



CLOU AQUA C2.5H AND AQUA C2.5S BESS

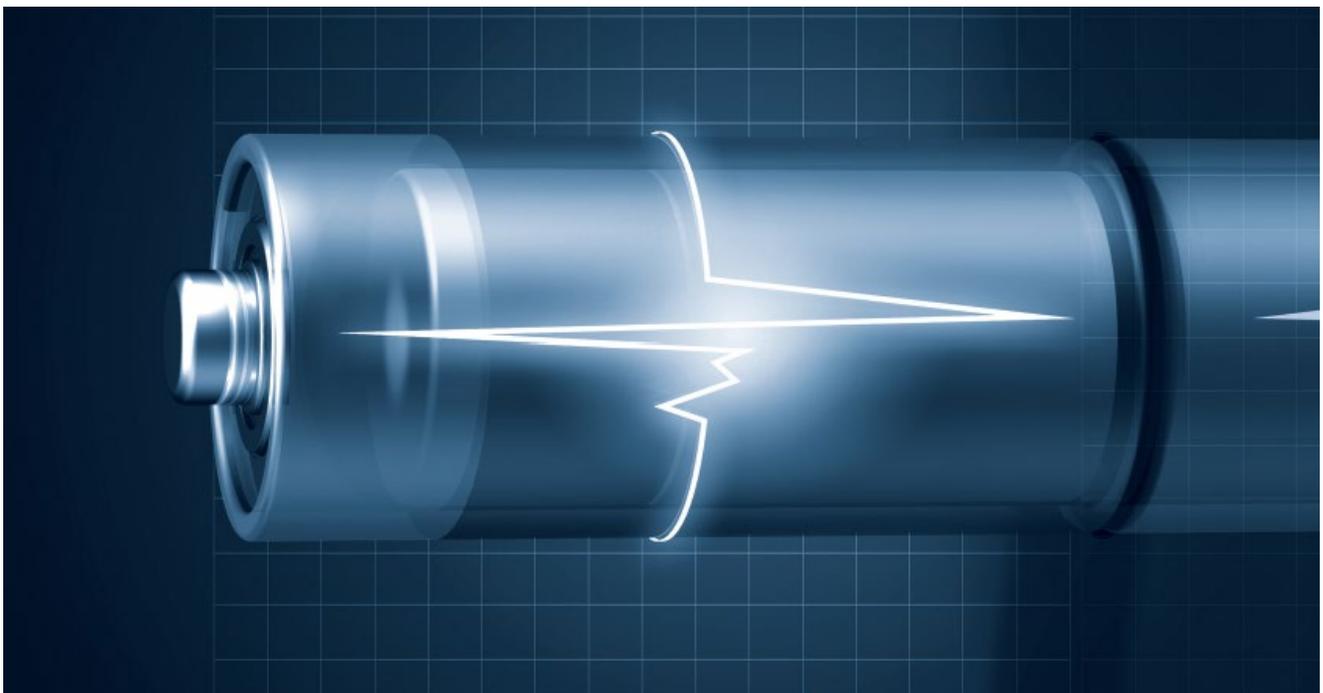
# BESS Technology Review Report

SHENZHEN CLOU ELECTRONICS CO., LTD.

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**Task and objective:**  
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## List of abbreviations

The following table lists some of the abbreviations used in this Report.

Abbreviation	Meaning
AC or a.c.	Alternating Current
ACE	Actual Charge Energy
AER	Actual Energy Retention
Ah	Ampere-hour
AHJ	Authority Having Jurisdiction
ALT	Accelerated Life Test
AMERt	Adjusted Minimum Energy Retention
BAMU	Battery Array Management Unit
BCMU	Battery Cluster/String Management Unit
BESS	Battery Energy Storage System
BLC	Block Local Controller
BMS	Battery Management System
BMU	Battery Management Unit
BOL	Beginning of Life
CC	Central Control or Constant Current (depending on context)
CFD	Computational Fluid Dynamics
CFM	Cubic Feet per Minute
CP	Constant Power
CQE	Customer Quality Engineer
CSR	Corporate Social Responsibility
C-rate	Current Rate
C&I	Commercial and Industrial
DC or d.c.	Direct Current
DCIR	Direct Current Internal Resistance
DFMEA	Design Failure Mode Effects Analysis
DNV	Det Norske Veritas
DOD	Depth of Discharge
DVT	Design Verification Test
ECO	Engineering Change Order
ECR	Engineering Change Request
EHS	Environment, Health and Safety
EMC	Electromagnetic Compatibility
EMS	Energy Management System
EOL	End of Life
EPC	Engineering, Procurement, and Construction
ERG	Emergency Response Guide
ERP	Emergency Response Plan
ESS	Energy Storage System

Abbreviation	Meaning
FAT	Factory Acceptance Test
FMEA	Failure Mode Effects Analysis
FSS	Fire Suppression System
HALT	Highly Accelerated Life Testing
HMA	Hazard Mitigation Analysis
HMI	Human Machine Interface
HQ	Headquarter
HVAC	Heating, Ventilation, Air Conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated Gate Bipolar Transistor
IQC	Incoming Quality Control
IP	Intellectual Property or Ingress Protection (depending on context)
kWh	Kilo Watt-hour
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LFP	Lithium Iron Phosphate (LiFePO <sub>4</sub> )
LTSA	Long Term Service Agreement
MBMU	Module Battery Management Unit
MES	Manufacturing Execution System
MRTE	Minimum Roundtrip Efficiency
MTBF	Mean Time Between Failures
NG	Not Good
NPC	Neutral-Point Clamped
OQC	Outgoing Quality Control
O&M	Operation and Maintenance
P	Power
PE	Protective Earth
POC	Point of Connection
PPE	personal protective equipment
PQE	Process Quality Engineer
SPCS	String-Power Conversion System
SQE	Supplier Quality Engineer
PCS	Power Conversion System
PE	Protective Earth
PPE	Personal Protection Equipment
PQE	Process Quality Engineer
Q	Quarter
QMS	Quality Management System
QPA	Quality Process Audit
QSA	Quality System Audit

Abbreviation	Meaning
RTE	Roundtrip Efficiency
R&D	Research and Development
SAT	Site Acceptance Test
SOC	State of Charge
SOE	State of Energy
SOH	State of Health
SPCS	String Power Conversion System
SQE	Supplier Quality Engineer
THD	Total Harmonic Distortion
THDi	Total Current Harmonic Distortion
TMS	Thermal Management System
UL	Underwriters Laboratories
UN	United Nations
V	Voltage
Wh	Watt-hour
WMS	Warehouse Management System



## EXECUTIVE SUMMARY

Shenzhen CLOU Electronics Co., Ltd. (“CLOU” or the “Customer”) engaged DNV China (“DNV”) to conduct a technology review of the following integrated Energy Storage System (ESS) products: Aqua C2.5H and Aqua C2.5S. In the remainder of the report, DNV will refer to them as “Aqua C2.5H” and “Aqua C2.5S” or commonly as “Aqua C2.5” or the “Product”.

### Company Overview

CLOU is an electrical equipment manufacturer which was established in 1996 and focuses on Research and Development (R&D) of energy storage and smart grid technologies. In 2021, CLOU launched the Yichun Gigafactory to significantly expand production capacity. In 2023, Media, a Fortune Global 500 company, became its largest shareholder, supporting CLOU’s growth in Energy Storage and Smart Grid sectors.

CLOU’s production capacity includes 5 GW/year for Power Conversion System (PCS) and 12 GWh/year for Battery Energy Storage System (BESS) in China, along with plans for a 4 GWh/year (Phase I) facility in Indonesia that is expected to reach full capacity in the second half of 2026. Its products focus on commercial & industrial (C&I) and utility-scale solutions. By November 2025, CLOU has secured contracts totaling approximately 12 GWh in BESS projects. The company has filed over 1,500 patents in various fields, including about 600 patents related to energy storage technologies.

### Product Overview

The focus of this review is on the following products:

- Aqua C2.5H: A DC BESS with a nominal capacity of 5,015 kWh and rated power of 2,500 kW (0.5P). It does not integrate PCS by default.
- Aqua C2.5S: An AC BESS with a nominal capacity of 5,015 kWh, and power configurations of 0.5P (2,500 kW) or 0.25P (1,250 kW). It incorporates String Smart PCS (SPCS).

Both the Aqua C2.5H and Aqua C2.5S adopt an all-in-one, non-walk-in BESS design, which is typical for utility-scale systems. DNV notes that the architecture of the Aqua C2.5 series is consistent with other liquid-cooled BESS products currently available in the market. At the time of report preparation, CLOU had not provided all requested test-validated data for review, including charge and discharge capacity, roundtrip efficiency (RTE), and auxiliary losses assessed across different ambient temperatures and P-rate operating conditions.

### Battery Component Evaluation

The battery cell is the core building block of the Aqua C2.5 BESS. The Aqua C2.5 BESS uses 314 Ah Lithium Iron Phosphate (LFP) cells supplied by two manufacturers: REPT and CALB. DNV finds that the cells’ capacity, efficiency, and temperature performance are consistent with specifications and comparable market products. The stated cycle life is based on simulated data rather than end-of-life testing; DNV recommends further validation with long long-term testing.

Each pack contains 104 cells connected in series, and one string is composed of four packs, providing a total energy of 417.9 kWh. The BMS features a three-level architecture (Battery Management Unit - BMU, Battery Cluster/String Management Unit - BCMU, Battery Array Management Unit - BAMU) with fault handling, alarms and warning systems, insulation monitoring, Stage of Charge/State of Health (SOC/SOH) calculation, and cell balancing. Based on the provided BMS protection logic diagram, DNV notes that the current protection logic does not permit continued operation in the presence of minor faults, which may reduce system availability under non-critical conditions. In general, DNV concludes the designs are typical for this type of products, but recommends further validation with actual system about BESS system cycle life degradation, thermal management and performance. In addition, the SOH/SOC estimation strategy follows the typical



industry norms, while DNV notes that the SOH estimation is mainly a runtime reference, which may not present an accurate. The actual SOH verification would be performed following the LTSA.

DNV notes that CLOU has developed an active balancing strategy for its battery cells, capable of balancing not only within the same module but also across different modules. DNV considers this as an advantage and exceeds the capabilities typically offered by conventional BESS products on the market. DNV recommends CLOU to provide further data to verify and support the performance of this active balancing design.

## Power Conversion System Component Evaluation

For CLOU's Aqua C2.5S series, SPCS are integrated with each battery string inside the BESS container. The integrated SPCS supports two configurations: four DC/AC converters arranged as two pairs in parallel for 0.5P operation condition (CL430HX-IEC/UL) and two independent converters for 0.25P operation condition (CL215HX-IEC/UL).

The SPCS employs a three-level Neutral-Point Clamped (NPC) topology, allowing it to convert DC power from the battery into AC power grid integration in higher efficiency, less switching losses, and better power quality in comparison to the two-level SPCS topologies.

The SPCS is rated as 1,500 V d.c. maximum applications and has a DC input voltage range between 1,164 V d.c. to 1,500 V d.c. Temperature ranges from -30 °C to 50 °C. The allowable humidity range is 0-100%. The SPCS offers a four-quadrant operation and a range of power factor from 0 leading to 1 to 0 lagging, based on the datasheet. Total Harmonic Distortion (THD) at nominal power is less than 3%. The maximum efficiency of the SPCS is 99%, which is supported by the CEC test report. The CEC efficiency test data across different DC input voltages show minimal variation in the efficiency curves, which indicate the efficiency would be maintained within a narrow range, and in line with good market practices.

CLOU has provided design documents for components sizing and derating considerations, which follows the good industry practices. Additionally, DNV recommends CLOU to also conduct Mean Time Between Failures (MTBF) analysis, Design Verification Test (DVT) and Accelerated Life Test / Highly Accelerated Life Testing (ALT/HALT) verifications to evaluate the reliability and long-term stability of the SPCS.

According to the provided design documents and test reports for certification, DNV considers CLOU's SPCS design and performance in line with typical market norms.

## Compliance and Safety Evaluation

CLOU has obtained multiple certificates and test reports for the Aqua C2.5 product series - including UL 1973, IEC 62619, UL 9540A, UL 1741, UL 9540, EN 62477-1, and various grid code certifications - covering the battery cell, pack, rack, SPCS, and complete BESS system. These certifications demonstrate compliance with the fundamental codes and standards required for the North American and European markets. However, final installation remains subject to approval from the relevant Authority Having Jurisdiction (AHJ) and/or local utilities, in accordance with applicable regional regulations.

The BESS enclosure is rated IP55 and incorporates a multi-layer fire and explosion protection architecture, including detectors, aerosol suppression, sprinklers, and an NFPA 69-aligned ventilation system. DNV finds that CLOU's electrical safety design, arc flash analysis, hazard mitigation measures, and emergency response planning are consistent with industry-standard practices, while noting that site-specific adaptations will be necessary during project implementation.

## Installation and Integrated System Review

The Aqua C2.5H and Aqua C2.5S are 20-foot containerized LFP BESS units with similar architectures, resulting in largely consistent installation and integration requirements. The BESS containers arrive fully integrated with batteries installed, and



CLOU provides mirrored container variants to support flexible site layouts. Installation includes foundation welding, grounding, and a structured electrical wiring process. Commissioning follows industry-standard steps - cold checks, hot testing, SOC calibration, and capacity verification - to confirm safe and reliable operation. CLOU's maintenance program includes annual and semi-annual inspections, which DNV considers appropriate and in line with industry expectations.

## Quality System and Manufacturing Review

DNV conducted a detailed assessment of Yichun CLOU Energy Storage Technology Co., Ltd., the manufacturing site for CLOU's battery packs and BESS containers. The review covered certifications, quality systems, supplier management, manufacturing processes, and on-site factory observations.

Yichun CLOU has obtained ISO 9001, ISO 14001 and ISO 45001 certification, which is aligned with industry standards. Yichun CLOU has an in-house Quality Department with 80+ employees, divided into Research and Development (R&D) Quality, Quality Management System (QMS) & Supplier Quality Engineer (SQE), Customer Quality Engineer (CQE) and Process Quality Engineer (PQE). DNV recommends centralizing and standardizing documentation control. DNV reviewed quality processes, engineering change control and supplier chain management and found them meeting expectations.

DNV visited the Yichun facility on October 23, 2025, during active production of battery packs, battery strings, and BESS containers. DNV considers CLOU's automation and QC implementation above typical industry average. DNV considers current environment, health and safety (EHS) practices adequate but recommends stronger controls for hazardous chemicals and personal protective equipment (PPE) enforcement.

## Product Support

CLOU has established a reasonably comprehensive global support and warranty system, including structured service teams, response processes, spare-parts strategy, and performance guarantees.

CLOU offers three warranty plans, with Plan 2 serving as the default option. These warranty plans cover repair services, preventive maintenance and consumables and remote monitoring. Customers with special needs may negotiate alternative terms. Standard warranty period for BESS is three years, which may be extended annually up to the 20<sup>th</sup> year of system operation. DNV considers the terms consistent with industry standards.

CLOU's performance guarantees cover system availability, capacity, and roundtrip efficiency (RTE), and take effect once the system passes the site acceptance test (SAT). CLOU guarantees an annual availability level of 96%. DNV notes that the guaranteed power is not equal to the rated power, and this distinction should be clearly defined in the agreement. CLOU has provided the following annual performance estimates for energy retention and RTE for reference purposes. DNV recommends that detailed warranty terms and LTSA should be reviewed and evaluated judiciously for specific projects.

# 1 INTRODUCTION

Shenzhen CLOU Electronics Co., Ltd. (the “Customer” or “CLOU”) has engaged DNV China Company Limited (hereinafter “DNV”) to complete a technical bankability evaluation of CLOU’s Aqua C2.5 series battery energy storage system (“BESS” or “ESS”). This evaluation is intended to serve as third-party vetting of the product. Within this report, DNV reviewed the company, the BESS designs, and integration capabilities. DNV opines on CLOU’s specification, design for functionality and safety, performance, service infrastructure, guarantees and warranties, and manufacturing capabilities.

DNV is a leading authority on consulting, implementation, research, testing, and certification of solutions for the energy sector. Recognized as a global leader in energy storage consulting, DNV provides strategic advisory services, innovative modeling tools, and independent testing and certification to clients across various sectors of the energy industry. DNV operates as an independent entity without ties to any vendor, investments, affiliations, or financial interest with any equipment or service providers.

## 1.1 Report scope of work

The primary objective of this report is to assess factors that would affect the final product’s performance and reliability in the field and the company’s ability to deliver and service the products within its stated timeframe. Such factors will include the product design, quality of materials, product performance, regulatory compliance, reliability tests, and the manufacturing and quality control processes. DNV has divided the technical due diligence review into several main topic areas for evaluation as illustrated in Figure 1-1.



**Figure 1-1 Report Structure**

As part of the CLOU’s technology bankability review, DNV performed an inspection of CLOU’s manufacturing plant in Yichun, China. The objective was to confirm that CLOU has the processes in place to deliver the expected quantity and quality of the product for meeting the required standards in reliability and safety.

## 1.2 Approach

This report represents DNV’s final Independent Engineering review intended for financial institutions, CLOU’s customers, and project developers. DNV is uniquely qualified to conduct this study due to its extensive background and experience in independent engineering and technology due diligence for solar, wind, and energy storage.



DNV's approach to completing the technology review includes three levels of assessment. First, DNV will verify that the product and process claims align with product documentation (e.g., round-trip efficiency used in models matches the specification sheet), that there is consistency in the preparation of materials (e.g., the nomenclature for the product matches throughout), and that the claimed values are aligned with expectations based on industry norms. Second, DNV will compare the specified values against test data to validate the claims. Depending on the claims being assessed, this test data may be at bench scale, from simulations, from demonstration or pilot sites, or from third-party certifiers. The granularity and rigor of these tests impact the strength of DNV's opinion when comparing the tested results to the claimed characteristics, but typically this information will allow DNV to determine if the system is designed and tested appropriately for the intended application. Third, DNV will review real-world or field data. This information will provide confidence in performance over time, under a variety of uncontrollable conditions, and for a statistically meaningful number of systems. At the current maturity of the energy storage industry, DNV is typically not provided with sufficient field data, nor is there sufficient consistency across the industry, for there to be a single, industry- and financier-accepted definition of a "proven" technology. However, DNV can identify risks and recommend mitigants, based on parallels to other industries.

To perform the assessment, DNV relied on documentation provided by CLOU, a factory visit, as well as phone calls with CLOU staff associated with the topic areas covered. Further, the following customer meetings were conducted by DNV to align and close the gaps with respect to documentation provided by CLOU via Virtual data room.

### **1.3 Assumptions**

This report summarizes the DNV assessment of the technology and relies on the accuracy of the information provided by CLOU. CLOU has been forthcoming in providing the data that DNV has requested; where data was not provided or was incomplete is noted as such within the report. Within this report, DNV highlights the risk of any missing or incomplete data and reviews and opines on the information that has been provided to date.

This report is based on some information not within the control of DNV. DNV believes that the information provided by others is true, correct, and reasonable for the purposes of this report. DNV has not been requested to make an independent analysis or verification of the validity of such information. DNV does not guarantee the accuracy of the data, information, or opinions provided by others.

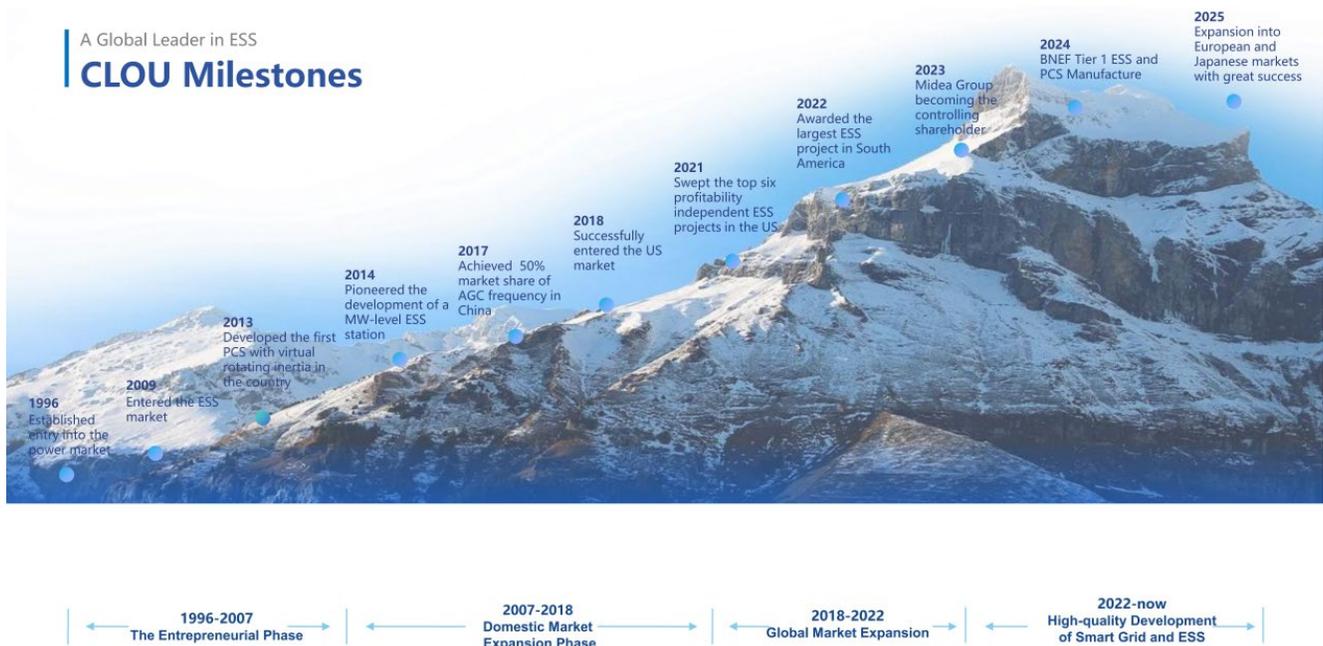
In preparing this report and the opinions presented herein, DNV has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. DNV believes that these assumptions are reasonable for the purposes of this report, but actual events or conditions may cause results to differ materially from forward-looking statements.

## 2 COMPANY OVERVIEW

### 2.1 Company overview

Shenzhen CLOU Electronics Co., Ltd. (“CLOU” was founded in Shenzhen in 1996 and listed on the Shenzhen Stock Exchange in 2007 (stock code: 002121.SZ). Originally in the electric-power sector, CLOU expanded into the ESS market in 2009 and acquired a PCS company in 2012. In 2021, CLOU significantly increased its manufacturing capacity by launching the Yichun Gigafactory.

In 2023, Midea, a Fortune Global 500 company, became CLOU's largest shareholder. Founded in 1968, Midea has evolved from a domestic appliance manufacturer into a leading global company. Midea will continue to support CLOU's growth in the ESS and Smart Grid sectors. In 2025, CLOU was recognized as a Bloomberg Tier 1 provider for both PCS & Inverter and ESS Manufacturing. The company's major milestones up to 2025 are presented in Figure 2-1 [1].



**Figure 2-1 CLOU company development chronology**

CLOU operates several R&D and manufacturing facilities for its global ESS business. In China, its annual PCS production capacity is 5 GW in Sichuan. For ESS, the annual production capacity is 18 GWh in Yichun. To expand its global footprint, CLOU is setting up a new manufacturing facility in Indonesia with an annual production capacity of 4 GWh (Phase I). The production line is currently in the commissioning and trial production and is expected to reach full capacity in the second half of 2026 [2]. Figure 2-2 shows an overview of CLOU's worldwide ESS facilities [3].



**Figure 2-2 CLOU's global ESS R&D center and manufacturing facilities**

## 2.2 Product history

Table 2-1 outlines CLOU's BESS product portfolio. While CLOU has historically offered a variety of BESS products, its current focus is on the C&I and utility-scale solutions. The company has over 10 years of experience in designing and producing both ESS containers and PCS systems.

**Table 2-1 CLOU's BESS product categories**

Application	Year	Capacity	Format	Cooling Method	Comment
C&I	2022	100 kW/200 kWh	Outdoor cabinet	N/A	GBT verified
	2023	100 kW/200 kWh	Outdoor cabinet	N/A	CE & UL listed
	2023	372 kWh	Outdoor cabinet	Liquid	N/A
Utility	2022	1.5 MW/1.5 MWh	20 ft container	Air	UL
	2022	2.6 MWh	20 ft container	Air	Battery O&M platform in China
	2023	3.7 MWh	20 ft container	Liquid	Battery O&M platform overseas
	2024	4.2 MWh	20 ft container	Liquid	300 Ah + cell application
	2025	5.0 MWh	20 ft container	Liquid	300 Ah + cell application

CLOU has expanded its international presence by establishing local teams and subsidiaries in its targeted regions, including the U.S. and Europe. The company has secured and implemented projects across a wide range of countries worldwide. As of November, 2025, CLOU has secured contracts totalling approximately 12 GWh in BESS projects. Figure 2-3 shows some examples of the global Aqua C2.5 BESS projects which are currently under execution [1].



Figure 2-3 CLOU's Aqua C2.5 field examples

## 2.3 Intellectual property

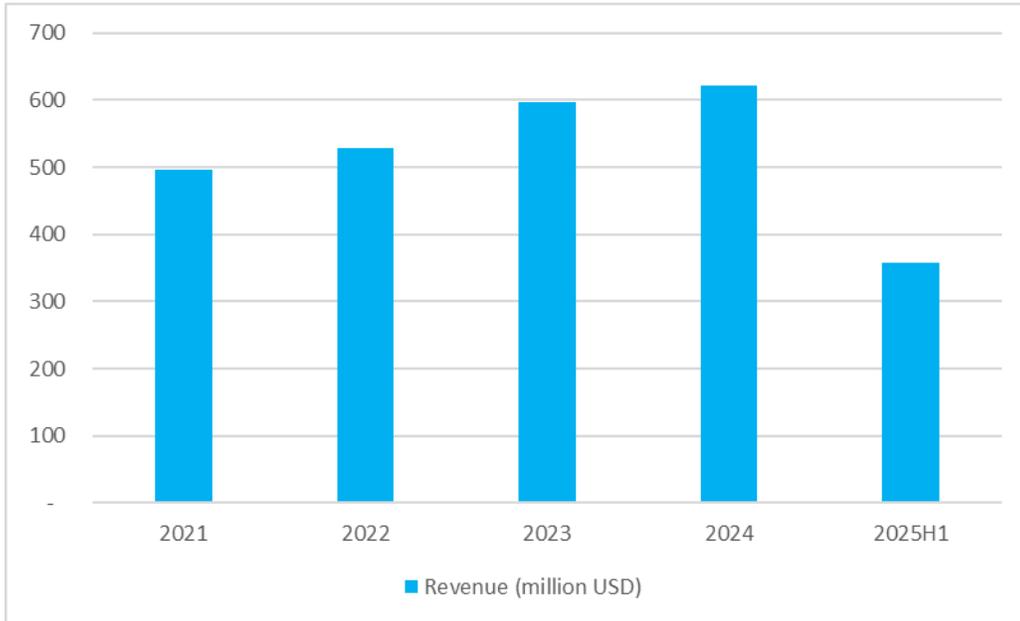
CLOU has applied for more than 2,200 patents and has filed over 1,500 patents across a variety of fields, including 600 related to energy storage technologies, such as battery modules, Energy Management Systems (EMS), Battery Management Systems (BMS), and PCS.

The company's electric patent strategy focuses on the following key areas: forward-looking layout and core protection, systematic management and maintenance, risk identification and avoidance, value mining and capitalisation, compliance and system building.

As part of the technology review, DNV does not act as a patent attorney. DNV does not provide patent advice and does not comment on whether CLOU's technology infringes other patents.

## 2.4 Financial status

Figure 2-4 shows CLOU's sales revenue from 2021 to the first half of 2025 (2025H1). The full-year 2025 revenue data is expected to be released in March 2026. The chart indicates that revenue increased from USD 496 million in 2021 to USD 622 million in 2024, and reached USD 358 million in the first half of 2025.



**Figure 2-4 CLOU's sales revenues from 2021 to 2025H1**

### 3 PRODUCT OVERVIEW

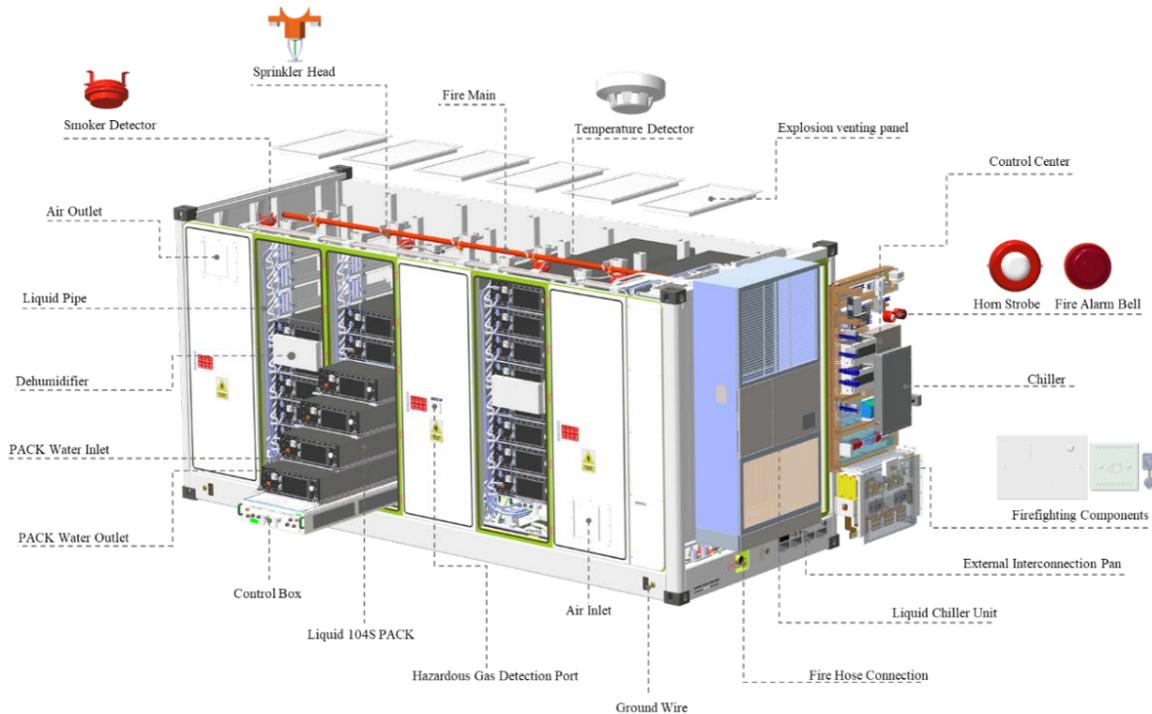
This section contains DNV’s review findings of CLOU’s Aqua C2.5 series BESS systems, including the following BESS products:

- **CLOU Aqua C2.5H (“Aqua C2.5H”)**: a DC BESS with a nominal capacity of 5,015 kWh, rated at 0.5P (2,500 kW), and available in configurations certified to either IEC or UL standards, depending on the selected cell type.
- **CLOU Aqua C2.5S (“Aqua C2.5S”)**: an AC BESS with a nominal capacity of 5,015 kWh, incorporating string power conversion systems (SPCS) and available in both 0.5P (2,500 kW) and 0.25P (1,250 kW) configurations. It is also available in configurations certified to either the IEC or the UL standards, depending on the selected cell type. The detailed model numbers are listed in Table 6-1.

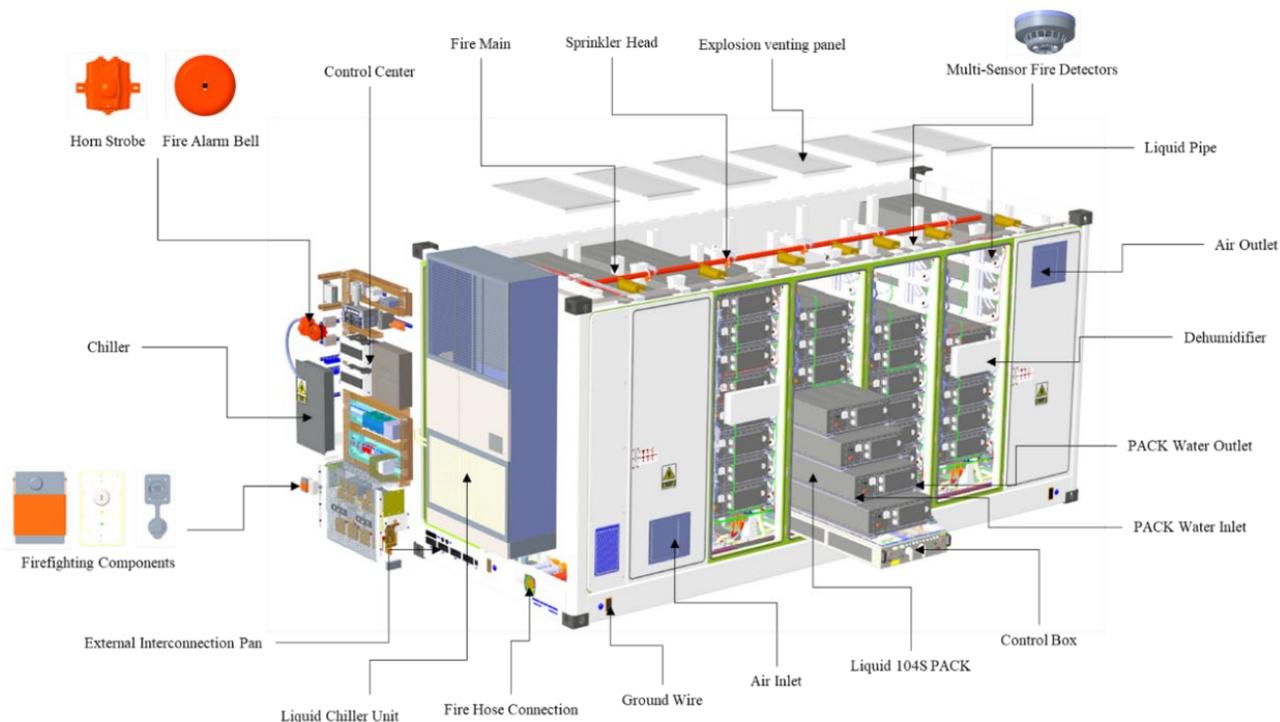
### 3.1 Aqua C2.5H

#### 3.1.1 Aqua C2.5H specifications

Aqua C2.5H is a fully integrated, DC BESS, and is made up of the following critical components (see Figure 3-1 and Figure 3-2):



**Figure 3-1 Interior view of CLOU's Aqua C2.5H IEC variant**

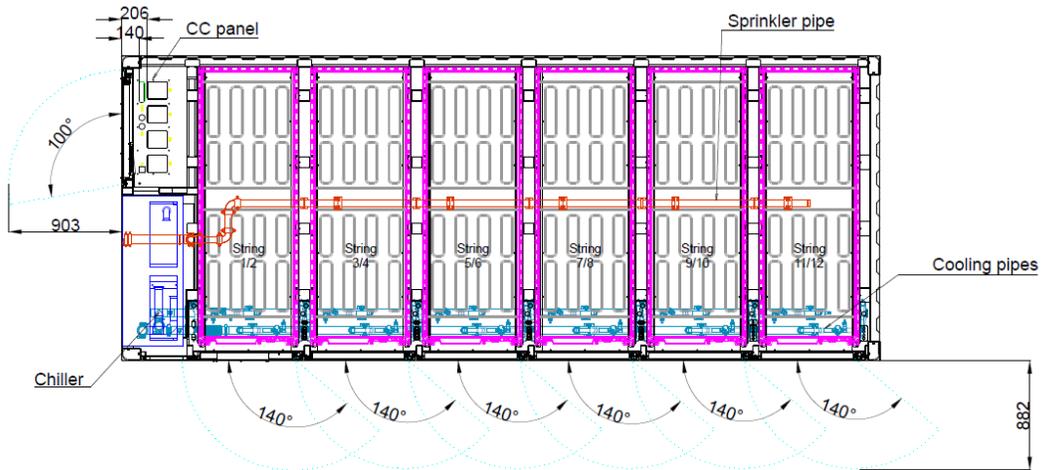


**Figure 3-2 Interior view of Aqua C2.5H UL variant**

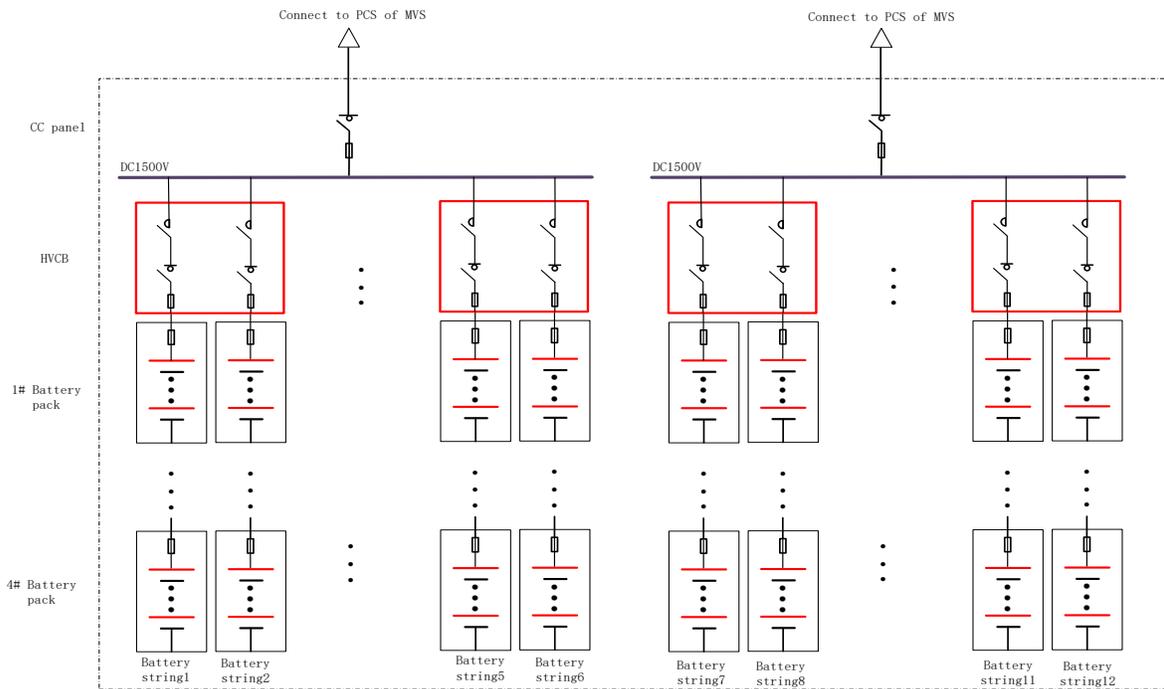
- **Energy Storage batteries** – The Aqua C2.5H systems are equipped with lithium-ion battery cells rated at 314 Ah, supplied by either REPT or CALB. DNV notes that each BESS system must utilize cells from a single supplier and shall not be configured with cells from different cell suppliers. The Aqua C2.5H systems, configured with REPT and CALB cells, have obtained UL and IEC certifications respectively. Each system comprises 12 battery strings, with each string consisting of four battery packs and one (1) high-voltage control box.
- **BMS** – All-in-one three-level BMS, including BAMU, BCMU, and BMU.
- **Central Control Panel (CC Panel)** – including DC collection, control and communication, and auxiliary distribution sections.
- **Fire suppression systems (FSS)** – including an automatic fire alarm system, an aerosol-based suppression system, a sprinkler system, a ventilation system, and an explosion prevention system.
- **Thermal management system (TMS)** – Equipped with a liquid cooling unit (60 kW rated cooling power, 24 kW rated heating power) to enhance battery cell temperature management, maintaining a more efficient cell temperature distribution. A dehumidification module (7 L/24 h dehumidification capacity) for the container's internal environment.
- **Auxiliaries** – such as alarms, chillers, pumps, grounding systems etc.

