

Intelligent Alert Systems

Improving Clean Energy Performance and O&M Productivity

Introduction

Distributed energy generation, such as PV and energy storage, are complex systems that require continuous monitoring and management to ensure optimal performance. Alerts play a critical role in the monitoring and management as they help in identifying, prioritizing, and addressing anomalies, communication faults, and performance deviations. However, if alert systems are not intelligently designed, then they can reduce system uptime and overburden O&M teams.

This white paper will address how alert systems can be optimized to not only improve asset performance, but also increase O&M productivity. Specifically, this white paper will focus on how to reduce, and even eliminate, false positives by providing an in-depth analysis and insight into their causes and solutions.

The white paper will analyze the following alerts:

01 PV System

02 Inverter

03 String

04 Battery

05 Voltage and Frequency

06 Performance

07 Meter

08 Cleaning

For each type of alert, the white paper will provide:

Alert Identification and Analysis: Identification of the underlying root causes, patterns, and implications of false positives.

Data Refinement: Transformation of raw data into actionable insights through advanced data analysis, standardization, and cleaning, plus trend recognition and model-based analysis.

Logic: Explanation of how the system can be improved

Actionable Automation: Definition of specific action items for automation that ensure efficiency and precision in handling false positives.

01

System-Level Alerts

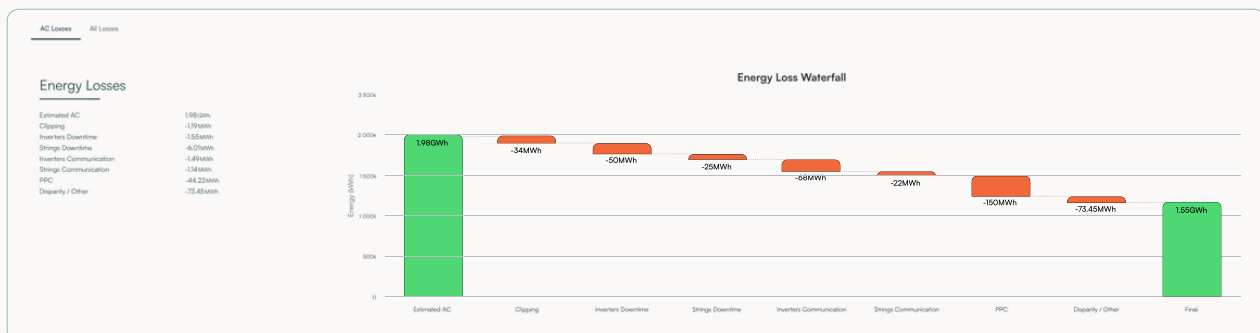
System-level alerts are crucial for PV monitoring, but false positives—especially between generation and communication alerts—cause inefficiencies and unnecessary interventions.

There are two main types of system-level alerts:

- 1. No Energy Yield from System:** Requires immediate attention as it indicates total generation failure due to outages, grid issues, or hardware faults
- 2. Communication Error in System:** Often misclassified as generation failure, leading to a high noise-to-data ratio. After communication errors are resolved, the data are typically uploaded.

While a "No Energy Yield" alert is critical for system performance, misidentifying communication errors as generation failures creates unnecessary noise and distracts from real operational issues. To enhance efficiency, it is crucial to accurately classify these alerts and automate the resolution of non-critical communication issues.

Logic: Dynamically analyze system behavior in real time, identifying whether a site is truly experiencing a generation issue or simply a communication delay. By assessing recent performance trends and intelligently distinguishing between data transmission gaps versus actual energy loss, the ecosystem reduces false alerts.



Waterfall analysis of energy and financial losses based on weather-adjusted expected versus actual production at a specific asset or a group of assets, at configurable time ratios



Monthly site-level production graph displacing actual solar production versus expected production, plus a comparison of actual production of nearby systems with normalized data.

Data Refinement: To improve the accuracy of system-level alerts and reduce false positives, there are four key data refinements that can be implemented:

- Smart classification of algorithms that differentiate between true generation failures and communication errors.
- Extended data verification can be used to dynamically adjust the evaluation window to filter out transient issues.
- Cross validation of data by using grid and inverter data to confirm if the faults are true.

Actionable Automation: To reduce the noise-to-data ratio and improve efficiency, self-healing alerts should be implemented, in which the system auto clears communication alerts once communication is restored so that no human intervention is required.

Improved system-level alerts provide significant advantages for stakeholders, including creating greater trust in the management and optimization software. The fine-tuning of these alerts enhances operational efficiency, improves system uptime, and increases scalability of O&M businesses.

02

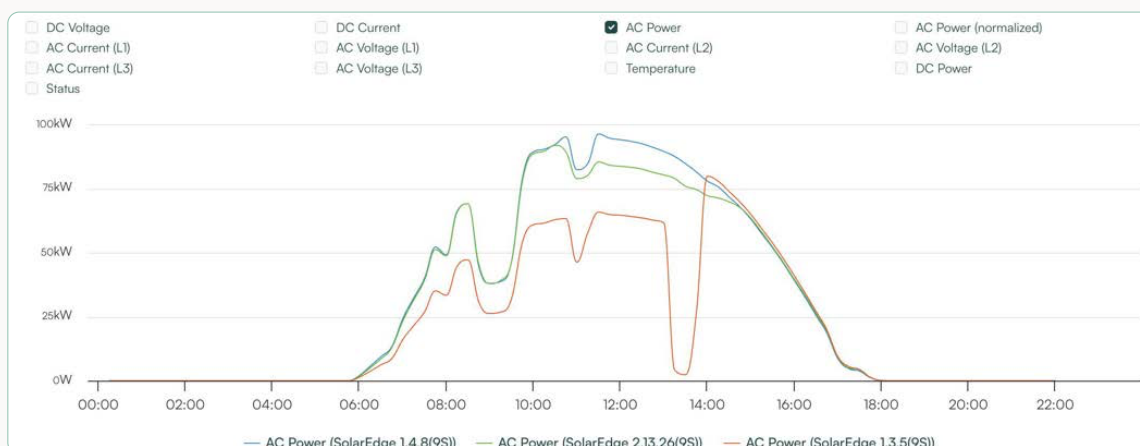
Inverter-Level Alerts

While inverter-level alerts are essential for diagnosing and resolving issues, their effectiveness depends on minimizing false positives - especially from shading, grid instability, and minor communication failures.

