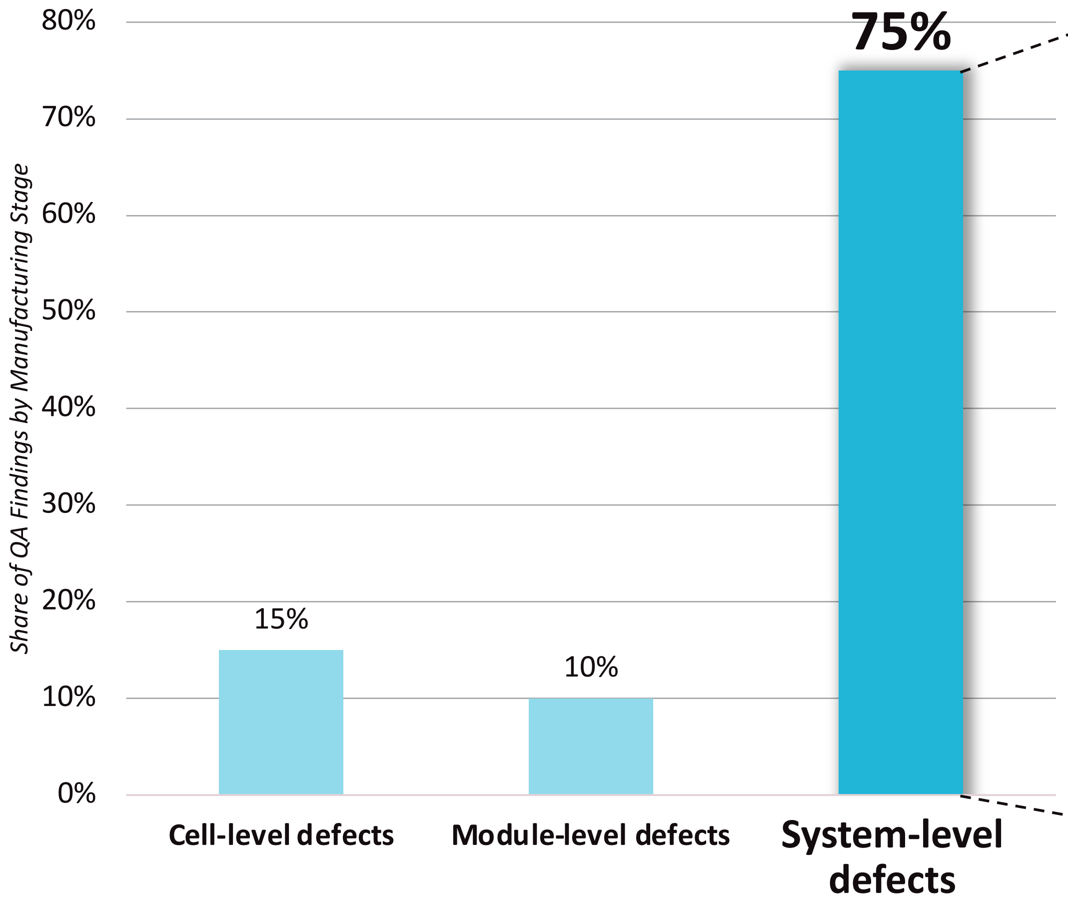
Global Energy Storage Manufacturing Quality Report 2026

Key risks and defect trends from our latest inspection data

May 2026

In 2025, the Vast Majority of Identified Quality Issues Were at the System Level

More than 1 in 8 inspected Energy Storage System (ESS) units had safety-critical issues relating to the battery management system, thermal management, or water ingress



Safety-critical failures:

4.7% of systems had issues in the **Battery Management System (BMS)**, increasing the risk of control system failure.

4.2% of systems had **thermal management issues**, raising the risk of overheating and accelerated degradation.

4.4% of systems had **water ingress issues**, increasing the risk of internal short circuits and component failure.

This report outlines the causes, consequences, and resolutions for these and other ESS quality risks.

Intertek CEA Has Conducted Factory Quality Audits On Over 70 GWh of Lithium-Ion Energy Storage Projects Since 2018

- **880+ inspections in 90 Energy Storage System (ESS) factories**
- **>60% of tier 1* ESS cell manufacturers audited worldwide**
- **3,370 total manufacturing issues identified**

Locations of Intertek CEA factory audits

Here are our key findings from our 2025 inspections...

**Tier 1: definition is based on BMI (Benchmark Mineral Intelligence)*

Our Audit Process: Intertek CEA Assigns a Severity to Each Finding Depending On the Risk Level of the Issue

A **finding** is an issue identified during inspection that indicates deviation from standard best practices, processes or product specifications.

Finding Severity	Definition
Critical	Findings that may result in severe safety risks and hazardous conditions. Critical findings are likely to cause damage to other products or property, trigger non-compliance regulatory issues, and generally constitute a breach of mandatory regulations.
Major	Findings that may reduce the battery's functionality or impact safety in either short or long term.
Minor	Findings which do not pose a clear risk of production failure, but rather fall outside the quality requirements.

