PREDICTIVE MAINTENANCE IN THE WATER INDUSTRY

Digital Transformation of Scottish Infrastructure

Condition monitoring for a wastewater treatment plant to reduce operational expenditure and risk, increase overall equipment effectiveness and maintain a high level of availability.

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Scottish Water provides water and wastewater services throughout the whole of Scotland. Every day they deliver 1.52 billion liters of drinking water and treat 1.10 billion liters of wastewater. Over 2.6 million Scottish households rely on their services.

Returning wastewater to the environment is a complicated process that protects the natural environment and controls the potential spread of waterborne diseases. The final stage of the wastewater treatment process is highly energy intensive, making up 53% of total energy consumed by Scottish Water and accounting for 71% of their carbon footprint. Wastewater treatment is a key focus of Scottish Water's efforts to deliver cost and efficiency savings through an ambitious transformation program, with the aim of achieving net-zero carbon emissions by 2040. Digital transformation is essential to achieving this goal, which is to capture new and existing operational data from across the infrastructure using sensors, and to send this data to the cloud. This allows a shift to be made from scheduled maintenance to preventive maintenance.

Customer
Scottish Water

Location
17 wastewater treatment sites throughout Scotland

Time frame
End-to-end engineering, planning, and delivery within just a few months (2022)

Scope of supply
Holistic condition monitoring solution based on available, stranded data (data that is not being leveraged) and connecting over 300 new assets by leveraging the following Siemens IoT solutions:

- SIMOTICS CONNECT 400 with the respective cloud-based analytics app Drivetrain Analyzer Cloud (previously called SIDRIVE IQ Fleet)
- SIPLUS CMS1200 as high-end vibration monitoring system in combination with Insights Hub Edge Analytics (previously called MindConnect Edge Analytics)

Scottish Water operates 1800 wastewater treatment plants across the country. 17 of the largest wastewater sites have been equipped with the new technology as part of their digital transformation program called 'Exemplar', in which they have invested more than £5 million so far.

THE CHALLENGE

Reducing OPEX and risk with condition monitoring

Scottish Water had a clear idea of what they were looking for in a condition monitoring solution for the transformation of their wastewater treatment plants:

Reduce operational expenditure (OPEX) by decreasing the need for maintenance personnel to make onsite visits.

Reduce risk of downtime as failure of critical assets can have a direct impact on people and the environment.

Monitor energy usage of assets to reduce energy consumption and help achieve their net zero emissions objective.

"This is a complex program of works and a critical part of our Digital Transformation journey, helping transform our wastewater business and drive a step-change in operational performance. It will allow us to make better operational decisions, be more efficient and to drive significant benefits, particularly in relation to energy consumption and responsive asset failures."

Joyce Gray, Wastewater Business Manager at Scottish Water

However, Scottish Water had some challenges in meeting these ambitious goals.

Integration with existing solutions
To minimize costs associated with new sensors, wherever possible, the condition monitoring solution needed to leverage existing data sources in existing systems. Being open to OT standards and cloud connectivity was therefore crucial for the success of the digital transformation.

Engaging users to drive change
In a survey conducted by Scottish Water, only a small percentage of employees were enthusiastic about the digital transformation efforts. An easy-to-use solution was needed to maximize impact and ensure high levels of adoption among operational staff.

Maximizing investment impact
Not all assets are equal when it comes to risk and costs. In order for the business case to be successful, the solution needed to be strategically focused on areas where it could generate the most substantial impact.

Scalable solution for a diverse infrastructure
Scottish Water has wastewater treatment plants all over Scotland, some serving large cities and others small towns. A template needed to be developed that Scottish Water could scale across their infrastructure without requiring external support.