There are six main root causes for inverter alerts:

- 1. No Energy Yield:** Indicates zero energy generation from a specific inverter. The alert has various causes, such as hardware faults or delayed awakening. False positives often stem from temporary shading, grid instability, or minor delays in awakening.
- 2. No Communication Error:** Communication failures between the system and the inverter may arise due to network issues or faults in the communication module. Temporary interruptions often result in unnecessary escalations.

Logic: Both “No Energy Yield” and “No Communication Error” alerts share the same logic as the system alerts. The exception is when a “No Communication Error” could also indicate lack of production. In this case the system compares site production to correctly identify the error.



Inverter level monitoring comparing AC power of different inverters.

3. Late Awakening: Occurs when power generation begins significantly later in the day than expected. Root causes may include shading, dirt accumulation, grid voltage irregularities, or hardware issues. This alert could also indicate system faults, such as low insulation resistance, grid over or under voltage, or current leakage.

Logic: Ensuring optimal power generation means identifying and addressing delays in system activation. By recognizing environmental and technical influences, alert mechanisms are refined to minimize disruptions and maximize efficiency—without relying on rigid time-based thresholds.

4. Low Insulation Resistance: Triggered when the system detects a drop in insulation resistance, which may indicate moisture ingress, cable degradation, or potential safety hazards, such as electrical leakage. Temporary fluctuations may be caused by environmental conditions.

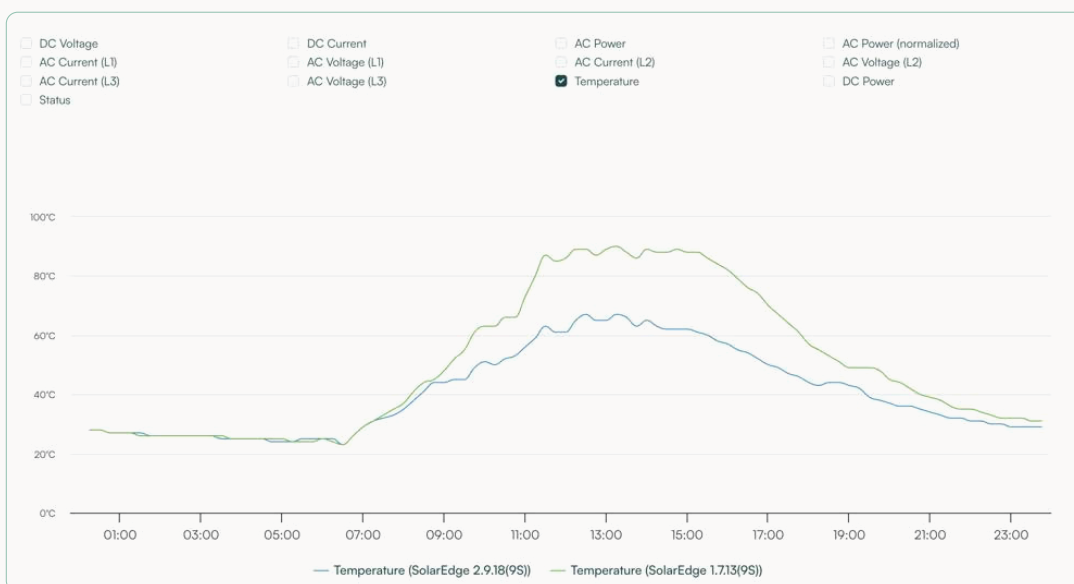
Logic: To enhance accuracy, insulation resistance levels need to be continuously monitored - distinguishing between transient variations and sustained low resistance that may pose a safety risk. By filtering out non-critical fluctuations, this approach minimizes false alarms while ensuring that genuine insulation faults are promptly identified and addressed.

5. Low Performance: Identifies an underperforming inverter, but external factors, including weather, soiling, or natural aging can create temporary fluctuations that do not necessarily indicate a failure.

Logic: The alert is created once an inverter is generating significantly less or more than nearby inverters. After the alert is open for a 24-hour period, the performance of the inverter is rechecked, and then either automatically closed or remains open.

6. High Temperature: Appears when inverters experience high operational temperatures that can impact performance, potentially leading to damage or shutdowns.

Logic: While predefined temperature thresholds provide a safeguard, rigid limits can sometimes misinterpret short-lived temperature fluctuations, generating unnecessary alerts that do not indicate a true risk. Rather than relying solely on fixed operating temperature ranges for each inverter type and model, the system also incorporates temperature impact on production; evaluates temperature trends, frequency of changes and duration; and analyzes contextual factors, such as ambient temperatures, to accurately alert and identify root causes for effective resolution.



Inverter-level monitoring comparing temperature differences between inverters.

Data Refinement: To improve the accuracy of inverter alerts and reduce false positives, the following data refinement strategies can be employed:

- **Dynamic Data Analysis with Thresholds:** Integrate real-time weather, irradiance data, and grid conditions into alert logic for contextual accuracy.
- **Data Cleansing, Standardization, and Statistics:** Detect and correct or remove errors to improve quality and reliability before analysis. Transform data into common formats and normalize to ensure consistency and comparability. Then leverage statistical insights to understand trends, anomalies, and overall data behavior.
- **Cross References:** Measure and compare to other inverters or against other data points to eliminate false positives.

Actionable Automation: There are a number of critical automations that can be implemented in order to reduce human intervention and improve O&M efficiency:

- **Smart Classification Algorithms:** Automatically differentiation between true inverter failures and transient environmental factors.
- **Self-Healing Alerts:** Auto-clearing of alerts when conditions normalize.
- **Tiered Alert System:** Automatically prioritize critical failures over minor inconsistencies.
- **Anomaly Detection Algorithms:** Leverage machine learning to identify unusual behavior patterns to identify performance degradation before issues occur.
- **AI-Based Root Cause Analysis:** Automate diagnostics to pinpoint inverter issues faster.

Enhancing inverter-level alerts helps to increase margins, maximize energy yields, and improve scalability. By decreasing the number of false alerts, smart alert systems reduce the amount of unnecessary human intervention and thus cut maintenance costs. While the early detection of issues enables the system to achieve increased uptime — improving its ROI. Overall, refining inverter-level alerts empowers O&M companies to expand its fleet without compromising on quality or requiring additional headcount.

