Brill Power

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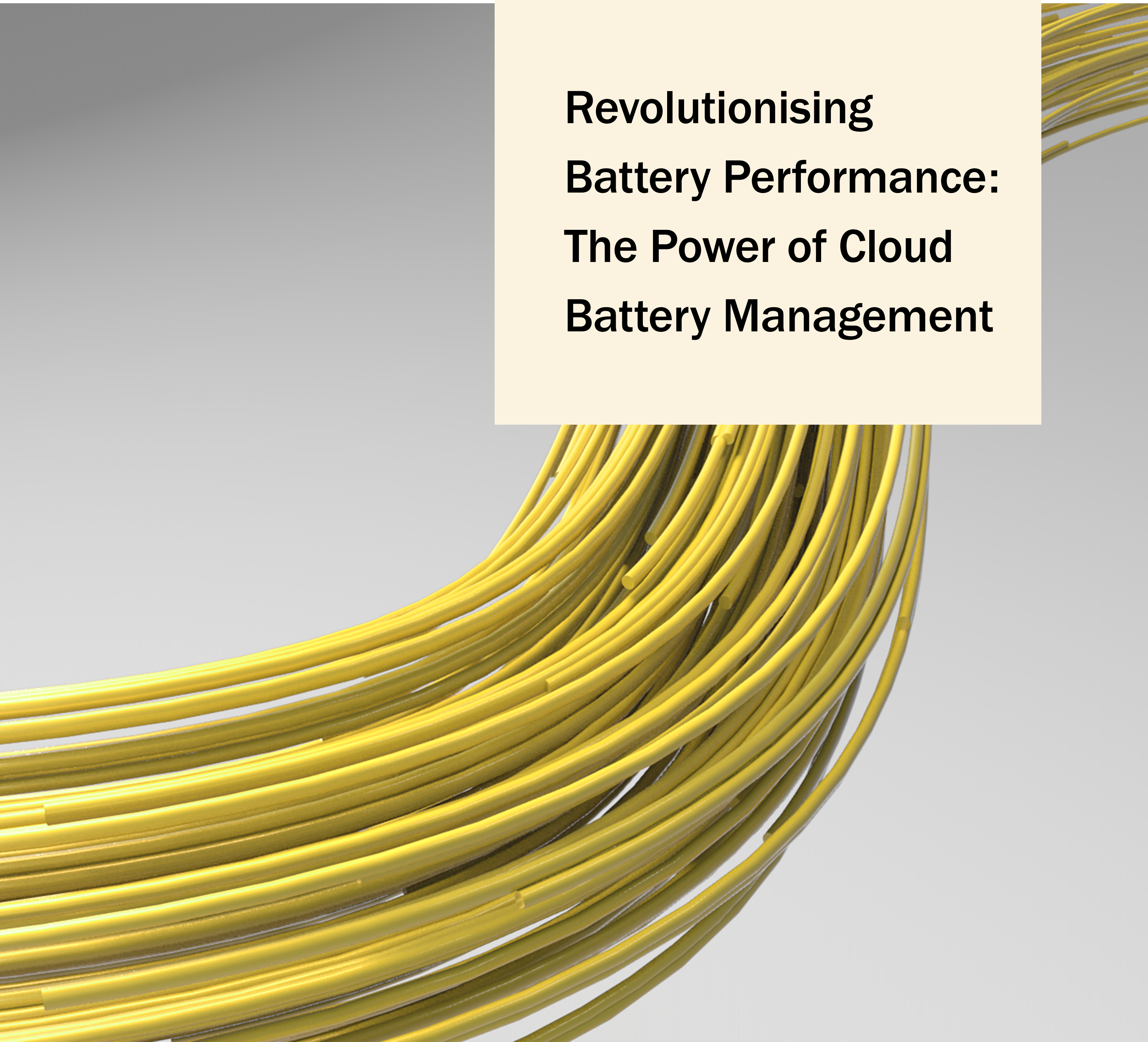
Revolutionising Battery Performance: The Power of Cloud Battery Management



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Introduction

The demand for efficient energy storage solutions has become paramount due to the pressing need for renewable energy integration, electrification of transportation, grid stability, demand-side management, decentralisation, and sustainability objectives. In this context, Brill Power offers a groundbreaking approach to address the limitations of conventional battery management systems (BMS).