Aqua C2.5H is an all-in-one, non-walk-in BESS system, which is a typical design feature for a 20-foot BESS system. The BESS system does not integrate SPCS by default. The architecture of the Aqua C2.5H is in line with other liquid-cooled BESS products in the market.

Figure 3-3 shows Aqua C2.5H's mechanical layout, and Figure 3-4 shows the DC single line diagram.



**Figure 3-3 Internal layout of Aqua C2.5H**



**Figure 3-4 DC Single Line Diagram of Aqua 2.5H**

Table 3-1 details the system specifications of Aqua C2.5H.

**Table 3-1 Aqua C2.5H system specifications**

Parameter	Specification
Cell type	LFP 3.2 V / 314 Ah
Cell supplier	REPT (UL certified, 0.5P) / CALB (IEC certified, 0.5P)
Configuration	12P(4*104)S
Nominal energy	5,015.9 kWh
Max. continuous charge/discharge power	2,507.9 kW
Nominal DC voltage	1,331.2 V d.c.
DC voltage (full power)	1,123.2 V d.c. to 1,497.6 V d.c.
Auxiliary power supply	480 V AC, 60 Hz (UL) / 400 V AC, 50 Hz (IEC)
SOC calculation accuracy	≤3%
Operating ambient temperature range	-30 °C to 50 °C
Relative humidity	≤100% RH (non-condensing)
Altitude	≤ 4,000 m
Noise (measured at 1 meter)	≤ 75 dB(A)
Protection grade	IP55
Corrosion-proof grade	C4 C5 (optional)
Snow load	30 lb / sqft
Wind load	Up to 129 mph
Seismic	IEEE 693 Moderate design level qualification IEEE 693 High design level qualification (optional)
Fire suppression	Dry pipes with sprinklers Ventilation system (NFPA 69 compliance) Aerosol (optional) Deflagration vent panel (optional)
UPS backup time	0.5 h 2 h (optional)
External communication interface	Ethernet (Modbus TCP)
Dimensions (W*D*H)	6,058 * 2,438 * 2,896 mm
Design life	20 years
Weight	43 tons

### 3.1.2 Aqua C2.5H system performance review

System-level performance testing includes charge and discharge capacity, RTE, and auxiliary losses evaluated under different ambient temperature and P-rate operating conditions. These tests are important for assessing system performance at beginning of life (BOL). At the time of report preparation, CLOU had not provided all of the requested test-validated data for review.

#### 3.1.2.1 Roundtrip efficiency

Table 3-2 shows the RTE data of CLOU’s Aqua C2.5H products for IEC and UL variants.

**Table 3-2 RTE of Aqua C2.5H [4]**

Aqua C2.5H 0.5P IEC variant	Aqua C2.5H 0.5P UL variant
93.9%	94.5%

DNV notes that the RTE of the Aqua C2.5H, measured from the battery DC side, generally aligns with expectations. However, auxiliary power consumption during both charging and discharging should be included in the RTE calculation, and IEC 62933-2-1 requires a minimum of two charge–discharge cycles. No detailed test procedures or supporting data were provided by CLOU. DNV therefore recommends that CLOU conduct additional testing under a broader range of operating conditions.

DNV notes that the RTE of Aqua 2.5H generally meets expectations. In addition, DNV acknowledges that the RTE data in Table 3-2 are based on CLOU’s theoretical analysis, and CLOU did not provide verification of these data at the time of writing this report.

#### 3.1.2.2 Auxiliary loss

CLOU has submitted the daily auxiliary load consumption data for the UL variant system [5]. The tests were performed under different ambient temperatures (-30 °C, 25 °C, and 50 °C) at 0.5P. Table 3-3 shows the auxiliary consumption of the product at these conditions.

**Table 3-3 Aqua C2.5H UL variant Daily auxiliary consumption**

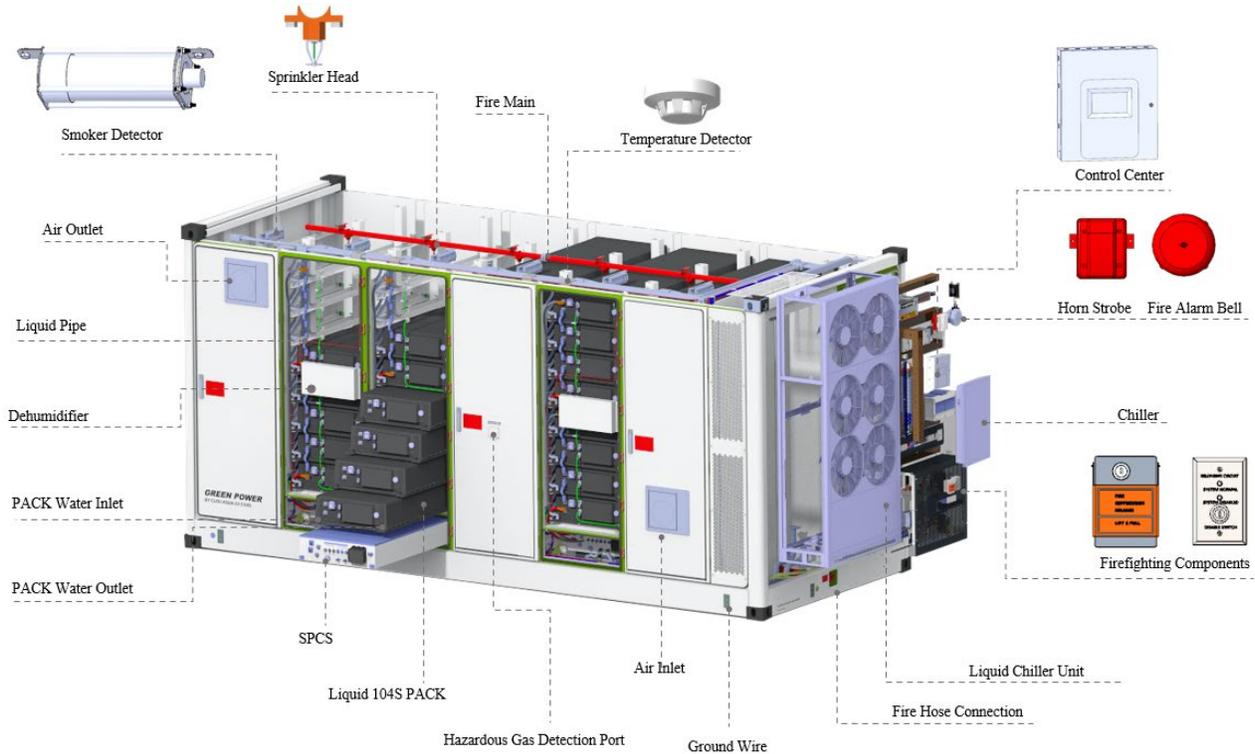
Operating condition	-30 °C / day			25 °C / day			50 °C / day		
	24 hours total (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	24 hours total (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	24 hours total (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)
Total (kWh)	121.05	10.73	14.11	160.98	35.46	45.32	254.93	32.23	61.36

DNV notes that the auxiliary consumption tests were conducted at 0.5P, the system’s maximum continuous operating power. As expected, the peak auxiliary power is highest at 0.5P. However, because operation at lower power ratings generally occurs over longer durations, assessing daily auxiliary energy solely at 0.5P may not represent the maximum case. DNV recommends that CLOU also evaluate auxiliary consumption across multiple power ratings (e.g., 0.1P, 0.2P, 0.3P) to ensure a comprehensive assessment.

## 3.2 Aqua C2.5S

### 3.2.1 Aqua C2.5S specifications

Aqua C2.5S is an AC BESS with SPCS installed inside. Figure 3-2 presents the interior view of Aqua C2.5S, and the major components include:



**Figure 3-5 Interior view of Aqua C2.5S BESS system**

- Energy storage batteries** – The Aqua C2.5S systems are also equipped with lithium-ion battery cells rated at 314 Ah, supplied by either REPT or CALB. DNV notes that each BESS system must utilize cells from a single supplier, and no system is configured with mixed cell types. The Aqua C2.5S systems, configured with REPT and CALB cells, have obtained UL and IEC certifications respectively. Each system comprises 12 strings, with each string consisting of four battery packs. Instead of integrating a high-voltage control box for each string, a string-level smart power conversion system is designed for the Aqua C2.5S system.
- BMS** – All-in-one three levels BMS, including BAMU, BCMU, BMU.
- Smart Power Conversion System (SPCS)** – The SPCS is the core component that enables bidirectional flow of electrical energy between energy storage systems and the power grid. It is used to control the charging and discharging process of batteries and perform AC/DC conversion. The SPCS is integrated into the battery container at string level, eliminating the need for high-voltage control boxes for the string. Additionally, the BCMU is integrated within the SPCS, which monitors the battery string voltage and current for string management, and communicates with Block Local Controller (BLC).
- CC Panel** – The CC Panel is mainly composed of three main sections: AC collection section, Auxiliary distribution section and Integrated Control Module section.

- **FSS** – Fire suppression system mainly consists of four parts: automatic fire alarm system, ventilation system, aerosol and water spray system (manual control).
- **TMS** – Equipped with a liquid cooling unit (50kW+50kW rated cooling capacity for battery and SPCS respectively, 24kW+6.5kW rated heating capacity for battery and SPCS respectively) to enhance battery cell and SPCS temperature management maintaining a more efficient and tighter cell temperature distribution. A dehumidification module (7L/24h dehumidification capacity) for internal environment of the container.
- **Auxiliaries** – such as alarms, chillers, pumps, grounding systems etc.

Figure 3-6 illustrates Aqua C2.5S' mechanical layout, and Figure 3-7 illustrates the electrical single line diagram.

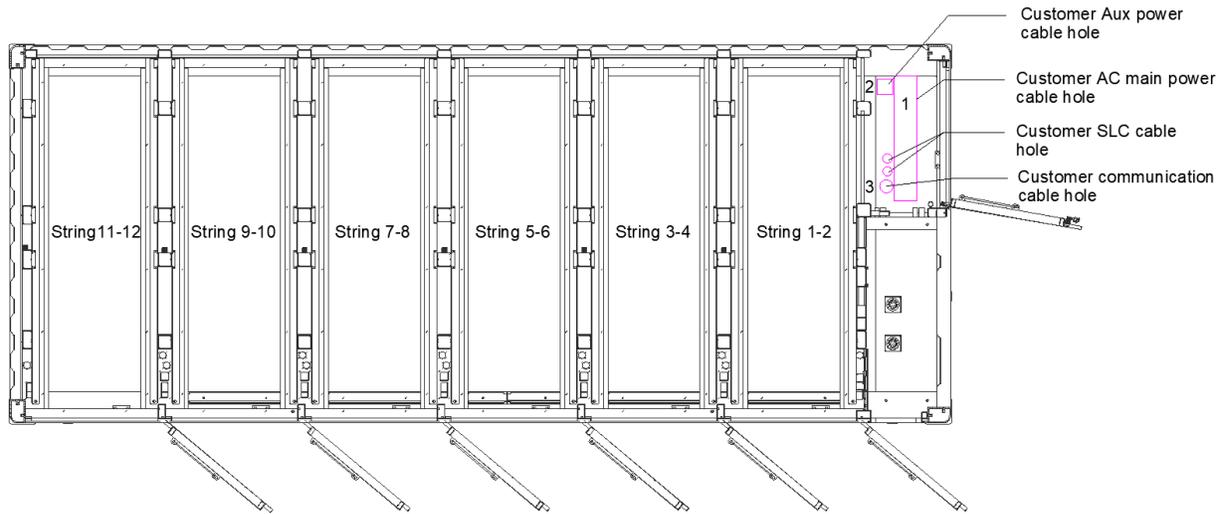


Figure 3-6 Layout of Aqua C2.5S

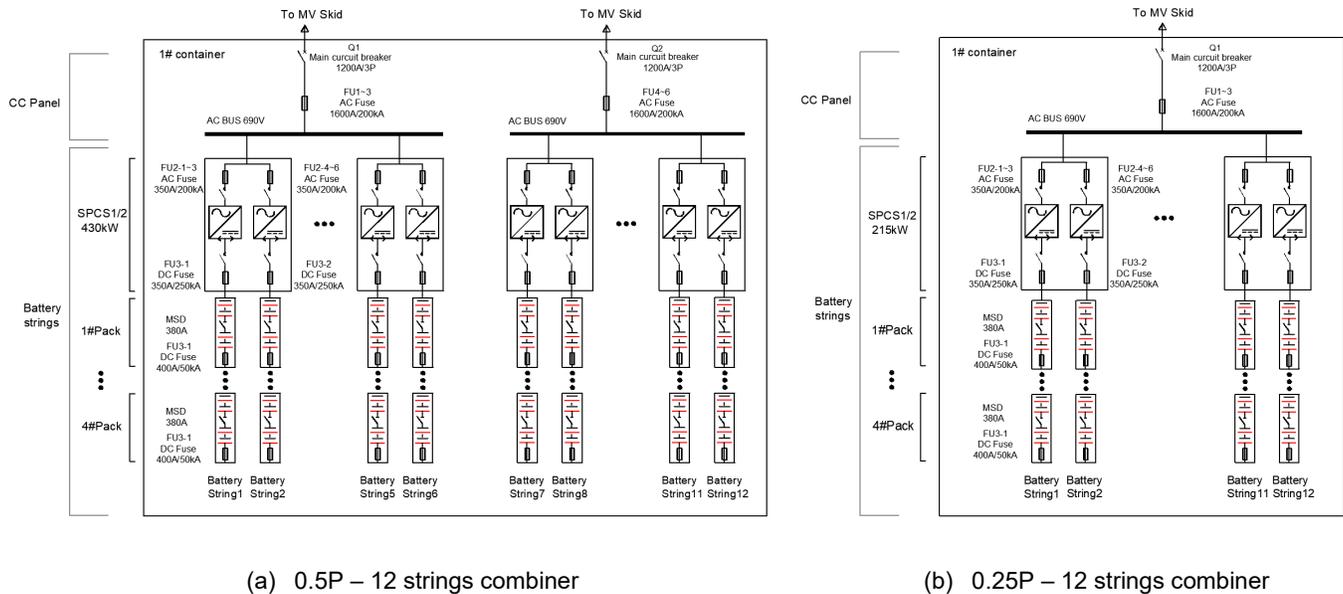


Figure 3-7 Electrical Single Line Diagram of Aqua C2.5S

Table 3-4 presents the system specifications of Aqua C2.5S.

**Table 3-4 Aqua C2.5S system specifications**

Parameter	Aqua C2.5S-5015-2500-2h	Aqua C2.5S-5015-1250-4h
<b>DC Parameters</b>		
Cell type	LFP 3.2 V / 314 Ah	
Cell supplier	REPT (UL certified) / CALB (IEC certified)	
Configuration	12P(4*104)S	
Nominal energy	5,015.9 kWh	
Nominal DC voltage	1,331.2 V <sub>DC</sub>	
DC voltage (full power)	1,123.2 V d.c. to 1,497.6 V d.c.	
<b>AC Parameters</b>		
Nominal power	2,580 kVA	1,290 kVA
Max. charge/discharge power	2,507.9 kW	1,254 kW
Maximum THD of current	< 3% (at nominal power)	
DC component	< 0.5%	
Nominal voltage	690 V a.c.	
AC voltage range	607 V a.c. to 759 V a.c.	
Nominal frequency	50 Hz / 60 Hz	
Termination (LV)	2,100 A * 3 phases	1,050 A * 3 phases
Power factor	≥ 0.99 (at nominal power)	
Power factor range	-1 to 1	
<b>System Parameters</b>		
Auxiliary power supply	400 V <sub>AC</sub> , 50 Hz / 60Hz	
Operating ambient temperature range	-30 °C to 50 °C (derating after 45 °C)	-30 °C to 50 °C (derating after 45 °C)
Relative humidity	≤ 100% RH (non-condensing)	
Maximum operational altitude	4,000 m	
Protection grade	IP55 (IEC) / Type 3S (UL)	
Noise (@ 1 meter)	≤ 75 dB (A)	
Corrosion-proof grade	C4 C5 (optional)	
Cooling method	Intelligent liquid cooling	
Snow load	30 lb / sqft	
Wind load	Up to 129 mph	
Seismic	IEEE 693 Moderate design level qualification IEEE 693 High design level qualification (optional)	
UPS backup time	0.5 h 2 h (optional)	
Fire suppression	Dry pipes with sprinklers Ventilation system (NFPA 69 compliance) Aerosol (optional) Deflagration vent panel (optional)	
External communication interface	Ethernet (Modbus TCP)	
Dimensions (W*D*H)	6,058 * 2,438 * 2,896 mm	
Design life	20 years	

Parameter	Aqua C2.5S-5015-2500-2h	Aqua C2.5S-5015-1250-4h
Weight	≤ 44 tons	
SPCS specifications	CL430HX-IEC/UL	CL215HX-IEC/UL
	Aqua C2.5S SPCS is discussed in Section 5	

### 3.2.2 Aqua C2.5S system performance review

System level performance testing includes charge and discharge capacity, RTE, and auxiliary losses evaluated under different ambient temperature and P rate operating conditions. These tests are important for assessing system performance at beginning of life (BOL).

#### 3.2.2.1 Roundtrip efficiency

CLOU has provided the estimated RTE of the Aqua C2.5S units at different ambient temperatures for both the 2-hour (0.5P) and 4-hour (0.25P) variants. The estimates cover operation at -30 °C, 25 °C, and 50 °C under rated power conditions, with the 4-hour unit at 25 °C shown below as an example. As the Aqua C2.5S integrates the SPCS within the container, the RTE is evaluated at the SPCS output, which is 690 V a.c.

**Table 3-5 RTE estimation of Aqua C2.5S-4h @ 25 °C**

Aqua C2.5S-4h 5015kWh RTE of 0.25P @25 °C						
<b>Charge efficiency</b>	DC charge efficiency	SPCS charge efficiency	Cable loss (fully charge, kWh)	Auxiliary loss (fully charge, kWh)	Fully charged energy (kWh) @ SPCS 690 V a.c.	Charge efficiency @ 690 V a.c.
	98.03%	97.9%	1.94	38.40	5,265.93	95.23%
<b>Discharge efficiency</b>	DC discharge efficiency	SPCS discharge efficiency	Cable loss (fully discharge, kWh)	Auxiliary loss (fully discharge, kWh)	Fully discharged energy (kWh) @ SPCS 690 V a.c.	Discharge efficiency @ 690 V a.c.
	98.03%	98.2%	1.94	30.20	4,795.51	95.62%
<b>RTE</b>			91.07%			

DNV notes that the estimation is based on a calculation formula that accounts for battery efficiency, SPCS efficiency, as well as cable and auxiliary losses during operation. This approach is consistent with common industry practice for evaluating system-level roundtrip efficiency.

For comparison, CLOU has also conducted tests on real systems, of which the results are illustrated in Table 3-6 and Table 3-7.

**Table 3-6 RTE test results of Aqua C2.5S-2h**

RTE test results of Aqua C2.5S-2h (CALB 314 Ah cell)						
Temperature (°C)	Auxiliary loss (kWh, Charge)	Auxiliary loss (kWh, Discharge)	Charged energy (kWh)	Discharged energy (kWh)	RTE, including auxiliary loss	RTE, excluding auxiliary loss
-30	24.3	26.2	5,588.5	5,064.2	89.76%	90.62%
25	34.2	51.2	5,596.8	5,057.6	88.91%	90.37%
45	64.7	63.3	5,594.2	5,057.1	88.25%	90.40%

**Table 3-7 RTE test results of Aqua C2.5S-4h**

RTE test results of Aqua C2.5S-4h (CALB 314 Ah cell)						
Temperature (°C)	Auxiliary loss (kWh, Charge)	Auxiliary loss (kWh, Discharge)	Charged energy (kWh)	Discharged energy (kWh)	RTE, including auxiliary loss	RTE, excluding auxiliary loss
-30	31.4	29.5	5,575.3	5,136.9	91.09%	92.14%
25	38.4	30.2	5,556.7	5,138.3	91.30%	92.47%
50	50.4	66.5	5,563.5	5,148.3	90.52%	92.54%

DNV notes that the test results indicate that the RTE of the Aqua C2.5S systems is slightly higher than the estimated values and generally consistent with typical market performance. However, both estimation and testing were conducted on Aqua C2.5S systems configured with CALB 314 Ah cells, although the same system type may also be assembled with REPT cells. DNV recommends conducting RTE tests for the REPT cell-based configuration under equivalent operating conditions to verify performance consistency across different configurations.

### 3.2.2.2 Auxiliary loss

CLOU has submitted the daily auxiliary load consumption data for both the UL and IEC system variants. The estimation was performed under different ambient temperatures (-30 °C, 25 °C, and 45 °C / 50 °C) and at two operating power levels, 0.5 P and 0.25 P, as illustrated in Table 3-8. It is noted that the major difference between the two configurations lies in the auxiliary system voltage, with 400 V for the IEC variant configuration and 480 V for the UL variant configuration. The daily auxiliary load consumption is identical for the same system P-rate configuration across the IEC and UL variants.

**Table 3-8 Aqua C2.5S Daily auxiliary consumption estimation**

(a) IEC system variant under 0.5P

Operating condition	-30 °C / day			25 °C / day			45 °C / day		
	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)
Total (kWh)	136.00	24.30	26.20	55.00	34.20	51.20	142.00	64.70	63.30
		186.50			140.40			270.00	

(b) IEC system variant under 0.25P

Operating condition	-30 °C / day			25 °C / day			50 °C / day		
	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)
Total (kWh)	99.00	31.40	29.50	42.00	38.40	30.20	158.00	50.40	66.50
		159.90			110.60			247.90	

(c) UL system variant under 0.5P

Operating condition	-30 °C / day			25 °C / day			45 °C / day		
	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)	20 hours standby (kWh)	2 hours charge (kWh)	2 hours discharge (kWh)
Total (kWh)	136.00	24.30	26.20	55.00	34.20	51.20	142.00	64.70	63.30
		186.50			140.40			270.00	

(d) UL system variant under 0.25P

Operating condition	-30 °C / day			25 °C / day			50 °C / day		
	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)	16 hours standby (kWh)	4 hours charge (kWh)	4 hours discharge (kWh)
Total (kWh)	99.00	31.40	29.50	42.00	38.40	30.20	158.00	50.40	66.50
		159.90			110.60			247.90	

DNV was informed that the estimation was based on actual test data obtained from IEC variant with CALB cells and UL variant with REPT cells, and the UL variant's test was conducted in the report provided by CLOU [6].

## 4 BATTERY COMPONENT EVALUATION

This section reviews and comments on the product's main building blocks and subassemblies. The review begins with the battery cell and then proceeds sequentially to cover the entire DC BESS (Aqua C2.5H) and AC BESS (Aqua C2.5S) electrical networks, including supporting systems.

### 4.1 Battery cell review

The battery cell is the core building block of the Aqua C2.5 BESS. CLOU selected two cell suppliers for its Aqua C2.5 BESS – REPT and CALB. DNV notes that, in line with typical industry practice, cells from different suppliers are never used together within a single BESS, as this is essential to avoid performance and manufacturing inconsistencies.

#### 4.1.1 Battery cell review - REPT 314 Ah cell

DNV conducted a bankability review of REPT's 314 Ah cell [7], and will leverage this report where appropriate.

Founded in 2017, REPT is the first enterprise invested in by Tsingshan Holding Group, a Fortune Global 500 company and a leading Chinese nickel and stainless-steel producer established in 1992. Tsingshan has invested USD 13 billion in new energy sectors, quickly developing an industrial chain that spans nickel cobalt ore resources, ternary material production, and power batteries production.

As of December 2020, REPT was ranked among the top 4 cell manufacturers in China for lithium-iron phosphate (LFP) cell shipments. REPT's supply accounted for 1.2 billion RMB, with commercial vehicles at 12%, passenger vehicles at 59%, BESS at 21%, and the remaining 8% in the special vehicle segment. By 2024, REPT achieved mass production of 314 Ah battery cells, with an energy density of 180 kWh/kg and a cycle life of over 10,000 cycles. This makes REPT a major supplier of 300 Ah+ cells. The company plans a minimum production capacity of 94 GWh in 2025.

DNV notes that REPT is vertically integrated in its battery manufacturing, from raw materials through research, development, design, and manufacture to the end product, with repurposing or recycling at the end of product life.

##### 4.1.1.1 Battery cell specifications

REPT's 314 Ah cells are prismatic and use LFP chemistry. Table 4-1 shows the cell's key technical specifications. The nominal P-rate of this cell is 0.5P (502.4 W) [7].



Figure 4-1 REPT 314 Ah LFP prismatic cell

**Table 4-1 REPT 314 Ah cell specifications [7]**

Parameter	Specification	Remark
Cell type/chemistry	Prismatic cell / LFP	
Cell model	CB75	
Nominal capacity	314 Ah/1004.8 Wh	25 ± 2 °C, 0.5P
Nominal voltage	3.2 V	
Operating voltage range	2.5 V to 3.65 V 2.0 V to 3.65 V	T ≥ 0 °C T ≤ 0 °C
Standard charging/discharging power	502.4 W	25 ± 2 °C, 0.5P
Working temperature	0 °C to 60 °C -20 °C to 60 °C	charge discharge
Storage temperature	-30 °C to 60 °C	
Dimension	71.75 ± 0.8 mm 174.0 ± 0.8 mm 204.4 ± 0.8 mm 206.8 ± 0.8 mm	thickness width shoulder height total height
Cell weight	5.76 ± 0.2 kg	
Energy efficiency	≥ 94.5%	25 ± 2 °C, 0.5 P
Energy density	174 Wh/kg 394 Wh/L	
AC Impedance (1kHz)	0.16 ± 0.05 mΩ	40% SOC
Shipping capacity	125.6 ± 3 Ah	40% SOC
Cycle life	≥ 9,000 cycles, 70% SOH	The detailed testing procedure is elaborated in Section 4.1.1.6.
Standard charge power	0.5P	25 ± 2 °C
Maximum continuous charge power	0.5P	25 ± 2 °C
Standard charge voltage	3.65 V	
Standard charging mode	0.5P constant power (CP) to 3.65 V	25 ± 2 °C
Standard charge temperature	25 ± 2 °C	Cell surface temperature
Standard discharge power	0.5P	25 ± 2 °C
Maximum continuous discharge power	0.5P	
Standard discharge temperature	25 ± 2 °C	The initial temperature of the cell and ambient temperature
Self-discharge	≤ 3%/month	within three months of cell shipping, Test temperature: 25 ± 3 °C, 40% SOC storage

#### 4.1.1.2 Battery cell capacity performance

The discharged capacity and energy of REPT's 314Ah cell are presented in Figure 4-2 [7]. All test results exceed the nominal capacity of 314 Ah and nominal energy of 1,004.8 Wh, meeting the cell's specifications.

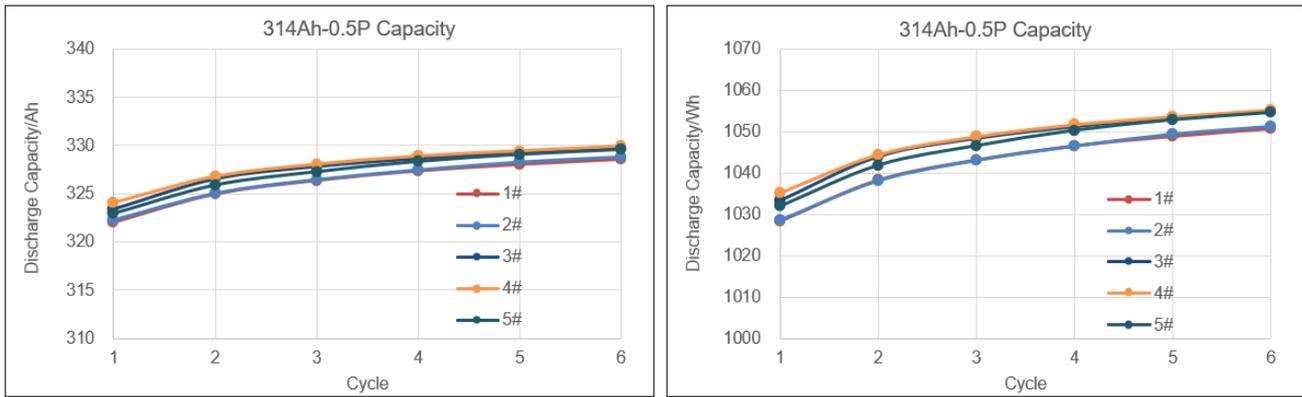


Figure 4-2 REPT 314Ah cell capacity (left) and energy (right) [7]

#### 4.1.1.3 Energy Efficiency

As displayed in Figure 4-3, the energy efficiency of the REPT 314Ah cell at 0.5P operation exceeds 94.5% during the initial five charge and discharge cycles [7]. DNV considers that the energy efficiency of greater than 94.5% under such conditions aligns with the typical test result of LFP cells in the battery industry.

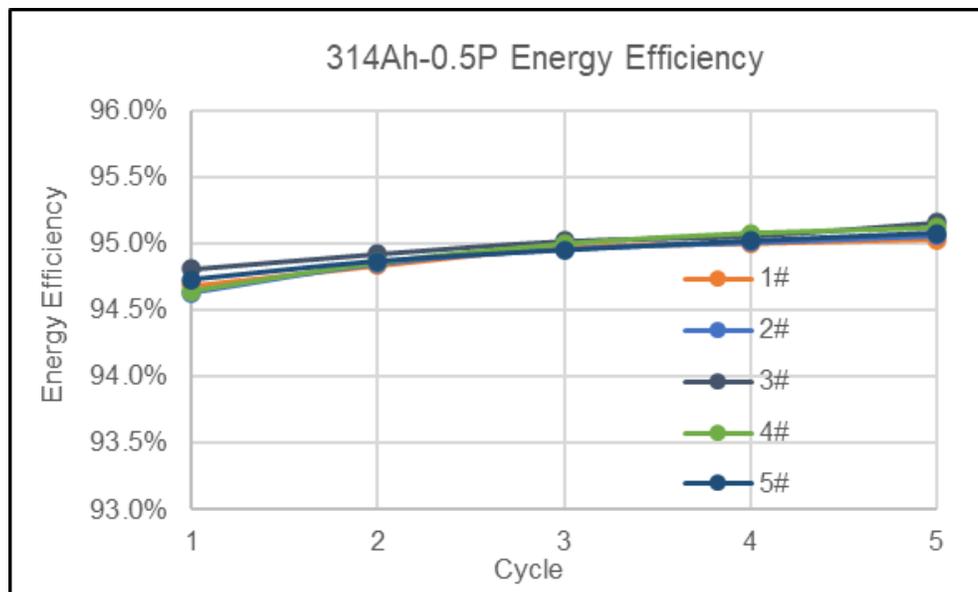
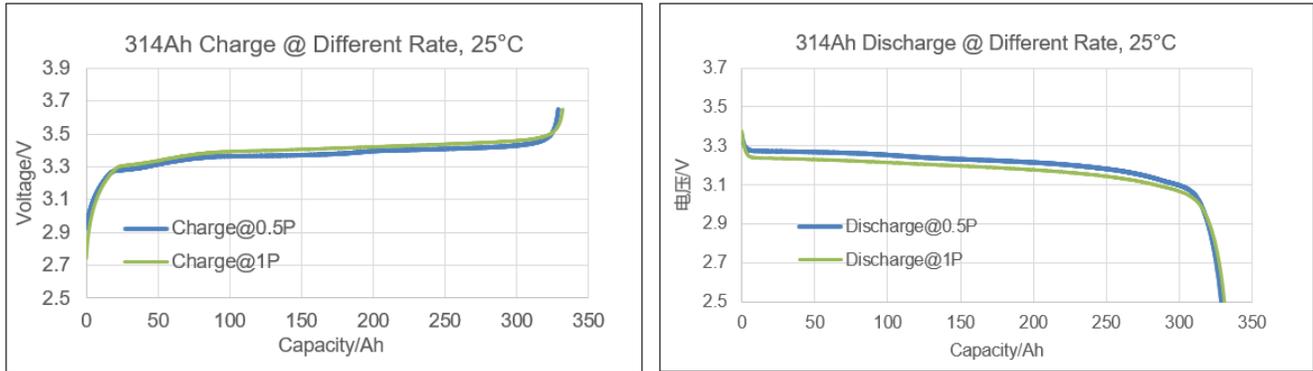


Figure 4-3 REPT 314Ah cell energy efficiency [7]

#### 4.1.1.4 P-rate performance

P-rate performance test illustrates how well the REPT 314Ah cell can perform at different P-rates. Figure 4-4 illustrates the Cell's 0.5P and 1.0P performance results, which DNV opines to be in compliance with industry standards [7].



**Figure 4-4 REPT 314Ah cell P-rate performance curves [7]**

DNV notes that both the capacity (energy) performance and efficiencies are in line with the cell's specifications and meets the expectations of similar products in the market.

DNV notes that both the capacity (energy) performance and efficiencies are in line with the cell's specifications and meets the expectations of similar products in the market [7].

Table 4-2 displays the results of the P-rate performance test. The energy efficiency results are 94.73% (0.5P) and 92.71% (1.0P). The higher P-rate causes energy loss through heat, resulting in the energy efficiency at 1.0P being lower than that at 0.5P. DNV notes that both the capacity (energy) performance and efficiencies are in line with the cell's specifications and meets the expectations of similar products in the market [7].

**Table 4-2 REPT 314Ah cell P-rate performance [7]**

P-rate	Charge capacity (Ah)	Charge energy (Wh)	Discharge capacity (Ah)	Discharge energy (Wh)	Charge capacity retention (%)	Discharge capacity retention (%)	Energy efficiency (%)
0.5P	328.78	1108.69	328.32	1050.26	100.00	100.00	94.73
1.0P	328.61	1115.10	326.60	1033.82	100.58	98.43	92.71

#### 4.1.1.5 High/low-temperature performance

Lithium-ion batteries' performance depends on the ambient temperature, testing them at a wide range of temperatures is crucial.

When operating at low temperatures such as 0 °C, -10 °C, and -20 °C, the discharge capacities of the cell were 5.0% to 6.5% lower compared to that at 25 °C. The discharge curves at these lower temperatures showed a shorter flat plateau, as shown in Figure 4-5. This indicates unfavorable reactions consuming lithium-ions, leading to energy loss as heat generation.

Conversely, at higher temperatures, such as 35 °C, 45 °C, and 55 °C, the discharge capacities exceeded 100% compared to the standard condition at 25 °C. However, it is important to note that these high-temperature conditions accelerate the degradation of Li-ion battery cells in the long term due to unfavorable reactions.

DNV opines that the optimal temperature range for LFP cells is between 15 °C and 30 °C. If the temperature falls below 15 °C, the battery's capacity will decrease, even in the short term. On the other hand, if the temperature goes above 30 °C, it will accelerate the battery's degradation in the long term. The performance illustrated in Figure 4-5 is in line with the expectation of similar products in the market [7].

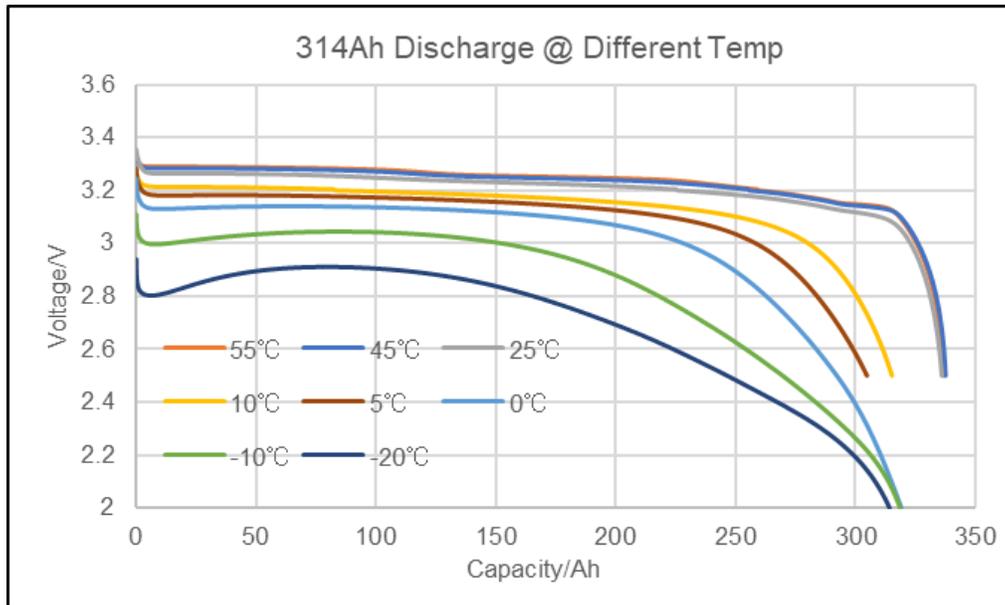


Figure 4-5 REPT 314Ah cell high/low-temperature performance [7]

#### 4.1.1.6 Cycle life test

Cycle life test demonstrates how fast cells will fade under specific operations.

Figure 3-7 depicts the cycle life performance of the cell with 0.5P at 25 °C. The cell retained approximately 94% of its capacity retention and approximately 95% of its energy efficiency after 1,520 cycles. This result at 1,520 cycles is comparable to a similar product tested at 1,500 cycles.

REPT extrapolated the predicted capacity retention of 70% per the specification's criteria. According to the simulation, the cell will meet the target, as the capacity retention will remain above 70% even after 10,000 cycles to fulfil the specification.

However, DNV cannot conclude the cycle life test will meet the specification due to insufficient data. Therefore, REPT should continue this evaluation to ensure that the cells meet the required standards [7].

