Huawei Energy Storage - Powering a Smooth Renewable Energy Transition in Romania

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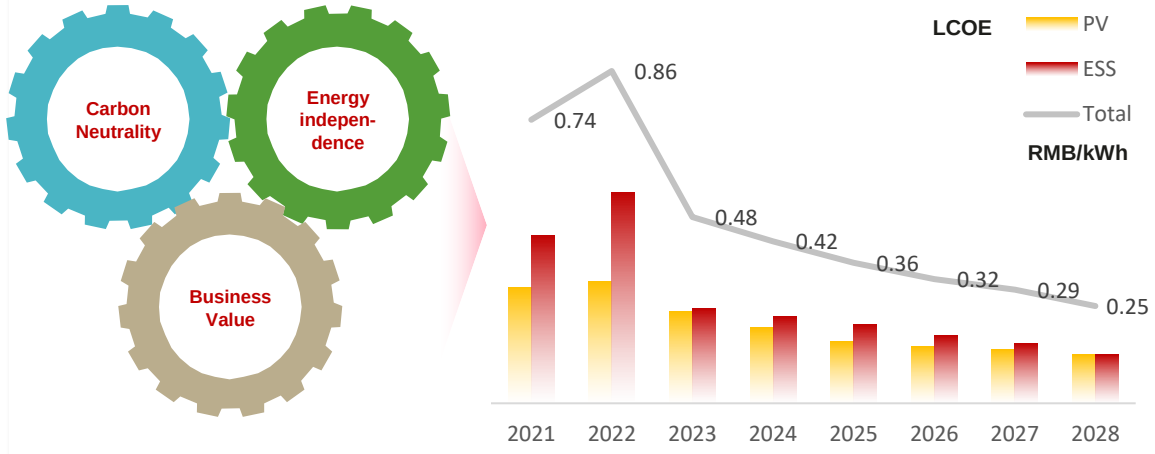
Background: Carbon neutrality has become a global consensus. Promoting energy independence and energy transition

"Three-wheel drive" accelerates RE energy development

China	Europe	USA	Japan
2030 Carbon Peak	Release the Green New Deal	Return to the Paris Agreement	New Deal on Green Energy
2060 Carbon Neutrality	**2050 Carbon Neutrality**	**2050 Carbon Neutrality**	**2050 Carbon Neutrality**

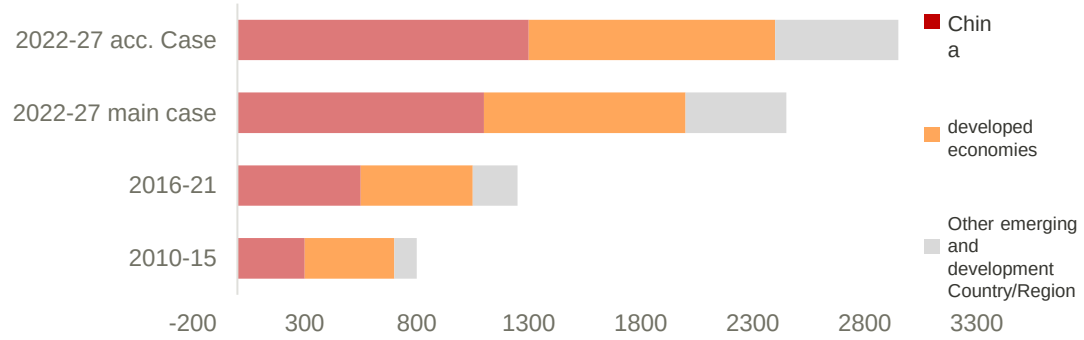
PV + ESS will be one of the lowest technologies in LCOE



"Two Replacements" Become Key Measures to Achieve Carbon Neutrality

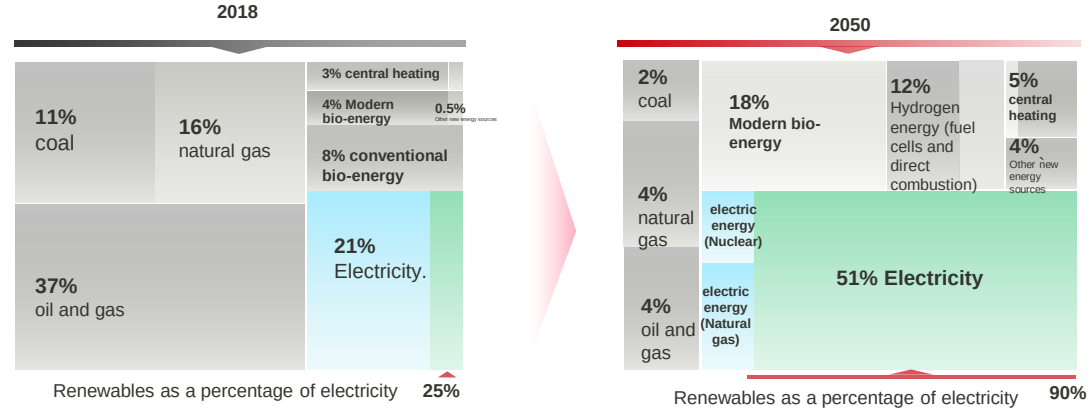
Clean the generation side and replace the generation side.

