AUTOMATION 2023

VOLUME 1

IIoT & Industry 4.0

- Long-life Lithium Battery Savings
- IIoT Gauges Tank Farm Efficiency
- GraphQL for Distributed Data Lakes
- Born Digital: PureCycle's Digital Community
- Digital Twins for Energy Storage Plants

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New Year, New (and Tried and True) Optimizations

In this January edition of AUTOMATION 2023, you'll find various use cases for familiar tools and equipment, as well as technologies that industries are just starting to incorporate. We explore a mix of traditional and nascent methods that lead to big savings along the way to Industry 4.0. Put long-life lithium batteries in the field for drastic IIoT-enabled savings on expensive labor costs. Use IIoT-ready gauging systems that deliver valuable data to keep plants up and running. Bring order to distributed data using GraphQL. See how a plastics recycler is rethinking plant design by creating a new digital community. Read about how digital twins are being used to increase efficiency at energy storage plants. As always, we look forward to your feedback on what you enjoyed, what was new to you, and what you'd like to see in future AUTOMATION ebooks.

Lynn DeRocco

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About AUTOMATION 2023

The AUTOMATION 2023 ebook series covers Industry 4.0, smart manufacturing, IIoT, cybersecurity, connectivity, machine and process control and more for industrial automation, process control and instrumentation professionals. To subscribe to ebooks and newsletters, visit: www.automation.com/newslettersubscription.

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Achieving **Long-term Savings** with Long-life Lithium Batteries

Ultra-long-life lithium batteries power remote wireless devices throughout the IIoT, with certain cells operating up to 40 years.

By Sol Jacobs, Tadiran Batteries

Extended life batteries are essential to remote wireless devices utilized throughout the IIoT, providing a major cost benefit by reducing or eliminating the need for battery replacements. Use of an ultra-long-life battery can translate into significant cost savings for remote wireless applications by eliminating the labor expenses related to battery replacement, which invariably exceeds the cost of the battery itself. This money-saving benefit is especially important for remote wireless devices being deployed in remote locations and hostile environments, where battery access can be highly cost prohibitive and sometimes impossible.

Figure 1. Ayyeka AI-enabled edge devices, such as this unit that tracks reclaimed water use in Orange County, Fla., use ultra-long-life bobbin-type $LiSOCl_2$ batteries to monitor hard infrastructure, delivering enhanced data intelligence by recognizing patterns, detecting anomalous events, providing real-time reporting, and enabling predictive modeling.

The use of battery-powered remote wireless devices has exploded to encompass everything from system control and data automation (SCADA) to automated process control, AI on the edge, M2M, machine learning, and other advanced technologies. Battery-powered devices monitor everything from structural stress to environmental quality, tank level and flow monitoring, energy usage, and asset tracking, as well as enable remote actuation and shut-off using two-way wireless communications. Ultra-long-life lithium batteries are the lifeblood of these devices, serving to increase system reliability, ensure continuous data flow, reduce long-term maintenance costs, support artificial intelligence, (AI)-enabled predictive maintenance programs, and more (Figure 1).

Low-power applications require primary batteries

There are two types of low-power devices. The vast majority of these devices operate mostly in a “stand-by” state and draw average current measurable in micro-amps with pulses in the multi-amp range to power two-way wireless communications. These applications generally rely upon industrial-grade primary (non-rechargeable) lithium batteries, especially when battery access is limited or in harsh environments. If the battery is easily accessible for replacement and operates within a moderate temperature range, then consumer grade batteries could be considered as a more economical solution.

There are also certain niche applications that draw average energy measurable in milli-amps with pulses in the multi-amp range, consuming enough average energy to shorten the operating life of a primary battery. These higher drain applications could require the use of an energy harvesting device in conjunction with a rechargeable Lithium-ion (Li-ion) battery to store the harvested energy. Industrial grade Li-ion batteries are now available that can operate for up to 20 years.

Numerous types of primary (non-rechargeable) chemistries are available, each offering unique performance benefits and trade-offs. These chemistries include alkaline, iron disulfate ($LiFeS_2$), lithium manganese dioxide ($LiMnO_2$), lithium thionyl chloride ($LiSOCl_2$), and lithium metal-oxide (Table 1).

Primary Cell	**$LiSOCL_2$ Bobbin-type with hybrid layer capacitor**	**$LiSOCL_2$ Bobbin-type**	**Li metal oxide Modified for high capacity**	**Li metal oxide Modified for high power**	**$LiFeS_2$ Lithium iron disulfate (AA-size)**	**$LiMnO_2$ Lithium manganese oxide**
Energy Density (Wh/Kg)	700	730	370	185	335	330
Power	Very high	Low	Very high	Very high	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very high	Moderate	Moderate
Passivation	None	High	Very low	None	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Moderate	Poor

Primary Cell	$LiSOCL_2$ Bobbin-type with hybrid layer capacitor	$LiSOCL_2$ Bobbin-type	Li metal oxide Modified for high capacity	Li metal oxide Modified for high power	$LiFeS_2$ Lithium iron disulfate (AA-size)	$LiMnO_2$ Lithium manganese oxide
Operating life	Excellent	Excellent	Excellent	Excellent	Moderate	Fair
Self-Discharge Rate	Very low	Very low	Very low	Very low	Moderate	High
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-20°C to 60°C	0°C to 60°C
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-20°C to 60°C	0°C to 60°C

Table 1. Bobbin-type $LiSOCl_2$ batteries are preferred for use in remote wireless applications. These cells deliver higher capacity and energy density, up to a 40-year operating life, and the widest possible temperature range, which is ideal for hard-to-access locations and extreme environments.

Among these primary chemistries, bobbin-type $LiSOCl_2$ (Figure 2) is overwhelmingly preferred for long-term deployments in remote locations due to its higher capacity and energy density, wider temperature range, and an incredibly low annual self-discharge rate of less than 1% per year for certain cells.

Figure 2. Bobbin-type $LiSOCl_2$ batteries are preferred for remote wireless applications, delivering high energy density, up to 40-year service life, and the widest possible temperature range, making them ideal for use in inaccessible locations and extreme environments.

The importance of low self-discharge

IIoT-connected devices utilize two-way wireless communications, thus demanding specialized power management solutions. To maximize battery life, these devices must be engineered to conserve energy by employing a variety of energy-saving techniques, including the use of a low power communications protocol (WirelessHART, ZigBee, LoRa, etc.), low-power chipsets, and proprietary techniques designed to minimize energy consumption when the device is in "active" mode. While extremely useful, these energy-saving techniques are often dwarfed by the energy losses associated with annual self-discharge.

Self-discharge is common to all batteries, as chemical reactions occur even when a cell is disconnected or in storage. The annual self-discharge rate of a battery can vary considerably based on its chemistry, the design of the cell, the current discharge potential, the quality and purity of the raw materials, and, most important, the ability to harness the passivation effect.

Use of an ultra-long-life battery can translate into significant cost savings for remote wireless applications by eliminating the labor expenses related to battery replacement.

Unique to $LiSOCl_2$ batteries, passivation involves a thin film of lithium chloride (LiCl) that forms on the surface of the lithium anode to limit reactivity while not in use. $LiSOCl_2$ cells can be constructed two ways: bobbin-type cells feature less reactive surface area, which is ideal for reducing self-discharge. However, the trade-off is an inability to deliver high rate energy. $LiSOCl_2$ batteries can also be made with spiral wound construction, which permits a higher rate of energy flow, with the trade-off being shorter operating life due to higher self-discharge.

Whenever a load is placed on the cell, the passivation layer causes initial high resistance and a temporary dip in voltage until the discharge reaction begins to dissipate the LiCl layer, a process that repeats each time the load is removed. The cell's ability to harness the passivation effect can be influenced by its current capacity; length of storage; storage temperature; discharge temperature; and prior discharge conditions, as removing the load from a partially discharged cell increases the level of passivation relative to when it was new.

Experienced battery manufacturers can optimize the passivation effect through the use of higher quality raw materials and by employing proprietary manufacturing techniques. While passivation can be highly beneficial to reducing the annual self-discharge rate, this process needs to be carefully harnessed to avoid over-restricting energy flow.

The challenges of powering two-way wireless communications

While standard bobbin-type $LiSOCl_2$ cells are ideal for harnessing the passivation effect, they are unable to generate the high pulses required for two-way wireless communications due to their low-rate design. This challenge can be overcome with a hybrid solution, where the standard bobbin-type $LiSOCl_2$ cell is used to deliver low-level background current while being augmented by a hybrid layer capacitor (HLC) that stores and delivers high pulses (Figure 3).

Figure 3. Bobbin-type $liSOCl_2$ batteries can be combined with a patented hybrid layer capacitor (HLC) to offer up to 40-year operating life while providing high pulses to power two-way wireless communications.

For industrial applications, this hybrid solution is often preferable to the use of supercapacitors, which are generally restricted to consumer applications due to various performance limitations. Generating high pulses electrostatically rather than chemically, supercapacitors suffer from inherent drawbacks such as short-duration power, linear discharge qualities that prevent use of all the available energy, low capacity, low energy density, and high annual self-discharge rates of up to 60% per year. Supercapacitors linked in series also require the use of cell-balancing circuits, which adds costs and bulkiness, and also consumes more energy to further accelerate their self-discharge rate.

Let the buyer beware

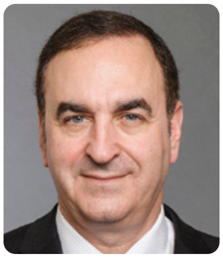
Major differences can exist between seemingly identical bobbin-type $LiSOCl_2$ cells. For example, a superior quality bobbin-type $LiSOCl_2$ battery can feature a self-discharge rate as low as 0.7% per year and is able to retain 70% of its original capacity after 40 years. By contrast, an inferior quality cell can have a higher self-discharge rate of up to 3% per year and lose 30% of its capacity every 10 years, making 40-year battery life unattainable.

