WEBINAR SUMMARY

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ElectronicDesign

Electrification—Current Sensing in Battery Energy Storage Systems (BESS)

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KEY TAKEAWAYS

- An introduction to current sensing technologies.
- An increased focused on sustainability is driving greater adoption of battery energy storage systems.
- Current sensor technology helps ensure BESS are operating safely and efficiently.
- Honeywell Sensing Solutions offers a range of sensors for BESS applications.

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OVERVIEW

The battery energy storage systems (BESS) market is expanding rapidly due to the increasing demand for renewable energy integration, data center support, grid stabilization, and effective energy management. With the rise in BESS adoption, ensuring system safety and reliability is paramount, and current sensors are essential in achieving this. Advanced sensors enhance safety, performance, and cost efficiency in energy storage solutions crucial for renewable energy and grid stabilization.

Honeywell Sensing Solutions provides a comprehensive portfolio of sensing, switching, and test and measurement technologies designed to meet the diverse needs of industries such as healthcare, transportation, industrial automation, and EV. With a focus on precision and reliability, these solutions enable optimized performance across critical applications. Supported by a team of expert engineers, Honeywell ensures personalized and innovative approaches, working collaboratively with customers to deliver tailored solutions that meet their specific requirements and performance standards, driving efficiency and ensuring long-term operational success.

CONTEXT

AJ Fowowe discussed the role of advanced sensing technology in optimizing BESS operation and explained how Honeywell Sensing Solutions' sensor portfolio improves BESS safety and efficiency.

KEY TAKEAWAYS

An introduction to current sensing technologies.

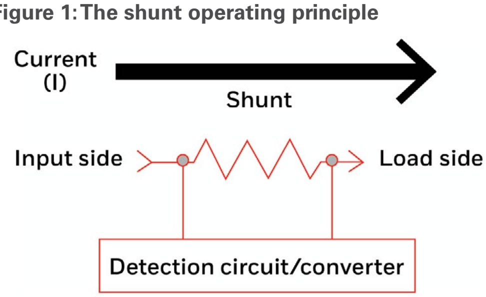
Different current sensing technologies offer different benefits and drawbacks. Understanding the capabilities of each helps determine the best-fit sensor for a given application. There are two main groups of sensors: 1) In-line, direct, no isolation current sensor technology; and 2) Non-contact, indirect, inherent isolation processor technology

1. In-line, direct, no isolation current sensor technology

Shunt-based current sensing lacks isolation, exposing the system to high voltage and increasing safety risks and potential damage. A separate isolation circuit is often required for protection and safe operation.

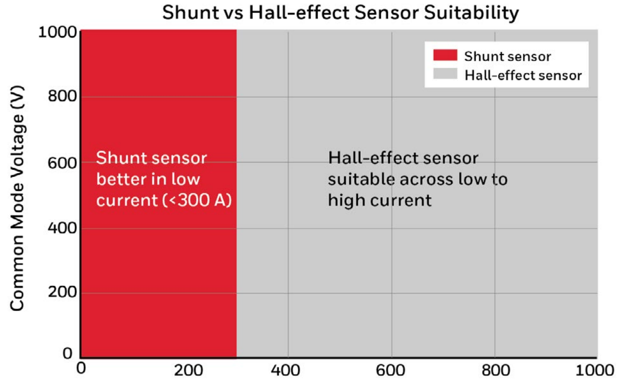
Function: In-line sensors use the principle of Ohm's Law (V=IR), installing a shunt resistor directly in series with the circuit to be measured, allowing all current to pass through it. An induced voltage drop is measured across the precision resistor (the shunt) and quantified. The voltage value is then used to determine the amount of current flowing through the conductor.

Figure 1: The shunt operating principle



Design: Shunt resistors are designed with very low resistance to minimize power loss while maintaining high accuracy in current measurement. However, at high currents (>300 amps), shunt resistors generate heat, causing efficiency losses, accuracy drift and potential system damage.