From 2022 to 2027, 2,400 GW of renewable energy will be installed, including 1,500 GW of photovoltaic.



Energy-side power substitution

By 2050, electricity will account for more than 50% of global energy consumption and become the main consumer.



Source: IEA and IRENA

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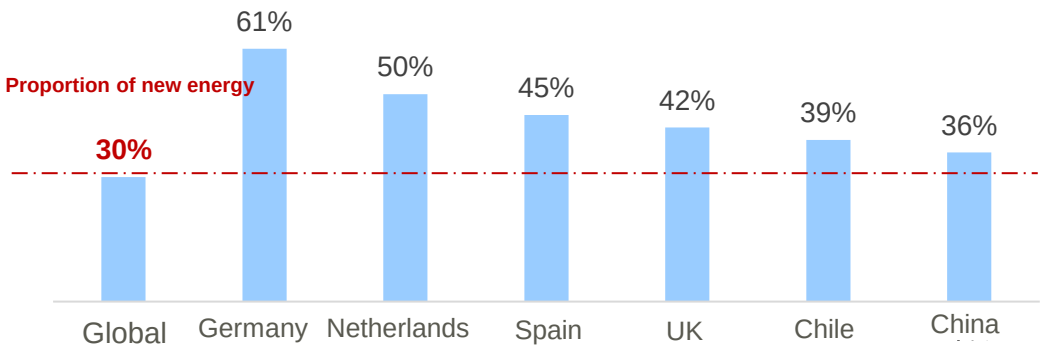
Challenges: High RE Energy penetration leads to weak grids and power system stability problems

Rapid RE Energy Penetration

Breakthrough two 30% milestones in 2023



Note: RE Energy Penetration Estimates in 2024

RE energy generation

9000TWh

30% +

Global RE energy
Energy yield ratio

Accumulated installed capacity of new energy

2600GW

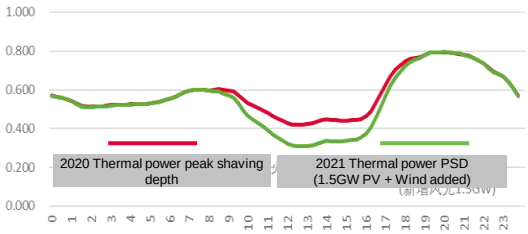
30% +

Global RE power generation
Installed unit proportion

Power grid security and stability bring severe challenges

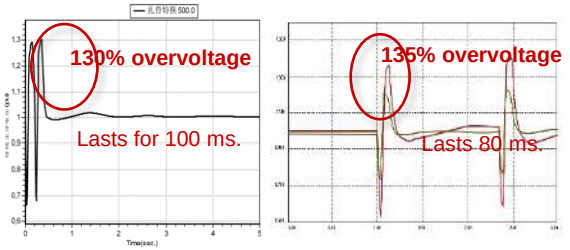
Peak and Frequency modulation

The thermal power operation in a province has reached the limit (40% depth).
No more peaking for new energy



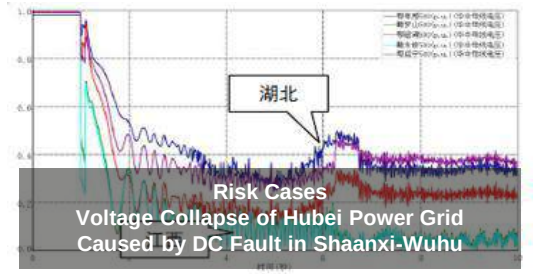
Transient overvoltage

Weak transient voltage control capability of new energy
130% + Overvoltage during HVDC failure



Voltage stability margin

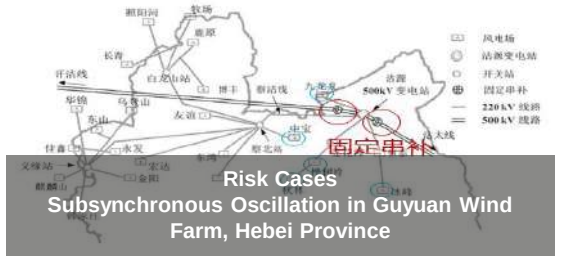
The transient active power and voltage support of new energy are insufficient. After the HVDC fails, the power is transferred in a large area, causing voltage collapse.