Choosing the ideal battery can be difficult, in part because the annual energy losses associated with higher self-discharge can take years to become fully apparent, and the predictive models used to estimate expected battery life tend to underestimate the passivation effect as well as the impact of long-term exposure to extreme temperatures. Various testing procedures are available to approximate expected battery life, with the best source being historical test data taken from cells being used in the field.

When extended battery life is essential to maximizing your return on investment (ROI), it pays to perform some added due diligence by demanding fully documented long-term test results along with historical in-field test data involving comparable devices under similar loads and environmental conditions. By paying more careful attention when evaluating competing batteries, you can achieve significant long-term savings by increasing the reliability and service life of your device.

For more information, visit Tadiran Batteries.

ABOUT THE AUTHOR



Sol Jacobs is the Vice President & General Manager of Tadiran Batteries. He has more than 30 years of experience in powering remote devices. His educational background includes a BS in engineering and an MBA.

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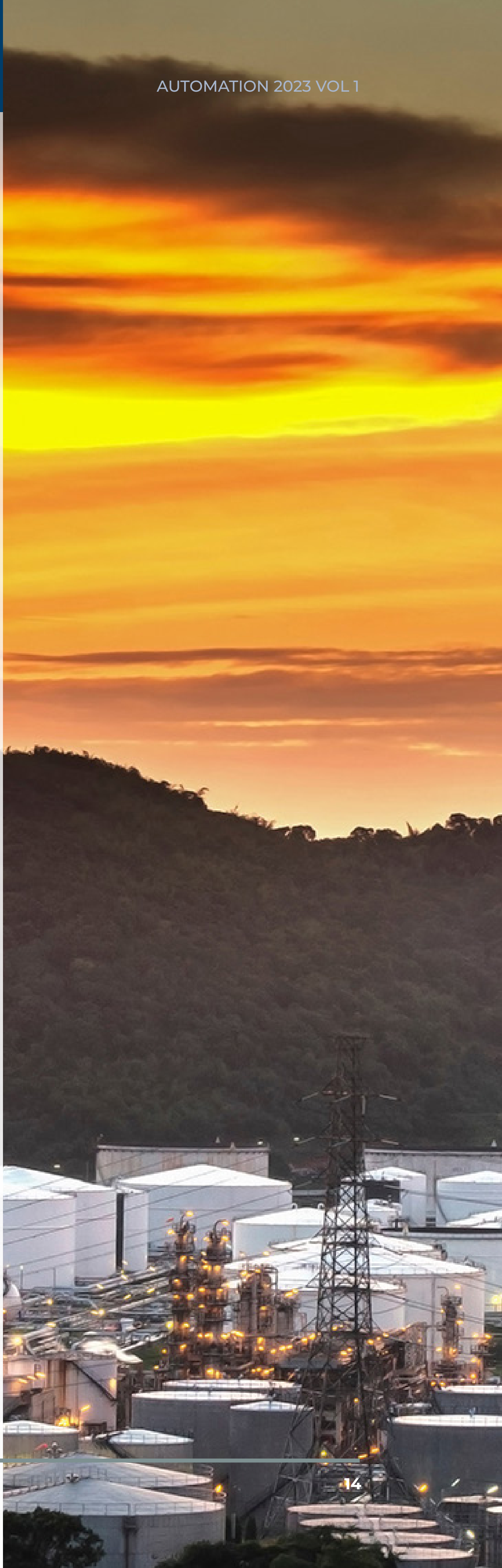

Smart Gauging Systems Improve Tank Farm Efficiency

IIoT-ready instrumentation can quickly enable data-driven reductions in failures and downtime.

By Cesar Martinez, Endress+Hauser

The second law of thermodynamics states the total entropy—or natural disorder—of any system increases or remains the same in a spontaneous process. This is a foundational facet, one of the building blocks of thermal physics at the molecular level, and regardless of debate among physicists, it almost always applies to visually tangible macrosystems as well.

This principle is arguably the strongest driver for control systems, given the whole point of control is to methodically manipulate inputs from an environment containing varying levels of disorder into specific outputs that bring about desirable outcomes. These points warrant the requirement of maintenance in every plant, because equipment naturally degrades over time. Mechanical components wear, electrical connections corrode, and even static objects degrade due to atmospheric contact, or exposure to chemicals and other hazardous conditions.

Putting a spotlight on tank farms, maintenance is necessary to ensure measurement accuracy and plant safety. Maintenance activities have evolved over the years, with new technology built into modern smart instruments, providing more methods to diagnose issues, share data, and verify measurement integrity.

Historically, these activities had to be conducted manually, requiring technicians to perform tasks in the field, often in hazardous conditions. But data-rich sensors and intuitive software solutions are making it much easier to identify and address problems, so plant personnel can improve their productivity while reducing downtime and incidents.

Inevitable breakdown

Degrading measurements in a plant can be thought of analogously as degrading fuel economy in an automobile. As a car racks up more miles, its engine and other mechanical components slowly wear down, requiring more fuel to drive the same distance, thereby decreasing fuel efficiency. This drop may be miniscule at first, but it can become more significant over time.

Data-rich sensors and intuitive software solutions are making it much easier to identify and address problems.

In the same way, measurement errors as instruments degrade in a plant environment may be small at first—often unnoticeably so—but as wear compounds, measurement drift increases. Additionally, as instruments age, there is a higher chance of complete failure.

In the past, maintenance teams performed service at routine intervals to reduce the effects of measurement drift, as well as the chances of total failure. But this sort of calendar-based maintenance strategy is inefficient, because some instruments may not need service at their appointed time, while others may fail before the maintenance interval. When the latter occurs, maintenance must be performed reactively and expensively, and downtime often ensues.

For tank gauging applications, reactive approaches frequently begin when a mass balance issue is realized. Troubleshooting these types of issues with traditional instrumentation can take inordinate amounts of time. Operators must visit each tank, making individual manual measurements to determine the source of the measurement errors. Once the issue is identified, often hours or even a day later, maintenance teams are called out to repair the problematic instruments.

Online diagnostics increase reliability and uptime

Today's smart instruments have a plethora of diagnostic data—one area of notable improvement over instruments of yesterday—and when combined with holistic tank gauging system solutions, operators can maintain their systems with much greater reliability. Instrument diagnostics and other functions make it easier to detect problems, with quicker troubleshooting and servicing when issues arise.

Centrally managed tank gauging systems provide a single repository for maintaining all components, including instruments, equipment, software, and maintenance devices. These systems can be easily connected to the cloud for enhanced monitoring and analysis solutions that generate insights, alerting maintenance teams of the ideal times to service instrumentation and equipment.

Using the software dashboard of these systems, operators can monitor field status at a glance, with anomaly and issue detection delivered via notification. When issues are detected, they are easier to troubleshoot because the system has predefined lists of error codes and descriptions, including cause and remedy. This can reduce the time spent troubleshooting and addressing issues in the field from hours to minutes.

Figure 1. Using an augmented reality application, support engineers can see everything the technician sees in the field, and then guide troubleshooting or maintenance efforts using a virtual pencil to highlight target components for the technician.

Increasingly, these modern solutions are equipped with augmented reality (AR) capabilities. Field technicians put on a set of connected AR goggles, remotely projecting what they see to a support engineer. This engineer can reference diagrams and instructions on a computer in an office, and not only tell, but show, the technician which parts to adjust by using a virtual pencil tool to highlight the desired component, easing maintenance procedures significantly (Figure 1).

But improved tools for addressing issues are not enough, as they need to be supplemented with diagnostics. In many cases, field devices sit untouched, without much idea of instrument health, until a process is disturbed, leading to unplanned, reactive maintenance activities. Using advanced tank gauging systems, personnel can access a history of events, current device status and health, and recommended remedies without spending any time at or on the tank (Figure 2).

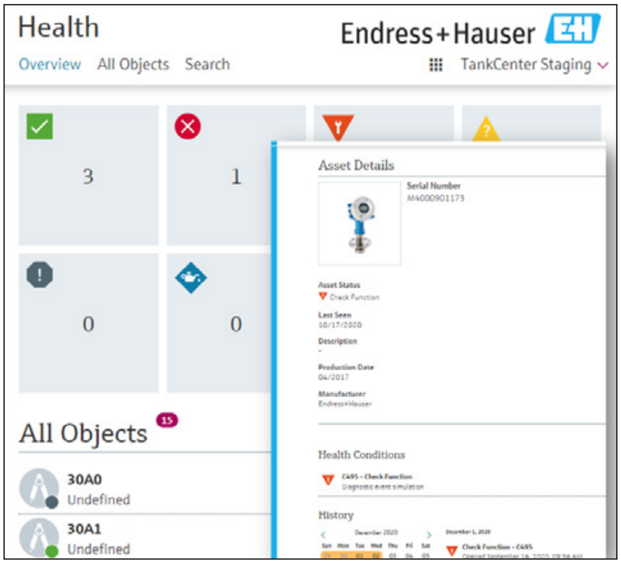

Figure 2. Dashboards and popups in an advanced tank gauging system provide an at-a-glance view of device health, event history, and other information.