03

String-Level Alerts

String-level alerts, identify issues at the inverter, string, or module level, provide critical insights into the health of PV systems. However, due to their sensitivity to data inconsistencies and environmental factors, these alerts are prone to false positives. Optimizing these alerts is crucial for minimizing unnecessary interventions, maximizing system performance, and improving operational efficiency. There are four critical string level alerts:

1. **No Current in String:** Indicates a possible disconnection or module fault. Temporary environmental factors, like shading or sensor inconsistencies can trigger false positives.

Logic: Instead of reacting immediately to a zero-current reading, the system intelligently assesses patterns and contextual factors to distinguish between temporary fluctuations and actual disconnections. By refining detection methods, this approach minimizes false alerts while ensuring that real issues are swiftly identified and addressed.

2. **No Voltage in String:** A key indicator of a potential total disconnection. Detecting these issues promptly is critical for maintaining energy production and system reliability.

Logic: Rather than relying solely on a zero-voltage reading, the system intelligently assesses voltage trends and operational context to differentiate between actual disconnections and temporary fluctuations.

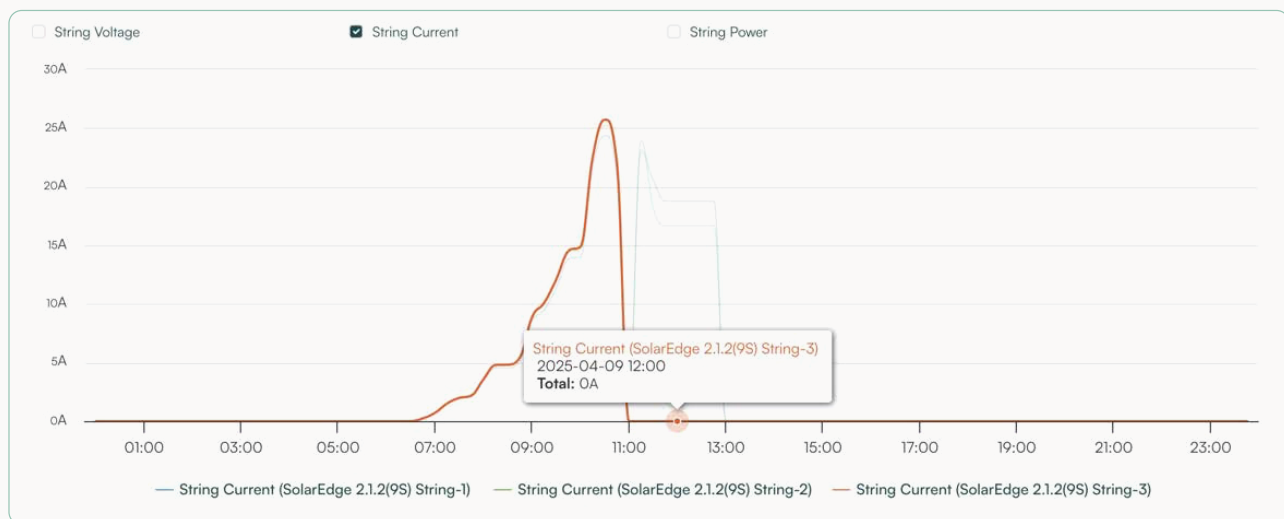
3. Low Current in String: Detects issues like module degradation, damage, or malfunctions that can impact system efficiency; however, temporary shading can lead to false positives. Static thresholds may not account for natural variations in sunlight or temporary shading, leading to false positives that create unnecessary noise.

Logic: Instead of using a static threshold-based approach and to enhance accuracy, the system dynamically evaluates current levels in relation to environmental conditions and historical performance trends. By distinguishing between expected fluctuations and true performance issues, this approach minimizes false alerts, ensuring that only meaningful deviations trigger notifications. If the alert is accurate and there are defects on the DC side, then these issues can be verified through thermal imaging and AI-based analysis.

4. No Data for String: A lack of monitoring data, often due to communication issues rather than an actual system fault.

While detecting potential failures is crucial, temporary data transmission gaps can sometimes trigger false positives.

Logic: Instead of generating an alert for every instance of missing data, the system intelligently assesses data flow patterns to differentiate between temporary communication lapses and persistent issues. This approach reduces false alarms, ensuring that only sustained data losses trigger alerts.



String-level monitoring comparing currents of different strings.

Data Refinement: Implement data cleaning and read-back verification in order to ensure data integrity by removing incorrect or corrupted data and validating stored information against original inputs, preventing long-term errors.

Actionable Automation: Strategic automations can be implemented that reduce the amount of required human intervention and improve operational efficiency:

- **Automated Data Redundancy Checks:** Cross-validation of string data with inverter and system-level data to confirm anomalies before generating alerts and filter out temporary inconsistencies.
- **Threshold Settings Optimization:** Dynamically adjusts alert sensitivity based on operational conditions, ensuring outliers and minor fluctuations do not trigger unnecessary warnings.
- **Self-Healing Alerts:** Auto-clear transient communication or shading-related alerts.
- **AI Anomaly and Outlier Detection:** Leverage AI to detect data outliers and identify true failures versus temporary variations.
- **Predictive Monitoring:** Detect early performance degradation before major faults occur by analyzing historical trends.

Refining string-level alerts improves diagnostic accuracy, optimizes technician efforts, and enhances overall PV system performance. With the elimination of unnecessary interventions, maintenance costs are reduced and O&M companies can improve margins. Additionally, smart alerts improve the ratio of employees to MW, enabling seamless fleet expansion with minimal operational burden. While early identification of performance issues prevents long-term energy losses, maximizing energy yield and improving system ROI.

04

Battery Alerts

String-level alerts, identify issues at the inverter, string, or module level, provide critical insights into the health of PV systems. However, due to their sensitivity to data inconsistencies and environmental factors, these alerts are prone to false positives. Optimizing these alerts is crucial for minimizing unnecessary interventions, maximizing system performance, and improving operational efficiency. There are four critical string level alerts:

Batteries

Type to search...

