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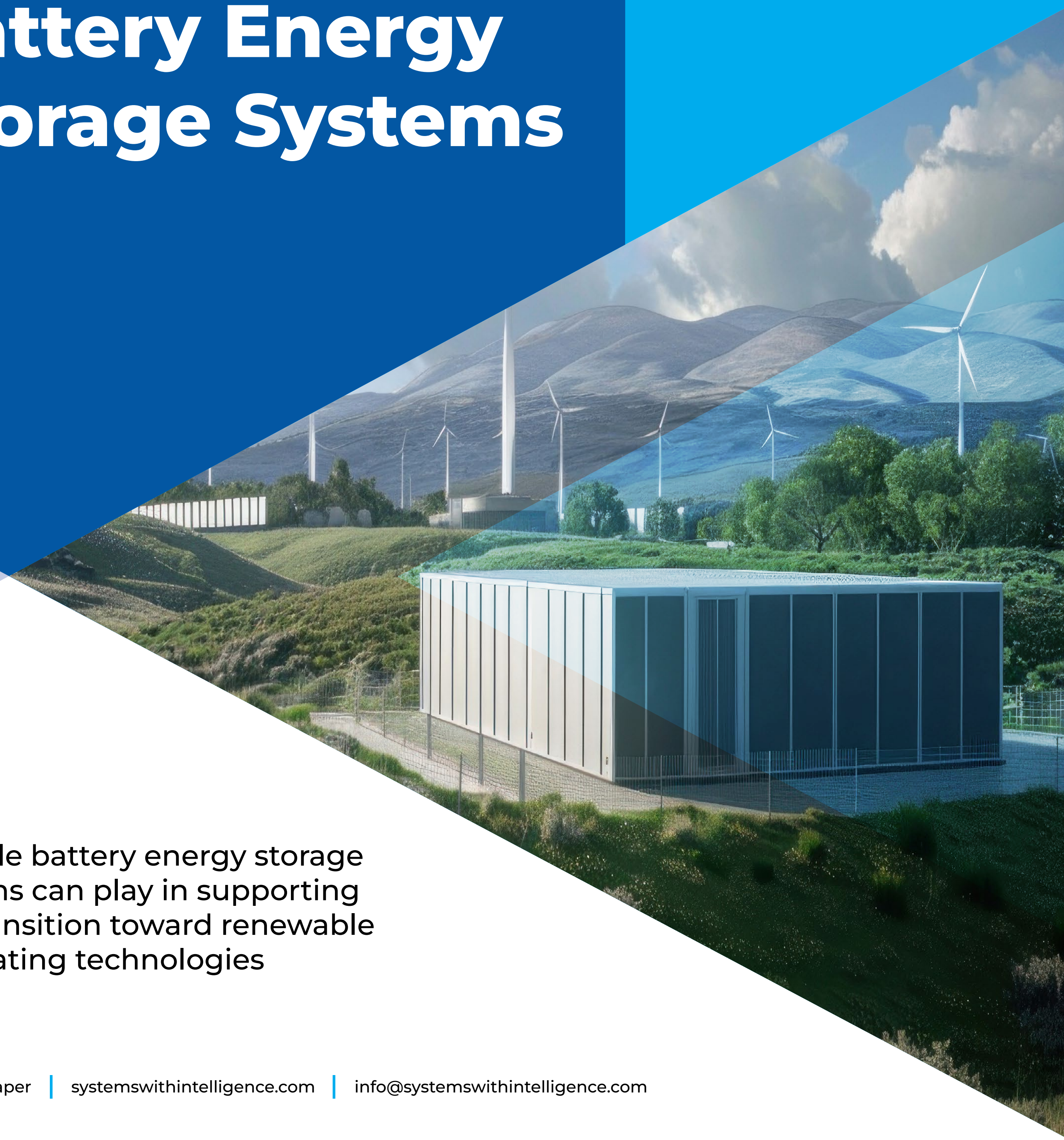
Continuous Monitoring For Battery Energy Storage Systems



The role battery energy storage systems can play in supporting the transition toward renewable generating technologies

Renewable energy is critical to the future of the global energy mix. Governments, utilities, and the general public are all demanding that energy generation continues to transition away from fossil fuels to help reduce greenhouse gas emissions while meeting growing electricity demand.