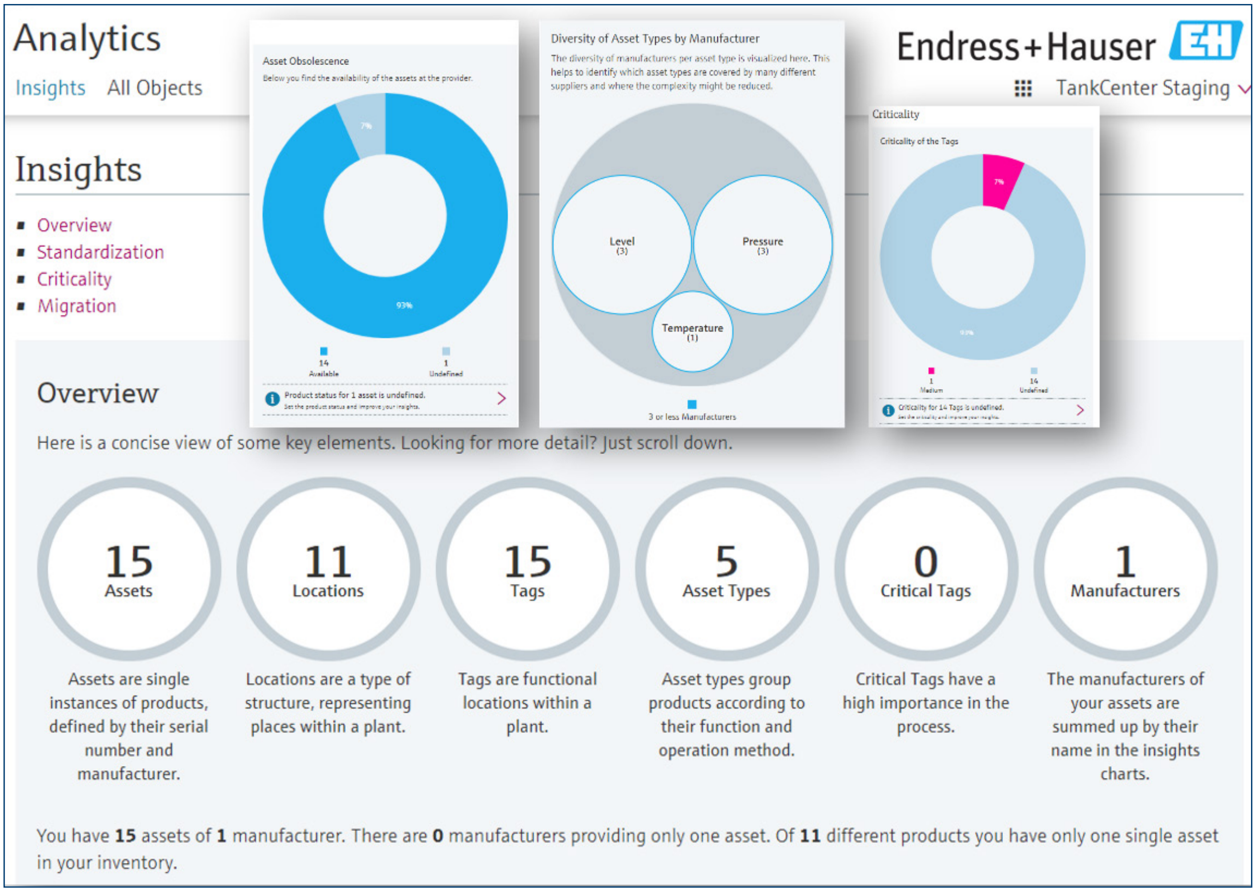

Figure 3. When connected to the cloud, users receive plant insights in the advanced tank gauging application.

By connecting this local process, diagnostic, and event data to the cloud, advanced computing becomes possible, providing a health status asset dashboard and proactive maintenance insights. Using cloud connections and analysis engines, centralized software can observe patterns, create connections between historical input conditions and output results, and use these patterns to generate insights (Figure 3).

Hardware, instrumentation, and communication configuration

A complete tank gauging system consists of instrumentation for measuring level and temperature and a scanner device in an electrical room to transmit data to a local or cloud-based information repository. Instruments must communicate via digital field protocols, such as HART, to send numerous diagnostic and process data points to the scanner device. A typical scanner can connect directly to a local database, or to an edge device, for uploading data to the cloud (Figure 4).

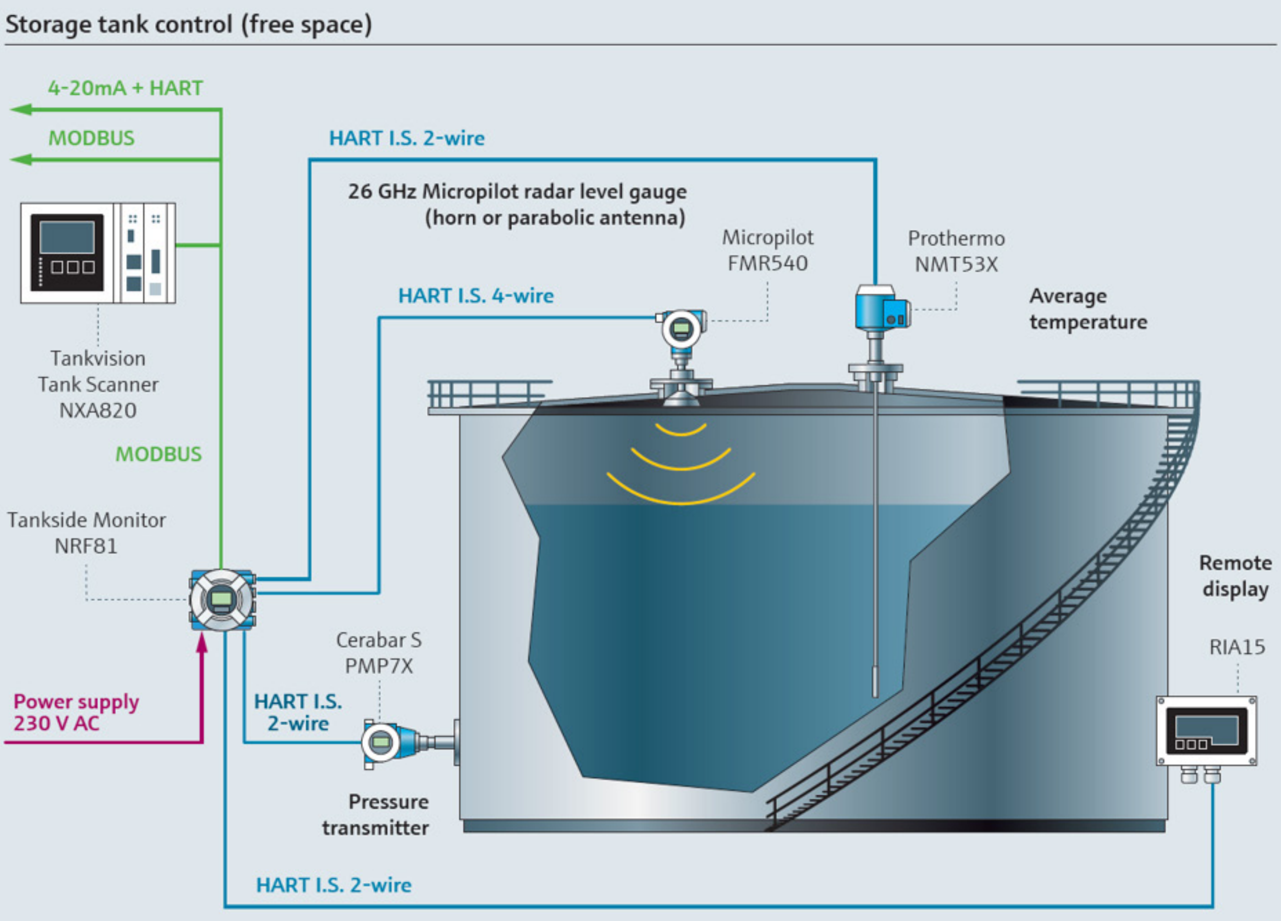

Figure 4. Example architecture for an advanced tank gauging system.

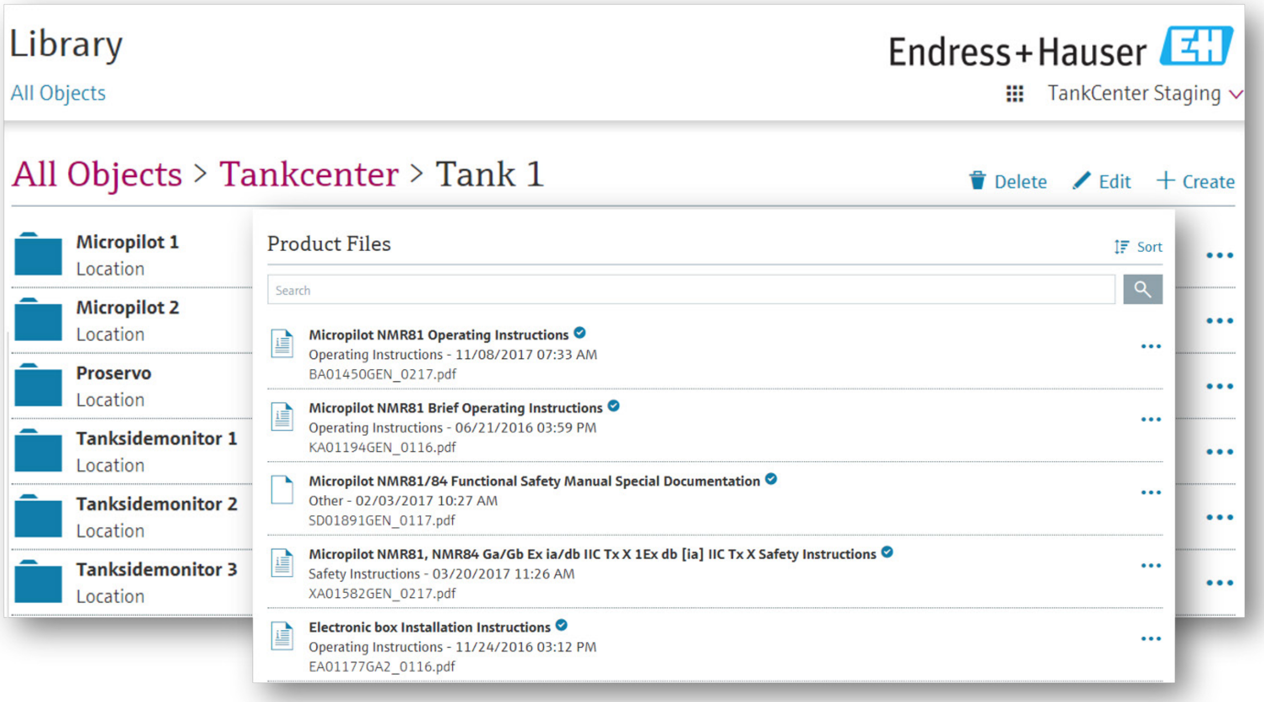

Figure 5. All relevant instrument documentation—including user manuals and calibration records—is automatically stored in an intuitive location in an advanced tank gauging application.