THE SOLUTION

Flexible, interoperable and secure condition monitoring

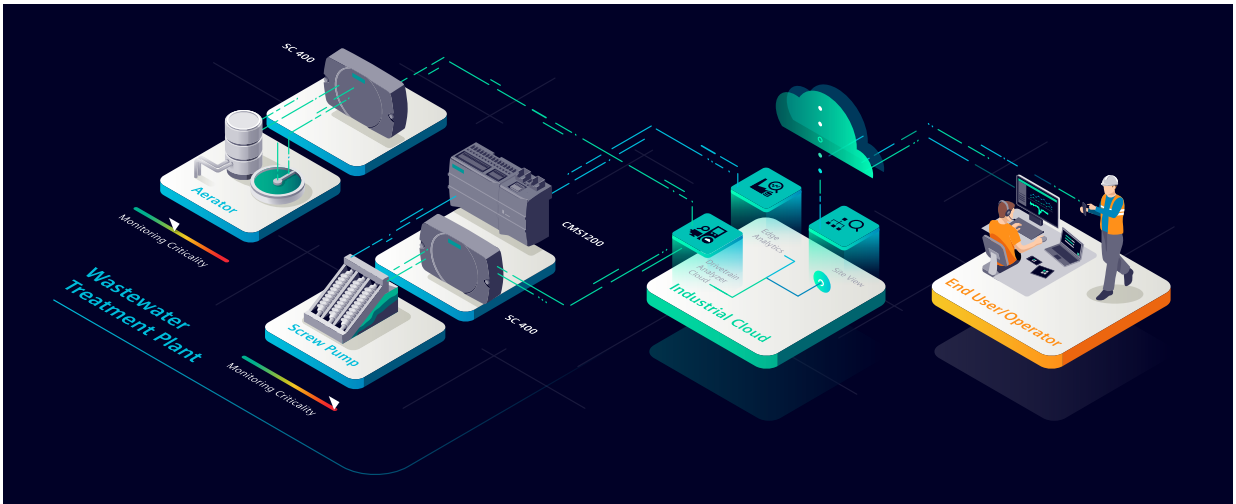
The starting point for the process was recognizing that industry best practice aligned with the process described in ISO 17359:2011. Working in partnership with Capgemini and local integrator Processplus, the collaboration delivered an integrated end-to-end solution.

Criticality of the assets
After reviewing the existing assets within the plant, it was clear that only 5-10% of the assets were highly critical to the operation of the wastewater treatment plant. The remaining equipment had a low to medium level of criticality, either due to redundant systems or minimal impact on operations in the event of a failure. Two examples that illustrate how the design of the monitoring approach varies according to criticality are aerators (medium criticality) and screw pumps (high criticality).

Managing process risk at minimal cost
The aerator increases dissolved oxygen levels in the tanks where bacteria break down the wastewater sludge. Aeration is energy intensive and an important factor when defining plant capacity. However, with multiple aerators at every plant, they are not critical to the operation of the plant, so a cost-effective condition monitoring solution such as SIMOTICS CONNECT 400 in combination with the respective cloud application Drivetrain Analyzer Cloud (previously called SIDRIVE IQ Fleet) was the perfect choice. A more comprehensive solution would have increased the cost but with limited value-added.

Avoiding costly unplanned downtime
Additional condition data was required for the screw pumps, which are used to dewater sludge. Failure of one of the screw pumps would result in long downtime, high maintenance and replacement costs and could also lead to plant flooding. This meant that a high-end condition monitoring solution was needed to monitor the mechanical condition of the application itself in addition to the SIMOTICS CONNECT 400 used for the pump motor. SIPLUS CMS1200 in combination with the Insights Hub Edge Analytics app proved to be the ideal choice for this application. With the high-resolution raw data provided by the sensor, failures of the screw pumps can be detected weeks and months in advance, enabling predictive maintenance and therefore reducing costs and the risk of downtime.

