NEXT GENERATION INFORMATION AND COMMUNICATION TECHNOLOGY FOR SMART WATER UTILITIES

BY CAROLINA MOYA

The process of making operational and maintenance decisions in a water network management involves the analysis of a huge number of highly interrelated variables. Current management software systems are based on data gathering and modelling technologies. Nevertheless, an increased complexity in monitoring is rarely a synonym of a better efficiency. Having taken this into account, it can be certainly suggested that new approaches and technologies are required to leverage the already existing ones. A combined work of artificial intelligence, machine learning and real-time predictive analytics forms a decisive part of the next generation of Information and Communication Technology (ICT) systems for Water Utilities.

Water distribution systems face socio-economic, sustainability and resilience related challenges which include: overuse due to population growth, underestimation of the value of water, lack of coordination among actors, operational issues (ageing, leakages, quality, pressure, etc.), increasing energy prices and the need to respond to climate change issues. Large amounts of water-related environmental data are already being reported from local to supranational level. However, there is still a lack of a holistic approach to the assessment of resource efficiency and environmental performance of water utilities.

Hydraulic, economic, social, environmental and quality variables are highly interrelated. An optimization of energy consumption, supply risk, water storage levels or pressure might cause low performances in other variables or even not reliable scenarios. Therefore, to be able to take reliable operational decisions in water distributions systems, it seems unavoidable to turn to multi-criteria approaches.

Next Generation ICT support for Water Utilities

Nowadays, the definition of Smart Water Networks is associated with Supervisory Control and Data Acquisition (SCADA), hydraulic modelling, Geographic Information Systems (GIS), Big Data analysis, etc. At best, all those software and datasets work collaboratively to achieve a better understanding of what is happening in the water supply system. But, is this really smart or is it all about data ingestion? Does always having a large quantity of data lead to smarter decisions? Data collection is currently useful, but the key factor should be to be able to extract all the knowledge that is actually available in each piece of data.

A Smart Water Network involves evaluation of problems, elaboration of solving strategies and decision making and action taking. This article is introducing an application of innovative ICT developed for and applied to the water distribution sector. WatEner represents a non-structural solution for Water Utilities management having a great impact on several matters (e.g. climate change, carbon footprint, balance sheets, water losses, non-revenue water, long-term infrastructure planning, water sources) leveraging past investments in sensors, simulation models or GIS data.

WatEner is a next generation ICT solution that combines the key factors of energy consumption with further operational requirements of drinking water supply, to improve the management of water supply networks. In this regard, the results of the test case of the Karlsruhe Water Utility in Germany will be next outlined.

Figure 1. WatEner. From information to knowledge

To achieve its objectives, WatEner makes use of innovative technologies in the generation of knowledge. Such knowledge is expressed as relations and foreseeable evolutions from existing information: sensor data, simulation models, GIS or infrastructure's technical characteristics. A set of Artificial Intelligence techniques is applied to provide short-term (real-time, operation) and long-term (infrastructure planning, maintenance) recommendations. Moreover, all the data, information and knowledge are shown in a very user-friendly web application, designed by and for water managers.

On the one hand, pattern recognition techniques are used to provide a ten-minute water demand forecasting for each district metering area of the network, based on the most similar day methodology. On the other hand, they are also applied for searching reliable operational strategies, taking into account customizable key performance indicator (KPI) which results related to key factors in water supply systems (e.g. energy efficiency, economic cost, water usage, quality of service, water quality).

Moreover, business rules inference engines are very powerful instruments in charge of the assessment of the operational strategy. The expert knowledge of the Water Utility team is captured and adopted in evaluating policies, best practices, supply risk assessment, feasibility and any other operational matter. Also, these techniques allow to gather and improve the expert knowledge and to maintain it within the organization.

Machine learning procedures provide the capability to continually improve the operational and planning recommendations. Through training modules designed for both expert water managers and operators, the ICT system and the expert staff learn how to operate better. Training modules will collect and assess operational strategies to face normal, abnormal or even theoretical situations.