Propelled by the fusion of online estimation methods in hardware and cutting-edge model-free, data-driven techniques in the cloud, Brill Power's innovative hybrid battery management system emerges as a transformative force in computing batteries' state of charge, state of health, and state of power. By seamlessly integrating the power of cloud computing, this hybrid BMS not only enhances battery life, performance, and safety, it also paves the way for a new frontier in sustainable energy storage solutions.

The promises of cloud-enhanced Battery Management Systems

Battery management systems (BMS) are electronic systems designed to monitor the safety and manage the operation of rechargeable batteries. They typically consist of hardware components such as sensors, microcontrollers, and communication interfaces, along with software algorithms for control and analysis. Typical BMS functions include safety protection, battery parameters monitoring, cell balancing, state estimation, and basic fault reporting. More sophisticated BMS may offer more advanced features and functions; for instance, a **Brill**Core BMS features intelligent fault diagnostics, active cell loading, and performance and efficiency optimisation (Figure 1).

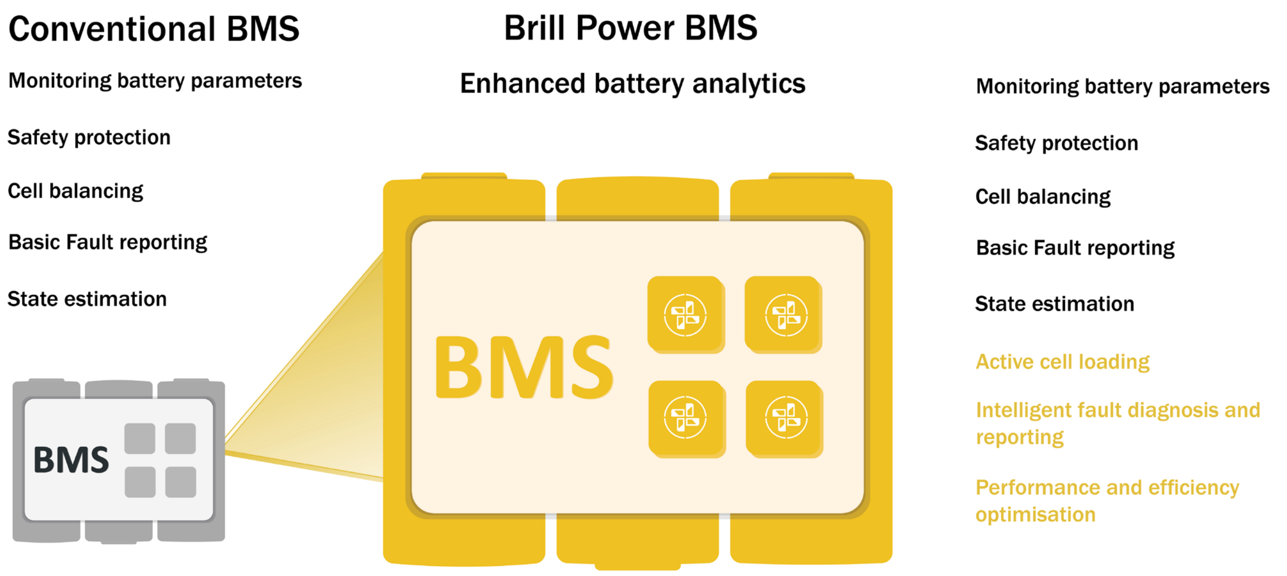


Figure 1. BMS practical goals

Within these functions, state estimation is crucial as it provides information about the condition and performance of rechargeable batteries, including several key operational metrics such as SoC, SoH, SoP and SoE. The level of complexity of the state estimation algorithms and their underpinning cell mathematical models can vary widely in the firmware embedded in the BMS.

Key SoX metrics estimated by a BMS

State of Charge (SoC)

Remaining battery charge as a percentage of its full capacity, a key metric for assessing available energy to power devices.

State of Health (SoH)

An indicator of a battery's overall condition and ability to store and deliver energy compared to its original capacity, offering insights into long-term degradation factors like capacity loss and aging effects.

State of Power (SoP)

An indicator of the level of electrical power a battery can deliver or accept. SoP is influenced by factors like SoC, SoH, charge/discharge rates, temperature, and internal resistance. SOP is crucial for managing power demands and maintaining stable performance without voltage drops or unexpected safety shutdown.

State of Energy (SoE)

Energy stored in the battery until full discharge, measured in watt-hours (Wh). It offers a more accurate view of the battery's ability to power a device by considering both SoC and cell voltage variations. SoE may be utilised to better predict whether a BESS can deliver on grid services.

