IoT Augmented Industrial Water Treatment

A dynamic and evolving landscape of connected technology presents a daunting opportunity to revolutionize the way we manage water treatment. With current technology, it is possible to know immediately when there is a system upset. Most new equipment is either equipped with connectivity standard or have an optional upgrade. This wave of connected devices presents a future where online visibility to all your system parameters are at your fingertips. The price point of connected equipment is decreasing, and the number of available connected options is increasing. Meanwhile, the cost of labor is going up, and the supply of labor is scarce. The following will analyze current state conventional water treatment methods, highlight some existing IoT (Internet of Things) augmented water treatment methods and project theoretical use cases and future IoT water treatment models leveraging connected devices to either optimize workflow or heighten quality control.

Origin of Networked Industrial Water Treatment Controllers

Interconnected controllers predate to the 1990s. Pulsafeeder's MCT210 in 1991, with the L2 option, was capable of interfacing with a networked computer through an analog modem. Also, a software suite called PULSAworks allowed users to access real-time system values by remotely changing operating parameters, viewing historical data, and even receiving a call out in the event of alarm conditions. The percentage of controllers sold with connectivity in the early 90s was around 5% due to the large costs associated with getting equipment networked, as well as the added cost of modems and need for a clean analog line. The equipment sales were simply pre-purchasing the communications functionality for future connectivity of which was rarely leveraged. Over the years, these previously premium and costly functions became more cost competitive. For example, analog wired connections became reliable digital connections which can either be wired or wireless. Less reliable, one-way protocols were even replaced with complete communication stacks; however, these initial improvements led to lackluster market adoption and diminished the value sell proposition of the platform. First generation networked controllers were also point-to-point communications with limited access to a single controller at a time. Building out multiple processes at a specific location was often time consuming and extremely cumbersome. These were groundbreaking features in this market, but it was still not enough. The introduction of first-generation interconnected controllers did not exhibit any noticeable market push on water treatment. The reliability, scalability, capability, and overall installed cost all needed to significantly improve to drive adoption rates.

Current State of Networked Devices

Most middle market industrial water treatment controllers are still not actively networked. Much of the existing installed infrastructure is simply incapable of managing a network stack and connecting to the internet. Newer middle market controllers in the last 10 years can handle all these protocols and more: Modbus, BACnet, and the full TCP/IP stack to get on the internet. Depending on the equipment and the manufacturer, systems can either interconnect with an optional communications card or remain standard with the base controller. Additionally, cellular modems can get process controllers online without relying on the customers' ethernet connection. The price point of online capable devices has decreased, the value proposition of the online capabilities has improved along with the demand for connectivity options. Depending on how you define middle market industrial water treatment, still only about 40% of new controllers sold in 2020 are equipped out-the-door with networking functionality, and a much smaller percentage of these devices are ever networked. Approximately 4-5% of current state middle market process controllers are networked; however, several market conditions are forcing water treatment to leverage online connectivity. Some of these factors which are driving connected options include: competition, regulation, resource management, and customers.

Current State of IoT

Currently, there are several technophilic companies choosing to standardize on remote communications. These companies leverage cloud connectivity and the value add of online tools as part of their business model. To do this, they either build in the price of connectivity in their service contracts or apply it as a fixed overhead expense as an integral part of their operations. Some companies, either by choice or to stay within regulatory compliance, are forced to lean on connectivity. Largely as a response to heightened visibility to legionella, some regulations exist which allow for lesser testing intervals when treatment is subsidized with online controllers. Markets are also pushing to migrate to a connected equipment package due to competitive pressure, upselling services or compliance reasons. To remain in compliance, the market share of connected devices has been growing steadily, and within the next few years, the majority of sold controllers will have connectivity options standard with around 25% of new controllers expected to be persistently online.