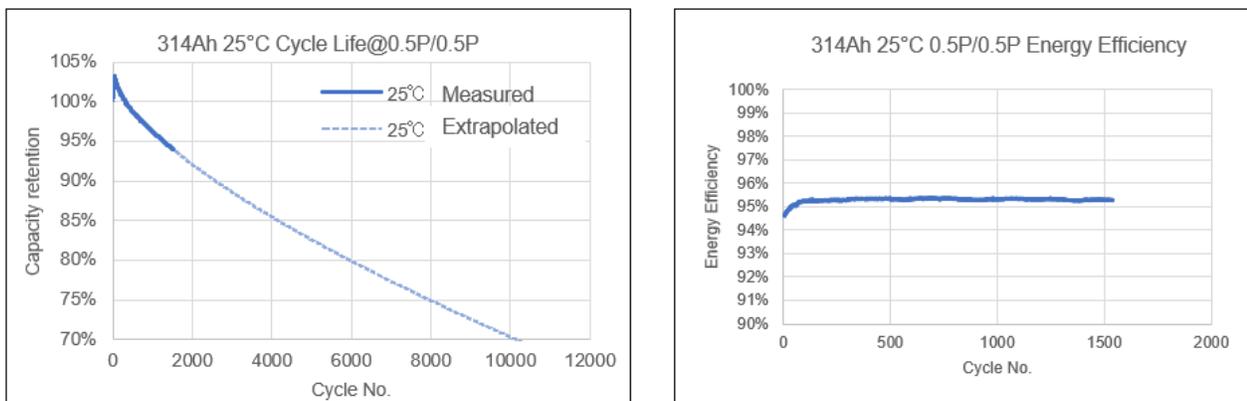
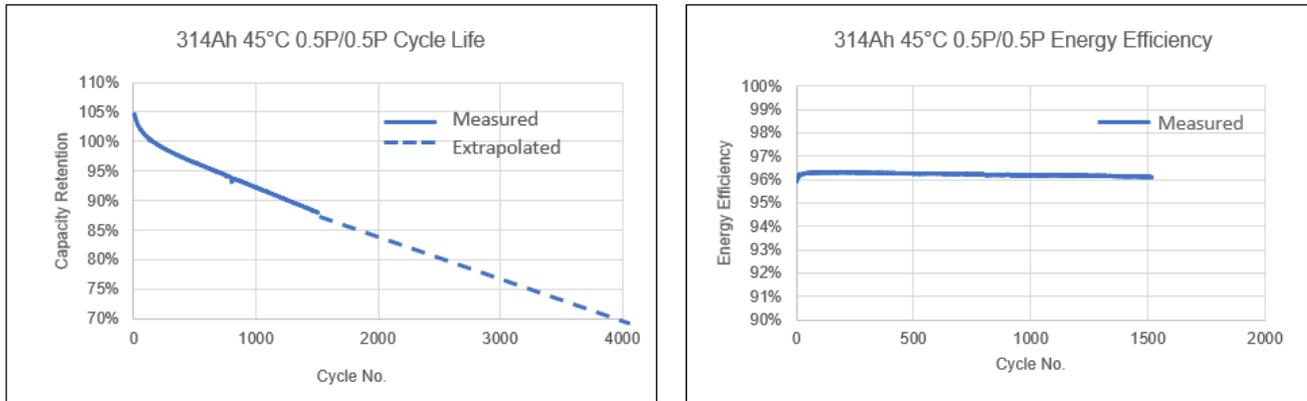


Figure 4-6 REPT 314Ah cell cycle life performance at 25 °C [7]

The cell's cycle life simulation at 45 °C indicates that the cell retains only 70% of its initial capacity after approximately 4,000 cycles, as displayed in Figure 4-7 [7].



**Figure 4-7 REPT 314Ah cell cycle life performance at 45 °C [7]**

The battery lifespan SOH 70% at 25 °C (10,000 cycles) is longer compared to SOH 70% at 45 °C (4,500 cycles). This reveals that higher temperatures accelerate the battery's long-term degradation, as discussed under high/low-temperature performance.

DNV notes that the cycle life claim is based on simulated data, not an end-of-life test. The end-of-life test is a long process, and once it closes and the data becomes available, there will be a more conclusive validation of the cell's cycle life performance.

## 4.1.2 Battery review - CALB 314 Ah cell

CALB Group Co., Ltd. (CALB) was founded in 2007, and its headquarters are in China. It is an early entrant in lithium-ion battery manufacturing, specializing in LFP cell manufacturing. By 2022, the company had six manufacturing plants, with a total production capacity close to 300 GWh annually. By 2025, CALB aims to increase its production to 500 GWh. Most of CALB's sales (about 90%) are EV batteries.

### 4.1.2.1 Battery cell specifications

These CALB 314 Ah cells also utilize LFP chemistry. An overview of the battery cell is provided in Table 4-3. DNV notes that both the capacity (energy) performance and efficiency performance are in line with the cell's specifications and meet the expectations of similar products in the market. Some key performance metrics are reviewed in the following subsections.



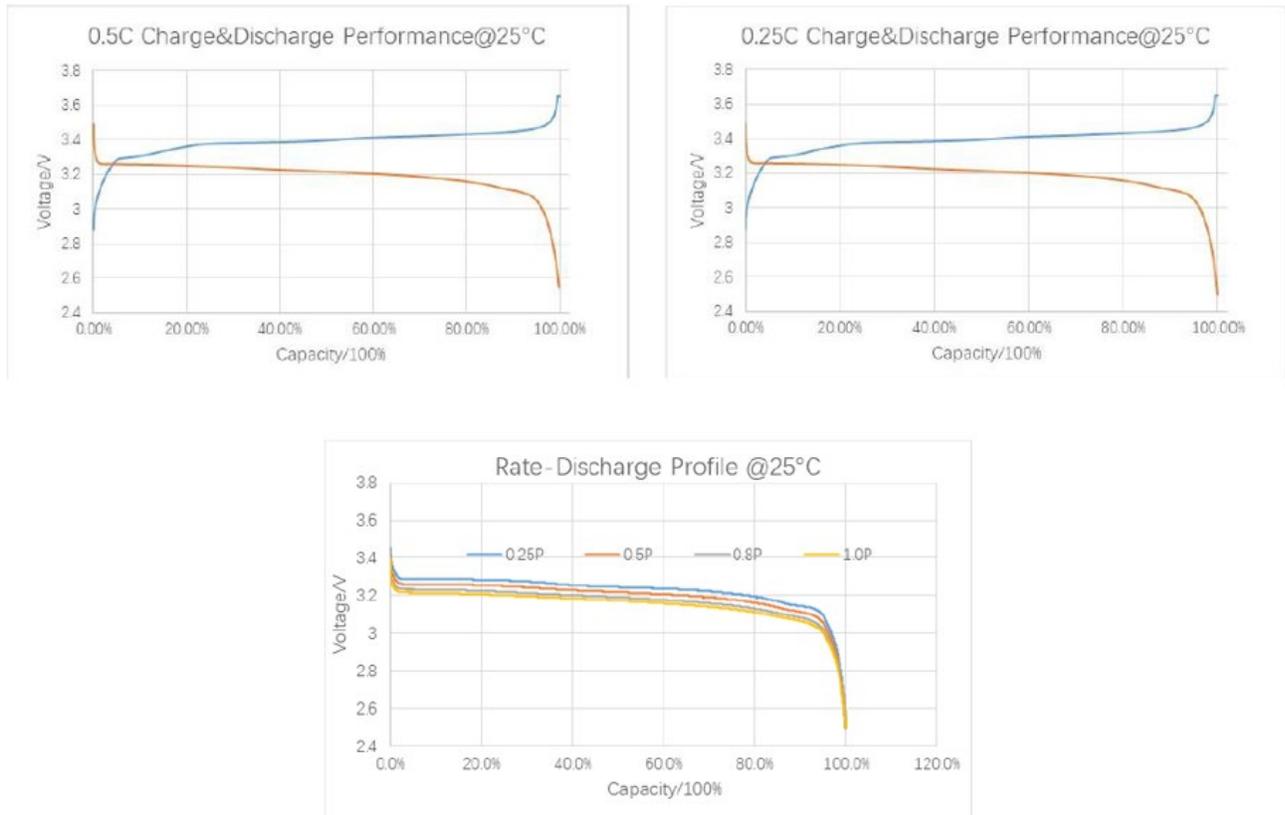
**Figure 4-8 CALB 314 Ah LFP prismatic cell overview**

**Table 4-3 CALB 314 Ah cell specifications [8]**

Item	Parameter	Remark
Cell type / chemistry	Prismatic / LFP	
Cell model	L173F314	
Nominal capacity	314 Ah / 1,004.8 Wh	
Nominal voltage	3.2 V	
Operating voltage range	2.5 V to 3.65 V 2.0 V to 3.65 V	0 °C < T ≤ 60 °C -30 °C ≤ T ≤ 0 °C
Standard charging/discharging current	157 A	
Maximum charging/discharging current	314 A	
Working temperature	0 °C to 55 °C -30 °C to 55 °C	charge discharge
Storage temperature	-40 °C to 60 °C	
Dimension	71.57 ± 0.5 mm 174.4 ± 0.8 mm 204.57 ± 0.8 mm 207.2 ± 0.5 mm	thickness width shoulder height total height
Cell weight	5.56 ± 0.15 kg	
Energy density	392.8 Wh/L	
Internal resistance	≤ 0.23 mΩ	
Cycle life	≥ 6,000 cycles, 80% SOH	25 °C 0.5P, 2.5 V to 3.65 V

#### 4.1.2.2 Battery cell capacity performance

The reported charge and discharge curves of CALB 314 Ah LFP cells at different C-rates are in Figure 4-9. The reported RTE of CALB 314 Ah at 0.5 C-rate and at room temperature is >94.5%. At 0.25 C-rate and at room temperature, the energy efficiency is >96.0%. DNV considers these results to align with similar products in the industry.



**Figure 4-9 CALB 314Ah cell capacity**

#### 4.1.2.3 High/low-temperature performance

Figure 4-10 presents discharge capacity results of CALB 314 Ah LFP cells at different temperatures. At low temperatures, the cell had the lowest capacity. DNV notes that this is an expected behavior and not product deficiency.

The tests at -30 °C, -20 °C, -10 °C and 0 °C were performed at a discharge cut-off voltage of 2.0 V, which is lower than the 2.5 V typically used to rate the capacity of 314 Ah. As a result, a higher capacity was observed at this reduced cut-off voltage. DNV acknowledges this outcome as consistent with industry standards for similar products, indicating that the observed increase in capacity aligns with expectations for LFP batteries when tested under such conditions.

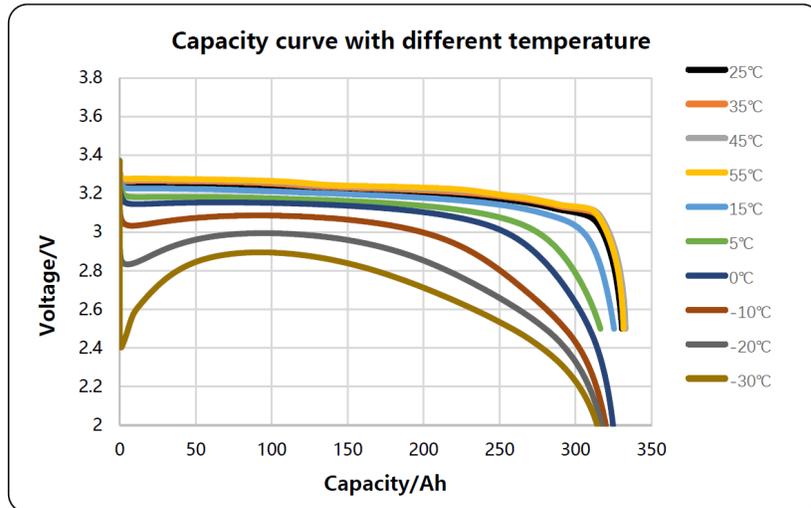
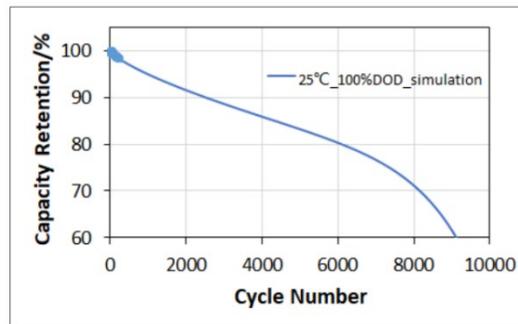
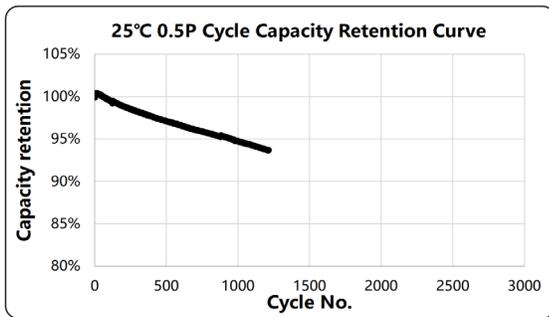


Figure 4-10 CALB 314Ah cell high/low-temperature performance

#### 4.1.2.4 Cycle life test

Figure 4-11 shows the results from cycle life testing at 25 °C and 45 °C with 100% depth of discharge (DOD) at 0.5 P-rate. CALB’s 314 Ah cell shows capacity retention of approximately 94% and 90% after approximately 1,200 cycles for 25 °C and 45 °C, respectively, which are typical compared to similar cell products in the market. DNV advises following up with the cell vendor and confirming the progress of the cycle life test.



According to the

provided bankability report [9], cell L173F314 has a cycle life of 6,000 cycles – under 25 °C, 0.5C and 100% depth of discharge (DOD) – before its SOH drop to 80%. It is shown in the following Figure 4-11.

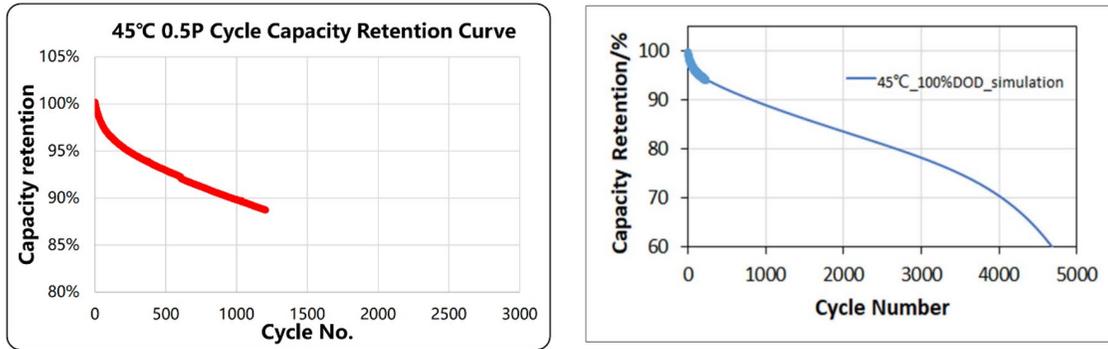


Figure 4-11 CALB 314Ah cell cycle life at 25 °C and 45 °C

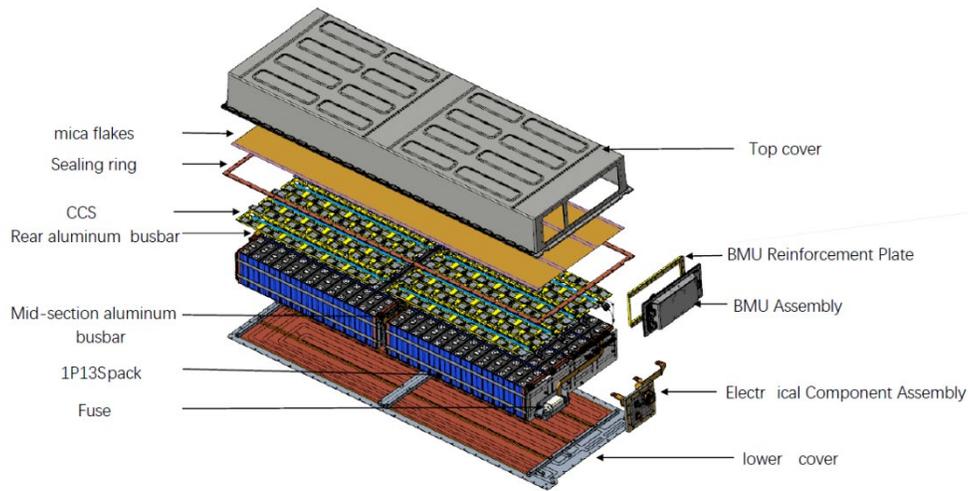
DNV notes that the cycle life claim is based on simulated data, not an end-of-life test. The end-of-life test is a long process, and once it closes and the data becomes available, there will be a more conclusive validation of the cell’s cycle life performance.

## 4.2 Aqua C2.5H battery pack and string

### 4.2.1 Battery pack design and specifications

The battery pack used in Aqua C2.5H consists of 104 pieces of 314 Ah cells connected in series (1P104S). The battery pack is equipped with a BMU, which monitors safety parameters associated with the pack level and reports to the string level BCMS. The safety parameters include, but are not limited to, cell voltages, temperature, and cell equilibrium states in real time. Figure 4-12 illustrates the appearance and exploded view of the packs, while Table 4-4 presents the pack specifications.





**Figure 4-12 Interior appearance of a pack**

**Table 4-4 Technical specifications of Aqua C2.5H battery pack**

Item	Specification	Remark
Configuration	1P104S	
Nominal Capacity	314 Ah	25 ± 2 °C
Nominal Voltage	332.8 V d.c.	
Voltage range	280.8 V d.c. to 374.4 V d.c.	
Nominal Energy	104.49 kWh	25 ± 2 °C
Peak power	52.2 kW	0.5P
Weight	666 kg	Weight variation among cells is within ±5 kg.
Operation ambient temperature range	Charge: 0 °C to 55 °C Discharge: -30 °C to 55 °C Recommended: 20 °C to 45 °C @ 0.5P; 15 °C to 40 °C @ 0.25P	
Storage Condition	-30 °C to 50 °C (Recommended: 20±5 °C) @40%SOC	Conditioning may be required to transition to the operating range
Relative humidity	≤ 95% RH (No condensation)	
Dimensions	790 * 2,210 * 245 mm (W*D*H)	

## 4.2.2 Battery string design and specifications

Each battery string consists of four battery packs in series, according to the 1P4S configuration. The battery string is controlled through a BCMU and protected by a control box. The battery string specification is outlined in Table 4-5. Each rack accommodates two strings, arranged vertically.

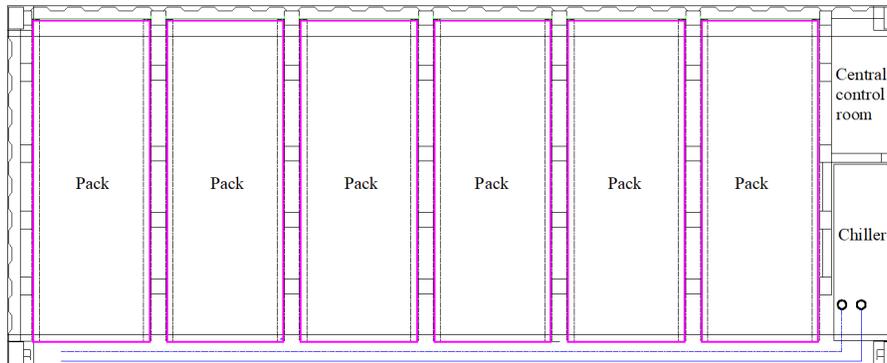
**Table 4-5 Technical specifications of Aqua C2.5H battery string**

Item	Specification	Remark
Rated Capacity	314 Ah	
Nominal voltage	1,331 V d.c.	

Item	Specification	Remark
Voltage range	1,123.2 V d.c. to 1,497.6 V d.c.	
Nominal energy	417.9 kWh	25 ± 2 °C
Maximum continuous power	208.9 kW @ 0.5P 104.4 kW @ 0.25P	
Configuration	4S (series)	
Operation ambient temperature range	20 °C to 45 °C @ 0.5P 15 °C to 40 °C @ 0.25P	
Weight	5,833 kg	One rack with two strings
Relative humidity	≤ 95% RH (Non-Condensing)	
Scope of Supply	<ul style="list-style-type: none"> <li>• Packs</li> <li>• String</li> <li>• BMS</li> <li>• HVCB</li> <li>• DC power cables, communication and auxiliary cables in every string</li> </ul>	

### 4.3 Thermal management system

The TMS of the BESS, as illustrated in Figure 4-13, adopts a liquid cooling system to regulate the temperature of the batteries and also for the SPCS in Aqua C2.5S series. The chiller is provided by Taybo (Shanghai) Environmental Technology CO., Ltd.



**Figure 4-13 Schematic diagram of the TMS**

The TMS has four operating modes – heating, standby, self-circulation, and cooling – selected based on the batteries' and SPCS' operational status, including high cell temperature, temperature variation, operating power, and coolant temperature. These parameters are continuously transmitted to the TMS controller to adjust the control and operating modes. This strategy, based on comprehensive operational status, is considered “Forced Control” by CLOU. If communication is lost between the TMS controller and the chiller unit, or no command is received from the TMS controller for more than 60 seconds, another “Automatic Control” strategy is adopted. In this strategy, the chiller regulates the coolant temperature based on the chiller’s preset configurations. DNV notes that the TMS strategy meets good industry practices.

Table 4-6 illustrates the detailed “Forced Control” strategies for the batteries and SPCS. This thermal control is designed to ensure uniform cell performance, prolonged cycle life, and stable system operation under a wide range of environmental conditions. Table 4-7 and Table 4-8 provide the main technical parameters of the liquid cooling units for Aqua C2.5H series

and Aqua C2.5S (0.25P) series. Considering that the Aqua C2.5H and Aqua C2.5S (0.5P) products have the same battery configuration, DNV notes the TMS specifications for the respective battery systems to be the same.

For the thermal management of the SPCS, as the SPCS module quantities would be doubled for Aqua C2.5S 0.5P variant compared to Aqua C2.5S 0.25P variant, DNV notes that the SPCS' cooling capacity would be also be doubled, which is supported by CLOU's TMS sizing calculation report to be discussed in the following subsections.

In addition, a dehumidifier would be installed for the central control room with the specifications listed in Table 4-9, which will help to regulate and maintain the humidity for safety and long-term reliability.

**Table 4-6 SPCS TMS Forced Control strategy**

Status	Description
Inputs	Maximum Insulated Gate Bipolar Transistor (IGBT) temperature: $T_{max\_IGBT}$ SPCS power: $ P $ Outlet coolant temperature: $T_{out\_SPCS}$
Scenario 1 STATIC	If $ P  < 10$ kW → STATIC stage: 1) If (previous stage was charge/discharge) AND (current unit mode == Cooling) AND ( $T_{max\_IGBT} > 40$ °C): - Start 10-min timer and keep Cooling. - During timer: a) If $T_{max\_IGBT} < 40$ °C → Stop Cooling → Standby. b) Else after 10 min → keep Cooling, then: i) If $T_{out\_SPCS} > 55$ °C → continue Cooling until $T_{out\_SPCS} < 52$ °C. ii) Else ( $T_{out\_SPCS} \leq 55$ °C) → Standby. 2) Else → Standby.
Scenario 2 CHARGE/DISCHARGE	Else ( $ P  \geq 10$ kW) → CHARGE/DISCHARGE stage: 1) If $T_{max\_IGBT} \geq 60$ °C → request Cooling; exit Cooling when $T_{max\_IGBT} \leq 50$ °C → Self-circulation. 2) Else → request Self-circulation. 3) Additionally, if $T_{out\_SPCS} \leq 15$ °C → request Heating; exit Heating when $T_{out\_SPCS} \geq 25$ °C.
Enforcement by unit (setpoints & hysteresis):	- Cooling entry: $T_{out\_SPCS} \geq 48$ °C; fan max at $T_{out\_SPCS} \geq 58$ °C; exit at $T_{out\_SPCS} \leq 43$ °C. - Heating entry: $T_{out\_SPCS} \leq 15$ °C; exit at $T_{out\_SPCS} \geq 25$ °C. - Otherwise Self-circulation ( $15$ °C < $T_{out\_SPCS} < 48$ °C).

**Table 4-7 Technical specifications of chiller unit for Aqua C2.5H**

Parameter	Specification
Product model	TB-CWM60-V-EN-C-D6-10
Power supply	3/PE AC 380 V to 480 V/50Hz/60Hz
Cooling/Heating capacity	60 kW / 24 kW
Cooling/Heating power	38 kW / 27 kW
Rated current	48 A / 33 A (cooling/heating)
Rated flow rate	500 L/min @ 15m
Noise	≤ 80 dB(A)
Protection class	IP55
Dimension	1,200 * 500 * 2,400 mm (W*D*H)

**Table 4-8 Technical specifications of chiller unit for Aqua C2.5S (0.25P)**

Parameter	Specification
Product model	GWGR-BX500P500BHF-H/D-L0.25
Power supply	3/PE AC 380 V to 480V/50Hz/60Hz

Cooling/Heating capacity for batteries	40 kW / 24 kW@480 V / 15.8 kW@380 V
Cooling/Heating capacity for SPCS	30 kW / 7 kW@480 V / 4.4 kW@380 V
Cooling/Heating power	26.9 kW / 29.2 kW
Rated flow rate	500 L/min
Noise	≤ 75 dB(A)
Protection class	IPX5
Dimension	1,200 * 515 * 2,400 mm (W*D*H)

**Table 4-9 Technical specifications of the dehumidifier**

Parameter	Specification
Product model	MC03CDNC4A
Power supply	24 V DC
Dehumidifier capacity	7 L/D
Power rating	170 W (rated) / 230 W (maximum)
Air flow rate	65 m <sup>3</sup> /h
Protection class	IPx2/C3M
Dimension	280 * 550 to 595 * 70 mm

### 4.3.1 Cooling and heating capacity calculation

#### 4.3.1.1 Calculation for battery cells

##### Heat load for batteries

- Cell heat generation

When this report was filed, CLOU provided the cooling capacity calculation documentation [10] for both batteries and SPCS to support the cooling capacity sizing for Aqua C2.5H 0.25P and Aqua C2.5H 0.5P variants respectively. The battery cabinet of a Unit consists of 12 battery strings, each with 4 packs of 104 cells. CLOU has assumed a heat generation of 13.77 W under 0.5P charging conditions for each cell, and 14.32 W under 0.5P discharging conditions. The total heat generation power from a unit is calculated as:

$$P_{battery,charge} = p_{charge} \times n = 13.77 \times 104 \times 48 = 68.74 \text{ kW}$$

$$P_{battery,discharge} = p_{discharge} \times n = 14.32 \times 104 \times 48 = 71.49 \text{ kW}$$

where  $p_{charge}$  and  $p_{discharge}$  denote the heat generation from a cell during operation

- Heat radiation and transfer from the ambient environment

CLOU's calculation considers heat radiation and transfer to address the heat absorption of the battery enclosure from the environment. This consideration is based on the assumption that the maximum ambient temperature  $T_x$  is 45 °C, the target control temperature inside the container  $T_f$  is 35 °C, and the temperature on the outer surface of the container  $T_w$  (maximum temperature) is 65 °C.

The metal plate thicknesses are  $\delta_1 = \delta_3 = 1.6$  mm, the insulation wool thickness is  $\delta_2 = 50$  mm, the thermal conductivity of the metal plates is  $\lambda_1 = 16.3$  W/(m·K), and the thermal conductivity of the insulation wool is  $\lambda_2 = 0.039$  W/(m·K).

The 20-ft container has dimensions of 6,058 mm (length), 2,438 mm (width), and 2,896 mm (height). Generally, only heat radiation from the three-sided surface is considered. The heat radiation from the double-layer metal plates and the interlayer insulation wool to the interior of the container is:

$$P_s = q_s \times S_s = \frac{T_w - T_f}{\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_1}} \times (L \times H + L \times W + W \times H) = 0.92 \text{ kW}$$

On the other hand, the container is also subject to heat transfer from the ambience to the container. The heat transfer is considered for the remaining three surfaces, which includes heat transfer from air to container for two vertical surfaces, and heat transfer from soil to container on the bottom surface. The total heat transfer is calculated as:

$$P_{in} = q_{in-1} \times S_1 + q_{in-B} \times S_B = \frac{T_x - T_f}{\left(\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_1}\right)} \times (L \times H + W \times H) + \frac{T_x - T_f}{\frac{\delta_1}{\lambda_1} + \frac{\delta_4}{\lambda_2} + \frac{\delta_3}{\lambda_1}} \times (L \times W) = 0.25 \text{ kW}$$

The total heat load during BESS operation is then calculated as:

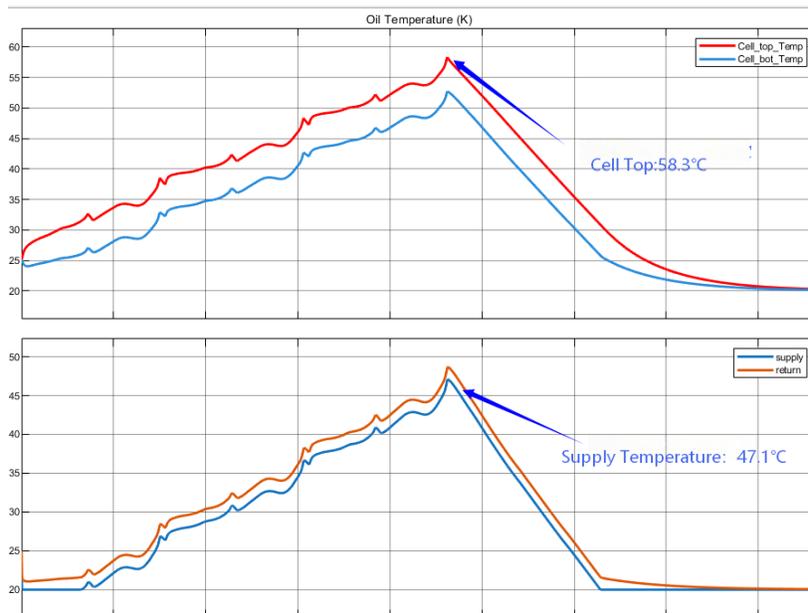
$$\text{Heat load during charging: } P_{total,charge} = P_{battery,charge} + P_s + P_{in} = 68.74 + 1.17 = 69.91 \text{ kW}$$

$$\text{Heat load during discharging; } P_{total,discharge} = P_{battery,discharge} + P_s + P_{in} = 71.49 + 1.17 = 72.66 \text{ kW}$$

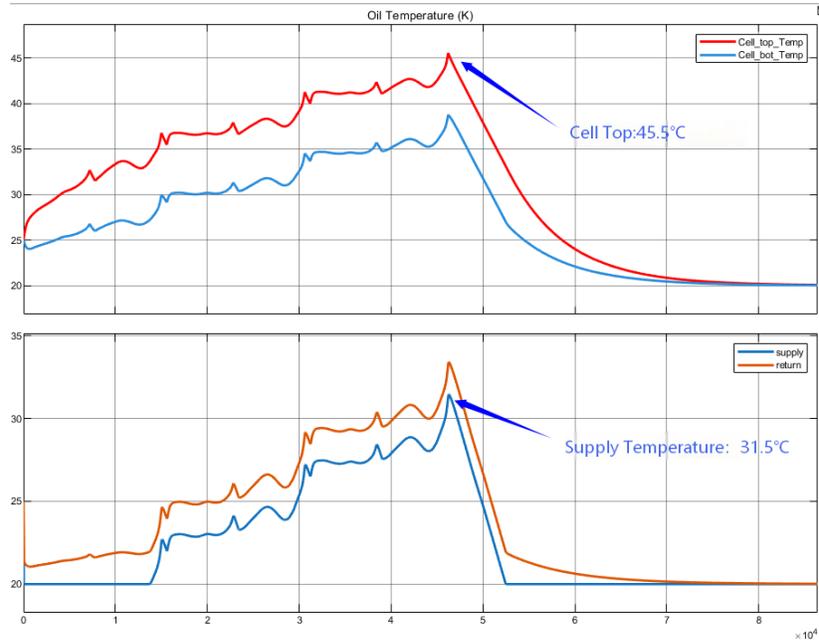
DNV notes the calculation procedure of the heat load is in line with DNV's expectation and common industry practices.

### Cooling capacity evaluation for batteries

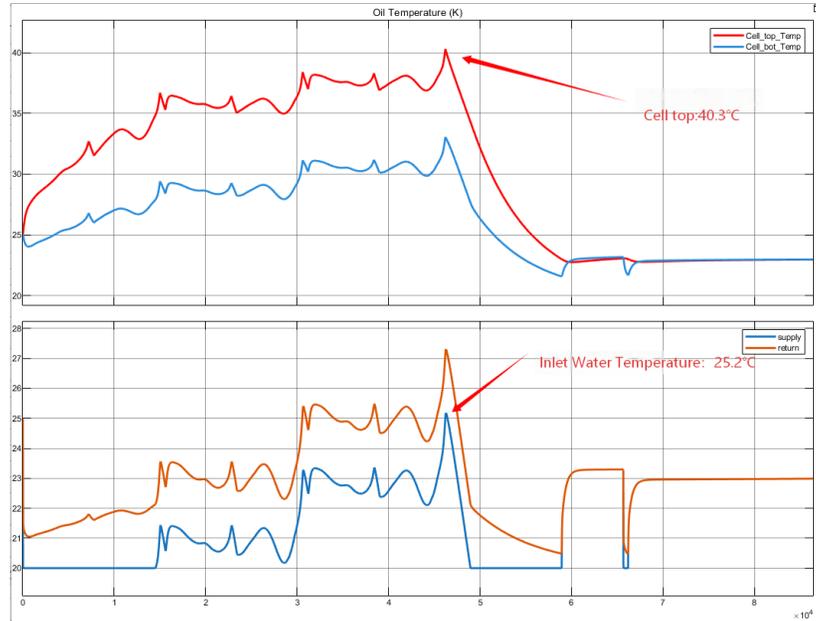
Based on the heat load calculation, CLOU evaluated three cooling capacities, i.e., 45 kW, 55 kW, and 60 kW. The evaluation assumed an ambient temperature of 45 °C and an initial cell temperature of 25 °C. In addition, the coolant flow rate is considered to be 480 L/min, which is within the designed value of 500 L/min. At the time of writing this report, the detailed evaluation approach was unavailable. Generally, DNV notes that the common industry practice is to evaluate the remaining heat energy after deducting cooling capacity for a full operating cycle, and then convert it to the temperature rise of the batteries and enclosures based on the heat capacity. The temperature rise would be compared with the allowable temperature range of the battery cells to determine whether the cooling capacity meets the design requirement. Figure 4-14 illustrates the evaluation results at 0.5P from simulation provided by CLOU [10].



(a) Temperature of the battery cell on the top and the coolant @ 45 kW cooling capacity



(b) Temperature of the battery cell on the top and the coolant @ 55 kW cooling capacity



(c) Temperature of the battery cell on the top and the coolant @ 60 kW cooling capacity

**Figure 4-14 Evaluation of cooling capacity**

DNV was informed that the evaluation was based on three consecutive charge-discharge cycles. The temperature of the battery cells on top, where the temperature is typically highest within the container, and the temperature of the inlet coolant

were taken into account to determine performance. The evaluation concludes that a cooling capacity in the range of 55 kW to 60 kW would meet the design requirements.

### Heating capacity calculation

The heating requirement is considered for the scenario in which the ambient temperature is  $-30\text{ }^{\circ}\text{C}$ , and the battery cells need to be heated from their initial temperature of  $-30\text{ }^{\circ}\text{C}$  to  $20\text{ }^{\circ}\text{C}$  before the system can operate normally to charge or discharge.

The heating requirements include coolant heating, battery cell heating, and heat loss from the container to the ambient. The required energy to heat up the coolant to  $20\text{ }^{\circ}\text{C}$  is calculated as:

$$Q_{coolant} = C_c \times M_c \times \Delta T = 3.2 \times 214.67 \times (20 - (-30)) = 34347.2 \text{ kJ}$$

Where  $C_c$  denotes the specific heat capacity of the coolant, and  $M_c$  denotes the mass of the coolant.

The energy required to heat up battery cells to an average of  $20\text{ }^{\circ}\text{C}$  is:

$$Q_{cell} = C_b \times M_b \times \Delta T = 1060 \times 28853.76 \times 50 = 1529249.28 \text{ kJ}$$

Where  $C_b$  denotes the specific heat capacity of the battery cell, and  $M_b$  denotes the mass of the battery cell.

The heat loss consideration covers all the six surfaces of the battery container, and the total heat loss power is:

$$P_{loss} = \frac{T_x - T_f}{\left(\frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_1}\right)} \times S_{5\_surface} + \frac{T_x - T_f}{\frac{\delta_1}{\lambda_1} + \frac{\delta_4}{\lambda_2} + \frac{\delta_3}{\lambda_1}} \times S_{bottom} = 2.78 \text{ kW}$$

Considering a heating capacity of 24 kW, the duration required for heating the battery system up to  $20\text{ }^{\circ}\text{C}$  operational-allowed temperature would require roughly 20.47 hours. DNV notes that this calculation is targeting at the most extreme condition with the batteries' lowest temperature at  $-30\text{ }^{\circ}\text{C}$ . The heating time required would be proportional to the temperature change for the batteries to achieve an average temperature of  $20\text{ }^{\circ}\text{C}$ .

#### 4.3.1.2 Heat load of SPCS

As the SPCS's efficiency would be relevant to the operational conditions, its heat generation would also depend on these conditions. Based on CLOU's analysis, the Aqua C2.5S' (0.5P) total heat generation from the SPCS under various loading conditions is estimated as below Table 4-10.

**Table 4-10 SPCS heat generation**

Heat generation	100% Rated	110% Rated	120% Rated
Discharging	45.41 kW	50.52 kW	55.1 kW
Charging	57.79 kW	66.41 kW	72.45 kW

To meet the design requirements, the cooling capacity should be 55 kW for discharging and 72.45 kW for charging. Although the overall losses during charging would be higher, CLOU clarifies that the temperature on the IGBT junctions would be lower compared to the same operating conditions as discharging, as illustrated by the recorded test data in Table 4-11. Therefore, a same cooling capacity requirement of 55 kW has been considered for both charging and discharging. Based on Table 4-11, DNV agrees with CLOU's clarification in general.

