Real-time Monitoring Platform to Improve the Drinking Water Network Efficiency

SUMMARY

Recent advances in real-time water sensing technology have enabled new opportunities for improved assessment and management of water distribution systems. The implementation of WaterWiSe, a real-time, on-line hydraulic and water-quality monitoring system in Singapore is helping improve efficiency and maintaining supply standards across the water distribution network. As its primary data source, WaterWiSe uses a network of integrated multi-sensor probes that transmit data in real-time through wireless sensing nodes from within a pipe network.

The WaterWiSe multi-sensor probe (Figure 1), jointly developed by Visenti and YSI (Xylem) measures several parameter types: pressure, acoustic (hydrophone) and water quality (pH, ORP, Conductivity, Temperature, fDOM & turbidity). It is directly inserted into the flow on pressurized pipes within the network through standard tapping points.

Water quality data (Figure 2) is typically sampled and transmitted at 5 minute intervals and pressure and acoustic data is sampled at higher rates (hundreds of Hz). The deployment of these multi-probes at optimal locations allows long-term, real-time, in-situ water quality and hydraulic measurements that enable applications such as rapid on-line leak detection and water contamination event identification.
This paper illustrates, through several case studies, how the WaterWiSe sensors deployed in Singapore have provided important information on the system’s hydraulics and water quality dynamics. This has helped improve energy savings, allowed detection of system inefficiencies, and enabled improved decision support for system operators.

**INTRODUCTION: The WaterWiSe Technology**

This paper presents the deployment of an integrated system called WaterWiSe™ for Non-Revenue Water (NRW) Management and improved Operational Efficiency. At the heart of this system sits a comprehensive data management and analytics engine that provides the necessary data archival and processing facilities to various business intelligence applications built on top. The entire solution suite is Cloud-enabled; that is, it can be either deployed on one of the state-of-the-art Cloud platforms, or it can be installed on premise within utilities' data center as a private Cloud.

The NRW management application of WaterWiSe comprises a comprehensive set of tools that help track sources of NRW as follows: (1) at the transmission system level (transmission lines, reservoirs & tanks); (2) in metered areas through water balance; (3) on pipes within the distribution system using high-rate pressure transients; and (4) at the customer level using automated metering solutions (AMR/AMI).

The operational efficiency application of WaterWiSe helps to address the water utility’s most common pain points and take actions in response to NRW, Asset Management, Operational & Energy Efficiency and Water Quality deterioration issues. These include: 24/7 pipe-burst and water-quality-event alerts sent to the relevant utility engineers; live hydraulic state estimation of the water network; realistic valve, pump & water-customer scenario-simulations for impact assessment & capacity planning; and pumping system optimization for reduced energy costs and improved water quality.

The WaterWiSe Cloud-enabled solution is a scalable and extendable system for managing various types of data. It provides support for data from various sources such as customers’ meters, flow meters, pressure sensors & water quality sensors; it supports a large number of existing data standards. Ability to seamlessly add a new sensor/data source; it allows Integration with SCADA systems for data acquisition; and it can be integrated with GIS data sources such as ESRI, Google Maps, Leaflet etc.

The data analytics platform (see the user friendly interface below in Figure 3) comprises a comprehensive suite of data mining and hydraulic network simulator engines. This allows rapidly...
implementing additional analytical applications based upon customer requirements using a pool of sophisticated domain-specific algorithms written by leading industry domain experts.

The WaterWiSe sensing technology shown below (in Figure 4) includes two types of sensors: (1) high rate pressure sensors and (2) multi-probes combining the pressure and hydrophone measurements with the YSI/Xylem water quality sensors to monitor parameters such as conductivity, temperature, pH, ORP and turbidity in pipes throughout the distribution network. All sensors are connected to the WaterWiSe™ software and data analytics system and help utilities identify water contamination, detect leaks & valve malfunction, and predict customers’ water demand.

Figure 3: WaterWiSe™ User Friendly Interface

Figure 4: WaterWiSe™ Sensing technology
APPLICATIONS

The WaterWiSe™ Platform NRW Management tools

1) Pressure transient based leak detection & localisation: WaterWiSe™ includes a state-of-the-art system that uses high rate pressure transients to detect pressure anomalies within the distribution system. Unlike acoustic-based leakage detection methods that are effective only at quiet hours of the night, the WaterWiSe™ leak detection system operates 24/7, in real-time, and provides notifications on leaks and bursts locations through interactive user-friendly dashboard, SMS and Email. The system makes use of optimally placed high-rate pressure sensors on the distribution pipes and analyzes this data in real-time to detect anomalies.

2) Pipe isolation impact analysis: the WaterWiSe™ network operations' simulator provides a tool for running a “what-if” scenario once a pipe leakage has been detected and localized. This tool is used to identify critical valves needed to shut-off in order to isolate the affected pipe. In addition, it identifies the customers that may be affected as a result of this isolation.

3) On-line SCADA/AMR-based NRW Management: the system learns the flow and customers’ consumption patterns and determines the expected consumption on various trend scales such as daily, weekly, monthly, seasonal and yearly. Sophisticated statistical algorithms are then applied to determine anomalies in the flow/consumption patterns that can provide important information related to water loss at the customer premises.

4) Transmission pipes condition assessment: By learning the pressure profiles of key water mains in the distribution system, WaterWiSe™ builds a picture of characteristic transient signatures that help in classifying them with respect to severity (i.e., transients that are indicative of deteriorating pipe wall conditions and degradation of the inner pipe linings). This is used to identify and notify on “hot-spots” within the transmission system, where there is high probability of a future leak due to the degraded pipe conditions.