Although asset information is often stored manually today, advanced tank gauging systems give users access to a cloud-based library for asset information by scanning a QR code on each device. The resources include the right user manuals (Figure 5), associated product certificates, and instrument calibration information, with data uploaded at the time of automatic calibration procedures.

Outdated tank farm at a refinery

A refinery with a tank farm previously used traditional level sensors installed on top of the tanks. On multiple occasions, an allocation manager noticed a significant error during a product mass balance reconciliation. This required notifying operations staff and investigating further.

Operations personnel then verified levels in the storage tanks by performing manual dipping procedures, identifying differences in readings between the manual dips and the level sensor readings for each tank. Once this was done, they manually created a report of their findings, and sent this to the maintenance department.

Using this report, maintenance personnel created a work order in a disparate work management system, then sent specially trained staff to remediate the identified instrument issues. This frequently required multiple trips back and forth between the tank and the shop to exchange tools and consult user manuals.

Retrofit with a modern tank gauging solution

To reduce the effort required to identify, validate, and address these frequent problems, and to improve personnel safety and productivity, the refinery retrofitted its existing equipment using smart instruments and a liquid tank gauging solution. This provided a path to proactively address these sorts of issues with state-of-the-art Industrial Internet of Things (IIoT) technology.

The new level instrumentation came fitted with round-the-clock self-diagnostic capabilities with a connection to the liquid tank gauging solution health app. This app constantly monitors level sensor health, reporting the information to the dashboard and issuing alarms when anomalies are detected.

The refinery has had significantly fewer issues since the upgrade, but when anomalies or problems do arise, the system proactively identifies the issue without human intervention, automatically logging it and opening a work order in the connected computerized maintenance management system. It defines and categorizes the issue by device according to the NAMUR NE107 standard, and reports it immediately in the liquid tank gauging solution health app.

An alarm is sent to the maintenance department, and a technician logs in to the app to confirm the alarm and read the diagnostic information, including root cause, suggested remedy, and a link to the user manual. Alarm details are also provided, identifying the time the anomaly or problem was detected.

Fully informed of the context, the technician is empowered to grab the right tools the first time before venturing to the tank. And in the event specialized technical support is required, AR goggles provide a means for additional guidance from a remote technical expert with intimate knowledge of the system. This third-party support alleviates the need for the refinery to hire and retain highly technical talent.

Examining total cost of ownership

Frustration with the old instrumentation was not the only motivator for the previously mentioned refinery's system upgrade. It also studied total cost of ownership (TCO), a critical performance indicator for evaluating the benefit of tank gauging systems. Typically, about 20 percent of this cost is attributed to initial purchase and startup costs, and 80 percent is attributed to operational costs. Although purchase price cannot be overlooked, operational costs are typically much more consequential over the life of these systems.

TCO can be reduced by:

- standardizing with a tank gauging system
- enabling cloud connectivity for enhanced monitoring and insights
- implementing process and safety improvements
- reducing time spent on top of the tank
- eliminating obsolete equipment to reduce excess maintenance
- engaging third-party support to reduce in-house technical expertise requirements.

From thermodynamics to business continuity

The second law of thermodynamics is not exclusive to physics classrooms and textbooks. Left unmitigated, efficiency in any electrical, mechanical, chemical, or other industrial system inevitably decreases over time. The old world of tank gauging systems required extensive manual intervention to address issues and maintain measurement accuracy, but the next frontier automates most of these tasks.

Equipped with smart instrument features in a central repository—such as self-diagnostics, automatic calibration verification, and record keeping—along with the computing and alerting capabilities of the cloud, modern tank gauging systems are empowering plant personnel to move away from reactive firefighting to proactive and predictive maintenance methods. This helps maintain measurement accuracy, improves personnel safety, and increases system uptime, leading to fewer delays in transfer and distribution, and greater business continuity and reliability.

For more information, visit Endress+Hauser.

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All figures courtesy of Endress+Hauser

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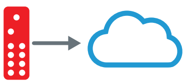

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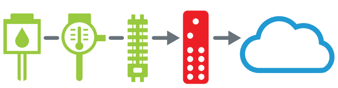

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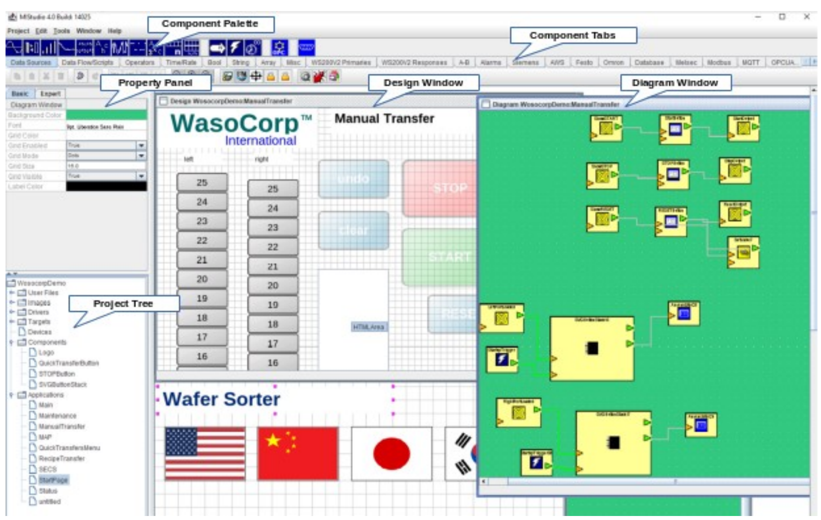

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Diving into Distributed Data Lakes Using GraphQL

By Jim Redman, ErgoTech Systems

Unstructured data comes in many forms and can give engineers useful information not offered by structured data.

The main goal of Industry 4.0 is to provide increased efficiency, productivity, and flexibility in manufacturing by using data and advanced technologies to optimize production processes. Increasingly, this data includes "unstructured" data. Unstructured data does not have a predefined format, for example, spreadsheets, waveforms, log files, images, and videos. This data can provide engineers with valuable insights that are not available from traditional, structured manufacturing data alone, providing context and insights.

Data lakes provide a powerful way to process large amounts of structured and unstructured data. Data lakes have changed from a centralized, monolithic architecture to a distributed approach that integrates other systems, such as ERP and MES systems, and even data from shared drives such as spreadsheets and log files. This distributed data lake uses “data virtualization” or “data fusion” to provide a simple, location-independent solution for querying data from all these sources.

Ease of access to the data lake and inclusiveness of data have become particularly important for AI and machine learning applications. Available tools are making building machine learning models simple, but the barrier continues to be incomplete or inaccurate data sets. While we are still mesmerized by the science fiction-seeming capabilities of AI/computer-generated images and large language models such as ChatGPT, failures of these models are usually related to a lack of data, not the underlying algorithm. A data lake can provide both high-quality and more complete data, leading to better performance and more accurate models.

Many of the available “big data” tools can be used to build a data lake; however, GraphQL has emerged as a powerful tool for data fusion allowing precise and actionable data queries over the heterogeneous data sources. GraphQL is a flexible and powerful query language that provides a unified and intuitive way to access and retrieve data.

Structured vs. Unstructured Data

Structured data is data that is organized in a specific format, such as a table or a schema, and can be easily searched, indexed, and analyzed by a computer. Timestamped production data is a good example of structured data. Structured data has a predictable format, which makes it easy to process using traditional data processing tools like SQL.

Unstructured data, on the other hand, is data that does not have a specific format or structure and is not easily searchable, indexed, or analyzed by a computer. Examples of unstructured data include text documents, waveforms, log files, spreadsheets, images, and videos. Unstructured data is characterized by a high degree of variability and a lack of predictability, which makes it more difficult to process using traditional data processing tools.

Data can also be semi-structured. This means that it has some structure but not enough to be considered structured data. An example of semi-structured data is JSON or XML, which have some structure but also contain unstructured data.

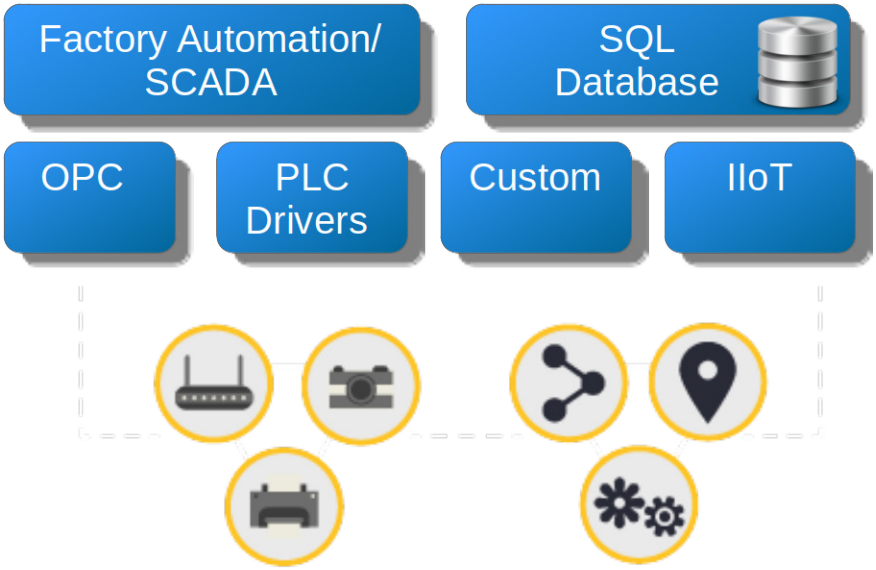

Figure 1. Data is collected from tools, equipment, and many other assets, and stored in a SQL database.