**Table 4-11 SPCS components max. temperature under ambient temperature 45 °C [11]**

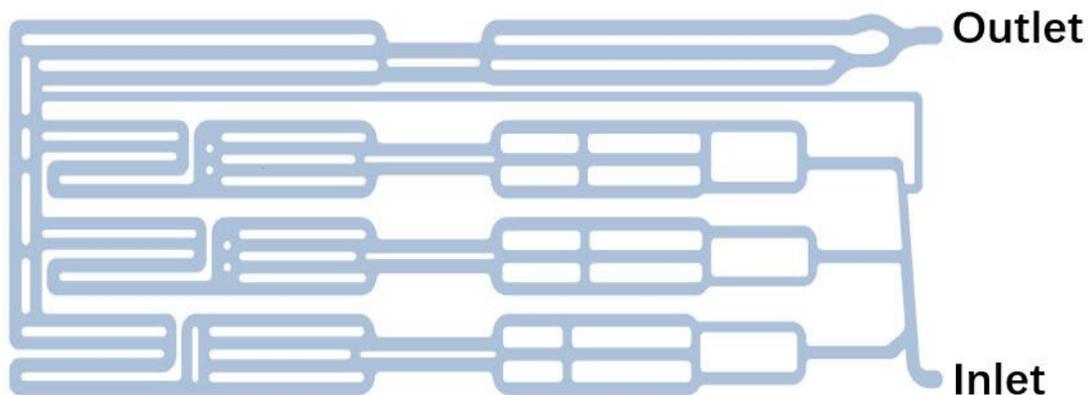
Item	Rated - Discharge	1.1× Rated - Discharge	1.2× Rated (1 min) - Discharge	Rated - Charge	1.1× Rated - Charge	1.2× Rated (1 min) - Charge	Remark
Inverter efficiency (%)	84.29	88.04	88.52	85.13	88.25	88.84	Silicone cable from the inverter inductor of Unit 1
AC efficiency (%)	80.30	83.45	83.91	80.89	83.56	84.17	AC output board cable
U-D12 Phase U IGBT Upper Bridge D6 (°C)	103.348	110.918	114.552	100.114	105.199	110.422	Copper baseplate temperature of Phase U, refer to points 99 and 100
U-T12 Phase U IGBT Upper Bridge T4 (°C)	123.056	132.632	139.146	89.335	92.9	96.364	
U-T13 Phase U IGBT Upper Bridge T2 (°C)	106.098	112.653	117.995	112.882	119.52	126.337	
U-T11 Phase U IGBT Upper Bridge T1 (°C)	119.463	127.556	134.683	83.936	86.854	89.384	
V-T14 Phase V IGBT Upper Bridge T3 (°C)	105.979	113.065	118.393	121.942	130.201	138.735	Copper baseplate temperature of Phase V, refer to points 90 and 91
V-T12 Phase V IGBT Upper Bridge T4 (°C)	126.739	136.627	144.454	91.713	95.78	99.677	
V-T13 Phase V IGBT Upper Bridge T2 (°C)	108.17	115.723	121.245	116.608	123.916	131.593	
V-T11 Phase V IGBT Upper Bridge T1 (°C)	122.842	132.255	139.571	83.922	86.987	89.758	

### 4.3.2 Thermal performance

CLOU conducted a CFD simulation to evaluate the flow rate uniformity and the thermal performance of Aqua C2.5S 0.5P model [12]. DNV notes that the thermal simulation is an interim design step, not a validation of the product's performance. DNV recommends verifying the simulation results through testing or actual operation data.

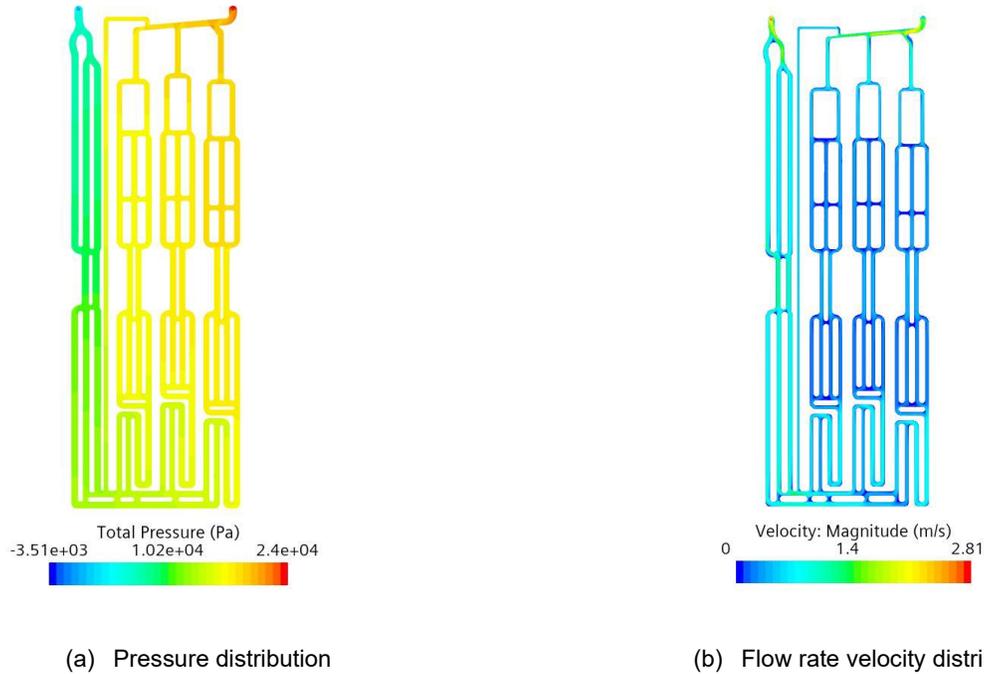
#### 4.3.2.1 Pack cooling plate design evaluation

Cooling plates are placed inside the battery packs and beneath the battery cells. The cold plate flow channel structure adopts a series parallel composite flow channel structure, which is composed of multiple S-shaped flow channels in parallel, as illustrated in Figure 4-15.



**Figure 4-15 Cooling plate structure**

Based on this structure, Figure 4-16 illustrates the pressure distribution and flow rate within the cooling plate.

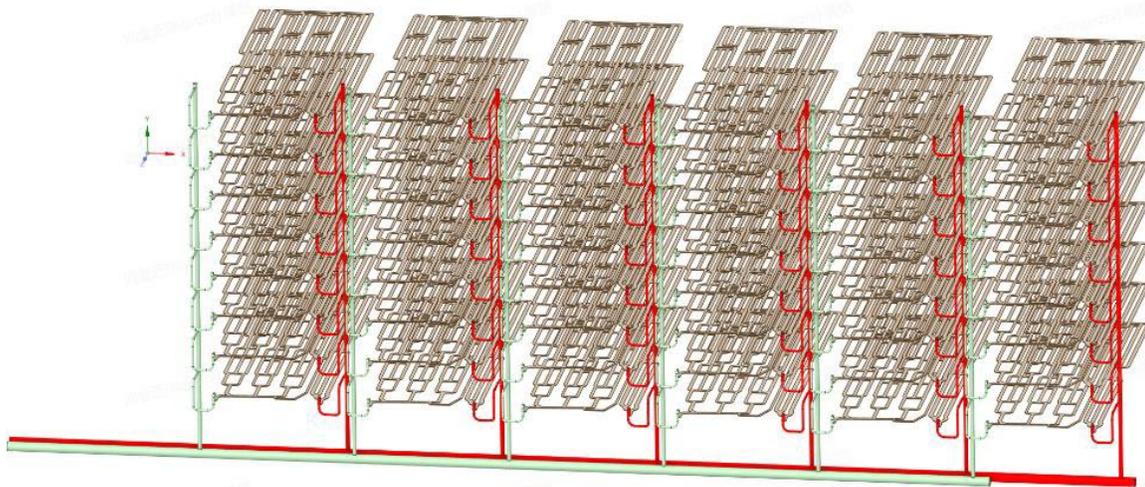


**Figure 4-16 Battery pack cooling plate simulation results**

#### 4.3.2.2 System flow distribution uniformity evaluation

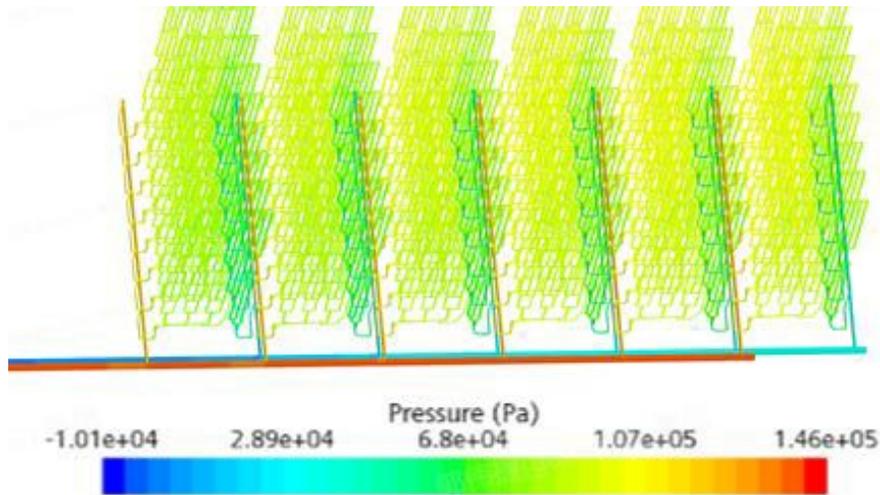
The Aqua C2.5 BESS product series consists of 12 battery racks, each containing 4 battery packs. The pipeline of the entire system is modelled as Figure 4-17. The simulation boundaries considered are:

- Inlet flow rate: 48 packs, total flow rate 520 L/min;
- Flow state: Turbulent model;
- Fluid medium: Mixed solution of ethylene glycol and water (1:1).



**Figure 4-17 Pipe and cooling channel simulation 3D model**

Figure 4-18 illustrates the system-level pressure distribution based on this pipeline model. The inlet and outlet pressure drop is around 139 kPa.



**Figure 4-18 Simulation result of pipeline pressure**

Affected by pipeline resistance, the flow rate of coolant in the cold plate decreases as it is further away from the inlet and outlet positions. A further simulation on the pipeline flow rate among battery packs of a stack indicates that the highest flow rates occur in RACK-2 and PACK-3, and the lowest flow rates occur in RACK-11 and PACK-1. The maximum flow rate between the cold plates is 10.87 L/min, the minimum flow rate is 10.37 L/min, and the maximum flow deviation is 2.9%, as illustrated in Figure 4-19.

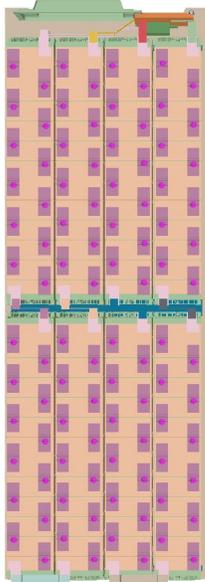
Flow distribution (L/min)	RACK-11	RACK-9	RACK-7	RACK-5	RACK-3	RACK-1
PACK-1	10.37	10.38	10.44	10.5	10.59	10.75
PACK-2	10.38	10.39	10.44	10.51	10.6	10.74
PACK-3	10.38	10.41	10.47	10.51	10.61	10.78
PACK-4	10.43	10.46	10.5	10.55	10.65	10.81
Flow distribution (L/min)	RACK-12	RACK-10	RACK-8	RACK-6	RACK-4	RACK-2
PACK-1	10.49	10.52	10.55	10.61	10.72	10.86
PACK-2	10.4	10.43	10.48	10.53	10.61	10.77
PACK-3	10.51	10.53	10.57	10.62	10.73	10.87
PACK-4	10.46	10.5	10.53	10.61	10.7	10.84

**Figure 4-19 Distribution of Pack Flow in Battery Stack (L/min)**

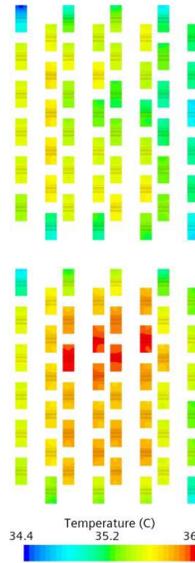
#### 4.3.2.3 Pack-level thermal performance evaluation

The pack-level thermal performance simulation considers three different inlet flow rate scenarios, i.e., 10 L/min (reference design mass flow rate), 10.87 L/min (maximum mass flow rate), and 10.37 L/min (minimum mass flow rate). The inlet temperature and outlet temperature are 20 °C and 25 °C, respectively, in all three scenarios. Temperatures are simulated from bus bars and battery cells as illustrated in Figure 4-20.

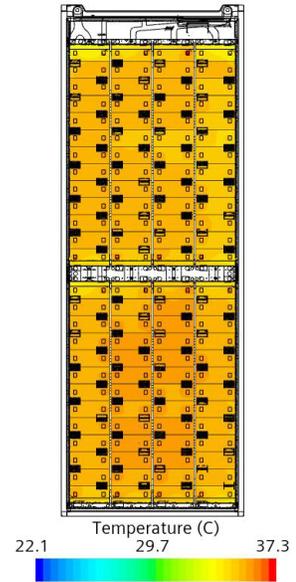
Reference Design Mass Flow of PACK



(a) Busbar temperature monitoring point

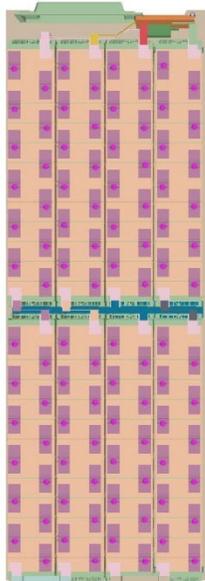


(b) Max temperature of busbar

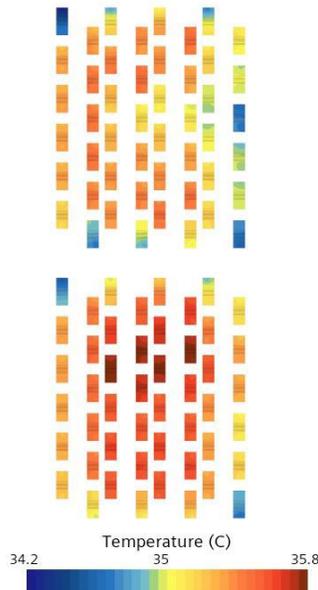


(c) Max temperature of cell

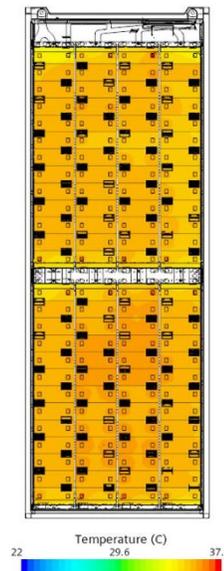
Maximum mass flow rate



(d) Busbar temperature monitoring point

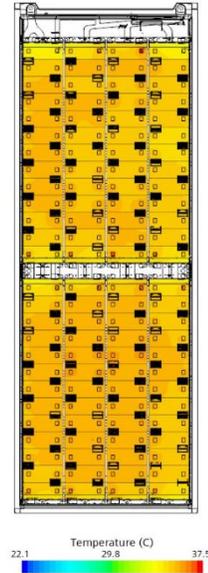
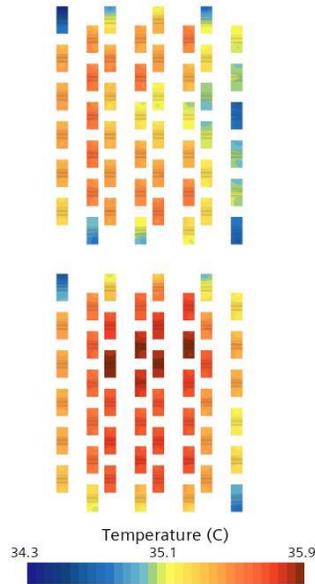
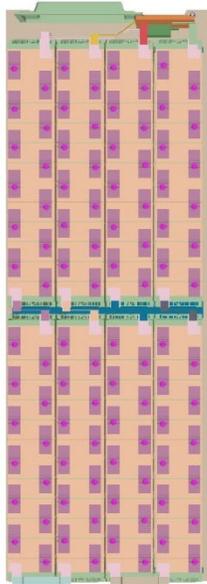


(e) Max temperature of busbar



(f) Max temperature of cell

min mass flow of PACK



(g) Busbar temperature monitoring point

(h) Max temperature of busbar

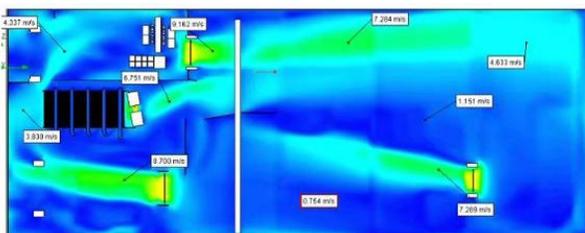
(i) Max temperature of cell

Figure 4-20 Battery pack thermal simulations

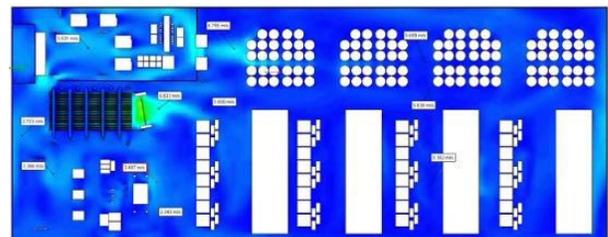
#### 4.3.2.4 SPCS thermal performance simulation

The heat dissipation solution of SPCS comprises two aspects: using liquid cooling plates to meet the heat dissipation requirements of IGBTs and inverter inductors; and equipping it with internal heat exchangers and fans to lower the internal ambient temperature.

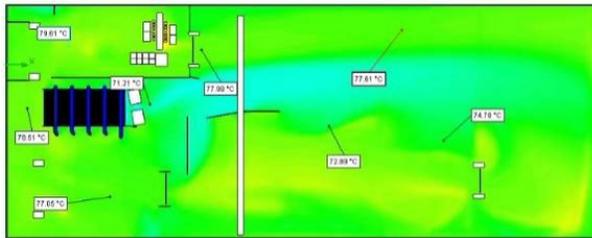
Under the condition with an inlet flow rate of 16 L/min and an inlet water temperature of 58 °C, the thermal simulation results are as follows:



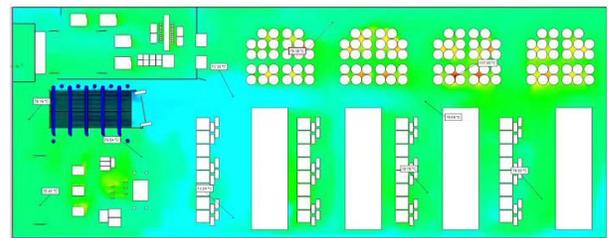
(a) Upper layer air flow velocity



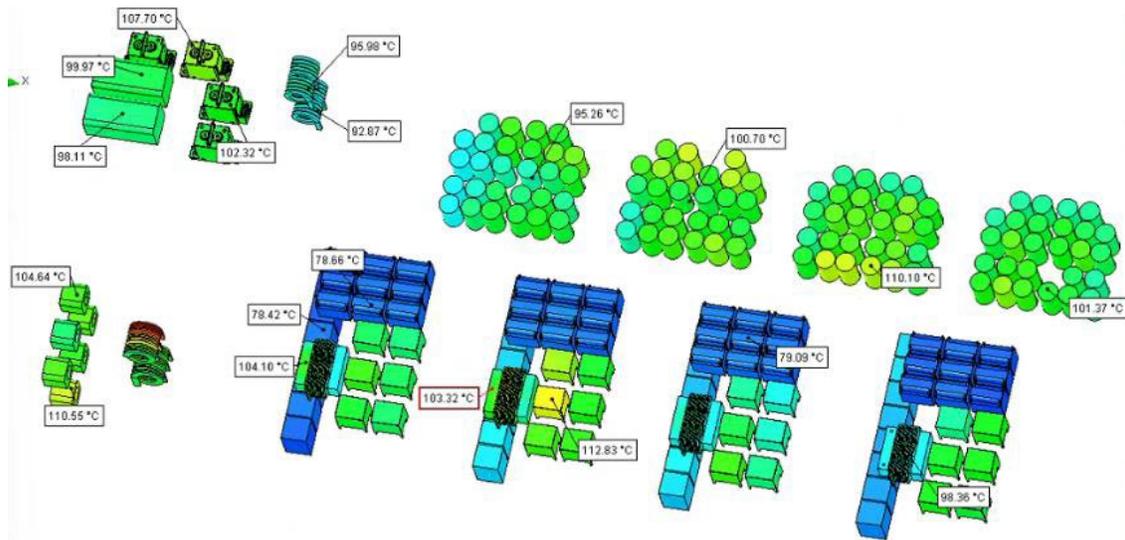
(b) Lower layer air flow velocity



(c) Upper air layer temperature



(d) Lower air layer temperature



(e) The device temperature

**Figure 4-21 SPCS thermal simulations**

The device temperature data is summarized in Table 4-12

**Table 4-12 Simulated device temperature**

Device	Temperature (°C)
100A common-mode inductor	95.8
21uh silicon steel inductor	112.5
220A three-phase inductor	133.4
FCS	85.4
LCL contactor	112.7
LCL filter capacitor 79.4	79.4
outlet	65
outlet of the heat exchanger	55.7
Input DC contactor	107.5
DC output fuse	99.9

Under the current simulation scheme, the maximum internal air temperature is 77 °C, and devices are within the operating temperature range. The maximum junction temperature of the IGBT is around 125 °C.

Though no validation test document has been provided by CLOU, the high/low temperature test report of the system [13] indicates that the system could operate within the designed safety requirements.

## 4.4 BMS functionality, faults, and alarms

### 4.4.1 BMS architecture

The BMS is self-developed by CLOU and has three hierarchical levels as illustrated in Figure 4-22 and the details are listed in Table 4-13.

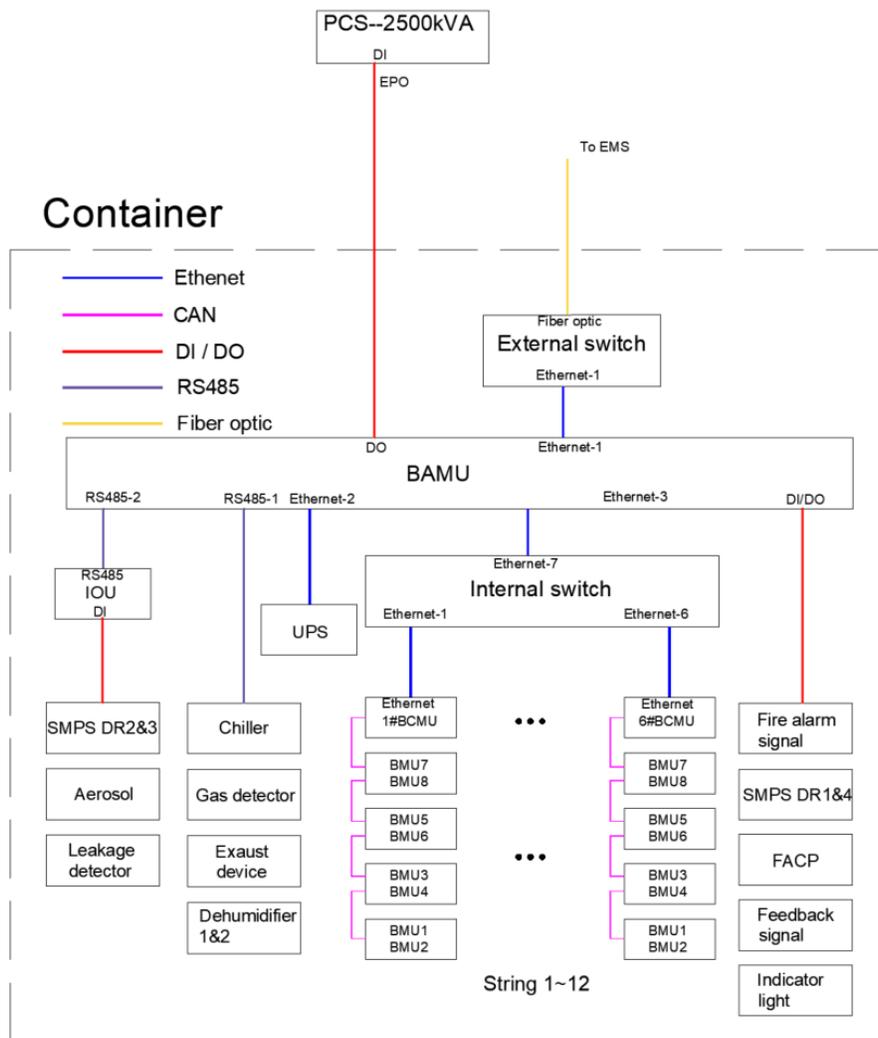


Figure 4-22 BMS control system diagram [14]

**Table 4-13 Summary of BMS levels**

BMS Level	Location
BMU - Pack level	<p>Communication: communicates with BCMU by CAN BUS.</p> <p>Data collection: collects cells voltages, cells temperature, cells balancing status.</p> <p>Balancing system: active balancing system.</p> <p>Parameter configuration: configures communication parameters, control mode and threshold values through CAN communication.</p> <p>Data storage: stores communication parameters, control mode and threshold values.</p>
BCMU - String level	<p>Communication: communicates with BMU and BAMU modules.</p> <p>Data collection: calculates collected voltage values, current value, ground resistance of the string when disconnected.</p> <p>Calculation: SOH</p> <p>Control: controls the connection/disconnection to the main DC bus of the string.</p> <p>Alarm and protection: send alarm and protects the string under abnormal conditions.</p> <p>Balancing system: control cells balancing improving the consistency of cells within one string.</p> <p>Events logging and data storage: records and stores faults, alarms and operation events of string.</p>
BAMU – System level	<p>Communication: communicates with BCMU.</p> <p>Data collection: collects devices states such as Liquid cooling unit, fan, FSS and so on.</p> <p>Calculation: calculates array SOC, SOH, available energy, voltage/temperature values for the string(s).</p> <p>Control: supervises the participation of the string.</p> <p>Alarm: alarms/warns the array under abnormal conditions.</p> <p>Automatic calibration: Intelligent strategy for calibrating battery capacity.</p> <p>Events logging and data storage: records and stores faults, alarms and operation events of the string.</p>

DNV notes that this BMS architecture is typical for this class of products.

#### 4.4.2 Fault-handling state machine

A fault-handling state machine in a BESS BMS defines how the system transitions between normal operation, warning, limited operation, and shutdown states in response to measured conditions, self-check results, and external commands. Its importance lies in ensuring personnel and equipment safety, maintaining grid continuity through graded fault responses, meeting certification and regulatory requirements, and coordinating with SPCS/EMS to manage power limitations or shutdowns in an orderly manner.

CLOU's fault-handling state machine provides a structured framework illustrating how the control system responds to faults of varying severity (see Figure 4-23). DNV notes that CLOU has implemented a graded fault management strategy, in which a Level 3 (lowest level) fault places the system in standby mode, while a Level 1 (highest level) fault immediately shuts down the system regardless of the operating current. This graded approach enables protection actions to be proportionate to the fault severity. However, DNV observes that the current design does not permit continued operation in the presence of minor faults, which may reduce system availability under non-critical conditions.

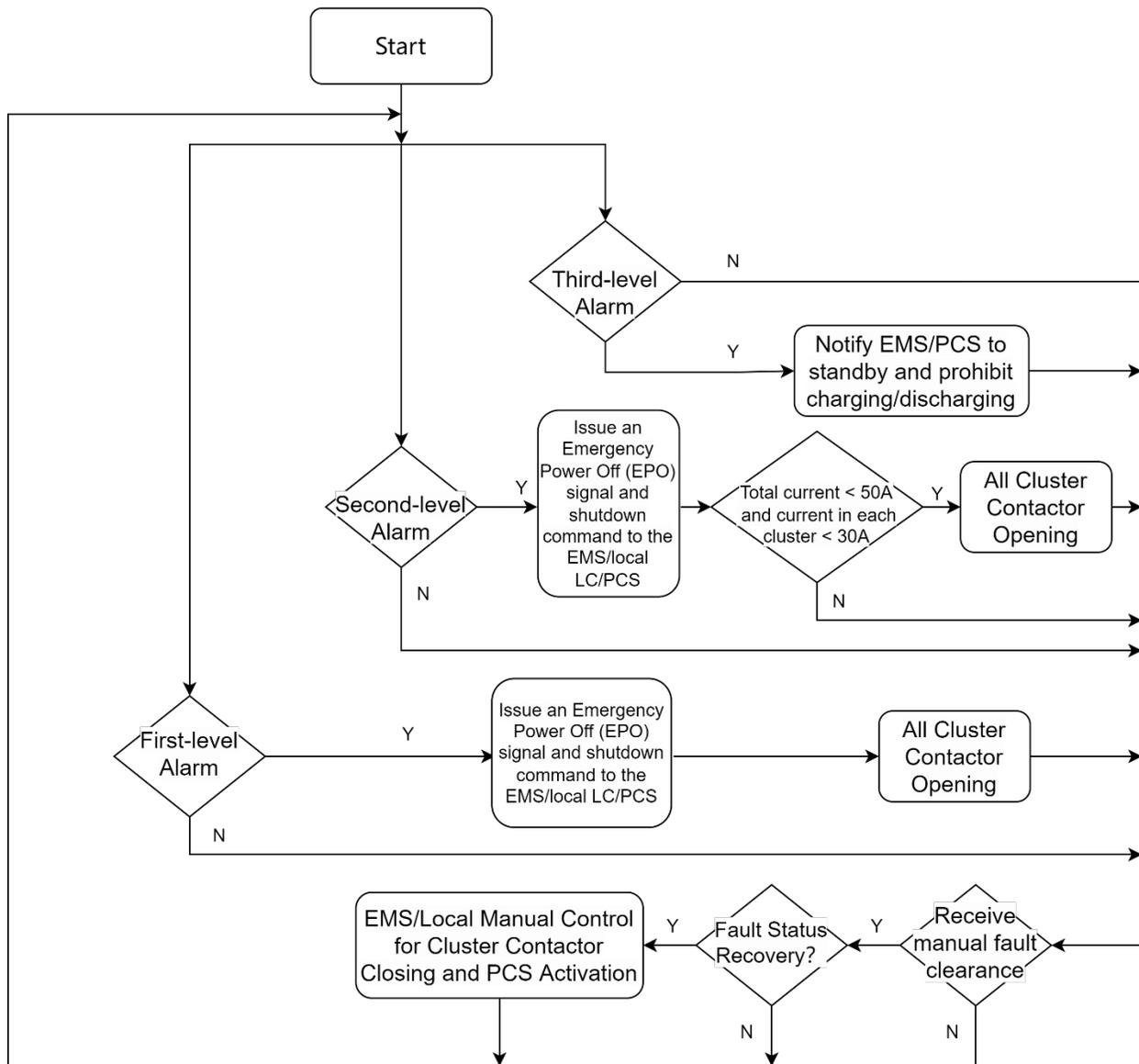


Figure 4-23 BMS fault handling state machine [15]

### 4.4.3 Measurement accuracy

CLOU has tested the sensors' measurement accuracy, which is presented in the provided test report [16] as illustrated in Table 4-14.

**Table 4-14 Measurement accuracy of sensors [17]**

Sensor	Measurement range	Sampling error	Sampling period
Cell voltage sensor	< 5 V	≤ 0.005 V	≤ 100 ms
	5 ~ 15 V	≤ 0.2%	
String voltage sensor	< 500 V	≤ 5 V	≤ 100 ms
	≥ 500 V	≤ 1%	
String current sensor	< 500 A	≤ 2 A	≤ 50 ms
	≥ 500 A	≤ 1%	
Cell & pack temperature sensor	-20 ~ 65 °C	≤ 1°C	≤ 1 s
	-40 °C ≤ T < -20 °C or 65 °C < T ≤ 125 °C	≤ 2°C	
Insulation resistance measurement	60 V < U < 400 V	≤ ±15 kΩ for R ≤ 50 kΩ or ≤ ±30% for R > 50 kΩ	
	≥ 400 V	≤ ±15 kΩ for R ≤ 75 kΩ or ≤ ±20% for R > 75 kΩ	

The BMS is also responsible for calculating and estimating the State of Energy (SOE), which indicates the amount of usable energy remaining for dispatch and serves as a key operational indicator for the BESS, supporting functions such as energy scheduling, performance monitoring, and system protection. The estimation accuracy has been tested to be within ±5%, which is in line with the industry norms.

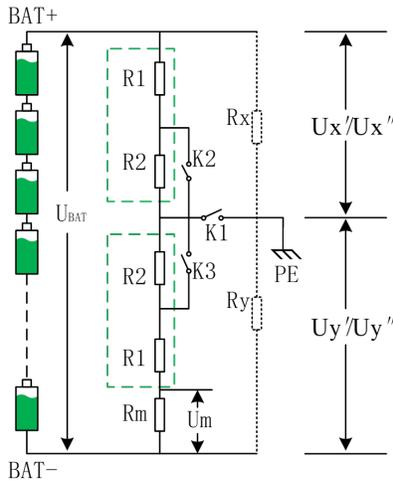
#### 4.4.4 Alarms and warning systems

A cursory review of the 3-level BMS protection list [16] shows that the document is functionally appropriate, covering key areas such as insulation faults, fire events, and key operational voltage or current anomalies. DNV notes that the test report is based on GB/T 34131-2023, and recommends explicit mapping to IEC/UL protection requirements (e.g., UL 9540, IEC 62619) to ensure standard conformity and audit readiness.

#### 4.4.5 Insulation monitoring

The DC side of the BESS uses an ungrounded configuration. Short-circuit faults primarily include inter-pole and pole-to-ground short circuits. During a pole-to-ground short circuit, because the BESS is ungrounded, there is no fault current path, and the BESS continues to operate unaffected. However, pole-to-ground faults can cause overvoltage between the DC bus and ground, posing risks to both system safety and the personal safety of operators.

An insulation monitoring circuit, as illustrated in Figure 4-24, is integrated into the BCMU to detect the insulation resistance between the input ports of the battery network (BAT+/BAT-) and the protective earth (PE). DNV notes that such a measurement circuit is technically valid for basic insulation verification and is typical in the market. In addition, DNV would highlight that adopting multiple IMDs (which would come with BCMUs for different strings) would cause interference issues when activating together with this circuit. Extra cautious on comprehensive and exquisite logic design on BMS/EMS should be taken by designer or developers in project's detailed engineering stage.



**Figure 4-24 Insulation monitoring circuit**

#### 4.4.6 SOC/SOH calculation

SOC estimation enables the real-time determination of a battery’s available capacity, facilitating efficient energy management and preventing overcharging or over-discharging. SOH estimation provides insights into the battery’s ageing and available capacity, enabling timely maintenance, augmentation, and accurate prediction of energy availability and planning. Together, these metrics enhance battery reliability, availability, performance, and safe operation.

According to the provided documentation on SOH algorithm [17], the BMS calculates SOH by measuring the charged capacity triggered by a fully charge operation from full discharge, with the formula below:

$$SOH_{cal} = ((x_2 - x_1) - (y_2 - y_1)) \div Rated_{Ah}$$

Where  $x_1$  and  $y_1$  denote the recorded charged and discharged energy at the beginning of current fully charge cycle (the end of previous fully discharge cycle), and  $x_2$  and  $y_2$  denote the recorded charged and discharged energy at the end of current fully charge cycle.  $Rated_{Ah}$  is the system’s rated capacity in Ah.

Additionally, CLOU would calibrate the SOH based on measurement from previous calculations based on the formula below:

$$SOH_F = SOH_{cal} \times k + SOH_{Last} \times (1 - k)$$

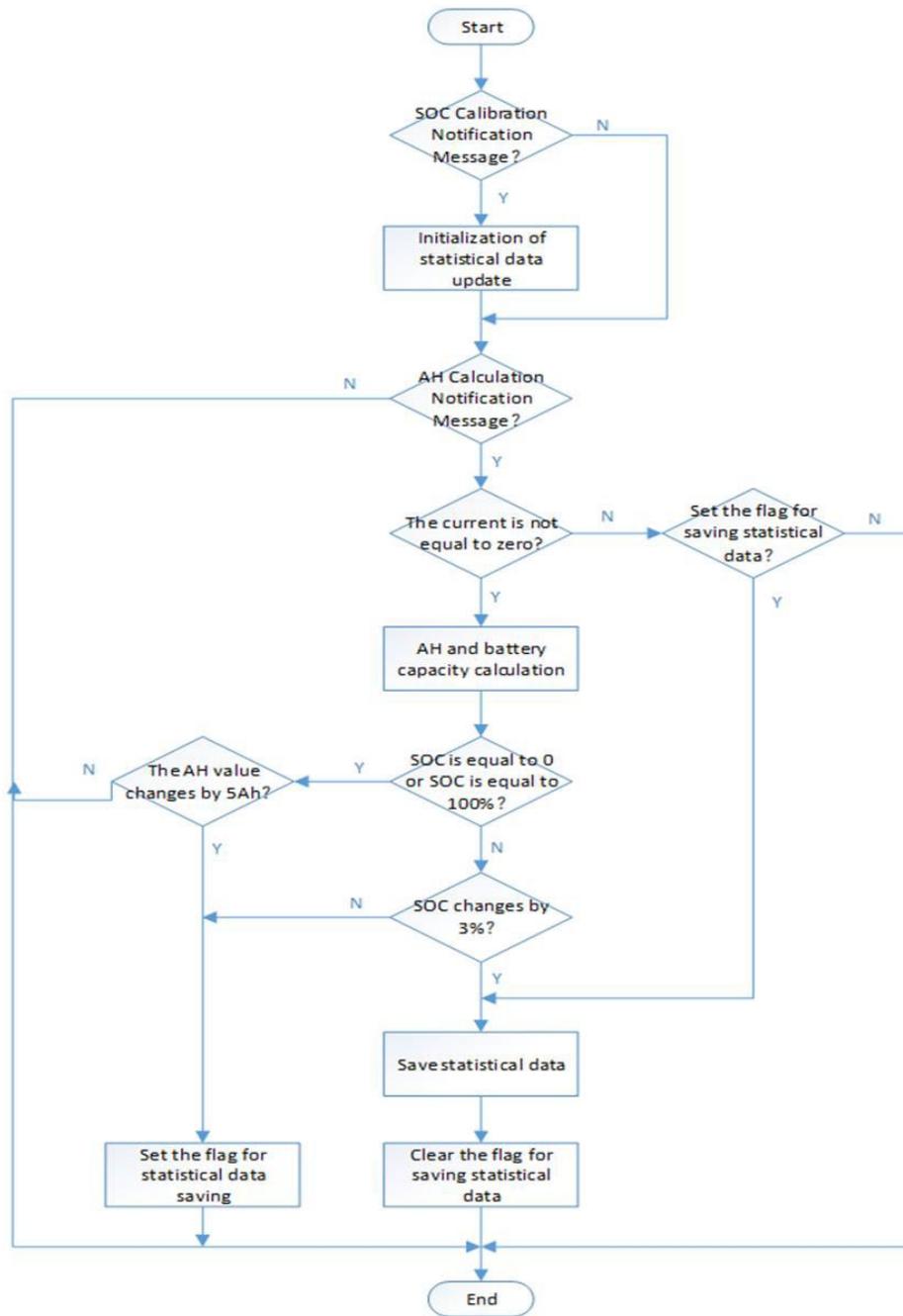
Where  $SOH_{Last}$  is the SOH value from previous calculation, and  $0 \leq k \leq 1$  is a correction factor.

