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The Water Reclamation Facility of the Future

and the Role of Instrumentation and Process Control

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THE FUTURE STATE OF THE WATER RECLAMATION FACILITY IS STARTING TO TAKE SHAPE.

The re-designation of plants from wastewater treatment to water reclamation underscores the shift. The elements of change are clear: a focus on nutrient removal and recovery, net zero energy and greenhouse gas emissions, carbon management and microconstituents. Beyond specific water quality initiatives, utilities are also being challenged to do more with less, to step beyond effluent compliance, and to improve ratepayer value. In response to these needs, groundbreaking projects and innovations highlight the new business state for the water utility.

For water reclamation facilities, there are three new 'criticals' to meeting these new challenges: right-sized equipment, smart automation and real-time asset management. To some extent, each of these items are being addressed today. So, why are these same elements are still denoted as new 'criticals' for the future?

Right-Sizing

Historically, right-sizing has been singularly focused on future design capacity. The investment to build a water reclamation facility is significant. The financing platform for these facilities requires a long-term view of capacity. For the designer, the physical plant needs to have a service life that extends beyond the financing term for the facility. Right-sizing for capacity, while sufficient in the past, no longer meets the needs of the industry. The advanced biological processes that are being developed and employed today to meet the new treatment objectives are highly specific and require optimal process conditions at all times. This new requirement now means that right-sizing include turn-down capabilities. Without this capability, operations cannot deliver optimum performance from start-up to current conditions, and through ever-changing future loading rates.

From a design perspective, the tools for turn-down right-sizing are currently not available. Historically, right-sizing for capacity did not require precise design tools. Standard industry models were considered more than sufficient for capacity right-sizing. Moreover, state design guidelines often contain conservative sizing requirements. This further amplifies the gap in right-sizing.

The operational specificity for the modern water reclamation facility requires continuous, real-time process optimization and operational support. This level of operational precision and support is beyond what can be cost effectively and physically accomplished with manual operations. On the other hand, standard industrial controls require regular retuning to maintain the level of automation precision and accuracy required for intended process performance; still remaining inefficient and operationally complex.

Similar to the impacts on equipment right-sizing, the real-time operational demands of the modern water reclamation facility directly impact asset management protocols. The new challenge for asset management programs are the instruments and the uptime of control equip-

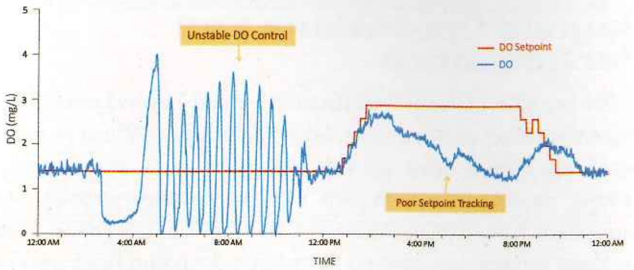


Figure 1: Performance of a Standard Industrial Control System.

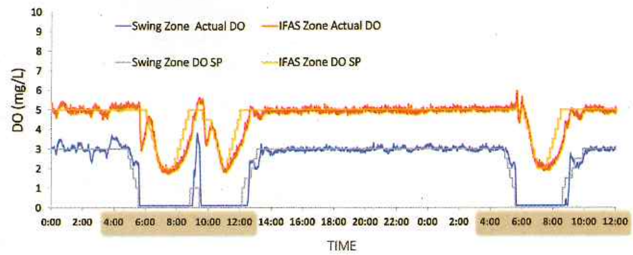


Figure 2: Performance of a Smart Automation Solution.

ment. High operational specificity cannot be attained without a constant stream of valid operational data and real-time operational control. Historical approaches such as "fix it when it breaks" results in gaps in performance, and broad sweeping preventative maintenance strategies impose significant labor and financial burdens on plant staff.

Smart Automation

The conjoining technology that provides the platform for each of these new criticals is next-generation digital solutions or smart automation. With smart automation, we step into the 4th Industrial Revolution. The key attribute that differentiates smart solutions from conventional, standard industrial controls is the ability to convert plant data into operations and management action. In total, solutions that leverage smart process control systems step beyond automation and effectively provide plant staff with an operations management tool to get the most from the facility.

In regards to the automation performance of the control system, smart automation systems use data to self-tune the operating function of the control system. This means that automation performance is no longer conditional on manual retuning. The reported half-life of a standard industrial PID (Proportional, Integral and Derivative) control loop is six months, according to a report by ABB. Further, the same report notes that 75 percent of the installed control systems are not adding process value and a full 30 percent of the installed systems are being operated in manual mode. This should not be interpreted as a failure or limitation of the control system; rather a deficiency in the magnitude of the selected P, I, and D control loop constants and a need for more frequent tuning. The elimination of the tuning requirement is a key advancement to the beneficial use of automation controls.