What Happens When We Find a Critical or Major Issue

Intertek CEA's Defect Resolution Protocol

1. Notification

We alert the buyer and describe the issue and risks

2. Escalation

In conjunction with the buyer, we bring the issue to the manufacturer and require that the issue is fixed prior to shipping

3. Corrective Action

The manufacturer either fixes the problem or makes a new item entirely

4. Verification & Re-inspection

We re-inspect and confirm that the problem has been addressed.

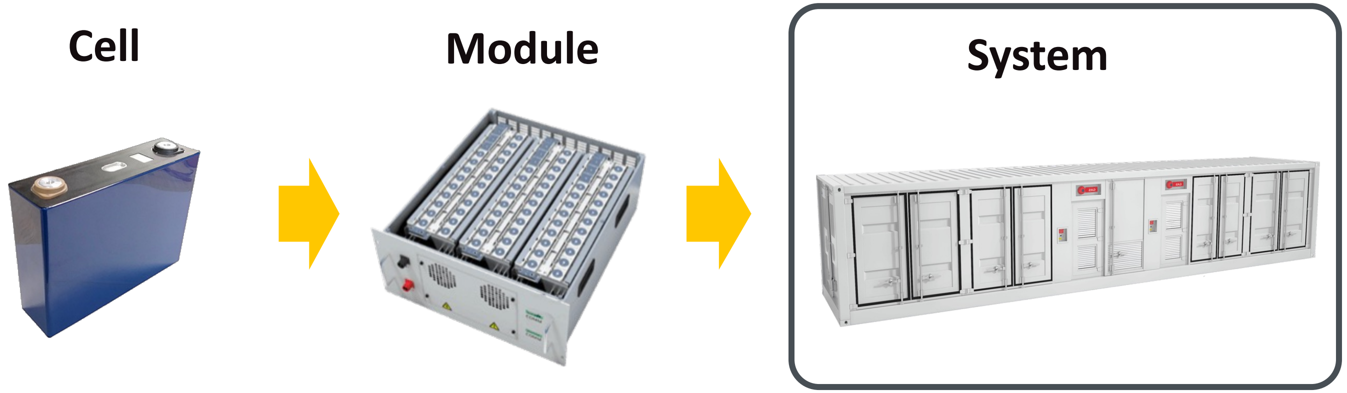
Outcome: None of the systems Intertek CEA inspected were shipped with unresolved defects.

Distribution of Total Findings

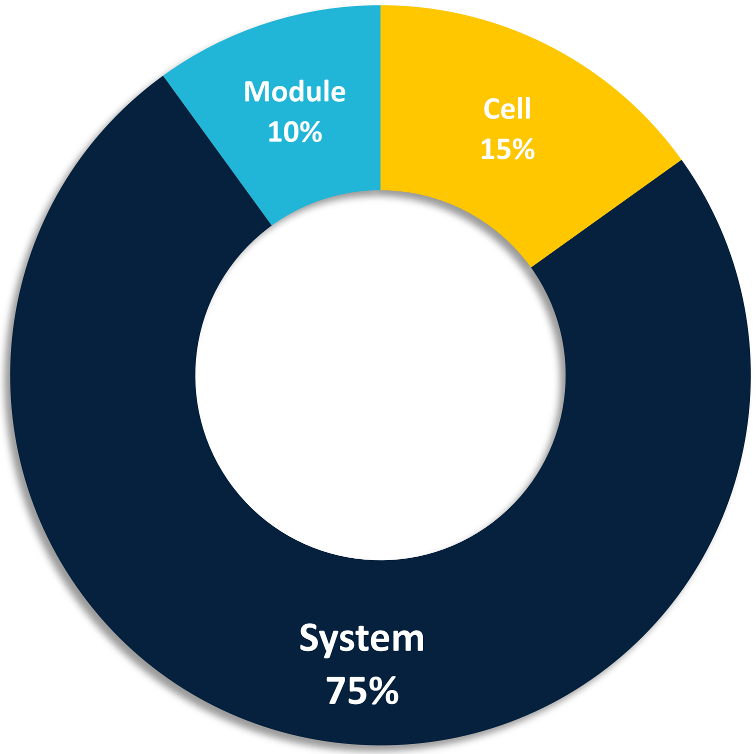
As the industry continues to scale, quality problems at the integration stage continue to be challenging to fix.
System-level defects accounted for nearly 75% of our QA findings.

The high number of system-level issues is mainly caused by the following contributors:

- The ESS integration process is **highly manual** and labor-intensive, with weaker quality control often carried out by outsourced integration companies who have little incentive to ensure long-term performance.
- **Rapid product iteration** prevents production processes from maturing.
- Systems are **very complex** and are vulnerable to underlying problems originating from defects in upstream components that were not caught during earlier quality checks.



Distribution of all ESS Findings



Breakdown of System-level Findings

The majority of system-level findings occurred in the balance of systemand enclosure.
Performance test findings usually indicate larger or more complex problems.

