WHITE PAPER

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INSPIRING INNOVATIONS

Energy monitoring in an IIoT world

Applications, concepts, and integration

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Introduction

Smart instrumentation, monitoring, and the connected factory represent an exciting new era in industrial automation known as the Industrial Internet of Things (IIoT). IIoT is transforming the way we design and operate all kinds of equipment and even influences plant design as a whole. The promises of smart factories that can reduce energy consumption and boost uptime are firmly rooted in monitoring and collecting data on equipment of all types.

The emphasis on monitoring within IIoT is by design, as monitoring is one of the single-best mechanisms there is for improving operational efficiencies. It is not uncommon for monitoring to be overlooked as nothing more than an energy-efficiency product. However, looking at energy monitoring only as a tool to reduce energy consumption leaves a lot of additional cost-saving opportunities on the table. Simply put, monitoring enables operational improvements from several angles.

INSIDE:

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The goals of this white paper are to:

- Introduce the three basic ways monitoring can help achieve savings
- Explain how energy monitoring and the IIoT story are interwoven
- Provide a high-level overview of how to interpret basic energy data
- Share some real-world application examples
- Give some insight on selecting and investing in energy monitoring equipment

Section 1: Three ways to leverage energy data

Meet RAE

RAE is an acronym that makes it easy to break down the primary benefits of energy monitoring. RAE stands for Reliability, Accountability, and Efficiency. Each represents one of the three major ways monitoring can improve profitability.

Though all three concepts are related, they each have unique benefits and cost-saving mechanisms. Taking advantage of RAE as a whole substantially increases the return on investment (ROI) in monitoring equipment, especially when compared to implementing energy-efficiency improvements alone.

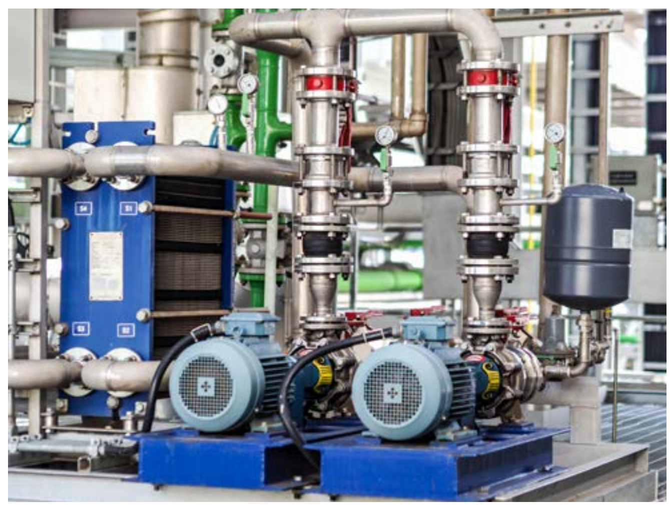
Reliability

The single-most important benefit of energy monitoring in the industrial world is not energy savings, but rather, uptime and reliability improvement. Energy signatures and power quality within systems play large roles in unlocking predictive maintenance, also known as just-in-time maintenance (JITm). Unlike run-to-fail or preventive maintenance programs, downtime and/or excessive spending on interval-based equipment replacement can be minimized or avoided altogether.

JITm at its core involves monitoring energy usage, utilization, and quality, comparing it to historical baselines, and then flagging anomalies as action items to investigate before a failure occurs. These types of anomalies can be the result of typical wear and tear, the need for periodic maintenance, or equipment end-of-life, to name a few. Monitoring can also be used to detect other conditions that would require regular maintenance typically associated with a certain amount of runtime. When issues like tooling wear, filter contamination, or consumable materials depletion are accurately detected, the maintenance team can schedule windows to optimally balance maintenance needs with production uptime.