4 of 4 items

Period: Daily

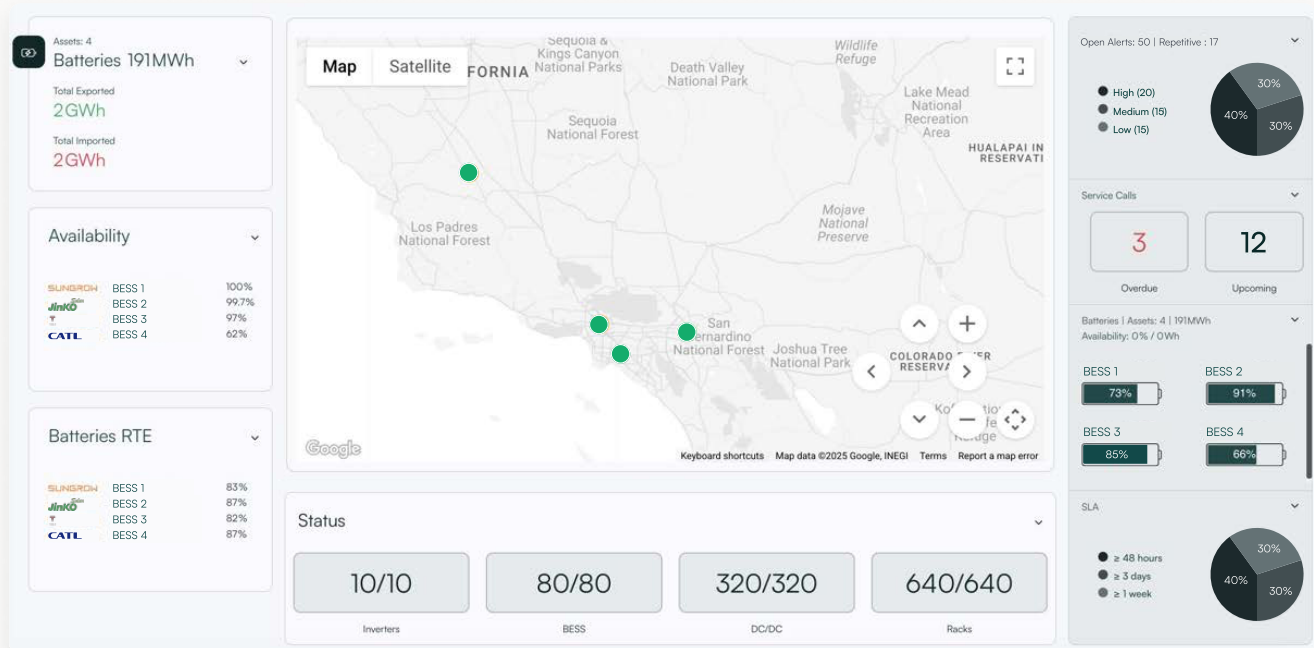
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NAME ↑	ACTIVE BESS ↑↓	ACTIVE DC/DC ↑↓	ACTIVE STATUS ↑↓	ACTIVE POWER ↑↓	ACTIVE POLICY ↑↓	LAST SEEN ↑↓	SOC ↑↓
BESS 1	12/12	46/48	Charging -4408kW	Charging -4408kW	Auto	13:30:00	85%
BESS 2	12/12	46/48	Charging -7300kW	Charging -7300kW	Auto	13:30:00	73%
BESS 3	12/12	46/48	Charging -9654kW	Charging -9654kW	Auto	13:30:00	66%
BESS 4	12/12	46/48	Charging -2883kW	Charging -2883kW	Auto	13:30:00	91%

Summary table of all batteries, including relevant KPIs, such as revenue, expenses, energy, and performance. Alerts and current status of each battery are also displayed.

1. Battery/Storage Communication: Triggered when the monitoring agent fails to transmit data to the cloud. This could result from network disruptions, hardware issues, or temporary connectivity failures. Once communication is restored, missing data is automatically pulled into the system to prevent information loss

Logic: To minimize false alerts, the system assesses the duration and frequency of communication gaps, distinguishing between short-lived disruptions and persistent failures. By intelligently filtering transient connectivity issues, this approach ensures that only significant communication losses trigger alerts, allowing for timely troubleshooting while reducing unnecessary noise.



Dashboard displaying energy performance, financials, and health KPIs for battery energy storage systems, including revenue, alerts, and status.

2. High-Temperature: Generated when system components, including a cell, module, pack, rack, or the entire system, operate at elevated temperatures that could impact performance, efficiency, or safety. While necessary to prevent overheating and potential damage, occasional temperature spikes due to environmental conditions may not always indicate a critical issue.

Logic: To improve accuracy, the system continuously monitors temperature trends at all system levels, distinguishing between temporary fluctuations and sustained overheating risks. This ensures that alerts are only triggered when temperature levels pose a genuine threat to system integrity, reducing false alarms while enhancing system protection and reliability.

3. Voltage Fluctuations: Created by abnormal voltage levels at the cell, pack, or container level. These deviations can indicate potential system imbalances, hardware malfunctions, or grid-related fluctuations. While crucial for maintaining system stability, temporary voltage variations may not always signify a critical issue.

Logic: The system continuously monitors voltage behavior, distinguishing between transient fluctuations and sustained anomalies. By identifying only persistent or extreme deviations, this approach reduces false positives while ensuring that real voltage risks are promptly addressed.

4. High/Low State of Charge (SOC): Activated when the battery's charge level falls outside the recommended thresholds, potentially signaling overcharging, deep discharge, or long-term battery degradation. Maintaining an optimal SOC range is essential for battery health, performance, and longevity. However, momentary fluctuations may not always indicate a critical issue.

Logic: The system continuously tracks SOC trends, factoring in operational conditions and expected charge/discharge cycles. By distinguishing between temporary deviations and sustained issues, this approach minimizes false alerts while ensuring that real risks—such as overcharging or excessive depletion—are promptly identified and addressed, enhancing battery efficiency and lifespan.

5. Imbalance: Initiated when significant power discrepancies are detected among battery cells. This can indicate degradation, uneven charging, or potential faults that may impact overall battery performance and efficiency. Minor fluctuations in power distribution may not signal a serious issue.

Logic: The system continually monitors power levels across all cells, identifying persistent imbalances rather than temporary variations. By ensuring that only meaningful deviations trigger alerts, this approach helps prevent false positives while enabling proactive maintenance and extending battery life.

6. State of Health (SOH): Triggered when battery degradation is detected, potentially affecting its longevity, capacity, and overall performance. Monitoring SOH is crucial for optimizing battery lifecycle management, but temporary variations or expected wear over time do not always need to be flagged as critical issues.

Logic: The system constantly analyzes SOH trends, distinguishing between natural aging and abnormal degradation patterns. By identifying only significant declines in battery health, this approach minimizes false alarms while enabling proactive maintenance, ensuring optimal battery performance and longevity.

7. Faults: Activated when critical system issues, such as ground faults, short circuits, or insulation failures, are detected. These faults pose serious safety risks and can lead to system downtime or equipment damage if not addressed promptly.

