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Numerical model of a district water distribution system in Bucharest

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Abstract

"Teiul Doamnei" Pumping Station in Bucharest supplies the WDN of a district with about 40,000 inhabitants. The pumping station was refurbished in 2004, and variable speed pumps were installed. Due to this refurbishment and other improvements of the water networks, performed by the Water Company of Bucharest, the total energy consumption for 2012 dropped to about 25% with respect to the value recorded for 2004. The numerical model of the pumping station and it's attached water network with 250 pipes and 212 nodes was created in EPANET. Variable speed driven pumps functioning algorithm was implemented in EPANET via ruled-based control statements. The overall variation of pumps' speed allowed by the controls is between 70% and 100%. For each of the 12 months in 2012, from the water consumption recorded at the pumping station, a mean daily value of the flow rate was derived. The daily variation of the hourly flow rate has been considered according to Romanian standard for drinking water supply quantities in urban sites of about 40,000 inhabitants. This variation was introduced in EPANET as flow pattern over a 24h period. The mean daily value of the flow rate for each month, divided by the number of consumption nodes of the network, was added as base demand at each consumption node. The simulations were performed for a 24h period, for each month, with a time step of 5 minutes (although flow rate variation is hourly, due to the limitations of EPANET, the hydraulic time step must be smaller than the flow rate pattern step). Monthly energy consumption computed values are in good agreement with the corresponding values recorded at the pumping station. The model we created can prove useful in performing other analysis in order to assess the functioning of variable speed driven pumps in a WDN.

Keywords: Water demand; variable speed driven pump; energy consumption; EPANET

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1. Introduction

In the past years, pumping stations in Bucharest are refurbished in order to achieve a higher overall efficiency. The refurbishment is mainly based on the procurement of new pumps, with increased efficiencies and on changing the operating algorithm of the pumping stations by means of at least one variable speed driven pump in each group.

Generally, in the functioning algorithm of a pumping station equipped with variable speed pumps, and operating under variable demand, the most important ruling parameter is the pressure on the discharge pipe of the pumping station. Sometimes, in more advanced systems, pressure measurements in key points along the pipe network serviced by the pumping station are also taken into account. Basically, when the pressure in the discharge pipe becomes lower than a pre-established value (due to the increase of water demand in the network), the speed of the pumps is increased so that the pressure stays above the lower limit. Similarly, when the pressure in the discharge pipe becomes higher than a pre-established value (due to the decrease of water demand in the network), the speed of the pumps is also decreased so that the pressure stays below the upper limit. Variable speed driven pumps permit the adjustment of the upper and lower limit to very close values, so that variations of pressure in the network are almost undetectable by the end-user of the water.

In our paper, we try to quantify the energy consumption of such a system, by using a numerical model for a pumping station located in Bucharest, Romania, in the "Lacul Tei" residential district (in the proximity of the Technical University of Civil Engineering), namely the "Teiul Doamnei" Pumping Station, which supplies the water distribution network for about 40,000 inhabitants in that area. The pumping station was refurbished in 2004, and old pumps with constant speed were replaced with variable speed pumps. In a previous paper published in 2004, while the refurbishment was performed, Georgescu et al. (2004) were predicting a 54% reduction in energy consumption due to the new pumps and new operating algorithm, based on a simplified numerical model of the pumping station and serviced network. In fact, the energy consumption dropped by 59% in 2005 with respect to 2004. Due to this refurbishment and to other improvements of the water distribution network, performed by the Water Company of Bucharest, the total energy consumption dropped continuously since. Undoubtedly, a major factor in this reduction was played by the metering of the service-pipes policy adopted by the Water Company of Bucharest. In 2012, the consumption dropped with about 75% with respect to the value recorded for 2004. Moreover, during the whole year 2012, only a single pump was used for operation, among the four identical pumps existing in the pumping station, insuring on its own the necessary pressure level in the network and thus the necessary flow rate. One must highlight that the start/stop and operating speed of the pumps are now controlled automatically in the pumping station, based on measurements of the pressure on the discharge pipe of the station.

Under those circumstances, a more accurate numerical model of the network and pumping station is needed (with respect to the one presented in 2004), to analyze the operation conditions of the network and of the pumps. In this paper we present this model. The numerical model is built using EPANET, a free software for hydraulic network analyses, provided by the U.S. Environmental Protection Agency. It allows the use of variable water demands over a specified period of time, as well as variable speed driven pumps. It also allows the use of command sets (simple controls, and rule-based controls) that can simulate the operating algorithm of the pumping station (Rossman, 2000). The input data consist of the layout, geometric and hydraulic parameters of the network, characteristic curves of the pumps (head versus flow rate curve, and efficiency versus flow rate curve), as well as the values of the pumped water volume recorded at the pumping station during 2012, which yield the values of the daily averaged flow rate. The water demand pattern, variable during the day, is taken from the Romanian standards, with hourly time step. The results should yield an energy consumption of the numerical pumping station close to the real one recorded in 2012. Model calibration is performed by the implementation of the actual operating algorithm of the pumping station (parallel coupled pumps, one driven with variable speed) and comparison of the computed results with the measured data for 2012, in terms of energy consumption.

2. Model of the Water Distribution Network

The water distribution network model consists of 250 pipes, one reservoir (that replaces here the main water