Accountability

There is also some benefit to maintaining monitoring and logging equipment that is independent of utility metering. Operating energy meters independently of the utility allows facility managers to verify billed energy quantities, as well as time of day and usage rate data. It also allows them to have logs of this data, in addition to the quality of service delivered. Logs and independent data points can be a significant help in cases of utility failures or billing disputes. These logs are frequently used to hold utilities accountable for remediation if a customer is overcharged or if there is a utility-side issue that results in damage to equipment/lost production time.



Preventing downtime, saving energy, and improving asset performance are just a few of the benefits of proactively monitoring energy.

A significant side benefit of maintaining logs is the ability to conduct a more thorough failure analysis in the event of sudden failures. These types of failures are different than those prevented by JITm because they typically occur as a result of issues with the quality of the power delivered and are not a function of machine wear. Just as IT departments use event logs to determine what was happening before, during, and after an unexpected outage, maintenance departments can use energy logs as tools to assess power system conditions surrounding a failure. This may reveal a root cause, or it could expose equipment

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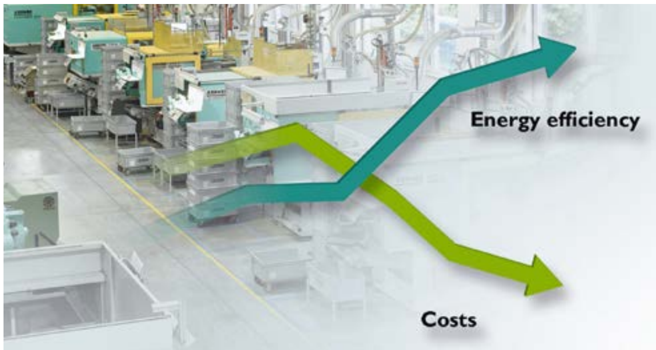
vulnerability issues. Accordingly, the maintenance department can take the necessary corrective actions to avoid future downtime.



Saving energy ultimately translates into lower costs and a better bottom line.

Efficiency

Efficiency, specifically energy efficiency, is often seen as savings through reduced consumption by switching to high-efficiency electrical devices – think NEMA premium efficiency motors and transformers, or LED lighting upgrades, for example. While these types of upgrades do indeed improve efficiency, efficiency improvement overall is a broad topic that also includes the often-overlooked element of optimization.

Efficiency optimization involves correcting inefficiencies in processes and machine cycles alike. Some of these inefficiencies are the result of machine malfunction. Other inefficiencies are present simply because certain machines or processes have never been optimized. The most common types of inefficiencies would primarily include wasteful machine cycles, equipment failures resulting in excessive energy consumption, and parasitic loads. For example, a material transfer conveyor belt that runs continuously for minutes or hours at a time, even when not needed, can be switched off when not in use.

Monitoring plays a critical role in optimization by providing a clear picture of how much energy is used and how it is being used. Data collected by monitoring is compared to historical consumption, utilization, and the machine's production yield/throughput. Once usage baselines are established, and performance metrics are defined, undesirable conditions can be identified and eliminated.

Section 2: How is IIoT impacting energy monitoring (and vice versa)?

Energy monitoring with cloud connectivity is no longer a specialized affair

Broadly speaking, there are two sets of monitoring data that can be analyzed to achieve the benefits of RAE: instantaneous data and a comparison of current versus historical data. Both have their own place in the toolbox of process optimization, and each one can vary in terms of the story it tells and the complexity of that story. In the earlier days of energy monitoring, the effectiveness of monitoring the data and acting on it was often limited to the local integration. The process relied on specially trained staff to take advantage of the incorporated systems.

IIoT solutions have begun to bridge the gap between localized industrial control systems and powerful cloud-based analytics engines previously unknown to the industrial segment. As mentioned earlier in this paper, monitoring the basics can provide some great insights into maintenance events that need tending to now.

Next-generation devices with native cloud connectivity, combined with the rich array of cloud platforms and services commercially available today, afford industrial users greater IIoT accessibility than ever before.