Direct Benefits

Smart automation provides three direct benefits in automation performance. First, equipment output is precisely paced to deliver the desired operating conditions for intended process performance. Figure 1 shows the performance of a standard industrial control system. For this application, a blower and air distribution valving are being operated to yield a residual dissolved oxygen (DO) condition in a multitude of control zones. A 24-hour time interval is presented in this chart. As shown, the operating condition within this single control zone (blue line) deviates significantly from the setpoint (red line). DO oscillates between values as low as 0 mg/L and as high as 4 mg/L. From a process performance perspective, the plant is not delivering the intended operational result. Further, since an operating condition above the setpoint requires more input, the energy use for the system is greater than required.

Figure 2 shows the performance being provided by a smart automation solution in a similar process application. A two-day operating window is presented in this chart. In this application, the operating condition for two control zones is shown. As presented, the operating condition in each control zone is being maintained to within a tight tolerance to the setpoint. For this application, the intended operational results are more likely to be attained as there is minimal deviation from the target setpoints.

A second deliverable is equipment service life. One of the smart automation systems available in the market today uses tactical automation logic. This logic reduces the number of control events required to maintain the desired operating condition by an order of magnitude. Today, adjustments are done in multiples of minutes, not seconds. This directly extends the service life of the associated control and mechanical equipment.

Figure 3 on page 32 shows the high operating frequency common with standard industrial control systems. A two-day operating window is presented in this chart. As shown, control events (black line) occur at a high frequency. This is a result of the independent nature of the cascaded and nested control loops used in the system.

Figure 4 on page 33 shows the control event frequency for the referenced smart automation system. A 24-hour operating window is presented in this chart. In this application, adjustments occur every few minutes (valve position percent). In one study, the estimated reduction in control event frequency approached 90 percent. As shown in Figure 4 on the bottom, the multiple valve position percent lines show the most-open-valve control logic being used to efficiently distribute air throughout the system. In this case, OX-1 (blue line) is the selected most-open-valve. This means that the flow path for air to this zone is mostly open; thereby

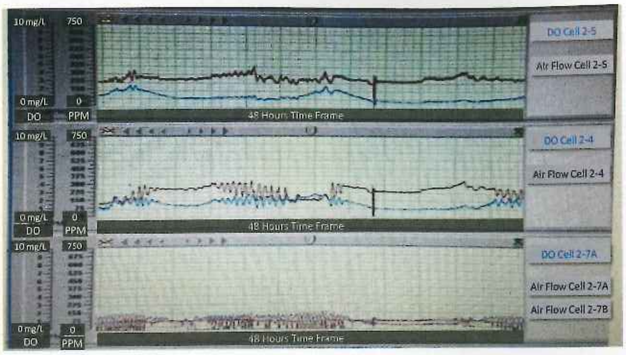


Figure 3: High Operating Frequency Common with Standard Industrial Control Systems.

minimizing the operating pressure requirement for the blower. The valve position for the parallel, non-MOV control zones are subsequently adjusted to yield the desired airflow distribution. Due to the specific operating conditions at this facility, blower output control and a single valve produces the desired process operating conditions in the four control zones in this plant. The resultant airflow to the four controlled zones is shown in Figure 4.

The third benefit, smart automation solutions have also expanded to provide real-time process optimization. Unlike standard control systems that automate to a manually determined setpoints, smart process optimization solutions evaluate process performance in real-time and dynamically adjust setpoints to meet intended process performance. Figure 5 shows the process optimization performance at a reference facility. As shown, the DO setpoint in three control zones is being dynamically adjusted based on an influent loading parameter. Further, when combined with a tuned automation system, the control system can now deliver intended process results with few deviations in process performance. For the reference facility, the actual and predicted effluent ammonia are close equals.

The same referenced smart solution also supports multi-level operational objectives. Low energy use is a common operational objective across all plant operations. For any given output condition, there are a large number of discrete operating process setpoints that will yield the desired process condition. The referenced smart solution evaluates a multitude of setpoint conditions and selects the specific set that requires the least amount of energy. A common secondary energy management objective is to reduce total energy cost in addition to total energy consumption. In this case, the rate of treatment is inversely adjusted to the cost of electric power; when electric power rates are high, treatment rates are decreased and visa-versa. For regulated facilities including water reclamation facilities, the operating objectives are managed to meet daily maximum and average discharge requirements.

Beyond Operations and Performance

The benefits of smart automation extend beyond operations and automation performance. Smart solutions that use process-based algorithms now provide designers with plant-specific process models. These models support detailed process and equipment right-sizing initiatives. In addition, the robust basis for these models can be used to justify a deviation from general design standards. For aeration equipment, the single qualitative variable that is used in designing an aeration system is alpha (α). Alpha is the parameter that corrects for waste-stream characteristics and impacts on process water oxygen transfer efficiency. This single parameter can range from 0.25 to 0.80 for the most widely applied diffused air technology in the industry. Smart aeration automation systems evaluate real-time operating data to quantify alpha. This information can help ensure that diffuser and blower equipment is properly right-sized for the facility.

Asset Management

The third and final critical to operating a water reclamation facility of the future is asset management. The tactical nature of smart automation systems is now being used to support multi-level fault detection, isolation and recovery (FDIR) protocols. This is the final weak-link in plant automation. Advanced FDIR protocols continually monitor and initiate isolation protocols when a fault is detected. The most frequent faults that occur within a plant include equipment or instrument failures and invalid instrument output signals. Knowing when a fault occurs doesn't necessarily result in stable optimized process performance. FDIR keeps plant staff informed and assured that the appropriate actions will be implemented when a failure occurs. Objectively this increases the probability of success.