Risk Cases
Voltage Collapse of Hubei Power Grid Caused by DC Fault in Shaanxi-Wuhu

Wide frequency oscillation

Stability margin decreases after the synchronous power supply ratio decreases.
Low-frequency/sub-sync/hypersync oscillation risk



Risk Cases
Subsynchronous Oscillation in Guyuan Wind Farm, Hebei Province

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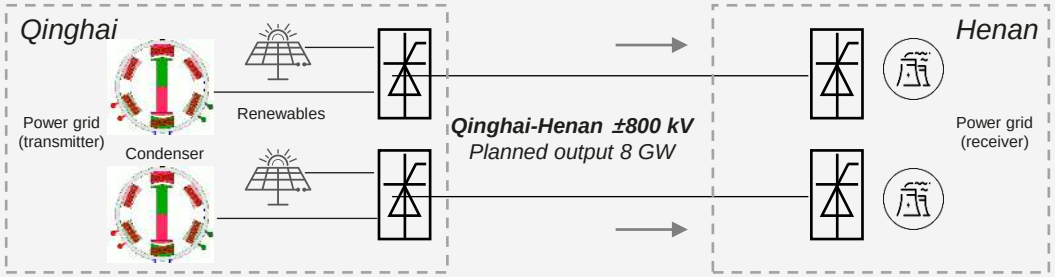
Challenges: Power transmission and integration are difficult due to week power grids; traditional solutions face challenges including high investment, difficult O&M, and inflexible configuration

Power transmission limiting due to week grids in areas with a high proportion of Active responses and restrictions in the industry
renewables (such as the Qingnan-Henan DC transmitter)



1 GVar condensers improve the power supply capability by 2 GW, increasing revenue by 0.17$ billion/year

Condenser	Power Transmission Capability	Revenue Increase
None	2GW (25%)	/
21 (1 GVar in total, ~113$ million)	4GW (50%)	0.17$ billion/year
? ? ?	8GW (100%)	? ? ?

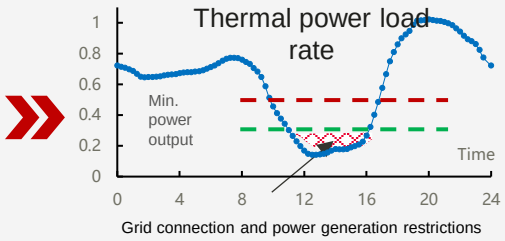
**Qinghai-Henan HVDC used as an example*

① Condenser + conventional ESS

- 24-hour attendance of rotating devices and regular site visits for O&M, resulting in high costs
- High lifecycle investment of condensers (such as electricity fees)

② Thermal power plant

- Environment pollution
- Thermal power plants: shutdown (old) + restriction (new)



- Thermal power load is not restricted by the minimum power output.
- Flexible revamping reaches the technical limit.