Cloud-based systems take it a step further, using predictive analytics and real-world data collected by sensors such as energy meters to effectively change maintenance procedures entirely. It suddenly becomes possible to predict when a failure may occur in the future, thanks to algorithms tuned to industrial processes. Cloud solutions can also be used to track production costs in dynamic ways, by providing dashboards that allow for statistics at both the micro and macro levels.

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Along with a shift in the way we collect and process data comes fundamental changes in communications and programming requirements. Cloud services are built on internet-based programming languages and protocols such as HTML5, REST API, and MQTT. These interfaces are rapidly becoming the norm for asset management and remote monitoring across many industries in the industrial space.

As IIoT evolves, more and more companies are tapping into the ease of use and the powerful benefits of analytics, dashboarding, and remote monitoring cloud services. You can expect to see more industrial products that feature these protocols natively. For example, Phoenix Contact recently released the first energy meter for the industrial market with native MQTT support. This followed the successful market launch of our PLCnext platform, which serves as an IIoT gateway for traditional industrial devices. There are other manufacturers also offering a range of products that focus on converting information from legacy systems to internet-based services, and that number continues to grow each year.

Regardless of the mechanism used to get to the cloud, the demand for these technologies is not based purely on hype; there are many benefits, as discussed throughout this paper and in a host of industry forums.

Energy monitoring in the control cabinet is rapidly becoming commonplace.

Why is energy monitoring such a hot topic these days?

In the past, there were few commercially available systems or programs that made energy management simple. Energy management brings with it many benefits, but it was generally considered a highly specialized application that could be challenging to integrate effectively.

Thanks to recent advancements in both technologies and services, many off-the-shelf energy management solutions are becoming available today. There are also a host of companies building their own cloud-based solutions for machines and systems to sell as an option or as a service to their customers. These solutions are in high demand because they make it easier than ever to tap into the potential profits energy monitoring can produce. This has subsequently spurred significant demand for energy-monitoring hardware.

Modern control cabinet energy meters simplify the process of measuring energy data in a given machine, system, or facility and streamline the communication of that data via Ethernet or serial network. They have been designed with IIoT solutions in mind, representing an exciting new generation of hardware that perfectly complements the growing trend of smart factories and smart industries.

IIoT: How did we get here, and what does it mean?

In recent years, internet connectivity has exploded, and artificial intelligence has changed the way we approach problem-solving across all parts of life. We have seen a dramatic downward shift in cost and integration complexity of products and services of all types. The introduction of smart devices, coined the Internet of Things (IoT), has made this trend possible. Broadly speaking, smart devices leverage connectivity, analytics, and data to make our lives, homes, utilities, and even entire industries smarter and more connected. As a result, we can monitor and control just about anything, from anywhere, autonomously or manually.

The industrial segment of the economy is experiencing a related reinvention of its own, known collectively as the Industrial Internet of Things (IIoT). Like the Internet of Things, IIoT relies on three basic layers of software and hardware that, when combined, enable profit-enhancing smart capabilities such as remote diagnostics and predictive maintenance.

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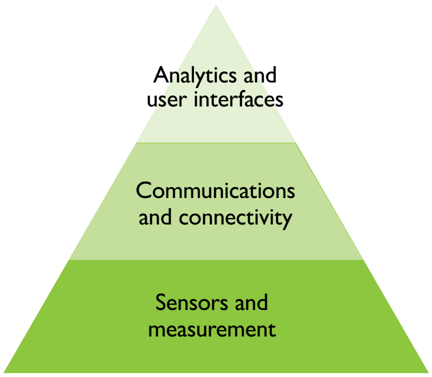
The three fundamental pieces of an IIoT solution

1. Basic measuring and sensor devices (hardware)
2. Communications and connectivity (hardware/software)
3. Analytics and user interfaces (software)



Simplified IIoT solution

Even though IIoT solutions require multiple levels of equipment and resources, they all rely on one key thing: data. Data is generated by measuring basic system conditions, like power, pressure, and temperature, for example. Without information about system status and performance, we could not display real-time data about systems remotely, and we couldn't harness the power of analytics to make our factories, buildings, and machines smarter and more reliable.

