



PROCESS INSTRUMENTATION

How Digitalization Can Boost Natural Disaster Resiliency in Municipal Water and Sewerage Treatment

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Digitalization of the municipal water treatment industry is fragmented today, with instrumentation, control, and automation technologies mixed with manual operational activities. While such infrastructures can be sub-optimal in their efficacy, efficiency, and visibility, they can be detrimental to community and environmental health and well-being in cases of hydro-geological events, such as severe storms and earthquakes. The good news: When natural disasters strike, digitalization can help get municipal water treatment back online quickly and effectively.

■ Addressing resiliency in water treatment and delivery

Wastewater treatment and delivery are core to public health and to the world's water industry, which is expected to reach nearly \$915 billion a year in size by 2023.¹ With the ever-increasing population and urbanization around the globe, both are vital capabilities under continuous capacity and budget pressures — not to mention aging infrastructure.

As such, the resiliency of water treatment and delivery facilities and capabilities in the face of natural disasters that are growing in frequency and intensity is a critical concern.

Unfortunately, despite the nearly trillion-dollar size of the global water market, the rate of investment is considered to fall far short of what's required to maintain the current status of this critical infrastructure, while also keeping pace with growing demands of rapid urbanization, environmental protection, and climate change.²

For example, according to the United Nations, 55 percent of the world's population lives in urban areas as of 2018, growing to 68 percent by 2050.³ Given current population projections, that means 2.4 billion more people will be urban dwellers in the next three decades. The same report projects that 90 percent of the U.S. population will be urban-dwellers by 2050.⁴ And, in the U.S., municipal water issues are significant, as Siemens' own literature explains:

“... municipalities lose about 6 billion gallons of water to leaks every day, and inefficient energy practices result in excess energy costs of up to 30 percent. The nation’s aging infrastructure includes over 2 million miles of water distribution pipes, most past their life expectancy. With up to 240,000 water main breaks each year, plus smaller breaks, up to 14–18 percent of total water distribution is lost”⁵

Those pressures further compound the uncertain ability of water treatment plants (WTPs) to rebound after natural disasters, especially given the increasing frequency and intensity of weather-related events. So-called “500-year” monster floods, hurricanes, tornados, fires, and droughts are occurring in multi-year cycles, not century-long ones. The 14 WTPs of New York City, for example, suffered \$95 million in damage from the flooding storm surge of 2012’s Hurricane Sandy, prompting the city to put one of the world’s first water resiliency plans in place, backed by a \$20 billion infrastructure-hardening fund that aims to counter the effects of climate change.⁶

So, given these circumstances, what does water treatment and delivery resiliency mean? And how can it be strengthened? One definition that’s considered to be widely accepted in the industry UK’s Ofwat Resilience Task and Finish Group comes this:⁷

“Resilience is the ability to cope with, and recover from, disruption, and anticipate trends and variability in order to maintain services for people and protect the natural environment, now and in the future.”

The good news is how advanced technologies — such as the Siemens Smart Water platform, especially the SIWA water decision support system — are helping water customers worldwide to modernize their treatment and delivery infrastructures while improving efficacy, efficiency, visibility and, yes, resiliency.

This paper aims to help readers understand how advanced technologies for electrification, automation, and, especially, digitalization can help water and waste water operators ensure their resiliency as a measure of how quickly they can restart their treatment processes and deliver water services to their customers.

■ Key digitalization technologies that are transforming WTPs, improving resiliency

Digitalization’s potential for water resiliency draws from a combination of key technologies: smart sensors/instrumentation, digital twins, the industrial Internet of Things (IIoT), cloud, advanced analytics/artificial intelligence, lifecycle management, and cybersecurity. What follows are more specific details on each, with examples from Siemens portfolio to illustrate their application in solutions available today.

■ Smart sensors, instrumentation, and controls

These devices take sensing inputs from their physical surroundings and, when detecting specific conditions, can initiate pre-determined, field-level functions via built-in computing capabilities.

The latter include edge-based, pre-processing of data, relaying only significant and actionable intelligence, such as KPIs that exceed their parameters or behavioral anomalies to higher-level distributed control systems. Alerts can be issued, so operators can take steps to mitigate or remediate



SIWA Optim

the causative issue. Sensors and instrumentation can be self-calibrating, too, and feature self-diagnostics, which can be accessed via their communication features.