While SoC and SoH are common values computed by most BMS with various levels of accuracy, SoE and SoP are more advanced metrics that only more advanced BMS can provide.

BrillCore BMS product provides all these states with high accuracy by using cutting-edge algorithms and cell mathematical models.

Synergistic solutions: Why BMS alone isn't enough without the cloud

A tight integration between an advanced BMS and a cloud computing platform can address many challenges that embedded BMS, or Cloud platforms cannot solve on their own. Relying solely on an embedded BMS has limitations such as:

- **Limited Processing Power**: embedded systems often lack the processing power needed for complex data tasks, especially with large datasets or real-time needs.

- **Limited Data Storage Capacity**: their restricted data storage space reduces the ability for long-term data trends analysis.

- **Real-time Connectivity**: Establishing and maintaining real-time connections to external networks can be difficult, impeding data transmission or remote management.

- **Scalability and Update Issues**: Scaling and updating embedded systems for evolving battery management needs through the system lifetime is challenging and costly.

Likewise, a Cloud platform cannot do it all due to:

- **Latency**: Latencies due to Internet communication cause delays that are unsuitable for real-time battery safety monitoring or control.

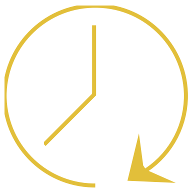
- **Data Privacy and Security**: Storing battery data in the cloud raises privacy and security concerns despite providers' efforts, including risks of unauthorised access, breaches, or compliance issues.

- **Data Rates and Infrastructure**: Reading numerous sensors in large batteries generates vast data volumes. Uploading all this data to the cloud demands substantial communication infrastructure and incurs high internet costs.

Turning data into actionable insights

In the first instance, uploading battery BMS data to a battery analytics platform unleashes the computational and storage capabilities of the cloud to enable safer and more reliable operation of battery energy storage systems (BESSs).

Data storage and management
A cloud-enhanced BMS stores battery data centrally, facilitating access and collaboration among stakeholders. It enables warranty tracking by providing detailed insights into battery performance, allowing proactive issue resolution.



Real-Time Monitoring and Analysis
Cloud-connected sensors enable continuous transmission and analysis of battery data, facilitating rapid anomaly detection and predictive maintenance. This is crucial for BESS portfolio management, ensuring efficient operations and timely safety interventions.

Predictive Maintenance and Diagnostics
Advanced algorithms running in the cloud use machine learning combined with cutting-edge battery models to analyse historical data, discover trends and identify potential failures. Predictive maintenance strategies can then be implemented to improve battery uptime and longevity.

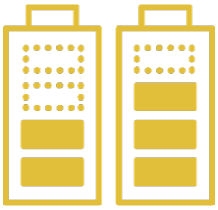
BrillAnalytics Monitor is an example of such a BESS monitoring platform that ingests, processes and stores BMS data to the cloud enabling users to monitor the status of their battery asset in real-time and improve ROI through error flagging and battery performance assessments.

BrillAnalytics Health takes battery analytics a step further by automatically analysing large amount of BMS data to deliver actionable insights into the current and future health of BESSs for predictive maintenance and diagnostics. This allows BESS asset managers to make informed decisions on system usage strategy, improve safety and reduce the risk of failure.

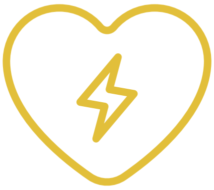
Beyond the insights: closing the feedback loop.

Better still, a BMS tightly integrated with a cloud analytics platform enables control actions and software updates to be automatically sent back to the BMS, closing the feedback loop between the BMS and the cloud analytics platform. This integration offers the scalability and flexibility to adapt to changing requirements (e.g. new load profiles arising from stacked revenue sources), accommodate varying system sizes and complexities (e.g. system size augmentation, cell-to-cell variation, mixed cell chemistries), and adjust its safety and control strategies in line with the changing behaviour of an ageing battery asset (reducing capacity and power capabilities).

More specifically, we can have:

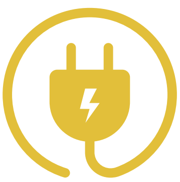


Improved embedded SoX estimation accuracy
Not all cells and modules show the same behaviour in a BESS, especially as the system ages. Cloud-based analysis can help identifying cell-to-cell and module-to-module variations and fine-tune the cell model underpinning SoX estimation to each specific cell or module in the system as they degrade.
This results in more accurate SoX estimates (SoC, SoH...) over the entire lifetime of the system.



