Based on 261 AC: A White Paper on 200MWh / 100MW Distributed Energy Storage Applications

R-MP261135A1

MPack 261A

2025 1ST EDITION

Prepared by: Renon Power Global Energy Systems Division
Release Date: November 12, 2025
Document Number: RP-WP-261AC-V3.9-NA

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RenonPower

We Care About Sustainability

With our own R&D team and automatic production factory, we are dedicated to delivering innovative, reliable, and affordable energy storage solutions to global customers.

At Renon, we believe that sustainable energy is the future. We are committed to reducing carbon emissions and preserving our planet for future generations. That's why we invest heavily in research and development, leveraging the latest technologies to design and manufacture energy storage systems that are efficient, scalable, and adaptable.

Our products are designed to meet the needs of a wide range of applications, from residential and commercial buildings to industrial facilities and utility-scale projects. Whether you're looking to reduce your energy bills, increase your energy independence, or support your sustainability goals, Renon has the right solution for you.

Our commitment to quality and customer satisfaction is unwavering. We work closely with our clients to understand their unique needs and provide customized solutions that meet or exceed their expectations. We also provide comprehensive technical support, maintenance, and warranty services to ensure that our customers get the most out of their investment.

Join us on our mission to make renewable energy within reach.

PROVIDE INNOVATIVE, RELIABLE, AND AFFORDABLE ENERGY STORAGE SOLUTIONS TO CUSTOMERS WORLDWIDE.

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Executive Summary

I. Background & Objectives

In response to the peak electricity prices and flexibility shortages in North America, Renon Power has launched the 261 AC IP54 liquid-cooled outdoor energy storage system, constructing a standardized energy storage network of 20 distributed sites × 10MWh/5MW = 200MWh/100MW.

This white paper aims to systematically elaborate on Renon Power's 200MWh/100MW distributed energy storage architecture based on the 261AC liquid-cooled energy storage system, showcasing the company's innovative achievements in areas such as AI intelligent scheduling, matrix-level EMS architecture, AC medium-voltage grid connection systems, and the compliance pathway for North America FEOC.

Through this document, Renon Power provides energy investors, aggregators, EPC companies, and large end-users with a set of practical, replicable, and aggregable systematic technology and commercial implementation standards, assisting clients in optimizing returns and achieving long-term asset appreciation in the energy storage markets of North America, Europe, and Asia-Pacific.

II. Global Competitive Landscape

Brand	Core Positioning	Technical Characteristics
Fluence	Utility-level energy storage	Platform-based EMS + AI scheduling capability is outstanding
Tesla Megapack	Full-stack integrated system	Autobidder algorithm + VPP commercialization is leading
Wärtsilä GridSolv	North American traditional electricity market	Grid compatibility + strong integration capability for electricity trading

Renon Power achieves significant differentiation in reliability, scalability, cost efficiency, and intelligent control through the IP54 outdoor 261 AC module + AI aggregation EMS architecture.

III. Customer Needs & Pain Points

Demand Type	Typical Pain Points	Goals
Peak Load Pressure	Fast charging stations, hotels, and shopping malls impact the power grid during peak times	Peak shaving ≥ 40%, enhance grid flexibility
Widening Price Gap	Peak-valley difference > 0.3 USD/kWh	Utilize TOU and DR for monetization
Long Investment Cycle	Traditional energy storage ROI > 6 years	AI Revenue Optimization → ROI ≤ 4 years
Challenges in Safety Compliance	High Requirements of UL 9540/NFPA 855/IEEE 1547	System-Level Compliance Certification + NRTL Registration

IV. System Configuration & Architecture

1. System Configuration:

Hierarchy	Composition	Nominal Parameters	EMS Limit (Operating Caliber)
261 AC cabinet	Liquid Cooling BESS + PCS 135 kW	261 kWh / 135 kW	—
Array	5 cabinets + row cabinets EMS = 1 array	1.305 MWh / 675 kW	—
Site	8 arrays (40 cabinets) + booster transformer + station-level EMS	10.44 MWh / 5.40 MW	10.00 MWh / 5.00 MW
Project	20 stations + cloud EMS aggregation	208.8 MWh/108 MW	200 MWh/100 MW

2. Architecture logic: Cabinet → Array → Matrix → Site → Cloud EMS.

AI prediction, electricity price learning and strategy feedback, achieving second-level scheduling + revenue closed loop + full lifecycle monitoring.

V. Operational & EMS Strategy

- AI prediction of load and electricity price, optimizing charge and discharge plans;
- Station-level EMS limit 10 MWh/5 MW, ensuring balance of lifespan and performance;
- Matrix-level EMS implements SOC balancing and fault isolation;
- The cloud EMS is responsible for VPP aggregation and revenue optimization.
- AI O&M system automatic diagnosis > 95%, availability ≥ 99.9%.

VI. Business Model and Profit Model

Model	Applicable Scenarios	Revenue Sources
EaaS Energy Leasing	Highways/Shopping Centers	Peak shaving + Arbitrage + DR + Aggregate Revenue
Joint Venture (JV) Model	Hotel/Park Clients	Electrical cost savings + carbon credits + revenue sharing
Aggregator VPP model	Regional operator	Scheduling service fee + revenue sharing
Self-investment and operation	Energy investors	Full income self-holding + asset returns

- **Main sources of revenue:**
  a. Peak shaving and valley filling45–55%
  b. Aggregation 5–10%
  c. Demand Response 15–20%
  d. Carbon revenue 3–5%
- **AI Revenue Engine:** Updates electricity price forecasts and scheduling models every 24 hours, increasing revenue by 10–18%.
- **Annual Revenue:** Approximately 200,000 USD/station
- **ROI (Return on Investment): 3.8–4.5 years**
- **IRR (Internal Rate of Return): 16–18%**

VII. Empirical Case Results

Scenario	Scale	Core Results
Highway Service Area	200 MWh/100 MW	Peak-to-valley difference decreased by 48%, ROI is 4.3 years
Five-star hotel group	300 MWh/150 MW	Electricity cost reduced by 25%, carbon emissions reduced by 340 tCO_2e/year
Costco shopping center fast charging project	5.2 MWh/4 MW	Peak load decreased by 36%, ROI is 3.8 years

VIII. Integrated Benefits

- Economic benefits: IRR 16–18%, annual cash flow > 3M USD;
- Environmental benefits: annual emission reduction > 6000 tCO_2e;
- Social benefits: Support VPP aggregation and flexible scheduling of the power grid;
- Brand Value: Compliant with UL 9540/NFPA 855/IEEE 1547 international standards, establishing a benchmark project in North America.

IX. Conclusion

The Renon Power 261AC distributed energy storage system, centered around a matrix-level EMS architecture + AI intelligent scheduling, achieves a full lifecycle intelligent closed loop from single cabinet autonomy to multi-station aggregation. The system supports 15kV standard grid connection, is compatible with mainstream North American VPP/Aggregator platforms, and forms a closed-loop ecosystem of "autonomy × aggregation × prediction × revenue" through the AI revenue engine and cloud O&M system. This marks Renon Power's official entry into a new phase of global smart energy storage systems and energy aggregation platforms, laying a core foundation for the future AI-Driven Energy Autonomy Network.

1. Global Energy Storage Landscape & Market Competition Situation

1.1 Global Market Trends & Forecasts

a. From 2024 to 2030, the global energy storage industry is expected to maintain a high growth rate with an average annual CAGR of around 25%, among which:

- **North America:** Driven by the IRA Act, FEOC compliance, and state-level capacity markets, both project investment and system delivery volumes are reaching new highs;
- **European market:** Accelerated implementation of energy security, RE Power EU policies, and capacity pricing mechanisms is shifting energy storage systems from individual units to aggregation and AI evolution;
- **Asia-Pacific region (China, Japan, Australia):** Becoming a manufacturing and technology export center, driving rapid declines in BESS costs.

b. By 2030, the global cumulative installed energy storage capacity is expected to exceed 1.2 TWh, among which:

Region	Proportion	Main Driving Factors
North America	≈ 232%	IRA Subsidies + Independent Energy Storage Marketization + AI Aggregated Trading
Europe	≈ 28%	Electricity Price Fluctuations + Carbon Trading + Transnational VPP Access
Asia-Pacific	≈ 35%	Photovoltaic/Wind Storage Synergy + Decrease in Manufacturing Costs
Others	≈ 5%	Africa/Middle East/Latin America Emerging Markets

c. Renon Power's 261 AC distributed systems are at the core intersection of this global trend: supported by modular + AI EMS, achieving replicable global implementation under the trend of "Energy as an Asset."

1.2 North America/Europ /Asia-Pacific Policy & Incentive Frameworks

a. North America (USA/Canada)

- The Inflation Reduction Act (IRA) provides a 30–50% tax credit (ITC), with FEOC compliance becoming a core threshold for projects.
- States (CAISO, ERCOT, NYISO) introduce capacity markets, DR, and Ancillary Service revenue mechanisms.
- BESS projects must comply with UL 9540/9540A, IEEE 1547, NFPA 855 standards.

b. Europe

- REPowerEU+Fit for 55 promotes the expansion of distributed energy storage + aggregator models;
- Countries such as Germany, Italy, and Spain have launched a dual incentive system of "capacity income + flexibility market";
- The European Commission has developed the Cyber Resilience Act (CRA) to strengthen compliance with energy storage cybersecurity.

c. Asia-Pacific

- China's "dual carbon" strategy drives the scale-up of BESS;
- Japan's FIP mechanism + renewable energy dispatch balancing market promotes VPP growth;
- Australia's NEM framework supports AI aggregation and energy storage arbitrage.

1.3 Global Top 3 Competitor Review

Enterprises	Representative Product	EMS System	Business Model	Technical Characteristics
Fluence	Gridstack/ Sunstack	Fluence IQ Digital Platform	SaaS+Energy Trading as a Service	Emphasize Cloud Scheduling and Auxiliary Services
Tesla Energy	Megapack 2.0	Autobidder AI Market Platform	Full-Stack Self-Holding EaaS/Asset Trading	Highly Integrated, Profit-Oriented
Wärtsilä Energy	GridSolv Quantum	GEMS EMS 2.0	EPC+O&M+Capacity Market	Emphasizing Grid Connection and System-Level Safety

Renon Power Positioning Comparison

- More Detailed Architecture: Five-layer structure of cabinet–array–matrix–station–cloud;
- More Flexible Equipment: 261 AC outdoor liquid cooling IP54;
- Smarter EMS: AI Revenue Engine + Matrix-Level Collaboration;
- More comprehensive compliance: North America UL + FEOC + NIST full chain.

1.4 Renon Power Global Competitive Positioning & Advantage Map

a. **Strategic Positioning:** Upgrading from "Energy Storage Equipment Manufacturer" to "AI-Driven Distributed Energy Platform (AI -Driven Distributed Energy Platform)."

b. **Competitive Advantage Map**

Dimension	Renon Power	Top 3 Average Level	Differentiation Advantages
System Architecture	Cabinet – Array – Matrix – Station – Cloud Five Layers	Three Layers	The architecture hierarchy is more refined
Modular Capability	261 kWh can independently connect to the grid IP54 liquid cooling	Indoor unit type	Outdoor integrated unit, no machine room required
EMS Intelligence	AI strategy + matrix collaboration + revenue optimization	Only station-level scheduling	Self-learning + AI prediction
Data Intelligence	Whole life cycle self-diagnosis + profit feedback	Phase-wise collection	Complete closed loop
Safety and Reliability	Five-level security + AI defense	System level	More detailed security layers
Grid-connected and Compliant	15 kV ANSI + UL 9540A + FEOC	Different standards in various regions	Leading localization in North America
AI Profitability	IRR Increase 8 – 15% (Forecast)	—	AI-Driven ROI Optimization

1.5 Four Major Customer Segment Penetration Trends & Market Opportunities

a. Energy Investors (Independent Power Producers)

- Focus on IRR/Asset Turnover/Long-term PPA Contracts;
- Goal: Achieve Stable Yield in the IRA + VPP Market.
- Demand: Compliance + High Availability > Revenue Volatility.

b. Aggregators (Virtual Power Plant Operators)

- Core: Dispatch Speed + Data Visibility + API Interface Standards;
- Trend: Multi-system collaboration → AI prediction + distributed aggregation response.

c. EPC and System Integrators

- Focus: Delivery cycle + construction simplification + standardized interfaces;
- Opportunities: Matrix-level EMS can be delivered in parallel → reducing construction cycle by 20%.

d. Major Electricity Consumers (Commercial & Industrial Users)

- Includes data centers, manufacturing parks, cold chain storage, supermarkets, and charging networks;
- Focus on electricity price fluctuations and demand charge control;
- Opportunities: The 261 AC system can directly connect to the grid on the 15 kV medium voltage side, achieving a three-in-one effect of "peak shaving + DR + AI benefits."

1.6 Conclusion

The global energy storage industry is moving towards an era of "smart autonomy + AI aggregation + revenue optimization." In this context, Renon Power, centered around matrix-level EMS + AI revenue engine, constructs a 15 kV distributed energy storage system that meets UL 9540/FEOC/VPP standards, becoming the most promising fourth pole after Fluence, Tesla, and Wärtsilä.

2. Customer Focus & Pain Points & System Engineering Architecture

2.1 Customer Focus Analysis

Four core customer groups (energy investors, aggregators, EPC companies, large end-users) generally focus on:

- Investment security and recovery cycle;
- System reliability (safety > grid connection > returns > operation and maintenance);
- Delivery cycle and site adaptability;
- Intelligent level (EMS strategy, self-learning, revenue forecasting);
- Compliance (UL 9540/NFPA 855/IEEE 1547/NEMA 3R/IP54);
- Verifiable revenue and replicability.

2.2 Customer Pain Points & Solution Logic

Pain Points	Performance	Renon Power Solutions	Differentiation Advantages
System Complexity	Multiple Sites, Multiple Control Levels	Adopt a Five-Layer EMS Architecture, Supporting AI Automatic Coordination	The architecture hierarchy is more refined
Safety Concerns	Extreme Outdoor Temperatures	IP54 Liquid Cooling 261 AC + AI Thermal Management	Self-learning + AI prediction
Unstable Returns	Price Fluctuations	AI Revenue Prediction + Dynamic Scheduling	Complete closed loop
Compliance Pressure	North America UL/NFPA Standards	Overall System UL 9540+NFPA 855 Pre-certification	More detailed security layers
Maintenance and Repair Difficulties	Multi-site Distribution	AI O&M + Remote Expert Collaboration	Leading localization in North America

2.3 Project Objectives

- Build a 200 MWh/100 MW distributed energy storage demonstration network;
- Overall system complies with UL 9540/NFPA 855/IEEE 1547;
- Each station has independent operation and aggregation response capability;
- Achieve peak shaving and valley filling + demand response + profit maximization;
- Delivery cycle ≤ 30 days/site;
- Operational availability ≥ 99.9%.