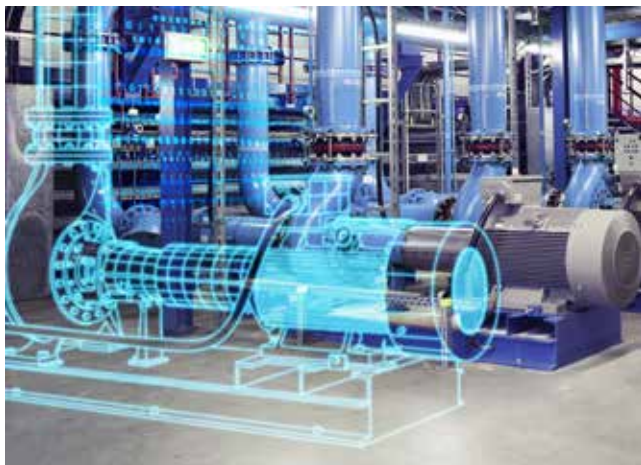
In case of a disaster, smart sensors, instrumentation, and controls are designed to be robust in an aggressive environment. Sensing elements are hermetically sealed and are even safe to use in hazardous environments. Industrial smart sensors and controls can be fully protected to provide front-line visibility to WTP operating conditions. This can help operators to triage their efforts to get their WTPs back online in the fastest possible timeframe.

Siemens offers three solutions that can help WTP resiliency — along with day-to-day efficiencies — especially when connected to higher-level, industrial control systems (ICSs) such as SIMATIC PCS 7 distributed control system (DCS), S7-1500 programmable logic controllers (PLCs), and WinCC SCADA and HMI visualization software:

□ **SIWA OPTIM:** This highly scalable management system that supports the operation of (remote) water supply systems. With the objective of minimizing the costs of obtaining energy and water, SIWA OPTIM calculates the most economical pump, well and water tank schedules. Supply reliability and system reliability and availability are ensured at all times. Schedules can also be designed for different scenarios, for example, emergency operation management, maintenance planning, the development of planning variants for conversions or new buildings, or the procurement of backup units. It helps ensure the efficient use of energy for operating pumps and pumping stations. It also assists plant operators in selecting pump sets and setting their speeds, so both fixed- and variable-speed pumps can achieve their optimal efficiency. Customers have reported energy savings up to 15 percent using SIWA OPTIM software.

□ **SIWA Leak:** With this system, water delivery operators can detect medium and small leaks promptly and accurately to the nearest meter. The sensitivity of the system can be optimally configured by setting the parameters accordingly. In order to also detect slow leaks, SIWA Leak combines a series of commonly used methods and processes, such as flow-volume and pressure-drop analytics. Its algorithms take into account pressure, flow, and temperature as the most important KPIs. If an earthquake or some other geological event disrupts a municipality’s sewage or water delivery infrastructure, this technology can help determine much sooner where new leaks may have occurred, so they can be addressed to minimize lost revenue.

■ **SIWA Sewer Management System:** With its special software component library, the SIWA Sewer Management System can be adapted to any existing sewer network. A digital process connection can facilitate the creation of a high-performance ICS that can be integrated into existing automation solutions with relative ease. This gives operators the visibility and actionable intelligence to help them by controlling valves, pumps and weirs on the basis of current measurements of precipitation, water level and discharge. It also enables them to react more quickly and appropriately to external events, such as storm-water incidents, to ensure optimal utilization of capacity and minimize or eliminate overflow discharges into natural water bodies.



■ Digital twins

Digitalization is quickly dissolving the boundaries that exist between the physical systems, processes, and operations of WTPs and their digital twins, starting with their 2D and 3D designs developed in software CAD applications. Simply put, a digital twin is a virtual proxy for each of a WTP's assets, and it can be extended to model and simulate the operation of an entire WTP. In use, it can help operators to understand, predict, and optimize WTP performance in order to improve plant-wide treatment efficiencies, including reducing energy use. Digital twins can be used for WTP resiliency planning by simulating "what-if" scenarios that would be difficult if not impossible to model otherwise. Siemens water solutions that can leverage the digital twin concept are:

□ **SIWA Concept:** This software calculates the hydraulic behavior of water supply systems, taking into account dynamic information from all measurement points to illustrate complex correlations and flows. Scenarios can also be analyzed with different hydraulic behaviors or alternative automation models. By enabling automation functions to be tested without risk, SIWA Concept helps cut the time needed to design, engineer, and deploy the most cost-effective and safe automation concept. Use of the module also reduces the overall time and costs for engineering and commissioning. During a WTP's operating phase, operators can use the software to simulate the varied effects of different types of operation. These simulations also provide a way to evaluate proposed plant expansion projects or capacity adjustments needed to improve plant resiliency.