DNV notes that this runtime estimation approach relies on the actual charge–discharge capacity measurements recorded during operation and is consistent with typical industry norms. Though this calculation may not give accurate results fully aligned with the actual conditions, this would serve as a reference for the SOH trend. The accurate SOH would be tested following the LTSA in a defined period, for verification of the contractually guaranteed performance.

The SOC calculation method uses the ampere-hour integration method [18], with an integration period of 100 ms (tick timer) and an integration unit of mAh. The SOC integration formula is as follows:

$$SOC_{(t)} = SOC_{(0)} + \frac{\int_0^t Idt}{Q_{max}} \times 100\%$$

Figure 4-25 shows the SOC calculation flow chart.



**Figure 4-25 SOC calculation flowchart [18]**

Due to errors in the collection of time and current, there will be a corresponding error in SOC over time. For this SOC calculation strategy, accuracy normally relies on regular correction. CLOU has implemented the Lagrange Interpolation method for SOC correction, which interpolates OCV-SOC curves derived from different operating C-rates. The SOC correction will be performed only at the two ends of SOC, i.e., the low SOC/OCV range during discharge and the high SOC/OCV range during charge. The cell voltage thresholds for this correction are below 3.2 V or above 3.4 V. Once an

individual cell voltage falls within the correction range, the SOC correction calculation will be performed every five seconds for three minutes, until the power limit reaches zero or system protection trips.

DNV notes that such SOC calculation and correction strategy meets industry norms.

#### 4.4.7 Cell balancing

Variations in production and daily operations lead to inherent inconsistencies among battery cells, most notably in individual cell capacity, internal resistance, self-discharge rate, and charge/discharge efficiency. These inconsistencies not only contribute to long-term capacity degradation and reduced battery lifespan but also cause immediate system-level capacity loss in serially connected battery strings due to SOC mismatch. Although this short-term capacity loss can be recovered through effective cell balancing, its impact on system performance is immediate. Therefore, a fast and robust cell balancing strategy is more vital than mitigating long-term degradation. Cell balancing methods include:

- **Passive balancing:** Passive balancing dissipates excess energy through resistors. Although straightforward, it can be less efficient for large-capacity cells (e.g., 280 Ah or 314 Ah). For instance, discharging just 2 Ah from a 280 Ah cell through a 20-ohm resistor would take approximately 11 hours. This method requires reducing the charge of all cells to match the lowest-capacity cell, which can make the balancing process relatively slow, especially in large-scale applications, though it remains a simple and cost-effective approach in certain contexts.
- **Active balancing:** Accomplished through energy transfer between cells, this method significantly improves efficiency and reduces balancing time. Instead of dissipating energy, active balancing selectively charges lower-capacity cells, rapidly aligning their capacity with that of the others. This approach addresses the shortcomings of passive balancing and is particularly suited to high-capacity BESS applications. However, it also increases system complexity and cost, and the frequent high-current inter-cell charge/discharge operations may accelerate cell capacity degradation over time if not properly managed.

CLOU employs a bidirectional active balancing strategy for its battery cells, capable of balancing not only within the same pack but also across different packs (see Figure 4-26). As each battery pack comprises eight sub-modules, an active balancing module is implemented for each sub-module within the BMU. This configuration enables simultaneous balancing of up to eight cells within a single module. Furthermore, the balancing function can be extended at the string level, allowing one cell from each sub-module across different battery packs to be selectively charged or discharged. This enables energy transfer both within and between packs within the same string. DNV notes that this combined inter-pack and intra-pack active balancing strategy, together with the supporting hardware design, exceeds the capabilities typically offered by conventional BESS products in the market. However, no test data on this active balancing has been provided for DNV's review to further evaluate its performance.

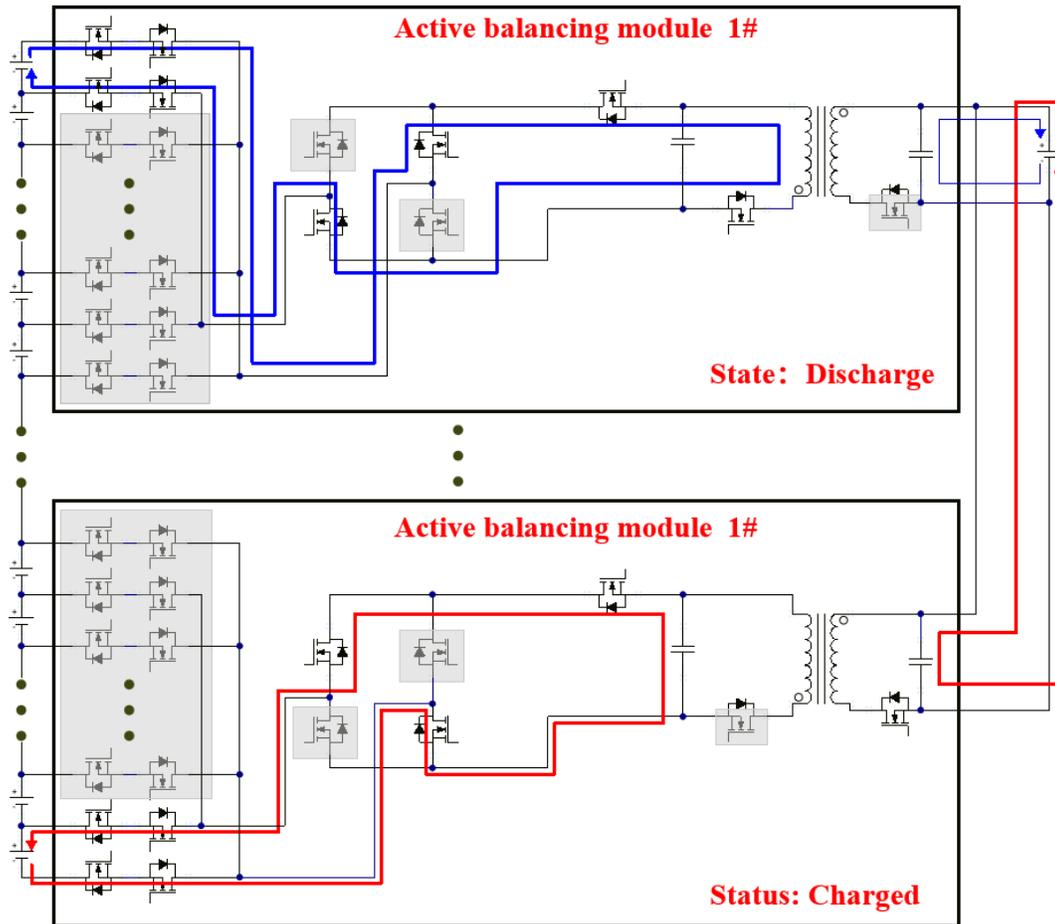


Figure 4-26 Overall hardware architecture of active balancing [19]

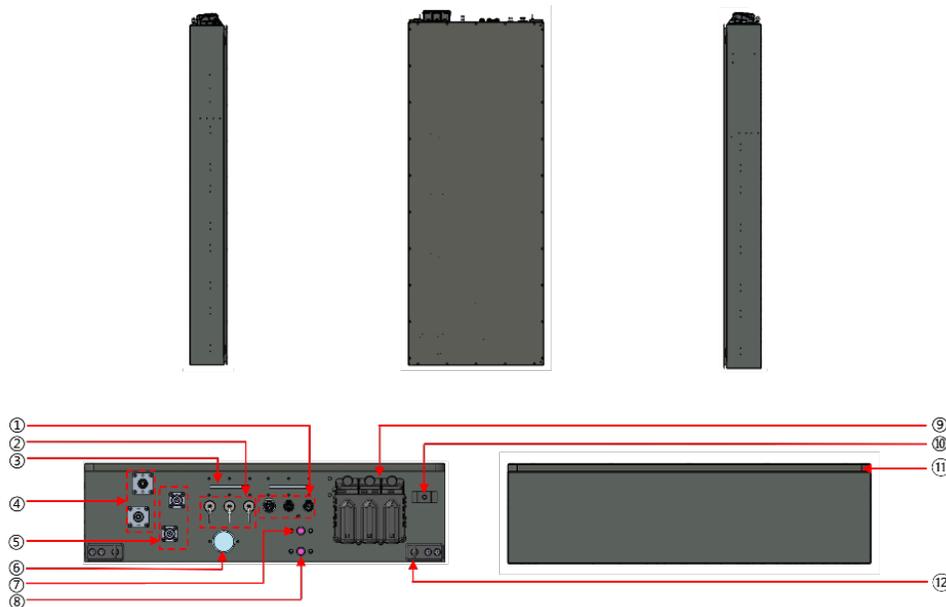
## 5 STRING-LEVEL SMART POWER CONVERSION SYSTEM EVALUATION

### 5.1 SPCS overview

For the Aqua C2.5S series, string-level SPCS are integrated with each battery string inside the BESS container. The SPCS is manufactured by CLOU. To accommodate different power rating configurations, CLOU offers two models with different power ratings: CL215HX-IEC/UL and CL430HX-IEC/UL. Each SPCS is designed with two DC input ports for connecting two battery strings. The internal block diagram Figure 5-2 below illustrates different quantities of DC/AC power converters are paralleled within each SPCS, in order to support mainstream 0.5P and 0.25P application scenarios.

- Under the 0.5P operating condition, four DC/AC converters are used in total inside CL430HX-IEC/UL, arranged as two pairs, with each pair connected in parallel to one battery string.
- Under the 0.25P operating condition, only two DC/AC converters are used in total inside CL215HX-IEC/UL, and they operate independently, with each converter connected to one battery string.

Within the SPCS, the two DC/AC converters (or pairs) are independently controlled, each equipped with a dedicated power control board. In addition, for CL430HX-IEC/UL, the two DC/AC converters within one pair share a single communication control board for external communication. Figure 5-1 illustrates the appearance of the SPCS.



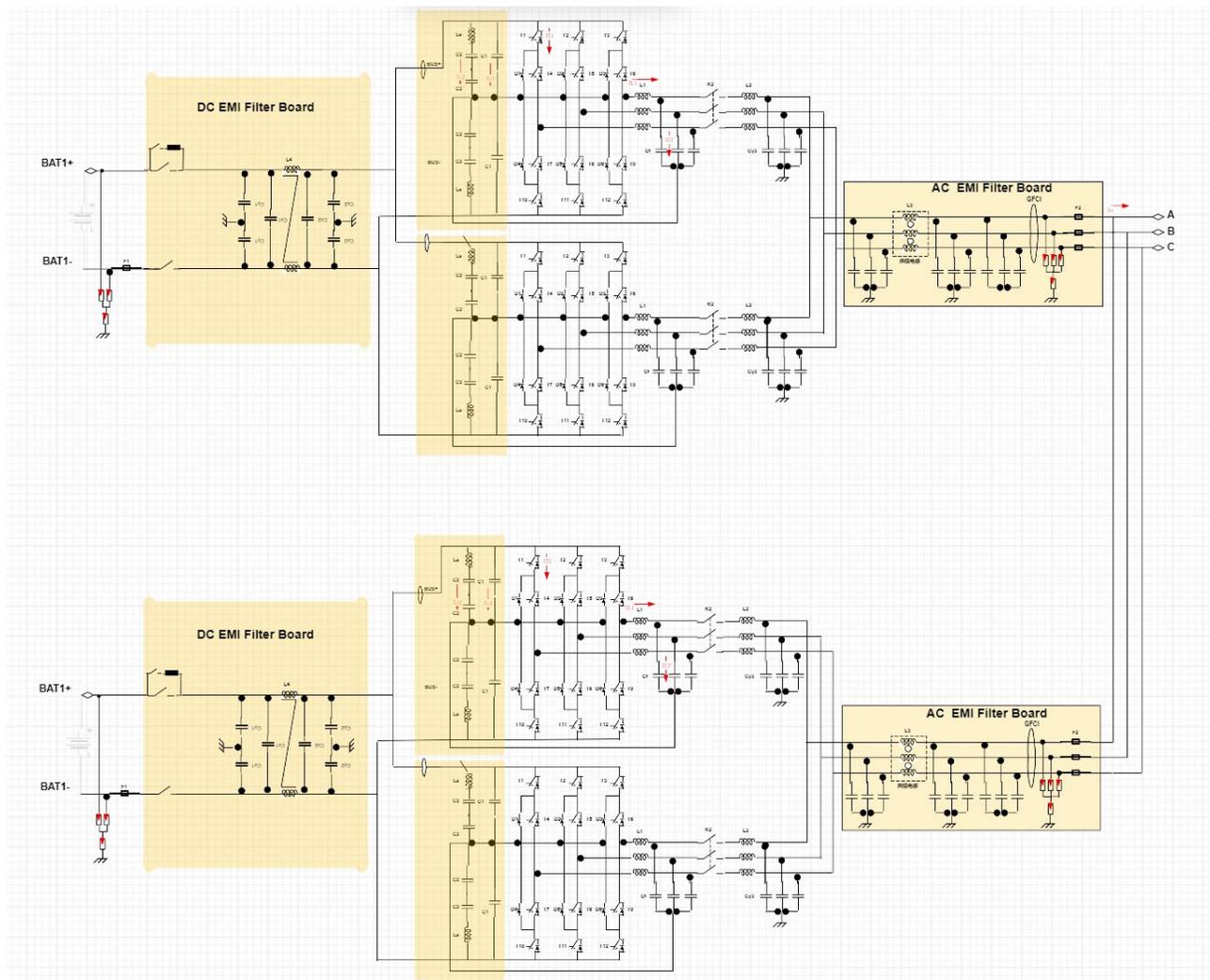
**Figure 5-1 Appearance of the SPCS**

### 5.2 SPCS topology and configuration

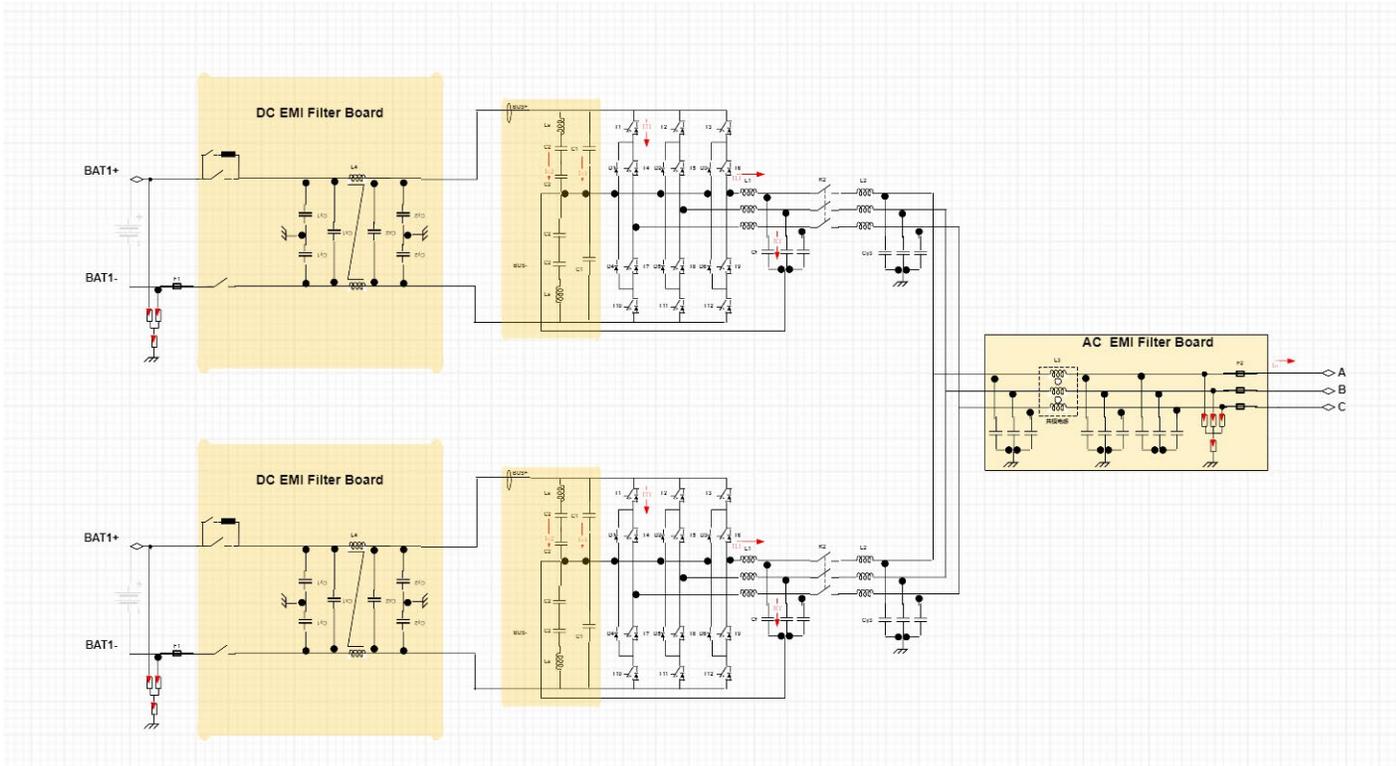
Figure 5-2 shows the topology of CLOU's SPCS. The SPCS employs a three-level NPC inverter topology, which is common and suitable for high-power and high-voltage applications such as grid-tied energy storage systems. Compared with two-level SPCS topologies, this topology enables the SPCS to convert DC power from the battery into AC power for grid integration with higher efficiency, lower switching losses, and better overall power quality. However, the NPC topology presents inherent challenges, most notably the risk of voltage imbalance between the two series-connected DC-link capacitors. As illustrated in the schematic, the series-connected inductor and capacitor branches between the DC terminals

and the corresponding neutral clamping points of each inverter leg primarily serve as a balancing and ripple-filter network. Their key roles are to:

- Maintain midpoint voltage stability, thereby preventing neutral-point drift; and
- Suppress high-frequency common-mode currents during dynamic operating conditions, reducing stress on the DC-link capacitors and improving overall system reliability.



(a) CL430HX-IEC/UL



(b) CL215HX-IEC/UL

Figure 5-2 Topology of CL430HX-IEC/UL and CL215HX-IEC/UL SPCS

### 5.3 Technical specifications

The SPCS main circuit is composed of low-voltage electrical system, EMC filters, power unit, and LCL filters. The low-voltage electrical system includes surge protectors, fuses, and isolating switches. The EMC filters consist of both DC and AC filters. The power unit comprises the boost circuit, DC bus capacitors, IGBTs, and their drivers. Table 5-1 and Table 5-2 show the specifications of the SPCS.

Table 5-1 SPCS CL430HX-IEC/UL specifications [20]

INPUT RATINGS:	Stand-alone or Utility interactive mode	Charging mode
Maximum input voltage	1,500 V d.c.	690 V a.c.
Range of input operating voltage	1,000 V d.c. to 1,500 V d.c.	607.2 V a.c. to 759 V a.c.
Range of input operating voltage with full power	1,060 V d.c. to 1,500 V d.c.	690.0 V a.c. to 759 V a.c.
Maximum input current (dc/ac) (I <sub>max-dc</sub> )	230 A d.c. * 2	396 A a.c.
Maximum input short circuit current (dc/ac)	30 kApk	2.86 kApk, 0.61 Arms @ 27.13 ms
Max. Branch Circuit overcurrent protection	≥ 1.25*I <sub>max-dc</sub> (external)	≥ 1.25*I <sub>max-ac</sub> (external)
Maximum input source backfeed current to input source	N/A	N/A

OUTPUT RATINGS:	Utility interactive mode	Stand-alone mode	Charging mode
Output power factor rating	Default 1 (-1 to 1, 0 leading ~ 0 lagging adjustable)		DC
Operating voltage range (L-L)	607.2 V a.c. to 759 V a.c.	607.2 V a.c. to 759 V a.c.	1,000 V d.c. to 1,500 V d.c.
Number of Phases	3Ø, without neutral	3Ø	N/A
Operating frequency range or single frequency	57.0 Hz to 63.0 Hz	57.0 Hz to 63.0 Hz	N/A
Nominal output voltage	690 V a.c.		1,060 V d.c. to 1,500 V d.c.
Normal output frequency	60 Hz		DC
Maximum continuous output current (ac) (Imax-ac)	396 A a.c.		230 A d.c. * 2
Maximum continuous output active power	473 kW		473 kW
Maximum continuous output apparent power	473 kVA		--
Maximum output fault current (ac) and duration	2.86 kApk, 0.61 Arms @ 27.13 ms 0.74 kArms @ 1 cycle 0.45 kArms @ 3 cycles 0.35 Arms @ 5 cycles		1.245 kApk, 1.199 kArms @ 314 ms
Max. Branch Circuit overcurrent protection	≥ 1.25*Imax-ac (external)		≥ 1.25*Imax-dc (external)
Line Synchronization Characteristics / In-rush current	10.9 A @ 5 cycles	N/A	N/A
Normal operating performance	Category B	N/A	N/A
Abnormal operating performance	Category III	N/A	N/A
Utility interconnection voltage and frequency trip limits and trip times	Compliance with IEEE 1547-2018, IEEE 1547a-2020.	N/A	N/A
Trip limit and trip time accuracy	Voltage:	+/-1% Vnom	N/A
	Frequency:	+/-0.01 Hz	N/A
	Time:	+/-1%, but not less than 34 ms	N/A
Normal operation temperature range	-30 °C to 65 °C		
<b>Output power temperature derating and maximum full power operating ambient</b>	<b>DC Input</b>	<b>-30 °C</b>	<b>65 °C</b>
Output power	1,000 V d.c.	46 kW	46 kW
	1,060 V d.c.	473 kW	473 kW
	1,331 V d.c.	473 kW	473 kW
	1,500 V d.c.	473 kW	473 kW
Enclosure Rating Type	Type 3R		
Communication Protocol	IEEE Std 2030.5		

**Table 5-2 SPCS CL215HX-IEC/UL specifications [20]**

<b>INPUT RATINGS:</b>		<b>Stand-alone or Utility interactive mode</b>		<b>Charging mode</b>
Maximum input voltage		1,500 V d.c.		690 V a.c.
Range of input operating voltage		1,000 V d.c. to 1,500 V d.c.		607.2 V a.c. to 759 V a.c.
Range of input operating voltage with full power		1,060 V d.c. to 1,500 V d.c.		690.0 V a.c. to 759 V a.c.
Maximum input current (dc/ac) (Imax-dc)		115 A d.c. * 2		198 A a.c.
Maximum input short circuit current (dc/ac)		30 kA <sub>pk</sub>		1.245 kA <sub>pk</sub> , 1.199 kA <sub>rms</sub> @ 314 ms
Max. Branch Circuit overcurrent protection		≥ 1.25*Imax-dc (external)		350 A a.c.
Maximum input source backfeed current to input source		N/A		N/A
<b>OUTPUT RATINGS:</b>		<b>Utility interactive mode</b>	<b>Stand-alone mode</b>	<b>Charging mode</b>
Output power factor rating		Default 1 (-1 to 1, 0 leading ~ 0 lagging adjustable)		DC
Operating voltage range (L-L)		607.2 V a.c. to 759 V a.c.	607.2 V a.c. to 759 V a.c.	1,000 V d.c. to 1,500 V d.c.
Number of Phases		3Ø, without neutral	3Ø	N/A
Operating frequency range or single frequency		57.0 Hz to 63.0 Hz	57.0 Hz to 63.0 Hz	N/A
Nominal output voltage		690 V a.c.		1,060 V d.c. to 1,500 V d.c.
Normal output frequency		60 Hz		DC
Maximum continuous output current (ac) (Imax-ac)		198 A a.c.		115 A d.c. * 2
Maximum continuous output active power		236.5 kW		236.6 kW
Maximum continuous output apparent power		236.5 kVA		--
Maximum output fault current (ac) and duration		2.86 kA <sub>pk</sub> , 0.61 Arms @ 27.13 ms 0.74 kA <sub>rms</sub> @ 1 cycle 0.45 kA <sub>rms</sub> @ 3 cycles 0.35 Arms @ 5 cycles		1.245 kA <sub>pk</sub> , 1.199 kA <sub>rms</sub> @ 314 ms
Max. Branch Circuit overcurrent protection		350 A a.c.		≥ 1.25*Imax-dc (external)
Line Synchronization Characteristics / In-rush current		10.9 A @ 5 cycles	N/A	N/A
Normal operating performance		Category B	N/A	N/A
Abnormal operating performance		Category III	N/A	N/A
Utility interconnection voltage and frequency trip limits and trip times		Compliance with IEEE 1547-2018, IEEE 1547a-2020.	N/A	N/A
Trip limit and trip time accuracy	Voltage:	+/-1%V <sub>nom</sub>	N/A	N/A
	Frequency:	+/-0.01 Hz	N/A	N/A
	Time:	+/-1%, but not less than 34 ms	N/A	N/A
Normal operation temperature range		-30 °C to 65 °C		

Output power temperature derating and maximum full power operating ambient	DC Input	-30 °C	65 °C
Output power	1,000 V d.c.	23.7 kW	23.7 kW
	1,060 V d.c.	236.5 kW	236.5 kW
	1,331 V d.c.	236.5 kW	236.5 kW
	1,500 V d.c.	236.5 kW	236.5 kW
Enclosure Rating Type	Type 3R		
Communication Protocol	IEEE Std 2030.5		

### 5.4 Environmental characteristics

The IP rating of CLOU’s SPCS is IP66 as indicated in the IEC 62477 test report. The protection level is TYPE 3R [21] [22].

According to the documentation provided by CLOU [23], when the internal temperature exceeds 65 °C, the SPCS shuts down to prevent thermal stress or failure. Figure 5-3 shows below an altitude of 4,000 m, the derating curve for SPCS output power based on ambient temperature conditions when the altitude is below 4,000 m. DNV does not assess its credibility for lack of sufficient supporting evidence.

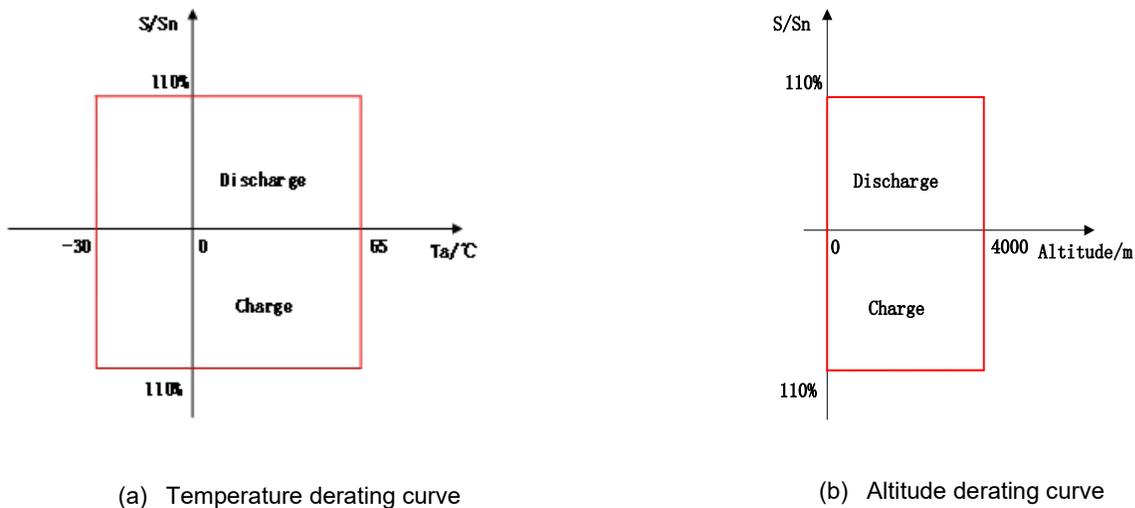


Figure 5-3 SPCS derating curve [23]

CLOU has also provided an internal test report covering noise level testing, high-temperature, and low/high-humidity testing, vibration testing, and drop testing [24]. According to the report, the maximum noise level measured at a one-meter horizontal distance from the SPCS during operation was 64.1 dB(A) at the front side during charging. This value is below the 70 dB(A) limit adopted by CLOU for the test. The SPCS was subjected to storage at high temperature (65 °C) and low (0% RH) / high (95% RH) humidity conditions, then restored to 25 °C in accordance with the procedures outlined in GB/T 34120-2023 and IEC 62477-1. After temperature restoration, the SPCS operated normally and continued to meet insulation requirements. In addition, the SPCS underwent vibration testing in accordance with ASTM D4169 Level 2, as well as two free-drop tests from a height of 25 cm. Both tests confirmed that the SPCS continued to operate without abnormality. DNV notes that the environmental design features of CLOU’s SPCS meet expectations.

The environmental characteristics test reports provided by CLOU were based on the CL430HX-IEC/UL model. Considering the design similarity between the CL430HX-IEC/UL and the CL215HX-IEC/UL, DNV considers that the CL215HX-IEC/UL would also meet the same standards.

## 5.5 Power quality and grid support

This section reviews characteristics that affect the supplied power quality and SPCS features that support the AC grid. Power quality encompasses AC line harmonics, power factor, and DC current injection.

### 5.5.1 Measured THDi and requirement $\leq 3\%$

According to the technical datasheet in Table 5-3, total current harmonic distortion (THDi) for the CL430HX-IEC/UL and CL215HX-IEC/UL models meet requirements of EN 50549-10:2022. DNV reviewed harmonic measurement results from a type test report conducted by Dongguan BALUN Testing Technology Co., Ltd., a laboratory of TÜV NORD (Hangzhou) Co., Ltd. The highest harmonic is approximately 1.17% for the 5th harmonic at 33% loading [25].

In addition, DNV notes that the SPCS has also been certified to UL 1741 and IEEE 1547 based on the Descriptive Report issued by CSA Group on 25 September 2025 [26].

**Table 5-3 Current harmonic content during discharge, from test report of EN 50549-10:2022 [25]**

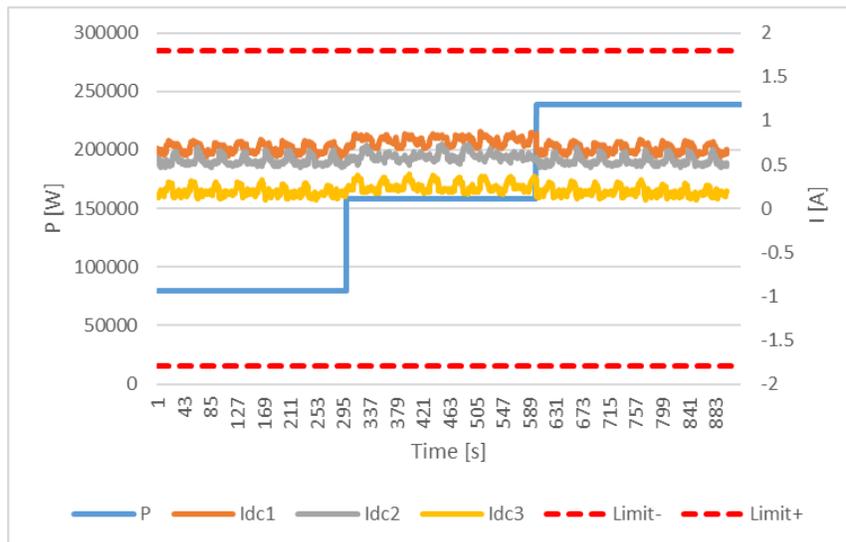
5.7.2.2 Verification procedure for harmonics, interharmonics and higher frequencies up to 9 kHz							P
Model:							
Power Level	33%		66%		100%		
Harmonic	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Current Magnitude (A)	% of Fundamental	Harmonic Current Limits (%)
2nd	0.307	0.085	0.360	0.100	0.546	0.152	8.000
3rd	0.802	0.223	0.720	0.200	0.539	0.150	21.600
4th	0.280	0.078	0.346	0.096	0.422	0.117	4.000
5th	4.210	1.170	2.620	0.728	1.976	0.549	10.700
6th	0.294	0.082	0.352	0.098	0.349	0.097	2.670
7th	3.094	0.860	2.629	0.731	2.243	0.623	7.200
8th	0.364	0.101	0.388	0.108	0.381	0.106	2.000
9th	0.741	0.206	0.691	0.192	0.524	0.146	3.800
10th	0.390	0.108	0.411	0.114	0.394	0.110	1.600
11th	0.871	0.242	1.503	0.418	1.344	0.374	3.100
12th	0.398	0.111	0.466	0.129	0.427	0.119	1.330
13th	1.022	0.284	1.171	0.326	1.357	0.377	2.000
14th	0.466	0.129	0.449	0.125	0.532	0.148	N/A
15th	0.723	0.201	0.667	0.185	0.580	0.161	N/A
16th	0.397	0.110	0.505	0.140	0.551	0.153	N/A
17th	1.181	0.328	1.020	0.284	1.468	0.408	N/A
18th	0.442	0.123	0.560	0.156	0.509	0.142	N/A
19th	0.748	0.208	1.215	0.338	1.544	0.429	N/A
20th	0.468	0.130	0.491	0.136	0.560	0.156	N/A

48th	0.014	0.004	0.015	0.004	0.015	0.004	N/A
49th	0.023	0.006	0.022	0.006	0.030	0.008	N/A
50th	0.008	0.002	0.009	0.003	0.012	0.003	N/A
<b>THD [%]</b>	--	1.598	--	1.455	--	1.420	13
<b>PWHD [%]</b>	--	5.750	--	5.236	--	5.109	22
<b>Note:</b>							
Samplerate: 20 kHz							
Choose the maximum value of three phases							

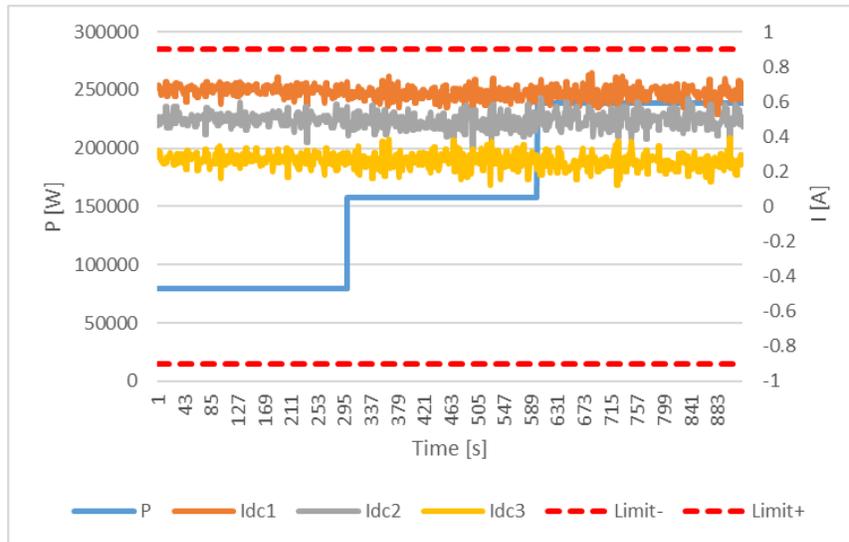
### 5.5.2 Measured AC-side DC current injection

DC current injection into the AC power supply is common with inverters, which can supply both AC and DC current. Nonetheless, it is crucial to limit the DC current to less than 0.5% of the rated current, as specified by IEEE 1547.1-2020 and EN 50549-10:2022. This limitation helps prevent adverse interactions between the inverter and the power system, such as transformer magnetic saturation and excessive waveform distortion.

Figure 5-4 shows the AC-side DC current injection data for the CL430HX-IEC/UL and CL215HX-IEC/UL SPCS at different power ratings. Based on the rated current values and the test results, all measured DC components across L1, L2, and L3 remain within the permissible limits [25].



(a) DC injection of CL430HX-IEC/UL



(b) DC injection of CL215HX-2

**Figure 5-4 AC-side DC current injection from EN 50549-10:2022 test report [25]**

Similar to the THD test, DNV notes that the CL430HX-IEC/UL and CL215HX-IEC/UL SPCS have also passed the DC injection requirement under IEEE 1547, while the test report does not contain detailed test results.

## 5.6 CEC/European efficiency

One of the key metrics for power inverters is operating efficiency across the full range of output power levels and typical DC input voltages. Peak efficiency within the operating range is fundamentally determined by the manufacturer's selection of components and embedded control functions. The specification sheet for the CL215HX-IEC/UL SPCS lists a maximum efficiency of  $\geq 99\%$ , as reported in a draft type test report for CQC Mark Certification. DNV notes this maximum efficiency meets the expectation. Figure 5-5 shows the SPCS's efficiency under different voltage and load conditions [27].



**Manufacturer**

Name: SHENZHEN CLOU ELECTRONICS CO., LTD.

