Preface

Automation and digitization are becoming more and more important in the water industry. The drivers for using these new technologies are increasing legal requirements, continued high cost pressure and increasing water scarcity in many regions of the world. For this reason, both Germany and the European Union have set up a number of applied and practice-oriented research programs dealing with the development of innovative IT applications and the application of model-based production planning algorithms based on simulation and optimization. The research project EWave, funded by the Federal Ministry of Education and Research (BMBF), pursues the goal of expanding an existing process control system with a decision support system (DSS) (for energy and/or resource efficient operation. Over the past few years, requirements for drinking water supply have become more and more demanding. While the secure supply of high-quality drinking water for the public was the priority during the past decades, rising energy costs and flexible energy tariffs now also require that energy is used efficiently. Water supply companies must therefore rise to the challenge of continuing to prioritize a secure supply of high-quality drinking water while coping with the increasing demand for energy and cost efficiency. Therefore, the operation of drinking water supply systems, such as urban supply networks or long-distance water pipes, is an extremely complex task which can no longer be carried out without the use of modern tools. Today, such supply systems use state-of-the-art technology and are controlled via SCADA systems (Supervisory Control and Data Acquisition) and partly automated function sequences. The operators must ensure a reliable supply of excellent quality drinking water for consumers at reasonable costs. Within the project EWave an innovative energy management system (EMS) has been developed which was trialed at Rheinisch-Westfälische Wasserwerksgesellschaft mbH (RWW), a water supplier with a typical network structure. The new software tool which can be used as decision support system (DSS) is able to devise energy-optimized operating plans for plants for water collection, treatment and distribution within the supply system. Moreover, the fluctuating energy supply from suppliers' own power plants are co-ordinated with the energy supplied by one or more other energy suppliers. The scope for optimization calculation is restricted by technical and operational aspects. Here too, the quality and security of the supply, in particular, must be guaranteed at all times. Water suppliers' electricity consumption is highest for water treatment and water distribution. Therefore, as far as energy optimization is concerned, the focus lays on both specifying the running times and switching times of the network pumps and setting the required water production output to the available water plants. As conditions on the electricity market are changing, shorter contract terms with differing rates and diverse pricing packages can be expected. This means that, on the one hand, new opportunities for optimization open up; on the other hand, operating procedures which have been predominately static so far must become more dynamic. That also implies that knowledge and experience accumulated over decades by the operating personnel is partly devalued and must be further developed. The BMBF project closes this gap by using mathematical optimization methods to determine an operation mode at optimal costs. Parameters developed within the project are used to assess the energy efficiency and profitability of a company. This efficiency assessment allows for a comparison of different plants and waterworks. In addition to energy efficiency, hydraulic efficiency was calculated to assess hydraulic plant components. An overall assessment of the plant is realized by calculating the plant efficiency.

In Part I ICT solutions for water supply systems are introduced in a general manner. The advances in information and communication technology (ICT) have already led to new technological solutions in the water industry. This continues a trend that started long time ago, but in many cases has been limited by several technical restrictions. Chapter 1 describes the ICT basics that are relevant for the water industry and lays the theoretical foundations for understanding the newly developed energy management system. Chapter 2 summarizes the main conditions from the real pilot system to be met during operation and the potentials for improvement to be exploited are translated into various requirements for the development of the new tool. To meet the current requirements for such a DSS, several workshops for water supply companies were conducted. During these workshops, experiences gained with energy management systems were exchanged and further aspects were added to the list of requirements.

Part II deals with theoretical aspects which are essential to develop a decision support system for water supply system. Chapter 3 outlines that knowledge about current and future demands for drinking water and energy is a relevant boundary condition for an optimized operation. Energy demands depend on the hydraulic conditions within the waterworks and the entire distribution network of the relevant pressure zone. Therefore, a water demand forecast tool has been developed. The hydraulic simulation model, described in Chapter 4, is based on a network abstraction that describes network components, such as pipes, storages, valves, or pumps by mathematical equations and connects them with each other in a network graph. The resulting nonlinear, differential-algebraic equation system is then automatically generated and numerically solved with suitable methods. Chapter 5 explains a newly developed integrated optimization approach for decision making and operational support. As a result, the user receives operating schedules on a 15 minute scale. For this purpose, discrete-linear, and continuous-nonlinear mathematical optimization methods are combined. First, a mixed-integer optimization model is solved in order to derive all discrete decisions (primarily pump schedules). Second, these results are used for the discrete optimization variables and subsequently optimizes the continuous variables such as pump speed, valve opening degrees, or water volumes.

Part III describes the application of the new energy management system in a real plant environment at RWW. In Chapter 6 it is shown that network abstraction is necessary in order to ensure that the entire water supply network is considered within the dynamic simulation model. This is realized by combining regional subnetworks to superior pipe and storage elements, thus preserving the large-scale network structure. Chapter 7 deals with the setup of the simulation model. This model consists of two parts: The relevant processes within a waterworks and the distribution network for drinking water. These parts are connected by the drinking water pumps. Calibration is made separately for single network elements like pumps and valves and for the aggregated network. The calibration of e.g. pumps can be done automatically, whereas the calibration of the network is largely a manual process. The achieved accuracy is appropriate for practical application and the further optimization process. Chapter 8 explains the configuration of the real automation system and how existing data is made available to the project partners for model construction, calibration of the models and for test runs of the tool.

Chapter 9 discusses the new ICT architecture of the new DSS that has a modular structure based on existing modules of the SIWA Smart Water Systems by Siemens AG. The calculation starts with an import and pre-processing of current plant data. Subsequently, a simulation run is initiated in order to assess the current status of the plant. In addition, the estimated water demand is calculated. On this basis, the pump schedules are optimized for a preview period of 24 hours and displayed to the user on a graphical user interface (GUI). This process is repeated every 30 minutes. The representation of the results is explained in Chapter 10. Several industry-specific key performance indicators (KPI) are calculated for water works Dorsten-Holsterhausen. The graphical user interface shows the optimized switching points for all pumps in the network in a very easy way. These switching points can be used by the operators to reduce the energy consumption while securing the safety of supply.

Part IV summarizes the pilot application at RWW. Experiences and advantages of the innovative decision support system for water supply systems are discussed. Chapter 11 describes the installation of the tool as pilot application directly on site at the RWW facility in the waterworks Dorsten-Holsterhausen. In a first step, the tool was run in parallel to the real operation, without applying the setpoints on the real plant. After familiarization by the operators, the optimized setpoints were applied to the plant control. In terms of the supply system considered here, optimization yielded an energy savings potential of approximately 10%, based on historical data.

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