What role does energy management play in the IIoT story?

Much like a fingerprint, every machine or system has a unique energy signature that tells a story about its operational cycles. By measuring this signature and then comparing it to real-time conditions, changes in time can be noted and acted upon. This is the basis for many just-in-time maintenance programs, which leverage the data they acquire to predict when a failure may occur.

In other instances, energy monitoring can be used to measure and protect against undesirable conditions, such as voltage sags and swells or poor power quality, that damage equipment. It can also help prevent surprise utility fees for excessive energy demand or poor power factor and can provide independent data in the event of utility disputes. In yet another benefit, energy management can enhance operational efficiency and utilization rates of equipment and machines.

Just-in-time decisions require real-time data acquisition

There are many examples of how this story plays out, not only in terms of predictive maintenance, but also in terms of predicting costs, productivity, quality, and failure rates. Close monitoring and acting on these key metrics can significantly enhance profitability.

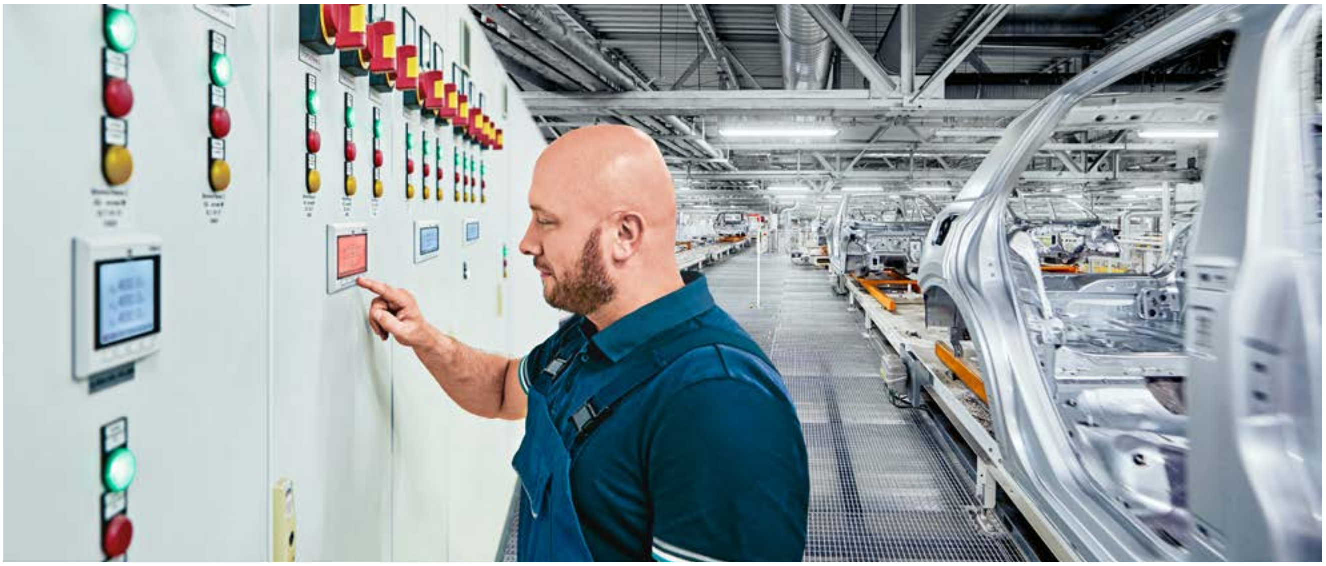
Machine data with cloud connectivity can be used to predict failures and reduce operating costs from virtually anywhere.

Fundamentally speaking, however, the ability to tap into these metrics and leverage them for maximum profit requires an IIoT solution. Recall that an IIoT solution cannot exist without data. Energy meters are the foundational devices that measure and communicate electrical system data accurately and efficiently, so that you can monitor it, manage it, and act upon it.