2.4 System Architecture

1. Hierarchical Structure

Sampling → Parameters → Operating Strategy → Scheduling → Safety → Forecasting → Upgrading → Logs → Data Storage.

2. Physical Structure

Cabinet → Array → Matrix → Site → Cloud EMS.

- Cabinet: 261AC energy storage cabinet, built-in PCS 135kW and local EMS;
- Array: 5 cabinets + rack (built-in rack-level EMS) = 1 array;
- Matrix: 5 arrays = 1 matrix, matrix-level EMS manages power and balancing;
- Site: 8 arrays (40 cabinets) + boost transformer + station-level EMS → single station 10MWh/5MW;
- Cloud: Project-level local EMS + cloud EMS unified scheduling for 20 stations.

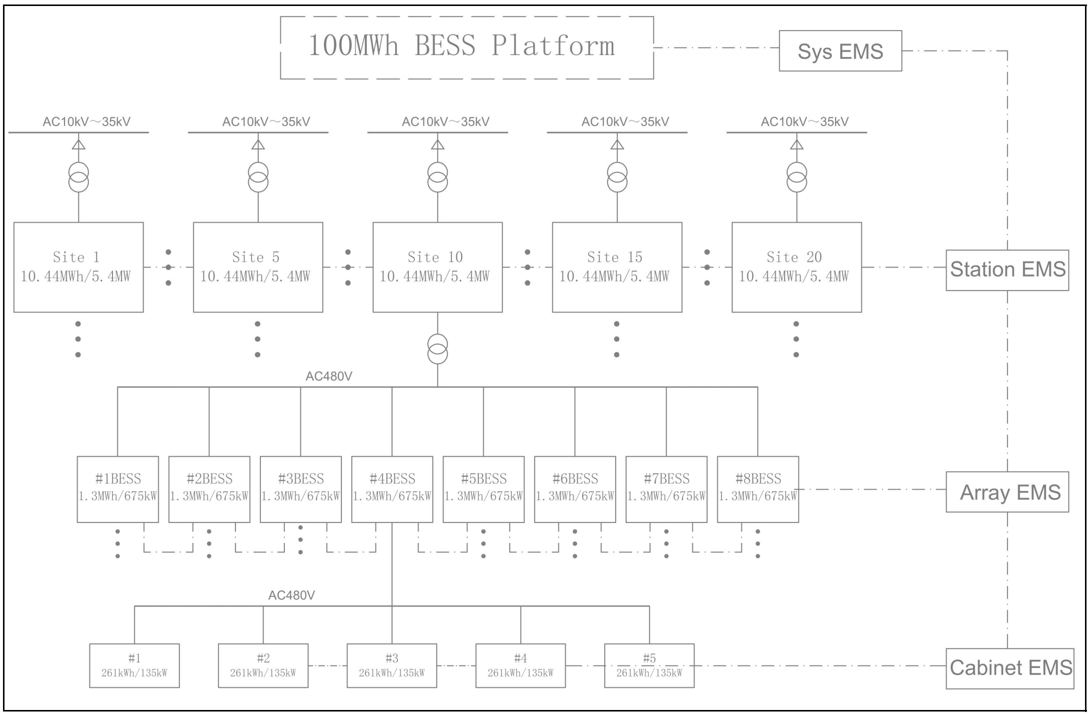
a. Cabinet EMS functional positioning: the lowest-level execution unit and data collection unit, directly managing the smallest battery unit (135kW/261kWh).

b. Array EMS functional positioning: coordinating controller, managing a "battery array" composed of 5 battery cabinets (675kW/1.3MWh).

c. Matrix EMS functional positioning: the core optimizer and coordinator within the energy storage station. Multi-array coordination: receiving data from multiple Array EMS, providing unified management and coordination of all battery arrays within the entire station.

d. Station EMS functional positioning: the "brain" of the entire energy storage station and the external interface. Provides a complete operational view of the entire station, including all key performance indicators (KPIs), alarms, and performance reports, enabling full station monitoring.

e. Cloud EMS functional positioning: a centralized, cross-regional asset management platform. Simultaneously monitors and manages multiple energy storage stations distributed across various geographical locations, achieving aggregated monitoring. Through coordinated control, it "virtually" combines multiple stations into a larger resource under the electricity market environment, participating in ancillary services markets and maximizing revenues.



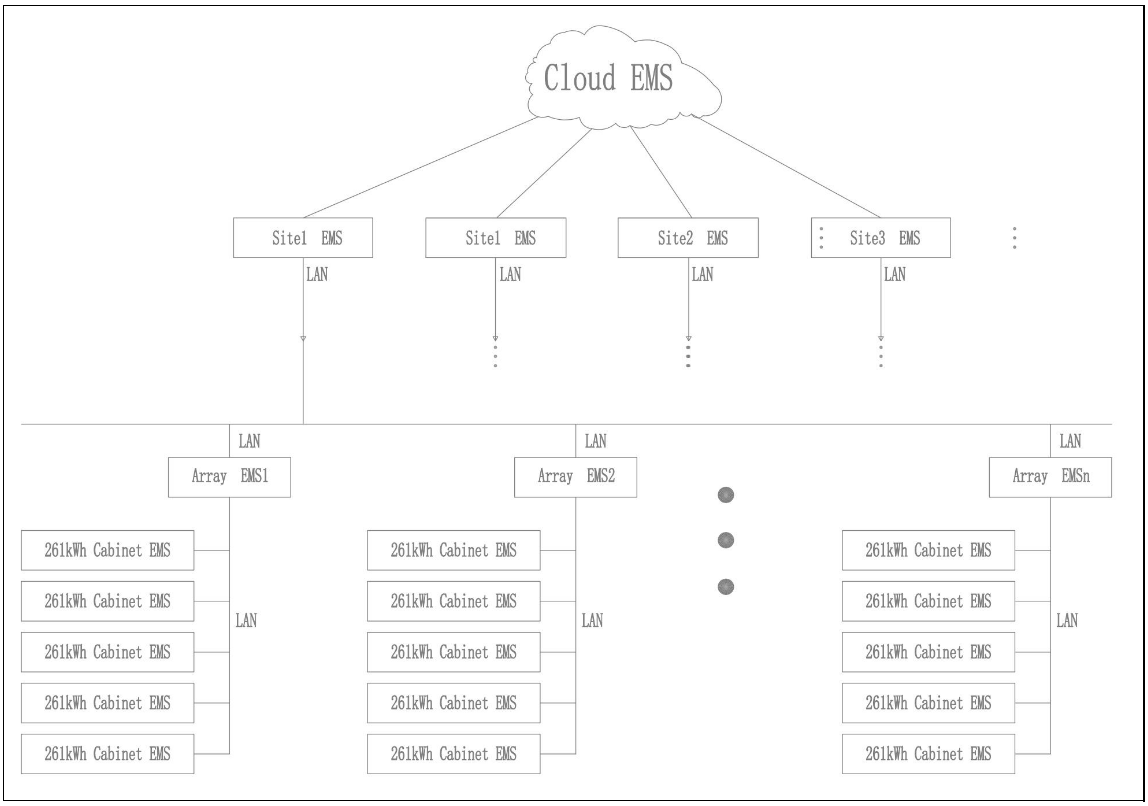
2.5 System Configuration Overview (Scheme A)

Hierarchy	Composition	Nominal Parameters	EMS Limit (Operating Calibration)
261AC Cabinet	Liquid Cooling BESS + PCS 135 kW	261kWh/135kW	—
Array	5 cabinets + 1 row of cabinets	1.305MWh/675kW	—
Site	8 arrays (40 cabinets) + booster transformer + EMS	10.44MWh/5.40MW	10.00MWh/5.00MW
Project	20 sites + cloud EMS	208.8MWh/108MW	200MWh/100MW

Note: The available energy for each station is fixed at 10.00MWh (DoD≈95.8%) through the station-level EMS, with a power limit of 5.00MW, reserving about 4% of energy and 8% of power redundancy to extend lifespan and prevent derating.

2.6 EMS Topology & Data Flow

- Matrix-level EMS: Executes power distribution between arrays and AI balancing control;
- Station-level EMS: Limits the main meter power to ≤5MW and monitors SoC distribution;
- Cloud EMS: Aggregates data from 20 stations, performs revenue forecasting, and strategy rewriting;
- Communication Protocol: Modbus TCP + IEC 61850 + MQTT encrypted transmission;
- Delay Indicator: End-to-end ≤ 300 ms.



2.7 Site Planning

Dimension	Content
Quantity	20 distributed stations
Single Station Configuration	8 arrays × 5 cabinets = 40 cabinets (10.00MWh/5.00MW fixed)
Total project Scale	200MWh/100MW
Grid-connected	0.48kV→15kV step-up connection
Fire protection	Matrix partition FK-5-1-12 gas fire extinguishing + ventilation system
Construction Period	≤ 30 days/site (with civil construction conditions)
Operation and Maintenance Mode	AI O&M + Remote Expert Collaboration

2.8 Installation & Deployment Process

a. Shipping out the whole cabinet after factory FAT qualification;
b. Site hoisting → Cable connection → Communication verification;
c. EMS loading → Safety check → Grid connection testing;
d. Sign SAT report after 72 hours of stable operation.

Average Installation Cycle: ≤30 days per site; parallel deployment of 20 sites only takes 4–8 weeks.

2.9 O&M Management System

a. Key Monitoring Items

- Limit Accuracy = Actual/Set Deviation ≤ ±1 %;
- Redundancy Utilization = the proportion of the nominal and limit difference call usage;
- AI self-healing rate ≥ 95%; availability rate ≥ 99.9%.

b. Tool Chain: Cloud O&M Dashboard + Mobile App + AI Expert collaboration platform.

2.10 Conclusion

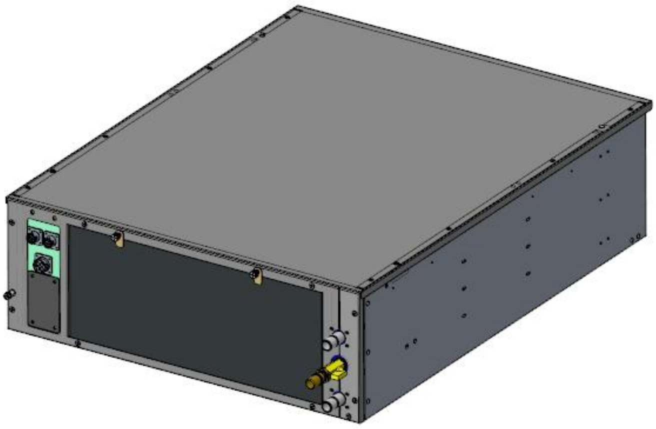
This chapter clarifies the engineering structure of the Renon Power 261 AC system under the 200 MWh/100 MW project:

- Single station 10 MWh/5 MW pegged operation, achieving a balance between lifespan and performance through EMS limits;
- Modular arrays + matrix architecture support rapid deployment and high parallel construction;
- The AI EMS system achieves multi-station collaboration and revenue optimization.

This architecture maintains the "5 cabinets = 1 array" standard, achieving precise control of usable energy, flexible compatibility with grid connection, and quantifiable investment returns for the distributed energy storage system template.

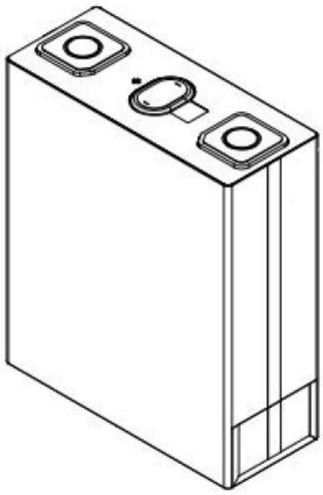
3. Core Components & Quality Standard System

3.1 Energy Storage System (Cell/Module/PACK/Liquid Cooling)



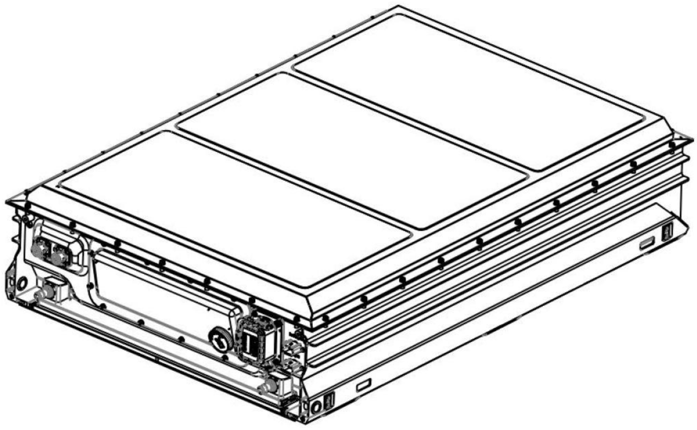
a. Cell Selection Standards

- Type: Lithium Iron Phosphate (LFP) rectangular aluminum case;
- Energy Density ≥ 174 Wh/kg; Cycle Life ≥ 8,000 times (@80% DOD);
- Operating Temperature –20 ~ +60°C;
- Complies with UL 1973/IEC 62619/UN38.3 standards.



b. Liquid Cooling Battery Pack

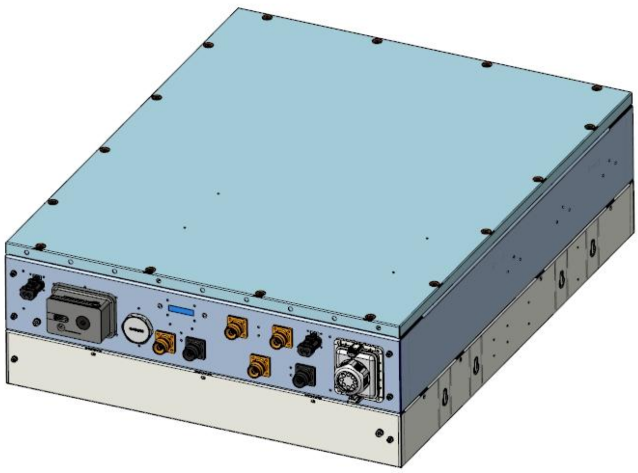
- Equipped with NTC temperature sampling and individual cell voltage sampling (±1mV accuracy);
- Module-level BMS supports CAN and 485 dual-channel communication.
- Configured with a balancing circuit + fast fuse + emergency stop interface;
- Thermal design: fluid simulation + liquid cooling plate temperature difference ≤ 3°C;
- Fire separation at PACK level (2mm steel plate + ceramic insulation layer).



c. Liquid Cooling System

- Dual circulation cooling architecture: battery circuit + PCS circuit;
- Coolant: 30% ethylene glycol aqueous solution; flow rate ≥ 8L/min per PACK;
- Supports operating environment from -40 to +55°C;
- Fault self-diagnosis + AI predictive thermal management.