Data warehouses vs. data lakes

A data lake and a data warehouse are similar in that both are used to store and manage large amounts of data, but there are some key differences in architecture and usage. In manufacturing, we've been building "data warehouses." In this architecture, data is collected from tools, equipment, and many other assets, and stored in a SQL database (Figure 1).

A data warehouse is a centralized repository for structured data that is typically used for reporting and data analysis. Data in a data warehouse is organized, cleaned, and transformed before it is loaded into the warehouse, making it easy to query and analyze.

This design has served us adequately in manufacturing. Much of the data we're collecting lends itself readily to storing in a database table. We can collect groups of data, such as registers from a PLC, and store them with a timestamp. Each record is a row of data. The data is classic ABC—Analog, Binary, and Character—manufacturing data and a good fit for a SQL database.

As we come to report on or analyze this data, it quickly become clear that our dataset is incomplete. In almost all organizations there are IT-related assets, MES, ERP, and other systems from which we also need data. Furthermore, many organization have different databases and multiple data warehouses—each with additional information. These silos of information are not readily integrated and often have been created for different functions and are being managed by different organizational units.

Increasingly, diagnosing problems relies on data other than the simple ABC data. For example, the availability of low-cost cameras means that we can monitor equipment and, ideally, grab an image or video of the tool as an error occurs. We would like to link these images with the manufacturing data, but a traditional data warehouse handle images poorly, if at all.

Solving a problem or preparing a report or a presentation therefore relies on us having access to all of these sources of information, including data that is stored in SQL databases and a variety of other systems, on our local hard drive, or company-wide shared drives. Data such as images or waveforms may still be on the equipment that we access with FTP or similar applications. The format of this data may not be well defined. Information is often in spreadsheets, log files, web pages, drawings, custom formats, PDFs, or other documents. To use it, we must determine the nature and significance of each file.

At each stage, we apply our experience and knowledge to learn where the information is in the organization and the significance of each data item. To build automated applications, such as AI models, would require each application to replicate this. It would need knowledge of all locations, data formats, and the significance of the data. Without organized management, this is clearly impractical. Furthermore, adding data would require modifications to many applications, and any changes to the structures would break the entire workflow. A data lake can overcome the problems of a data warehouse and provide a data management solution for all data, both structured manufacturing data and unstructured data.

The initial approach was to build a monolithic, centralized data lake to be the repository of all data in an organization. This approach uses "big data" tools to build a highly scalable, yet cost effective centralized data store of structured and unstructured data in its raw form. Ideally, this software platform would provide a single ecosystem for big data analytics and data science initiatives.

It quickly becomes clear that this goal—a single location for all data—even if it were attainable is undesirable. It's difficult to see a purpose for duplicating data that is already part of a working system, such as a data warehouse, MES, ERP, etc. into a data lake. It's immediately obvious that it's wasteful, both in terms of storage and data collection resources and data management effort. Synchronizing this data is also technically challenging.

Few organizations of any size have a single data warehouse for logistical, organizational, and many other reasons. Different departments and divisions build stores for different use cases, or IT systems are adopted as part of an acquisition, so even manufacturing data is stored in different databases. A universal data lake would face the same issues.

What we need is not to put all this data into a centralized system, but to be able to query, view, and extract this data as if it were in a single system. Rather than try to copy all of our existing sources of data into a central system, we need to "wrap-and-embrace"—integrate these platforms so that they can be searched as a single platform.

With this concept, the data lake moves from being a centralized system to a heterogeneous and distributed set of data platforms. These platforms are integrated by "data virtualization," allowing users and applications to query the data without caring about where or how the data is stored.

All of our existing data platforms, the data warehouses, MES, ERP, IT systems, and shared drives become a part of the data lake not by moving the data from these systems to a central system but by providing a virtualization layer. The platforms are integrated to present users, data scientists, and application developers with a fusion of all of the data—a distributed, fused data lake.

Data virtualization

In a data warehouse queries are straightforward. Data warehouses are typically based on a SQL database, so queries can be crafted in SQL and the schema of the data is well defined.

It's common to abstract SQL queries with a "REST" API. REST (Representational State Transfer) is the most widely used architectural style for building web services, and it's been around for quite a while. RESTful APIs are based on the HTTP protocol and use standard HTTP methods like GET, POST, PUT, and DELETE to interact with resources. This is especially common when the resources are located remotely, for example in the cloud.

Other technologies, SOAP, MQTT, and many of the IOT protocols can be used in place of a REST API, but as we move to a data lake, the challenge in all these cases is defining the payload of the protocol—how do you ask for data and what's the significance of the data returned.

Typically with these technologies, once implemented, the data format is fixed. With REST or other solutions, there is very little flexibility in the data request/response. In particular, the main issues with REST are:

- Over-fetching: The client often receives more data than is needed, which results in increased network traffic and slower response times.
- Under-fetching: The client often has to make multiple requests to different endpoints to fetch all the data needed for a given view, which results in increased complexity and slower response times.

These problems worsen as the complexity of the data increases.

Data virtualization with GraphQL

In 2012, to address the limitations and inefficiencies of their existing REST APIs, Facebook (now Meta) developed GraphQL. GraphQL was open-sourced in 2015 and has been widely adopted and used by many organizations and companies, as well as being a standard for developing APIs.

GraphQL is a query language and runtime for building and executing client-server queries. In GraphQL, the client makes a request to the server specifying the fields it wants to retrieve. The server responds with the requested data, structured in the same way as the request. This allows the client to retrieve exactly the data needed, not more, as it would with a REST API.

A GraphQL server presents a schema to the client. The schema defines the structure of the data that can be queried and serves as a contract between client and server. It can be used to validate queries and ensure that the client only requests data available on the server. Adding GraphQL as our virtualization layer resolves the major challenges of the distributed, fused data lake.

The GraphQL adapters, which are implemented as GraphQL servers, solve the problem of attaching significance to data of all types. The adapter provides the schema for the custom data it is wrapping without regard to any other system. This makes for relatively small, self-contained, and self-describing components (Figure 2). For standard data types, such as SQL, these adapters already exist. GraphQL supports a wide range of languages so these adapters can be

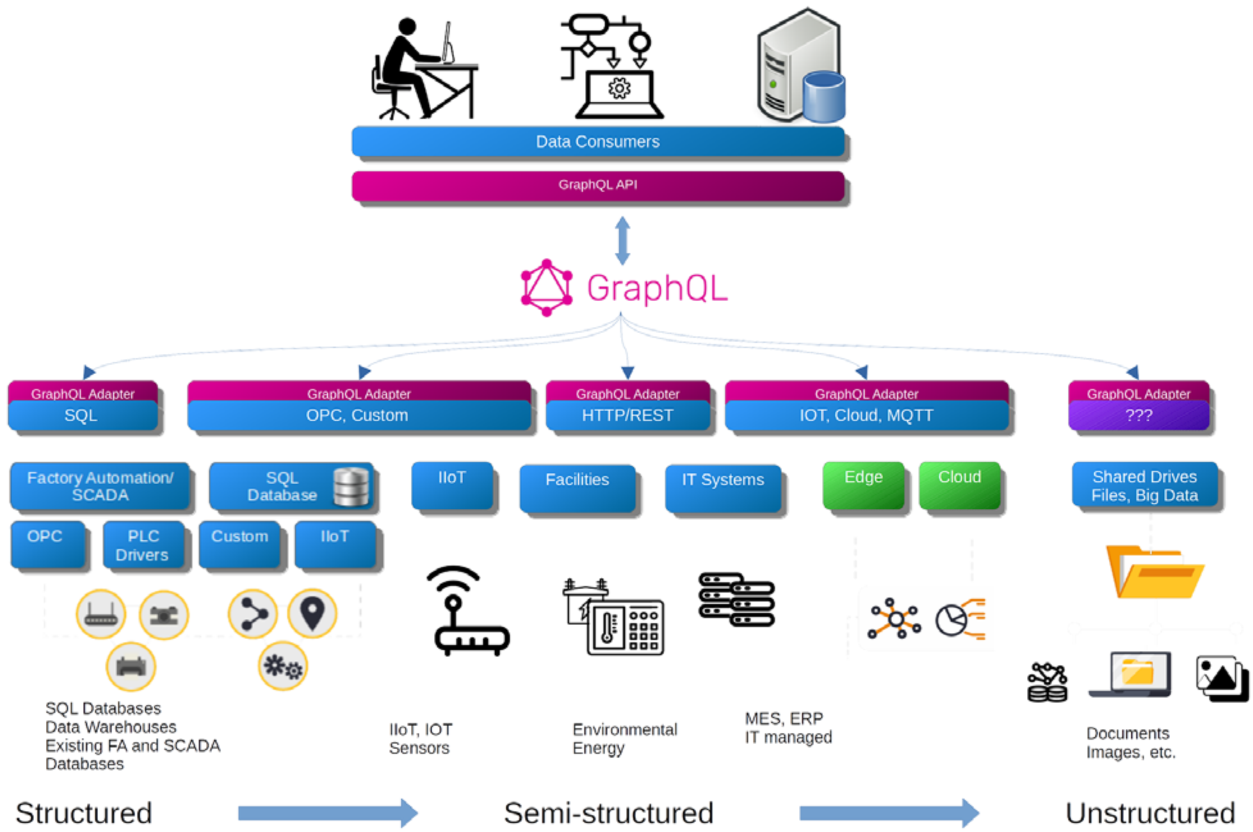

Figure 2. The adapter provides the schema for the custom data it is wrapping without regard to any other system. This makes for relatively small, self-contained, and self-describing components.

created programmatically or in a no-code/low-code environment. The simplicity of defining the adapters means that they can be created by the data-owners, who know the nature and significance of the data best. They can accurately describe unstructured and structured data.