Securely combining OT with IT in the Industrial Cloud
Scottish Water needed to utilize data sources that already existed in installed systems whenever possible to reduce the cost of new equipment. The out-of-box connectivity solution that was provided makes this possible. All data from remote assets and systems can be captured and uploaded to the cloud to provide the basis for further analysis. Cybersecurity is the key prerequisite for Scottish Water to safeguard critical assets, protect sensitive information and assure business continuity. Certified to ISO 27001, Siemens provides a holistic cybersecurity approach for Scottish Water and enables them to comply with national laws and regulations.

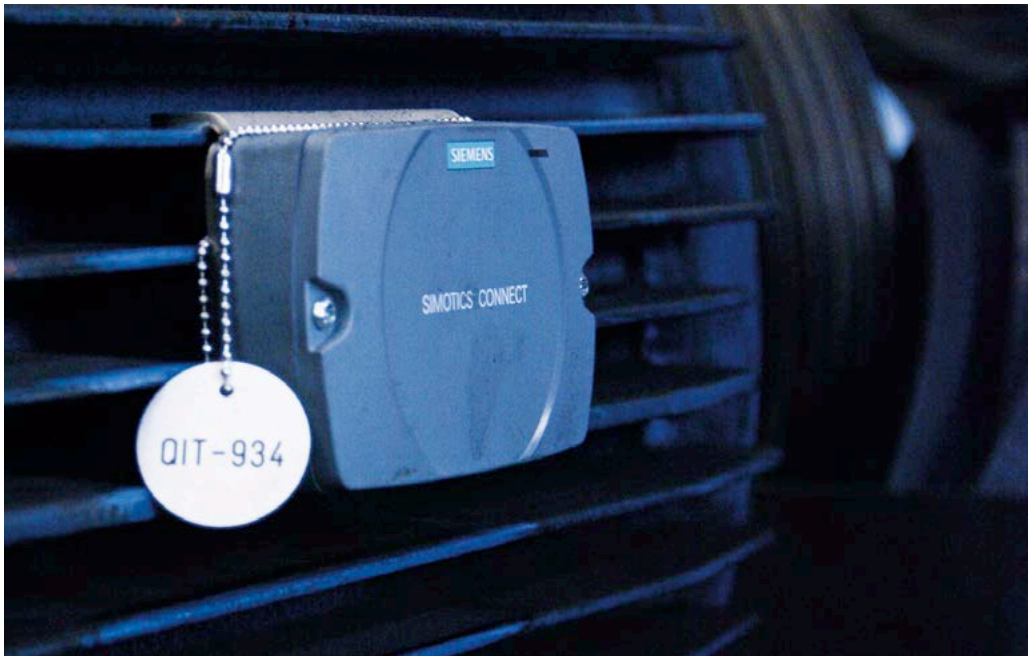


Monitoring low-to-medium critical assets with a cost-effective plug-and-play solution

To monitor the aerator, SIMOTICS CONNECT 400 was used as a sensor module mounted on the aerator's motor. The data captured by the sensor is then transferred to Drivetrain Analyzer Cloud, a cloud application dedicated to monitoring low-voltage motors and the loads they are driving.

System overview of the condition monitoring of an aerator used at a wastewater treatment plant of Scottish Water.

Easy and seamless installation while the aerator remains operational
The commissioning phase was incredibly straightforward. SIMOTICS CONNECT 400 is a non-proprietary solution and can be used with Siemens and third-party motors. It makes no difference whether the motor is operated directly online (DOL), with a motor starter or with a variable frequency drive (VFD). Once the SIMOTICS CONNECT 400 sensor modules had been mounted on the aerator motors while they were still operational – a quick and straightforward process – the modules were ready for commissioning. Using the intuitive SIDRIVE IQ Config mobile application, the project team was able to commission SIMOTICS CONNECT 400 in just a few minutes. With the sensor module connected to the Internet via a network comprising a wireless access point and an LTE/Wi-Fi router, data could be transferred from the plant to the Internet.