Battery energy storage systems (BESS) will be an essential technology that helps enable this transition. The ability to store energy for future use reduces the variability of intermittent electricity sources such as wind and solar photovoltaic (PV), allows for grid balancing and frequency control, and improves the economic viability of new renewable generating facilities.

However, the expansion of BESS facilities will introduce new operations and maintenance challenges. Utilities must ensure that both the batteries and the supporting infrastructure, including transformers, inverters, switchgear, and ancillary systems are operating safely and reliably. In addition, utilities will need to ensure these remote sites have security monitoring to protect the valuable investments and ensure their reliable operation.

Rather than rely solely on time-based, physical inspections, utilities should implement Touchless™ Monitoring solutions that leverage utility-grade visual and thermal sensors to provide continuous, 24/7 monitoring of high-value BESS assets.

This white paper will briefly discuss the growing trend toward renewable generating technologies and the role that BESS technologies can play in supporting this transition. It will then highlight some of the unique maintenance challenges that utilities will need to address before demonstrating how Touchless™ Monitoring solutions can be used to take a proactive approach to maintenance, improve system reliability, and secure valuable assets.

By implementing an integrated solution to meet safety, inspection, operation, and security requirements, utilities can optimize the cost and complexity for new installations.

The Rise of Renewable Energy Generation

Recent decades have seen significant investments in renewable energy technologies, especially onshore wind and solar PV.

In the United States, wind energy now accounts for 10 percent of total electricity generation, while solar makes up 5.6 percent. In Canada, where low-emitting hydroelectric power already contributes to the majority of the overall energy mix, wind accounts for 6 percent while solar makes up only 1.18 percent.[1]

As technology has improved, the price of renewable energy has become competitive with traditional fossil fuels. The average cost of electricity from newly commissioned solar PV fell by 85 percent from 2010 to 2020, while the cost of new onshore wind projects fell by 56 percent over the same period.[2]

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Further, government emissions targets and Net Zero initiatives are driving investment. In the US, for example, the Inflation Reduction Act includes $370 billion in funding dedicated to accelerating the clean energy transition.[3]

Given these trends, capacity is expected to continue to grow. Low-emitting energy sources, including wind, solar, and battery systems, were the dominant form of new utility-scale generation in the US, representing more than three-quarters of total new capacity added in 2023.[4]

A recent McKinsey estimate predicts that global renewable electricity capacity will nearly triple from 2021 to 2030, with the vast majority of the increase coming from new onshore wind and solar PV installations.[5]

The Challenges With Wind and Solar Power

Despite the advantages of wind and solar generating technologies, a number of challenges will need to be addressed as they play a larger role in the global energy mix.

The most obvious challenge is that both wind and solar are intermittent and variable sources of power. In regions that are well suited to these technologies, capacity factors typically range from between 30 and 50 percent for wind and just 15 to 20 percent for solar.[6] A typical nuclear reactor, for comparison, generates power more than 93 percent of the time,[7] while natural gas-fired facilities can be dispatched within minutes to respond to sudden fluctuations in demand.

Additionally, the locations that are well suited to wind and solar may not necessarily be near areas where the electricity is consumed. As a result, significant investments will be needed to build new transmission and distribution infrastructure.

A recent study estimated that, in order to achieve net zero emissions by 2050, the US would need to expand high-voltage transmission capacity by 60 percent and invest more than $2.4 trillion in the transmission system.[8]

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Enabling Renewable Energy With Battery Energy Storage Systems

Battery energy storage systems, or battery storage power stations, are advanced technological solutions designed to store, manage, and release electrical energy when power is needed most.[9] They typically use lithium-ion, lead-acid, sodium-ion, or other advanced battery chemistries and are supported by a range of ancillary components including a battery management system, power conversion system, energy management system, and various control systems.

Utility-scale BESS supports the deployment of renewable power generation from wind and solar sources while improving the overall efficiency, reliability, and economic viability of these technologies.