Finally, the aim of the real-time predictive analysis is to check if during operation, the network situation evolution is proceeding as expected or if any anomaly can compromise the service. This module helps operators to track network events, detect service anomalies and compare them with the expected service KPI, not only in terms of quality of service, but also in energy, water and economic-cost efficiency. Furthermore, WatEner incorporates a rich set of dashboards designed for water managers, apt to enable easy access to events, operational recommendations and KPI. They are designed to incorporate the indispensable knowledge required by the distinct job profiles and the operational and business management in a Water Utility to perform their tasks in the best way possible. In addition, the platform is equipped with a special dashboard for the public/customers, intended to transparently provide information on the supply system, the quality of the service and the state of the water resources.

The case of Karlsruhe city

In 2009 the city of Karlsruhe (Germany) together with all its companies committed themselves to reduce their energy consumption and carbon footprint by 2% each year. Since then a lot of effort was made in drinking water supply already, e.g. investments in more energy efficient groundwater pumps feeding the water treatment facilities, power transformers, compressors and electric lighting. Stadtwerke Karlsruhe GmbH (SWKA) is the local energy (electricity, natural gas and long distant district heat) and drinking water supplier for the about 400,000 inhabitants of the region of Karlsruhe in Germany. Its shares are majority-owned by the city of Karlsruhe.

The SWKA network has four water works located around Karlsruhe that produce drinking water from the upper layer of an aquifer. The treatment of the raw water comprises the aeration and the removal of iron and manganese by biological sand filtration. Each of the water works has four network pumps with constant pump rates. The total drinking water consumption in the region of Karlsruhe is around 24 Hm^3 per year, or 65,000 m^3 per day.
The drinking water network has a length of more than 900 kilometers. Most of the city is located in one pressure zone, fed by all four water works. Attached to that pressure zone, there is a water storage tank of approximately 20,000 m^3 located about 50 m above street level, that stabilizes and controls the water pressure in this main pressure zone.
In this context, one of the present tasks for SWKA is the optimization of the daily pumping schedules of the treated drinking water fed into the distribution network and of the water storage tanks management. Furthermore, some important requirements have to be fulfilled: the water supply must always be assured, the highest possible water quality is not to be put at any risk and the energy costs should also be as low as possible.

In this case, the main objective of the implementation of WatEner sought to respond to the needs and requirements in terms of

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Figure 2. Average daily consumption day