47% of system-level findings are balance of system related

Why/How Does It Happen
Component defects and improper system integration procedures.
Example
• Liquid coolant leakage due to deformed flange plates, defective valves, loose pipe connections within the coolant circulation system • Malfunctioning temperature, smoke, gas sensors, audible and visual alarms due to internal mis-wiring • BMS fails to react when door alarm was triggered

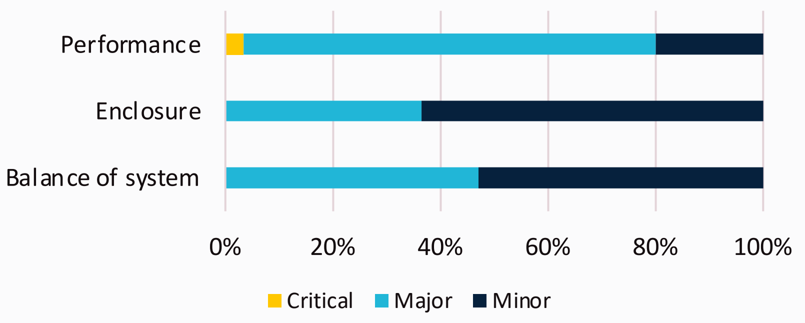
42% of system-level findings are enclosure related

Why/How Does It Happen
Defects from enclosure manufacturing process and mishandling during assembly.
Example
• Poor strength and rigidity:, door deformation, deformed rain shield, etc. • Poor wiring and cabling arrangement • Grounding insulation test failure • Water ingress issue • Appearance defects: painting specifications, markings, nameplate, uncleanness, etc.

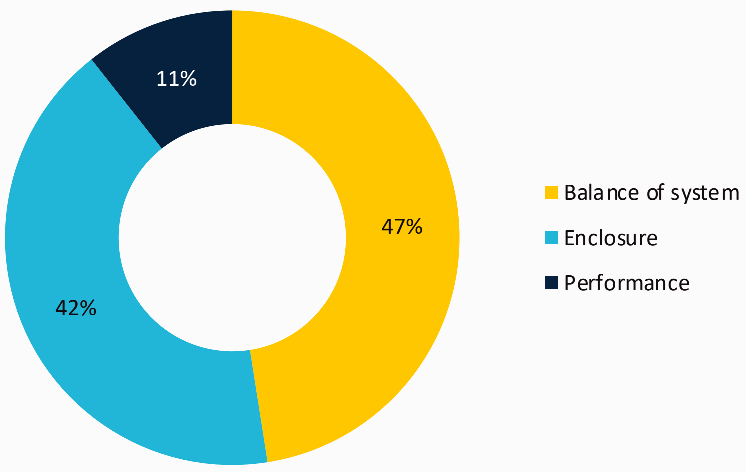
11% of system-level findings are performance test related

Why/How Does It Happen
A wide variety of control defects and/or improper testing procedure.
Example
• Underachieving capacity and Round-Trip Efficiency results from low uniformity and unstable operational temperature & voltage of battery cells. • Charging/discharging failure due to wiring issues in high voltage boxes, overheated battery cells, or malfunction in PCS power control

