How data analytics can optimize water and energy consumption in water supply system

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Data Science is a scientific field that combines statistics, mathematics, programming and data acquisition techniques to actively extract insights and information from data. In this article, it is discussed how two innovative techniques can be combined to improve the efficiency of a water distribution network, with significant economic and energetic savings. More, it presents the results obtained by the implementation of SCUBIC's platform in two water supply systems and how SCUBIC's technology can be applied to improve other engineering systems.

1 Water Supply Networks

Water is the most important commodity to humankind and is used by all sectors of the economy. However, water sources are normally far from the end consumer and have to be transported through large distances by pumping systems, which consume more than 35% of the total expenses in a water utility. So, energy efficiency plays a crucial large role in the sustainability of water utilities. Nevertheless, it is now possible to improve the efficiency of this process and to reduce the energy costs associated with pumping operations through the use of data analytics.

A water supply system (WSS) is composed by pipes, tanks, pumps, valves and sensors, which then is controlled by a supervisory, control and data acquisition system (SCADA). Normally, the pumping operations rely on a set of rules defined in the SCADA, specifying how and when each pump must operate. These rules are defined accordingly to several constrains, such as: the energy price variation, the tank levels, the average water consumption and by the operational manager expertise. However, these operational constraints are fixed and as water consumption varies over time they have to be fine-tuned. Although this may seem straightforward, a minor deviation from the daily optimal operation can induce huge economical losses by the end of the year.

The most efficient operation is the one that, on a daily basis, pumps the exact volume of water needed to satisfy the population at the lowest possible cost. However, achieving the optimal operation requires that WSS engineers have to calculate and change the operation on a daily basis and this is unfeasible. More, as water demands vary from day to day, accurately predicting the water demand has proven to be very difficult. Therefore, to reduce the operational cost of a WSS it is necessary to:

1. Accurate forecast of water demands, and
2. Dynamic optimization algorithms.

2 Solution

Over the years, many solutions and algorithms were proposed to optimize the operation of a WSS. The method here proposed and implemented on two WSS is based on a dynamic optimization algorithm that is composed by three interlinked stages. The first consists in the development of a virtual hydraulic model that represents the real operation of a WSS. This model describes how all the assets of a WSS interact with each other based on the pre-defined operational constraints. The second stage calculates on a daily basis the boundary conditions of the virtual model, which includes the water demand and tank levels at the beginning of the simulation. In the third stage, an optimization algorithm solves the hydraulic model for different inputs, in order to find the combination that originates the best results (lower cost). The following sections describe these stages.

2.1 Accurate water demand forecast

In the open literature, it is possible to find several methods that claim to accurately predict the water demands. SCUBIC team's expertise have proven that there is no solution that can fit all. Therefore, SCUBIC uses a combination of traditional and statistic methods and machine learning techniques to obtain the best accuracy. Nevertheless, machine learning methods have shown a higher accuracy, with the advantage of being capable of processing large amounts of relevant data from different data sources to model the phenomenon. Ensemble methodologies have also been documented to improve forecast accuracy by combining the best parts of each model. On the other hand, the traditional methods (e.g. ARIMA or Exponential Smoothing) are more failure-proof and better suitable for long-term forecasts. Therefore, the best forecast strategy varies regarding the water network and the time step selected.

2.2 Simulation

In order to test and validate what is the optimal operational strategy, a virtual model of the WSS is developed. This model must contain all the components and assets of the WSS and has to precisely simulate the hydraulic behaviour of the system. Therefore, the hydraulic model must undergo a calibration process that adjusts the model's parameters, such as pipes diameter and head-loss or pumps hydraulic and efficiency curves, to better represent the real physical network. However, this imposes several challenges, such as:

- Each water network has its own model;
- Modelling the equipment deterioration, pipe incrustations and corrosion is very difficult;
- The model must be re-calibrated from time to time;
- Implementation time increases with the number of physical components.

2.3 Dynamic Optimization

The final stage is the implementation of the dynamic optimization algorithm. This adjusts the operation (pumps' status) every day, taking into account the water demand forecast, energy price and network's operational constraints, with the goal of achieving the lowest cost of operation. There are several optimization algorithms in the literature that can be used to enhance the WSS operation. However, finding the best technique depends on several parameters such as: the number of pumps starts, the number of energy during the day or energy production from renewable sources.

3 Case Studies

SCUBIC is currently installed in two WSS, which supply the water distribution for approximately 80.000 people. The implementation of a dynamic control allowed these water utilities to reduce their specific energy cost (€/kWh) on average of 9%. More, by reducing the operation time of two parallel pumps in favor of a single pump (even if in more expensive periods), SCUBIC allows the reduction of energy consumption by 3% and the reduction of the number of pump starts extends the pump life expectancy and reduces maintenance cost.

4 Can this be applied in other industries?

SCUBIC's predictive algorithms can be applied to any type of data from any type of data sources. This feature allows SCUBIC to apply its algorithms to many engineering processes, delivering high accuracy predictions that can be used to reduce costs, increase the system performance or to enhance the system security. Moreover, the machine learning based data-driven solution is of fast implementation and with the capacity of dealing with huge amounts of data. Furthermore, a machine learning based methodology allows the applicability to a large variety of engineering problems, including but not limited to:

- supply chain and stock management;
- industrial process (mechanical, machining, chemical) optimization;
- energy efficiency;
- quality control;
- heating, ventilation and air conditioning systems.