INTEGRATION OF TELEMETRY DATA FOR HYDRAULIC MODELING OF THE WATER DISTRIBUTION SYSTEM IN MIKOŁÓW, POLAND

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ABSTRACT

This paper presents the preliminary results of a project aimed at employing a semi-automated system for hydraulic modeling of the water distribution system in Mikołów. Mikołów is a city located in Silesia, in the southern part of Poland and borders the Silesian Metropolis. The water distribution system serves about 40 000 people and covers an area of 30 km^2.

The total length of the water distribution system in Mikołów is about 310 km, with 117 km of service pipelines (2014). The net water demand is about 7500 m^3/d during an average day.

The tested system combines GIS and extensive telemetry to auto-calibrate and maintain a detailed all-pipe hydraulic model. Telemetry of the city water network consists of detailed monitoring for district metering area (DMA) substations and all structures (booster stations and water sources), full AMR (automatic meter reading) and remotely operated pressure reducing valves and system valves.

A critical element affecting the accuracy of the hydraulic model is the estimation and prediction of customer demand patterns. The AMR system is used to analyze the behavior of individual household-based water consumption and to detect anomalies. For calibration and validation of the model, the telemetry system was combined with temporary measurement points placed during the measurement campaign.

A network graph with complete and up-to-date parameters (based on data stored in the GIS database) is automatically generated and the complete hydraulic model is transferred to the in-house modeling software MOSKAN-W. GIS integration enables on-the-fly network skeletonization which is required for different types of analyses, especially for the optimization modules used here.

The development of the ICT system for the municipal water network in Mikołów provides a valuable tool to the utility managers. In addition, the ICT system has been shown to be an affordable, flexible and scalable tool providing significant operational benefits for water utilities of various sizes.

Keywords: water network, simulation, modeling, AMR, SCADA, data integration

1. Introduction

Currently, a typical water utility uses the following tools (modules) to support the decision making process: CIS (Customer Information System or just a billing system), GIS (Geographic Information System), telemetry system (AMR – Automatic Meter Reading, SCADA - supervisory control and data acquisition) and in most cases a hydraulic model (usually highly skeletonized to include only the main pipelines (Martinez *et al*., 2007; Boyle *et al*., 2013)). The focus is usually concentrated on maintaining CIS and GIS (mainly network mapping) because they are crucial for everyday routines. The telemetry system often collects enormous 'heaps' of information that is not used for anything of great importance. The typical usage is for signaling malfunctions (alarms), some basic control (usually manual - without feedback) and generation of daily reports. A hydraulic model, disconnected from GIS, is usually outdated and used only for some basic tasks (e.g. system capacity evaluation), although each utility employs their own practices. This particular situation is a result of an evolutionary process that began in the early 1970s as IT tools were coming into everyday practice in water utilities (Mays, 2000). Because of this iterative process linked to the evolution of software and hardware, connections and interfaces for data exchange between these tools were not created. It is now required to capitalize on recent IT advancements and practices to fully realize the advantages of integrated tools for water utility management.

To resolve this problem, water utilities can either scrap their currently used software and buy new, expensive integrated software solutions or try to create manual procedures to keep all information in separated modules up-to-date. To add yet another layer of complexity, it is common that each module is maintained by a different department, making information exchange even harder. Data redundancy, limited or no data exchange and outdated information are the main challenges faced by managers of complicated systems (Naphade *et al*., 2011; Sempere-Paya *et al*., 2013).

This research and innovation aims to meet the need for a scalable, automated and robust solution that can integrate existing (commercial, in-house and open source) software and hardware solutions into one package enabling a synergetic effect.

In this paper the concept of an original ICT (Information and Communications Technology) system is presented and illustrated through the case study of Mikołów, Poland (Wójtowicz *et al*., 2015a). In addition to Mikołów, this system was also tested for the largest water company in Poland (Wójtowicz *et al*., 2015b). The project in Mikołów was primarily focused on the estimation, prediction and automatic updating of customer demand patterns with the help of an AMR system, as it is a crucial element affecting the accuracy of the hydraulic model. The AMR data was used to analyze the behavior of individual household-based water consumption. Calibration and validation of the model was conducted by combining the telemetry data with temporary measurement points deployed during the measurement campaign.

2. Overview of the mikołów water distribution system

Mikołów is a city located in Silesia, the industrial region in the southern part of Poland. A large part of the water network is under influence of mining activities causing frequent ground surface subsidence. The water distribution system (WDS) in Mikołów serves about 40 000 people. The total length of the WDS is about 310 km, with 117 km of service pipelines (2013). The net water demand is about 7500 m^3/d during an average day. The layout of water network is presented in Figure 1.