Severity Scale of System-Level Findings



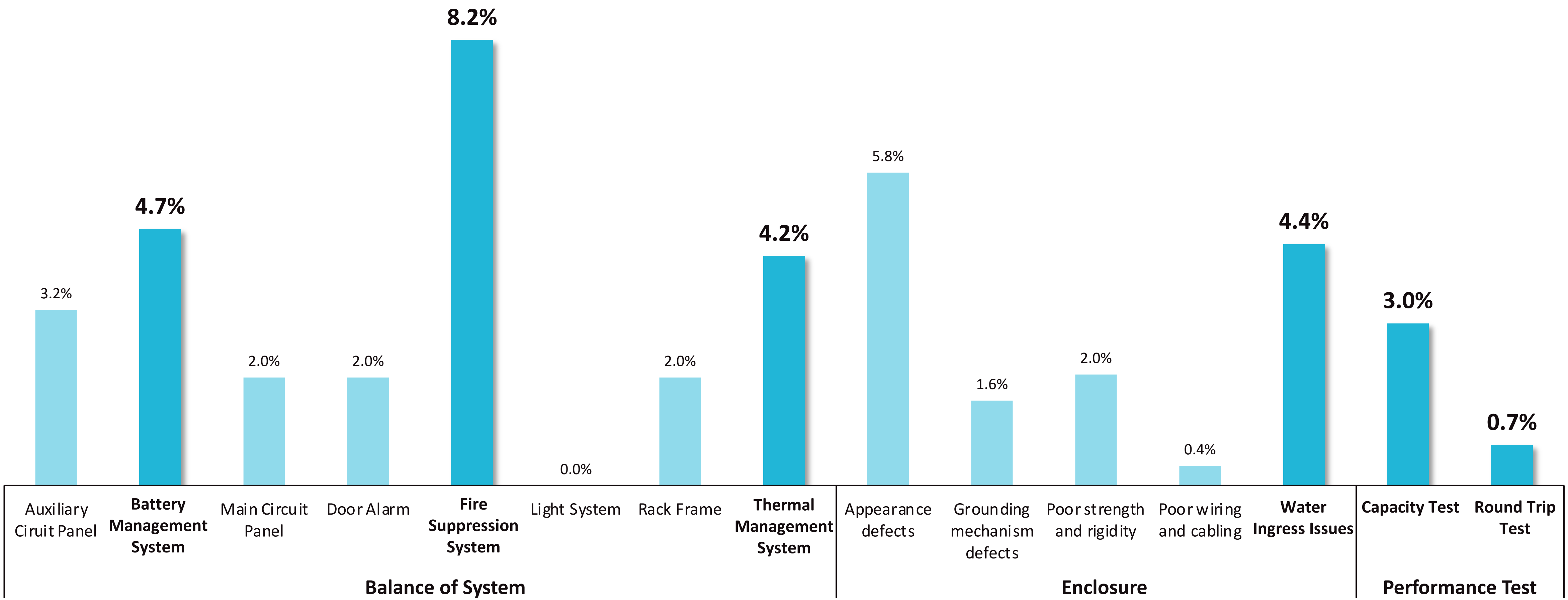
Distribution of System-Level Findings



Most System-Level Defect Types Have a Safety Impact; 3.7% Failed Performance Tests

Failures in these systems can lead to fires, system shutdowns, or energy shortfalls — all with serious safety and financial consequences.

Frequency of system-level ESS defects over total inspected units



Case Study – Common Thermal Management System Findings

4.2% of inspected ESS units had thermal management system defects

Liquid-cooled machine leakage

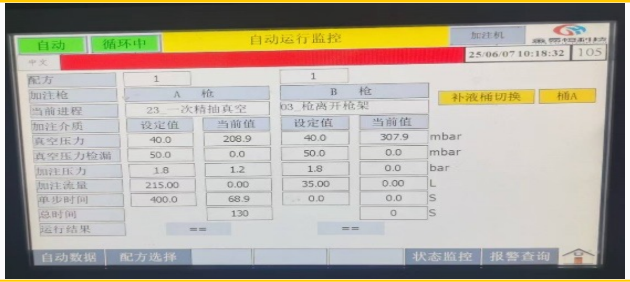
Why/How Does It Happen

Loose pipe connection: the clamp at the liquid-cooling pipe connection was not tightened, causing leakage in the liquid-cooled machine and preventing proper vacuuming during liquid filling.

Risk

Coolant leakage and incomplete liquid filling can compromise cooling-loop integrity, reducing coolant circulation and increasing the risk of insufficient thermal control, accelerated battery degradation, and leakage-related electrical safety issues.

Example



Expired calibration label on airtightness test meter

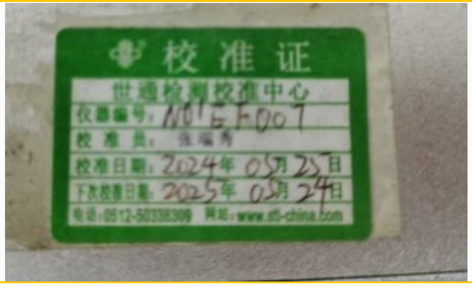
Why/How Does It Happen

Test equipment calibration-control failure: the air-tightness meter used to verify the liquid-cooling circuit had an expired calibration label, so the validity of the airtightness test could not be assured.

Risk

Unreliable airtightness verification can allow liquid-cooling leaks to pass QC, increasing the risk of undetected coolant loss, reduced cooling performance, accelerated degradation, and downstream electrical safety issues.

Example



Case Study – Common Battery Management System Findings

4.7% of inspected ESS units had battery management system defects

Data from several battery modules cannot be retrieved

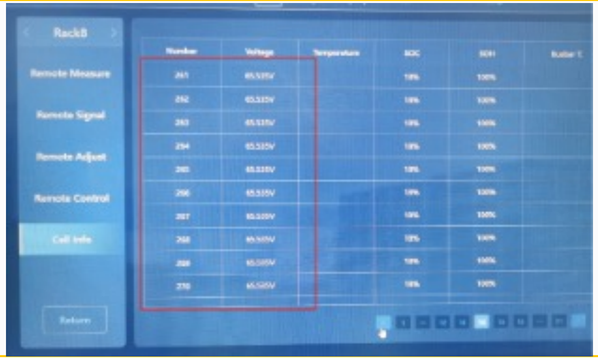
Why/How Does It Happen

Loose wiring-harness connection

Risk

Battery cells within these modules may not be detected, which can lead to hidden degradation, accelerated aging, and undetected thermal runaway.

Example



Rack-level BMS address cannot be configured during functional testing

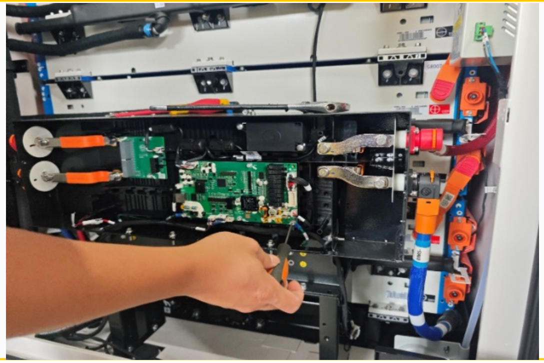
Why/How Does It Happen

Quality issue with the BMS mainboard

Risk

The entire battery rack may not be identified or monitored by the system-level BMS, and detection and protection functions may not operate during normal operation.