IoT Case Study Snapshot



Customer: Georgetown Utility Systems, City of Georgetown, Texas; 30 miles north of Austin; population 52,300.

Challenge: Cost-effectively connect remote water treatment sites with faster, more reliable data transmission capable of withstanding the extreme heat of Central Texas summers.

Solution: Deploy high-performance Siemens RUGGEDCOM WIN technology to augment the city's mission-critical broadband network with licensed 4.9 GHz wireless capability.

Results: An extremely reliable, future-ready, high-bandwidth wireless network, with thousands of dollars in labor cost-savings along with hundreds of thousands of dollars in cost-avoidance.

□ **SIWA OTS:** This application provides an effective training tool for new operator staff. They can use the software to prepare offline for the various operating sequences of a WTP and learn the correct procedures for responding to extreme situations without affecting the actual day-to-day running of the WTP or a provider's water supply. This can help WTPs and water supplier personnel be part of a resiliency action plan, as they will know what to do should a natural catastrophe occur. As a training tool, SIWA OTS can be used in a virtual commission phase of new-build WTPs or expansions, ahead of the actual project completion.

■ Industrial Internet of Things (IIoT)

Connectivity is at the core of the IIoT with the IIoT a specialized subset that can link field-level devices to higher-level systems — whether the latter are on-premise or in the cloud — for processing data. Increasingly, this connectivity is wireless at the field level, but can also involve legacy wireline or require wireline communications for backhaul applications.

Wireless communications with SIMATIC S7 PLCs at pumping stations, which are frequently remote and below surface levels, can be facilitated by Siemens SCALANCE and RUGGEDCOM switches and access devices. These can be housed in waterproof cabinets inside the pumping stations, with their antennas elevated to provide communications back to a central system management location.

In cases of natural disasters, such IIoT configurations can help to provide critical status reports of pumping station conditions, so WTP operators can gain better situational visibility and intelligence, so they can prioritize their response most effectively. Communication protocols can include IEEE 802.11 Wi-Fi, 802.16 WiMAX, 4G LTE cellular, and, if necessary in especially remote locations, satellite communications.

WTPs can increase their resiliency by deploying private networks that use SCALANCE or RUGGEDCOM Wi-Fi access points as repeater relays or WiMAX long-distance wireless technology. This way, operators can reinstate communications across their pumping footprint potentially faster than the public networks can re-establish their communications.

■ Cloud platforms

Modeled similar to electric utilities, the cloud provides a combination of computing, storage, networking, cybersecurity and application utilities, all on a pay-as-you-go basis, with virtually unlimited, on-demand scalability. For WTPs and associated pumping stations, cloud-based SCADA systems can be impervious to extreme weather events, floods, earthquakes, and other natural disasters.



Hosting options for such systems include Siemens MindSphere, the cloud-based, open IoT operating system designed for industry. It can provide a secure and turnkey platform-as-a-service (PaaS) that is available on either Amazon Web Services (AWS) or Microsoft Azure hosting. One of the key benefits of using MindSphere as the hosting PaaS instead of employing AWS or Azure directly is that Siemens stands behind it as a single source for procurement and support. Another is that Siemens understands the rigorous demands of industry.

For secure remote access to the a WTP's SCADA or higher-level ICs, Siemens offers the SINEMA Remote Connect (RC) server, which can also be hosted in the MindSphere PaaS. It's easy-to-use and offers end-to-end connection

management of distributed networks over the Internet. This includes secure remote access to underlying networks for maintenance, control, and diagnostics purposes.

Communication between SINEMA RC server and remote users is via VPN tunnels governed by stored access rights. Connections are encrypted via OpenVPN and TLS 1.2. within the VPN tunnel, communication uses the TCP or UDP protocol. The SINEMA RC Server can be configured via its web-based management (WBM) tool. The connection via the Internet/WAN to the WBM uses the HTTPS protocol for extra security. To establish a connection to the WBM of the server, multifactor authentication is now in standard use.

In all cases using Siemens MindSphere, data in transit is always encrypted using the latest SSL algorithms TLS 1.2. Data at rest is stored on high-performance servers in data centers that meet the highest standards for data security, protected against cyberthreats and natural disasters.

Siemens MindSphere also offers a MindApp, which can provide WTP operators with the ability to remotely monitor the activity and health of their process measurement equipment without the need for SCADA systems or other process control solutions. Using Siemens MindSphere, information can be uploaded to the cloud and then used to provide WTP operators with real-time monitoring of multiple assets, retrieving real-time data from multiple remote sites for users almost anywhere, anytime. In addition, users of this MindApp can receive alarms, alerts and notifications without delay, sent directly to their tablet or phone if they prefer.