Model Number: CL215HX-IEC/UL

Output Voltage

(Vac) 690

Submit one form for each different Output Voltage

Enter the Tare Loss as a positive value

Maximum Continuous Output Power: 236.841 kW

Night Tare Loss: 34.62 W

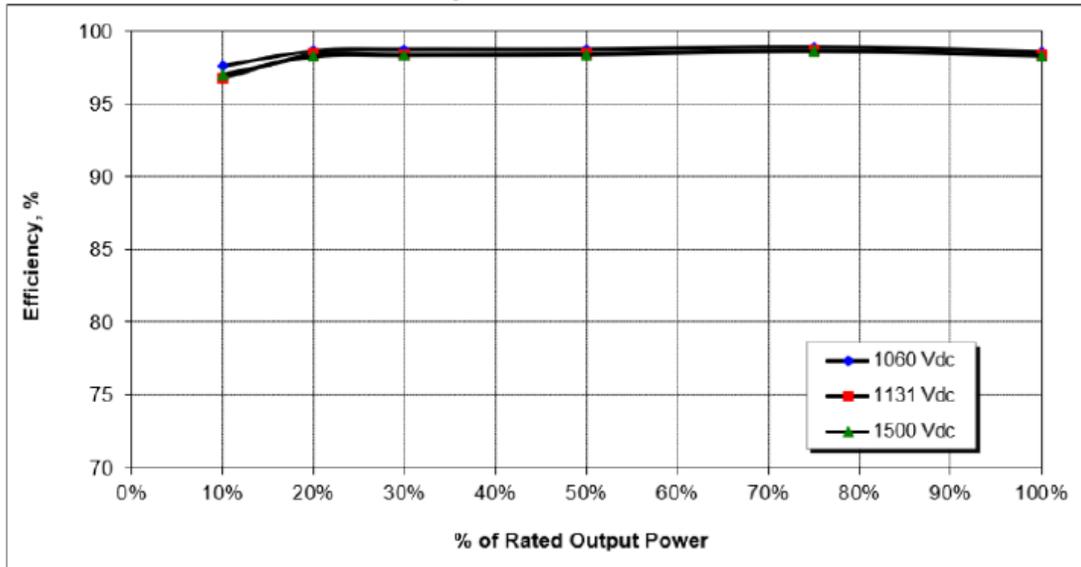
Vmin: 1060 Vdc

Vnom: 1131 Vdc

Vmax: 1500 Vdc

		Power Level (%; kW)						Wtd
		10%	20%	30%	50%	75%	100%	
Input Voltage (Vdc)		23.684	47.368	71.052	118.420	177.631	236.841	
Vmin	1060	97.59	98.60	98.70	98.71	98.89	98.56	98.75
Vnom	1131	96.73	98.40	98.39	98.47	98.69	98.36	98.50
Vmax	1500	97.01	98.24	98.33	98.36	98.59	98.29	98.42

CEC Efficiency = 98.5%



(a) CL215HX efficiency curve



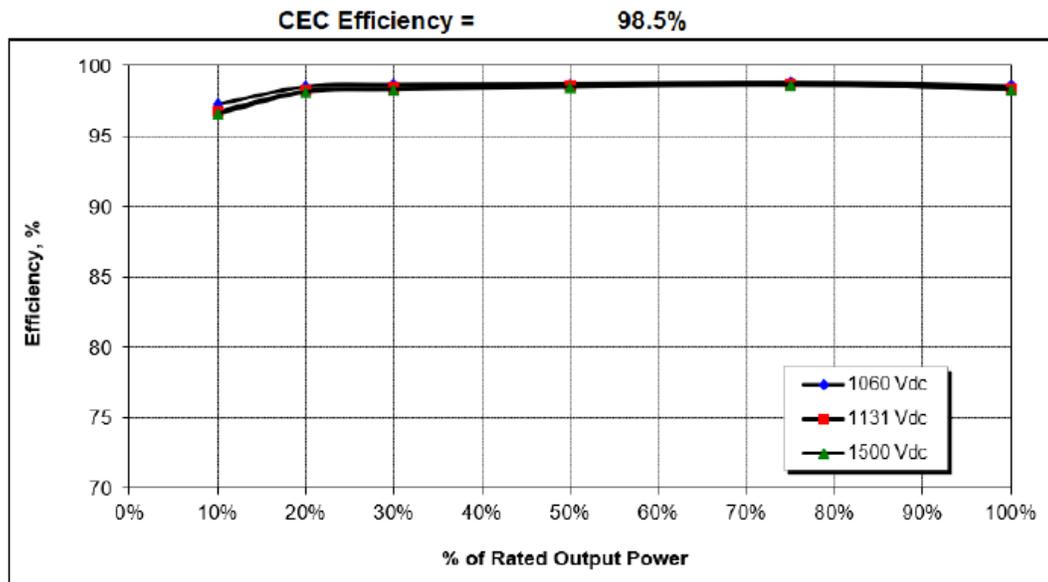
**Manufacturer**  
 Name: SHENZHEN CLOU ELECTRONICS CO., LTD.  
**Model Number:** CL430HX-IEC/UL  
**Output Voltage**  
 (Vac) 690

Submit one form for each different Output Voltage

Enter the Tare Loss as a positive value

**Maximum Continuous Output Power:** 473.495 kW      **Night Tare Loss:** 72.52 W  
**Vmin:** 1060 Vdc      **Vnom:** 1331 Vdc      **Vmax:** 1500 Vdc

Input Voltage (Vdc)	Power Level (%; kW)						Wtd
	10%	20%	30%	50%	75%	100%	
	47.350	94.699	142.049	236.748	355.122	473.495	
<b>Vmin</b> 1060	97.25	98.53	98.66	98.71	98.85	98.56	98.70
<b>Vnom</b> 1131	96.75	98.23	98.42	98.57	98.68	98.37	98.51
<b>Vmax</b> 1500	96.57	98.11	98.31	98.45	98.63	98.31	98.43



(b) CL430HX efficiency curve

**Figure 5-5 CL215HX and CL430HX SPCS efficiency curves [27]**

In addition to the efficiency measured at a specific operating point, CEC efficiency refers to the weighted efficiency of inverters as defined by the California Energy Commission, which accounts for inverter performance across various power levels. DNV notes that the CEC efficiency calculation follows the formula below and is consistent with the typical industry practices.

$$Eff_{CEC} = 4\% \cdot Eff_{10} + 5\% \cdot Eff_{20} + 12\% \cdot Eff_{30} + 21\% \cdot Eff_{50} + 53\% \cdot Eff_{75} + 5\% \cdot Eff_{100}$$

The test data for the SPCS's CEC efficiencies show relatively flat curves, indicating that efficiencies are maintained within a narrow range. DNV notes that CLOU's SPCS CEC efficiencies meet the typical expectation for similar products of this scale in the market.

Another weighted efficiency metric for inverters is the EU efficiency. Similar to the CEC efficiency, EU efficiency calculates the efficiency across various operating points with different weights from the CEC efficiency, following the formula below:

$$Eff_{EU} = 3\% \cdot Eff_{5} + 6\% \cdot Eff_{10} + 13\% \cdot Eff_{20} + 10\% \cdot Eff_{30} + 48\% \cdot Eff_{50} + 20\% \cdot Eff_{100}$$

Each specific market may have its own selection of CEC efficiency and EU efficiency, and DNV recommends that CLOU also test the EU efficiency to demonstrate compliance with different regional standards, ensure comparability across markets, and strengthen credibility for global customers. In addition, some aggregators / plant designers may be concerned on some specific loading points such as 90%, which is not covered in the CEC/EU efficiency tests. DNV also recommends CLOU to expand its tests to provide a more comprehensive efficiency evaluation with various loading conditions.

## 5.7 Design for reliability

### 5.7.1 Component selection and derating

One important element of achieving high product reliability is the selection of quality parts and the design for operation at appropriate stress levels, which will allow the components to perform reliably throughout their service lifetime. It is common for electronic product manufacturers to implement in-house design guidelines that define the stress levels at which individual components are permitted to operate. These guidelines include derating factors below the component specification limits for parameters such as semiconductor device junction temperature, capacitor ripple current, applied voltage, and ambient temperature. CLOU has provided the component selection and derating consideration documents [28, 29, 30, 31, 32, 33] outlining the stress-derating considerations for all main components across different SPCS boards, including IGBT modules, metallized film capacitors, electromagnetic elements, and Hall sensors.

DNV notes that CLOU's design considerations demonstrate good compliance with good industry practices.

### 5.7.2 MTBF

DNV considers that an important analytical approach for evaluating the reliability of a SPCS is to calculate the product MTBF during the development process and use it to improve the product. DNV also considers that consistently using a rigorous analytical reliability approach is important, and that the primary benefit of the MTBF methodology is to identify components that most negatively impact product reliability. DNV considers the MTBF study an indicative tool for evaluating the design, and it can later be compared against actual field data and failure rates.

DNV notes that this product of SPCS is relatively new at the time of writing this report, CLOU has not conducted MTBF. DNV recommends CLOU to conduct such analysis to evaluate the long-term reliability of the equipment.

### 5.7.3 Design failure mode and effects analysis (DFMEA)

Failure mode and effects analysis (FMEA) originated in the 1950s as a systematic technique developed by reliability engineers to analyze potential failures, primarily within military systems. It serves as an initial step in studying system reliability. The process involves a meticulous examination of components, assemblies, and subsystems to identify potential failure modes, their underlying causes, and the consequences for the overall system. Each component's failure modes and their impacts on the system are documented in dedicated FMEA worksheets, available in various versions tailored to specific applications. FMEA's effectiveness lies in identifying potential failure modes, drawing insights from previous experiences with similar products or processes, and applying fundamental principles of failure physics. Its applicability spans different stages of a product's lifecycle, making it valuable across development and manufacturing sectors.



The DFMEA for CLOU's SPCS contains multiple potential failure modes, impacts, and protective measures across SPCS subsystems [34] [35] [36] [37]. The DFMEA includes a detailed analysis of high-risk components such as capacitors, IGBTs, relays, control boards, and cooling systems.

DNV notes that the DFMEA for CLOU's SPCS to be in line with the common industry practices.

## 5.8 Product testing

Testing of a SPCS is an extensive and multifaceted process that includes several stages from initial functional verification to accelerated life testing. This meticulous testing regime is essential for confirming the performance and dependability of SPCS.

### 5.8.1 DVT

Before mass production, there was a single prototyping stage with ongoing design and process enhancements. During this phase, CLOU conducted verification tests or analyses—covering thermal, electrical, and mechanical aspects—along with component sizing and selection.

### 5.8.2 ALT/ HALT

ALT is an effective approach to evaluate the operational lifespan of new inverter models more quickly. It involves exposing the product to conditions beyond normal operational limits and using specific acceleration factors to trigger component or device failures. Common stress factors include voltage, temperature, and vibration. When integrated with statistical modelling, ALT outcomes offer meaningful insights into an inverter's expected service life. DNV notes a strong link between the industry's most reliable products and comprehensive ALT testing.

HALT is another method for testing electronic equipment within a condensed timeframe to ensure reliable performance over its intended operational life. HALT involves subjecting the equipment to extreme conditions such as high and low temperatures, cycling, and vibration. Any issues or weaknesses that arise during HALT must be promptly addressed.

As the SPCS product is relatively new, DNV was informed that CLOU has not conducted DVT or ALT/HALT on SPCS at the time of writing this report. DNV recommends that CLOU perform these tests, which could help identify potential design defects and validate the product's long-term reliability and robustness.

## 5.9 Product field history

Recent high failure rates of power inverters in the energy storage and renewable sectors have led to a demand for their field reliability history during due diligence. DNV views a proven track record in the field as one of the most essential factors when reviewing inverter products. When historical data are available, evaluations include the sample size, operational duration, failure types and counts, and the manufacturer's methods for documenting and analysing these issues.

For assessing field performance, DNV considers two key time periods that offer insights into reliability. After one year of operation across a large sample, early issues such as infant mortality and latent defects should be detected and resolved. The second is after several years of operation, when longer-term degradation and wear-out mechanisms can be assessed.

DNV also notes that the SPCS is a newly released product from CLOU, and there is currently no long-term field data available.

## 6 SAFETY AND COMPLIANCE EVALUATION

Safety is a critical design and operational aspect of energy storage devices. The safety of an energy storage system builds on the battery cell and is relevant at every stage of the product's lifecycle, informed by both code requirements and best practices. When assessing an energy storage device's safety program, DNV applies a risk management approach, considering both the likelihood of an emergency event and its severity. DNV reviews certifications, test data, and quality management processes to address the likelihood factor of the equation; and reviews emergency response, installation protections and suppression/detection systems to address the severity factor of the equation. In general, DNV considers certifications to codes and standards to be minimum requirements. Since codes and standards do not necessarily align with best practices, DNV expects a robust safety program to go beyond the basic requirements.

DNV has reviewed the relevant safety-related documentation for the cell, pack, and unit used in CLOU's Aqua C2.5H and Aqua C2.5S systems. Table 5-1 shows the model numbers associated with Aqua C2.5H and its subassemblies.

**Table 6-1 Model numbers of the BESS components**

Component	Aqua C2.5H system		Aqua C2.5S system		
	Market	IEC variant (for the European market)	UL variant (for the North American market)	IEC variant (for the European market)	UL variant (for the North American market)
Cell		CALB L173F314	REPT CB75	CALB L173F314	REPT CB75
Pack		CL530PB314G104A	CL530PB314B104A	CL530PB314G104A	CL530PB314B104A
String		CL532CB314G10404A	CL532CB314B10404A	0.5P: CL532CB314G10404B  0.25P: CL532CB314G10404C	0.5P: CL532CB314B10404B  0.25P: CL532CB314B10404C
SPCS		-	-	CL430HX-IEC/UL, CL215HX-IEC/UL	
System		CL510C20-2507.9/5015.9-P36NA	CL510C20-2507.9/5015.9-P37NA	0.5P: CL510C20-P2508/5015-P36NA  CL510C20-P2508/5015-P36NB	0.5P: CL510C20-P2508/5015-P37NA  CL510C20-P2508/5015-P37NB
		CL510C20-2507.9/5015.9-P36NB	CL510C20-2507.9/5015.9-P37NB	0.25P: CL510C20-P1254/5015-P36NA  CL510C20-P1254/5015-P36NB	0.25P: CL510C20-P1254/5015-P37NA  CL510C20-P1254/5015-P37NB

## 6.1 Regulatory compliance evaluation

### 6.1.1 Standards, codes, and testing

The CLOU's BESS and its subcomponents are designed to comply with international standards generally accepted to demonstrate minimum safety requirements in the system design for North American and European installations. These standards include certifications by Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) standards, as well as UL and United Nations (UN) testing. Table 6-2 shows the complete list of key standards and tests which Aqua C2.5H and Aqua C2.5S obtained and completed.

**Table 6-2 Standards and tests list**

Component	Claimed Standard	Title	Certification/Test verified
Cell/string (REPT cell)	UL 1973:2022	Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications	The cell obtained UL 1973 certificate on 20 November 2023, issued by TUV Rheinland [7].  The battery string obtained UL 1973 certificate on 30 May 2025, issued by CSA Group [38].
Cell/Pack/String (REPT cell)	UL 9540A:2019 (Fourth edition)	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	TUV Rheinland issued the cell-level UL 9540A test report on 12 December 2023 [7].  CSA Group issued the module(pack)-level UL 9540A report on 05 June 2025 [39].  CSA Group issued the string (unit)-level UL 9540A report on 30 May 2025 [40].
BESS (REPT cell)	UL 9540 Third Edition	Standard for Safety of Energy Storage Systems and Equipment	CLOU's Aqua C2.5H obtained UL 9540 certificate on 11 June 2025, issued by CSA Group [41].
Cell/String (CALB cell)	IEC 62619:2022	Safety requirements for secondary lithium cells and batteries for use in industrial applications	The cell obtained IEC 62619 certificate on 13 September 2023, issued by TUV SUD [42].  The battery string obtained IEC 62619 certificate on 08 April 2025, issued by TUV Rheinland [43].
String (CALB cell)	IEC 63056:2020	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems.	The battery string obtained IEC 63056 certificate on 28 April 2025 [44].

Component	Claimed Standard	Title	Certification/Test verified
SPCS	EN 62477-1:2012+A1+A12 (Low Voltage Directive 2014/35/EU)	Safety requirements for power electronic converter systems and equipment – Part 1: General	The SPCS obtained EN 62477-1 certificate on 04 July 2025, issued by TUV Nord [45].
SPCS	EN IEC 61000-6-2:2019 EN IEC 61000-6-4:2019 (EMC Directive 2014/30/EU)	Electromagnetic Compatibility (EMC)	The SPCS obtained EN IEC 61000 certificate on 29 May 2025, issued by TUV Nord [46].
SPCS	Grid codes	EU: EN 50549-2:2019+A1:2023, EN 50549-10:2022 Poland: PN-EN 50549-2:2019, PSE 2018-12-18, 2016/631 EU (NC RFG), PTPIREE 2021-04-28	Compliant [47] [25]
SPCS	UL 1741 (Third Edition, Revision 19 May 2023)	Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources Note: includes Supplement SB and IEEE 1547.1-2020 with the SRDs of IEEE 1547-2018, IEEE 1547a-2020, California Electric Rule 21 and Hawaiian Electric Co. SRD-V2.0. While the grid support function evaluated according to IEEE 1547.1-2020, the interoperability is verified with IEEE 2030.5-2018 communication protocol.	The SPCS obtained UL 1741 and CSA C22.2 No. 107.1 certificates on 25 September 2025, issued by CSA [48].
	CSA C22.2 No. 107.1-16	Power Conversion Equipment	

Component	Claimed Standard	Title	Certification/Test verified
SPCS	FCC part 15B:2021	Federal Communications Commission – Part 15 Radio Frequency Devices – Subpart B Unintentional Radiators	Compliant [49].
	ICES-003 Issue 7	Information Technology Equipment (including Digital Apparatus)	
SPCS	IEEE Std 2800-2022	IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems Note: includes compliance with applicable requirements of NOGRR No. 245 and P2800.2/D3.2	Compliant [50].
BESS (CALB cell)	IEC 61000-6-2:2019 IEC 61000-6-4:2019	Electromagnetic Compatibility (EMC)	CLOU's Aqua C2.5H obtained IEC 61000 certificate on 23 May 2025 [51].
BESS (CALB cell)	IEC 62477-1:2022	Safety requirements for power electronic converter systems and equipment – Part 1: General	CLOU's Aqua C2.5H obtained IEC 62477 certificate on 30 May 2025 [52].
BESS (CALB cell)	IEC 62933-5-2:2020	Electrical Energy Storage (EES) Systems – Part 5-2: Safety Requirements for Grid-Integrated EES Systems – Electrochemical-Based Systems	CLOU's Aqua C2.5H obtained IEC 62933 certificate on 19 June 2025 [53].

Component	Claimed Standard	Title	Certification/Test verified
Cell/Pack/BESS (REPT cell)	UN 38.3	UN Recommendations on the Transport of Dangerous Goods	<p>The cell obtained UN 38.3 test report on 23 October 2023 issued by ZAIQ<sup>1</sup> [7].</p> <p>The pack obtained UN 38.3 test report on 23 January 2025 issued by CVC<sup>2</sup> [54].</p> <p>The BESS system obtained UN 38.3 test report on 12 March 2025 issued by CVC [55].</p>
Cell/Pack/BESS (CALB cell)	UN 38.3	UN Recommendations on the Transport of Dangerous Goods	<p>The cell obtained UN 38.3 test report on 21 July 2023 issued by Guangzhou MCM Certification &amp; Testing Co., Ltd. [56]</p> <p>The pack obtained UN 38.3 test report on 25 April 2025 issued by Guangzhou Customs District Technology Center [57].</p> <p>The BESS system obtained UN 38.3 test report on 15 May 2025 issued by Guangzhou Customs District Technology Center [58].</p>
Cell	REACH	Screening of substances of very high concern (SVHC) subject to the candidate list by European Chemical Agency (ECHA) according to Regulation (EC) No. 1907/2006 of REACH and its amendments	<p>REPT cell: Test passed on 11 July 2023 [7].</p> <p>CALB cell: Test passed on 28 June 2023 [59].</p>
Cell	RoHS	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment, 2011/65/EU Annex II, and its amendment	<p>REPT cell: Test passed on 11 July 2023 [7].</p>

<sup>1</sup> Zhejiang Academy of Science & Technology for Inspection and Quarantine

<sup>2</sup> CVC Testing Technology Co.,Ltd

## 6.2 UL 9540A testing

UL 9540A testing is a destructive test method used to evaluate the thermal runaway impacts on a BESS and gather data to assist in assessing or developing mitigation measures for failure events, propagation of failures, or consequences of an event, such as an explosion or fire. The test, which does not have pass/fail criteria, can be performed on a cell, pack, or unit level. UL 9540A is currently considered the most appropriate published methodology to provide comprehensive, consistent, and reliable third-party data for battery failure testing. DNV notes that Section 1207.1.5 of the 2021 IFC dictates that all ESS must be tested per UL 9540A.

CLOU has tested their battery cells, packs, and units in accordance with the 4<sup>th</sup> edition of the UL 9540A test methodology.

### 6.2.1 Cell-level testing

REPT's 314 Ah cell has been tested according to the 4<sup>th</sup> edition of UL 9540A. A total of five samples were tested using the same procedure to assess the repeatability of the cell's behavior. The venting temperature and the thermal runaway onset temperatures were averaged across four samples. The fifth sample was utilized for vent gas capture. Table 6-3 outlines the key test results of the UL 9540A test on REPT's 314 Ah cell [7].

**Table 6-3 REPT's 314 Ah cell level UL 9540A test results**

Test parameter	Results or data collected
Thermal Runaway Methodology	External heating using thin film with 4 °C/min to 7 °C/min thermal ramp
Average Gas Vent Temperature	127.9 °C
Average Thermal Runaway Temperature	179.8 °C
Venting Gas Volume	188 L
Gas Composition	H <sub>2</sub> 54.373%, CO <sub>2</sub> 24.614%, CO 10.095%, Hydrocarbons 10.918%
Lower Flammability Limit at Ambient Temperature	7.7%
Lower Flammability Limit at Vent	7.1%
Max. Explosion Pressure (Pmax)	115.7 psig
Burning Velocity (Su)	79.8 cm/s

Test method and deviations: DNV did not identify deviations from the test method described in UL9540A. The cell-level UL 9540A report outlines the testing methods and results in a manner consistent with the requirements of UL 9540A, 4th edition, section 7.

Venting and thermal runaway temperatures: The cell venting temperature and thermal runaway temperature were 127.9 °C and 179.8 °C, respectively. The cell showed a 51.9 °C difference between the temperature at cell venting and the thermal runaway event, which meets the expectation. The large temperature difference between the venting and the thermal runaway may provide enough time for safety systems to detect and respond to thermal events.

Gas composition and volumes: During the UL 9540A test, the measured hydrogen gas composition was 54.373%, which is slightly high yet within the typical range. The cell level UL 9540A test demonstrated evident thermal runaway with flammable gas, which can lead to catastrophic consequences such as fire or explosion. To ensure safe operation, it is crucial to

investigate the thermal runaway characteristics at higher levels, such as battery packs and racks. Therefore, the UL 9540A test must also be performed at the module (pack) and unit levels where REPT's 314 Ah cells are used.

## 6.2.2 Module(pack)-level testing

CLOU's battery module has been tested to the 4<sup>th</sup> edition of UL 9540A. Thermal runaway was induced by applying a film heater at the center of the main face of the cell. The initiating cell underwent thermal runaway, leading to cell-to-cell propagation to an adjacent cell in the pack. The test results indicated that smoke was released during the test; however, no fire was observed. Table 6-4 outlines the main results and observations of the module level UL 9540A test [7].

**Table 6-4 CLOU's battery pack UL 9540A test results**

Test parameter	Results or data collected
Number of damaged cells	2 (including 1 initiating cell)
Battery pack weight loss	682.1 kg before test; 680.6 kg after test
Measured peak chemical heat release rate HRR	1.57 kW
Measured peak smoke release rate SRR	0.243 m <sup>2</sup> /s
Total smoke release TSR	49.55 m <sup>2</sup>
Gas composition	83.5 L H <sub>2</sub> , 25.2 L CO, 50.6 L CO <sub>2</sub> , 164.4 L hydrocarbons (methane equivalent)

As shown in Table 6-4, the thermal runaway of cells generated 83.5 L of hydrogen, 25.2 L of carbon monoxide, 50.6 L of carbon dioxide, and 164.4 L of hydrocarbon gases. DNV notes that the total gas volume, including the constituents, was much less than what DNV observed in other battery packs that use 314 Ah cells in the market. CLOU shall clarify these results further.

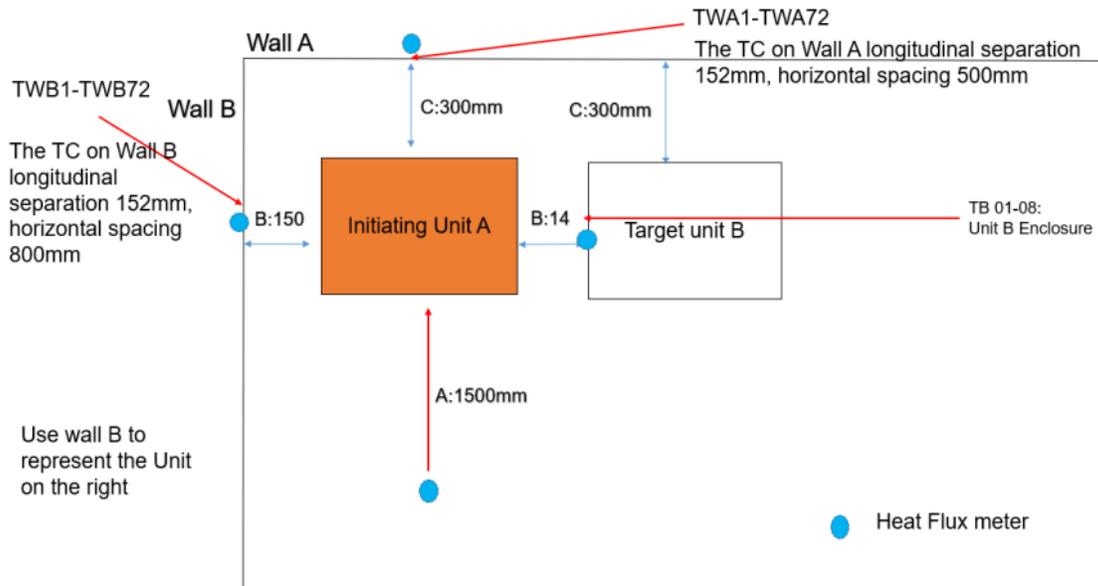
Hydrogen and hydrocarbons, such as methane and propane, are explosive and flammable gases. In addition, carbon monoxide is a highly flammable gas that can readily form an explosive mixture with air. Carbon dioxide is an asphyxiant. DNV considers it best practice to utilize the module-level UL 9540A results to validate the safety design features of the BESS. More detailed information regarding the safety features is included in Section 6.4.2 herein.

## 6.2.3 Rack (unit)-level testing

CLOU's battery string was tested to the 4<sup>th</sup> edition of UL 9540A test. For the purposes of the test, a Unit was considered an open battery rack without an enclosure. The test sample comprised 8 packs without an HV box. In the unit-level test, a complete Unit was installed and surrounded by a target (dummy) Unit and walls at the intended installation distance. Thermal runaway was induced in the battery cells of one of the packs in the initiating Unit. The UL 9540A unit-level methodology outlines procedures for different types of installation, including indoor and outdoor ground-mounted systems. The test report indicates that this Unit has been tested for non-residential indoor ground-mounted use [7].

The test set-up is as follows:

- Two instrumented walls were constructed to form a half perimeter around two sides of the initiating and target units.
- 2 units were used in the test (see Figure 6-1)
- Figure 6-1 displays the minimum separation distances between the unit and the wall, and between units.



**Figure 6-1 Unit level UL 9540A test setup**

During the test, no flaming explosive hazards, including deflagration or detonation, were observed. Furthermore, there was no flying debris, sparking, electrical arcs, or other electrical events observed. No integral fire suppression system was used during the test.

Table 6-5 provides an overview of the performance conditions set forth by UL 9540A and a summary of the Unit test observations.

**Table 6-5 Summary of UL 9540A unit (rack) level test results**

Performance condition	Test observation/remark
Flaming outside the initiating BESS unit is not observed	No flaming was observed internally or externally of the Unit during the test.
Surface temperatures of modules within the <u>target</u> units adjacent to the initiating unit do not exceed the temperature at which thermally initiated cell venting occurs, as determined in 7.3.1.8.	The maximum surface temperature of the packs within the target Units was 21.1 °C, far below the cell venting temperature of 127.9 °C reported in the cell-level test.
For units intended for <u>installation in locations with combustible constructions</u> , surface temperature measurements on wall surfaces do not exceed 97 °C of temperature rise above ambient temperature per 9.2.15.	The maximum surface temperature on the adjacent walls was 23.1 °C, far below the 97 °C temperature rise performance criteria.
Explosion hazards are not observed, including deflagration, detonation, or accumulation (to within the flammability limits in an amount that can cause a deflagration) of battery vent gases.	Explosion hazards were not observed during the test (internal and external).
Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m <sup>2</sup> .	Heat flux is 0 kW/m <sup>2</sup> in the center of the egress.

Pack-to-pack and unit-to-unit propagation were not observed during testing. The outlined performance criteria have been met, indicating that the separation distances used during testing provide an adequate thermal barrier between packs and can therefore be used as the minimum separation distances for installation.

Although the string level tests were treated as UL 9540A unit level test, it is applicable for indoor floor mounted installation. If the battery strings are intended to be installed in a cabinet or container which has few spaces and high tightness, flammable

gas concentrations due to thermal runaway could be greater than 25% lower flammability limit (LFL), which present high fire and explosion hazards. CLOU shall apply appropriate explosion protection measures to the BESS container.

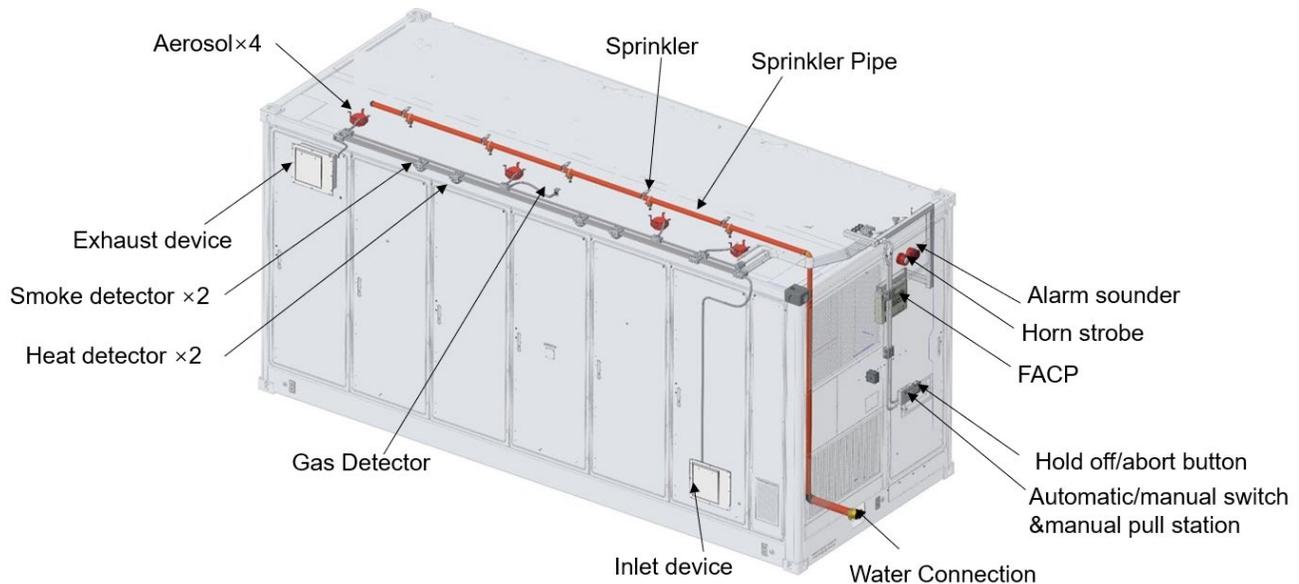
### 6.3 CLOU enclosure design

CLOU’s Aqua C2.5 BESS is enclosed in a 6,058 mm x 2,438 mm x 2,896 mm enclosure with an IP55 ingress protection rating. In general, an IP55 rating indicates the level of protection an enclosure provides against solid objects (first number) and liquids (second number). The first number “5” indicates complete protection against contact with live or moving parts inside the enclosure and against harmful dust deposits. The ingress of dust is not totally prevented, but cannot enter in an amount sufficient to interfere with the satisfactory operation of the enclosure. The second number “5” indicates that water projected by a nozzle against the enclosure from any direction will have no harmful effect. DNV finds CLOU’s BESS suitable for outdoor use.

### 6.4 Fire and explosion protections

#### 6.4.1 Fire suppression system

The fire suppression system comprises four main components: an automatic fire alarm system, an aerosol suppression system, a ventilation system, and a sprinkler system (manual control), as illustrated in Figure 6-2.



**Figure 6-2 Illustration of fire suppression system [60]**

Table 6-6 shows the key fire protection components in Aqua C2.5H.

**Table 6-6 Fire detection and suppression system devices in Aqua C2.5H**

Device	Model	Certification	Quantity	Unit
Fire alarm control panel (FACP)	MRP-2002E	UL 864	1	Set
Smoke detector	55000-326IMC	UL 268 EN 54-7:2018	2	pcs

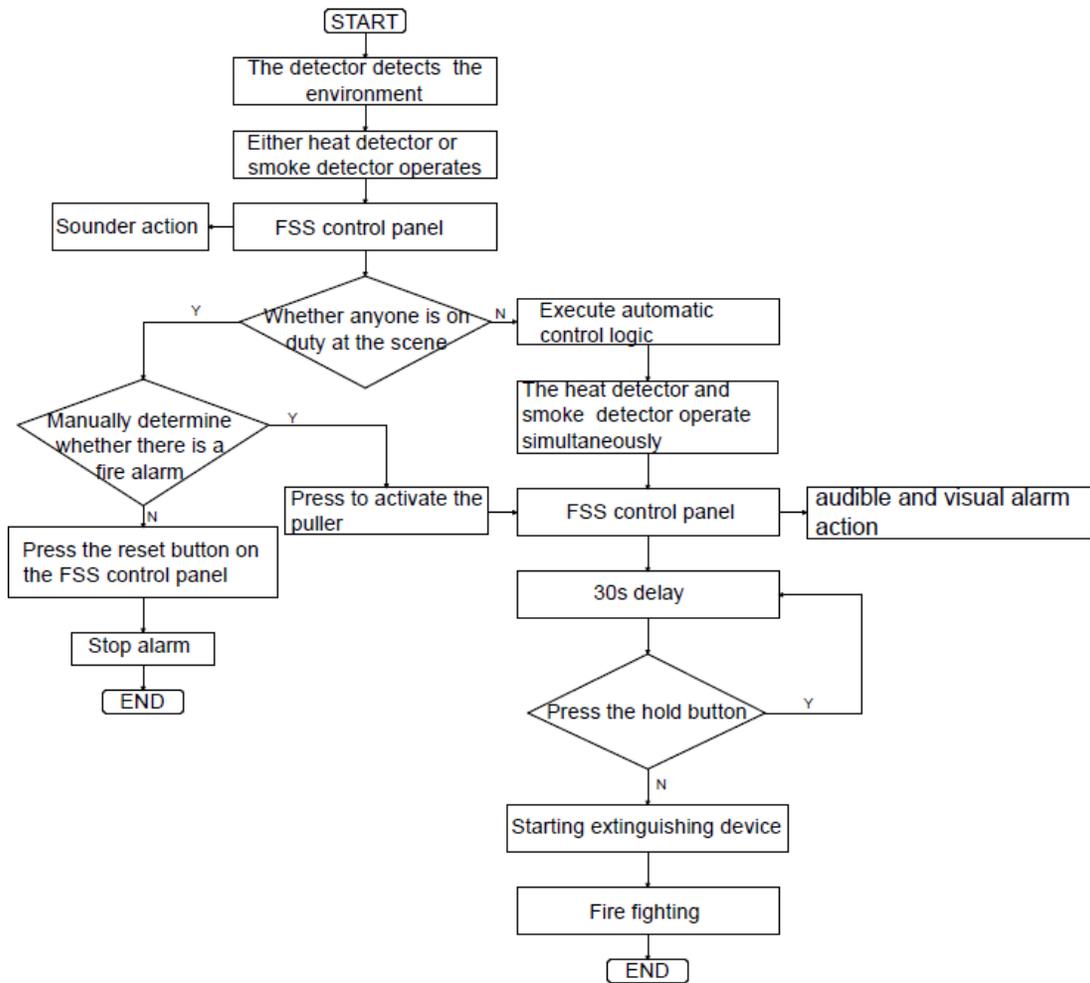
Device	Model	Certification	Quantity	Unit
Heat detector	55000-139IMC	ANSI/UL 521 EN 54-5:2017+A1:2018	2	pcs
Alarm bell	B6-24	UL 464 EN54-3:2001+A1:2022+A2:2006	1	pcs
Horn strobe	P2RK	UL 464 EN 54-3:2001+A1:2002+A2:2006 EN 54-23:2010	1	pcs
Manual pull station	HPS-DAK-SR	ANSI/UL 38	1	pcs
Maintenance switch	RCDS-1	ANSI/UL 864	1	pcs
Sprinkler	V2707	ANSI/CAN/UL/ULC 199	5	pcs
Hose coupling	DN65	/	1	pcs
Aerosol	PF-500S	ANSI/CAN/UL/ULC 2775	7	set
Gas detector	LT-SEN-M	UL 864; CAN/ULC-S527	1	pcs
Ventilation system – air intake louver	VP1A-KL-1	/	1	set
Ventilation system – air exhaust louver	VP1B-KL24	/	1	set
Deflagration panel (optional)	VIGILEX VL-SS, VD-SS, and V-SS	EN 14797:2006; EN 14491:2012; EN 14994:2007	6	pcs
Fan knob switch	RS1	/	1	set

The functions of the FSS mainly include:

- Automatic fire alarm system & Aerosol suppression system
  - 1st stage alarm: When either the heat or the smoke detector is activated, the FACP controls the activation of the alarm sounder and transmits the 1<sup>st</sup> stage alarm signal to the BAMU.
  - 2nd stage alarm: When both the heat and the smoke detectors are activated simultaneously, the FACP controls the activation of the horn strobe and transmits the 2<sup>nd</sup> stage alarm signal to the BAMU. After a 30-second delay, the aerosol release of the FACP is released
- Manual control: In case of emergency, the aerosol release can be initiated by pulling the manual pull station.
- Maintenance mode: When conducting tests or maintenance inspections, it is necessary to change the automatic mode to manual mode.

Note: Before the 30-second delay ends, the aerosol release signal can be paused by pressing and holding the hold-off/abort button.

Figure 6-3 shows the control flow diagram of the fire alarm system and the FSS.



**Figure 6-3 Control flow diagram of the fire alarm system and the FSS [61]**

If water fire protection is needed for cooling and temperature reduction, in case of a 1st stage alarm,

- 1) The interface of the fire hydrant at the station can be manually connected to the water interface of the water fire protection through the fire hose.
- 2) During the construction stage, connect the water interface of the water fire protection to the water source (a switch needs to be set up, which is usually off; open in case of fire).

There are five water sprinklers, each provides a water flow rate of about 57 L/min, which exceeds the design margin (totaling 282 L/min versus the design margin of 149 L/min) [62].

FSS will send status signals to BAMU, including aerosol release signals, 1st-stage alarms, 2nd-stage alarms, and fire system fault alarms.

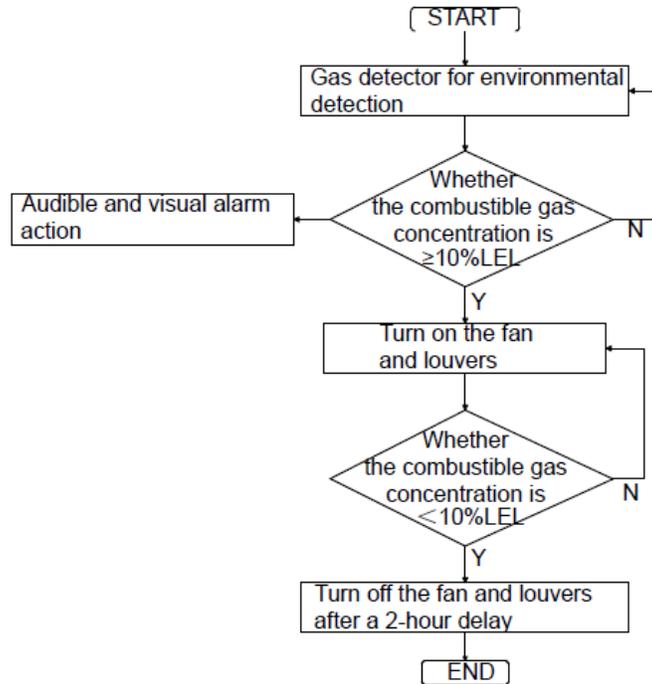
DNV notes that the FSS design in Aqua C2.5H meets expectations.