Section 3: What's flowing through your wires, and how can it help you?

Measured energy parameters as tools of insight

Each point of measurement provides a unique insight into system or machine health. Regardless of the piece of equipment or the industry segment you find it in, voltage, current, and power all flow through the conductors that make the machines run. These fundamental energy-monitoring parameters can help tell a system's story. Decoding that story affords the opportunity to unlock the primary monitoring benefits mentioned in the previous section.



Stable supply voltage is necessary for the reliable operation of any system. Under-voltages are especially troubling, often leading to equipment damage and malfunction.

Voltage

Broadly speaking, voltage is a good indicator of overall system health. Issues with a power supply, whether it is an AC system or a DC system, often manifest themselves in voltage abnormalities. Because voltage touches every component in the system, the overall reliability of any system is closely linked to a steady, clean-source voltage. This is true from subsystems like a control cabinet or a DC bus to something larger like a facility's AC distribution system. Voltage stability as a factor of reliability even applies to entire electrical grids.

Practical example:

Anomalies in voltage within AC systems can result in many problems. One of the most common issues seen with utility power quality is low line voltages. Most electrical motors will only tolerate +/-10% of their nameplate voltage before they begin to experience damage. Under-voltages in AC induction motors cause them to draw excessive current, which results in heating of the windings and, eventually, thermal failure of the insulation within the motor. By monitoring and logging incoming voltage, the equipment can be safely switched off when a low-voltage condition is detected. Logging the low voltages also protects you if some equipment still suffered damage during the voltage-sag event. Insurance companies or the utility company can use this data to determine who will pay for losses sustained as a result of the low voltage event.

Current

Just as voltage is a good indicator of system health, current is a good indicator of individual load health. If one were to consider any electrical device – a light fixture, a water pump, or an electric heating element, for example – it is true that the device will draw current at a relatively consistent level. A device or process might draw higher or lower currents as different functions cycle on and off. However, even those high and low current points will be consistent.

Current is the go-to parameter to monitor in many industrial applications. Failed or failing heaters, lights, motors, and solenoids can all be detected by monitoring current.

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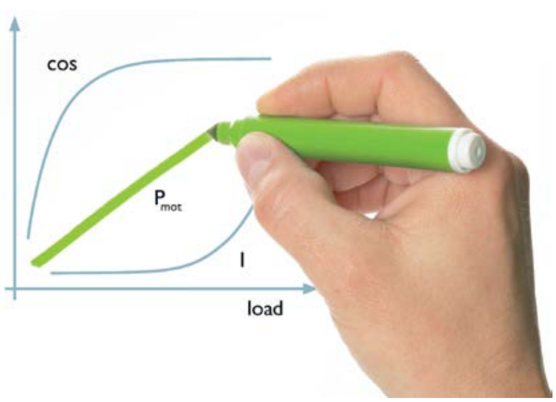
Once devices or systems begin to break down, they start to malfunction, which will result in changes in current draw. By comparing historical current draws to present current draw, changes in current, ergo breakdown of equipment, are quickly spotted and can be rectified immediately instead of reaching the point of catastrophic failure.

Practical example:
Heat traces are a low-tech but critical component used in many process industries to keep liquids moving through pipes at a constant temperature. A failed heat trace can be a big problem, as pipes may foul with solidified products, or adverse chemical reactions may occur if the required temperature is not met.

Detecting a failed heat trace is quite simple. The current of the heat trace will drop to 0 amps when the heat trace fails; a maintenance event can be initiated either manually or automatically on the spot. This could include an automatic purging of the pipe, a switch-over to secondary heat traces, or a notification for an operator to open a bypass valve.



In relative terms of how much work a motor is producing, power is a far more useful parameter to track than current, thanks to its linear nature.