Applications for Battery Energy Storage Systems

- Peak shaving
- Load management
- Energy arbitrage
- Frequency response
- Emergency backup power
- Emission reduction
- Voltage support

The Future of Battery Energy Storage Systems

Investment in utility-scale, front-of-the-meter (FTM) BESS is expected to grow significantly in the coming decade. Grid-scale storage, especially using batteries, is essential to managing the impact of renewable energy on the power grid and handling hourly and seasonal variations to keep the grid stable and reliable.[10]

A recent International Energy Agency (IEA) report showed that more than 1,200 GW of battery storage would be required to triple global renewable energy capacity by 2030.[11]

Growth in batteries outpaced almost all other clean energy technologies. [12] McKinsey found that more than $5 billion was invested in 2022, up more than three times the level from 2021. The same report estimates that the global BESS market will grow to between $120 billion and $150 billion by 2030.[13]

“Growth in batteries outpaced almost all other clean energy technologies in 2023”

At the same time, the cost of batteries has fallen dramatically.[14] Over the past 15 years, battery costs have fallen by more than 90 percent. Lithium-ion battery costs for stationary applications could fall below $200 per kWh, with installed costs falling between 50 and 60 percent.[15]

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These trends are leading to rapid growth in capacity. In the US alone, large-scale battery storage capacity is forecast to grow from just 1 GW in 2019 to 98 GW in 2030.[16] By that same year, the IEA predicts that global installed capacity will reach 967 GW.[17]

New Maintenance Challenges for Battery Energy Storage Systems

Introducing new technologies to the grid also introduces more complexity, which in turn creates new challenges for the Operations & Maintenance department.

Utilities now have to manage a mixture of traditional generating assets, renewable energy sources, and large-scale energy storage facilities, which each have completely different behaviours and maintenance requirements.

This mix requires greater coordination, oversight, and responsiveness. And the consequences of a catastrophic failure are greater than a typical substation.

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Further, the presence of large numbers of batteries will mean that effective maintenance will be even more important to ensure the safety and reliability of the power grid.

Already, accidents, fires, explosions, and arc flashes have occurred at BESS facilities which have damaged equipment and put workers at risk. These incidents, if not avoided in the future, pose serious threats to the development and adoption of BESS.

Common failures can include transmission line faults, transformer faults, and other similar issues on the alternating current (AC) side of the BESS. More significant and potentially serious issues can occur on the direct current (DC) side of the BESS, including sensor faults, internal short circuit faults, and external short circuit faults which can result in thermal runaway or explosions. These issues can be caused by aging insulation, degradation of cables, or incorrect connections.[18]

One analysis of BESS failures found that integration-related failures were among the most common attributable causes. The majority of these incidents related to a failure of the elements of the BESS, including the cabling, enclosures, power conversion systems, transformers, or liquid cooling systems.[19]

An undetected fault or issue can result in catastrophic failure that results in significant damage or injury to both equipment and personnel, especially when dealing with highly combustible and explosive materials.

Safety must be considered at every level of the project, from installation and commissioning through to operation and decommissioning, due to the potential public health and environmental impacts of a failure. And security must be continuously monitored to prevent unauthorized access that could damage equipment and lead to injury or death.

Thermal Runaway

Thermal runaway is a chain reaction that occurs when increased temperatures result in the prolonged release of energy within the lithium-ion battery resulting in further uncontrolled temperature increases, fire, and explosions.[20] Physical damage to the battery cell, degradation, aging, and poor battery maintenance can all result in a thermal runaway event.

Because the battery serves as a source of fuel, a thermal runaway creates an uncontrollable and self-heating fire that is difficult to extinguish. Many battery vendors advise that firefighters simply allow the fire to burn itself out, though this can have negative consequences for surrounding communities.

As energy storage facilities transition to a higher density and smaller footprint, with more units packed more closely together, the risk of a thermal runaway spreading to multiple batteries increases.[21]

Toxic and Hazardous Gases

In addition to the risk of thermal runaway, lithium-ion batteries have the potential to release toxic and hazardous gases that can negatively impact human health and damage surrounding ecosystems.

An analysis of smoke from a battery fire found high levels of hydrogen fluoride, hydrogen cyanide, hydrogen chloride, sulfur dioxide, and various fluorinated phosphorus and lithium-based compounds. Further, samples from runoff found elevated levels of lithium, nickel, manganese, and cobalt in the water.[22]

Labor Shortages

Compounding these risks is the reality that many utilities are facing a shortage of skilled and experienced workers, especially those who have the specialized training needed to maintain and manage BESS facilities.

Today, the average age of a US utility worker is over 50,[23] while more than 50 percent of workers are expected to retire within the next decade.[24] At the same time, fewer people are entering the industry, with utilities increasingly competing against high-tech and other industries for the new generation of talent.