3.2 PCS Power Conversion System



Item	Parameter	Description
Rated Power	135kW AC	Single Cabinet 261AC Integrated PCS
Rated Voltage	480VAC Three-Phase	Grid Side
Efficiency	≥ 97.8% @Rated Load	Including Inversion and Filtering Losses
Power Factor	–0.9 ~ +0.9 adjustable	Grid-connected/Off-grid Compatible
Harmonics	THD ≤ 3 %	IEEE 519 Compliance
Parallel Capability	100% Redundant Parallel Operation	Supports Array/Matrix-Level Paralleling
Grid Certification	UL 1741 SB/IEEE 1547/CSA 22.2	North America Compliance

Functional Features

- Bidirectional transformation: Supports charging and discharging ±135kW;
- Fast response: Active < 100ms, reactive < 50ms;
- AI control: Dynamic adjustment of power curve & harmonic compensation;
- Protection system: Full coverage of over-voltage, over-current, islanding, and feed-in protection.

3.3 MPPT/Inverter System

- Utilizes high-frequency IGBT inverter topology with DSP control;
- PV input voltage 600~1000VDC; Efficiency ≥ 99%;
- Equipped with dual MPPT interfaces for PV+BESS, compatible with hybrid systems;
- Automatic tracking of PV power points + energy storage charging and discharging switch.
- Automatic switching between grid-connected and off-grid modes, supporting black start.
- Inverter Mode Configuration:
  a. Grid-Connected Mode: Operates in parallel with the grid AC bus synchronously;
  b. Island Mode: Maintains local microgrid power supply when the main grid is disconnected;
  c. Black Start Mode: Independently starts the system without external power.

3.4 Firefighting System & Safety Linkage Mechanism

a. Layered Protection

- Cell Level: Alarm at temperature ≥ 65°C, cut-off at ≥ 75°C;
- PACK Level: Independent temperature sensing + gas concentration detection;
- Array Level: Smoke detection + wind speed monitoring;
- Matrix Level: Independent gas fire extinguishing;
- Station level: Fire linkage + ventilation and exhaust system.

b. Linkage Logic

- Local EMS detects anomalies → triggers array alarm;
- Matrix EMS receives signal → executes local fire extinguishing + power cut;
- Station level EMS → cloud O&M → remote alarm & event archiving.

c. Execution Standards: UL 9540A/NFPA 855/FM200/ISO 14520.

3.5 Dynamic Environment Monitoring System

- Monitoring range: Power supply, temperature and humidity, water leakage, smoke, access control, video surveillance, fans;
- Sampling frequency: 1Hz~10Hz;
- Interface standards: Modbus TCP/RTU/SNMP/MQTT;
- Functional Features:
  a. Real-time monitoring + AI anomaly prediction;

b. Adaptive air cooling/liquid cooling achieved in conjunction with Matrix EMS;
c. Data upload from site-level EMS to cloud-based AI operation and maintenance platform.

3.6 Supply Chain Traceability with TS16949 Quality System

Renon Power manufacturing system uses TS16949 + ISO 9001 + ISO 14001 + ISO 45001 as the quality and environmental management framework, ensuring closed-loop control of products at all stages of design, procurement, production, testing, shipment, and delivery.

Main Features:

- Component coding traceability system: Each PACK/BMS/PCS/EMS has a unique SN + QR code;
- Process control: 100% automatic detection + aging testing for key processes;
- FMEA analysis system: Design FMEA + Process FMEA + Customer feedback closed loop;
- AI quality control platform: Big data analysis of abnormal trends → automatic improvement suggestions;
- Supply chain rating: Tiered management mechanism based on PPAP and MSA audits.

3.7 Certification & Validation Plan

Category	Standards/Organizations	Coverage
Safety	UL 9540/UL 9540A/NFPA 855	System-Level Safety Certification
Electrical	IEEE 1547/UL 1741 SB	Grid Compatibility
Battery	UL 1973/IEC 62619	Cells and Modules
Environment	IP54 / NEMA 4X / IEC 60068	Outdoor Protection and Environmental Adaptability
Quality	TS16949/ISO 9001/ISO 14001	Manufacturing Process and Quality System
Cybersecurity	NIST SP 800-82/ISO 27001	Cloud EMS Data Protection

3.8 Conclusion

Chapter 3 establishes the manufacturing and quality assurance standards for the Renon Power 261 AC system: from battery cells to systems, each layer is controlled, based on TS16949, guided by UL9540, and centered on AI quality control, building a globally distributed energy storage manufacturing system that is mass-producible, traceable, and auditable.

4. EMS Control System & AI Data Logic Architecture

4.1 EMS Hierarchical Structure

The Renon Power EMS system adopts a five-layer distributed collaborative architecture: Cabinet → Array → Matrix → Site → Cloud.

Hierarchy	Main Functions	Control Granularity	Data Interaction Path
Cabinet EMS	Single cabinet monitoring, BMS management, temperature control, real-time sampling	261kWh level	Internal CAN → Column level Modbus
Array EMS	Array power distribution, parallel operation within the column, local safety	5 cabinets = 1 array	Modbus → TCP/IP
Matrix EMS	Multi-array power coordination, local scheduling, self-healing control	5 arrays = 1 matrix	TCP/IP → Station level Ethernet
Site EMS	Station-level power pinning, safety protection, black start, grid connection interface	8 matrix ≈ 52MWh site	Station-level server → cloud
Cloud EMS	Aggregated scheduling, AI revenue forecasting, strategy dispatch, remote O&M	Project/Region level	MQTT/HTTPS encrypted channel

Key Features:

- Hierarchical autonomy × centralized coordination: Each layer can operate independently, with unified scheduling at the station level.
- Bi-directional communication chain: upstream data (sampling → logging → revenue), downstream strategy (forecasting → scheduling → control).
- AI Participation: Starting from the matrix layer, AI decision-making participation is established, with the station level as the AI core.

4.2 Local EMS Strategy Engine

a. Each Cabinet EMS is equipped with an independent DSP controller and an MCU edge computing module:

- Sampling frequency at 1 kHz;
- Latency < 5 ms;
- Control cycle < 50 ms.

b. Core Algorithms:

- Power dynamic allocation—based on real-time SOC/temperature/current balancing strategy;
- Adaptive control—automatically adjusts charge and discharge curves according to load fluctuations;
- AI collaborative interface—reserved for AI edge model invocation (predictive power/thermal management model).

4.3 Matrix EMS Collaboration

a. **Definition:** Each 5 arrays make up 1 matrix, configuring 1 matrix-level EMS.

b. **Functions**

- Power balancing: Monitor SoC differences of 5 arrays ≤ 3 %;
- Thermal coordination: Share liquid cooling temperature difference data → unify adjustment of fan/pump speed;
- Fault isolation: Automatically disconnect local anomalies and restructure power distribution within the matrix;
- AI predictive response: Execute strategies from station-level AI (peak shaving/frequency modulation/energy storage switching);
- Communication channel: Ethernet TCP/IP → station-level EMS backbone network.

c. **Advantages**

- Dividing complex sites into autonomous units;
- Enhance N+X redundancy capability;
- Support for parallel construction and module-level debugging.

4.4 Site EMS Management & Safety

a. **Functional Modules**

- Peak Shaving Limiter;
- FR & VAR Control;
- Black Start and Island Mode;
- Safety protection: overcurrent, backfeed, island detection, abnormal isolation;
- Real-time SoC management and power curve smoothing;
- Two-way AI strategy interface with cloud EMS.

b. **Protection Chain:** Local hardware protection + matrix-level software defense + cloud AI anomaly detection.

4.5 Cloud EMS Platform

a. **Core Responsibilities**

- VPP Aggregation: Connects to ISO/Aggregator platforms;
- AI Profit Engine: Real-time prediction of electricity price × power = profit;
- Energy Trading Interface: Supports CAISO/ERCOT/PJM standards;
- Remote O&M Management: Equipment health monitoring, AI self-learning, system updates;
- Lifecycle Analysis: LFP degradation forecasting, AI maintenance scheduling.

b. **Architectural Features**

- Based on MQTT + HTTPS dual channels;
- Data center deployment in AWS/Azure hybrid cloud environment;
- Support RESTful API openness to third-party platforms.

4.6 AI Dispatch Engine

The AI Dispatch Engine is the "brain" of the Renon Power EMS system:

- Input: Load Forecast × Electricity Price Forecast × Weather Forecast × Equipment Status;
- Output: Power Dispatch Instructions + Revenue Optimization Strategies;
- Model Framework: LSTM + Reinforcement Learning (Deep RL);
- Adjustment Cycle: 10 s – 15 min dynamic configurable;
- Effectiveness: Revenue increase of 8–12%, response delay < 1 s.

4.7 AI Profit Intelligence

Revenue Engine Formula:

$$Profit = \sum_{t=1}^{T} \left(P_t^{dis} \times Price_t^{peak} - P_t^{chg} \times Price_t^{valley}\right) - Cost$$

- Combining Load/Weather/Market Multi-dimensional Inputs;
- Dynamic energy allocation curve correction (SoC planning + electricity price forecasting);
- Automatic identification of arbitrage windows and DR events;
- Station-level EMS → Matrix-level EMS → Cabinet EMS hierarchical execution.

Result: Single station IRR increased by about 8–15%, revenue fluctuation reduced by over 20%.

4.8 Third-Party EMS/Aggregator Compatibility System

- Interface protocols: IEC 61850/Modbus TCP/MQTT/OpenADR 2.0b;
- Access scenarios: ISO scheduling/Aggregator platform/cloud AI forecasting system;
- Security mechanism: TLS 1.3 encryption + digital certificate + mutual authentication;
- Interoperability verification: Tested compatibility with CAI SO, ERCOT, NYISO platforms.

4.9 EMS Competitive Edge Summary

Core Competence	Renon Power EMS	Traditional EMS
Hierarchical Structure	Cabinet – Array – Matrix – Station – Cloud	Station – Cloud Two Layers
Decision Mechanism	Distributed AI Autonomy + Centralized Strategy	Linear Instructions
Response Speed	< 1s	3 – 5s
Profitability	AI Prediction + Arbitrage + DR Overlay	Fixed Power Plan
Safety Protection	Five-level Security + AI Anomaly Detection	Single Point Protection
Grid-Compatible	15kVA NSI Standard/UL 9540A Compliant	State-level Differentiated Adaptation

Core Competence	Renon Power EMS	Traditional EMS
Operational Capabilities	AI Health Diagnosis + Remote Self-Repair	Artificial Inspection
Openness	API Integration VPP/Aggregator	Closed-source System

4.10 Conclusion

Renon Power EMS system is centered around the core logic of "Autonomy × Collaboration × Intelligence × Profit":

- Achieve fine-grained power regulation and safety isolation at the matrix level EMS layer;
- Globally coordinated scheduling through the station-level AI strategy engine;
- Realize profit forecasting and lifecycle management through the cloud-based EMS platform.

This makes Renon Power one of the few distributed energy storage system brands globally that possesses station-level autonomy + cloud aggregation + AI profit closed-loop.

5. System Data & Intelligent Operation Closed-loop System

5.1 Overall Data Architecture

The data architecture of Renon Power 261 AC system centers on the core loop logic of "Sampling → Parameters → Strategies → Scheduling → Prediction → Revenue".

Structural Layers:

- Data Acquisition Layer—Battery Cells, PCS, Sensors, Environmental Monitoring;
- Data Aggregation Layer—Matrix EMS aggregates array-level data;
- Data Modeling Layer—AI Feature Extraction and Prediction Algorithm Training;
- AI Decision Layer—Strategy Deployment, Power Optimization, and Scheduling Control;
- Feedback Loop Layer—Revenue Write-back, Log Tracking, and Anomaly Correction.

Platform Carrier: Cloud EMS + AI Engine + Edge Computing Nodes.

5.2 Sampling & Sensor Network

Sampling Level	Sampling Content	Frequency	Accuracy	Description
Cell	Voltage, Current, Temperature	1Hz	± 1mV	Cell-Level Data Collection + BMS Synchronization
Module	Voltage, temperature, balance state	1Hz	± 0.2%	Module BMS sampling
System	Total voltage, current, SOC, SOH	0.5Hz	± 0.5%	PACK level summary
PCS	Input/output voltage, current, power, PF	1Hz	± 0.1%	Power Accuracy Monitoring
Environment	Temperature and Humidity, Leakage, Smoke, Wind Speed	0.2Hz	—	Dynamic Environment Monitoring System
Communication	Message Delay, Bandwidth	Real-time	—	Network Health Monitoring

Features: Multi-node Redundant Sampling + AI Filtering Algorithm for Automatic Anomaly Removal.

5.3 Parameter Management & Self-Learning

a. **Goal:** Enable the EMS system to have dynamic learning and self-correction capabilities.

b. **Mechanism**

- Parameter Initialization: Automatically loaded based on factory test curves and project configurations;
- AI Self-Learning: Monitor actual SOC curves with a prediction deviation of <2%, real-time algorithm adjustment;
- Multi-Station Collaborative Update: Cloud aggregation of operational data from each station → Generate new predictive models;

- Data Retention Period: No less than 5 years, supporting full lifecycle traceability.

