

Valve status identification by temperature modelling in water distribution networks

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Abstract

Within recent years, drinking water utilities have started to collect daily, or even more frequent, data from the source to the consumers' households. In most cases, this information is used to monitor the state of the water distribution network, including the identification of differences in the supplied and consumed/billed water. Newer data streams, such as the collection of temperature data from household smart meters, can provide insights into the quality of the supplied water. Temperature data have another benefit that is not fully exploited: when the soil temperature is different from the source temperature of the water, the water may cool down or warm up and the change in temperature stores valuable information about its path to the consumer.

To explore the potential of distributed temperature measurements, we combined a heat transfer model with a hydraulic model to simulate the temperature change throughout a water distribution network. Our model was developed to facilitate an identification of valve location and status (opened/closed) in the networks without field visits. An unknown location or status of valves can complicate maintenance works or renovation projects of networks, or hinder accurate tracking of drinking water quality. Traditionally, checking and correcting unknown/incorrect valve status is time-consuming and costly, and therefore a nuisance for water utilities.

To identify the actual valve status throughout a water distribution network, we applied a genetic algorithm. The algorithm intends to converge towards a set of valves settings that minimizes the mean squared error, obtained by the residuals between the available observed and simulated pressure, flow and temperature data. To demonstrate our method we used two cases: 1) a theoretical set-up, with real temperature, pressure and flow measurements at the inlets of a real district metered area in Northern Copenhagen. In this set-up, five valves were closed and the temperature simulation based on this set-up was stored as the 'perfect solution'. Next, the genetic algorithm's aim was to identify the set of five closed valves by starting with a network where all valves were open. The robustness of this approach was assessed by adding noise to various parameters in the network (e.g. soil conductivity) and by varying the temperature data available (e.g. time scale). 2) a model set-up based on the Novafos transportation network, was generated. In this set-up, we used flow and pressure measured at inlets and outlets of the network, and temperature measured at two locations in the network. It was investigated whether the algorithm converged towards valve settings known to the utility.

Results of the first set-up revealed that the genetic algorithm converged successfully after around 10,000 simulations to identify the correct set of valves. Selected valves with a high effect on the temperature distribution in the network were identified as early as during the first generations of the genetic algorithm. Likely, the sole application of conventional pressure and flow measurements would not have identified these valves as their status has a very low impact on the pressure drop in the network. In the real case set-up, it was found that high discrepancies between modelled and simulated values were caused by incorrect network descriptions in the hydraulic model. The hydraulic model was not able to represent the real distribution of the water in the network and showed a marked difference between observed and modelled temperatures that could not be explained by errors in the thermodynamic model alone. Our modelling results revealed fundamental flaws in the hydraulic model set-up not previously identified. This shows a potential for exploiting water quality data such as temperature in the calibration and validation of hydraulic models for water distribution networks. Also, the real case study showed that high-quality input data are needed to run the method adequately. In the future, the method will be tested on a district metered area with real temperature measurements from smart meters.

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