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Real-time pump scheduling optimization in water distribution systems

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Abstract

A Water Distribution System (WDS) is required to convey fresh water from the main water sources to consumption nodes. Depending on the topography of an area, water typically needs to be pumped to elevated parts of the network or service reservoirs to ensure that sufficient pressures are maintained in the WDS. Pumping stations contribute most to the overall energy consumption of a water utility as well as to its greenhouse gas footprint. Pumping stations consist of a number of pumps that run together or individually during different times of the day. This study presents an optimal pump scheduling strategy based on the two local search strategies to minimize pumping costs in a WDS. In the first stage of the model, a linear formulation of the pump scheduling problem is defined in the Microsoft Excel spreadsheet. An initial pump combination was found using Microsoft Excel Solver (ME-Solver) which is an optimization add- on to Microsoft Excel. Compliance of the solution obtained by the ME-Solver with all of the hydraulic constraints was confirmed using the EPANET hydraulic simulator. An initial feasible solution was improved by a local search algorithm derived from the L1 algorithm originally proposed by Tolson et al. 2009. The performance of the new hybrid algorithm was compared with the ME-Solver which is based only on linear programming optimization. The results show that, the newly developed hybrid algorithm can reduce the pumping cost more than using just the ME-Solver. The newly proposed hybrid algorithm, which combines linear programming with another local search method, can be applied to optimize pump schedules in real-time.

Keywords: Water Distribution Systems, Real-time pump scheduling optimization, Microsoft Excel Solver, Hybrid algorithm

1. INTRODUCTION

Pumping stations are an important part of a Water Distribution System (WDS) and must be designed to generate enough energy to provide minimum water pressures at different consumption nodes in a WDS. Pumping stations are often designed to meet the maximum design discharge which may occur for just a limited time during a day [Barutcu et al, 2010]; therefore, it is important to consider time-varying water demand in a WDS. Pumping stations can include a single pump or, more commonly, multiple pumps and must be installed at suitable locations in the network. Pump drives for water supply and distribution pumps are typically electric motors. Diesel or other fuels will be considered as a power source, only for emergency use [Headquarters, 1992]. According to this description, electricity must be provided to operate pumping stations. The energy consumed by the pumps forms a significant portion of daily expense for WDS operation [Wu, 2007]. Therefore, the adoption of an optimal pump schedule can reduce the operating costs significantly. The current study investigates the development of an efficient method for pump scheduling optimization. In recent years, a number of pump scheduling optimization methods have been investigated by different researchers. These methods are different in terms of their accuracy, run time and user interfaces. In the following paragraphs, some of the popular optimization techniques are described.

Linear programming (LP) is one of the oldest optimization technique and has been applied in different studies [Jowitt and Gersmanopoulos, 1992. Pasha and Lansey, 2009]. LP is a quick method and is also easy to implement. However, it may be unable to find a globally optimal solution. Dynamic Programming (DP) is another optimization method that has been applied to pump scheduling optimization [Sabet and Helweg, 1985. Zessler and Shamir, 1989]. DP can be used as a real-time method, but it has a number of limitations. The method can be used for small scale WDS where it was observed that the solutions obtained by this method were only locally optimal. A number of optimization methods including Genetic Algorithms (GA)