## 6.4.2 Explosion protection measures

Aqua C2.5H is equipped with an active ventilation system, which is required to comply with NFPA 69 design guidelines.

The control logic of the exhaust system works in the following mechanism (see Figure 6-4):

- When the concentration of combustible gas within the BESS enclosure exceeds 10% lower explosive limit (LEL), the FSS will open the motorized louvres and activate the exhaust fan. The FACP controls the activation of the horn strobe.
- The ventilation system will shut down automatically after 2 hours of operation only if the flammable gas concentration is continuously below 10% LEL; otherwise, it will continue to run.

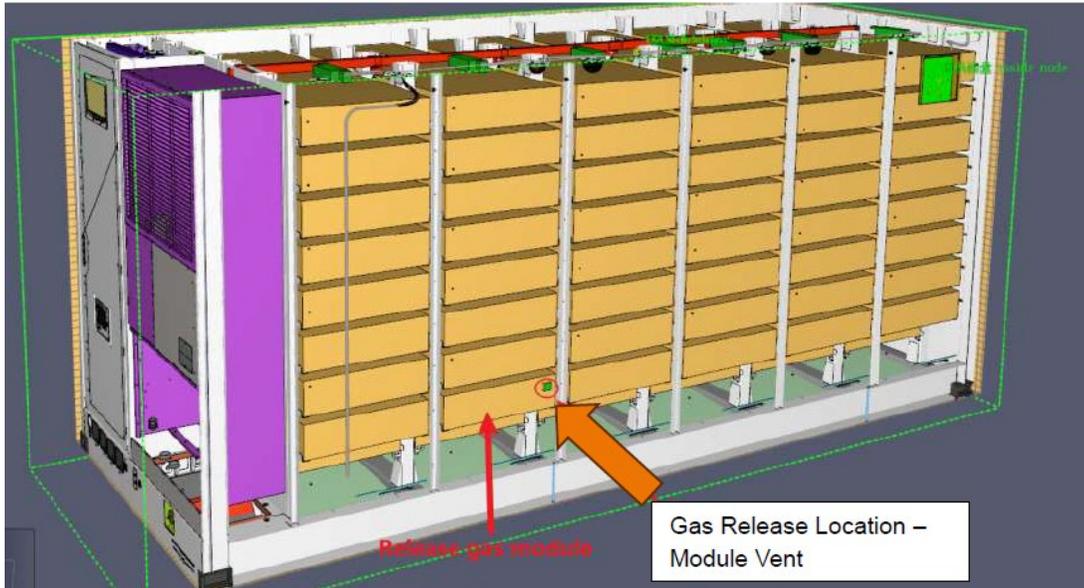


**Figure 6-4 Flow diagram of the ventilation exhaust system [61]**

DNV notes that the ventilation system remains open during aerosol release, which complies with the intent of NFPA 69, that is, the ventilation system shall be unconditionally activated upon detecting flammable gases.

The NFPA 69 simulation applied the following assumptions [60]:

- The thermal runaway characteristics of a single cell are based on the cell-level UL 9540A results for the 314 Ah cell manufactured by REPT.
- The composition of the off-gas matches that determined by the cell-level UL 9540A test. The simulation assumed that two cells experienced thermal runaway, yielding a gas release rate of 6.6 L/s, including a 5% safety factor for a conservative representation of the thermal runaway case.
- The simulation assumed a 15-second delay between the activation signal from the gas sensor and the initiation of fan operation for a conservative representation of the thermal runaway case.
- The BESS had one gas detector located on the ceiling of the container.
- The exhaust fan's airflow rate was 593.1 CFM, which is lower than the rated airflow of 912.4 CFM stated in the manufacturer's technical specification sheet.



**Figure 6-5 Locations of the gas release location**

The results of the CFD modelling indicate that the average global concentration of the combustible gas mixture remains steady at 0.868% once the exhaust system reaches full operational capacity, which is below the LFL of 25% (1.775%). DNV notes that CLOU shall investigate the impact of different gas release locations other than those in the current NFPA 69 report, as shown in Figure 6-5.

DNV notes that the explosion-protection design of Aqua C2.5H complies with the requirements of NFPA 69 and meets expectations.

DNV notes that complying with NFPA 69 does not entirely eliminate the potential for explosion hazards.

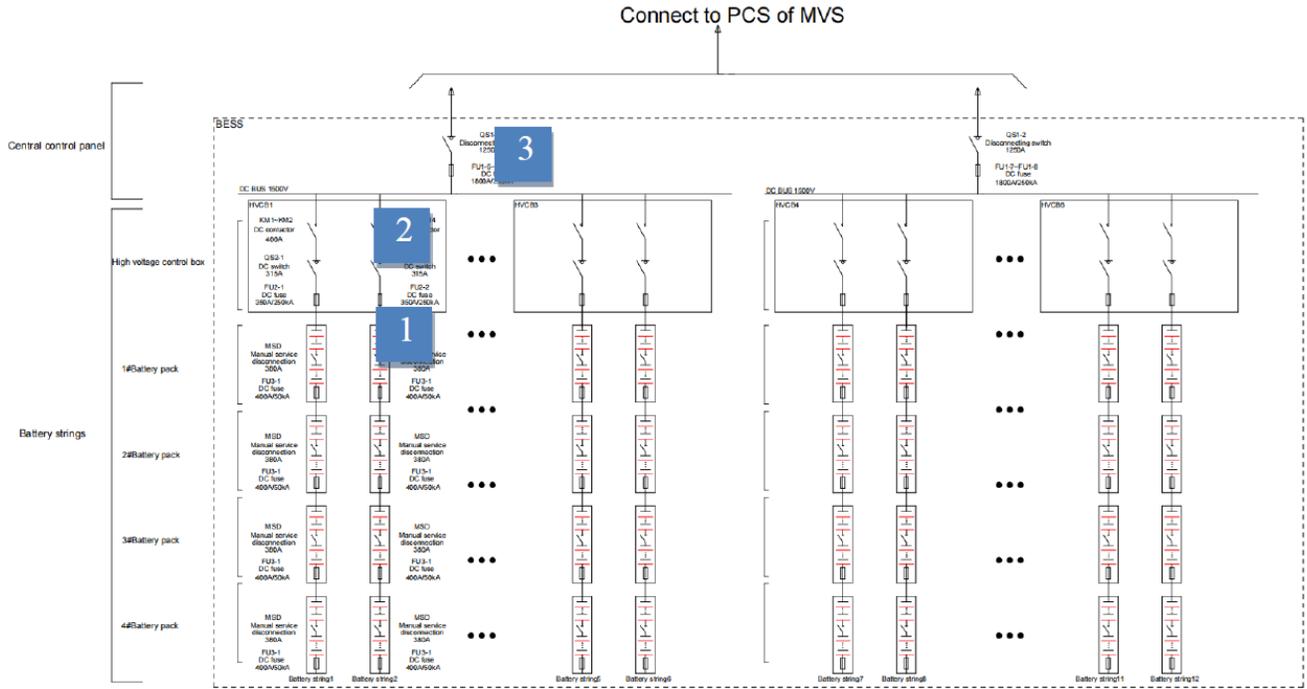
At the time of writing this report, a report demonstrating compliance with NFPA 68 requirements is not available.

## 6.5 Electrical safety

Electrical hazards can occur during BESS operation and maintenance, such as electric shock, overcurrent, and arc flash, and should be protected with appropriate measures.

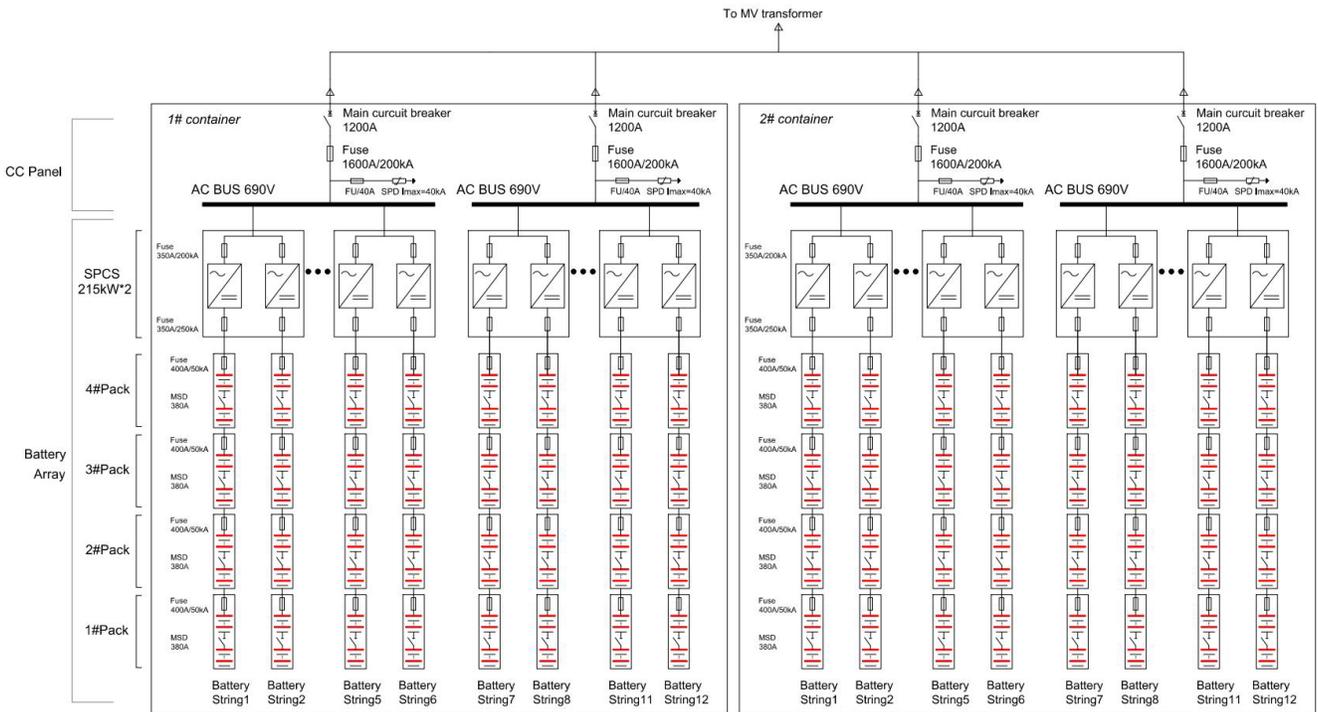
Electric shock is a common electrical hazard and is addressed in standards, codes, and regulations for electrical components and equipment. Compliance with these standards, codes, and regulations meets the minimum requirements against electric shock.

Due to the high short-circuit current of batteries, overcurrent protection is essential in the BESS. As illustrated in Figure 6-6, Aqua C2.5H BESS has three levels of overcurrent protection: a pack-level fuse, a string-level HVCB fuse, and a system-level CC panel fuse, rated at 400 A, 350 A and 1,800 A, respectively [63]. The electrical safety design features of Aqua C2.5H meet expectations.



**Figure 6-6 Aqua C2.5H BESS electrical layout**

The electrical layout of Aqua C2.5S BESS (Figure 6-7) shows the overcurrent protections at battery packs, battery strings / SPCS DC side, SPCS AC side, and the CC panel [64]. Its DC-side design is similar to that of the Aqua C2.5H BESS, and the AC-side fuse ratings are 350 A for the SPCS and 1,600 A for the CC panel. These ratings and their breaking capacities are compatible with the batteries and the system. The electrical safety design features of Aqua C2.5S meet expectations.



**Figure 6-7 Aqua C2.5S BESS electrical layout**

Arc flash is an electrical explosion or discharge, which occurs between electrified conductors during a fault or short-circuit condition. It is not possible to completely avoid arc flash hazards when working near live parts, such as battery terminals. The incident energy of an arc flash and PPE ratings shall be evaluated and marked on the equipment. CLOU conducted an arc flash risk assessment for the Aqua C2.5H and Aqua C2.5S BESS in accordance with NFPA 70E and IEEE 1584 standards. [63] [64]. The maximum calculated incident energy is 2.76 cal/mm<sup>2</sup> at the DC bus of Aqua C2.5H BESS and 5.6 cal/mm<sup>2</sup> at the MV terminal of Aqua C2.5S BESS. CLOU has provided warning labels based on the assessment results shown in Table 6-7 and Table 6-8. DNV notes this approach to be consistent with the industry's best practices.

**Table 6-7 Aqua C2.5H BESS DC arc flash assessment results**

Fault location	Faulted BUS ID	Calculated Incident Energy (cal/cm <sup>2</sup> )
1	Input_HVCB1	2.04
2	Output_HVCB1	2.53
3	6P4S_1#BAT Bus	2.75
4	C1-DC1-OUTBus1	2.76
5	PCS_BAT Bus	2.76
6	1P1S_BAT Bus	0.241

**Table 6-8 Aqua C2.5S BESS AC arc flash assessment results**

No.	Equipment	Label	Calculated Incident Energy (cal/cm <sup>2</sup> )
1	SPCS terminal	SPCS1/2-AC output	0.4
2	CC Panel	CC Panel	5.4
3	MV terminal	MV terminal	5.6

## 6.6 Hazard mitigation analysis

Hazard mitigation analysis (HMA) is an industry best practice that is established by Chapter 4 of NFPA 855. NFPA 855 is the Standard for the Installation of Stationary ESSs, which DNV considers the most comprehensive set of best-practice guidelines in the industry. It is further required under Section 1207.1.4 of the 2021 IFC as the basis for increasing the maximum allowable quantities (600 kWh for Lithium-ion ESS).

The HMA report, which Atar Fire produced [65], contains the HMA of the following failure modes:

- A thermal runaway or mechanical failure condition in a single ESS unit.
- Failure of an energy storage management system or protection system.
- Failure of a required protection system, including but not limited to HVAC, exhaust ventilation, smoke detection, fire detection, fire suppression, or gas detection.

Atar Fire evaluated CLOU's AQUA C2.5H by the following approval conditions:

- Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in Section 9.6.4 of the NFPA 855.
- Fires and products of combustion will not prevent occupants from evacuating to a safe location.
- Deflagration hazards will be addressed by an explosion control or other system.

DNV notes that the HMA meets the expectations. However, DNV notes that it is essential to evaluate the residual risk associated with each failure mode, taking into account all existing mitigation measures.

## 6.7 Emergency response guide

Emergency response guide (planning) is a crucial aspect of the BESS project safety. Emergency response planning provides guidance and training to facility and first responder personnel, accounting for the existing safety features of the BESS. The combination of system safety features and proper guidance and training ensures safe operation and response during an emergency or safety event associated with the BESS. An Emergency Response Guide (ERG) can help inform CLOU's site-specific Emergency Response Plans (ERP).

CLOU's ERP contains information on fire protection & safety measures, firefighter action guidelines, and post-fire handling measures. DNV finds that the initial ERP generally addresses BESS-related hazards and associated action plans. This generic ERP will require site-specific updates on a project-by-project basis. Accordingly, DNV recommends updating the ERP with all relevant site-specific information for each project. Typically, the ERP will be effective from the start of commissioning through the end of decommissioning for a project.

## 7 INSTALLATION AND INTEGRATED SYSTEM EVALUATION

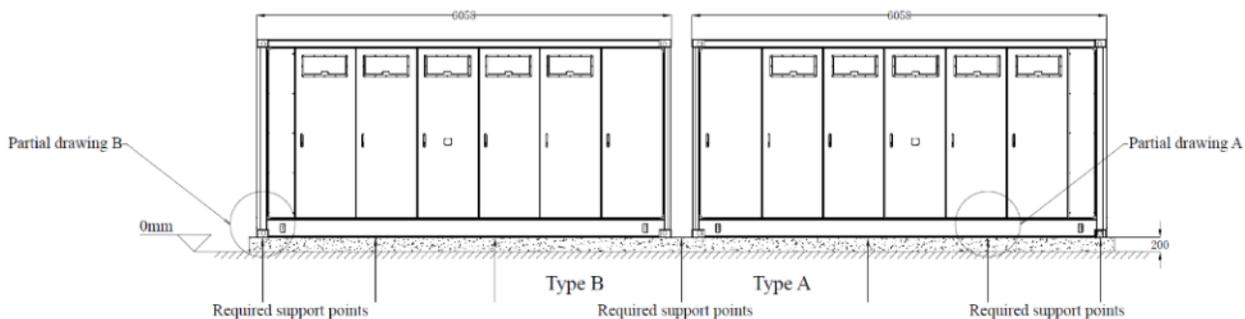
As part of its evaluation of the installation and integration processes of Aqua C2.5H and Aqua C2.5S, DNV received and reviewed:

- Aqua C2.5H Containerized BESS user manual, published by CLOU [66] [67]
- Aqua C2.5S Containerized BESS user manual, published by CLOU [68]
- 5.2 Aqua C2.5H-5015-IEC-Requirements for spacing between ESS boxes [69]
- 5.2 Aqua C2.5H-5015-UL-Requirements for spacing between ESS boxes [70]

Aqua C2.5H and Aqua C2.5S are both 20-foot utility-scale containerized systems with comparable weight and similar configurations including LFP battery cells, BMS, FSS, TMS, and auxiliaries. As a result, the installation requirements are generally consistent, apart from differences in electrical wiring, commissioning, and start-up procedures, which arise from variations in system design.

### 7.1 On-site system integration

Aqua C2.5H is fully integrated at the factory and arrives at the project site with battery packs inside the 20-foot container to reduce installation cost. Two of the container faces contain doors; one set at the front for access to the battery packs and one set on the container side for the chiller and electrical compartments. CLOU maintains two variants of the container: Type A and Type B, which are mirror images of one another and can be observed in Figure 7-1. The mirror image configuration of the two variants allows for side-by-side container installation, back-to-back installation, or a combination of both.

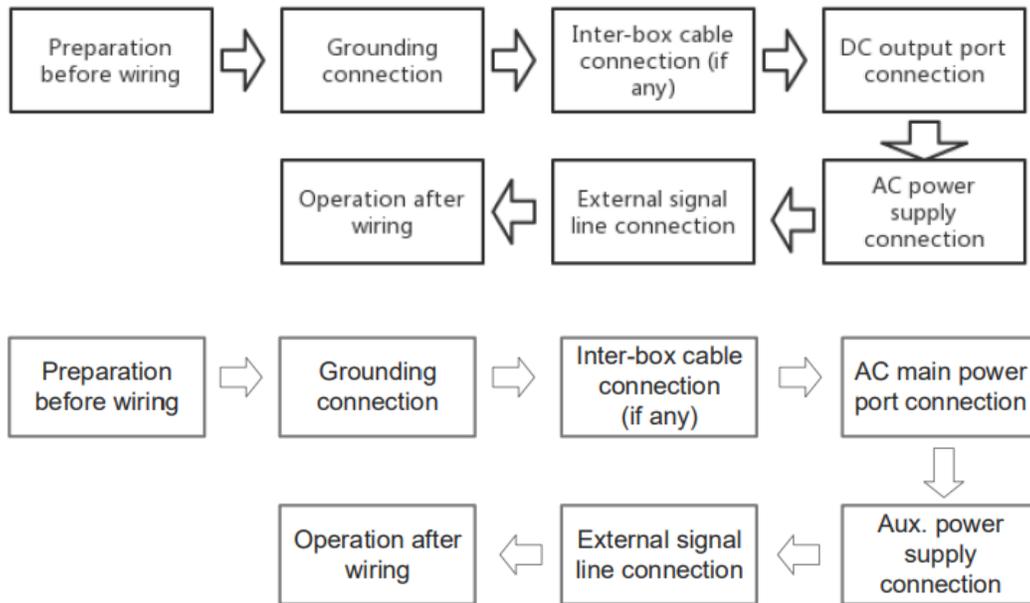


**Figure 7-1 Type A and B configurations of the Aqua C2.5H BESS container**

BESS containers which are transported to their final resting spot on site are to be welded to the foundation, which is required before personnel are allowed to access the battery compartment for the electrical installation and wiring.

After the containers are secured to the foundation, personnel must connect a cable from the site grounding network to three external grounding points and one internal ground bus bar.

For the electrical wiring portion of the on-site integration, CLOU provides a list of tools to complete the work and specified that only qualified and trained operators can perform electrical connection, which DNV notes meeting industry expectations. Figure 7-2 in the user manual shows the order of major electrical wiring connections.



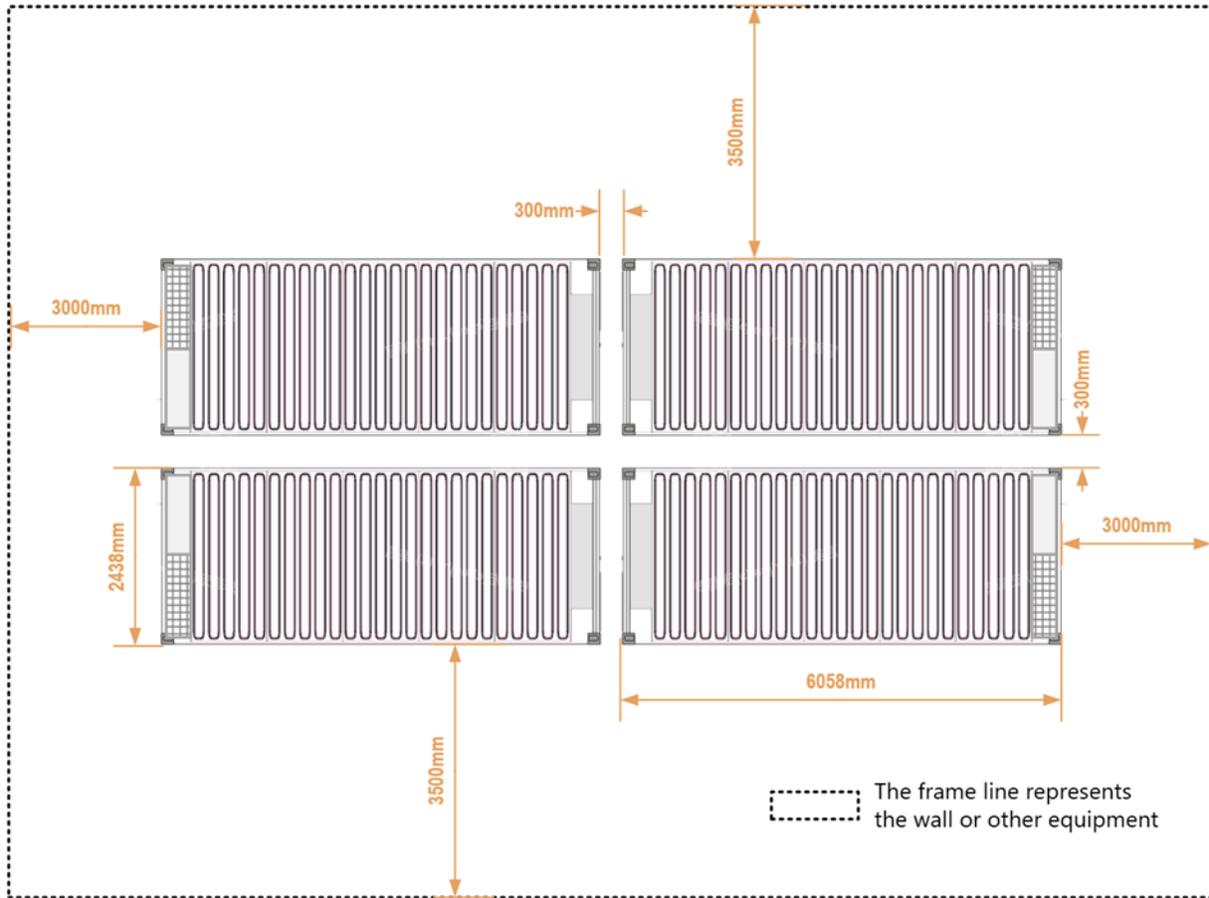
**Figure 7-2 Wiring workflow diagram of Aqua C2.5H (above) and Aqua C2.5S (below)**

All cables/wires like DC power, AC auxiliary, communication, SLC and grounding are routed from the bottom of the enclosure, where the BESS maintains pre-made inlet and outlet holes. Once all connections are made to/from the container, the holes shall be tightly sealed with suitable materials.

The wiring process for a single container begins with connecting power cables (DC for Aqua C2.5H, AC for Aqua C2.5S) from the external PCS (Aqua C2.5H) or SPCS (Aqua C2.5S) to the collection bus in the electrical cabinet. After the DC power cables are wired, personnel should connect auxiliary AC power supply cables to the enclosure auxiliary power bus, located in the same cabinet. This is followed by routing the SLC cable through the bottom of the electrical cabinet to the local SLC controller. After all electrical and communication connections are made, a thorough wiring inspection is required to be performed. All tools are to be removed from the enclosure, and all enclosure penetrations are to be sealed. Once the above is complete, personnel can install the UPS units inside the electrical cabinet.

## 7.2 System space requirements

Figure 7-3 illustrates the minimum spacing requirements for two containers installed side-by-side and back-to-back. Each container measures approximately 2,438 mm in depth and 6,058 mm in width. When installed in this configuration, a clearance of 3,000 mm is required on the battery door side of each container to allow the doors to open fully without obstruction. Additionally, a clearance of 3,500 mm must be maintained between the containers and any surrounding walls or equipment. The spacing between the non-door faces of adjacent containers should be at least 300 mm. This arrangement ensures safe access and operational functionality within the installation area.



**Figure 7-3 CLOU BESS enclosure spacing diagram**

### 7.3 Site requirements

Adhering to specific site requirements is crucial for ensuring the reliability, safety, and longevity of integrated energy storage systems. Proper foundation construction and site preparation prevent issues such as equipment misalignment, door malfunctions, and operational inefficiencies. By meeting standards for mechanical support, cable routing, and maintenance access, the system can operate effectively under various conditions, reducing the risk of failures and costly repairs.

Before the CLOU BESS is to be installed on-site, the installation site must be prepared in accordance with the Owner’s approved permitted design and must ensure that the site meets the requirements for a “remote” designation according to NFPA 855 (i.e. be located more than 30.48 m from buildings, lot lines, public ways, hazardous materials). The Owner/Engineering, Procurement, and Construction (EPC) is responsible for preparing the soil to support the equipment installation. Local codes and standards, as well as the equipment weight, should be considered when evaluating soils, drainage, environment impact or other factors. Suitable foundations for the containers include concrete pads, concrete piers, helical screw piers or other types if the equipment anchoring requirements are met. However, the manual does not explicitly state those requirements, CLOU thinks the Owner/EPC is responsible for determining the application’s suitability. If temporary areas are required, they must be stable, dry, and protected from tampering.

## 7.4 Commissioning and maintenance

CLOU’s user manual details the commissioning steps to bring a container online. The BESS can only be put into operation after it is confirmed by trained and qualified professionals and allowed to interconnect by the local grid authority. The manual also recommends that before powering up, BESS with long downtime must undergo a comprehensive and detailed inspection to ensure all indicators meet requirements.

The commissioning process of Aqua C2.5H contains several steps, including:

- Cold Check
- Hot Testing
- Power Flow
- System Balancing and SOC Calibration
- Plant-Level System Control Verification
- Capacity Test

The initial cold check includes a record review of both mechanical and electrical installation steps, which cover container placement and anchoring, mechanical inspections, equipment grounding checks, and wiring verifications among others. The container exterior is also visually inspected for signs of leaks or damage and the chiller is inspected to ensure the coolant reservoir is full. Personnel then perform a high potential (hipot) voltage withstand and equipment grounding tests to ensure that no fault currents are detected.

Hot testing of the system includes a power-on sequence of the auxiliary breaker inside the container and commissioning of the FSS, which includes testing and calibrating the gas and smoke sensors. The chiller is then turned on to ensure that the coolant is flowing properly without leaks. The auxiliary rack is then turned on before the power switches (DC for Aqua C2.5H, AC for Aqua C2.5S) are closed, allowing the batteries to charge and discharge.

Further commissioning involves the use of the human-machine interface (HMI), which takes the form of a local web page. Through the HMI an operator is able to access real-time monitoring data of the strings and associated packs, as well as control balancing functions and assume control of the external PCS or SPCS output. To complete the commissioning process, operators perform a SOC calibration of the packs, followed by a final capacity test to measure the total usable energy of the unit.

Although DNV did not review a sample commissioning checklist, it considers the Aqua C2.5H’s commissioning process to be in line with industry norms.

DNV also reviewed the maintenance part of the user manual. The manual describes routine maintenance activities to be conducted at yearly and semi-annual intervals. Table 7-1 details the yearly maintenance steps, while Table 7-2 details the semi-annual maintenance tasks.

**Table 7-1 Yearly maintenance schedule for Aqua C2.5H**

Maintenance task list	Inspection method
Enclosure exterior	Visually verify the anchor bolts fixing the enclosure to the foundation and inspect for corrosion. Visually verify if the exterior is damaged, peeling paint, rusting, etc. Visually verify if door locking is normal and the sealing gasket(s) of every enclosure door is in good condition. Visually verify the external grounding point(s) is in place and secure, inspect for sign of corrosion with the metal frame.

Maintenance task list	Inspection method
Enclosure interior	Visually inspect the interior for dirt, foreign objects, accumulated dust, pest intrusion and water leaks. Inspect the interior for damage, peeling paint, oxidation, and other conditions. Verify the fastening points of the cabinet inside the enclosure for firmness and the presence of rust.
Battery pack and control box	Inspect the battery rack and equipment for signs of damage or deformity. Verify the temperature and humidity inside the battery rack. Verify that all packs and control box power wires and communication cable are tightly connected.
Inlet and outlet vents	Inspect the status of the ventilation exhaust fan and the louvers for dust blockages.
Chiller	Refer to chiller user manual for specific instruction to perform maintenance operation. Before shutting down the chiller, verify if there are abnormal noises and fans rotating without impediments.
Wiring and Cable Arrangement	Verify that all the input and output holes are well sealed. Inspect whether there is any damage to the power wires, auxiliary cable/wires and signal cable, especially whether any external surface in contact with the metal surface has cut marks.
Grounding and Equipotential Connections	Ensure internal grounding and bonding connections are in place and inspect signs of corrosions. Verify the grounding resistance value, not exceed 4Ω. Verify if the internal equipotential connections in the system are correct.
Central Control Room	Cycle all breakers in the LV panel. Visually inspect the auxiliary power cables and terminals wiring for dust, dirt and debris. Visually inspect the auxiliary power cables and terminal for damage or sign of abnormal heating. Visually inspect the auxiliary power cables and terminal wiring for any loose connection. Visually inspect the isolator switch and fuses for any signs of damage or abnormal heating. Visually inspect the UPS for any signs of damage or abnormal heating
Screws	Inspect for loose or missing screws inside the container.

**Table 7-2 Semi-annual maintenance schedule for Aqua C2.5H**

Maintenance task list	Inspection method
Ventilating system	Functional tests shall be conducted quarterly in accordance with 10.4.4.4 in user manual, and with the agreement of the system designer and AHJ, the test interval period may be extended for a maximum of 2 years.
Software maintenance	Confirm the configurable parameters in HMI. Confirm for updates to the software
Inlet and outlet vents	Inspect the status of the ventilation exhaust fan and the louvers for dust blockages. Inspect the ventilation control unit, ensure normal conditions.
Environmental temperature and humidity inspection	Verify if the recorded environmental temperature and humidity are within the specified operating range. Visually inspect condensate drain tubes to verify the tubes are free and clean of any dust, dirt or debris.
Basic functionality check	Verify the operation status of the DC contactor and ensure the open/close signal function is normal. Measure whether the 24V output voltage is within the specification range. Inspect the UPS battery operation record, whether current, voltage, and temperature are within usage range.

The manual also recommends that thermal imaging checks should be performed on each cabinet every 5 years immediately following the annual capacity test. The battery pack, control box, DC connectors and DC bus bar terminal lug connections are all to be thermally imaged to determine if there is any temperature condition outside the average values for the BESS.

DNV considers the maintenance schedule and additional thermal imaging to meet industry expectations.

## 8 QUALITY AND MANUFACTURING REVIEW

DNV has performed a review of the manufacturing and quality processes related to the battery packs and BESS containers produced at Yichun CLOU Energy Storage Technology Co., Ltd. (hereafter “Yichun CLOU”) in China. The manufacturing facility Yichun CLOU is a wholly owned subsidiary of Shenzhen CLOU Electronics Co., Ltd. and belongs to Midea Group.

### 8.1 Quality system evaluation

#### 8.1.1 Manufacturing management certificates

Yichun CLOU holds international management system certificates for ISO 9001:2015 (quality system), ISO 14001:2015 (environmental system), and ISO 45001:2018 (occupational health and safety system) [71] [72] [73]. Table 8-1 summarized the certifications, holders and their corresponding validity dates.

**Table 8-1 CLOU manufacturing facility quality certifications**

Standard	Description	Number	Authority	Validity
ISO 9001:2015	Quality management systems	CN19/32121.13	SGS	3 April 2026
ISO 14001:2015	Environmental management systems	CN19/32123.14	SGS	3 April 2026
ISO 45001:2018	Occupational health and safety management systems	CN20/30048.14	SGS	3 April 2026



**Figure 8-1 Yichun CLOU ISO 9001 & ISO 14001 & ISO 45001 certificates**

The latest external audit was performed in December 2024. Two minor findings were identified and have been corrected.

Beyond compliance with these standards, which is viewed as aligned with best practices, DNV has assessed Yichun CLOU quality management in each phase of the product and process life in detail. This review is covered in the following sub-sections.

## 8.1.2 Manufacturing quality management

Yichun CLOU has an in-house Quality Department comprising over 80 employees, organized into four specialized sections – R&D Quality, QMS and SQE, CQE and PQE.

Documentation is controlled at different locations based on their categories: quality manual and common procedures are managed by QMS while the working instructions are saved on local server. Some documents were updated without version number, such as the Customer Complaints Handling Procedures (document no. QMQ-NY-G3-09-11-2024). DNV recommends that all the documentation should be controlled in the same way and managed by specific personnel to the documentation control procedure.

DNV reviewed the quality documentations related to the incoming quality control (IQC), manufacturing and outgoing quality control (OQC). DNV notes that the reviewed documentation meets expectation.

CLOU has clear procedures for material or process changes to the Engineering Changes Management Instructions (document no. QMA-NY-G3-06-31-2025). The PLM system is used to control the working flow from engineering change request (ECR) to engineering change order (ECO) as shown in Figure 8-2. DNV views this is in line with the industry standard.

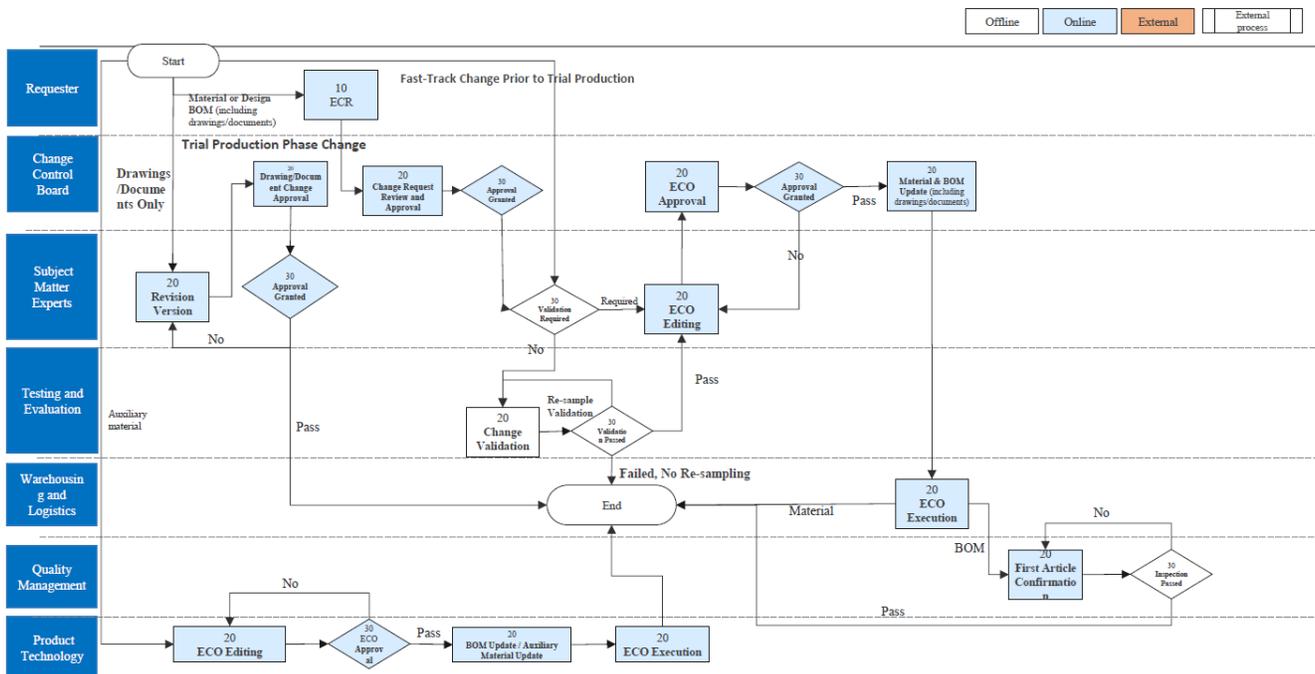


Figure 8-2 ECO working flow on PLM system

## 8.1.3 Supply selection and assessment

DNV reviewed CLOU's Supplier Development and Qualification Instruction (document no. QMA-NY-G3-14-13-2025) and the supplier audit records. CLOU has some basic requirements and a preliminary audit process for new suppliers. The documentation specifies that the on-site audit should include quality system audit (QSA), quality process audit (QPA) and corporate social responsibility (CSR). The records reviewed by DNV show that they comply with the requirements of the documentation.

**Table 8-2 CLOU's approved suppliers**

Component	Supplier
Battery cell	REPT, CALB
Container	Hesheng
Liquid cooling system	Taybo
Fire suppression system	Kentec, Apollo, Honeywell, Iron Man, Context Plus, Fire-Lite, etc.
PCS	CLOU

For the approved and qualified suppliers, CLOU conducts monthly performance evaluation to ensure sustained quality and operational consistency across its approved lists. The evaluation consists of three aspects – quality, delivery and cost according to the documentation Supplier Performance Management Measures (document no. QMA-NY-G3-14-03-2024a). Suppliers are evaluated and assigned a rating of A, B, C or D with corresponding actions taken in accordance with CLOU's criteria.

DNV views the supplier management is in line with the industry standard.

## 8.2 Manufacturing evaluation

Yichun CLOU Energy Storage Technology Co., Ltd. is located at No. 358, Chunhua Road, Yichun Economic and Technological Development Zone, Yichun City, Jiangxi Province, P. R. China. Figure 8-3 shows the entrance to the company.



**Figure 8-3 Main entrance of Yichun CLOU Energy Storage Technology Co., Ltd.**

Yichun CLOU is responsible for the assembly of battery packs, battery strings, BESS containers and SPCS.