SIMOTICS CONNECT 400 (SC400) mounted on one of the aerators in a wastewater treatment plant of Scottish Water.

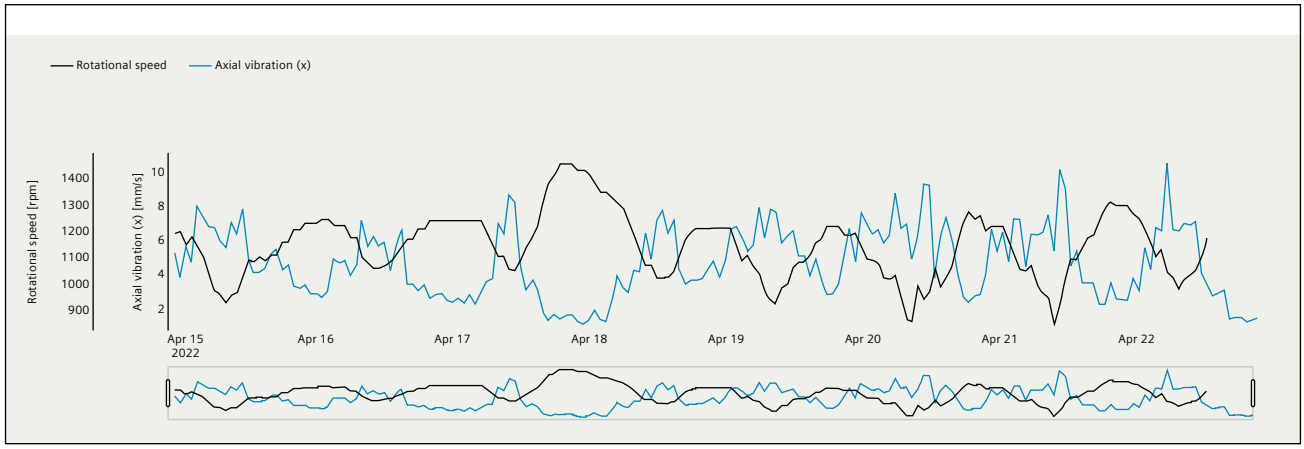
Power of the cloud
Drivetrain Analyzer Cloud, the cloud-based application that collects and combines the data from the sensor modules, provides powerful analytics and a transparent dashboard and operates in the background 24/7 anywhere in the world. When an anomaly is detected, automatic notifications are sent to the operator, so that actions can be taken to avoid unplanned aerator downtime. The app is constantly being updated and new features are added so that Scottish Water can obtain a better insight into the condition of the aerators.

Analytics based on the digital twin of a motor
The sensor module measures the magnetic field, temperature and vibration data of the aerators. From these three measurements, additional values can be calculated with high accuracy based on a digital twin of the motor, which was created using data on the motor rating plate. Increased vibration velocity (v-RMS) could indicate a mechanical fault, such as misalignment or unbalance.
Increased motor torque or energy consumption indicates a higher load and thus possibly a blockage in the aerator. As laid down in ISO 17359:2011, these monitoring points correspond to the identified failure modes for an aerator.