■ Advanced analytics/artificial intelligence

Of course, maximizing WTP and water delivery resiliency depends on having systems and equipment well-maintained at all times, because poorly maintained equipment can break down under the additional stress storm waters can bring. That's where analytics of WTP sensor data coupled with artificial intelligence (AI) can play an important role.

Analytics using AI can reveal performance anomalies and deviations from expected system behavior patterns that could otherwise escape human cognition. Data fuels the AI algorithms so they can "learn" and refine themselves (i.e., machine learning) to continually improve the performance of the AI algorithms. By doing so, alerts can be sent to operators — along with actionable intelligence — so they can make informed decisions about mitigating or remediating issues before disruptions occur.

What's more, this approach can enable the use of condition-based maintenance, which dispenses with scheduled maintenance in favor of maintenance when assets need it. This can greatly simplify WTP maintenance activities and save costs without putting treatment and delivery assets at risk.

■ Conclusion: Time to act is now

Making digitalization real — and realizing its benefits and competitive advantages — is a journey best taken in steps. The good news is that needed technologies are no longer the exclusive domain of large municipal WTPs, but now within reach of small and medium-size WTPs and water delivery systems, thanks to scalable, pay-as-you-go, cloud models that use open standards. It does require rethinking workflows/processes to really capitalize on opportunities for operational improvements and resiliency.

Cybersecurity — Always a Top Priority



Because the water industry is a critical infrastructure and cyber threats are always increasing in frequency and sophistication, it's key that both WTPs and water delivery systems be monitored 24x7x365.

The Siemens industrial security concept is based on a multi-level "defense in depth" model based on the recommendations of IEC 62443, the leading standard for security in industrial automation. The cybersecurity concept protects all the relevant levels simultaneously — from the plant management level to the field level and from access control to communications security. It includes plant security as well as network security and system integrity, hardening plant security and reducing vulnerability risks.

Greater resiliency in the face of natural disasters is one of the biggest benefits of the digitalization of WTP and water delivery infrastructure. Chances are, today's operating models that mix instrumentation, control, and automation technologies with manual activities will find it difficult to rebound from hydro-geological events. With greater end-to-end digitalization of their entire WTP operations, water managers can plan to recover much more effectively and quickly should major disruptions result from extreme weather or geological events, such as earthquakes.

But WTP operators don't have to wait until disaster strikes to reap the many other benefits of greater digitalization. From the initial deployment of the types of digitalization technologies and going forward, they can achieve significant savings in energy and other operating costs as well as staff time. They can also realize much more operational visibility and fewer day-to-day disruptions. Digital leak detection can also recover lost revenue and improve margins.

Given the types and availability of the technologies described in this paper, digitalization has never been more affordable or practical to be within reach of WTPs and water delivery systems of all sizes. While disaster contingency planning to improve resiliency is certainly a necessary and worthwhile effort, the improvements in day-to-day operations via digitalization investments made today can pay for themselves in a few short years. And yet, from day one of that payback period, digitalization can help the operators of WTP and water delivery infrastructure be much better prepared to deal with natural disasters than ever before.

¹ "Global Water Market Forecast, Updates for 2018-2023." *Global Water Intelligence*. <https://www.wateronline.com/doc/global-water-market-to-reach-b-by-as-oil-gwi-forecasts-reveal-0001>

² *IBID*.

³ *World Urbanization Prospects: The 2018 Revision*. United Nations. <https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf>

⁴ *IBID*.

⁵ "The Cost Of Water: Leak Detection, Economy Pumping And Dosing." *Siemens Process Instrumentation*. 2018. <https://www.wateronline.com/doc/the-cost-of-water-leak-detection-and-economy-pumping-0001>

⁶ "What China Can Learn from New York City about Wastewater Management," by Danielle Neighbour and Gillian Zwicker. *Scientific American*. March 8, 2019. <https://blogs.scientificamerican.com/observations/what-china-can-learn-from-new-york-city-about-wastewater-management/>

⁷ *Resilience Task & Finish Group Final Report*. 2015. UK Water Services Regulation Authority (i.e., Ofwat, formerly Office of Water Services.) https://www.ofwat.gov.uk/wp-content/uploads/2015/12/rpt_com-20151201resiliencetaskfinish.pdf

Legal Manufacturer

Siemens Industry, Inc.
100 Technology Drive
Alpharetta, GA 30005
United States of America
Telephone: +1 (800) 365-8766
usa.siemens.com/pi
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