Logic: To ensure a swift and accurate response, the system non-stop monitors fault indicators and prioritizes alerts based on severity and persistence. By distinguishing between transient anomalies and true system failures, this reduces false positives while also ensuring that critical faults receive immediate attention, enhancing safety and operational reliability.

8. Combustible Gas Signal: Produced when gas levels exceed safe thresholds, indicating a potential safety hazard. Detecting gas buildup early is crucial to preventing fire risks, equipment damage, or hazardous working conditions. However, minor fluctuations in gas readings may not always signify an immediate threat.

Logic: Improving reliability, the system continuously monitors gas concentration trends, differentiating between temporary variations and sustained increases that pose real risks. By ensuring that only significant and persistent gas levels trigger alerts, this approach minimizes false positives while enhancing safety measures and proactive risk mitigation.

9. Smoke Detection: Alerts when smoke is detected in the system environment, signaling a potential fire hazard or electrical malfunction. Early detection is critical for preventing damage, ensuring safety, and mitigating risks to equipment and personnel. However, occasional false triggers can occur due to environmental factors, like dust or temporary air quality changes.

Logic: The system consistently monitors smoke levels and cross-references data with other environmental and operational indicators, such as irradiance. By filtering out non-critical anomalies and detecting only sustained or escalating smoke presence, this approach minimizes false alarms while ensuring rapid response to true battery fire risks.

10. DC-DC Alarm: Triggered when irregularities are detected in the DC-DC converter, which plays a critical role in voltage regulation and power conversion. Issues in this component can impact system efficiency, battery performance, and overall energy stability. However, transient fluctuations or minor deviations may not always indicate a critical failure.

Logic: The system monitors DC-DC converter performance to distinguish between short-term anomalies and persistent failures. By filtering out non-critical fluctuations and only triggering alerts for significant deviations, false alerts are minimized while also ensuring that real issues are promptly addressed to maintain system reliability and efficiency.

11. Key Stop: Generated when the emergency stop mechanism is activated, either manually or due to a system fault. This safety feature is designed to immediately halt operations to prevent potential hazards, equipment damage, or unsafe conditions. However, unintended activations or brief interruptions may not always indicate a critical issue.

Logic: To improve accuracy, the system constantly monitors the conditions surrounding a Key Stop event, distinguishing between deliberate shutdowns, accidental triggers, or true emergency situations. By ensuring that only necessary interventions are escalated, this approach minimizes unnecessary downtime while maintaining safety and operational integrity.

12. DC Auxiliary Switch Disconnected: Produced when the system detects that the auxiliary DC switch has been disconnected. This may result from routine maintenance, wiring issues, or unexpected system interruptions. While crucial for maintaining system integrity, temporary or intentional disconnections should not always trigger unnecessary alerts.

Logic: Continuously monitoring the auxiliary DC switch status allows the system to distinguish between planned maintenance, momentary disruptions, and actual disconnection faults. By filtering out non-critical events, this approach minimizes false alarms while ensuring that genuine system issues are promptly identified and addressed, enhancing operational reliability and efficiency.

13. Performance Alerts: There are two main battery performance alerts, round trip efficiency (RTE) and battery availability. An RTE alert is triggered when there is a deviation from a predefined threshold, which may indicate energy losses in conversion, degradation or system inefficiencies that impact overall performance. A false alert can occur due to battery load, imbalanced charge and discharge differential rates between packs, and temperature differences between the cells. While a battery availability alert is caused when availability is lower than expected, suggesting a capacity reduction, potential faults, or operational misalignment with demand. This alert may also be caused when demand is higher than expected, charge/discharge cycles are misconfigured, or if the storage management is faulty. False alerts could be activated due to an inverter malfunction.

Batteries RTE		
	NY School	82%
	NJ Warehouse	83%
	CA Manufacturing plant	83%
	TX Municipality	84%

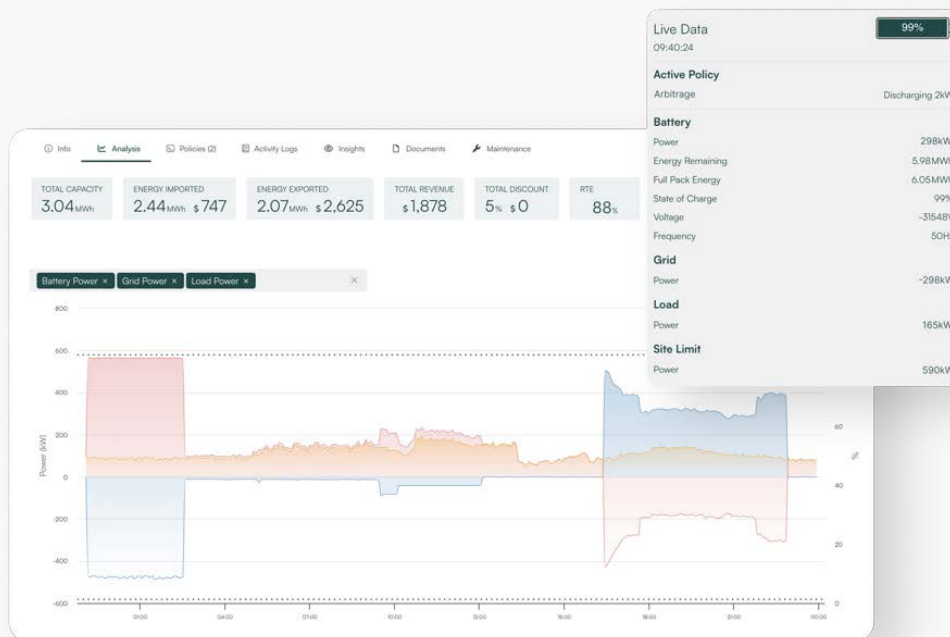
BESS RTE summary tracking, based on configurable time period.

Logic: While repeated threshold breaches can indicate aging cells, thermal instability, or hardware faults, requiring preventive action, false alerts can be addressed by dynamically tracking and continuously monitoring performance based on key formulas, such as PR, APR, RTE, availability, SOC, and SOH..

Data Refinement: To improve the accuracy of battery alerts, there are critical data refinement strategies that can be implemented:

- **Data Cleaning:** Remove data inconsistencies, correct data errors, and handle missing data to maintain monitoring accuracy.
- **Data Filtering:** Identify and isolate irrelevant or noisy data, such as temporary fluctuations caused by environmental conditions, to enhance precision.
- **Normalization & Standardization:** Ensure all data points, including power output, battery status, and environmental parameters, are recorded in a uniform format for improved comparison and trend analysis.