Example



Parameter limits were not readable in the HMI

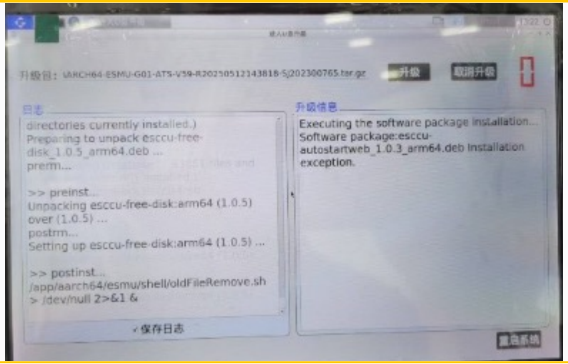
Why/How Does It Happen

The BMS software version had not been updated

Risk

Abnormal operation may occur, with an increased risk of delayed fault recognition when alarms occur because safety limits may be unknown or unverifiable.

Example



Case Study – Common Water Ingress Findings

4.4% of inspected ESS units had water ingress issues

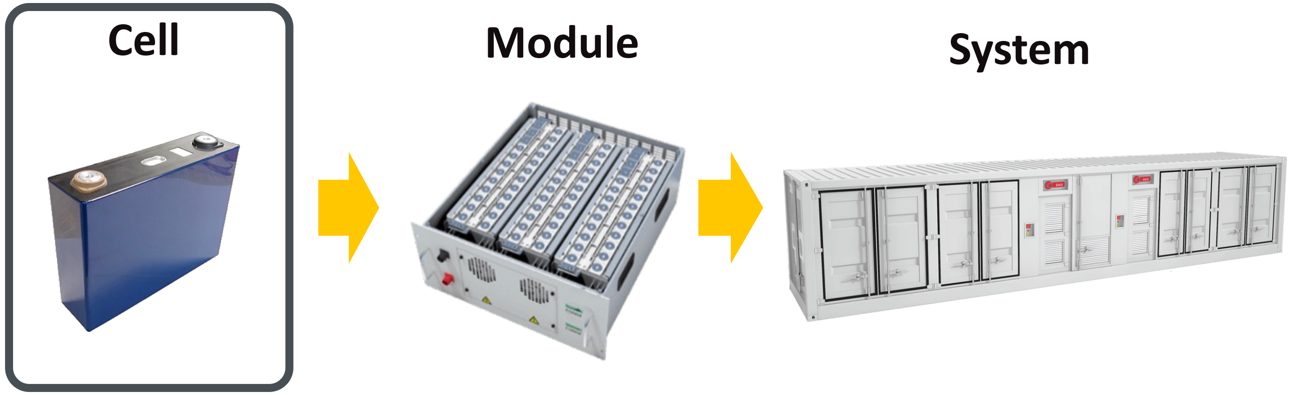
Why/How Does It Happen
Gaps exist between the liquid-cooling chiller and the AC/DC control cabinet.
Risk
Water ingress into the AC/DC control cabinet through gaps around the liquid-cooling chiller may cause a short circuit in the auxiliary circuit, leading to system shutdown.
Example

Why/How Does It Happen
Deformation occurred in the central area of the enclosure due to improper container transfer.
Risk
Water ingress into the battery compartment through gaps in the deformed enclosure base may cause a short circuit in the main power circuit, potentially leading to battery thermal runaway.
Example

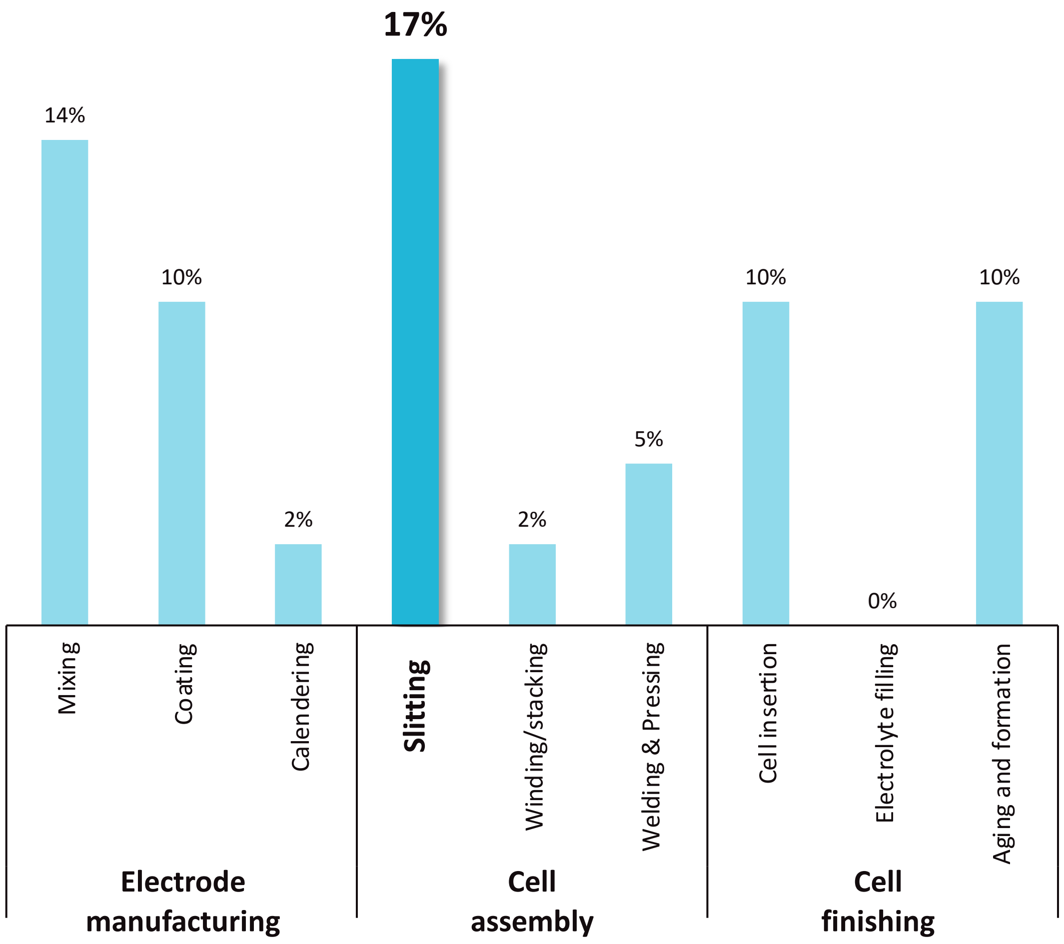
Why/How Does It Happen
A reserved drainage hole, designed for liquid-cooling pipe maintenance, was not properly sealed during the water spray test.
Risk
Water ingress through the holes into the battery control compartment may cause HV box control failure and system shutdown.
Example

