Integrated ICT system for management of large-scale water distribution network of Upper Silesian Waterworks in Poland

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Abstract: The paper presents description and planned application of an integrated ICT system and its numerical algorithms to support the complex management of a large water transfer and distribution system - Upper Silesian Waterworks PLC (USW). The USW is the biggest water company in Poland and one of the biggest in Europe. The algorithms are included as software modules into the structure of the ICT system. Their tasks are mathematical modelling, forecasting, approximation, optimization and control and using them in different combinations, the operation and maintenance of a large municipal drinking water supply system can be efficient, fast and cost-effective.

Keywords: Waterworks management, mathematical modelling, computer simulation, optimization, approximation algorithm, automatic calibration, hydraulic model, case study.

Introduction

The world trend in computerization of waterworks is the implementation of integrated information communication technology (ICT) for comprehensive management and decision support (Sempere-Payá et al., 2013). An integrated management system for a water network usually consists of GIS (Geographical Information System), SCADA (System of Control and Diagnostics Analysis) and CIS (Customer Information System) systems, which are integrated strictly with some modelling, optimization and approximation algorithms. Due to this strict cooperation under several programs all tasks of a water network management can be automatically executed or computer supported and these tasks concern the technical as well as organizational, administrative and economic problems (Studzinski, 2013). Under these latter problems the planning of aging water network revitalization is of a special importance as it has an essential impact on the reduction of failure rate in the water network.

The aim of the current project is to design, develop and implement structures, algorithms and computer programs into a single integrated system supporting comprehensive control and management of a complex water supply system for large agglomerations of more than 1 million residents.

Silesian Waterworks PLC

The ICT system will be implemented for the water transfer and distribution system of Upper Silesian Waterworks PLC (USW) – the biggest water company in Poland and one of the biggest in Europe delivering water to over 3 million customers, on the
area covering about 4.3 thousand square kilometres, with the main water network which is over 880 km long. This water distribution system incorporates central and western sub-regions of Silesia (Silesian metropolis) supplying water in the amount of about 400 000 m$^3$/d (in 2012). The USW distribution system is a mix of pressure and gravity mains (with diameters from 300 mm up to 1800 mm) conveying the water to several local (municipal) distribution systems. The USW system is composed of 11 water treatment plants, 19 pumping stations and 9 complexes of storage tanks and reservoirs (with total capacity of 374 000 m$^3$). The large area of the water supply system is characterized by a great diversity of terrain altitude, heavy concentration of industry (including coal mines, steel, energy, automotive, machinery and chemical) and by mining damages. The telemetric system of USW is composed of over 150 monitoring points where pressure and flow rates are measured. In selected locations additional measurements of turbidity and chlorine residual in water are taken (in total over 800 sensors are used). The data from SCADA system and also mobile (temporary) measurement points will be used for calibration and validation of the network hydraulic model (Kapelan et. al., 2007; Savic et al., 2009).

The problems associated with the management of the USW lies in its size, in a large number of sources with varying levels of water quality, a large number of wholesale customers (coal mines) determining the flows of water in the water supply, in a large diversity of age and material of pipes, and in significant dispersion of critical facilities and of the entire water supply system. The proposed ICT system for management and control of the large water supply system will have an impact on the progressive elimination of the weaknesses of USW which include: oversized production capacity in relation to the current water demand, the need for maintenance and repair of approximately 60% of the pipelines, the periodic change in the water quality, limited flexibility in the market activities. Furthermore, almost half of area covered by USW system is under strong influence of mining damages. The way to improve the weaknesses is to keep in good working order the infrastructure facilities and the water treatment plants by optimizing the structure of sources, optimizing the process of water distribution and by maintaining in proper technical conditions the distribution network through optimal management of emergency repairs, renovations and upgrades.

![Figure 1 Structure of Upper Silesian Waterworks water distribution system.](image-url)
**Concept of an ICT system for Upper Silesian Waterworks PLC**

At the Systems Research Institute in Warsaw an integrated ICT system for comprehensive water network management has been developed which structure is shown in Fig. 1 (Studziński, 2013).

![Block diagram of the ICT system for water networks management.](image)

**Figure 1** Block diagram of the ICT system for water networks management.

The ICT system developed consists in total of 22 programs cooperating each other in different combinations depending on the tasks to be solved. Three modules are responsible for the realization of the management tasks solved by using the hydraulic model and optimization algorithms (in module MOSUW), by using the approximation algorithms (in module Kriging applications) and by using the algorithms of mathematical modeling (in module Objects identification).

All programs of the MOSUW module work with the hydraulic model of the water network and while realizing the tasks concerning the model calibration, the water system optimization and planning, the pumps control and the planning of SCADA, they use a multi-criteria optimization algorithm (Straubel and Holznagel, 1999). By the solution of other tasks only multiple simulations of the hydraulic model under different work conditions of the water network are executed.

Programs in Kriging application module use the algorithms of kriging approximation that enable to picture in graphical form the value distributions of parameters connected with the water network and with its operation (Bogdan and Studzinski, 2006).

In last module Objects identification several programs are collected to mathematically model the dynamical processes by means of the time series methods with the least squares algorithms such as Kalman’s, Clarke’s, maximum likelihood, linear and nonlinear regression algorithms (Hryniewicz and Studzinski, 2002).

The key component of the ICT system is the Branch Data Base (BDB) of the GIS system that records all information and technical, technological and economical data of the water network, of its objects and of the water consumers accessed to the water network. The BDB is the main source of input data for the hydraulic model that supports the calculations of all programs collected in the modules MOSUW and Kriging applications. All programs of the ICT system communicate each other and with the Branch Data Base. These exchange files are used e.g. to generate the water network graphs from GIS to the hydraulic model (MOSUW-H) or to export the results of hydraulic calculation to the optimization program (MOSUW-O) while optimizing...
the water network. Through this cooperation of several programs while solving different management tasks for the water network a synergy effect arises that the efficiency of the running programs boosts essentially. In the following some functions of the ICT system are mentioned that can be executed only due to the cooperation of several programs what shows on the necessity of integration of different programs in frame of an united information system: hydraulic calculations of the water network (cooperating programs GIS, CIS and MOSUW-H for hydraulic calculations), automatic calibration of the hydraulic model (programs GIS, CIS, SCAD and MOSUW-K for calibration), discovering and localization of the leakage points at the water network (GIS, SCADA, CIS and MOSUW-A for water leaks detection), optimization and planning of the water network (GIS, CIS and MOSUW-O for network optimization), control of the pump sets installed on the water network (GIS, CIS and MOSUW-P for pumps control), optimal planning of the SCADA system for the water network (GIS, CIS and MOSUW-M for measurement points localization).

The appropriate programs from the MOSUW module realize the above functions but they have to be supplied with the input data by GIS, CIS and also by SCADA systems. The components GIS, SCADA and CIS are adopted from commercially available software and integrated within environment of the comprehensive ICT system. All programs of the MOSUW module use the data computed by the hydraulic model and its calibration and validation decide on the exactness and quality of all management tasks executed by the ICT system. The quality of the final hydraulic model will be assessed according to the WRC standards (for measurements of pressure and flow rate).

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References