- **Aggregation:** Consolidate data from multiple inverters, battery units, and sensors to provide a clearer, high-level overview of system performance.
- **Data Enrichment:** Integrate external data sources such as weather forecasts and grid demand patterns to improve predictive analytics and system optimization.
- **Anomaly Detection & Correction:** Use AI-based analysis to detect irregularities, such as abnormal inverter performance or deviations in battery charging cycles, and flag potential issues before they impact system efficiency and ensure alerts are only triggered when intervention is necessary.



Dynamic monitoring screen and automated site commands for BESS, including KPIs such as revenue, expenses, faults, and status.

Actionable Automation: Strategic automations can be implemented that reduce the amount of required human intervention and improve operational efficiency:

- **Automated Data Redundancy Checks:** Cross-validation of string data with inverter and system-level data to confirm anomalies before generating alerts and filter out temporary inconsistencies.
- **Threshold Settings Optimization:** Dynamically adjusts alert sensitivity based on operational conditions, ensuring outliers and minor fluctuations do not trigger unnecessary warnings.
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05

Voltage and Frequency Level Alerts

Voltage and frequency alerts are essential for protecting PV systems from grid-related issues and internal faults. However, these alerts require precise thresholds and contextual awareness to avoid false positives, which can lead to unnecessary human interventions and operational inefficiencies. There are 4 key voltage and frequency alerts that require deep insights and analysis:

Battery	
Power	-0.87kW
Energy Remaining	2.59MWh
Full Pack Energy	3.04MWh
State of Charge	85%
Voltage	415V
Frequesncy	50Hz

Live technical monitoring for battery KPIs

1. AC Voltage Too High: Indicates that voltage levels have surpassed safe operational limits, potentially signaling a grid instability or an internal system issue. However, temporary voltage fluctuations may be misinterpreted as persistent faults, leading to unnecessary alerts.

Logic: Since static thresholds may be misinterpreted short-lived voltage spikes as faults, to enhance accuracy, the system evaluates voltage trends over time rather than reacting to single threshold breaches. By distinguishing between transient spikes and sustained overvoltage conditions, this approach reduces false alarms while ensuring that genuine risks are promptly identified and addressed, improving grid stability and system reliability.

2. DC Voltage Too High: Designed to protect the inverter from exceeding its maximum input capacity to prevent potential trips or damage. However, natural variations in irradiance may create false alerts that do not indicate an actual risk.

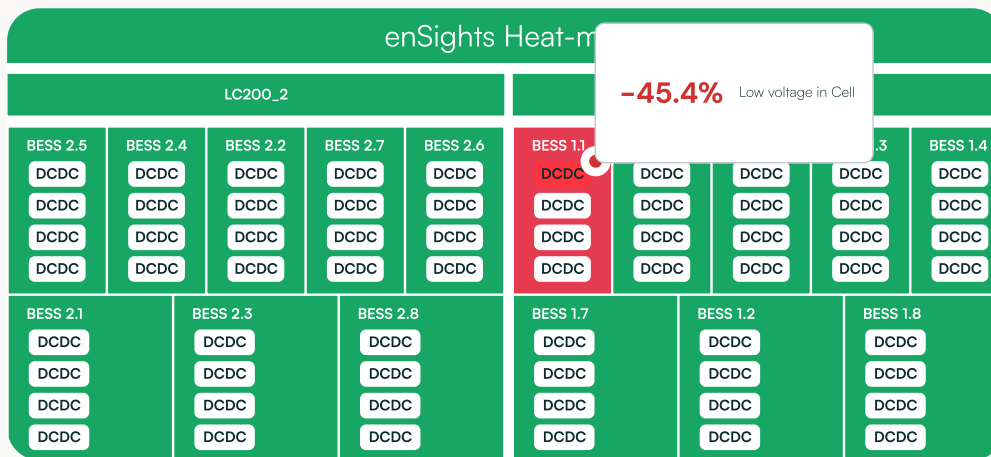
Logic: To improve accuracy, the system dynamically assesses DC voltage levels in the context of environmental conditions and operational trends, instead of using a rigid threshold. By distinguishing between short-lived fluctuations and sustained overvoltage risks, this approach minimizes false positives while ensuring that real threats to inverter stability are promptly addressed.

3. AC Voltage Too Low: Signals that voltage has dropped below acceptable levels, often due to grid instability. While critical for system protection, momentary dips in voltage can sometimes trigger unnecessary alerts.

Logic: Rather than reacting to every brief voltage drop, the system intelligently analyzes patterns over time to differentiate between transient grid fluctuations and sustained undervoltage conditions. This ensures that only persistent issues generate alerts, reducing false positives while maintaining grid stability and system reliability.

4. AC Frequency Out of Range: Triggered when grid frequency deviates from safe operating limits, which can disrupt inverter performance and lead to shutdowns. Ensuring grid compliance is critical, but momentary frequency fluctuations can sometimes cause unnecessary alerts.

Logic: To improve accuracy, the system continuously monitors frequency trends and evaluates the duration and severity of deviations. By distinguishing between brief anomalies and sustained frequency instability, this approach reduces false positives while ensuring that true grid compliance issues are identified and addressed promptly, maintaining system efficiency and reliability.



Drill down to cell- and string-level analytics for root cause identification and anomaly detection. Gain performance insights with real-time alerts on voltage, frequency, and more.

Data Refinement: To minimize false positives and enhance the reliability of voltage and frequency alerts, the following measures should be adopted:

- **Dynamic Thresholds:** Adjust thresholds based on historical grid performance and time-of-day patterns to account for normal fluctuations.
- **Event Duration Analysis:** Trigger alerts only when voltage or frequency deviations persist beyond a pre-defined duration, reducing the impact of transient events.

Actionable Automation: Implementing automations reduce unnecessary alerts to prevent O&M inefficiency:

- **Self-Healing Alerts:** Auto-clear transient issues once resolved.
- **Predictive Grid Monitoring:** Identify grid trends to prevent unnecessary system shutdowns.
- **Automated Root Cause Analysis:** AI-driven diagnostics to pinpoint actual issues and reduce noise-to-signal ratio.