15% of the Total Findings Occurred During Battery Cell Manufacturing

- Although battery cell factories have the highest level of automation, they make up a larger number of findings (compared to battery modules) due to their lengthy production processes and higher precision requirements, leading to more room for error.
- Audit findings on cells typically have a higher severity rating as cells are the building blocks of the energy storage system, and defects can be detrimental to system performance and safety.
- **Slitting** carries a high risk of burrs on electrodes, which can pierce the separator and trigger thermal runaway. Even minor deviations from SOPs or limitations in detection equipment are recorded as findings, contributing to the high frequency.



Frequency of issues found in total audited cell workshops



Breakdown of Battery Cell-Level Findings

The majority of battery cell-level findings occurred during **electrode manufacturing** and **cell assembly** due to poor process control and measurement issues.

38% of cell findings occur during electrode manufacturing

Why/How Does It Happen
Improper measurement system analysis and process control

Example

- **Mixing:** Viscosity testing standards were manually altered, reducing measurement reliability
- **Coating:** No defined machine response when surface density exceeded limits
- **Calendaring:** Temperature and airflow in the drying area were not controlled to standard

34% of cell findings occur during cell assembly

Why/How Does It Happen
Improper process and quality control execution

Example

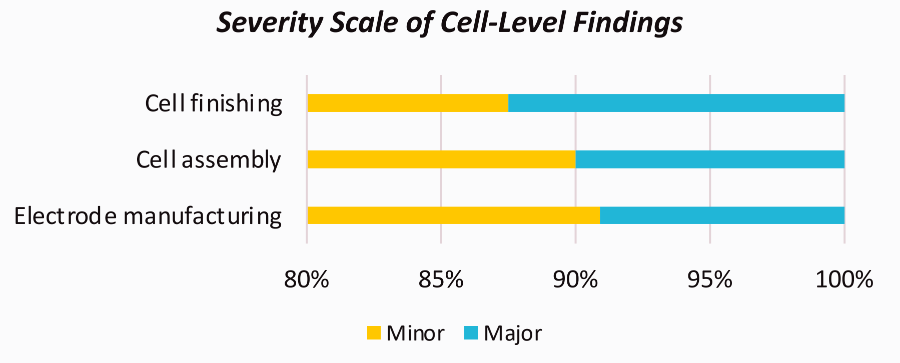
- **Slitting:** Electrode cutting depth was inconsistent with specifications
- **Welding & Pressing:** Electrode tab alignment after hot pressing was not calibrated or routinely checked

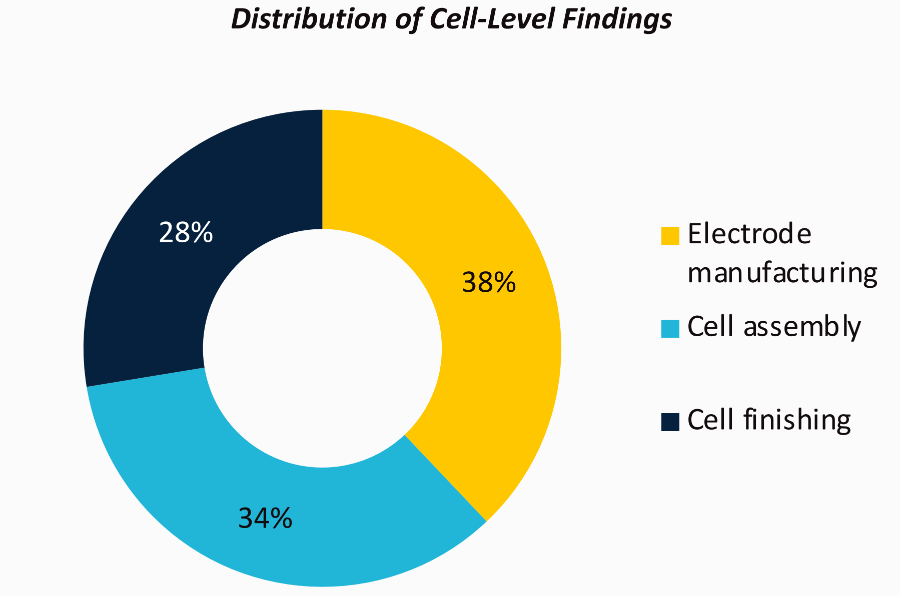
28% of cell findings occur during cell finishing