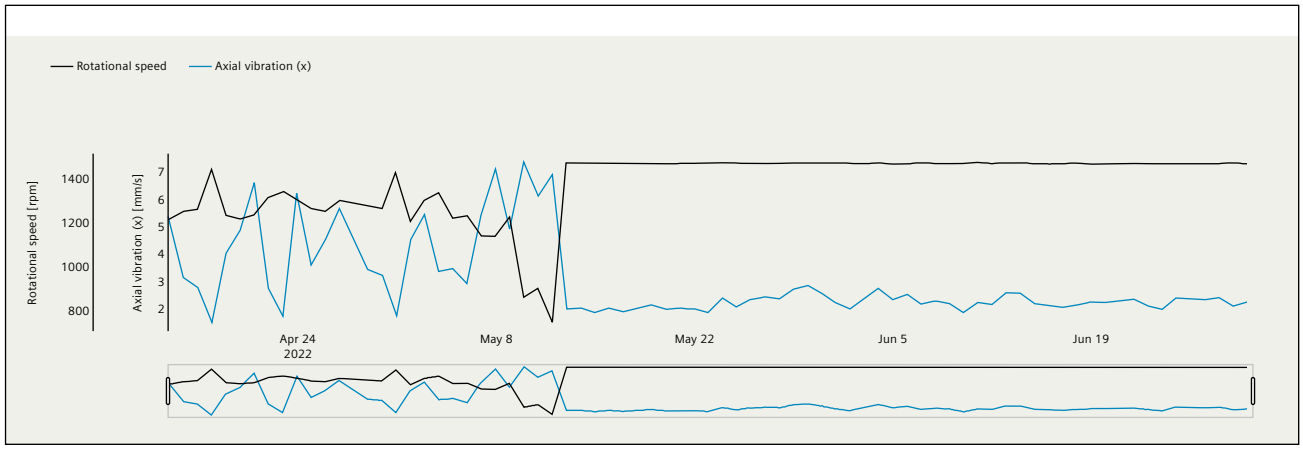
Artificial intelligence indicates the motor status
The embedded AI-based analytical capabilities of Drivetrain Analyzer Cloud calculate the health status of several KPIs, including bearing condition, unbalance and misalignment. A traffic light in the application indicates the condition of the motor, which is calculated in the background after a short calibration time by automatically detecting the operating point and analyzing frequency spectra. With this feature, the most common causes of motor and aerator failures can be detected in a way that is easy to understand and with a high degree of reliability and dependability.

Energy savings versus reduced asset life

The aerators at Scottish Water's Laighpark site use a variable frequency drive (VFD) to adjust the speed of the motors. With energy reduction being a key element of their digital transformation strategy, Scottish Water continuously operated the aerators below their rated speed of about 1500 rpm to reduce energy consumption. However, this strategy had its downside. Drivetrain Analyzer Cloud data showed that reducing energy consumption by lowering the motor speed increased vibration levels, as the aerators were operated closer to or at their resonant frequency.



Drivetrain Analyzer Cloud detected a system resonance with high vibration levels when the aerators were running at reduced speeds; thus leading to a reduced service life.



Until Scottish Water has a better understanding of the optimum operating point (tradeoff between energy consumption versus service life/risk of downtime), the aerators are being operated at 1500 rpm to minimize the risk of outages.

Continuously exceeding aerator vibration levels

In addition to using the AI-based condition monitoring, which provides off-the-shelf anomaly detection and automated, operating point-specific threshold settings, global warning levels for vibration levels have been set according to what is outlined in ISO 108163, which provides guidelines as to where the threshold levels for vibration velocity should be set.

For the aerators, the warning threshold was set at 4.5 mm/s and the alarm threshold at 7.1 mm/s. When the aerator was operating at its design speed of 1500 rpm, vibration levels were well below these recommended limits. However, as the speed was reduced, the vibration levels consistently exceeded the alarm threshold, with vibration levels increasing to more than five times the normal levels; as a consequence, the aerator was being slowly but continuously damaged.