DNV visited the production lines in Yichun CLOU, which are dedicated to Aqua C2.5H BESS manufacturing, including the assembly of battery packs, battery strings, SPCS and BESS containers on October 23<sup>rd</sup>, 2025. CL530PB314B104A battery

pack, CL532CB314B10404A battery string, CL215HX-IEC/UL SPCS, CL510C20-2507.9/5015.9-P36NA and CL510C20-2507.9/5015.9-P36NB containers were being produced during the visit. This visit focused on providing an overview of incoming material inspection, production processes, and quality management throughout product testing.

### 8.2.1 Facility overview

Yichun CLOU was established in November 2017, with an area of approximately 25 acres and about 400 employees. This factory conducts the assembling, debugging and testing of battery packs, BMSs, SPCSs and BESSs. While this factory also processes cable harnesses.



**Figure 8-4 Layout of Yichun CLOU [74]**

There is one pack workshop and two BESS assembly workshops. The production capacity is determined by battery packs production as Table 8-3.

**Table 8-3 Yichun CLOU pack production capacity**

No.	Production line	Quantity	Annual Capacity (GWh)	Remark
1	Air-cooling pack production line	2	3	Operational
2	Liquid-cooling pack production line	2	9	Operational
Total		4	12	

### 8.2.2 Incoming/Raw Material Receiving

The incoming inspection area in Yichun CLOU factory is divided into several small areas to manage the materials or components at different stages, such as “to be inspected”, “inspected OK” or “inspected NG (Not Good)”. Each area was marked with clear label and frame, and non-conforming materials were fenced in designated, red-framed area.

And Yichun CLOU’s incoming inspection conducts several basic inspections to the raw materials, including dimensions checking, color checking, visual confirming and technical documentation checking.

DNV opines this approach for non-conforming materials management is in line with the expectation for similar production facility and the incoming inspection test capability aligns with the basic expectations in the industry.



**Figure 8-5 Incoming inspection area and non-conforming materials area**

Battery cells were stored at the specific three-dimensional warehouse shown in Figure 8-6, while regular components were stored at other warehouses shown in Figure 8-7. And electronic parts were stored in an isolated room, as shown in Figure 8-8, which's temperature, humidity and static were controlled. The warehouses were well organized and managed via Warehouse Management System (WMS). DNV finds CLOU's warehouse management to align with expectations.



**Figure 8-6 Battery cell warehouse and the automatic entry port**



**Figure 8-7 Common components warehouse**



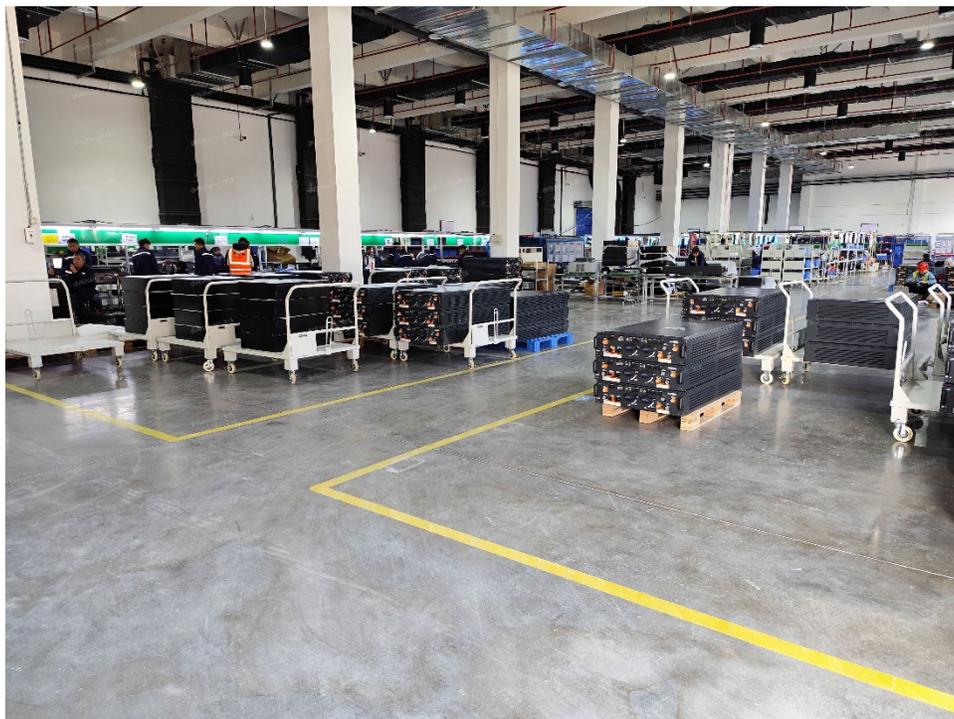
**Figure 8-8 Electronic parts storage room (static electricity elimination device outside the door)**

### 8.2.3 Manufacturing line review

Figure 8-11 and Figure 8-12 show an overview of the battery pack workshop, BMS assembly workshop and BESS container assembly workshop.



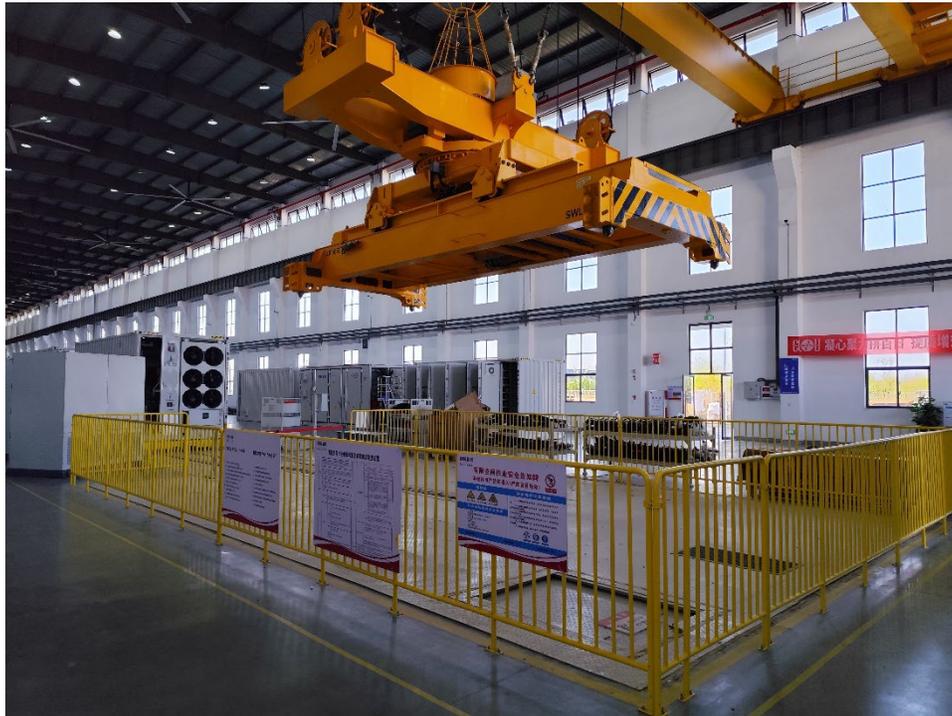
**Figure 8-9 Overview of battery pack workshop**



**Figure 8-10 Overview of BMS assembly workshop**



**Figure 8-11 Overview of SPCS assembly workshop**



**Figure 8-128 Overview of BESS container assembly workshop (beginning of the production line)**

Figure 8-13, Figure 8-14 and Figure 8-15 illustrate the processes for battery and BESS container manufacturing at Yichun CLOU, including many critical processes, such as pack stacking, laser welding, and safety and functional testing.

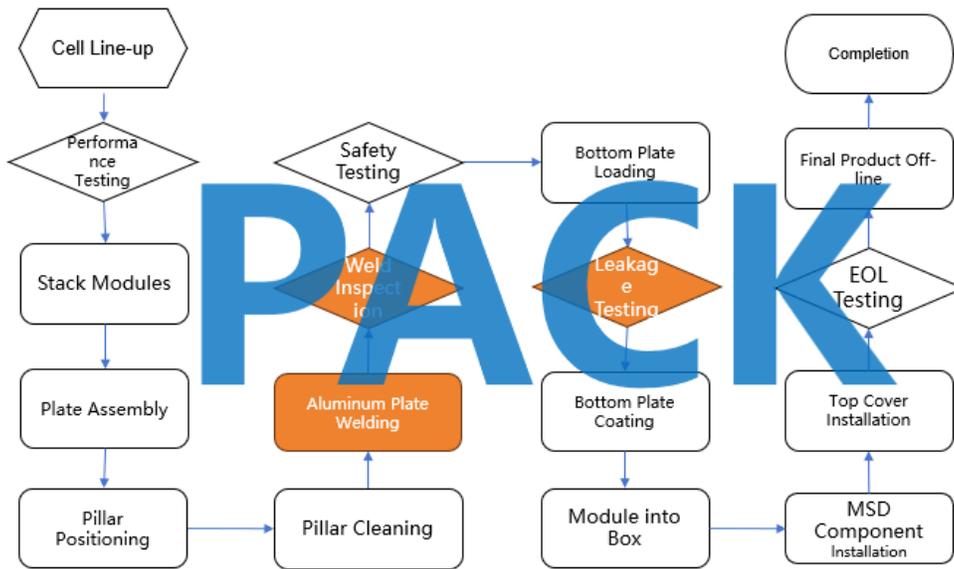


Figure 8-13 Battery pack process flow

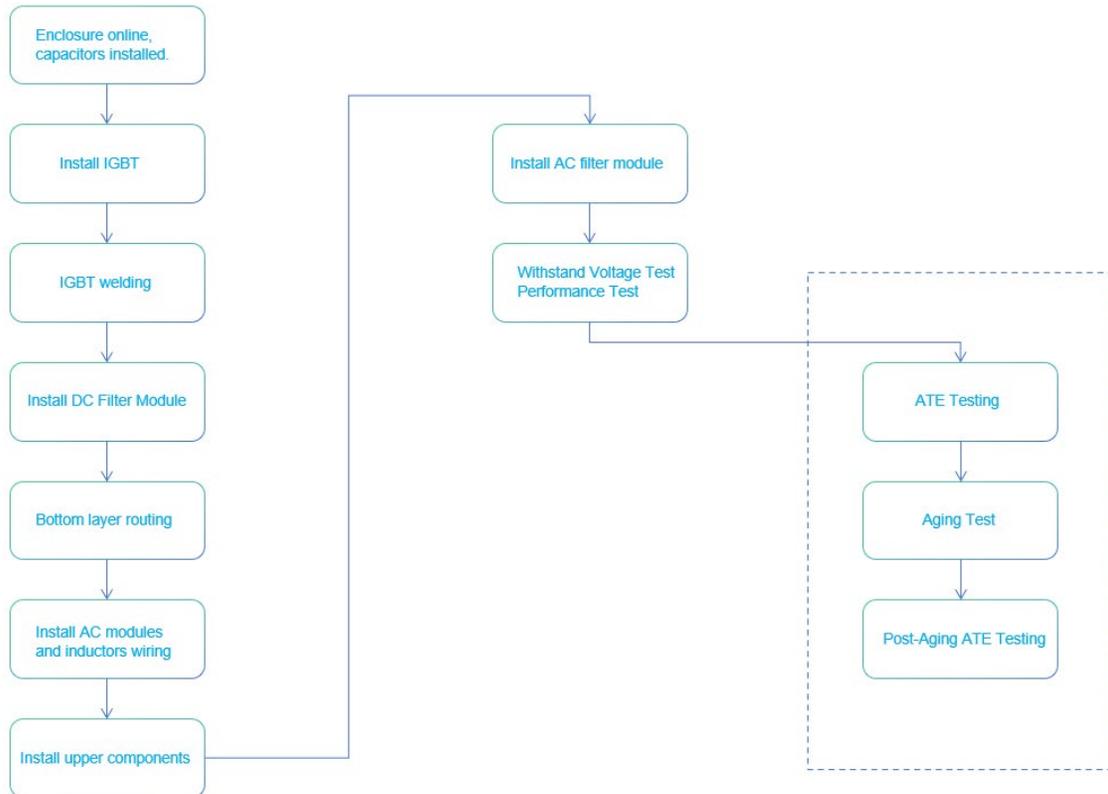
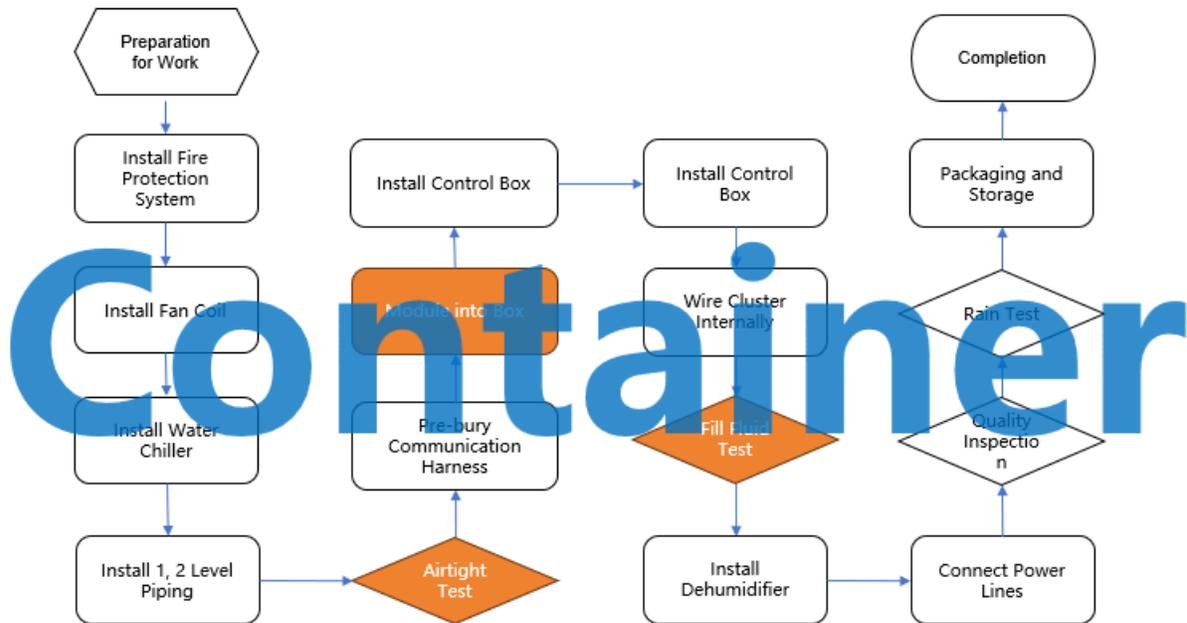
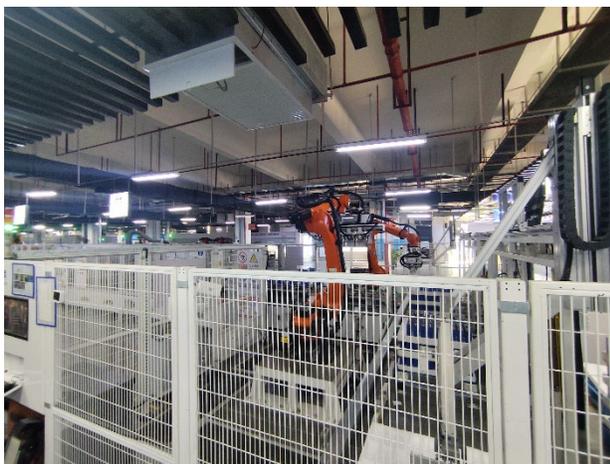


Figure 8-14 SPCS process flow



**Figure 8-15 BESS container process flow**

DNV visited the liquid-cooling battery pack production line for CL530PB314B104A and witnessed the manufacturing processes as shown in Figure 8-16. The production lines in pack workshop are highly automated and managed through Manufacturing Execution System (MES). The processes are classified into regular, important and critical. In-line quality control stations were set up after the critical processes to monitor the consistency of manufacturing, such as machine visual inspection, tightness test, insulation test, and direct current internal resistance (DCIR) measurement. DNV considers CLOU’s automation and quality control implementation above typical industry average.



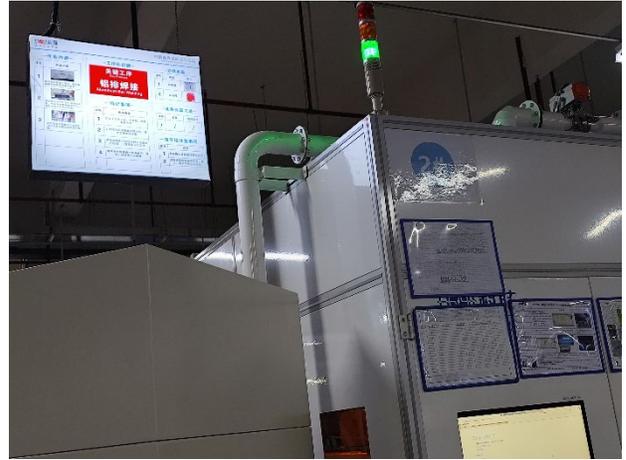
Cell feeding



OCV and IR test



Plasma cleaning of the battery cell surface



Welding of terminals



Welding quality CCD check and manual double check



Coating on the liquid-cooling plate



Placing the sub-module into the pack's enclosure



Air leakage test to battery pack



Safety test and DCIR measurement



AGV applied for transporting the battery pack among different workstation

**Figure 8-16 Liquid-cooling production line in the pack workshop**



**Figure 8-17 Assembled battery packs**

Regarding the CL215HX-IEC/UL SPCS manufacturing process, according to the production scheduling plan and production activity arrangement of Yichun CLOU on the day of the visit, DNV was only able to witness the final assembly process of the SPCS part. Other critical processes of PCBA production, ATE testing, and burn-in testing were not witnessed by DNV during the visit. For users or readers who are interested in this part of the content, further communication and confirmation with CLOU are required.

The BESS container integration process is shown as Figure 8-18. Based on observations during the visit, DNV believes that Yichun CLOU's BESS integrated production line and process are in line with industry expectations.



**Figure 8-18 Install packs into container and the monitor in one of the work station for showing the SOP**

The finished packs were stored in the workshop and then transported to the BESS container assembly workshop. When completed all the assembly processes, BESS containers were moved to the testing area where factory acceptance tests (FAT) were performed. Then FAT program includes visual inspection, torque check, ground resistance test, hi-pot test, communication test, auxiliary system test, charging / discharging test and other functional tests. DNV opines the FAT is in line with expectations for similar products.



**Figure 8-19 Finished product testing area**

Once the FAT procedure is completed, the finished BESS products will transfer to the specific storage area, then packing in the packing lot and waiting for the shipment.



**Figure 8-20 Finished BESS storage area and packing lot**

DNV found that Yichun CLOU had conducted lots of safety measures and training as shown in Figure 8-21. DNV opines these practices are in line with the average expectation in the industry and recommends Yichun CLOU further improving their EHS management, such as the management to hazardous chemical substance and correct PPEs equipment to the production line workers.



Warning labels and Lock-out-tag-out



First aid



EHS training venue

**Figure 8-21 Safety measures**

## 9 PRODUCT SUPPORT

DNV has reviewed the service infrastructure documentation provided by CLOU [75]. The evaluation of the service infrastructure is for the purpose of ensuring that CLOU can handle both software and hardware issues that may arise during the operation of its BESS products and can deliver its services in a timely manner. DNV reviews the service infrastructure against best industry practices to identify risks.

### 9.1 Service organization overview

As illustrated in Figure 9-1, CLOU has a Global Service Team comprising over 35 employees dedicated to overseas after-sales support and commissioning, operating from its headquarters (HQ) in China as well as regional offices in Europe, North America and South America. CLOU also has third-party service partners in each overseas regional office. Figure 9-2 presents several third-party service partners in North America along with the types of services they provide.

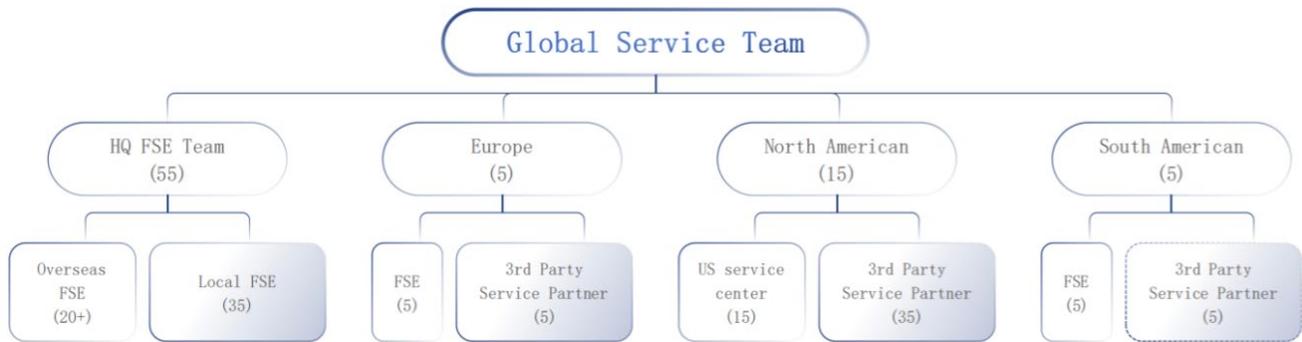


Figure 9-1 CLOU's global service team

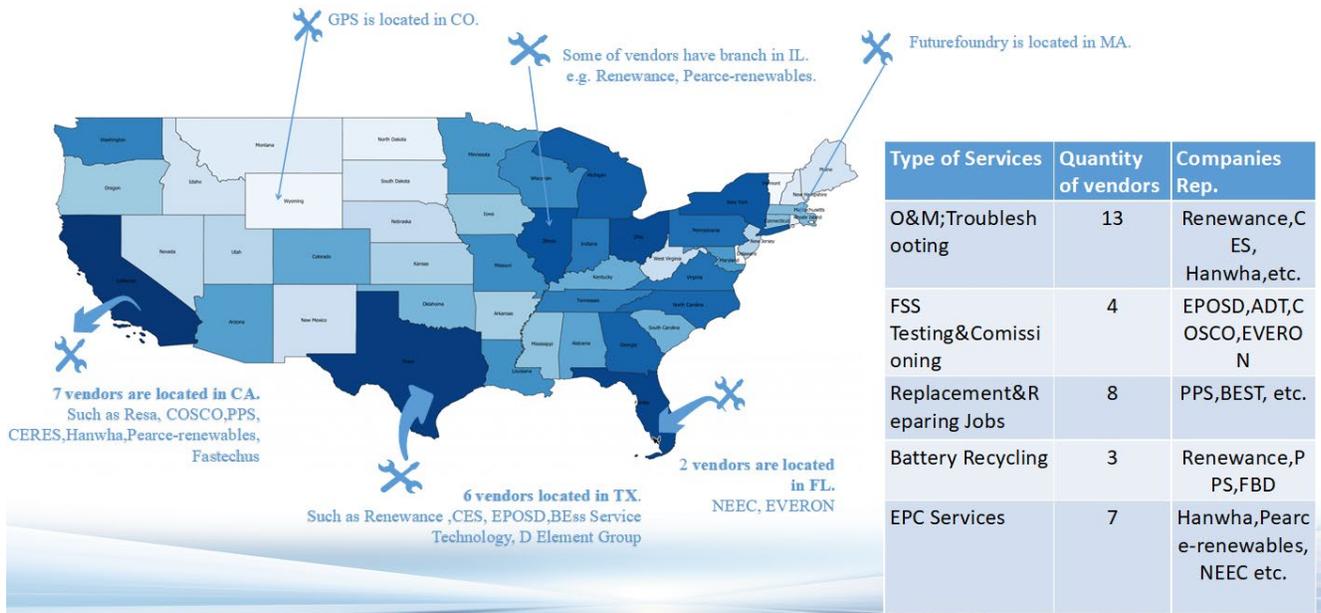


Figure 9-2 CLOU service vendors in North America

CLOU plans to establish a spare-parts storage warehouse in Bulgaria, which is expected to become operational in 2026.

The main after-sales service scope of CLOU includes maintenance, trouble shooting, spare parts storage management and training. Upon receiving a service request, CLOU initiates issue identification, conducts a preliminary evaluation, performs troubleshooting, and dispatches on-site technicians to address the problem. The company guarantees a total response time of no more than 48 hours.

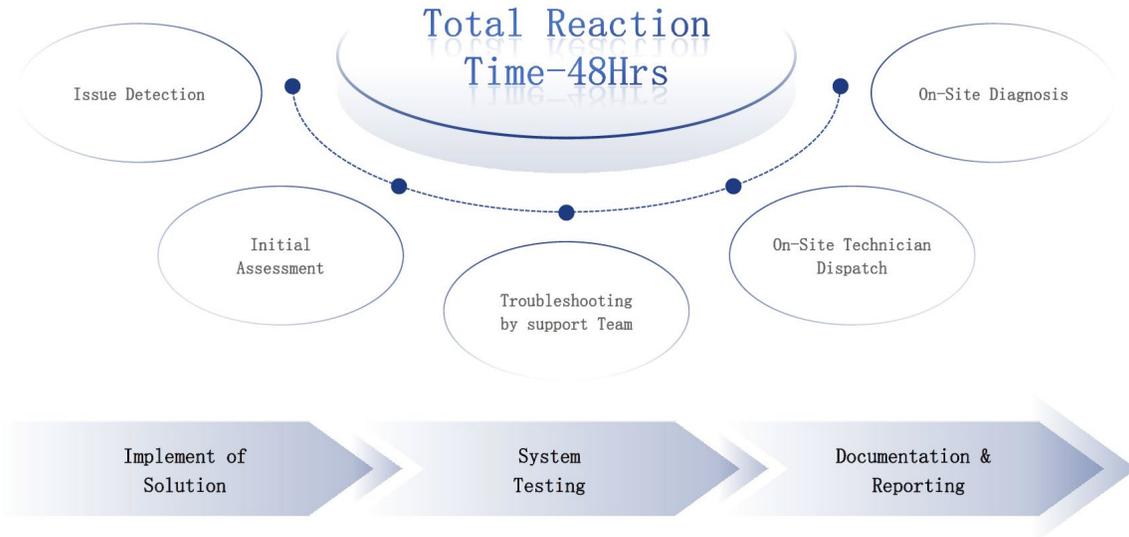


Figure 9-3 CLOU's after-sales response flow

## 9.2 Warranty

### 9.2.1 Warranty plans

CLOU provides three warranty plans as shown in Table 9-1 [76]. Plan 2 is the standard warranty provided by CLOU. If customers have specific requirements, they may negotiate with CLOU.

Table 9-1 Warranty plans

Features	Plan 1	Plan 2	Plan 3
Standard Warranty Period	3 years	3 years	3 years
Premium Warranty Period	5 years	5 years	5 years
Repair Services	Included	Included	Not included*
Spare Parts for Repair Services	Included	Included	Included
Maintenance Services	Included	Not included*	Not included*
Consumable Spare Parts	Included	Not included*	Not included*
Performance Guarantee	Included	Included	Included
Availability Guarantee	Included	Included	Not included*

Note: \* Items marked "Not Included " are subject to additional charges. Extended warranty is available at an additional charge.

#### Warranty period

DNV notes that the warranty period begins earlier of the following two dates:



- the date of final acceptance; or
- three months after the delivery of the last CLOU equipment.

DNV advises customers to pay attention to the early start-date clause, as it may reduce effective warranty duration if commissioning is delayed.

Standard warranty period for BESS is three years, which may be extended annually up to the 20<sup>th</sup> year of system operation. The coverage provided during the extended warranty period depends on the extended warranty plan selected by the buyer, and the relevant specific equipment supply contract. CLOU also provides annual renewal options. DNV considers the terms consistent with industry standards.

### **Repair services**

If a product failure falls within the scope of repair services, CLOU will dispatch service personnel to the project site to inspect and repair the defective products or components. For emergency situations, CLOU will respond within 4 hours of receiving the service request and, if necessary, initiate on-site personnel dispatch within 48 hours. For non-emergency cases, CLOU will respond within 8 working hours and initiate dispatch within the same 48-hour timeframe, if required.

### **Spare parts**

CLOU will supply customers with an initial three-year stock of spare parts required for warranty-related replacements, based on anticipated failure rates and system configuration. Customers are responsible for the proper storage, inventory control, and tracking of these parts. During the warranty period, CLOU will prioritize using this initial supply to address quality-related issues, and any remaining parts will be provided free of charge. CLOU reserves the right to replenish or reallocate spare parts at its sole discretion.

Any additional spare parts supplied after the initial delivery shall be supplied on Delivered-at-Place (DAP) delivery terms and conditions (Incoterms 2020) with the customer being responsible for import clearance and duties.

The customer self-replacement process (applicable only to Plan 3) involves the following steps: (i) submitting a replacement request along with fault diagnosis or supporting evidence; (ii) CLOU will evaluate the issue to determine whether it falls under warranty coverage; and (iii) if confirmed, CLOU will authorize the customer to carry out on-site replacement of the faulty component.

For Plan 1, CLOU will conduct annual on-site inspections for spare parts inventory and provide necessary maintenance services.

### **Preventive maintenance services and consumable spare parts (for Plan 1)**

Preventive maintenance services are categorized into semi-annual preventive maintenance and annual preventive maintenance. The maintenance plan will be based on the CLOU Operation and Maintenance Manual, as mutually agreed upon.

Equipment components with a lifespan of less than 20 years - excluding liquid cooling units and piping - are classified as consumables. The list of consumable parts required for annual maintenance will be included in the Consumable Spare Parts List, which will be jointly finalized by both parties. A standard Consumable Spare Parts List includes coolant of liquid cooling system, UPS backup battery, FACP backup battery, leakage detection controller, temperature and humidity sensors, SPD and filters.

### **Remote monitoring**

CLOU offers remote monitoring services as a paid optional service to enhance system visibility and enable early anomaly detection during business hours. Due to data protection laws in certain countries, this service is subject to regulatory approval and may not be available to all customers.

DNV considers the agreement to contain the necessary provisions and meet basic expectations. Certain clauses, though, are relatively general, and further review by CLOU and the customer would help refine the detailed contract terms.

### 9.2.2 LTSA

A LTSA is a contract between an equipment manufacturer or service provider and the asset owner that covers ongoing maintenance, parts, and technical support over an extended period—typically 5 to 20 years. CLOU had not provided the LTSA for review at the time this report was issued.

### 9.2.3 Performance guarantees

CLOU’s performance guarantees include availability, capacity and RTE, which start from the date of passing the SAT [77] [78].

- **Availability**

The annual availability is calculated as following formula.

$$\text{Annual Availability} = \sum_{i=1}^{4 * \text{Unexcused Time}} \text{MIN} \left( \frac{\#Racks_{Operational_i} * Rack Power Rating}{POI Guarranteed Power}, \frac{\#PCSs_{Operational_i} * PCS Power Rating}{POI Guarranteed Power}, 1 \right)$$

Where:

“**#Racks Operational**” and “**#PCSs Operational**” are only calculated during Unexcused Time and are average values during such interval.

“**Operational**” means the piece of equipment in reference is electrically connected to the point of interconnection. For avoidance of doubt, if one, or more, PCS is not Operational all racks connected to it, are not Operational;

“**Unexcused Time**” is measured in hours and is equal to the difference of 8,760 or 8,784 during leap year hours and “Excused Time” in hours;

“**Interval**” “i” means fifteen (15) minutes;

“**Excused Time**” is any portion of an Interval of one or multiple of specific conditions defined in the availability guarantee specifications, such as any scheduled preventive maintenance, component outage or curtailment that is caused by equipment not supplied by supplier, etc.

“**POI**” is point of interconnection.

Multiplying the ‘Unexcused Time’ by 4 converts it to hours, since each interval represents 15 minutes. The annual availability level guaranteed by CLOU is 96%. DNV notes it meets industry expectations.

- **Capability and roundtrip efficiency**

The capacity level means actual energy retention (AER), which is the energy discharged by the BESS components as a whole measured at the point of connection (POC).

Roundtrip efficiency (RTE) is defined as the ratio of the AER over the ACE measured at the POC:

$$RTE = \frac{Wh_D}{Wh_C} = \frac{AER_t}{ACE_t}$$

Where

Actual charge energy (ACE) means the energy charged to the BESS components as a whole measured at the POC.

When performing the annual capacity level and RTE test, CLOU requires components preventive and corrective maintenance in advance. The BESS is to be fully cycled at “the guaranteed power” between the lowest achievable and 100% SOC, and rest one hour between charging and discharging. DNV notes that the guaranteed power is not equal to the rated power, and this distinction should be clearly defined in the agreement.

The annual capacity test may be repeated up to two additional times if the AERt and/or RTE results fall below the minimum roundtrip efficiency (MRTE) or the adjusted minimum energy retention (AMERt) performance criteria. Conducting a total of two or three test cycles aligns with common industry practice.

CLOU has provided the following annual performance estimates for energy retention and RTE for reference purposes. DNV recommends that detailed warranty terms and LTSA should be reviewed and evaluated judiciously for specific projects.

Table 9-2 and Table 9-3 present the estimated 20-year energy retention for the Aqua C2.5H and Aqua C2.5S, respectively, for the IEC variant (CALB cells) and the UL variant (REPT cells) [79] [80] [81]. It is assumed that the system operates at one charge–discharge cycle per day at either 0.5P or 0.25P and an ambient temperature of 25 °C. DNV notes that the estimation is based on the degradation characters of battery cells used in the system, and may not be able to fully represent the overall degradation feature of the system.

**Table 9-2 Energy retention estimation of Aqua C2.5H**

Cycle	Year	Aqua C2.5H 0.5P IEC variant		Aqua C2.5H 0.5P UL variant	
		SOH upper limit	SOH lower limit	SOH upper limit	SOH lower limit
0	0	101.19%	98.51%	99.76%	98.50%
365	1	96.71%	94.03%	94.01%	92.75%
730	2	93.59%	90.91%	90.77%	89.51%
1095	3	90.82%	88.14%	88.06%	86.80%
1460	4	88.27%	85.59%	85.63%	84.37%
1825	5	85.86%	83.18%	83.40%	82.14%
2190	6	83.57%	80.89%	81.30%	80.04%
2555	7	81.36%	78.68%	79.32%	78.06%
2920	8	79.22%	76.54%	77.42%	76.16%
3285	9	77.15%	74.47%	75.59%	74.33%
3650	10	75.12%	72.44%	73.82%	72.56%
4015	11	73.15%	70.47%	72.10%	70.84%
4380	12	71.21%	68.53%	70.42%	69.16%
4745	13	69.32%	66.64%	68.78%	67.52%
5110	14	67.45%	64.77%	67.17%	65.91%
5475	15	65.62%	62.94%	65.57%	64.31%
5840	16	62.82%	61.14%	63.98%	62.72%
6205	17	62.04%	59.36%	62.38%	61.12%

Cycle	Year	Aqua C2.5H 0.5P IEC variant		Aqua C2.5H 0.5P UL variant	
		SOH upper limit	SOH lower limit	SOH upper limit	SOH lower limit
6570	18	60.28%	57.60%	60.75%	59.49%
6935	19	/	/	59.08%	57.82%
7300	20	/	/	/	/

**Table 9-3 Energy retention estimation of Aqua C2.5S**

Cycle	Year	Aqua C2.5S 0.5P IEC variant	Aqua C2.5S 0.5P UL variant	Aqua C2.5S 0.25P IEC variant	Aqua C2.5S 0.25P UL variant
		SOH	SOH	SOH	SOH
0	0	100.0%	100.0%	100.0%	100.0%
365	1	96.9%	94.5%	100.0%	98.5%
730	2	94.0%	91.6%	99.7%	95.9%
1095	3	91.3%	89.2%	97.5%	93.7%
1460	4	88.9%	87.0%	95.4%	91.8%
1825	5	86.6%	85.0%	93.5%	90.0%
2190	6	84.3%	83.2%	91.7%	88.3%
2555	7	82.2%	81.5%	90.0%	86.8%
2920	8	80.2%	79.8%	88.4%	85.3%
3285	9	78.2%	78.2%	86.8%	83.8%
3650	10	76.2%	76.7%	85.2%	82.5%
4015	11	74.3%	75.2%	83.7%	81.1%
4380	12	72.5%	73.7%	82.2%	79.8%
4745	13	70.6%	72.3%	80.7%	78.5%
5110	14	68.8%	70.9%	79.3%	77.3%
5475	15	67.1%	69.5%	77.9%	76.0%
5840	16	65.3%	68.1%	76.5%	74.8%
6205	17	63.6%	66.7%	75.2%	73.6%
6570	18	61.9%	65.3%	73.9%	72.3%
6935	19	60.2%	63.8%	72.6%	71.0%
7300	20	/	62.2%	71.3%	69.6%

The data indicate that, while the Aqua C2.5H and Aqua C2.5S UL variants exhibit slightly lower energy-retention ratios than the IEC variants during the initial years of operation, their long-term energy retention is higher. CLOU has not conducted any further analysis or explained this matter.

Table 3-2 shows the estimated 20-year RTE for CLOU's Aqua C2.5H products [82] [83]. DNV notes that the RTE of Aqua C2.5H generally meets expectations.

**Table 9-4 RTE evaluation of Aqua C2.5H**

Cycle	Year	Aqua C2.5H 0.5P IEC variant		Aqua C2.5H 0.5P UL variant	
		RTE upper limit	RTE lower limit	RTE upper limit	RTE lower limit
0	0	94.04%	93.88%	94.48%	94.40%
365	1	93.76%	93.59%	94.08%	93.99%

Cycle	Year	Aqua C2.5H 0.5P IEC variant		Aqua C2.5H 0.5P UL variant	
		RTE upper limit	RTE lower limit	RTE upper limit	RTE lower limit
730	2	93.56%	93.37%	93.83%	93.73%
1095	3	93.36%	93.16%	93.61%	93.50%
1460	4	93.17%	92.95%	93.40%	93.29%
1825	5	92.97%	92.75%	93.20%	93.08%
2190	6	92.78%	92.54%	92.99%	92.87%
2555	7	92.58%	92.33%	92.79%	92.66%
2920	8	92.38%	92.11%	92.59%	92.45%
3285	9	92.18%	91.90%	92.39%	92.24%
3650	10	91.97%	91.67%	92.18%	92.03%
4015	11	91.75%	91.44%	91.97%	91.82%
4380	12	91.53%	91.20%	91.76%	91.60%
4745	13	91.30%	90.95%	91.54%	91.37%
5110	14	91.06%	90.69%	91.32%	91.14%
5475	15	90.81%	90.43%	91.09%	90.90%
5840	16	90.56%	90.15%	90.85%	90.65%
6205	17	90.29%	89.86%	90.60%	90.39%
6570	18	90.01%	89.56%	90.33%	90.11%
6935	19	/	/	90.04%	89.82%
7300	20	/	/	/	/

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## **About DNV**

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property, and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software, and independent expert advisory services to the maritime, oil & gas, power, and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter, and greener.