5.4 Smart Dispatch & Predictive Feedback

a. AI Dispatch Engine integrates three major dimensions

- Time Dimension: Daily/Weekly/Monthly/Seasonal load patterns;
- Spatial Dimension: Differences in array/matrix/site distribution;
- Economic dimension: electricity prices, PPA, DR events, peak-valley arbitrage.

b. Running Logic

- $\text{Schedule}_t = f(\text{Predict}_{\text{Load}}, \text{Predict}_{\text{Price}}, \text{SOC}, \text{Weather})$
- Scheduling cycle: 10 seconds – 15 minutes, AI dynamically adjusts the charge and discharge curve.
- Feedback signals (temperature/current/power/profit) are written back in real-time → model automatically optimizes.

5.5 AI Safety Monitoring & Fault Diagnosis

Detection Levels	AI Functions	Action Response	Goals
Cell	Temperature Rise Trend Prediction	30-minute advance alarm	Prevent thermal runaway
Module	Abnormal internal resistance identification	Module isolation	Reduce diffusion
PCS	Waveform anomaly detection	Switch to backup channel	Prevent grid impact
Matrix	Power fluctuation analysis	Dynamic power redistribution	Maintain stability
Station Level	Communication Delay Analysis	Switch Redundant Links	Ensure Real-time Control
Cloud	Revenue Deviation Detection	Correction Strategy	Maintain IRR Stability

AI Algorithm: Based on Isolation Forest + LSTM Time Series Anomaly Detection.

5.6 Remote Upgrade & Event Logging

- Upgrade strategy: Cloud EMS → Station level → Matrix → Array → Cabinet; supports grayscale release;
- Log system: Operating log, fault log, revenue log are stored at different levels;
- Time synchronization: NTP unified clock accuracy ±100ms;
- Security mechanism: TLS 1.3 encryption + signature verification to prevent malicious tampering.
- Log types:
  a. Operation log (command record).
  b. Alarm log.
  c. Revenue log.
  d. Forecast deviation log.

5.7 Lifecycle Intelligent Loop

a. Closed-loop Logic

- Sampling → Parameters → Strategies → Scheduling → Security → Prediction → Upgrading → Logs → Earnings → Rewriting → Retraining.
- AI automatically calibrates the SOC curve and energy decay;
- Each matrix runs data uploaded to the cloud and then participates in model training again;
- Forms a self-evolving system through feedback from earnings and operational data.

b. Key Results

- Operational data traceability rate of 100%;
- Average system energy efficiency improved by 2.3%;
- Earnings stability increased by 15%;
- O&M manual intervention reduced by 35%.

5.8 Conclusion

Chapter 5 defines the closed-loop data system of Renon Power EMS and AI: through multi-layer sampling + AI prediction + strategy distribution + earnings rewriting, it achieves data-driven self-learning and self-evolving system. The 261AC system thus possesses the complete closed-loop capability of "data autonomy → intelligent evolution → earnings enhancement."

6. AI Intelligent O&M System

6.1 AI Health Diagnosis & Life Prediction

a. Core Objective

- Achieve health prediction and lifespan management for the entire lifecycle of BESS, avoiding passive maintenance.

b. Technical Framework

- Algorithm Model: LSTM + ARIMA hybrid prediction + residual learning network;
- Input Data: Temperature, Current, Voltage, Cycle Count, Internal Resistance, Aging Rate;
- Output Indicators: SOH (State of Health) + EOL (End of Life) prediction.

c. Key Functions

- Real-time Health Profile — Automatically generate health curves for each PACK;
- AI prediction of degradation—identifying potential performance decline 90 days in advance;
- Decision on Extending Battery Life — Automatic Adjustment of Charge and Discharge Strategies to Extend Battery Life by Over 15%.

6.2 Anomaly Warning & Self-Healing Mechanism

Module	Anomaly Type	Warning Time	AI Response Action
Cell	Thermal Runaway/Voltage Drift	30 min in advance	Power Reduction + Cooling Acceleration
PCS	Harmonics/Overcurrent	Real-time	Dynamic Rate Limiting + Bypass Switching
Communication	Packet Loss/Delay > 300ms	Within 10 seconds	Activate Redundant Link
EMS Matrix Level	Policy Execution Delay	Real-time	Switch to Backup Scheduling Thread
Cloud	Revenue Forecast Deviation > 10%	1 Hour	Automatically Retrain Model

- Self-healing path: Event detection → Anomaly identification → Local isolation → Policy repair → Redeployment.
- Mean Time to Repair (MTTR) ≤ 2 hours;
- System availability ≥ 99.9%.

6.3 Smart Work-Order & Remote Expert System

a. AI O&M Platform Module

- Smart Ticketing — AI automatically generates maintenance tasks and dispatches based on event priority;
- Remote Expert Hub — On-site engineers can collaborate in real-time via AR glasses or mobile video;

- Knowledge Graph — Automatic indexing and matching of system faults and solutions.

b. Benefits

- Fault troubleshooting time reduced by 50%;
- Travel costs for personnel reduced by 40%;
- Customer satisfaction improved by 30%.

6.4 Energy Efficiency & Digital Twin

a. Digital Twin platform logic: Physical device → Data mirror → AI simulation → Optimized decision → Feedback control.
b. Function: Real-time simulation of equipment operating status, predicting system energy consumption and efficiency;
c. Model accuracy: >95%;
d. AI energy efficiency analysis: Identifying sources of loss (cooling, conversion, standby), generating energy-saving recommendations;
e. Results: Overall energy efficiency improved by 2–4%, station-level energy consumption decreased by approximately 8%.

6.5 Mobile & Cloud O&M Integration

Module	Function	Description
Mobile App	Real-time monitoring + remote control	AI Algorithm Pushing Alerts and Profit Reports
Cloud Control Console	Unified Device Management + Policy Scheduling	Distributed Sites Can Be Centrally Managed
Permission System	Three-Tiered Decentralized Control	HQ→Region→Site
Security Mechanism	Multi-Factor Authentication + End-to-End Encryption	NIST SP 800-82 Standard Compliance

User Experience: AI automatically summarizes performance KPIs (energy efficiency, yield, health), generating a visual dashboard.

6.6 Comparison of Fluence Edge & Tesla Autobidder AI Operational Capabilities

Dimension	Renon Power AI O&M	Fluence Edge	Tesla Autobidder
AI Health Prediction	☑ LSTM Predicts Degradation	Partial	Not Public
Self-Healing Mechanism	☑ Local Isolation + Strategy Recovery	Manual Intervention	Automatic Restart
Digital Twin	☑ Device Level + System Level	Partial Station Level	None
Cloud-Mobile Collaboration	☑ Real-time Bidirectional Control	Web End	Cloud Centralized
Response Speed	< 1s	2 – 5s	Approximately 3s
Efficiency Improvement	+2 ~ 4%	Below +1%	—

Dimension	Renon Power AI O&M	Fluence Edge	Tesla Autobidder
O&M Cost Reduction	– 35%	– 15%	– 20%

Renon Power AI O&M system leads the global Top 3 average level with a "Prediction + Self-healing + Collaboration + Twin" four-dimensional architecture.

6.7 Conclusion

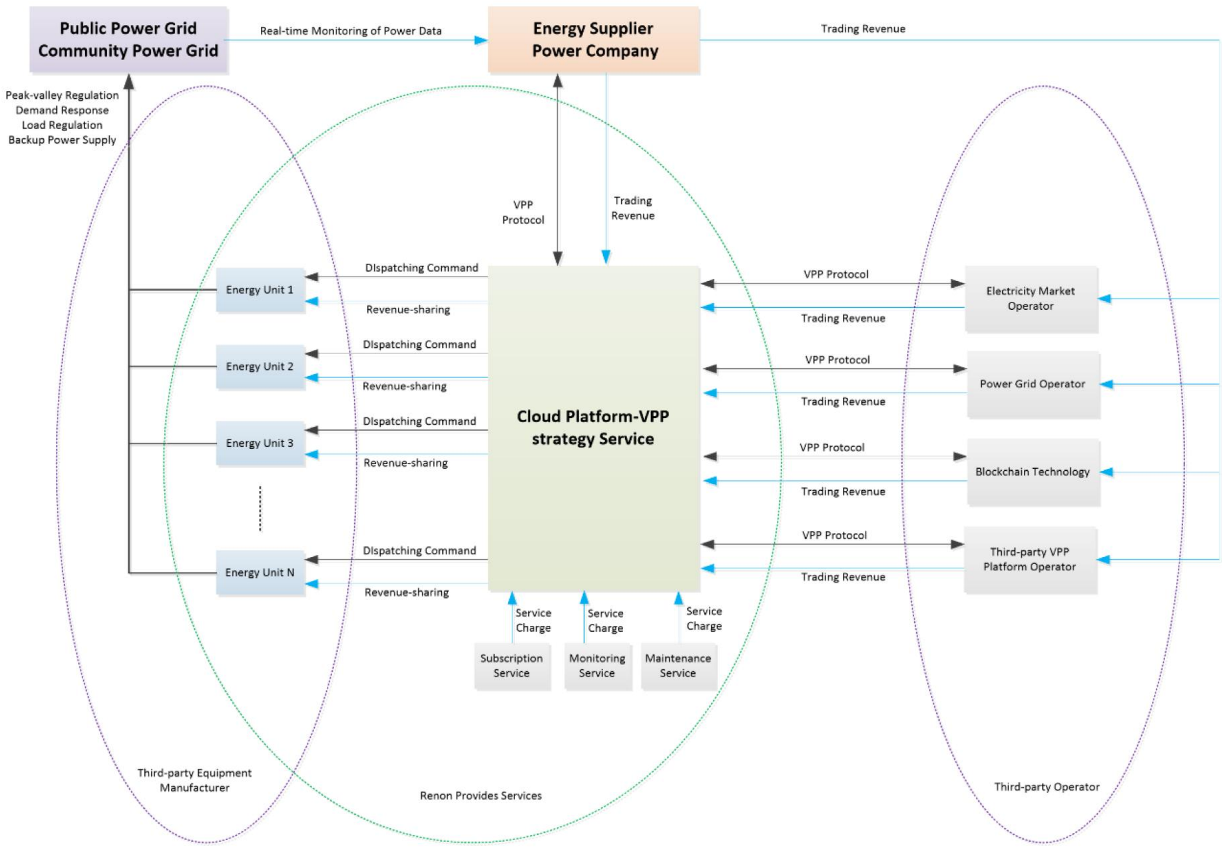
Chapter 6 defines Renon Power's core AI competencies during the operation and maintenance phase:

Through predictive maintenance + digital twin simulation + remote intelligent collaboration, a closed-loop operation and maintenance system for the entire lifecycle is formed, ensuring system availability ≥ 99.9%, reducing O&M costs by 35%, and decreasing revenue fluctuations by over 20%. This marks Renon Power's upgrade from "equipment supplier" to "AI intelligent operation and maintenance ecosystem provider."

7. Energy Management & Operation Control Strategies

7.1 Multi-Energy Coordination & Aggregation Response Logic

Renon Power's 261AC distributed energy storage system adopts the operation logic of "AI autonomy + multi-station aggregation + revenue priority," supporting PV + storage + load + fast charging + grid multi-energy collaboration to achieve optimal energy control at the regional level.



a. Control Hierarchy:

- Station-level EMS: Responsible for the comprehensive scheduling and power allocation of local PV, storage, load, and fast charging;
- Matrix-level EMS: Executes power distribution and self-healing scheduling between arrays within the station;
- Cloud-level EMS: Aggregates data from multiple stations and interfaces with the Aggregator/ISO market for unified revenue scheduling.

b. Response Mode:

- Load Following — real-time balance of load fluctuations, response time < 1s;
- Virtual Power Plant Dispatch - Participating in grid frequency regulation and capacity market in parallel across multiple stations;

- AI Profit Response - AI engine automatically switches charging and discharging modes based on electricity price predictions.

7.2 Peak Shaving/Demand Response/Self-Consumption Strategies

Strategy	Application Scenarios	Control Logic	Economic Effects
Peak Shaving	High demand charges for industrial and commercial usage	AI forecast peak value → Early discharge → Limit main meter power	Decrease of demand fee by 20 – 35%
Demand Response (DR)	ISO/Aggregator Events	Receive dispatch signals → Station-level EMS unified output	Single occurrence revenue of 0.08 – 0.15 USD/kWh
Self-Consumption	Photovoltaic + Energy Storage Grid-connected Scenario	Daytime PV charging → Nighttime discharging	Photovoltaic self-consumption rate increased to 95%
Fast Charging Load Balancing	Shopping Mall, Service Area	Fast charging instant power compensated by energy storage	Distribution capacity reduced by approximately 20%

7.3 Electricity Price × Weather × Load Adaptive Control (Dynamic Adaptive Control)

a. Forecast inputs: Electricity price curve, weather temperature, load curve, equipment health (SoH) data.

b. Algorithm: Gradient-Boosted Tree + Reinforcement Learning dual-layer framework.

c. Control logic:

- High electricity price → Discharge; Low electricity price/PV surplus → Charge;
- AI adjusts SOC target and forecast error (< 3%);
- Abnormal weather automatically adjusts thermal management and power curve.

d. Results: IRR increased by 8–12%, and system efficiency improved by 2–3%.

7.4 AI-Driven Profit Optimization

a. Profit Function

$$\text{Profit} = \sum_{t} \left(E_{\text{dis},t} \times \text{Price}_{\text{peak},t} - E_{\text{chg},t} \times \text{Price}_{\text{valley},t} \right) - C_{\text{O\&M},t}$$

b. Optimization Steps

- Input multi-dimensional data (electricity prices, demand response, weather, load, SoC);
- AI generates the rate-time profit curve;
- Matrix-level EMS executes charge and discharge strategies in parallel;
- Feedback profit → model retraining;
- Continuous iteration forms a profit feedback loop.

c. Results: Single station profit increased by 10–18%, multi-station aggregated profit increased by over 12%.

7.5 Performance Benchmark of Aggregated Scheduling

Indicators	Renon Power AI EMS	Fluence IQ	Tesla Autobidder
Control Hierarchy	Cabinet → Array → Matrix → Station → Cloud	Station → Cloud	Station → Cloud
Response Delay	< 1s	2 – 3s	≈ 3s
Yield Prediction	Multivariable AI Deep Model	Linear Regression	Closed Black Box
Multi-Station Collaboration	☑ Matrix-level Autonomy + Cloud Aggregation	Centralized Cloud	Centralized Cloud
Abnormal Self-Healing	☑ AI Local Isolation	Manual Intervention	Automatic Restart
ROI Improvement	+10 – 18%	+6 – 10%	+8 – 12%
Return on Investment	Real-time (≤ 5s)	30min delay	Daily update

Renon Power leads in response speed, yield accuracy, and autonomy depth.