Condition monitoring provides transparency

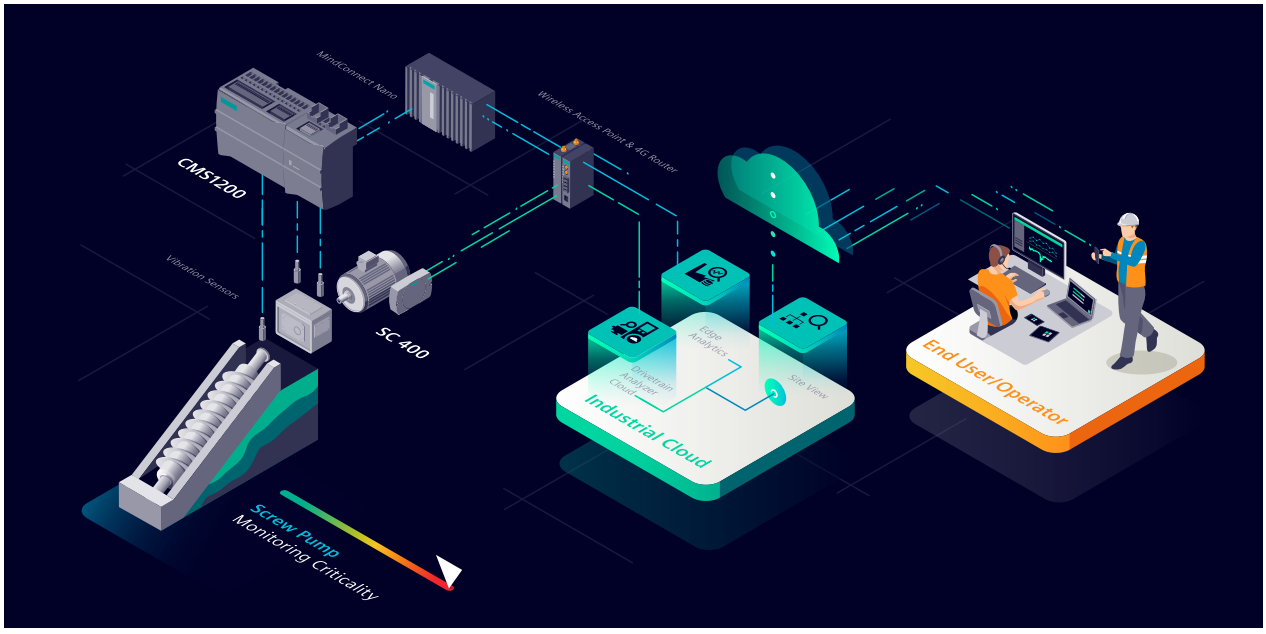
While Scottish Water had continually calculated the return on investment of using VFDs for their aerators, only taking into account the hardware and installation costs associated with implementing a VFD, they had overlooked the impact of a VFD on the expected service life of the aerator. The data provided by SIMOTICS CONNECT 400 and Drivetrain Analyzer Cloud made this tradeoff clear to the team at Scottish Water, clearly showing the correlation between reduced motor speed and reduced service life of an aerator. To take this key insight into consideration, the motor speed has been adjusted to increase the service life.

"The insights coming from Drivetrain Analyzer Cloud had an immediate operational benefit. Variable speed drives can dynamically adjust motor speeds to ensure that aeration levels are maintained with the least energy usage. Within days of deployment, it was clear that certain operating modes may reduce energy use, but at those low speeds the resonance of the system induced high levels of vibration that would decrease the life of the asset. Now, Scottish Water is capable of finding an overall optimum operating point and can optimise the TOTEX of the overall process, which includes energy cost, maintenance efforts, risk, and eventually an earlier replacement. By utilizing this information, Scottish Water will be able to easily increase the overall asset life by up to 15%."

Nathan Wield, Wastewater Operations West Manager at Scottish Water

Condition Monitoring of highly critical assets using process, electrical and physical data

The availability and operational readiness of screw pumps in a wastewater treatment plant have the highest priority, as failure or incorrect operation could lead to structural damage or even localized plant flooding.
The SIPLUS CMS1200 condition monitoring system was implemented as preventive measure.



System overview of the condition monitoring of a screw pump used at a wastewater treatment plant of Scottish Water.

More data for higher transparency
SIMOTICS CONNECT 400 provides a high level of transparency about the status of a motor. But for a highly critical screw pump, additional insight into the mechanical condition of the application was needed. By analyzing data from sensors installed on the gearbox and the screw, along with the existing data sources captured from VFDs and PLCs, the required level of transparency can be achieved. With this innovative solution, both motor anomalies and problems with the screw can be identified before they impact operation of the wastewater treatment plant.