Figure 2: Shunt resistor design makes it suitable for low-current (<300 amps) applications



2. On-contact, indirect, inherent isolation processor technology

Technologies like Hall effect, AMR, and current transformers measure current indirectly through magnetic fields or flux, ensuring safety and protection from high-voltage circuits by maintaining electrical separation.

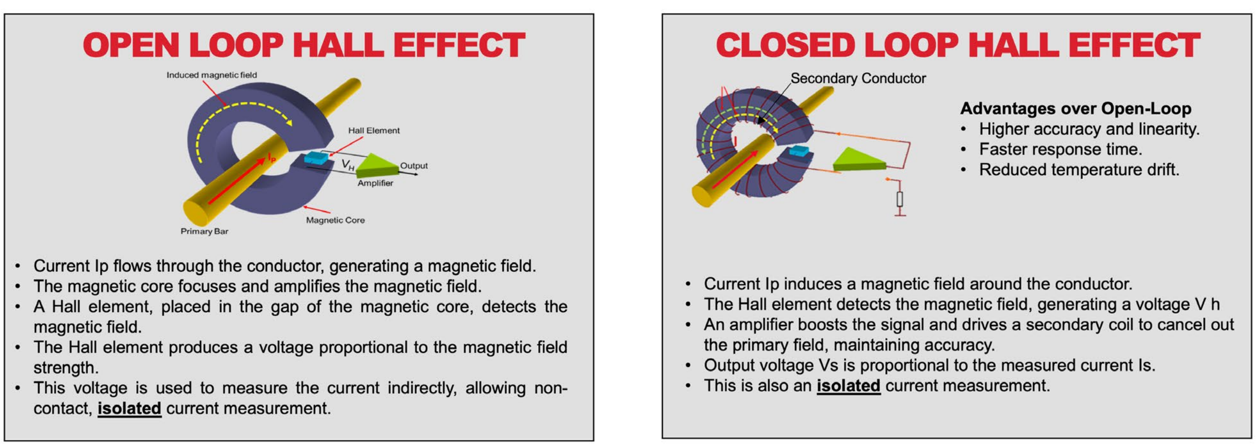
Function: Indirect processors use the principle of Amperes Law, sending current through a conductor to produce a magnetic field around the conductor with an amplitude directly proportional to the current. By measuring and quantifying the magnetic field, the amount of current flowing through the conductor can be derived from that value.

Design: There are two methods used in non-contact processors: Hall effect and flux gate technology.

- Hall effect. A current-carrying conductor is placed in a perpendicular magnetic field, causing a voltage difference across the conductor due to the deflection of charge carriers. The Hall effect sensor is placed in proximity to the conductor, inducing a Hall voltage, which is used to measure the magnetic field strength around the conductor and quantify the current flowing through the conductor. Typically, Hall effect technology can support up to 2500 amps.

  Hall effects sensors come in two types: open loop and closed loop. Both are completely isolated and provide an indirect way of measuring currents through a conductor, but there is a cost-performance tradeoff between the two. Closed loop uses a secondary coil to balance the measurement of the magnetic field, significantly increasing accuracy and linearity.

Figure 3: Open loop versus closed loop Hall effect sensors



- **Flux gate technology.** An open-loop flux gate relies on the principle of magnetic induction. Its core is made of ferromagnetic material that enables it to measure low-level magnetic fields or electric currents. It operates by detecting the changes in magnetic flux caused by an external magnetic field, without directly connecting to the current-carrying conductor.

  The magnetic core has two windings: a primary coil is wound around the core and is used to generate a magnetic field by driving a periodic alternating current (AC) through it. The external magnetic field from the current-carrying conductor affects the saturation point of the core, causing the magnetization of the core to shift and resulting in a change in the magnetic flux density. When this occurs, a differential voltage is induced, which the sensor amplifies and processes to determine the current. A secondary coil is also wound around the core and detects the changes in magnetic flux caused by the external field.