In the last 5 years, regulatory entities have increased their supervision of evaporative cooling systems. The presence and risk associated with legionella has been a driving factor for more legislated oversight. This is leading companies to find creative ways to meet the heightened testing and reporting requirements. New York City is the most stringent area in North America for keeping open loop cooling systems compliant. For example, New York City Chapter 8 Title 24 requires performing routine manual water quality monitoring of temperature, pH, conductivity, and biocide concentration. To remain compliant, monitoring must occur at least three times per week with no more than two days between monitoring. This manual process is required unless it is automated. To replace the need for manual testing, reports from IoT augmented water treatment equipment can be used to stay in compliance instead. Without online visibility, facilities personnel would need to perform the testing, the number of required service visits would need to skyrocket, and the cost of a service contract increase to counterbalance labor elements. In this instance, many accounts simply upgraded all the water treatment equipment to online as well as have a dedicated online controller. This option was much easier than tripling your workforce overnight or reducing the capacity of the current staff.

While leveraging online connectivity and reporting is great in theory for automating an otherwise very manual process, reliability of this solution is paramount. In the real world, there are still some hurdles to overcome. If we shift our mentality to require online connectivity as an integral part of our business to manage our evaporative cooling systems, which is common in New York City to maintain regulatory compliance, then reliability becomes vital. We want technology and connectivity to synergize and augment our business as usual and automate what would otherwise be manual processes; however, Russell Baskin President of Tower Water has found out the hard way that this is easier said than done. “Several setup steps have now been added to our standard start-up procedure”, Baskin states as he reports the need to bring controllers in house for configuration prior to deploying on the field. Additionally, the pain point of establishing a cell modem connection and maintain it reliably over time is one more thing to manage as it commonly complicates installs. “Initial connectivity can require changing which cellular carrier the modem connects to or feeding long antenna wires up a few floors where there is better cell signal.” Since these installs depend on connectivity, Baskin has invested in several internal resources to develop fail safes and procedures to catch if a modem or controller were to go offline and stop reporting so they can quickly troubleshoot and keep their customers compliant with reporting requirements. He is constantly looking for smarter tools which work with his company and solve problems versus creating different problems. When everything is functioning as it should, these tools help move burden and unnecessary busy work out of the working day so they can focus on other aspects of their organization.

Another real-world application for leveraging IoT devices to augment water treatment is EVAPCO's Pass-Protect® Passivation Solution. EVAPCO 's proprietary process enables customers to put immediate heat load on a newly installed cooling system while preserving system longevity. The process itself is a two-step process: the first step is a factory applied pre-treatment and the second is a tightly monitored and controlled in-field passivation process. The in-field portion of the passivation requires site specific chemistry, a Factory Authorized local service partner, support from installing contractors, and EVAPCO's online feed and control panels. Remote monitoring of this process through Pulsafeeder's Pulsalink online portal allows for 24/7 visibility to critical system parameters during the infield passivation process to help EVAPCO and their Partners identify potential issues before they become problems.

The Partners work with Jamie Downie, Startup and Commissioning Specialist at EVAPCO Water Systems, to set up site-specific reports and alarms. Downie observes, "the response from our partners is that they like getting the daily reports to see how the passivation numbers are trending. The ability to see real time data reduces site visits and improves the passivation outcomes for our customers." This technology use-case adds a level of quality control to the critical passivation process and ensures, should any system upsets occur, swift corrective actions can be implemented prior to any system damage.

Theoretical Today Use Cases

Continuous innovation of industrial water treatment equipment presents a vast number of future possibilities. Today's largest water treatment issues can be completely solved by some future technology, and some of this technology already exists in either an adjacent market or at a higher price point. With current technology, it is possible to connect a cooling tower controller to the internet and receive routine graphical reports of key system parameters (see **Figure 1**). Additionally, an immediate notification can be sent to a smartphone, or as an email, about any system upsets, such as high conductivity. While simple knowledge is powerful, knowing that key parameters stay within desired ranges allows us to validate quality of service for self-verification, company quality control and a high service level to the customer. How else can we leverage data today? What are some improved workflows which use technology in today's state which allow for efficient use of all our resources? For a little bit of theoretics, if all our control equipment were online and reliably networked, could we fundamentally shift our service model? With complete transparency to all probe measurements, tank levels, water meters and more, it is simple to mine information from accounts prior to rubber hitting the road.