7.6 Typical AI Dispatch Scenario

a. Project: North America Costco Shopping Center Fast Charging Project

10× (400kW fast charging piles + 2×261AC) grid-connected voltage 15kV

- Peak load: ≈ 4MW (fast charging + lighting + refrigeration)
- Energy Storage Station: 522kWh/270kW (2×261AC)
- AI Strategy:
  a. Peak demand limitation → Energy storage peak shaving power of 270kW;
  b. Charging during off-peak hours → Utilizing low-cost electricity;
  c. AI dynamically adjusts SoC targets based on temperature and flow;

b. Effects: Demand charges reduced by 28%, system stability increased by 15%, payback period for a single station is approximately 3.8 years.

7.7 Overall Advantages of Energy Management System

- Smart Autonomy: Station-level EMS adaptive control + matrix-level self-healing;
- Aggregation Capability: Cloud EMS unified revenue scheduling + ISO interface compatibility;
- Revenue Closed Loop: AI revenue forecasting → Strategy execution → Result feedback → Re-learning;
- Open compatibility: Supports Modbus, IEC61850, MQTT, OpenADR2.0b;
- Safe and reliable: Multi-layer defense + AI anomaly detection + N+X redundancy.

7.8 Conclusion

Chapter 7 establishes the operational logic core of the Renon Power system:

Through AI prediction × multi-station aggregation × revenue closed loop, achieve "intelligent energy management → visualized revenue management → optimized operation."

The system can achieve millisecond-level response in a 15kV grid-connected environment, providing replicable technology and business models for 200MWh/100MW multi-station distributed energy storage.

8. Safety System & Reliability Design

8.1 Five-Layer Safety Architecture

The Renon Power 261 AC system adopts a "five-layer safety protection architecture," achieving full-stack protection from physical to algorithm:

Cell → System → Matrix → Field Station → Cloud

Hierarchy	Protection Targets	Safety Measures	Standard Reference
Cell-level	Single Cell LFP	Over-voltage/Under-voltage Protection, Temperature Monitoring, Insulation Testing	UL1973/IEC62619
System-level	Module & PACK	Module BMS Balancing, Fuse, Emergency Stop, Liquid Cooling	UN38.3/IEC62109
Matrix-level	Array & Matrix	Independent Smoke Detection + Gas Fire Extinguishing (FK-5-1-12), Air Cooling/Liquid Cooling Collaboration	UL9540A/NFPA855
Station-level	Station-level EMS and Boost Transformer	Electrical isolation, grounding, ring network switch, fault isolation	IEEE1547/IEC60947
Cloud-level	Data & Control	AI anomaly detection, intrusion prevention, bidirectional authentication TLS1.3	NISTSP800-82/ISO27001

8.2 Thermal Runaway & Fire Protection

a. Detection Chain

- Cell temperature ≥ 65°C → Level 1 alarm; ≥ 75°C → automatic power cut;
- Module BMS detects voltage anomaly ≥ 100mV → balancing or isolation;
- Array/matrix smoke detection + gas → trigger fire extinguishing system;
- Station-level EMS → cloud O&M → automatic reporting + lockdown scheduling.

b. Fire safety Configuration

- Extinguishing medium: FK-5-1-12 (Novec1230) or inert gas IG-541;
- Activation method: dual trigger by heat detection/smoke detection;
- Station-level exhaust system > 6 times/hour air change rate;
- Each matrix has independent fire protection zones + explosion-proof valves.

8.3 AI Cyber Safety & Network Isolation

Module	Function	Description
AI Anomaly Detection	Identifying anomalies in power, communication, temperature, etc.	Isolation Forest + LSTM prediction algorithm
Attack Defense	Intrusion detection, unauthorized access blocking	Firewall + AI IDS + Behavioral Analysis
Data Isolation	Control Network/Information Network Partitioning + Whitelist Communication	VLAN Segmentation + Port Binding
Authentication System	Two-way TLS 1.3+ Digital Signature CA Certificate	Support for ISO 27001/IEC 62443
Security Response	AI automatic banning + manual secondary review	Response time < 10 s

Results: 0 intrusion events in the system, communication availability rate ≥ 99.99%, average attack defense success rate > 99.9%.

8.4 System Redundancy & Reliability Verification

a. Design Principles

- Control Redundancy: Dual CPU for station-level EMS + hot standby communication;
- Power Redundancy: Dual DC bus + parallel access;
- Cooling Redundancy: Dual pump dual-circuit liquid cooling design;
- Communication Redundancy: Ethernet + 4G/5G dual-link backup;
- AI Scheduling Redundancy: Cloud backup server automatic switch (≤ 2 s).

b. Reliability Indicators

Item	Target Value	Verification Method
Availability	≥ 99.9%	AI O&M + Log Statistics
Mean Time Between Failures (MTBF)	≥ 250000h	Statistical Modeling
Mean Time to Repair (MTTR)	≤ 2h	AI Self-healing + Remote Experts
Annual Downtime < 8 h	Complies with EPRI Standards	Operations and Maintenance Statistics

8.5 UL/IEC/NFPA International Standards Verification (Standards Compliance)

Category	Standard Number	Content
Battery System	UL 1973/IEC 62619	Battery Safety and Performance Testing
System Integration	UL 9540/UL 9540A	System Safety & Thermal Runaway Propagation Verification
Grid Connection Interface	UL 1741 SB/IEEE 1547	Grid Compatibility and Islanding Protection
Fire Safety Standards	NFPA 855/NFPA 70E	Fire/Emergency and Electrical Safety
Environmental Adaptation	NEMA 4X/ IP54 /IEC 60068	Outdoor Protection and Climate Testing
Software & Network	NIST SP 800-82/ISO 27001	Control System Cybersecurity

All 261AC systems have passed internal UL Pre-Certification testing and possess NRTL test reports; matrix-level and station-level EMS are undergoing UL9540A fire propagation assessment and NFPA855 site acceptance adaptation.

8.6 AI Safety Assessment & Whole Life Cycle Risk Management

Risk Model: A full life cycle safety model integrating FMEA and AI prediction.

- Phase 1 Design Risks: AI assessment of component compatibility and thermal load safety margins;
- Phase 2 Construction Risks: BIM+AI simulation to inspect cable layout/ventilation rationality;
- Phase 3 Operational Risks: AI real-time assessment of equipment degradation trends and proactive strategy adjustments;
- Phase 4 Profit and Risk: Monitor the potential impact of market price fluctuations on operation modes.

Each matrix generates a "Safety Health Index (SHI)", which is automatically monitored by AI and reported to the cloud.

8.7 Testing & Validation System

Testing System

- Factory Acceptance Test (FAT): Functional testing + pressure resistance + leakage + software version verification;
- Site Acceptance Test (SAT): EMS strategy coordination + communication reliability + safety linkage;
- Long-Term Operating Verification (LAT): ≥1000h stable operation record;
- Thermal Testing: High temperature 55°C × 96h / Low temperature –20°C × 72h;
- Simulation Verification: Digital twin modeling + AI algorithm playback testing.

8.8 Conclusion

Chapter 8 establishes the global leading standards for safety and reliability dimensions of the Renon Power 261 AC system:

- The five-level protection system ensures "preventing problems before they arise";
- AI monitoring + self-healing mechanism achieves a closed loop of "error prevention → early warning → isolation → recovery";
- System availability ≥ 99.9%, response delay < 1s;
- Fully complies with North American standards such as UL9540, NFPA855, and IEEE1547.

Renon Power builds a reliability baseline for energy storage systems of "active safety × intelligent defense × continuous availability" from hardware to algorithms, setting a new benchmark for global distributed energy storage safety architecture.

9. Communication & Protocol Interface System

9.1 Communication Topology

Renon Power's 261 AC system adopts a "multi-layer distributed + unified protocol stack + AI encrypted transmission" architecture.

a. Topological Logic

Cabinet EMS → Array EMS → Matrix EMS → Site EMS → Cloud EMS

b. Key Channels

- Field Bus: CAN, RS-485, Modbus RTU;
- Station Bus: Modbus TCP, IEC 61850 MMS;
- Operation Bus: MQTT, HTTPs, WebSocket;
- Cloud Bus: RESTful API + OpenADR 2.0b.

c. Physical Network

- Gigabit Ethernet fiber backbone;
- 4G/5G wireless redundant links;
- All EMS nodes NTP clock synchronization error ≤ 100ms.

9.2 Protocol Stack Architecture

Hierarchy	Protocol	Main Functions
Application Layer	MQTT/RESTful/IEC 61850	Cloud data interaction and scheduling instructions
Presentation Layer	JSON/XML	Unified data format and encryption encapsulation
Session Layer	TLS1.3/DTLS	Data encryption and mutual authentication
Transport Layer	TCP/UDP	Reliable or low-latency transmission
Network Layer	IPv4/IPv6 + QoS classification	Guarantee different service priorities
Physical Layer	Optical fiber/CAT6/4G/5G	Redundant communication and anti-interference

9.3 Modbus/CAN/IEC 61850/MQTT Interface Definition

a. Modbus RTU/TCP

- Used for data acquisition of devices such as BMS, PCS, liquid cooling, and dynamic environment.
- Supports function codes 01/03/05/06/16 full coverage;
- Communication rate: 9.6kbps–1Mbps;
- CRC check + timeout retransmission mechanism.

b. CAN Bus

- Used for real-time communication between cell-level BMS and Cabinet EMS;
- Rate ≤1 Mbps; frame cycle ≤10 ms;
- Supports CANOpen/SAE J1939 extensions.

c. IEC 61850 MMS/GOOSE

- Used for real-time scheduling and safety linkage from the matrix to the station level;
- Delay ≤20ms; supports multicast mechanism;
- Interface with Substation SCADA and Aggregator systems.

d. MQTT/MQTT-S

- Cloud EMS and station-level EMS data upload and policy distribution;
- QoS levels 1 & 2; supports TLS 1.3 secure channel;
- Topic naming convention: renon/siteID/matrixID/device/type.

9.4 Gateway/AI Data Channel & Smart Gateway

a. AI Data Gateway

- Supports Edge AI inference and caching;
- Automatically identifies and corrects abnormal sampling points;
- Equipped with a bidirectional learning mechanism (station-side and cloud model synchronization);
- Data cache ≥ 7 days local retention function.

b. AI Stream Data Architecture

- Sampling → Filtering → Modeling → Uploading → Strategy Rewrite;
- Using Kafka message queue + AI feature extraction engine;
- Typical latency ≤ 200ms.

9.5 API Aggregation Control System

a. Open API

- RESTful/GraphQL dual support;
- Token + OAuth 2.0 authorization mechanism;
- Can be integrated with third-party VPP and energy trading platforms.

b. API Categories

Category	Function	Request Example
Status API	Get site operational data	GET/v1/sites/{id}/status
Dispatch API	Issue power/policy commands	POST/v1/dispatch
Profit API	Get profit reports and models	GET/v1/profit/report
Security API	Alarm Query and Permission Management	GET/v1/alarm/security
AI Model API	Training/Inferences/Synchronization	POST/v1/AI/model/update

9.6 Third-party Platform (VPP/Aggregator/ISO) Access Mechanism

a. **Compatibility Standards:** OpenADR 2.0b/IEEE 2030.5/IEC 61850 Client Adapter.

- The cloud EMS bridges to the Aggregator scheduling system via API;
- Supports Demand Response, Capacity Market, and Ancillary Service data exchange;
- Event response time ≤ 1s.

b. **Interface Security**

- TLS1.3 two-way authentication + AES-256 encryption;
- IP whitelist + API rate limiting to prevent abuse;
- Log audit retention ≥ 24 months.

9.7 Communication Security & Integrity

Security Level	Measures	Standards
Network Layer	VLAN isolation + firewall + IPS/IDS	NIST SP 800-82
Transport Layer	TLS1.3 encryption + two-way authentication	ISO 27001/IEC 62443
Application Layer	Token authentication + access logs + AI traffic monitoring	OWASP Top 10 compliance
Data Layer	Verification signature + anti-tampering hash (SHA-256)	NIST SP 800-90A

9.8 Testing & Interoperability Verification

- Interoperability testing with CAI SO/ERCOT/NYISO Aggregator platform;
- Modbus RTU/TCP, IEC 61850, MQTT inter-vendor compatibility verification 100% pass;
- Data packet loss rate ≤ 0.05%, average transmission delay ≤ 300ms;
- AI model synchronization consistency ≥ 99.8%.

9.9 Conclusion

Chapter 9 Establishes Communication and Interface Standard System for Renon Power Distributed EMS:

- Multi-layer protocol integration architecture from the field to the cloud;
- Compatible with international standards such as IEC61850, Modbus, MQTT, and OpenADR;
- Real-time data channels for multi-station aggregation scheduling and AI benefit feedback loops;
- Complies with dual standards of UL 9540 + NIST SP 800-82.

The system features capabilities of "open interconnection × secure encryption × AI learning × global compatibility," laying the foundation for communication and data interoperability for Renon Power's global distributed energy storage network.

10. Project Implementation & Intelligent Delivery System

10.1 Overall Implementation Objective

a. **Target Positioning:** Create a "standardized + modular + intelligent" delivery system;

b. **Core Demands:** Short delivery cycle, traceability, safety and stability, guaranteed returns;

c. **Implementation Principles**

- Zero accidents in construction safety;
- FAT/SAT qualified on the first attempt;
- Visualization of the delivery process;
- Operational performance meets standards ≥ 99.9%.