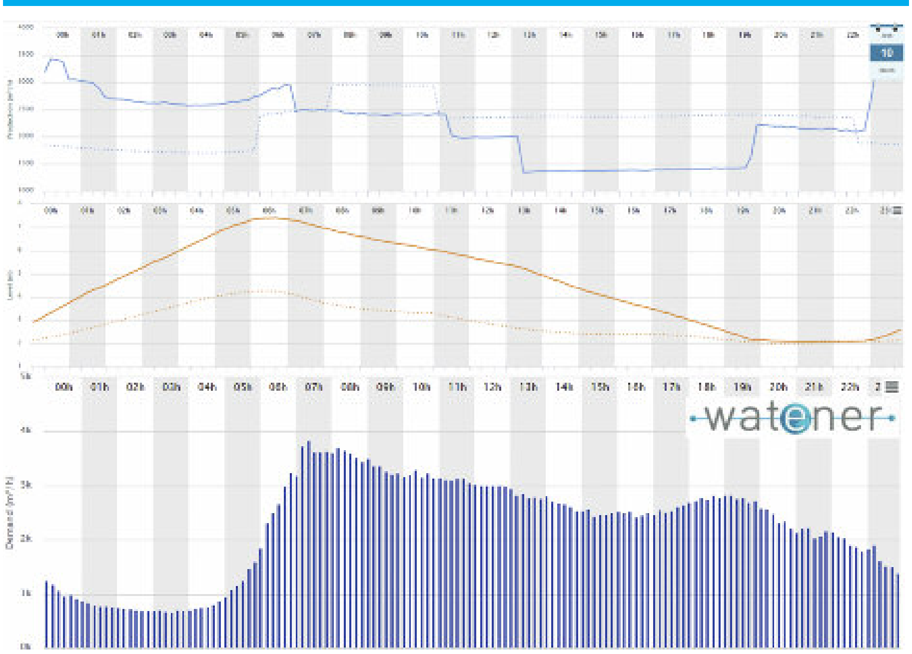
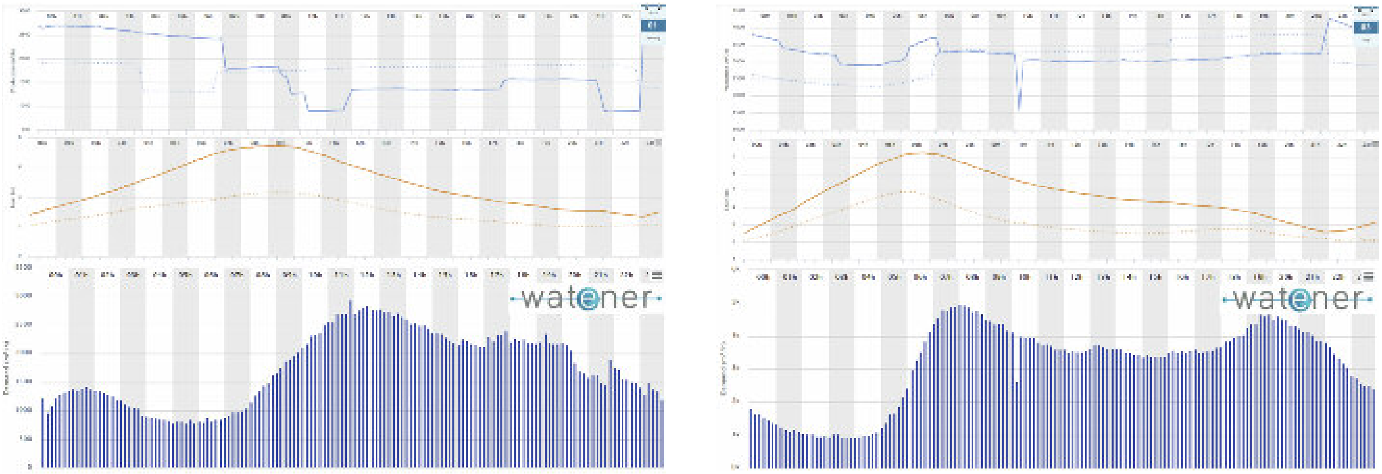


Figure 3. Minimum and maximum consuption days



energy saving and emission reduction, focusing on the following areas: (i) demand forecast of drinking water, (ii) management of the water storage tanks, (iii) pumping schedule of pumps feeding the network and, as a result, (iv) improvement of energy efficiency of the network pumps.

In this network, there are three main factors that can be used to adjust the energy efficiency. First of all, the water level in the main storage tank has a dominant effect on the entire network pressure. A lower water level reduces the pressure in the network and at the output of the water works' pumps, and it also increases the water output for a given energy use.
Secondly, it is possible to affect the energy losses by friction in pipes by maintaining the water velocity in the entire network close to the average velocity. This can be achieved by pumping homogeneous outflows in the water works, which causes less variable flow rates, lower pressure, lower friction and thereby lower energy consumption.

The third main factor is infrastructural; not all the pumps have the same energy efficiency. In most of the operational scenarios, using more efficient pumps increases the average energy efficiency.

Another important element not directly related to the supply network is the electricity tariff. The energy prices in Germany are most expensive from 8 am to 10 am and from 5 pm to 9 pm, and the cheapest ones are between midnight and 6 am. Regrettably, there is a coincidence between higher prices and higher water consumption periods.