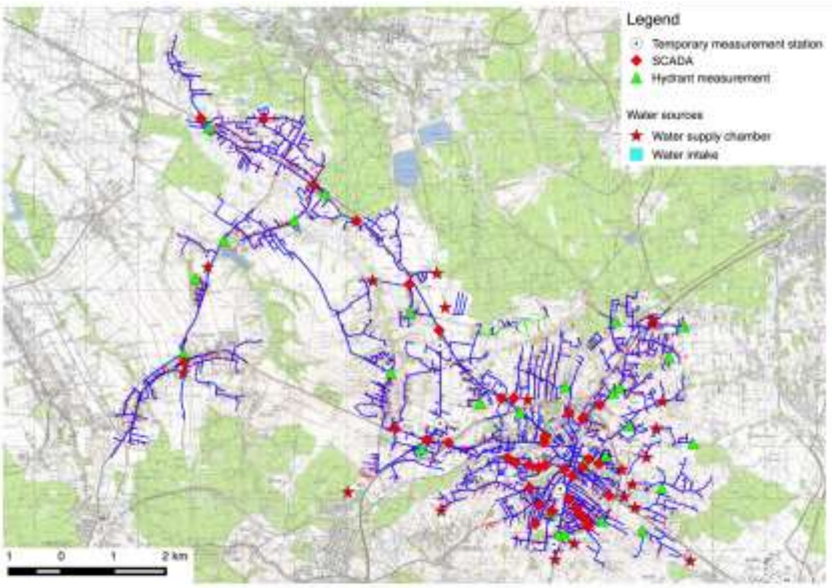

Figure 1: Layout of the hydraulic model (all-pipe) of the water distribution system in Mikołów, Poland

About 65% of the water for Mikołów is purchased from the external provider through regional water production and the main transportation system. The remaining water is supplied from two groundwater intakes located in the northwest part of the city (*cf.* Fig. 1).

The main concerns for the Mikołów water utility are damage from mining activities, ageing infrastructure and the resulting water losses. This specific situation requires a decision support tool capable of operating in a dynamic water network with frequent pipe failures caused by mining activity.

Outsourcing most of water production simplifies the distribution system. There is no need for storage tanks because water is taken from 19 conveniently located supply chambers connected to two main pipelines running along the boundary of the city.

3. The ict system for mikołów

The concept of the ICT system shown in Figure 2 was developed for the water supply system in Mikołów. This system is modular with seamless, two-way communication between components. The structure allows the exchange of any building block with the new or improved one, without loosing functionality.

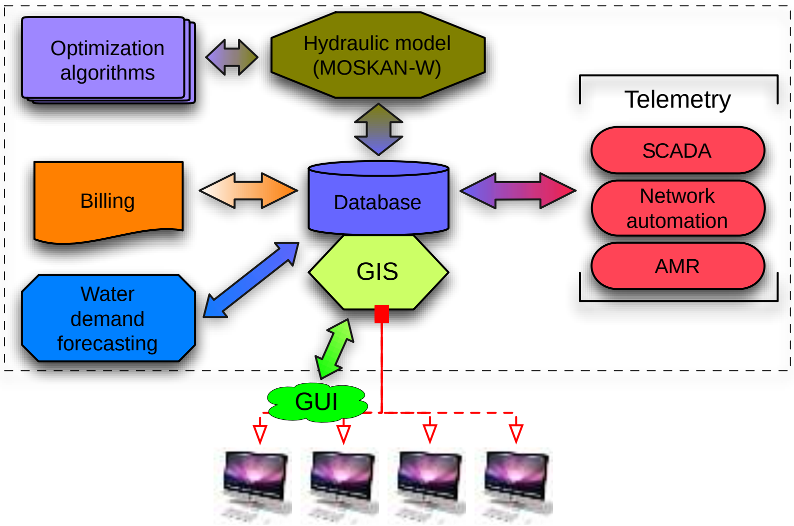

Figure 2: Block diagram of the integrated ICT system for Mikołów

This system (Fig. 2) consists of the following key components (commercial, in-house software and open source): **GIS** for creating and updating the information about the water network; **Telemetry** for monitoring and controlling the water network parameters, i.e. the flow and pressure values, customer demands and system utilities (valves, pressure reducing valves - PRVs etc.); **CIS** for managing the data of the water amounts consumed by the end users of the water network; **Hydraulic model** of the water network – all-pipe hydraulic model automatically generated from GIS database. MOSKAN-W was used which is the authors' in-house modeling software based on EPANET 2.0 **Programs and routines** with algorithms for mathematical modeling, optimization, approximation, control and planning were used for decision support and utility management.