Smarter voltage and frequency alerts enhance system reliability, efficiency, and scalability. By leveraging dynamic thresholds and automations, users reduce service costs, prevent unnecessary shutdowns, and improve system uptime. Overall, smarter alerts improve business efficiency and scalability.

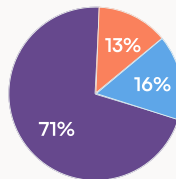
06

Performance-Level Alerts

Performance-related alerts provide essential insights into the operational efficiency of PV systems. They identify and address factors such as shading, soiling, or hardware inefficiencies that impact energy production. However, these alerts require precision to minimize false positives and maximize actionable insights. There are 2 important performance related alerts:

System Preferences

● Optimal (554)
 ● Average (128)
 ● Low (102)



Dynamic tracking based on configurable time periods. Performance analysis of selected systems (group or fleet) is displayed based on customizable rankings.

1. Performance Ratio (PR) / Temperature-Adjusted PR Out of Range: Deviations from expected values can indicate issues like shading, dirt accumulation, or temperature-related inefficiencies. However, temporary environmental changes—such as fluctuating irradiance or transient shading—can lead to false positives.

Logic: Rather than triggering alerts solely based on threshold breaches, the system intelligently analyzes PR trends over daily and monthly periods. By factoring in environmental conditions and expected performance variations, this approach minimizes unnecessary alerts while ensuring that real efficiency losses are detected and addressed.

2. Availability Out of Range: Significant variations from a system or an inverter's expected availability can indicate inefficiencies, unplanned downtime, or maintenance needs. However, brief outages or scheduled maintenance periods can trigger unnecessary alerts if not properly accounted for.

Logic: Instead of flagging every deviation, the system evaluates availability trends over daily and monthly periods, considering contextual factors like maintenance schedules and environmental conditions. This ensures that alerts are only generated for meaningful performance concerns, enabling more accurate issue detection.



Graphical display of KPIs such as APR, PR, and availability.

Data Refinement: To enhance the accuracy of performance-related alerts, important data refinement strategies should be implemented:

- **Threshold Customization:** Allow dynamic adjustment of PR and availability thresholds based on environmental conditions, system design, and historical data.
- **Time-Weighted Analysis:** Incorporate time-of-day and seasonal variations to account for natural fluctuations in performance ratios.

- **Advanced Normalization:** Adjust PR metrics for temperature and irradiance conditions to ensure accurate benchmarking against expected values.
- **Contextual Filtering:** Filter out anomalies caused by planned maintenance, transient shading, or short-term weather events before generating alerts.

Actionable Automation: To streamline responses to performance-related alerts, there are critical automations that can be deployed solutions, such as:

- **Root Cause Analysis:** Equip alert systems with diagnostic tools to identify likely causes (e.g., soiling, shading) with suggested corrective actions.
- **Performance Dashboards:** Provide visual summaries comparing system PR against benchmarks and highlight underperforming components.
- **Automated Reporting:** Generate daily, weekly, or monthly reports to track PR and availability trends, enabling proactive maintenance planning.
- **Predictive Maintenance:** Leverage machine learning models to forecast performance deviations based on historical and real-time data, reducing unplanned downtime.

Performance-related alerts are critical for maintaining PV system efficiency and optimizing energy yield. Refined alert logic that leverages contextual data and actionable automation, builds customer trust and confidence in its monitoring system while also empowering customers to make informed operational and investment decisions. Bottom line is that customers can achieve optimized energy yields with reduced operational costs.

07

Meter-Level Alerts

Meters play a crucial role in monitoring and validating energy production and consumption. However, meter-related alerts, such as communication failures or invalid data values, need to be fine-tuned to reduce false positives, ensure accurate diagnostics, and enhance system reliability. There are two key meter alerts that need to be considered:

1. **Meter Communication Alert:** Generated when the meter stops transmitting data to the monitoring system. This could be due to network disruptions, faulty hardware, or temporary connectivity issues. While detecting communication failures is essential, brief interruptions that self-resolve can trigger unnecessary alerts.

Logic: To improve accuracy, the system cross-checks inverter data to differentiate between a reading failure and a true communication issue. By filtering out short-lived disruptions and focusing on persistent meter failures, this approach minimizes false positives while ensuring that real connectivity issues are identified and addressed efficiently.

2. **Meter Invalid Values:** Triggered when the meter reports data that falls outside acceptable ranges, often due to sensor errors, calibration issues, or external grid conditions. While essential for detecting inaccurate measurements, false positives can occur when temporary fluctuations or anomalies are misinterpreted as faults.

Logic: To enhance accuracy, the system cross-references inverter data, radiation forecasts, and production calculations to differentiate between genuine meter errors and temporary inconsistencies. By integrating multiple data points, this approach reduces false alerts while ensuring that true measurement inaccuracies are promptly identified and addressed.



Comparison of RGM readings to actual PV production for smarter analysis.

SYSTEM	SYSTEM YIELD	EXPECTED	YIELD VAR.	METER YIELD	METER VAR.	INVOICE YIELD	REVENUE
Sys 1	58,732 kWh / \$7,910	57,890 kWh / \$7,790	322 kWh / +0.5%	58,600 kWh / \$7,880	-0.2%	58,410 kWh / \$7,860	\$7,865 / -\$45 / -0.6%
Sys 2	2,110 kWh / \$9,720	71,500 kWh / \$9,640	220 kWh / +0.3%	71,960 kWh / \$9,710	-0.2%	71,890 kWh / \$9,700	\$9,715 / -\$5 / -0.05%
Sys 3	13,650 kWh / \$5,840	43,300 kWh / \$5,790	180 kWh / +0.4%	43,500 kWh / \$5,830	-0.3%	43,470 kWh / \$5,820	\$5,825 / -\$15 / -0.25%

Summary table comparing PV production to RGM readings, with income comparisons, deviations, and alerts.

Data Refinement: By displaying the data in an easy-to-understand user interface, such as an Interactive Dashboards, technicians can quickly and easily compare meter data trends, identify patterns, and diagnose root causes.

Actionable Automation: To ensure technicians can quickly and effectively address issues, it is important to improve the efficacy of meter-related alerts by implementing the following:

- **Self-Healing Mechanisms:** Implement automated retries for communication failures before escalating to technicians.
- **Anomaly Flagging:** Automatically tag invalid values for further inspection while suppressing alerts for transient anomalies.
- **Proactive Notifications:** Send early warnings for meter calibration requirements or signs of hardware degradation.