Figure 1: Example Controller Probe and Relay Data

For instance, an online controller goes into a high conductivity alarm. We get notified at 9:23 AM of the system upset. There are at least two distinctly different reaction scenarios. Firstly, we confirm the controller status online and check some basic program parameters: the controller programming, presence of flow, and relay HOA status. After observing the controller's information online, we notice the conductivity is indeed high and the controller has entered an alarm state as a result; however, the bleed relay is not currently energized. In a matter of seconds, we can deduce the bleed relay is in a lock out status and we have just fed one of our biocide timers. The controller is fully functional, but seasonal demand has changed, and the tower is cycling up faster than normal. Remotely, we can make some adjustments to the program to compensate for this seasonal swing by making minor tweaks to the pre-bleed and lockout settings on our biocide timer. One hour after the lock out period has expired, the bleed relay can open again, our conductivity goes back within range, and we get notified the alarm has cleared. We now have a more refined program and did not need to adjust our schedule to accommodate an emergency visit.

In another reaction scenario, when we check our high conductivity alarm, we might see the bleed relay has been energized for hours. Despite the continuously energized bleed valve, the conductivity in the process continues to rise. When the probe measurements do not match our control measures, we know there is something wrong, and we would like to notify onsite personnel and schedule an impromptu service visit to remedy the issue. Knowing the exact failure mode being troubleshoot and seeing the controller online prior to going onsite can ensure you bring the correct components to fix the issue the first time. With the right spare parts kit, you can pull in the timeline to remedy the issue and reduce burden involved. This accelerated responsiveness will help reduce company attrition rate, improve the percentage of time your chemistry is within desired control ranges, and fix most issues during the initial visit as opposed to making multiple trips.

All these measures impact a company's internal operations, such as account retention and human resource management. Keeping accounts and freeing up time are invaluable to having companies operate at their best. Nevertheless, these benefits still amount to customer hesitation. The upfront burden of modem costs, setup fees and the recurring data fees frequently seem difficult to justify. Additionally, the learning curve of figuring out a process and training your team to support connectivity can seem intimidating. These factors have stacked up to push a lackluster market adoption. On the other hand, many of the benefits of optimizing the controller programing is based on historical performance, and the cost impact of response time to the end customer is astronomical.

A simulation on a water treatment contract quantified is powerful since we can see the opportunity cost of not having online visibility to process control. To stay consistent, let us take the high conductivity example and run a simulation where we compare efficiency loss in a chiller as a function of response time. Statistically, without customer intervention, we will catch process issues at 50% of our service interval. Conversely, if we are notified of a high conductivity online, then we should be able to remedy the system within 24 hours of receiving the alarm. **Table 1** shows the system parameters of a computed simulated failure mode.

Parameter	Value
Frequency of Service	30 days
Cycle of Concentration Setpoint	3.5
Makeup Conductivity	150 μS/cm
Makeup Total Alkalinity	120ppm
Makeup Calcium Hardness	40ppm
System Tonnage	500
Drift Rate	0.05%
Cost of Power	15 c/kWh

Table 1: Sample Water Characteristics for Simulated Model

The cost of operating a chiller with these parameters, as featured in **Table 1**, for a year at 6,500 hours and a 70% average load during operation is approximately $220,000 a year. The difference in responding in 24 hours to system upsets versus 15 days is exorbitant for scale deposition. Deposited scale will indefinitely add to chiller inefficiency until removed, which typically involves some level of system shutdown. Responding within one day leads to less than one mil of deposition in our simulated example, and conversely responding in 15 days to this upset leads to over 1/64th of an inch of scale deposition (see **Figure 2**). This would cause your chiller to be 16.2% less efficient and likely lead to other various issues within the evaporative cooling system. Within the 15-day span alone, your customer would spend ~$1,200 more in energy. Should the scale stay on the chiller tube over the course of a whole year, it would cost an extra $35,640 per year to run that 500-ton chiller. The interesting aspect of this simulation is scale does not deposit immediately. The LSI needs to be in a scaling state for some time before the point of nucleation begins, then scale will ramp up the speed of deposition until the flow of the water in the chiller starts breaking off the deposits. The rate of deposition drops off asymptotically. The key difference is response time. A detailed view of the math used to power this tool can be found at: https://ewatermark.net/murphys-law-of-scaling-up/. This is a great example of a value-add service as online visibility can remove burden from customers and empower them with visibility to the process to ensure better quality control of the water treatment program.