Why/How Does It Happen
Improper process and quality control execution

Example

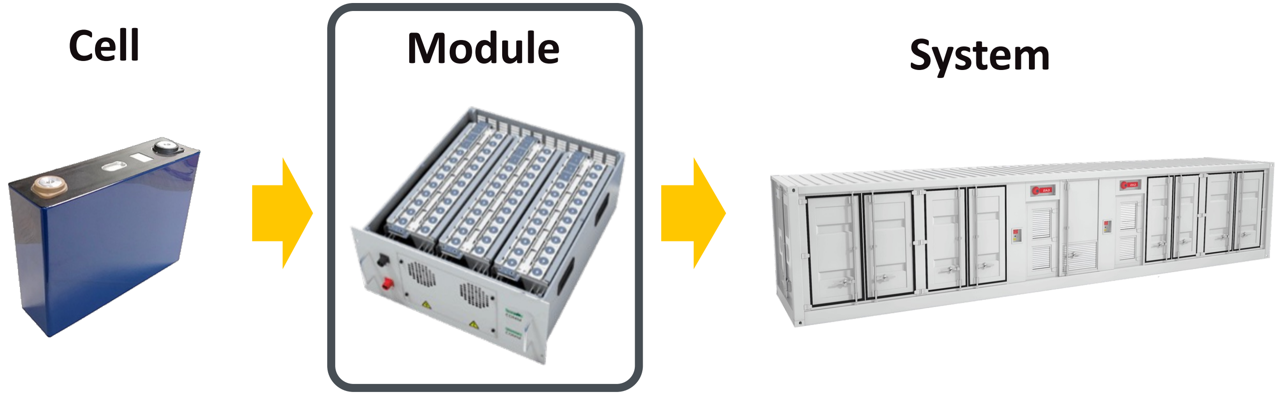
- **Cell insertion (jelly roll/stack):** No clearance inspection before final packaging.
- **Aging & formation:** Tooling was damaged and no spot-check inspections were performed.