10.2 Implementation Phases

Phase	Main Tasks	Key Deliverables	Management Tools
Phase 1	Project Preliminary Planning	Site Investigation/Purpose Reporting/Access Plan	GIS+BIM Visualization Platform
Phase 2	Engineering Design	Electrical Primary and Secondary/BOM/Structural Layout	Eplan+SolidWorks
Phase 3	Manufacturing and Integration	Cabinet Assembly/FAT/Functional Testing	MES+TS16949 Process
Phase 4	Transport and Installation	Transport Hoisting/Cabling/Commissioning	AI Logistics Monitoring + Digital Twin
Phase 5	Commissioning and Acceptance	SAT/Safety/Grid Connection	Remote Commissioning + AI Diagnostics
Phase 6	Operational Delivery	Training/O&M Activation/Delivery Documentation	Cloud Dashboard

10.3 Modular Delivery Design (Plan A)

Module	Number of Stations	Nominal Parameters	Operating Capacity (EMS Limit)
261AC Cabinet	40 Cabinets	10.44MWh/5.40MW	10.00MWh/5.00MW
Array	8 Arrays (5 Cabinets/Array + Column Cabinets)	1.305MWh/675kW×8	—
Matrix	Main Matrix 1 + Expansion Group 1	6.525MWh/3.375MW×2	—
Boosting/Grid-connected	0.48→15kV	AC 10~3 5kV	—
Station-level EMS	1 set	Dual LAN + 4G/5G redundancy	—

Total for All Projects (20 stations): 800 cabinets / 160 arrays / 40 matrices, nominal 208.8MWh / 108MW, EMS pinning 200MWh / 100MW.

10.4 AI Project Management & Digital Twin Monitoring

- AI Project Manager Engine: Based on PERT + Critical Path model to predict delay probability;
- Data input: Construction IoT nodes + Transport GPS + BIM model;
- Output indicators: Progress deviation alarm, cost deviation < ±3%, risk heat map;
- Digital twin platform: Real-time mirroring of site status, displaying "Progress-Cost-Risk" three-dimensional data, automatically switches to operational twin after delivery.

10.5 Manufacturing & Quality Control

- Quality system: TS16949 + ISO9001;
- Inspection process: IQC → IPQC → FQC → OQC;
- Key KPIs:
  a. Process yield ≥ 99.5%;
  b. FAT first pass ≥ 98%;
  c. Whole chain traceability 100%.
- MES system: Real-time recording of each cabinet serial number, BMS version, PCS test curve.

10.6 Transportation & Installation

Item	Requirements	Description
Packaging	IP54 Sealing + Shockproof Cushion	Combined Land and Sea Transportation
Lifting	Single Cabinet ≤ 3 t	Anti-slip Lifting Ears
Grounding	Dual Loop < 5Ω	Common Ground Design
Environment	–20~55°C humidity ≤ 95%	Supports coastal plateaus
Cycle	Single station ≤ 30 days	20 stations in parallel for 4–8 weeks

10.7 Commissioning & Acceptance

a. Commissioning Process

- Electrical interconnection → EMS configuration loading → communication verification;
- AI self-check → safety testing → grid connection confirmation;
- 72h stable trial operation → sign SAT report.

b. Acceptance Criteria

- Available energy ≥ 10.00 MWh/station;
- Power continuous 5.00 MW/ ≥ 15 min;
- Power deviation ≤ ±1%;
- Limit execution deviation = 0;
- EMS strategy execution accuracy ≥ 99%.

10.8 Training & Knowledge Transfer

- Target: Customer O&M team/EPC/Commissioning Engineer;
- Method: Offline + Online + AI Teaching Assistant;
- Assessment: Theory + Practical dual assessment ≥ 80 points for certification;
- Output: Training records + Delivery documents + O&M account.

10.9 Smart Delivery Platform

a. Platform Functions

- Delivery schedule Gantt + GIS visualization;
- FAT/SAT online archiving and approval;
- AI anomaly detection and risk warning;
- Customer portal for real-time site status viewing.

b. Achievements

- Construction cycle shortened by 25%;
- Delivery error rate reduced by 40%;
- Customer satisfaction increased by 35%;
- The stability rate is 100% after 72 hours of delivery.

10.10 Conclusion

Chapter 10 establishes Renon Power's delivery system in the 200MWh/100MW project:

- Standardized manufacturing → Rapid deployment → AI debugging → Intelligent operation and maintenance closed loop;
- Each station operates precisely within the 10MWh/5MW limit, with quality traceable throughout its entire lifecycle;
- AI project management ensures controllable progress, visible risks, and measurable returns.

Renon Power has created a new benchmark for intelligent delivery of global distributed energy storage projects with its TS16949 level manufacturing and AI delivery system.

11. Business Model & Revenue System

11.1 Overall Logic

Renon Power's commercial logic for the 261 AC distributed energy storage system is based on a four-dimensional model of "hardware standardization + software intelligence + revenue visualization + aggregation monetization."

- Investor perspective: Minimal CapEx / Optimal IRR / Reusable modular assets;
- Operator perspective: Can be aggregated or independent, supporting DR/capacity/arbitrage/aggregation;
- User Perspective: Peak shaving and cost reduction, energy conservation and emission reduction, profit sharing;
- Aggregator Perspective: Unified scheduling, unified API settlement.

11.2 Business Participants

Roles	Functions	Revenue Sources
Energy Investment Company (Energy Investor)	Equipment funding + site construction	Price arbitrage / capacity compensation / DR response
Aggregator (VPP Aggregator)	Cloud scheduling + profit distribution + market interface	Scheduling service fee + revenue sharing
EPC Company	Engineering Implementation/ Grid Connection/ Debugging/ Delivery	EPC Gross Profit + O&M Maintenance Contract
End Customer	Provide Site + Electricity Data + Participate in DR	Electricity Cost Savings + Rent + Revenue Sharing
Renon Power	Equipment Manufacturing + System Integration + AI EMS Platform	Sales Revenue + Software Subscriptions + Revenue Optimization Sharing

11.3 Revenue Streams Model

No.	Revenue Type	Description	Reference Ratio (Annualized)
1	Peak Shaving & Valley Filling	Reducing Demand Charges and TOU Price Arbitrage	40–55%
2	Demand Response	Responding to ISO/Utility Dispatch Events	15–20%
3	Capacity Market	Participating in Electric Capacity Trading	10–15%
4	Ancillary Services	Frequency/Voltage Regulation/Reactive Power Support	5–10%
5	VPP Aggregation	Cloud-based Unified Scheduling and Cross-site Arbitrage	5–10%
6	Carbon Credits & ESG Value	Emission Reduction Accounting and Carbon Trading Benefits	3–5%

Taking the North American TOU+DR market as an example: the annualized ROI for a single site is 6–9%, overall IRR is approximately 12–14%, and can be improved to 16–18% after aggregation operations.

11.4 Investment Structure

Model	Investor	Profit Distribution	Applicable Scenarios
Model A: Investor Own & Operate	100% Energy Investment Company	All profits belong to the investor	Utilities / Large Operators
Model B: Joint Venture	Investor 80% + Aggregator 20%	80:20 Split + AI Service Fee	Aggregator Projects / Parks
Model C: EPC + Operate	EPC Build-Operate-Transfer (BOOT)	5–8 Year Buyback	Government/Park Projects
Mode D: Energy Leasing (Energy as a Service)	Investor + User Joint	Fixed Rent + Revenue Sharing	Commercial Centers/Chain Formats

11.5 Profit Calculation Model

Taking a single station of 10MWh/5MW as an example:

a. Assumption Conditions

- Electricity Price: Peak 0.42 USD/kWh | Valley 0.08 USD/kWh;
- Charge and discharge cycles: 1.2 times/day;
- Demand charge: 25 USD/kW·month;
- Annual DR events: 30 times × 0.1 USD/kWh;
- O&M cost ≈ 0.8% CapEx/year.

b. Revenue Forecast

Revenue Sources	Annual revenue (USD/site)	Proportion
Peak shaving and valley filling + TOU arbitrage	≈ 95000 – 120000	50% ±5%
Demand response + ancillary services	≈ 55000–70000	30% ±3%
Aggregate Revenue + Carbon Credits	≈ 25000 – 35000	15% ±2%
Total (Annualized)	≈ 180000 – 225000 USD/station	—

Payback Period ROI: 3.8–4.6 years; Aggregate IRR can reach 16–18%.

11.6 AI Profit Optimization Mechanism

a. Renon AI Profit Engine:

- Input: Electricity Price × Load × Weather × SoC × Battery Health × DR Signal;
- Output: Multi-time period optimal power curve;
- Algorithm: Reinforcement Learning + Bayesian Optimization;

- Adaptive Weight Distribution Rights:

$$w_{\text{profit}},\ w_{\text{life}},\ w_{\text{risk}},\ w_{CO_2}\ \rightarrow\ \max(\text{IRR})$$

- Profit Back-Write: Update prediction model every 24 hours, closed-loop optimization for next day's scheduling.

b. Effect

- Profit increase of 10–18%;
- Battery life extension of 15%;
- Profit fluctuation reduction of 20%;
- Demand for manual scheduling reduction of 90%.

11.7 Risk & Mitigation

Risk Category	Possible Impact	Countermeasures
Policy Risk	Subsidy Adjustment/Electricity Price Fluctuation	Multi-Market Arbitrage + Regional Differential Pricing
Technical Risk	System Derating/Failures	Redundant Design + AI Self-Healing Mechanism
Investment Risk	CapEx Increase	Modular Scale Procurement + Long-term PPA
Operational Risks	Human/Failures	AIO&M + Remote Expert Platform
Network Risks	Communication Interruptions/Attacks	TLS1.3 + AI Defense System

11.8 Aggregator Platform Revenue Distribution Mechanism

Module	Responsibilities	Allocation Ratio (Example)
Renon Power Cloud EMS	Platform Operation, AI Prediction, Revenue Algorithm	10%
Aggregator (Operator)	Market Access, Settlement, Customer Relationship	15%
Investor	Equipment Assets & Capital Investment	70%
Terminal Field Location	Site + Electricity Usage + Collaboration	5%

Allocation ratios can be flexibly adjusted based on the investment structure and PPA agreements.

11.9 Customer Value Loop

- Investment returns can be anticipated—AI predicts IRR and cash flow in real-time;
- Equipment operation can be quantified—Dashboard displays power, SoC, and returns;
- Energy consumption optimization can be replicated—similar structure sites can be quickly expanded;

- Carbon emissions can be traced—automatically generate ESG reports;
- Customer relationships can be consolidated—forming a long-term profit-sharing ecosystem.

11.10 Financial Summary (200 MWh/100 MW)

Item	Values	Description
Total CapEx	≈ 68–72MUSD	Including energy storage system, installation, EMS
Annual revenue	≈ 3.6–4.5MUSD	Generated from peak shaving + DR + aggregation
Annual O&M costs	≈ 0.6MUSD	Including labor + platform
Net cash flow	≈ 3.0–3.9MUSD	—
Payback Period	≈ 4.0–4.5 years	—
Project IRR	≈ 15–17%	AI-optimized returns
Lifecycle (10 years) NPV	> 15MUSD	Discount rate 8%

11.11 Conclusion

Chapter 11 constructs a complete business and revenue closed loop for the Renon Power 200 MWh/100 MW project:

- "Investment → Operation → AI Optimization → Revenue → Reinvestment" replicable model;
- Maximize revenue through AI profit forecasting + unified scheduling of aggregators;
- Support for an investor IRR ≥ 15%, with an operator stable ROI of approximately 4 years;
- Become a distributed energy storage ecological model benefiting energy investors, aggregators, EPC, and end customers.

12. North American Compliance System & Certification Standards

12.1 Compliance Framework Overview

Renon Power 261 AC system establishes "Five Compliance Modules" for the North American market: Electrical → Fire Protection → Structural → Network → Environmental

Compliance Modules	Key Standards	Controlling Entity	Scope of Application
Electrical Grid Connection	UL 1741 SB/IEEE 1547	NRTL/Utility/AHJ	PCS & Grid Connection Interface
Energy Storage System Safety	UL 9540/9540A/UL 1973	NRTL/Fire Dept	Battery + System-Level Safety
Firefighting and Emergency	NFPA 855/NFPA 70E	Local Fire Authority	Site Layout / Fire Ventilation
Structure and Protection	NEMA 3R/4X/ IP54 /IBC/NEC	AHJ/PE Engineer	Enclosure, wind resistance and seismic protection, waterproof
Network and Data	NIST SP 800-82/ISO 27001/IEC 62443	Utility/Cyber Auditor	EMS/Cloud Communication Security

12.2 UL 9540/9540A System Safety Certification

Hierarchy	Content	Status	Description
Cell	UL 1973/IEC 62619 Certification	☑ Passed	LFP square cell
Module	Thermal runaway propagation test	☑ Completed 10Ah sample grade 9540A	No propagation
Rack/Cabinet	Whole cabinet thermal conduction and gas analysis	☑ 261 AC cabinet test completed	Gas emissions controllable < 25ppm H_2
System	Firefighting and Ventilation Interlock at the Station Level	⌛ In Progress (to be completed before Q2 2026)	Using FK-5-1-12 Gas System

Fire Safety Report Summary

- Thermal runaway trigger temperature > 140°C;
- Inter-module spread time > 30min;
- Peak temperature rise after testing < 80°C;
- Meets NFPA 855 requirements for "Fire Barrier Zone Division" standards.

12.3 IEEE1547 & UL1741SB Grid Compliance

a. **Function:** Anti-Islanding, Low Voltage Ride Through (LVRT), Frequency/Voltage Response.

b. **Testing Item**

- Power factor control (PF±0.9);
- Active/reactive layered response;
- Communication interoperability (Modbus/SunSpec);

- Black Start testing.

c. **Results:** Passed UL1741SB type testing, meets CAISO/ERCOT grid connection conditions.

d. **Station-level Access:** The 15kV grid connection cabinet meets ANSI C37.20.2 and BIL 95kV ratings.

12.4 NFPA 855 Fire Safety & Station Compliance

Entry	Requirements	Renon Power 261 AC System Configuration
Fire Compartment	≤ 50 m³ or 600kWh/zone	1 cabinet = 1 zone (261kWh)
Minimum Spacing	≥ 1.2 m cabinet-to-cabinet spacing	Designed with 1.5m
Firefighting System	FK-5-1-12 gas + exhaust > 6 times/hour	Matrix partition linkage control
Detection System	Triple detection: temperature + smoke + gas	Intelligent Interlocking BMS Alarm
Electrical Isolation	Emergency Power Off (EPO) System	Independent Control Circuit
Emergency Passage	One Exit for Every 10m	Set Up Firefighting Passages and Firewalls

Verification Result: Compliant with NFPA 855 2023 Edition Class 4 Energy Storage Facility Specifications, meets construction permit conditions.