These adapters remove the need to duplicate the data by providing access to data in place and the ability to query that data. The adapter also renders the location of the data irrelevant. It could be on-premise, in a remote location, or cloud-based. For further transparency, the GraphQL adapters can be aggregated, allowing complex queries to be executed against one server but with the results provided by multiple adapters.

The data lake is also hugely scalable. In particular, adding more data requires only the creation of an adapter to all the querying of the information by any client.

With the increasing amount of data generated by manufacturing systems, the importance of data lakes and advanced technologies such as GraphQL, AI, and machine learning will only continue to grow. Companies that are able to effectively leverage these technologies will have a significant competitive advantage in the industry.

For more information, visit ErgoTech Systems.

ABOUT THE AUTHOR

Jim Redman, as president of ErgoTech Systems, Inc., was delivering what has become "IIoT" systems way back in 1998. ErgoTech's MIStudio suite reflects his holistic vision to provide a single tool for integration and visualization from sensor to AI, and from tiny IIoT to worldwide cloud. Jim can be reached at jredman@ergotech.com.


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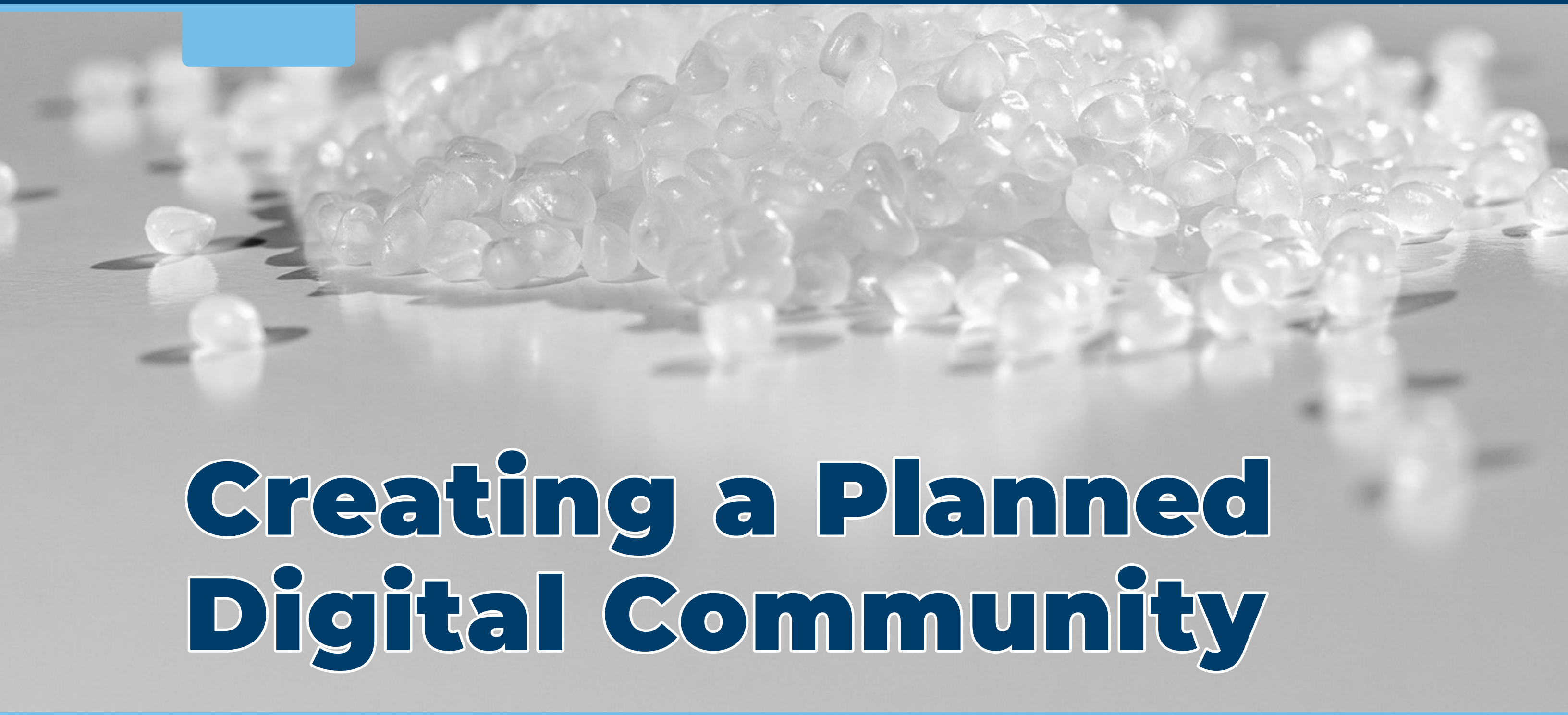


Creating a Planned Digital Community

A plastics recycler is skipping the transformation and going directly for its multi-site plant operations.

By Jack Smith, Automation.com

Digital transformation is in the sights of many companies. Some are well on their way along the journey to a smarter plant; others are just getting started. It would be great if a new greenfield plant could start at a point beyond transformation—born digital. PureCycle, a chemical processor looking to turn plastic waste into a renewable resource, is doing just that.

PureCycle is transforming polypropylene into versatile replenishable ultra-pure resin through a unique purification process that removes odor, colors, and contaminants. Its mission is to revolutionize plastic waste recycling, and it's doing that in part by rethinking plant design. It is centralizing the design and building of its plants in a way that allows it to copy and paste its plant modules.

PureCycle CEO Dustin Olson contacted James Haw, now Vice President of Program Management & Digital Strategy for the company, to discuss the new technological breakthrough in plastics recycling and seeking advice on automation technologies that could be applied to this new technology. The ensuing conversation touched on how to implement automation to set the company up for long-term success and avoid having to launch "digital transformation." Instead, the two discussed how to become a "born digital" plant from the start.

The resulting collaboration marked the beginning of what Haw describes as "a remarkable opportunity to work at PureCycle and implement an automated industrial process using cutting-edge foundational technologies to help create a planned digital community that would make costly transformations less likely and easier to implement."

Planning a digital community

Haw said that during development of a digital ecosystem, interfaces with other business systems are established to create a true digital thread so each system digitally extracts or writes information consistently.

> **"The digital footprint** for the entire operation is coordinated, designed, and built like a 'planned digital community.'"
> *—James Haw, Vice President of Program Management & Digital Strategy, PureCycle*

"The digital footprint for the entire operation is coordinated, designed, and built like a planned digital community," Haw said. "The reason is because application or system mismatches—and the integration work undertaken to force them to work with one another after the fact—has historically increased budget and schedule dramatically, and has resulted in a unique system requiring increased maintenance and development over its entire lifecycle. It's the *transformation* we will ultimately avoid."

"Our forward-thinking approach means our facilities are born digital," said Olson. In partnership with Emerson, "we are building smart facilities from the get-go," he said. "PureCycle is leapfrogging to the latest generation automation technology, employing virtual reality [VR], augmented reality [AR], and artificial intelligence [AI]. Projects can be completed faster and operate with world-class performance. It's pure digital through our unprecedented purification process and leading-edge approach."

Haw explains further: "What it means for us in the short term is that we get all the great things that provide value now, like highly integrated basic process control systems [BPCS]; digital twins; high-performance graphics; alarm rationalization, management, and adherence to alarm philosophy from the start; ergonomic control room and building design; building management; central hub support to worldwide facilities; mobility concepts as part of our culture; and harnessing AI to reach higher levels of autonomy—all from the beginning."

"We are building on existing ideas so we can scale faster, run more efficiently, and increase productivity, enabled through a digital plant built today for tomorrow," said Olson. "We aren't weighed down by concepts that don't work. PureCycle is centralizing the building of our plants, which allows us to copy and paste our plant modules. This replication approach from multiple production lines at one location will speed up the building process, decrease operating costs, improve efficiency, and enhance safety."

Olson said you can't leverage the full value of smart digital unless everything is smart digital. "If you went out to an existing plant and you upgraded a few control valves, monitors, and transmitters, that

PureCycle Plant on Track to Begin Production This Year

Munich-based KraussMaffei, manufacturer of plastics and rubber processing machines, delivered the final piece of the major equipment needed for PureCycle's Ironton, Ohio, plant on December 19, 2022. The delivery of the final extruder came sooner than anticipated amid supply chain difficulties and will enable PureCycle to stay on track to finish construction of the plant. Pellet production is expected to begin this year.

system would become a little bit better. But you're never going to be able to really leverage the power of digital unless the entire system and ecosystem is working together. This is where doing it straight out of the gate is much better."

Recycling reimagined: Purifying the plastic

PureCycle's patented process is using a technology that Procter & Gamble first developed in 2012. Our approach to innovation not only includes products and packaging, but also technologies that allow us and others to have a positive impact on our environment. This technology, which can remove virtually all contaminants and colors from used plastic, has the capacity to revolutionize the plastics recycling industry by enabling P&G and companies around the world to tap into sources of recycled plastics that deliver nearly identical performance and properties as virgin materials in a broad range of applications," said Kathy Fish, P&G's Chief Technology Officer.