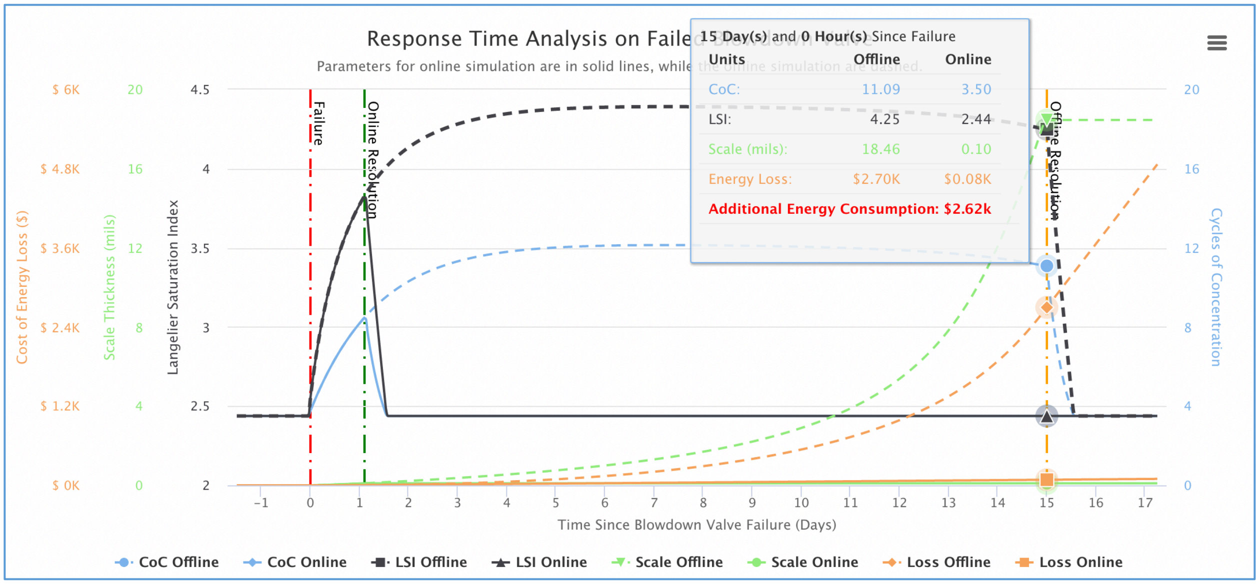

Figure 2: Graph of Example Simulation

Future Market Needs

Current state water treatment control technology is just the tip of the iceberg. While there is a lot we can do today, several innovations will need to follow suit to improve this platform. Metro Group on the eastern seaboard have been working with online controllers for over six years. For Metro to comply with State and local regulations in New York, online visibility and reporting is convenient and has even become necessary for some clients. Although of course, the equipment is only as good as its ability to measure important species in water. While some probes like a toroidal conductivity probe are extremely robust where measurements do not drift over time, industry standard pH and ORP probes degrade and require eventual replacement. Vinny O'Reilly of The Metro Group believes sensor electronics still have a way to go to meet the market needs since current probes are either relatively cheap and require more frequent calibration and replacement, or they cost too much for the market to bear. When you need to make water treatment decisions based on your online controllers' capabilities, you must be able to trust that your probe readings are accurate.

Conclusion

The power of future state process data on a large scale specific to water treatment systems is exciting. Today, technology can lead to incremental process improvements and optimizations which will spread over all the accounts we manage. Water and energy are both valuable resources. As water treatment professionals, equipment manufacturers, and chemical blenders, we can make a massive difference to the use of these resources. The amount of energy and water we are responsible for as an industry is astronomical, and it is a moral obligation to police the efficient use of them. Who knows what exactly the future looks like? We might have predictive failure analysis for systems performed on the cloud side. Merging of data between a chiller and its efficiencies and the water treatment program. A simplification of connectivity process and more and more smart devices managing processes. These advancements will compound all the time and raise the bar of industrial water treatment and expose opportunities in the marketplace. We are at a critical time in water treatment. Enforced regulations are trending to become more stringent. Our labor pool shortage and rising cost of talent will either force an increase in the cost of services or force innovation to efficiently use what resources we have. As the technology price continues to drop and connectivity becomes more affordable and streamlined, the opportunity for upselling services and removing complexity from the current status quo will be interesting to watch unfold. Whatever the future looks like or becomes, IoT will play an integral role in the next evolution of water treatment.