Embedded SoH recalibrated through cloud-based SoH diagnostics
Battery degradation is a slow process taking months or years to show significant variations. While a BMS can perform some embedded computation to assess SoH based on the current data it sees, SoH diagnostics are much better suited to cloud computation where long-term historical data is available to spot slowly developing patterns and trends related to SoH reduction.
A cloud platform can analyse these long-term trends to better diagnose SoH and recalibrate the BMS estimate for optimal operation.

Advanced Anomaly Detection for Improved Battery Safety and Maintenance
Cloud analytics platforms have a more comprehensive view of the battery system and can therefore detect anomalies that indicate potential operational inefficiencies, thermal runaway or other safety hazards. It can then alert the BESS operator to schedule preventive maintenance or even automatically trigger an immediate action on an advanced BMS to reduce the load or isolate distressed modules or strings.
This proactive approach mitigates risks and enhances the safety of battery systems.



Advanced Cloud-Based Control Techniques for Battery Optimization
Relying on precise SoX estimation, the cloud can execute diverse control techniques across modules and strings to achieve various objectives.
For example, it can regulate energy consumption and distribution within the system to minimise losses and optimise efficiency, or it can uphold battery performance within defined parameters to ensure both efficiency and longevity.

In the given context, Brill Power offers a unique cloud-based BMS named **Brill**Analytics which also stands on the shoulders of other Brill Power solutions including **Brill**OS and **Brill**Core, interconnected as shown in Figure 2.

BrillCore is a hardware with patented active loading technology to enable benefits such as up to 60% longer battery lifetime, up to 46% more energy from aged batteries, faster charging rates, and improved safety. Furthermore, it is scalable to any system and integrates DC/DC conversion.

BrillOS is the world's first future-proof, highly portable, chemistry-agnostic Operating System for batteries, with high precision monitoring algorithms, customizable settings, and over-the-air updates.

Finally, **Brill**Analytics delivers end-to-end data and insights for safe and optimal battery use, with predictive analytics and a flexible interface

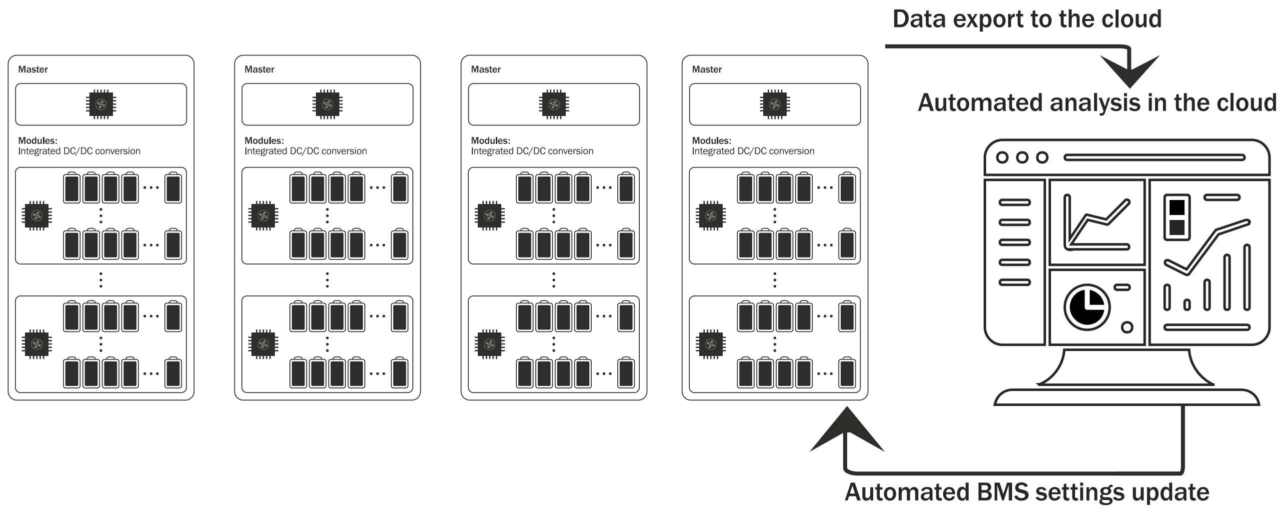


Figure 2. Diagrammatic description of Brill Power Cloud based BMS

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