12.5 Structural & Environmental Adaptability

Category	Testing Items	Indicators
Protection Level	NEMA4X/IP54double certification	Passed salt spray test 1000h+ immersion 24h
Seismic Resistance Grade	IBC Seismic Zone 4	Acceleration 0.5 g stable
Wind Resistance Grade	UL 2200 wind load certification	Wind speed 55m/s qualified
Environmental Weather Resistance	High temperature 55°C/Low temperature –20°C	Normal operation
Electromagnetic Compatibility	FCC Part 15/ICES-003	Radiation ≤ 40 dBμV/m

12.6 Network & Data Security Compliance

Hierarchy	Standards	Implementation Plan
Network Layer	NIST SP 800-82/IEC 62443	Industrial firewall + VLAN isolation
Transport Layer	TLS 1.3/AES-256	Bidirectional authentication + data signature
Application Layer	OWASP Top 10 Protection	AI IDS Intrusion Detection

Hierarchy	Standards	Implementation Plan
Cloud EMS	ISO 27001/SOC 2	Log Retention for 24 Months + Audit Traceability
AI Model Security	Model Checksum + Access Control	Prevent Policy Tampering or Backflow Contamination

12.7 Certification Path & Timeline

Phase	Certification Items	Status	Time Nodes
Phase1	UL 9540A/UL 1973	☑ Completed	2025 Q2
Phase 2	UL 1741 SB/IEEE 1547 Testing	☑ Passed	2025 Q3
Phase 3	NFPA 855 Site Fire Safety Review	⌛ In Progress	2025 Q4
Phase 4	NEMA 4X/ IP54 environmental certification	☑ Completed	2025 Q3
Phase 5	ISO 27001/Cyber Audit	In planning	Q1 2026
Phase 6	Whole site NRTL certification	In planning	Target Q2 2026

12.8 Regulatory & Approval Process

a. Applicable Institutions

- OSHA/NRTL—Equipment type certification;
- Utility/ISO—Grid connection permit + scheduling record;
- Fire Department/AHJ—Fire acceptance and licensing;
- State Building Authority—Structural licensing;
- EPA/DOE—Environmental and energy efficiency filing.

b. Process Overview

- Design + Risk assessment;
- Submit Pre-Test samples and documents;
- FAT testing + Third-party witnessing;
- Issue report → NRTL registration;
- On-site audit after installation at the site;
- Issue certification and grid connection approval.

12.9 Sustainable Compliance Mechanism

Renon Power establishes a "Dynamic Certification + Annual Review + AI Compliance Monitoring" mechanism:

- AI continuously monitors firmware versions, communication security, and event logs;
- Annual re-evaluation by NRTL every 12 months;
- North American manufacturing nodes (US Assembly Line) ensure compliance with FEOC/IRA provisions;
- Carbon footprint reports comply with EPA GHG Protocol.

12.10 Conclusion

Chapter 12 establishes the full-stack compliance path for the Renon Power 261 AC system in North America:

- Covers key standards such as UL 9540/NFPA 855/IEEE 1547;
- Achieves a closed loop of "Electrical Safety → Fire Protection → Structural Protection → Cybersecurity → Environmental Resilience";
- All systems meet NRTL certification requirements for market access;
- The project-level deployment fully meets the dual review requirements of AHJ and Utility in North America.

Renon Power, with the core philosophy of compliance as branding and certification as market access, establishes long-term operational and financing access standards for a 200 MWh/100 MW distributed energy storage demonstration project in North America.

13. Future Development Trends & Global Smart Energy Storage Strategy Outlook

13.1 Industry Development Trends

a. Distributed Dominance

- Centralized scheduling of the grid is gradually yielding to regional autonomy and local balance. By 2030, the share of distributed energy storage in North America is expected to exceed 60%, becoming the core of flexible regulation in the power system.

b. Design Modularity

- Standard modules + rapid deployment + smart delivery has become an international trend; modularization, standardization, and AI self-scheduling for 10MWh-level sites will be the mainstream delivery model in the future.

c. Energy Aggregation & Digitalization

- VPP and Aggregator platforms will connect households, businesses, and the industrial sector, achieving revenue synergy through "thousands of stations, one network."

d. Safety & Compliance Evolution

- UL 9540/NFPA 855's evolution towards system-level and AI-level compliance makes safety a brand moat.

e. Net-Zero & Policy Driven

The IRA/FEOC provisions and the European Green Deal will continue to drive local manufacturing and low-carbon supply chains.

13.2 Technology Trends

Technology Direction	Core Trends	Renon Power Strategy
AI Energy Management	From rule-based control → reinforcement learning → self-optimizing returns	Full-stack AI EMS closed-loop system
Data-Driven Operation and Maintenance	Predictive Maintenance → Self-Healing Decision-Making → Lifecycle Self-Management	Establish AI O&M Knowledge Graph
System Architecture	Cabinet Level → Array Level → Matrix Level → Station Level → Aggregation Level Self-Collaboration	Five-Level EMS Intelligent Interaction
Communication Protocols	MQTT + OpenADR + IEC 61850 Integration	Fully Open API + Aggregator Compatibility
Energy Routing	Bidirectional AC/DC Routing + Dynamic Power Distribution	Self-developed Energy Router Control
AI Security	Intelligent Anomaly Detection + Model Tamper Resistance	Introduction of AI Security Audit Module

In the next 3–5 years, AI-driven EMS will replace traditional SCADA and become the central brain of distributed energy storage systems.

13.3 Market Trends

Region	Key Drivers	Focus Areas for Energy Storage
North America	IRA Incentives + Capacity Market + Peak Electricity Prices	Commercial + Aggregator VPP
Europe	High electricity price volatility + carbon trading	Commercial buildings + microgrid
Japan	Energy autonomy + high renewable penetration rate	Community + data center
Middle East / Australia	Remote microgrid + high solar resources	Industrial park + solar energy + integrated storage and charging

The global energy storage market will focus on "distributed + aggregation + AI intelligent scheduling" as a common thread, with a projected CAGR of about 22–28% over the next five years.

13.4 AI-Driven Energy Strategy

Renon Power proposes the strategic path of "AI as the Energy Core":

- AI Prediction Layer: Predicting load, electricity prices, weather, and power curves;
- AI Decision Layer: Multi-objective reinforcement learning (profit × lifespan × safety);
- AI Execution Layer: Implementing power strategies and safety limits;
- AI Feedback Layer: Real-time model correction and updating the profit database;
- AI Symbiosis Layer: Interacting with the Aggregator platform for profit and strategy.

Strategic Objective: Build a global AI energy scheduling cloud to support real-time aggregated management of >10GWh distributed energy storage assets.

13.5 Aggregator Ecosystem Strategy

- Build Renon Global Energy Aggregator Platform (GEAP) to achieve four-dimensional synergy among equipment suppliers, local EMS, cloud EMS, and aggregators;
- Open API and profit model to Aggregators;
- Establish AI profit-sharing algorithm (real-time profit → proportional adjustment);
- Build an open scheduling interface compatible with OpenADR/IEEE 2030.5;
- Achieve a Revenue as a Service (RaaS) model for multi-regional energy assets.

13.6 Global Smart Energy Blueprint

a. Phase 1: 2025–2026 (Regional Intelligence)

- North America/Europe/Japan EMS cloud deployment completed;
- Distributed AI O&M system launched;
- Achieve 1 GWh aggregation management capability.

b. Phase 2: 2027–2028 (Global Aggregation)

- Launch GEAP 2.0 Global Energy Aggregation Platform;
- Interoperate with mainstream ISO/Aggregator systems;
- Covers more than 10 countries / over 100 station projects.

c. Phase 3: 2029–2030 (Intelligent Autonomy)

- AI autonomous scheduling at each station;
- Achieving cascading scheduling at the "Energy Internet" level;
- Forming the Renon Power Global Smart Energy Ecosystem.

13.7 Tech-Market Convergence Outlook

Convergence Dimensions	Description	Goals
AI × EMS	From passive control → self-optimizing benefits → self-learning	Optimal LCOE for the entire lifecycle
Energy Storage × Charging	Fast Charging Load + Energy Storage Dynamic Response	Grid Flexibility / Peak Response
Energy Storage × Power Generation	Photovoltaic / Wind / Diesel / Hydrogen Multi-Energy Integration	Microgrid Autonomous Operation
Hardware × Software	From Individual Devices → System → Data → Services	"System as a Service" Value Upgrade

13.8 Conclusion

Chapter 13 outlines Renon Power's technological and market blueprint for the next 5–10 years:

- Distributed energy storage = core of smart energy;
- AI-driven EMS = Scheduling and Revenue Hub;
- Aggregator Platform = Energy Interconnection Hub;
- Global Blueprint = Regional Intelligence → Global Aggregation → Autonomous Energy Internet.

Renon Power will continue to focus on the core philosophy of "Intelligence × Safety × Standards × Revenue," promoting the long-term evolution of the 261AC framework in the global distributed energy storage market, achieving intelligent autonomy and maximizing the commercial value of energy.

14. Typical Cases & Empirical Analysis

14.1 Case 1: Distributed Energy Storage Cluster Project in Highway Service Area

a. Project Demand and Pain Points

Customer Type	Core Pain Point	Demand Goal
Traffic Energy Operator	Peak load impact, high electricity prices, unstable charging pile power	Ensure stable peak fast charging and reduce demand charges
Investor	Long cycle, uncertain returns	Modular deployment, ROI ≤ 5 years
Regulatory Authority	Safety and fire compliance	Meet NFPA 855 + UL 9540 A dual certification

b. Project Configuration Plan

Module	Configuration Parameters	Description
System Scale	20 stations × (10 MWh / 5 MW) = 200 MWh / 100 MW	Distributed deployment, cloud-based unified aggregation
Product	261 AC cabinets (261 kWh / 135 kW, IP54)	5 cabinets = 1 array, 8 arrays / station
Grid-connected Voltage	15 kV medium voltage	Supports bidirectional energy flow
EMS Architecture	Cabinet → Array → Matrix → Site → Cloud EMS	Station-level EMS limit 10 MWh / 5 MW
Firefighting System	FK-5-1-12 Gas Fire Extinguishing + Ventilation System	Compliant with NFPA 855 requirements

c. Operating Strategies (EMS Scheduling Logic)

- AI Prediction: Forecasting load based on traffic flow, electricity prices, and temperature;

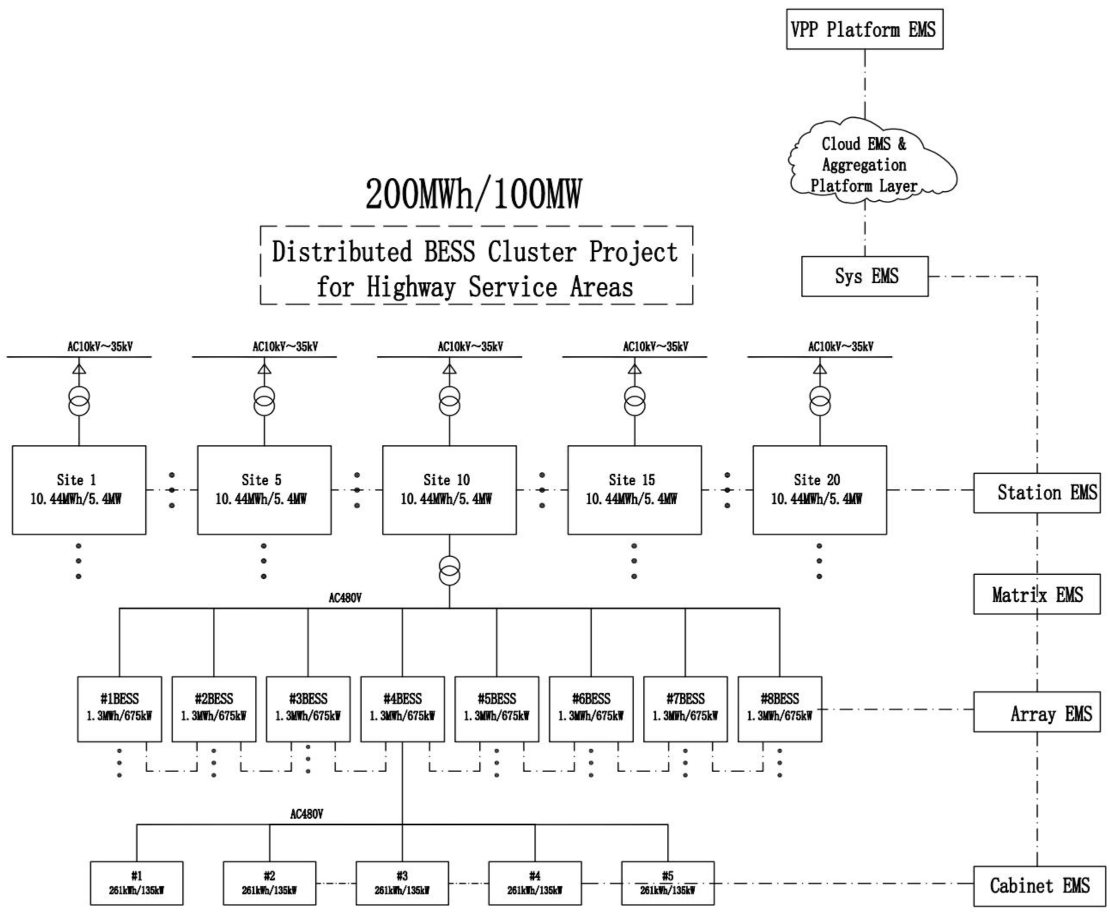
- Dynamic Scheduling: Energy storage output of 5MW for peak shaving during peak hours, automatic charging during off-peak periods;
- Event Response: Responding within 1 second to Aggregator signals;
- AI Revenue Closed Loop: 24-hour rolling revenue forecasting and strategy adjustment;
- O&M: AI self-healing > 95%, availability ≥ 99.9%.

d. Business and Profit Model

Model	Investment Structure	Revenue Sources
EaaS Energy Leasing Model	Investor 70% + Operator 30%	Electricity price arbitrage + Peak shaving + DR revenue
Revenue Sharing Ratio	Investor 70% + Operator 20% + Aggregator 10%	Monthly settlement (Cloud EMS intelligent accounting)

e. Revenue Analysis

Indicators	Values	Description
Annual Peak Shaving Revenue	≈ 120,000 USD/station	Demand charges decreased by more than 40%
DR and Ancillary Services	≈ 60,000 USD/station	Participate in ISO scheduling 30 times/year
Aggregation and Carbon Revenue	≈ 30,000 USD/station	Carbon reduction 320 tCO_2e/year
Total Revenue	≈ 210,000 USD/station	ROI ≈ 4.3 years, IRR ≈ 16%