Configuring the condition monitoring for the screw pump
The SIPLUS CMS1200 for the screw pump comprises a SIMATIC S71200 PLC and the SM 1281 condition monitoring module. This module offers a variety of analytical methods that are directly implemented in the unit, such as frequency-selective analysis or parameter-based analysis based on high quality raw data with a scanning frequency of up to 46 kHz. Cloud connectivity was required for Scottish Water, which was implemented using an SM 1281 connected to a MindConnect Nano via OPC UA. This ensures that the screw pumps can be quickly, easily and securely linked to the Industrial Cloud to implement the IoT connectivity required. To connect the MindConnect Nano to the Internet, an LTE Wi-Fi router was used in addition to the wireless access point that was needed for the wireless connection of the SIMOTICS CONNECT 400.

Sensor placement influences detectable root causes

The sensors of the CMS module were mounted on the gearbox and the screw. Different faults can be detected depending on how sensors are placed. These include faults associated with unbalance, alignment, bearing, mounting, frequency and resonance. The frequency-selective analysis embedded in the system, is complemented by a fast Fourier transformation (FFT) analysis of the vibration data, allowing the type of damage and root cause to be identified weeks or even months before the problem impacts actual operation. For example, a problem involving the motor-gearbox alignment will manifest itself as an increased frequency, which is twice the normal rotational frequency. Once this issue has been identified, the alignment can be corrected, preventing an unplanned downtime of the screw pump.

"The interplay of the Industrial Cloud, Mendix and the connectivity components in this specific case is exactly what we are aiming for in the future. Breaking down silos, being open and flexible in order to leverage the full potential from all data sources. Interoperable products, be it software or hardware, are the foundation for any predictive maintenance solution."