Table 1: A comparison of in-line sensing versus non-contact

Feature	Shunt Sensors (In-line)	Non-contact (Hall-effect & Fluxgate)
ac/dc compatibility	Works with both ac and dc currents	Works with both ac and dc currents
Electrical isolation	No inherent isolation; requires extra circuit	Provides inherent electrical isolation
Simplicity	Simple design but requires isolation circuit for safety	Simple with built-in isolation, no need for additional circuitry
Accuracy	Good for low-to-medium current measurement	High accuracy, especially in high-current applications
Linearity	Good linearity in low-to-medium current ranges	Excellent linearity across a wide current range
Heat dissipation	Generates heat at higher currents	Minimal heat generation
Temperature drift over lifetime	Higher drift at high currents	
Typical applications	Low-power (voltage) applications, general current sensing in low-to-medium currents	Ideal for high-power (voltage) applications, high-current measurement, and systems requiring electrical isolation

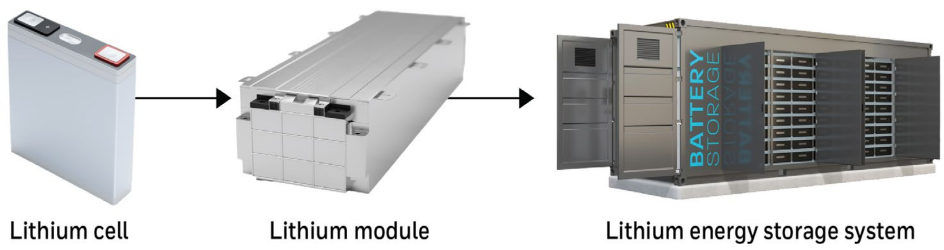
An increased focused on sustainability is driving greater adoption of battery energy storage systems.

BESS store and manage energy, ensuring reliability, efficiency, and integration with renewable energy sources. BESS enable several key benefits, including:

- **Grid stability.** The energy stored in BESS from renewables such as solar ensures a stable supply and balances demand.
- **Peak shaving.** By supplying stored energy during peak demand, BESS reduces grid strain.
- **Renewable integrations.** BESS store energy from renewable energy sources while the sources are online, then release energy back into the grid when the sources are offline, enabling continuous use during intermittent power supply.
- **Backup power.** BESS provide critical backup power during outages, ensuring reliability for essential systems.

At the core of BESS are lithium-ion battery cells that are placed into lithium-ion modules, which are then installed into racks in a large container. BESS power capacity ranges from 500kWh to 4GWh.

Figure 4: BESS basic architecture



Current sensor technology helps ensure BESS are operating safely and efficiently.

Advanced sensor technology is revolutionizing BESS, enabling monitoring and managing battery health, performance, and safety to optimize BESS operation. There are four main areas of monitoring and management that contribute to the safe operation of BESS:

Table 2: Key areas of BESS measurement and monitoring

Area of measurement and monitoring	Why measurement and monitoring matters	How measurement and monitoring helps
State of Charge (SoC) and State of Health (SoH) Estimation	Current measurement is essential for estimating the battery's state of charge (SoC) and state of health (SoH), both critical for maintaining optimal performance.	Ensures reliable operation by preventing excessive depletion or overuse of the battery.
Battery Health and Safety	Monitoring current ensures the system operates within safe parameters, preventing overcharging, over-discharging, and overheating, which can lead to battery damage or failure.	Detects abnormal current flow, which could indicate short circuits, faults, or safety issues that need immediate attention.
System Performance	Accurate current measurement helps track the charge and discharge cycles of the battery, providing insights into the system's efficiency.	Allows operators to ensure the ESS is functioning within its design limits, optimizing performance and lifespan.
Grid Integration and Stability	For energy storage systems connected to the grid, current measurement helps in maintaining grid stability by ensuring that power injections or withdrawals are accurately controlled.	Facilitates the smooth integration of renewable energy sources into the grid by managing fluctuations.