Power

Power is one of the most robust reference points of all when analyzing energy data. It can be used to predict failures, maintain uptime, and reduce costs. Unlike current, power is linear in many kinds of loads. This includes lighting, heating, and electric motors. Especially in the case of motors, power can be used as a performance metric that is so effective, it can sometimes replace specialty sensors in a process.

Practical example:
An electric motor will not see huge swings in its operating current when going from no load to ~¾ load, before rapidly increasing as it approaches full load; power, however, is linear across the same range. Being able to see precisely how much a motor is loaded introduces many opportunities for state of health and condition monitoring.

Motors are used to create motion for a variety of tasks, from simple ones like moving air with a fan, to complex CNC precision machining. In all cases, the motor driving these loads is highly sensitive to the amount of drag being created on the motor shaft. By monitoring power, it is possible to detect small changes in equipment with much more accuracy than current measurement alone. In a simple device like an air handler, a monitoring device can detect a slipping belt that needs replacement long before a human ear can hear it or the belt fails. In a machining process, the sharpness of the tooling can be accurately gauged by the power needed to complete a cut. In other uses, it can detect changes in viscosity of pumped fluid, or supplement load-cell sensors when determining the load placed on an overhead crane.

The applications of power monitoring expand far beyond the few examples cited here, but the principle of tracking small changes in operations remains the same no matter the application.

Section 4: Real-world applications of energy meters

Example 1: Remote monitoring of generators

Energy meters with direct Rogowski connection are well-suited to many applications, including power generation and switchgear monitoring.

A company in the power generation industry has a fleet of generators leased to customers at remote sites, including oil and gas exploration areas with no utility connections. Due to the critical nature of oil and gas development, uptime is essential, and failures are not tolerated. The leases for these generators have uptime clauses of >99% availability. To cut down on unexpected breakdowns and to monitor the generators' outputs in real time, the company uses energy meters to measure voltage, current, and power, and a cellular modem

Keeping data centers online and operational requires mission-critical cooling systems. In an industry in which downtime can cost $1M an hour in lost revenue, unexpected equipment failures are simply not an option.

to transmit the data via a cellular network from the remote sites to the company's headquarters. Access to this data enables just-in-time maintenance and reduced field service requests, saving money and keeping its customers satisfied.

Example 2: Asset management of injection molding machines improves profits

A company in the automotive industry specializing in plastic injection molding of bumpers and other body panels wants to more accurately bill its customers for produced goods. Electricity consumption represents a major component of the manufacturing cost, so the company has implemented energy meters on each machine to quantify energy consumption. For now, it will use this data to produce more accurate part pricing, but thanks to the revenue-grade metering capabilities of the energy meter used, it will eventually directly bill its customers for the electricity consumed during manufacturing of the parts. This has increased profits while also providing it with some just-in-time maintenance benefits.

Example 3: Predictive maintenance for critical data center loads

A company in the HVAC industry works with large internet-based companies to build custom data centers. Each of these sites contains HVAC equipment that is critical to the operation of the data center, as these systems remove the heat generated by the networking and storage equipment. A failure in the HVAC system could cause damages and outages that cost millions of dollars, so failure is not an option. Building management systems (BMS) in data centers constantly monitor equipment performance locally. Energy meters embedded in the HVAC control cabinets provide that data via Ethernet. As an optional service, this particular HVAC manufacturer offers real-time monitoring, predictive maintenance, and remote troubleshooting capabilities for its clients using a secure cellular modem independent of the data center network.

Other examples:

Because energy meters are a basic but critical tool for measuring AC power, they can be deployed in a very wide range of applications. This may include monitoring specific loads such as a single motor or heat trace. It could also be used as broadly as measuring the power of an entire facility. They can also be used to track energy production and consumption, especially for solar applications and within microgrids.

The benefits of energy monitoring can be realized in virtually all industry segments.

Section 5: Is energy monitoring the right investment for me?

A pragmatic approach to energy monitoring investments can lead to highly successful installations and a great ROI.