14.2 Case 2: Energy Storage System Network for Five-star Hotel Group

a. Project Demand and Pain Points

Customer Type	Pain Points	Demand
Hotel Group	High peak electricity costs and high backup power costs	Reduce operational electricity costs by over 20% and ensure emergency power supply
Investment Company	Long payback period	Stable income + monetization of carbon assets
Government and Fire Protection	Strict compliance requirements	Meet dual certifications of UL 9540 + NFPA 855

b. Project Configuration Plan

- Project scale: 30 hotels × 10MWh = 300MWh; each station 5MW connected to 15kV grid.
- System composition: 40 cabinets/station (261 AC × 40); station-level EMS connects to building BAS.
- Cloud EMS: Forecasting electricity prices and loads; dynamically scheduling charge and discharge power.
- Fire protection: Partition FK-5-1-12 + smoke detection linkage; system IP54 suitable for outdoor deployment.

c. Operational Strategy

- Model: Peak shaving + TOU arbitrage + emergency power supply + DR response;
- AI Control: Automatic switching among PV-BESS-Grid three modes;
- Strategy: Peak shaving on weekdays, backup on holidays + VPP response;
- O&M: Hotel O&M team remote monitoring + cloud-based AI alarms.

d. Business & Profit Model

Model	Investment Structure	Revenue Sources
JV Joint Venture Model	Investor 80% + hotel group 20%	Electricity cost savings + DR + ESG carbon credits
Profit Distribution	70% Investment Party + 20% Hotel + 10% Renon AI Platform	Quarterly Revenue Sharing Settlement

e. Revenue Analysis

Item	Revenue (USD/station)	Proportion
Electricity Price Savings	≈ 115000	52%
DR + Ancillary Services	≈ 55000	25%
Carbon Credits + Brand ESG Value	≈ 25000	12%
AI Optimization Gain	≈ 20000	11%
Total Annual Revenue	≈ 215000 USD/site	ROI≈4.0 years, IRR≈17%

14.3 Case 3: Costco Shopping Center Fast Charging + Energy Storage Integration Project

a. Project Demand and Pain Points

Customer Type	Pain Points	Demand
Retail Chain (Shopping Mall + Charging Station)	High Peak Fast Charging Load, High Electricity Prices	Reduce peak demand charges by ≥30% to ensure stable fast charging.
Investor	Long recycling cycle	Achieve ROI < 4 years through TOU arbitrage + storage and charging integration
Power Grid Side	Severe impact of fast charging	Enhance grid flexibility response and power balance

b. Project Configuration Plan

Module	Parameter	Description
Fast Charging System	400kW × 10 = 4MW	Dual-gun liquid-cooled charging pile
Energy Storage Unit	2 × 261AC cabinets = 522kWh / 540kW	Partial Load Balancing + Peak Shaving
Total System Capacity	5.22 MWh (total for 10 stations)	Connected to the grid at 15 kV
EMS Architecture	Station-level EMS + Cloud AI Scheduling	Fast charging load forecasting + Energy storage optimization output

c. Operational Strategy

- Charge storage with PV during the day, peak discharge during the night;
- Fast charging peak output from energy storage → Reducing grid peak pressure by 40%;
- AI dynamic forecasting of fast charging flow → Real-time power adjustment;

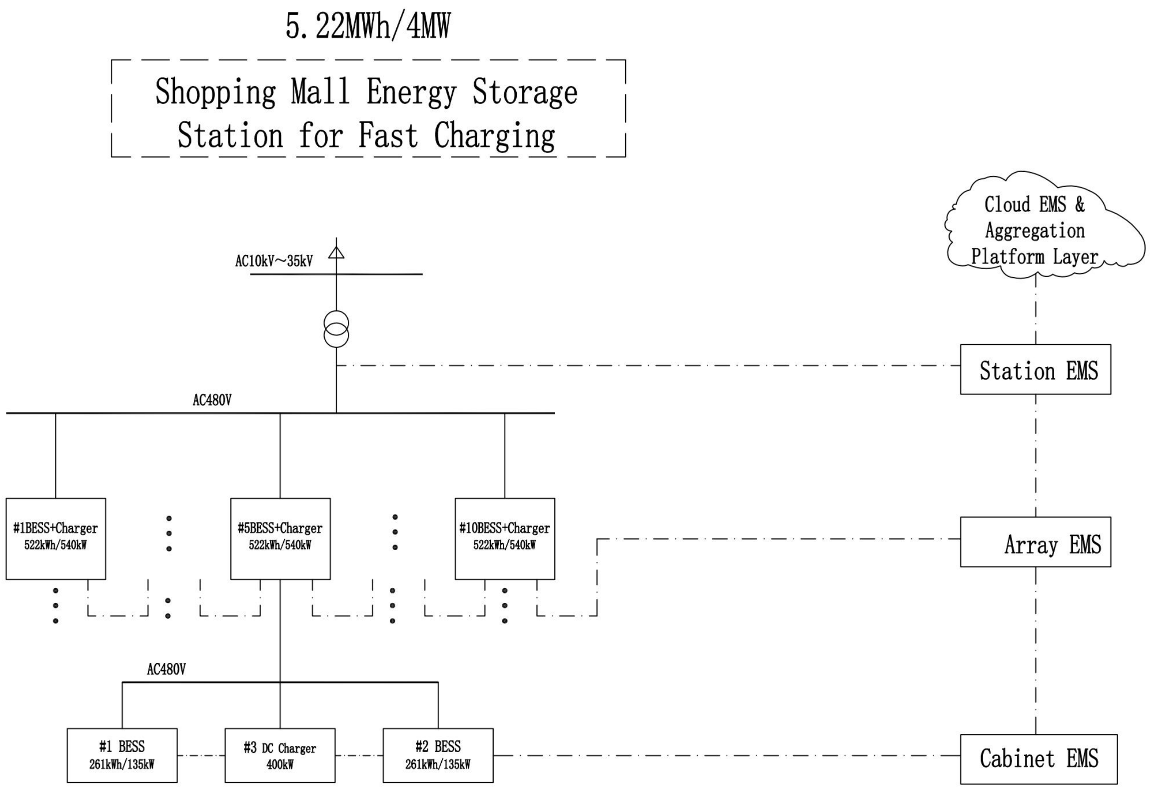
- Aggregation management → Unified scheduling of multiple stations to participate in DR and capacity markets.

d. Business and Profit Model

Model	Investment Structure	Revenue Sources
Joint Venture EPC + Operation Model	Investor 80%, Costco 20%	Peak shaving + DR + fast charging premium distribution
Profit Distribution	Investor 70%, Costco 25%, Renon EMS 5%	AI platform automatic settlement and revenue distribution

e. Revenue Analysis

Indicators	Values	Description
Demand Charge Savings	≈ 75,000 USD/year/station	Peak load reduction of 36%
TOU Arbitrage Earnings	≈ 55,000 USD/year	0.42 ↔ 0.08 USD/kWh
Fast Charging Service Premium	≈ 25,000 USD/year	Charging peak price difference revenue
AI Optimization Gain	≈ 15,000 USD/year	Revenue increase of 12–15%
Total Revenue	≈ 170,000 USD/year/station	ROI ≈ 3.8 years, IRR ≈ 18%



14.4 System-Level Verification

Indicators	Average	Excellent Interval
Availability	99.94%	＞99.9%
Power Error	± 0.8%	≤ 1%
Energy Limit Deviation	± 0.6%	≤ 1%
Response Delay	0.8s	≤ 1s
AI Revenue Forecasting Error	2.8%	≤ 3%
Aggregated Revenue Increase	+17.6%	—

14.5 Case Conclusion

- Customer Needs and Pain Points: Different formats (Transportation/Commercial/Hotel) all face peak load, price differences, and compliance challenges.
- Project Configuration: 261 AC modular architecture + EMS limit achieving 10MWh/5MW standardization.
- Operational Strategy: AI forecasting + revenue closed loop + remote collaboration.
- Business model: EaaS/JV/Joint venture operations flexibly adapt to customer types.
- Profit model: Peak shaving + TOU + DR + aggregation + multiple carbon revenue overlays.
- Revenue performance: ROI of 3.8–4.5 years, IRR of 16–18%, stable annual cash flow growth.

Renon Power 261 AC system has been empirically validated in three core scenarios: highway service areas, hotel groups, and commercial centers. It achieves a systematic closed loop of "clear demand → precise configuration → intelligent strategy → clear model → stable revenue," making it the most referential benchmark solution for the 200MWh/100MW distributed energy storage project in the North American market.

15. Appendix A — System Configuration List

15.1 Overall System Configuration

Project Parameters	Values	Description
Total Project Scale	200MWh/100MW	20 stations × (10MWh/5MW)
Single Station Capacity	10.44MWh (operational specification 10MWh)	Includes 40 × 261 AC cabinets + step-up transformer
Grid-connected Voltage	15 kV medium voltage	ANSI C84.1 Standard
System Architecture	Cabinet → Array → Matrix → Station → Cloud EMS	Five-level AI Scheduling System
Environmental Conditions	OutdoorIP54Liquid Cooling Protection	-30°C~55°C Operating
Operating Mode	Grid-connected/Isolated/Black Start Optional	Automatic Switch ≤50ms
Communication Protocol	Modbus-TCP/IEC 61850/MQTT/OpenADR	Compatible Aggregator Platform
Compliance Standards	UL 9540/9540A/NFPA 855/IEEE 1547/CSA C22.2 No.107.1	North America Full Certification Level Design

15.2 Core Equipment Configuration

a. Energy Storage System

Module	Model/Parameters	Quantity	Function Description
Liquid-Cooled Battery System	Renon261 AC Liquid-Cooled Integrated (261kWh/135kW)	40 units/station	Single cabinet energy storage + PCS + local EMS
BMS	Three-level (BMU–CMU–SBMU) architecture	1 set/cabinet	Real-time monitoring of cell temperature, voltage, SOC
Liquid Cooling unit	Dual-circuit cold plate + air cooling auxiliary	1 set/cabinet	±2°C uniform temperature control
Firefighting System	FK-5-1-12 gas fire extinguishing + smoke exhaust linkage	1 set/array	Compliant with NFPA 855 requirements

b. PCS/MPPT System

Module	Parameter	Quantity	Description
PCS Module	135kW Bidirectional AC/DC Conversion	1 set/cabinet	Grid-Connected and Off-Grid Dual Modes
MPPT Control Unit	Supports PV Direct Charging/Multi-Source Hybrid	Optional/Array	PV + Energy Storage Integration
Inverter Efficiency	≥ 97.8%	—	Including DC/AC conversion losses

c. Distribution and Grid-connected Equipment

Module	Parameter	Quantity	Description
Rack-level Distribution	AC 675kW rated/array	1 set/array	Including rack-level EMS node

Module	Parameter	Quantity	Description
Station-level Step-up Transformer	0.48kV→15kV oil-immersed/dry type optional	1 unit/station	Grid connection interface standard ANSI
Protection Device	Relay, isolation, grounding, and lightning protection complete set	Whole station	Meets IEEE C37 series standards

d. EMS System (Local + Cloud)

Hierarchy	Hardware	Function
Cabinet-level EMS	Embedded controller ARM 64 bit	Parameter sampling / strategy execution
Array-level EMS	Row cabinet main control PLC + communication module	Array scheduling / safety isolation
Matrix-level EMS	Industrial Server (8-core CPU + AI Acceleration Card)	SOC Equalization / Predictive Control
Station-level EMS	High-performance Industrial PC + Multi-gateway Module	Station-level Scheduling / VPP Response
Cloud EMS	Renon AI Cloud Platform	Revenue Optimization / Aggregation Scheduling / Remote O&M

15.3 Monitoring & Safety System

Monitoring Hierarchy	Content	Description
Real-time Data	Voltage, current, temperature, SOC, SOH, power 1s sampling	Upload Cloud AI Engine
Alarm System	Three-level Alarm (BMS→EMS→Cloud)	Automatic Isolation of Fault Units
Video Surveillance	Dual 1080P Thermal + Visible Light Fusion	Fire and Theft Dual Monitoring
Cybersecurity	TLS 1.3 Encryption + VPN Tunnel Isolation	Supports North American NERC-CIP Standards

15.4 Communication & Protocol Interface

- Internal Communication: Modbus-TCP/RS-485/CAN 2.0B.
- External Communication: IEC 61850/DL/T 860/MQTT/OPC UA.
- Aggregation Interface: OpenADR 2.0b/IEEE 2030.5/Restful API.
- Monitoring Platform: Web/Mobile/SCADA synchronized visualization on three terminals.
- AI Access: TensorFlow+PyTorch edge model deployment compatible.

15.5 System Performance

Indicators	Values	Description
System Availability	≥ 99.9%	AI O&M Automatic Diagnosis
Dispatch Response Time	≤ 1s	VPP/Aggregator Command Response
Power Accuracy	± 1%	Steady-state closed-loop control

Indicators	Values	Description
Energy Conversion Efficiency	≥ 92%	AC-to-AC full link efficiency
Noise	≤ 75dB (A) @1m	Liquid cooling silent operation
MTBF	≥ 100,000h	System Average Time Between Failures

15.6 Warranty & O&M

Item	Content
Whole Machine Warranty	10 Years / 30,000 Cycles
AI O&M Services	7×24h Cloud Monitoring + Predictive Maintenance
Lifecycle Management	AI Algorithm Tracking Cell Degradation Trends
Remote Upgrade	Supports OTA Firmware Updates and Policy Deployment
Operational Maintenance Interface	Open API access to EPC and Aggregator platforms

15.7 Compliance & Certification

- North American Certifications: UL 9540/UL 9540A/NFPA 855/IEEE 1547/CSA C22.2 No.107.1.
- Environmental Standards: IEC 61000/ISO 14001/RoHS 2.0.
- Quality Systems: ISO 9001/IATF 16949/TS 16949 manufacturing systems.
- Data Security: NIST SP 800-82/NERC-CIP compliant.

16. Appendix Conclusion

Renon Power 261AC Distributed Energy Storage System standardized configuration ensures:

- Modular delivery → Rapid deployment ≤48h/site;
- Intelligent operation and maintenance → O&M costs reduced by 35%;
- AI revenue → project IRR increased to 16–18%;
- Safety compliance → the entire system meets UL/NFPA dual standards;
- Replicable → unified BOM + open EMS interface adaptable to global markets.

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