According to Haw, PureCycle's patented recycling process dissolves polypropylene waste feedstock using a proprietary solvent, which then separates color, odor, and impurities from polypropylene to transform it into an ultra-pure recycled (UPR) resin (figure 1).

Figure 1. Facility site plan overview of the Ironton, Ohio, PureCycle plant.

“What if that same plastic could be recycled in such a way that it could be purified—or taken to a ‘virgin-like’ state—making it reusable in all its original use cases?,” asks Haw. PureCycle takes post-consumer and post-industrial polypropylene waste and does just that.

“Our innovative process essentially cleans the plastic at the molecular level. Feed prep works to remove biological impurities from the plastic waste, then the purification process is designed to remove color and other additives by scrubbing the molecule to produce an ultra-pure, virgin-like polypropylene that can be used in all its original use cases,” said Haw.

“The first plant is nearing completion in Ironton, Ohio (figure 2), and two more facilities are coming to Augusta, Georgia,” said Olson. With the company’s flagship recycling plant in Ironton, Ohio, expected to start pellet production in Q1 of 2023; a second plant in Augusta, Georgia, under initial construction; a site selected for its first European polypropylene recycling plant at Port of Antwerp Bruges’ NextGen District in Belgium; and its first polypropylene recycling plant in Asia currently on track to open in 2025, PureCycle is expanding globally and actively scaling its production capabilities.

Figure 2. Aerial view of the PureCycle plant in Ironton, Ohio.

Sustainability at the forefront

Olson said PureCycle will change how people view and use plastic. "We exist to attack the waste crisis and are about to make plastic cool again. The PureCycle era of plastic recycling is here. The problem we all face is huge. About 500 billion pounds of plastic are produced every year. Around one third of that is polypropylene. Nearly 10 percent of polypropylene is recycled currently. That's about 175 to 200 billion pounds of polypropylene per year, and less than 10 percent is recycled. That means about 20 billion pounds is recycled globally, leaving a 180-billion-pound hole. That's what we aim to attack."

According to Olson, the problem with plastic is not plastic itself. He said the problem with plastic is that we don't recycle it. "We have a pretty simple mission. We believe plastic can be a renewable resource. There's no reason that we have to put it in the landfill. There's no reason to incinerate it. There's no reason to allow plastic to leak to the environment. The problem with plastic is recycling. We have to find a way to keep reusing it. That's true circularity."

"PureCycle will close the loop on circularity," said Olson. "We have great environmental credentials. We're a true sustainability company. That's all we do. It's not a piece of our business. It is our entire business. There are many different technologies coming out, and we need them all. The problem is so big that we really shouldn't and can't rely on one solution to solve them all. But we believe ours is unique. Some technologies break down the molecule, but we're like a dry-cleaning plant for the molecule. We wash it. We wash the contaminants away and preserve the structure of the molecule."

> **"We believe** this is the way the world is going. We believe in an infinitely sustainable planet."
> *—Dustin Olson, PureCycle CEO*

Olson said PureCycle has the technology to accomplish the washing and reusing of molecules. "We believe this is the way the world is going. The problem with traditional recycled product is it takes a lot of sorting on the front end. When you put it all together, you end up with a product that's gray or dark or black. It can't be used in every application. We wash the molecule and leave behind the white clear product. We remove the odor, colors, and the contaminants that are on the outside and inside to produce a product that's just like fossil polypropylene."

Looking ahead

Olson said PureCycle's future is bright. "We're very excited to be part of this transition; we're very excited to be purely ESG [environmental, social, governance], where everything we do every day is focused on improving the planet. We're thankful of our relationship with Emerson and hopeful about where the planet's going in the future. There's value in helping the world get to a better place. And if we have an opportunity to be a leader in recycling and a leader in digital, then I think it'll be incumbent on us to do it."

ABOUT THE AUTHOR

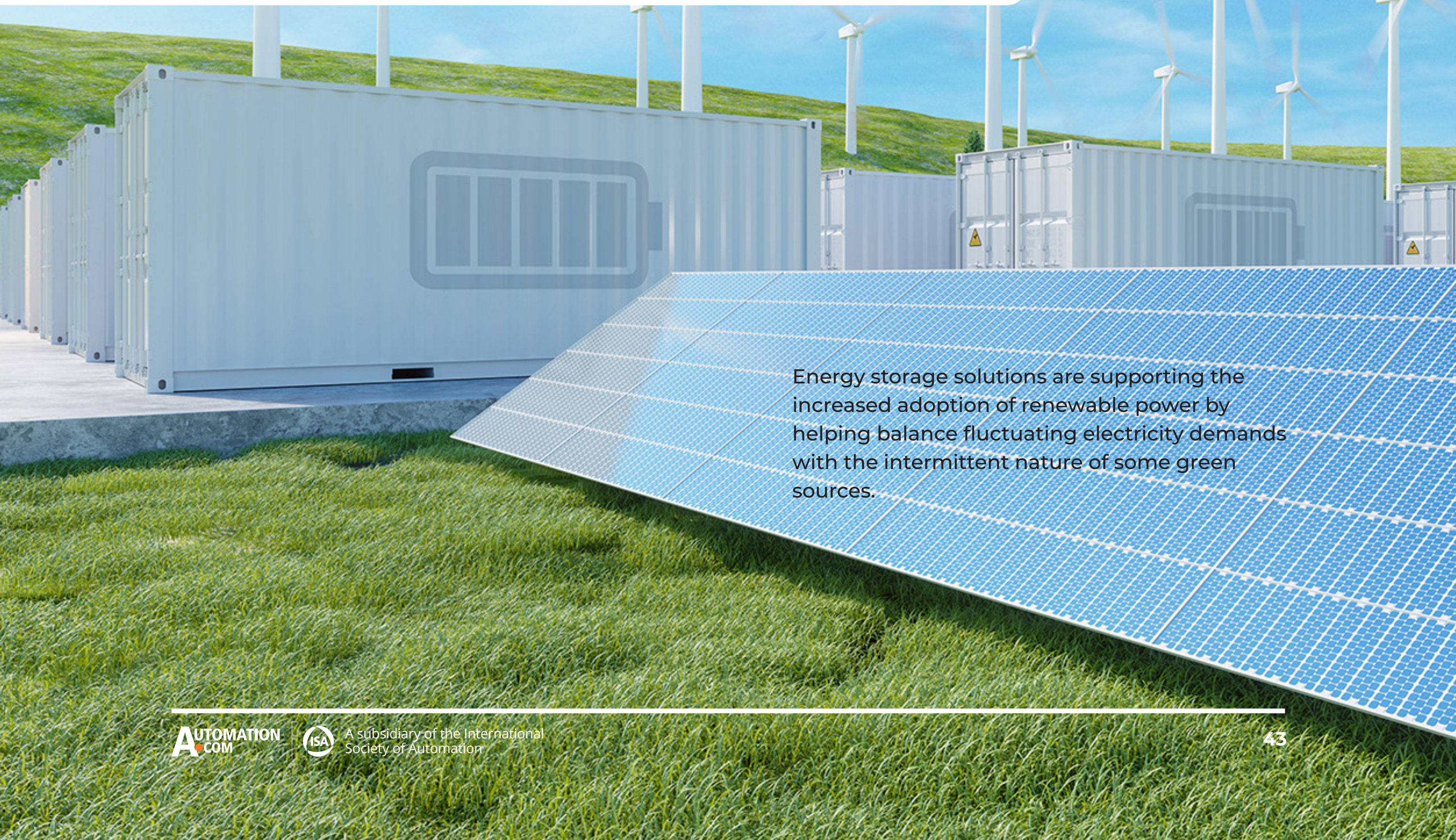
Jack Smith (jsmith@automation.com) is a contributing editor for Automation.com and ISA's InTech magazine. He spent more than 20 years working in industry—from electrical power generation to instrumentation and control, to automation, and from electronic communications to computers—and has been a trade journalist for more than 20 years.

Digital Twins Heat Up the Capabilities of Energy Storage Plants

Leveraging cutting-edge industrial automation with real-time simulation models.

By Alan Messenger, Optimal Industrial Automation

Renewable energy sources, such as RNG, provide multiple benefits. In addition to supporting ambitious decarbonization and net zero goals, they also offer the most economical way to create a decentralized power system. This, in turn, can help achieve universal, reliable, and affordable access to power.



Energy storage solutions are supporting the increased adoption of renewable power by helping balance fluctuating electricity demands with the intermittent nature of some green sources.

For these reasons, the use of alternative energy sources is increasing in popularity, representing almost 11% of power generated globally and forming a major part of the energy mix in many countries. For example, renewable energy use in Norway covered more than 60% of total consumption in 2018.

One of the key challenges that must be overcome to support the increasing adoption of renewable natural gas and other replenishable resources for power generation is balancing fluctuating electricity demands with the intermittent nature of some green sources. For example, to succeed in decarbonization efforts and avoid any wastage, it is essential to prevent curtailment. This occurs when a power generation system is prevented from exporting to the grid, usually because of a temporary constraint caused by congestion, essentially wasting potential low-carbon energy supplies.

The importance of advanced energy storage solutions

To fully utilize generation capacity, robust, reliable and highly efficient energy storage solutions are required, as they can provide the level of flexibility needed to maintain stable and consistent supply to the grid. Strategies such as these can support peak shaving and load shifting activities.

Compressed-air energy storage (CAES) in its various thermo-mechanical forms, is among the most promising technologies available at a commercial scale for high-capacity energy management. By saving potential energy in the form of compressed air, these systems are able to generate large amounts of power on demand.