Scaling a system to the user's needs and goals is a form of efficiency in itself. To avoid excessive spending and poor return on investment, it is necessary to scale the capabilities of the monitoring devices to the needs of the machine or process. It is also necessary to consider the overall impact of any one particular component on uptime. While some motors or heater elements may be redundant within a process, others may represent a critical failure point – the appropriate amount of monitoring, analytics, and maintenance should be prescribed accordingly.

For example, downtime of a simple conveyer belt application may not greatly impact overall production because it can be bypassed by using manual labor. Spending thousands of dollars on a dedicated energy meter might not make financial sense when a $100 voltage-monitoring relay will suffice to protect the motor.

Conversely, the intake pumps at a wastewater treatment facility are considered mission-critical to the operation of the plant. Should one of the pumps fail unexpectedly, the failure could adversely impact water treatment. The motor may cost $10,000, and it could be connected to a pump that costs tens of thousands of dollars.

It is fairly obvious that the water treatment plant operator would want to know everything they can about the pump's state of health. With this information, they could plan maintenance as needed, receive advance warning before any failures occur, and protect their investment in the pump itself. Run-to-fail is simply not an option in this application. As another cost-saving benefit, once monitoring is incorporated, the pumping station can switch to an as-needed maintenance schedule instead of a periodic routine maintenance plan that involves rebuilding/replacement on a fixed schedule regardless of equipment health.

Selecting monitoring equipment without overspending or underspecifying can be done by calculating how often a failure occurs, and how much the downtime costs you, and then comparing it to the cost of the monitoring device. For lower-end devices such as voltage/phase monitoring relays and basic current transducers, monitoring almost always pays for itself on the first outage it prevents. More advanced platforms that incorporate energy meters, power quality meters, and analytics can cost well over $10,000. Such a solution is not appropriate for every application, and it might not ever pay for itself. There are, however, processes in which just one outage prevention would pay for the system several times over. It can often be tricky to strike the perfect cost-benefit ratio no matter the investment, but having specific needs and goals in mind can help ground the selection of equipment in reality.

Conclusions

The decision to invest in energy-monitoring technology is often grounded in the somewhat vague promises of what IIoT will bring to the modern plant and its bottom line. Energy monitoring is generally sold as a money-saving technology, marketed as devices or platforms that can help users reduce energy consumption or energy costs. However, some issues continue to plague the industry in its quest to unlock the promised savings.

Many organizations invest in monitoring equipment but then fail to follow through on analyzing the data it returns. This reduces the equipment's ROI, and it greatly limits the realization of the promised benefits. It is an issue that stems from the fact that, in many cases, little is done to help customers, operators, and engineers realize the benefits of monitoring once the systems are in place and the integrators have gone home.

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However, engineers and operators shouldn't settle for underperforming or underutilized monitoring systems. By applying the RAE principles and implementing a JITm program, engineers and operators can realize those benefits much more quickly. An exciting new reality – one filled with uptime and cost-savings – displaces the underwhelming realities of systems that do not make use of the data they collect. Cloud systems can automate the display and analytics of energy data, further increasing maintenance insights, reducing energy consumption, and providing a better ROI.

As more and more purpose-built industrial cloud services and devices become available, the learning curve of installing and taking advantage of these devices is rapidly diminishing. Today's monitoring solutions feature streamlined integration from the device side with native support for cloud protocols, and on the other side, purpose-built industrial clouds and analytics engines that simplify start-up. This means taking advantage of advanced analytics is simply becoming a matter of measuring and communicating the data. No longer is it necessary to build a custom solution from the ground up to see the benefits.

Ultimately, when care is taken to properly implement monitoring, it can significantly reduce operational costs all around. It results in a better bottom line for everyone – reducing maintenance costs and utility bills, improving uptime, and enhancing profitability.

For more information about industrial energy meters with native cloud connectivity, visit:
www.phoenixcontact.com/EMpro

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