In the daily operation before WatEner, the storage tank was filled during night time to benefit from the lower energy prices and fed the distribution network during the day to supply the water demand and avoid pumping during periods of higher energy prices. Also, the pump schedules were created in real time by the water works operators, reacting to the observed behavior of the system. The multi-criteria approach of WatEner was adopted to combine the effects described above to design new pump schedules which optimize energy and do not compromise the quality and level of service. Hereafter, the real effects of the new pump schedules are shown using three significant days of the year 2015: the 1st of January as the lowest water consumption day, the 3rd of July as a very hot summer day and consequently with the highest water demand and the 3rd of March as an average working day.
The Figure 2 depicts the average consumption day management, showing the scenario before optimization (solid lines) and WatEner optimized one (dashed lines). The optimized scenario recommends a pumping schedule where the evolution of total outflow is close to the average during all day and the main tank fills less during the night, avoiding losses by friction and overpressure. Against what would have seemed to be an adequate option, this enhanced scenario through a minor pumping during valley tariff provides an energy saving of 7.5% and cost savings of 7.2% and ensures that water and service quality remain constant and unaltered.

The minimum and maximum consumption days present a similar situation. The WatEner recommendation is to apply a pumping schedule which fills less the main tank during the night and feeds the network with a total outflow close to the average, providing a more efficient

Table 1

	Low demand (January, 1st)		Average demand (March, 10th)		High demand (July, 3rd)	
Consumption	42,200 m^3		54,500 m^3		75,000 m^3	
	Original	**Optimized**	**Original**	**Optimized**	**Original**	**Optimized**
Network pressure	Tank filled to 7.7m	Tank filled to 4.1m	Tank filled to 7.5m	Tank filled to 5m.	Tank filled to 7.4m	Tank filled to 4m
Losses by friction	14 switching operations.	6 switching operations. Outflow close to the average.	20 switching operations.	8 switching operations. Outflow close to the average.	12 switching operations.	5 switching operations. Outflow close to the average.
Energy efficiency	0.2263 kWh/m^3	7.6% lower	0.2237 kWh/m^3	7.5% lower	0.2300 kWh/m^3	6.2% lower
Cost efficiency	0.0379 €/m^3	7.7% lower	0.0374 €/m^3	7.2% lower	0.0385 €/m^3	6.0% lower

operation in terms of energy and cost. Also, water quality and service quality are ensured.

Table 1 summarizes the three scenarios; all the numerical data is extracted from WatEner KPI set. The energy cost reduction for the average consumption day is 147€ (7.2%). With this day as reference the platform saves, only taking into account water production pumping costs, 54,000€ and 334.34 MWh (7.5%) per year.

Conclusion

The size of the population served by a Water Utility, the energy costs and other factors related to particular situation/region, have a major influence on the return on investment (ROI) and water/energy savings that can be achieved with the next generation of ICT solutions.
This article described the implementation of WatEner in a medium-sized Water Utility (400,000 inhabitants) in Germany. In larger and megacities in developed countries, as well as in cities in developing countries too, the savings are expected to be quite similar as in the Northwestern Europe pilot.

Next generation of ICT tools foster a change in the operational paradigm of water utilities by dealing wit relevant matters from a different perspective, specifically by:

- Leveraging of previous investments in monitoring, modelling, GIS and other tools.
- Adopting a multi-criteria and holistic vision of operations. These tools facilitate the assessment of different management strategies in the supply network, improving the savings and preventing inefficiencies in the entire network.
- Dynamically adapting in real-time to the continuous operational issues that can happen in a water supply network, such as temporary halts or services restrictions in some parts of the network for maintenance or failure.
- Adding flexibility to provide useful recommendations, regardless of the technical monitoring level of the water utility.

In conclusion, through the analysis of the above illustrated obtained results, it is reasonable to affirm that non-structural solutions inr the operation water utilities can have a beneficial impact on several significant matters of our age, such as climate change and carbon footprint, as well as affect positively business balance sheets and the control of water losses, all within the range of a reasonable investment.

Acknowledgments

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