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Hazardous Environments

BESS facilities and the surrounding transmission and distribution infrastructure are dangerous environments for workers to operate in. Despite improvements in safety procedures, up to 80 utility workers are killed each year in the US from injuries sustained on the job.[25] Simply driving to and from facilities can be dangerous as well, with nearly 1,300 driving deaths resulting from work-related crashes across all industries.[26]

Site Security

The remote nature of renewable generating and BESS facilities make them difficult to monitor and protect. Physical security measures, such as fences, barbed wire, and other barriers provide some level of protection, but the sites remain vulnerable to vandals, thieves, or other intruders. Damage to high-value assets or critical infrastructure caused by unauthorized access can have wide-ranging consequences for customers, businesses, and society and cost utilities in repairs, fines, and other expenses.

Touchless™ Monitoring Solutions for Battery Energy Storage Systems

Touchless™ Monitoring solutions from Systems With Intelligence leverage utility-grade visual & thermal sensors to provide utilities with continuous, 24/7 monitoring of high-value and critical BESS assets.

Thermal sensors provide early detection and warning of sudden or prolonged temperature anomalies outside of a set range, while visual sensors allow operators to remotely view the condition of the asset, check gauges, verify the issue, and assess safety risks before dispatching a crew to the site. Having grid edge security with alarm management integrated into the overall solution ensures these valuable assets can be operated reliably in remote areas.

Advanced visualization software automatically alerts the operator when a rule is violated through email or alarms connected to the SCADA system. Once an alarm is received, the Operations & Maintenance team can diagnose the issue and prioritize a response based on the severity of the fault and the expected time to failure.

The system has been designed and built to operate within the challenging conditions found in electric utility infrastructure, with sensors rated to withstand electromagnetic interference, severe weather, extreme temperatures, voltage surges and interrupts.

Touchless™ Monitoring Applications for Battery Energy Storage Systems

Visual and thermal sensors can be deployed throughout the facility to monitor a wide range of assets on both the AC and DC side of the BESS, including battery module enclosures, inverters, transformers, switchgear, relays, circuit breakers, cabling, and ancillary systems.

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For example, transformers are used to elevate the voltage from the BESS output to the grid's required voltage. Common causes of failure, such as overloading, insulation breakdown, short circuits, and cooling system failures all create heat that can be detected using thermal monitoring.

Switchgear including breakers, isolators, and relays protect the BESS from faults. Thermal sensors can provide early warning of heat caused by loose or corroded connections, wear, pitting, or aging insulation.

Repeated surges can cause thermal stress to surge arresters, leading to degradation and the potential for thermal runaway. Thermal monitoring can reveal thermal anomalies that indicate faults that should be corrected before failures occur.

Similarly, power electronic components such as insulated-gate bipolar transistors, capacitors, and inductors are all sensitive to overheating, with excessive stress leading to degradation, reduced efficiency, and eventual failure. Abnormal heat patterns indicate stressed components or other faults, signalling the potential for failure.

Finally, elevated temperatures at grounding points, joints, terminations, or cable runs can indicate loose connections, increased resistance, overloaded conductors, or potential electrical faults, all of which can lead to electrical fires.

With visual sensors, operators can conduct a visual inspection remotely from a central location. This allows crews to diagnose potential issues and assess safety conditions before arriving on-site, reducing the time, cost, and risk of the repair.

Utility-grade visual sensors can also be used for continuous security monitoring applications. Advanced AI and video analytics continuously monitor camera feeds and automatically alert the utility if a security threat is detected. The sensors can be integrated with other security equipment, such as alarms, lights, or speakers, to deter intruders until the security team arrives.

A Condition-Based Maintenance Strategy for Battery Energy Storage Systems

Utilities have long relied on time-based physical inspections and scheduled maintenance to ensure equipment is in good condition and operating efficiently.

However, these inspections are time-consuming and expensive. Technicians have to travel to the facility and use a mix of specialized devices to manually inspect hundreds or thousands of components.

The periodic nature of these inspections increases the likelihood that a fault goes undetected and unrepaired between site visits. Further, crews must be on site and measuring the component when the fault occurs, meaning they are likely to miss intermittent failures or issues caused by specific conditions not present during the inspection.

For example, degraded insulation could allow moisture to come in contact with a component during heavy rain, but if inspections are only conducted on clear, sunny days, it is unlikely that the issue will be detected.

With continuous monitoring, utilities can take a proactive approach to maintenance and repairs that mitigates the risk of catastrophic failure.

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Once deployed, utilities can transition away from time-based physical inspections and toward a Condition-Based Maintenance strategy.