Adam Cartwright, Head of IoT Applications at Siemens plc

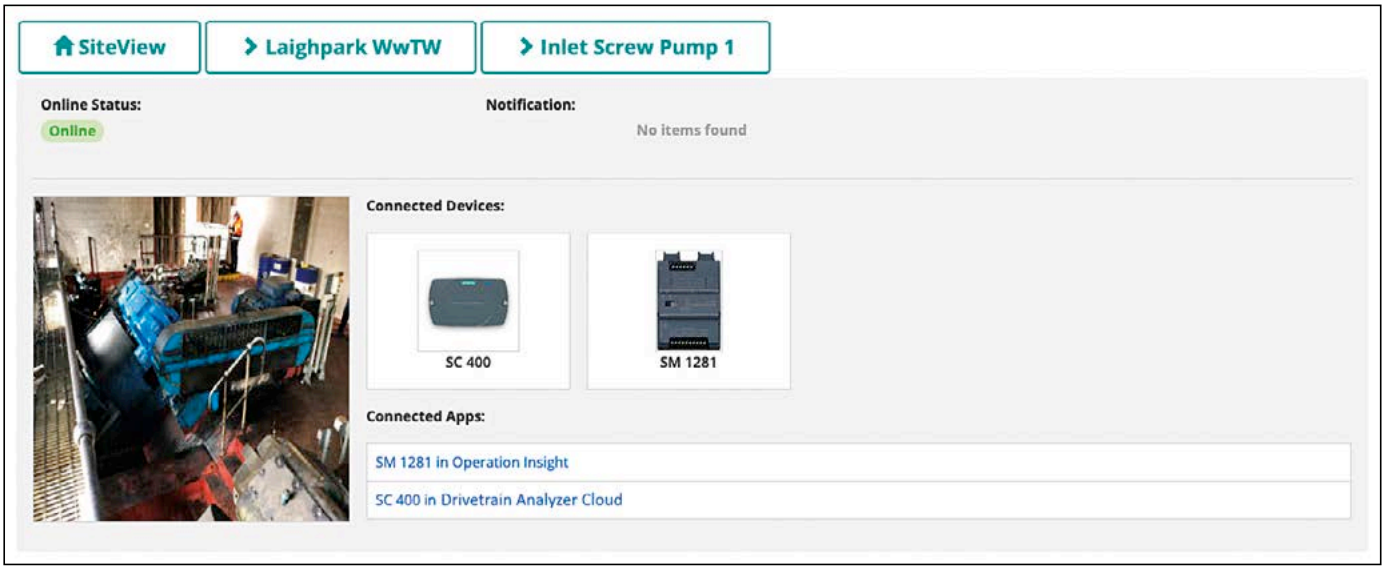
Combining edge with the cloud

The vibration data from CMS1200 is first pre-processed on the MindConnect Nano operational at the wastewater treatment plant. Edge Analytics is used to collect and preprocess data from the sensors attached to the SM 1281. The FFT calculation is performed as part of the application, and only the results are sent to the Industrial Cloud. The FFT is visualized for operators within SiteView, where they can obtain detailed information about their assets in the event of an alarm.

This strategy takes into consideration the time and spectrum domains providing an even higher level of transparency regarding how equipment could possibly degrade over time.

Low-code to maximize impact

SiteView, a cloud application built on the Mendix low-code platform, combines data from multiple sources to create a single dashboard. The application was developed in close collaboration with Scottish Water's maintenance staff to ensure ease of use and ultimately high adoption and usage. It not only displays data from the SC400 and CMS1200, but also from third party equipment such as soft starters, variable speed drives and PLCs. In the event of an anomaly involving any of the assets, a notification is displayed to tell the operator how to respond. At any time, an operator can click on a sensor to go to the respective cloud application running in the background for a more detailed view of the asset.



The SiteView dashboard showing a screw pump at Scottish Water's Laighpark wastewater treatment plant with the SC400 and CMS1200 (SM 1281) sensor modules mounted on it.

THE BENEFITS

Blueprint to scale the solution

By taking a modular approach to monitor equipment in a wastewater treatment plant, a highly scalable, secure and interoperable solution that can interface with existing systems has been created that can benefit the global water and wastewater industry.

Back to Scottish Water's initial objectives: Using the modular approach with SIMOTICS CONNECT 400 for assets with low to medium criticality and SIPLUS CMS1200 for highly critical assets, Scottish Water has been able to realize their goals for the digital transformation of their wastewater treatment plants, directly impacting thousands of Scottish lives and the environment. Siemens has also provided the Scottish Water team with blueprints giving them the opportunity to scale the solution to the other 1800 sites distributed all across Scotland. The blueprints for each application type not only include the information on how the hardware is connected and which software should be used, but also provide clear recommendations for actions on how to respond to problems detected on site and the criticality of the various faults.

"We are very encouraged by the early results coming through our pilot works. The innovative use of sensors and analytics in this way represents a much bigger shift towards predicting and preventing issues before they impact on our customers and environment – ensuring that vital services flow smoothly and efficiently."

Chris Toop, General Manager – Digital at Scottish Water

Reduced operating expenditures and risk of downtime
Previously, Scottish Water collected 600 samples a day from its 1800 wastewater treatment plants. By connecting equipment to the Industrial Cloud, they were able to reduce their reliance on site visits, resulting in significant cost savings. By monitoring vibration and temperature levels, Scottish Water's maintenance teams can proactively intervene when signals lie outside normal operating levels, reducing the cost of responsive asset failures by 10% while extending asset life by 5 to 15%.

Engaging users to drive change
Using the insights obtained through the condition monitoring equipment, Scottish Water is able to reduce energy consumption by setting the equipment to run at optimum operating levels. This not only results in lower power costs but also reduces carbon emissions. In doing so, they have taken a major step towards their goal of achieving net zero emissions.

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