Current sensors play a critical role in each key area. When designing a current sensor for an energy storage system battery management system (BMS), there are four factors to consider:

1. **Accuracy and resolution.** A highly accurate current sensor with high precision is critical for measuring small changes in current, especially during charging and discharging cycles. The sensor should provide accurate data over a wide range of current values. The current sensor must have sufficient resolution to detect small current variations that are important for battery management, such as idle currents or slow discharge rates. *Honeywell Sensing Solutions recommends non-contact sensors for greater accuracy and linearity, to ensure the battery is working optimally and SoC and SoH estimations are done correctly.*

2. **Overcurrent and fault protection.** The current sensor must handle overcurrent conditions safely without damage and trigger protective measures, such as alarms or system shutdowns, in case of overloads or short circuits. The current sensor must have fault detection capabilities to identify abnormal conditions such as short circuits, leakage, or insulation failure. *Honeywell Sensing Solutions recommends non-contact sensors, as they can endure exposure to a high current range without damage.*

3. **Isolation and power consumption.** Electrical isolation is necessary to protect the BMS from high-voltage battery systems. Galvanic isolation prevents the sensor from directly transmitting high voltage to sensitive components. The current sensor should consume as little power as possible, especially in low-power applications where efficiency is critical. Consider low-power designs to minimize energy consumption. *As shunt technology does not use galvanic isolation and requires inherent capacity on the battery system, Honeywell Sensing Solutions recommends non-contact sensors.*

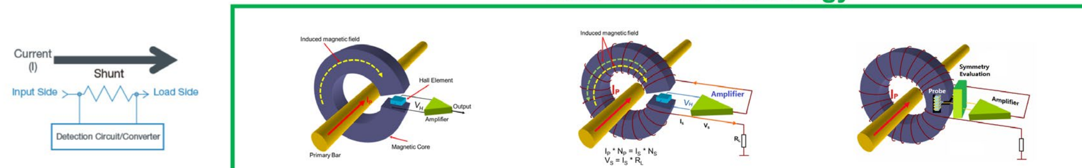
4. **Noise immunity and signal conditioning.** The current sensor must handle electrical noise and ensure stable output even in environments with electromagnetic interference (EMI) or switching noise from other system components. The current sensor must also incorporate proper signal conditioning (such as filtering) to ensure that the output is clean and usable by the BMS. *Honeywell Sensing Solutions recommends non-contact sensors for their high accuracy.*

Long-term precise current measurement is essential for maintaining battery health and minimizing maintenance costs in BESS. Accumulated sensor errors can negatively impact BESS performance, reducing its operational lifespan and increasing downtime. Early fault detection, efficient thermal management, and ensuring smooth, reliable system operation are critical for effective BESS management.

> "When you put all of these factors together, the key takeaway is that non-contact technology is a better option . . . versus shunt technology."
>
> *AJ Fowowe, Honeywell Sensing Solutions*