Decisions about maintenance and repairs can be made based on the actual health and performance of the BESS asset. This approach significantly reduces operations and maintenance costs, improves reliability and uptime, and enhances the long-term performance of critical assets.

The Benefits of Touchless™ Monitoring for Battery Energy Storage Systems

- Lower operations & maintenance costs
- Reduced risk of catastrophic equipment failure and environmental damage
- Greater reliability and performance
- Better allocation of scarce technical resources
- Enhanced worker safety and site security
- Improved asset management
- Integrated security monitoring for remote locations

Deploying Touchless™ Monitoring Solutions for Battery Energy Storage Systems

Touchless™ Monitoring solutions have been designed and built for the utility industry and are easy to procure, install, and use. But like any investment in technology, utilities should take a strategic approach to deployment to ensure a successful implementation and a positive return on investment.

Incorporate the Sensors Into the Project Plan

As new BESS facilities are being built, the best time to implement visual & thermal monitoring solutions is during the initial design and engineering phase. Doing this at the start allows the sensors to be installed during construction without any additional project management or budget approval. Optimizing the installation of conduit for power and communications is essential to a streamlined implementation. It also allows for better asset management, ensuring operators have data throughout the entire life of the facility.

Identify the goals of the project, the reasons for deploying the sensors, and how the sensors will be used by the Operations & Maintenance team. Determine what equipment is best suited to thermal and visual monitoring, and evaluate how the data will be incorporated into the utility's overall maintenance strategy.

Determine the Project Requirements

The features and performance of the hardware and software will depend on the site conditions and the equipment being monitored. Based on the site layout drawings, work alongside the vendor to determine what assets need to be monitored, where sensors should be installed, and whether any additional poles or mounting infrastructure is required to deploy the sensors.

Configure the Sensors and Software

Once deployed, the sensors need to be properly configured to ensure accurate data collection. Visualization software can be tailored to meet each user's specific needs and ensure they have access to the most relevant data for their roles. Work closely with the vendor to ensure that all components of the solution are properly set up.

Integrate With SCADA and Asset Management Solutions

Utilities already have numerous systems and technologies that capture data from various sensors and sources. To avoid data silos, new solutions must integrate with existing systems and display data in a single, unified dashboard.

Touchless™ Monitoring solutions integrate directly with SCADA and Asset Performance Management Systems using industry standard protocols. Work closely with the vendor to ensure that the monitoring systems is communicating and properly sharing data.

Conduct User Training

To make the most out of the solution, users must be able to confidently use the hardware, software, and data as part of their day-to-day work.

Initial user training should focus on the capabilities of the solution and ensuring that users can access relevant data when needed. Ongoing training can then provide more depth while also building on their ability to use data, monitor trends, identify patterns, report incidents, and respond to alerts.

Improving Operations & Maintenance for Battery Energy Storage Systems

Battery energy storage systems will play a critical role in the transition toward renewable electricity. The ability to store power during periods of excess production and discharge it during peak demand mitigates the variability and intermittency of wind and solar PV while also improving the economic viability of these technologies.

As electricity infrastructure becomes more complex, utilities must take a more proactive approach to operations, maintenance, and security. Physical inspections are no longer enough to ensure the health and performance of critical BESS and renewable generation assets.

A Touchless™ Monitoring solution that leverages visual & thermal sensors provides continuous, 24/7 monitoring. With greater visibility, utilities can transition toward a Condition-Based Maintenance strategy that reduces operation and maintenance costs, improves reliability, enhances security, and mitigates the risk of catastrophic equipment failure.

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systems with intelligence™

Systems With Intelligence is a renowned leader in providing trusted, intelligent, Touchless™ Monitoring Solutions for real-time visualization of industrial applications in harsh, remote locations.

With headquarters in Mississauga, Ontario, Canada, we help companies around the world, reduce operating and maintenance costs, while increasing reliability and safety. Touchless™ Monitoring Solutions from Systems With Intelligence are designed and built for oil & gas applications across the entire production process. Explosion-proof thermal, visual, and optical gas imaging (OGI) sensors provide operators with a continuous, 24/7 view of critical equipment and processes, while advanced software and analytics make it possible to detect, verify, and diagnose issues remotely.

With better visibility and control, oil & gas companies can reduce operations & maintenance costs, improve safety, optimize performance, and mitigate the risk of catastrophic failure.