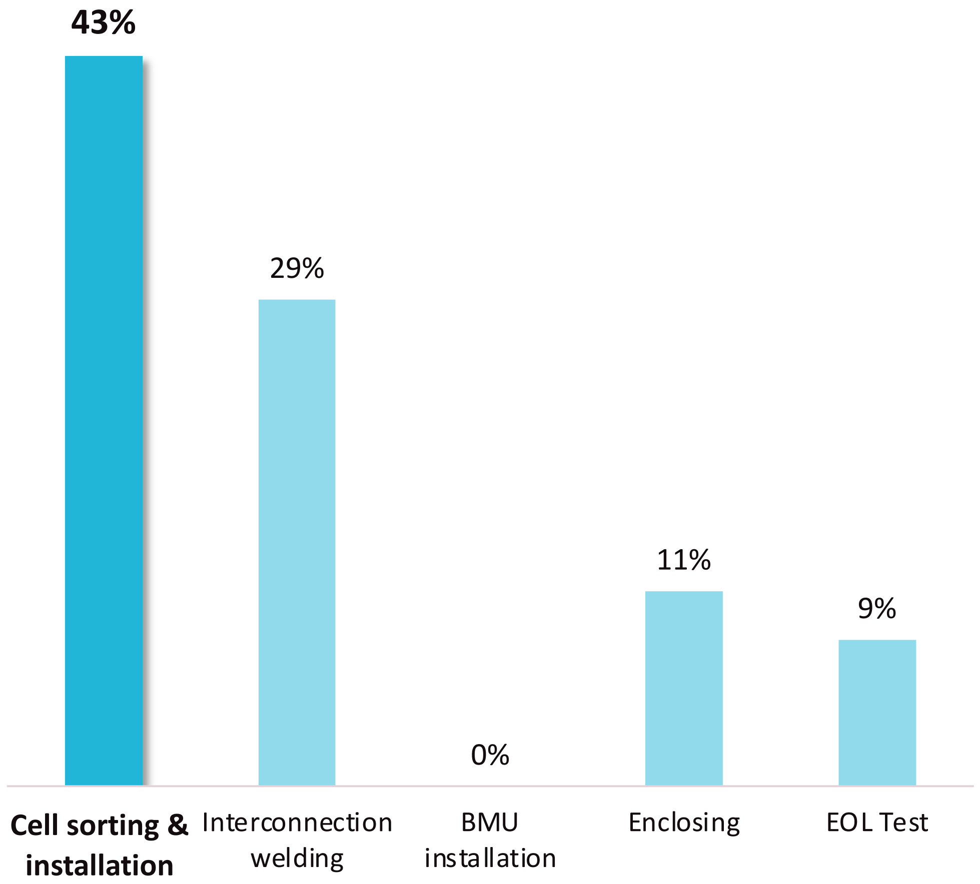


10% of the Findings Occurred During Module Manufacturing

- Module manufacturing lines are less automated than cell production, increasing the risk of material handling errors and inconsistent welding quality.
- Cell sorting and installation rely heavily on manual inspection and handling (appearance, cleanliness, gluing, fixturing, and electrical checks).
- Most issues arise during electrical testing, especially uneven OCV and poor control of cell-to-cell voltage variation.



Frequency of issues found in total audited module workshops



Breakdown of Module-Level Findings

The automation level of module production varies among manufacturers. **Welding quality issues** and environmental control pitfalls can lead to end-of-line (EOL) test failures.

47% of module findings occur at cell sorting and installation

Why/How Does It Happen
Manufacturing inconsistency due to manual operation and improper quality control protocols
Example
• Inconsistent control of cell-to-cell voltage variation • Missing plasma cleaning during cell loading • Inconsistent internal resistance across cells

31% of module findings occur during interconnection welding

Why/How Does It Happen
Lack of efficient quality control procedures and mis-operation risks
Example
• No welding slag inspection process in place • Scratches observed on aluminum connection bars • CCS welding defects identified, including loose slag

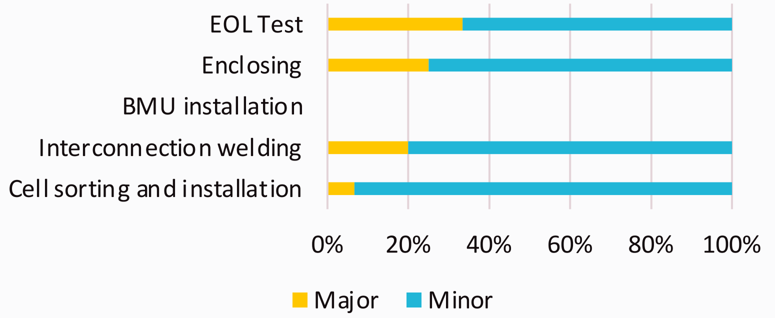
13% of module findings occur during enclosing

Why/How Does It Happen
Lack of efficient quality control procedures and mis-operation risks
Example
• Sealing gasket on the pack base not fully seated • Screw size in SOP did not match the control plan (CP)

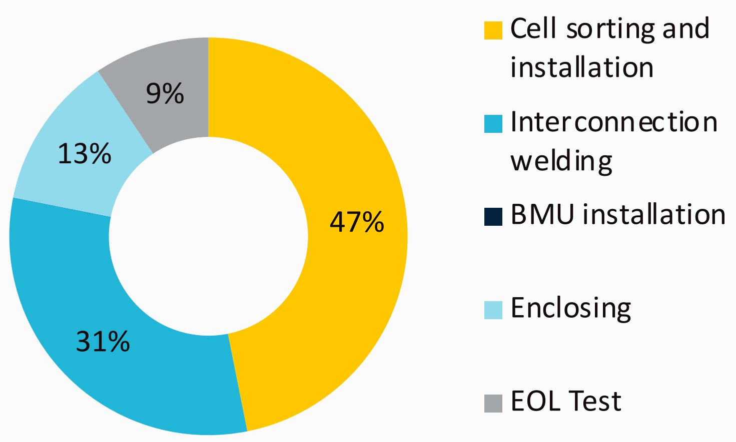
9% of module findings occur during electrcal testing and integration (EOL& BMU*)

Why/How Does It Happen
Module assembling inconsistency and uncalibrated test tools
Example
• Test equipment parameters not aligned with standards

Severity Scale of Module-Level Findings



Distribution of Module-Level Findings



**BMU: Battery Management Unit*

What Can You Do To Ensure the Long-term Financial Health of Your ESS Assets?

Golden FAT

- **Closing the Gaps**: We review your procurement contract, project requirements, and FAT checklist to ensure your energy system is safe and performs well, preventing any surprises.
- **Early Detection**: We identify risks in the supplier's checklists early to save costs and extend your system's operational life.
- **Expert Check-Up**: Our experts verify adherence to key safety and performance standards for a reliable energy system.
- **Negotiation Support**: We support you in negotiating and adjusting the FAT checklist deviations.

Factory QA

- **Factory Audit (FA):** Quality control engineers (QCEs) check factories with a 300+ point checklist, assess risks, and recommend fixes.
- **Inline Production Monitoring (IPM)**: QCEs monitor production in real-time, ensure quality, spot issues, and suggest corrections.
- **Pre-Shipment Inspection (PSI):** QCEs inspect and test a random sample of finished products, record findings, and advise on improvements.
- **Factory Acceptance Test (FAT):** QCEs inspect and test finished products for performance and suggest corrective actions.

Contact us for a consultation!

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