4. The hydraulic model

The detailed, all-pipe hydraulic model of the water distribution system was developed to take advantage of the AMR system (*cf.* Fig. 1). Only minimum network skeletonization was required. Optimization modules, however, required a higher level of simplification with this topic being beyond scope of this paper (Studziński, 2014).

The water network is divided into several district metering areas (DMA) by 20 remotely operated flow control valves allowing for the creation of dynamic district metering areas. Remotely operated pressure reducing valves are installed in these areas. Each individual water supply chamber supplying a particular DMA has a PRV installed to allow zone pressure control.

A network graph with all up-to-date parameters (based on data stored in the GIS database) is automatically generated and the complete hydraulic model is transferred to the in-house modeling software MOSKAN-W. GIS integration enables on-the-fly network skeletonization required for different types of analyses, especially for the optimization modules.

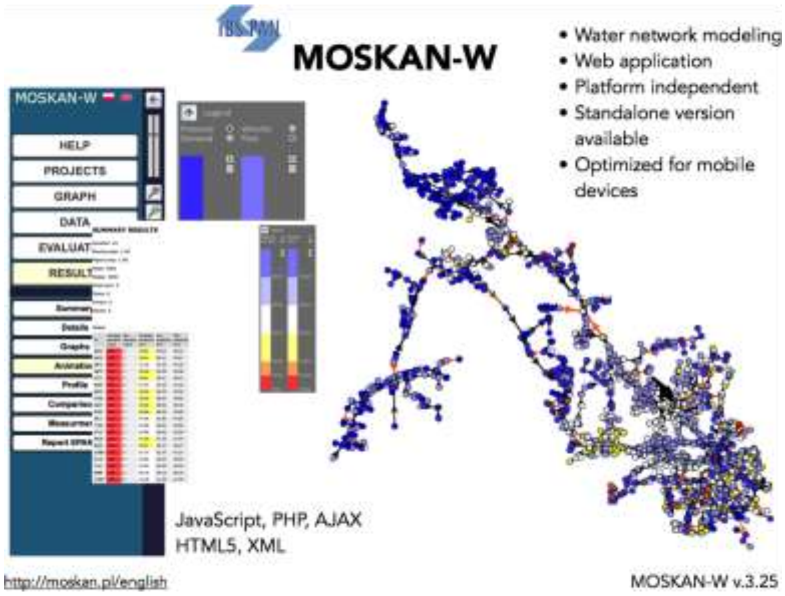

Figure 3: Overview of mobile hydraulic model MOSKAN-W (developed by IBS PAN Warsaw)

MOSKAN-W is a mobile application based on EPANET 2.0 code (Służalec *et al*., 2014). It is platform independent, allowing for modifications and integration. All calculations are performed on a server and the obtained results can be presented by means of the MOSKAN-W interface, GIS module or any EPANET compatible application (e.g. with XML format).

Because the hydraulic model uses information from GIS, which is usually well maintained, there is no risk of having outdated data or information redundancy. Network modeling requires additional data to be included in the database, but the workflow is the same. This reduces the time required for adoption and training.

The hydraulic model was initially calibrated and validated with data obtained from the telemetry system and measurement campaign (see Fig. 1 for location of sensors). Regular validation of the hydraulic model is a semi-automated process. The network operator can activate the hydraulic model update (with the optimization module employing the genetic algorithms method) according to the observed versus simulated difference (based on 50 measurement points for pressure and flow rate). Nevertheless, the authors' practice shows that periodic full calibration supported by a measurement campaign of the model is still necessary to maintain the required level of accuracy.

5. Conclusions

This case study presents test results of an integrated management tool for the medium sized water utility in Mikołów, Poland. This project provided the unique opportunity to use the Mikołów water supply network for testing various approaches to water consumption forecasting, near real-time data management and automatic hydraulic model updating.

Special focus was given to the application of the measurement database from the extensive telemetry system and the AMR for the hydraulic simulation model and multi-criteria optimization modules in the integrated ICT system.

The developed ICT system proved to be an affordable, flexible and scalable tool that can offer significant operational benefits for water utilities of different sizes.

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