Figure 5: Non-contact is the better choice of sensor technology for BESS

Non-contact Technology



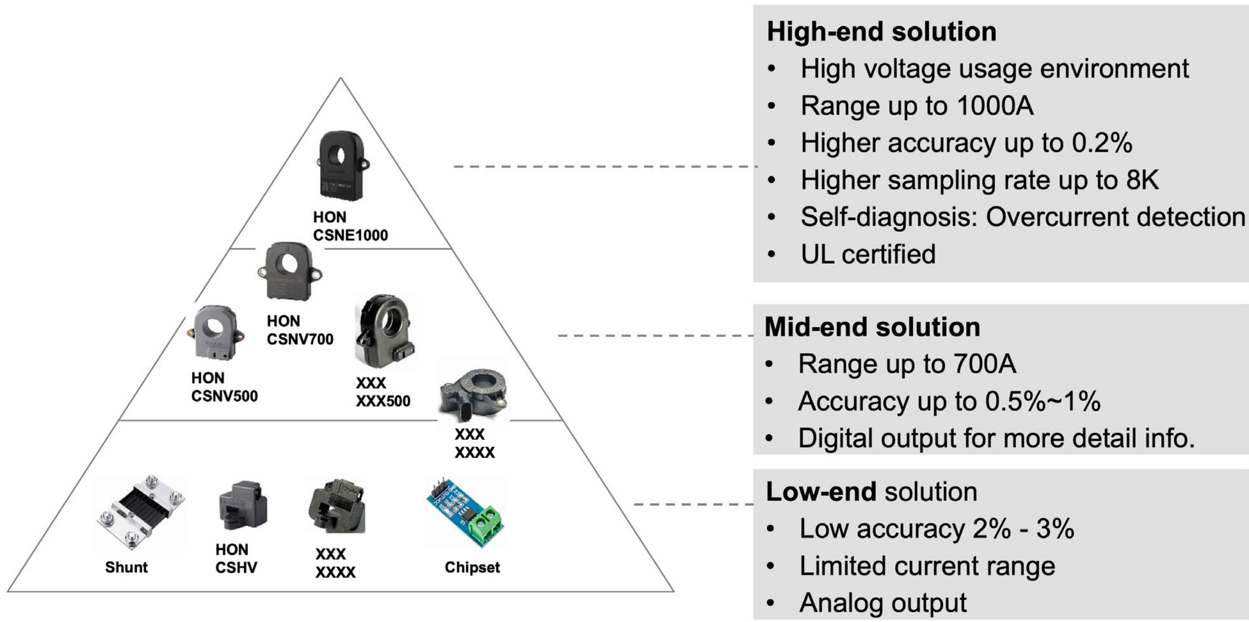
Sensing Type	Shunt Technology	Open Loop	Closed Loop	Flux Gate
Operating Principle	Measures voltage drop across a resistor proportional to the current.	Uses a Hall sensor in a magnetic core to measure current-generated magnetic fields.	Balances magnetic flux from the primary current with a secondary winding driven by a Hall effect device.	Uses a secondary winding to counteract the magnetic field generated by the primary conductor.
Benefits	• **Lowest cost** • Simple design (direct measurement)	• **Lower cost** • Higher measuring range • Wide operating temperature range	• **Highest full temperature accuracy** • **Strongest magnetic interference resistance** • Better di/dt performance • Low power consumption	• Higher full temperature accuracy • **Low zero offset** • High reliability • Lowest power consumption
Drawbacks	• Lower accuracy • Heat generation, limited to low currents • **No galvanic isolation**	• Lower accuracy • Prone to saturation & temperature drift	• Highest cost	• Higher cost • Limited operating temperature range

Honeywell Sensing Solutions offers a range of sensors for BESS applications.

Honeywell Sensing Solutions offers three different non-contact current sensors designed for BESS applications: the CSHV (open loop Hall effect), CSNV500 (closed loop Hall effect), and CSNV700 (flux gate technology) series.

And coming soon: the CSNE1000 series, specially engineered for BESS. CSNE1000 provides accurate readings for a battery management system to calculate SoC. The CSNE1000 is best in class for accuracy (up to 0.2%), with a higher sampling rate up to 8KHz using Delta-sigma modulation. The sensor is designed to perform optimally in a 2500V DC environment and supports up to a 15-year operating life.

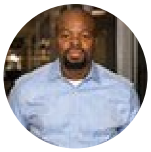
Figure 6: Honeywell offers current sensing options for different applications



ADDITIONAL INFORMATION

To learn more, visit Honeywell Sensing Solutions

BIOGRAPHY



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AJ Fowowe is the Director of Offering Management at Honeywell Sensing Solutions. Since joining Honeywell in 2016 as a Product Design Engineer, he has held various roles, including Marketing and Offering Specialist, where he supported markets such as heavy-duty transportation and industrial safety. In his current position, AJ is responsible for driving global portfolio growth, overseeing New Product Introduction (NPI) roadmaps, driving innovation, and developing commercialization strategies.

AJ's primary focus is on sensing needs within the Energy Transition sector. He supports various industries involved in this transition, including automotive, heavy-duty transportation, battery energy storage systems (BESS), and micromobility. AJ has led the launch of multiple current sensing and battery safety products globally, enhancing the safety and performance of clean energy systems. AJ resides in Dallas, Texas.