5) Pressure management: The quantity of leakage from a water distribution system is related to system pressure. Hence, reducing pressure during off-peak hours can reduce leakage. Pressure reduction can be accomplished through valve operation (using PRVs). The WaterWiSe™ system supports PRV operations by monitoring, simulating, and predicting the impact of the valve operation on pressures across the water distribution network.

The WaterWiSe™ Platform Operational Efficiency Tools

1) On-line water demand prediction: WaterWiSe™ provides water demand projections for customers within the water distribution network using a predictor-corrector procedure. This procedure incorporates the online data generated by consumer meters, pressure & flow sensors (15 min averages) and SCADA data from the service reservoirs, pumping stations and/or pressure & flow control valves. Thereafter, the prediction model also assimilates historical trends, weekly patterns, weather conditions and seasonal information (holidays etc.) in order to make rolling predictions of consumption for the next 24hrs period. The predictions are validated through comparisons with actual on-line measurements.

2) Live hydraulic simulation and impact assessment: the system provides a live interactive GIS-based simulator tool that exposes network assets such as pipes, valves, pumps, tanks and bulk meters with associated details. An operator can make changes in the network such as adding new demand in certain parts of the network, and then simulating the impact of new customers on the pressure and flow in the water supply network. The operator can also alter valve or pump configurations (open,
shut), or change pipe diameters to simulate network upgrades and assess the consequential pressure and flow in the network. The impact report can be used for decision support, before carrying out the actual operations in the field.

3) Dynamic Virtual DMA formation & analytics: the WaterWiSe platform provides an automated system for simplifying complex supply networks into virtual DMAs (Demand zones). This enables identifying a manageable number of supply zones and, if well defined, can be used to create actual DMAs by instrumenting the inlets and outlets of the virtual DMA with flow meters. It provides information about each virtual DMA in terms of demand, inlet and outlet points and valves that can be controlled to isolate the virtual DMA in case of water contamination.

4) Pump schedule optimization: in systems where water is pumped to consumers or storage tanks, the WaterWiSe™ platform can be implemented to reduce energy costs and improve water quality by optimizing the pump operation schedule based on electricity tariffs, pump efficiency, predicted consumption and water quality requirements. The tool is integrated with the utility operators who implement the pump schedules according to rules determined by a pump optimization algorithm that is driven by accurate water demand predictions and variable price tariff for energy use. The WaterWiSe™ system verifies through sensors and SCADA data that the pumps are operating according to schedule and that hydraulic and water quality constraints are met.

The WaterWiSe™ Platform Water Quality Management Tools

1) Water quality anomaly detection: the WaterWiSe™ system monitors the on-line water quality data, collected by the WaterWiSe probes or any other water quality sensors, to identify threshold violations and to track abnormal variations in the water quality data that may indicate the presence of water contamination or ineffective water disinfection.

2) Water age & source tracing: using the live calibrated hydraulic simulator, water age in the system is predicted and compared against the real-time water quality measurements being taken in the system. This helps to identify areas of high water age that may be of concern due to the expected low disinfection (e.g. chlorine) level. The mixing of water in the system from different reservoirs can also be predicted and visualized, showing relative percentages of water sources at any given location over user-defined time periods.

CASE STUDIES

The following paragraphs provide details of two selected WaterWiSe™ applications that were implemented successfully in Singapore since early 2013.

Leak/burst detection & pressure monitoring in Singapore’s Central Business District water supply network

Singapore’s National Water supply agency (PUB) implements the WaterWiSe platform’s integrated leakage detection & localization tool in the complex network of downtown Singapore. The network delivers 40 MLD to approximately 0.5 million customers. The network comprises of 550 km of pipelines and spread around an area of 60 Km². The system comprises of 35 pressure-monitoring/leak-detection devises in strategic locations around the network and implements a leak detection-localization system that manages pressure data streams, performs real-time analytics and sends SMS and Email notifications in real-time to the relevant field teams so that they can prioritize their response based on the event severity and respond quickly to the events to minimize negative impact on consumers.
Since its implementation in April 2013, the system has already detected several critical pipe bursts as shown above in Figure 5. In these events, it has been able to localize within 20 meters of the actual location. The user friendly system has also shown a potential to give early warning ranging from a few hours to a couple of days, before the water turns up on the surface.

**Demand forecasts and Pump optimization in the Queenstown supply network in Singapore**

Since March 2013, PUB operators have been implementing the WaterWiSe™ pump schedule in the Queenstown supply network. The schedule applies rules determined by a pump optimization algorithm driven by accurate water demand predictions and electricity price tariffs. The Queenstown water network is comprised of 50 km of pipelines delivering 10 MLD to 150,000 customers located on high grounds. Three booster pumps capable of pumping up to 1.8 MLD each are used to deliver water to the customers and to a large storage facility with max storage of 17 MLD. The pump optimization system (see the user friendly operator dashboard shown below in Figure 6) verifies in real-time through sensors and SCADA data that the pumps are operating according to the optimal schedule and that hydraulic and water quality constraints are met. The results thus far have shown 20% savings in energy costs. In addition water quality has improved, registering an increases of about 0.3 ppm in Chlorine concentration on average at the outlet of the storage tank. This pump optimization solution has also contributed to the reduction in Non-Revenue Water (NRW). Since water leakage is proportional to the pressure in the pipes, pumps were adjusted to supply adequate and not excessive pressure. The pressure adjustments were verified by Visenti’s on-line pressure measurements at critical locations within the distribution network. The 10% reduction in excessive pressure through improved pumping operation has contributed to an estimated reduction of 5 to 10% in background leakage rates.

![Figure 6: On-line pump schedule optimization](image)