Optimizing meter-related alerts is essential for ensuring the accuracy and reliability of energy system monitoring. By refining alert logic, incorporating advanced data validation techniques, and automating diagnostic processes, energy management and optimization solutions can provide customers with a seamless, trustworthy experience. A key reason that meter alerts are so critical is due to their impact on accurate billing and reporting. Reliable meter data ensures accurate energy production and consumption measurements, reducing billing disputes. Overall, these smart alerts not only boost operational efficiency, but also strengthens customer satisfaction and long-term value.

08

Washing Alerts

Automatic washing systems play a crucial role in maintaining PV performance, as they detect the optimal time for a cost-effective wash based on decreases in energy production and performance, but false alerts related to washing errors, power usage, and water consumption can lead to unnecessary interventions and inefficiencies. There are 3 key alerts that are important to refine:

22.69MWh / \$ 4,688

0Wh

Normalized / Expected: 5.13 / 5.04kWh/kWp

$\pm$ 1.9%

PR: 77.8%

Irradiance: 6.46kW/m²

Board ID: 1567Power Status:

Wash Schedule:

Last Wash: 2025-04-02 07:39Water Usage: 1,630L

KPI tracking (including status, water used, and alerts) for the washing system connected to the PV system, providing insights into impact of washes on energy production.

- 1. Washing Errors:** Triggered by misconfigurations or unnecessary activations, for example, a wash during the wrong hours or when performance is not low enough.
- 2. Power Errors:** Caused by unexpected power consumption deviations that may indicate system faults.
- 3. Water Amount Errors:** Generated in the event of excessive or insufficient water usage, which could signal leaks, system inefficiencies, or incorrect parameter settings

Logic: The Washing Alerts system operates through initial configuration followed by real-time monitoring, ensuring each wash cycle stays within predefined thresholds. Tracking resource consumption and timing enables the detection of deviations that signal inefficiencies or potential failures.

When irregularities occur, there is an automatic alert and if thresholds are critically exceeded, washing is paused to prevent waste or damage. With intelligent anomaly detection and proactive intervention, washing is optimized for efficiency and cost reductions, while also safeguarding system integrity.

TIME	BOARD ID	WATER USAGE VS PLANNED	USAGE DIFFERENCE
2025-03-31 07:41	1567	1,646L 1,646L	100%
2025-03-28 07:39	1567	1,529L 1,529L	100%
2025-03-26 06:39	1567	1,633L 1,633L	100%
2025-03-24 06:39	1567	1,647L 1,647L	100%
2025-03-21 06:39	1567	1,291L 1,291L	100%
2025-03-19 06:39	1567	1,474L 1,474L	100%
2025-03-17 06:39	1567	1,607L 1,607L	100%
2025-03-14 06:40	1567	1,400L 1,400L	100%
2025-03-12 06:39	1567	1,606L 1,606L	100%
2025-03-10 06:39	1567	1,683L 1,683L	100%
2025-03-07 06:39	1567	1,602L 1,602L	100%
2025-03-05 06:39	1567	1,616L 1,616L	100%
2025-03-03 06:39	1567	1,633L 1,633L	100%

Summary table of all historical washes, with alerts, times, water use, deviations and status.

Data Refinement: To improve the efficiency of washing, there are critical data refinement strategies that can be implemented:

- **Weather-Integrated Recommendations:** Avoid redundant washes by cross-referencing with weather forecasts.
- **Water Consumption Monitoring:** Detect abnormal usage patterns and leaks against predefined parameters.
- **Performance-Based Activation:** Ensure washing events align with actual soiling conditions to prevent unnecessary cleanings.

Actionable Automation: Automations can help to enhance and streamline responses to battery-related alerts. A few key automations that should be deployed are:

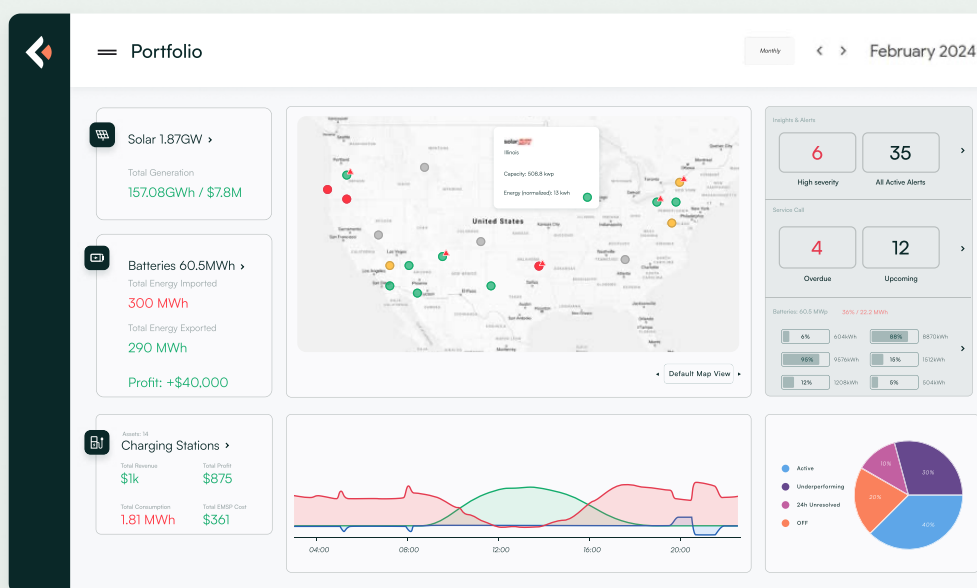
- **Automated Washing Optimization:** Recommend optimal cleaning schedules based on system performance and environmental factors.

Optimizing washing system alerts reduces false alerts, improves efficiency, and maximizes cleaning effectiveness. Through the integration of weather forecasts, performance monitoring, and AI-driven automation, management systems empower customers to implement smarter maintenance, reducing costs and increasing system uptime. Bottom line, smarter washing alerts eliminate unnecessary washes and water waste, while also enabling efficient washing management for large fleets.



Conclusion

Intelligent monitoring and alert management, that are optimized with automations, in clean energy systems are essential for maintaining reliable performance and maximizing energy yield. However, the benefits go far past simply improving asset performance. Critically, these smart alert systems also improve business efficiency — enabling improved margins and scalability. That's why enSights has implemented all of the data refinement and actionable automation into its AI-driven clean energy management and optimization ecosystem.



Dashboard displaying KPIs, including alert tracking, SLA tracking, battery status, and asset performance.