infrastructure to treat 100 % of discharged wastewater. Results were obtained with *MDQL* a multiobjective optimization algorithm based on a distributed reinforcement learning framework, and they were validated with mathematical programming.

1 Introduction

Water pinch technology (WPT) evolved out of the broader concept of process integration of materials and energy and the minimization of emissions and wastes in chemical processes. WPT can be seen as a type of mass-exchange integration involving water-using operations, which enables practicing engineers to answer important questions when retrofitting existing facilities and designing new water-using networks. There are three basic tasks in WP: a)Identification of the minimum freshwater consumption and wastewater generation in water-using operations (analysis), b)Water-using network design that achieves the identified flow rate targets for freshwater and wastewater through water reuse, regeneration, and recycle (synthesis), and c)Modify an existing water-using network

C. A. Coello Coello et al. (Eds.): EMO 2005, LNCS 3410, pp. 870–884, 2005.

to maximize water reuse and minimize wastewater generation through effective process changes (retrofit).

Nowadays most WPT problems are formulated as non linear highly restricted programming problems [2]; [13]; [14]. Important efforts have been made in order to make mathematical models more robust and applicable to real situations [1]; [7]; [9].

In general, WPT minimizes freshwater flow rate entering the system, using the mass balance and the contaminants concentrations at the inlet and outlet in all water-using operations as restrictions. Because of the diverse types of water-using operations, treatment effectiveness and cost, and types of contaminants, the criteria for efficient use of water is inherently non linear, multiple and conflicting [1]; [9]; [13]. Some of the criteria that easily arise are: equipment cost minimization, maximization of reliability (amount of contaminant captured in treatment plants), and minimization of wastewater production.

This paper presents a methodology that exploits specific features of the water and wastewater minimization problem. The formulation extends the domain of WPT analysis with elements of capital cost of the required pipe work. Consequently, the optimization is made based on cost efficient networks and networks featuring freshwater consumption. The methodology involves two criteria: the minimization of freshwater consumption and the infrastructure costs. Two techniques are used to solve the multiobjective optimization problem stated for the design of water-using systems: 1) weighted aggregation considering variation in the weight coefficients in order to construct the Pareto set [19], and 2) *MDQL*, which is a heuristic approach based on the exploitation of the knowledge generated during the search process.

The proposed multiobjective optimization model was applied for the case of the water distribution network in the city of Cuernavaca. An operation analysis considering two different strategies was performed: 1) reduction of leaks in the network and operation of wastewater treatment plants as they currently operate, and 2) reduction of leaks in the network, operation of wastewater treatment plants at their design capacity, and construction of new treatment infrastructure to reach 100 % wastewater treatment.

Section two presents the mathematical formulation for the bi-objective optimization problem and its description. In section three the function aggregation method and the MDQL heuristic approach are described. Section four describes the application case. Section five contains a discussion on the obtained results, general conclusions and future research directions.

2 Mathematical Formulation

The mathematical model describing a water demanding process considers two main components: a) freshwater sources available to satisfy demands, and b) water-using operations described by loads of contaminants and concentration levels. A case with two sources and two operations is sketched in Figure 1. The design task is to find the network configuration that minimizes the overall de-