An offshoot of fault detection is Reliability-Centered Maintenance (RCM). The same analytics that are used to detect faults are also being used to quantify losses in operating efficiency. Monetizing these operating efficiency losses allows management to pace maintenance events to the objectives of the business. For aeration, cleaning or component replacement is trig-

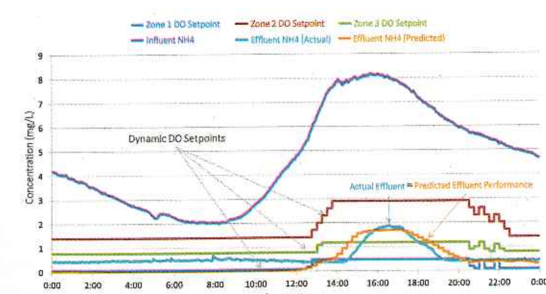
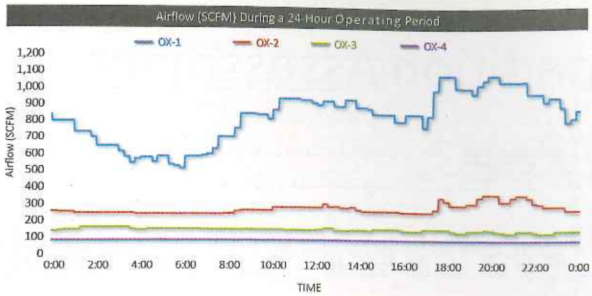


Figure 5: Process Optimization Performance at a Reference Facility.



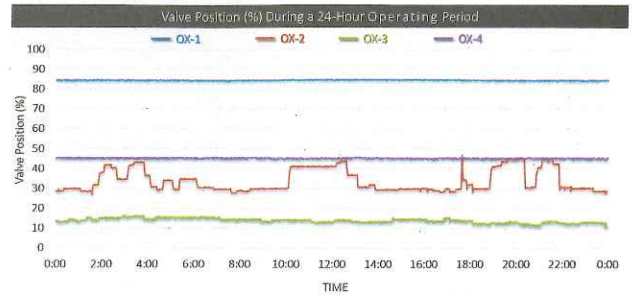


Figure 4: Control Event Frequency for the Referenced Smart Automation System.

gered when operating efficiency losses exceed the cost for the maintenance event. For other objectives, maintenance events are triggered to ensure maximum process capacity, uptime, and other plant specific objectives.

To derive the maximum benefit from smart automation; a collaborative relationship between the user, the digital solution and the smart solution technology provider is imperative. For FDIR, the isolation and recovery protocols are developed based on management and operator preferences. For RCM, the overarching business objectives set by management are embodied in the maintenance analytics.

The opportunity potential of smart automation and equipment right-sizing is significant. Two project briefs are provided to highlight the gains captured at these facilities.

Facility A is located in the Chesapeake Bay watershed, (Figure 6). This region has some of the most restrictive discharge limits in the country. The impact of the 2010 total maximum daily load (TMDL) program in this region has been remarkable. Reports of vegetation regrowth, water clarity, and crab and oyster population rebound are direct results from this program. The operation of the first and second stage biological process units at this facility are fully automated with a smart automation system. The system monitors influent load and paces a multitude of in-plant equipment to deliver the desired/intended result. For Facility A, effluent quality is the main operational objective. The plant discharges approximately half of its allocated waste load and reports an estimated 45 percent reduction in aeration energy using dynamic setpoint adjustments for dissolved oxygen.

Facility B is located in China, (Figure 7). The flow-rate to this plant is approaching 1 billion gallons of wastewater per day. The smart process optimization and aeration automation system installed in a portion of this facility resulted in an aeration energy savings of approximately $500,000 per year. The investment for the control system at this facility was fully recovered in less than two years.

Figure 6: Facility in the Chesapeake Bay Watershed (Facility A).

Figure 7: Facility in China (Facility B).

The adoption of next-generation, smart automation in the water reclamation space is paramount to meeting the environmental and financial sustainability objectives the we envision for the industry. However, smart automation solutions for the secondary biological process units as reviewed in this article is just one area where benefits abound. The conjoining of smart solutions across the entire plant and with other utilities including water, electric and smart city initiatives is the larger, overarching vision for instrumentation and process control solutions.

To accelerate the adoption of smart solutions, the industry itself needs to change. Collaboration is the ultimate new critical. This includes not only collaboration among technology providers, but also between plant staff and the digital solution itself. Further, smart automation is about knowledge and intelligence. The next-generation solutions in the plant are dynamic and represent a foundational technology of the utility, not a static black box that sits in the closet doing its own thing. Finally, the strength of the solution is only as strong as the weakest link. Smart solutions are complex and are instrument intensive. Their success requires robust plans for hedging against failure and a refocusing of plant staff to the new human criticals in the 4th Industrial Revolution.

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