Also, apart from access to a cavern, CAES facilities are not dependant on specific geographies, unlike pumped hydropower, and their daily self-discharge is very low, making it possible to effectively keep the stored energy for long periods without any considerable losses. In addition, due to the well proven nature of the underlying equipment, CAES plants typically have a designed lifetime of over 40 years, which keeps the overall costs per unit of energy (or power), among the lowest for all available storage technologies.

To achieve these results, CAES facilities can utilize different configurations, one being the innovative liquid air energy storage method, which leverages thermo-mechanical principles to advance the benefits of CAES. In the liquid air variant, air is purified and cooled to its liquid state during the charge phase. It is then stored at cryogenic temperatures and low pressure in suitable tanks. When discharged, the liquid air is pumped to a high pressure, evaporated, and heated to expand the liquid air stream. The resulting high-pressure gas drives a set of turbines in a power recovery unit.

Liquid air energy storage is the way forward

The liquid air energy storage cycle described above utilizes components that are commonly found in conventional power stations and industrial air separation plants. Therefore, they offer multiple advantages. Firstly, they are well proven and broadly accepted. Secondly, this equipment is widely available to support commercial-scale facilities. Finally, they have well-understood maintenance requirements.

The use of alternative energy sources is increasing in popularity, representing almost 11% of power generated globally and forming a major part of the energy mix in many countries.

Furthermore, the use of liquid air energy storage systems leads to energy densities that can be up to 8.5 times higher than conventional compressed air alternatives. Therefore it is possible to create compact plants that are more economical, efficient, easier to implement, and suitable for sites with limited available space.

In addition, the power generation cycle eliminates the need for combustion and the associated carbon emissions while also supporting 'cold recycle' practices. Waste heat from the liquefier compressors is recovered within the process for highly efficient operations, and the storage and recycling of thermal energy released during discharge can be used as part of a closed-loop system to support air liquification activities during charging.

Automating energy storage process control

A liquid air energy storage process offers *per se* unique financial and environmental benefits. Nonetheless, with temperatures ranging between -200 and +600 °C and pressures reaching up to 200 bar, small variations in these can impact performance significantly. This means that the optimum control of processing parameters throughout the different phases is key. This is essential to maintaining energy efficiency and low costs while maximizing the end results.

By supporting real-time feedback and feedforward systems as well as remote monitoring, industrial automation technologies provide an ideal solution to consistently deliver peak performance and efficiency. More precisely, fully integrated automated process control provides a highly available, responsive, and secure framework for monitoring and visualization, trending and analysis, and the management and synchronisation of all pieces of electromechanical equipment onsite.

By using this type of automated setup, liquid air energy storage plant operators can ensure the proper sequencing of all processes and promptly address any alarm to maximize uptime, ultimately delivering high efficiency and productivity. As a result, it is possible for facilities to realize dispatchable and predictable power distribution to the grid while also maintaining a low—or even net zero—carbon footprint.

Using this type of automated setup, liquid air energy storage plant operators can ensure the proper sequencing of all processes and promptly address any alarm to maximize uptime.

However, having precise control over operations to ensure optimum operations requires an in-depth understanding of the process and the ways in which all components work together and influence each other. Only in this way is it possible to effectively regulate all activities. As liquid air energy storage facilities are relatively new, this insight may not be readily available to plant managers.

Leveraging digital twin technology

Having a flexible automation setup that can support liquid air energy storage plants while helping to develop process knowledge is a key resource. Moreover, the use of advanced data analytics can enable the creation of an accurate and precise process model known as a digital twin.

This offers a real-time virtual representation of a physical asset. It uses data generated by sensors on the system as inputs and produces predictions about future behaviors. It then turns this data into accurate, accessible, and easily understandable information formats for immediate insights. As more data becomes available, the digital twin can be constantly updated to offer improved accuracy and additional capabilities. The most immediate benefit of such a framework is the ability to organize all process information and have a single, comprehensive process overview that allows for effective decision-making.

Digital twins empower operators to simulate different operating conditions and scenarios, evaluating the system's limitations without the need to run these in the physical world. This, in turn, helps improve cost-effectiveness and safety. Consequently, a digital twin application that encompasses all stages of a liquid air energy storage plant is a key tool that can be used to enhance process modelling and understanding while also enabling agile operations and driving continuous improvements. Furthermore, these virtual representations can go even further, interacting with their physical counterparts as cyber-physical systems (CPSs) to create even more proactive and flexible setups.

To fully reap the benefits of the latest industrial automation solutions, such as advanced process control and digital twins, energy storage facilities should partner with an expert system integrator. This can address the specific needs of the sector and is equipped to support innovative processing methods and technologies, delivering futureproof, scalable solutions that can grow with a business as well as advance it.

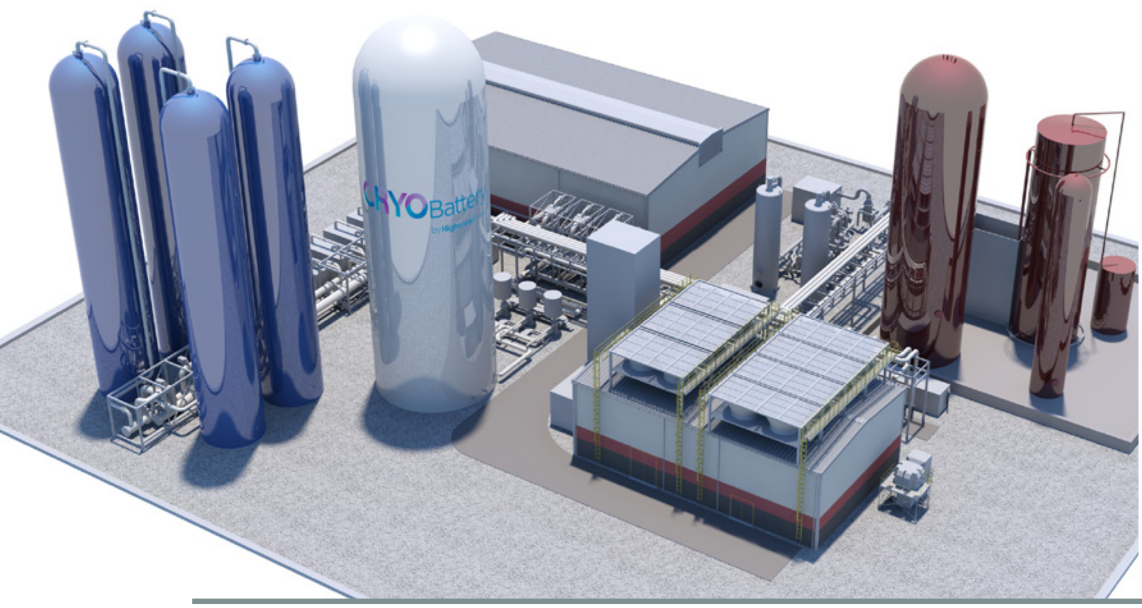
A digital twin of the first full-scale UK liquid air energy storage facility

Highview Power, a global leader in long-duration energy storage solutions, is supporting the global adoption of advanced cryogenic plants with its proprietary liquid air energy storage technology. The company's latest project is the construction of a 50 MW liquid air energy storage facility (with a minimum of 250MWh) in Carrington Village, Greater Manchester, UK.

Able to power approximately 200,000 homes for six hours a day, the plant will help balance the supply and demand for renewables. To ensure successful operations at this landmark facility, the company is collaborating closely with its automation and technology development partner, Optimal Industrial Automation.

The automation system integrator has been supporting Highview Power since the creation of the cryogenic energy storage specialist's first precommercial scale demonstration plant at the Pilsworth Landfill facility in Bury, Greater Manchester. Since the automation requirements of this initial facility were unspecified, due to the unique nature of the technology, an automation specialist that could handle the unknown and deliver a flexible solution was a must. Having already developed a proven system to address these challenges, starting with the instrumentation requirements and through to commissioning, Optimal was the obvious choice.

For its latest, larger project in Carrington, Highview Power was keen for the automated system to feature a digital twin of the liquid air energy storage facility for use in training and for marketing demonstrations. This would support the growth of good asset data, which is key to the continuous improvement of the process model and an increasingly detailed understanding. By doing so, the digital twin would ultimately support the optimization of this and future plants.



Highview Power, a global leader in long-duration energy storage solutions, is supporting the global adoption of advanced cryogenic plants with its proprietary liquid air energy storage technology.

as well as futureproofing energy storage operations, in line with the company's digital transformation strategy.

To develop this cutting-edge solution, Optimal had to address a number of exacting requirements. Firstly, the team had to select heavy-duty instruments that could withstand the operating conditions at the liquid air energy storage plant. Secondly, it was essential to create an automated setup that would be extremely accurate and reliable in order to promptly identify and act upon any change in the key processing parameters, such as temperature and pressure, while maximizing plant efficiency, performance, and safety.

When looking at the parameters that the digital twin needed to account for, it was necessary to enable it to interface with advanced mathematical models and simulation software platforms in addition to the physical automation system. To address this level of complexity, providing a solution that could support multithreading and multiprocessing functions was crucial.

Thanks to its extensive expertise in building, integrating, and optimizing automation systems for challenging and highly regulated industries, Optimal has a unique knowledge of a wide range of vendors' portfolios as well as the most suitable products available on the market. With this insight, the company was able to leverage high-performance components featuring world-class redundancy, availability, and fault-tolerance, as well as maximum connectivity. The automation system is now ready to support full operations at the Carrington facility. For more information, please visit Optimal Industrial Automation.

ABOUT THE AUTHOR

Alan Messenger has 30 years of experience in automation and control, 28 of which have been in sales of key technologies and solutions. His industry experience includes pharmaceutical manufacturing as well as more difficult, niche applications where a wide range of technical knowledge and skills are needed. He joined Optimal Industrial Automation in 2008 as an account manager and became the sales director in 2020. He can be reached at alan.messenger@optimal-ltd.co.uk.