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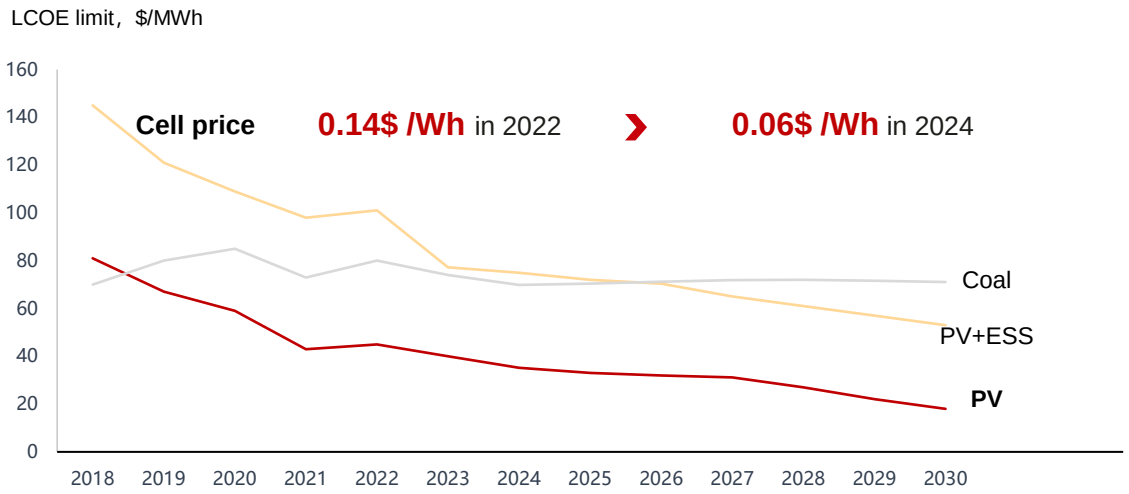
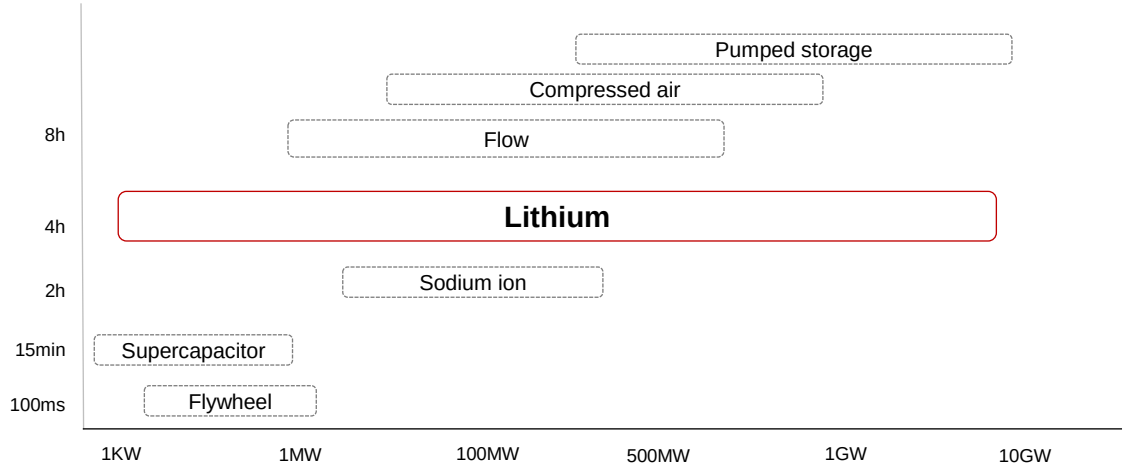
Trends 1 : Energy storage technology innovations accelerate PV+ESS grid parity, making ESS ubiquitous in new power systems

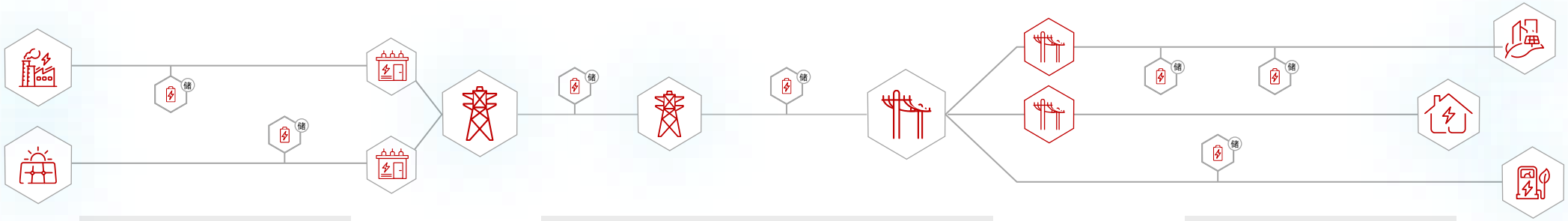
As the LCOS declines, ESSs will soon hit grid parity



Diversified materials, such as lithium, sodium and flow, meet the discharge rate requirements in multiple scenarios



Grid-forming ESS is essential for power generation, transmission, distribution, and consumption



Generation

Improving short-circuit capacity and inertia support
Improving power generation capability for weak grids

Transmission and distribution

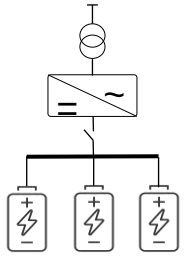
Power backup and voltage & frequency support
Improving grid connection and output capability

Consumption

Optimizing control capability after PV is connected
Improving connection and integration capability

Trends 2 : Grid forming technology will become the key to new power systems, creating innovative global models globally

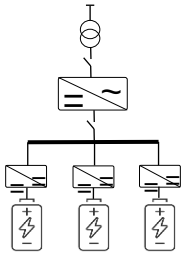
ESS grid connection architecture: extensive adaption of string solutions, high potential for high-voltage connection



Central

- Simple control
- Circulating current risk if rack voltages are inconsistent

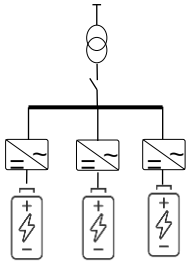
Grid ESS | Utility plant ESS



Distributed

- No circulating current
- High reliability and flexibility

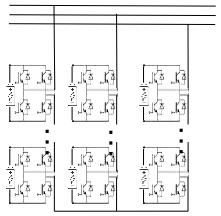
Power grid peak shaving | Renewable energy storage



String

- No circulating current
- Highest reliability and flexibility

Grid ESS | Distributed ESS | Microgrid ESS

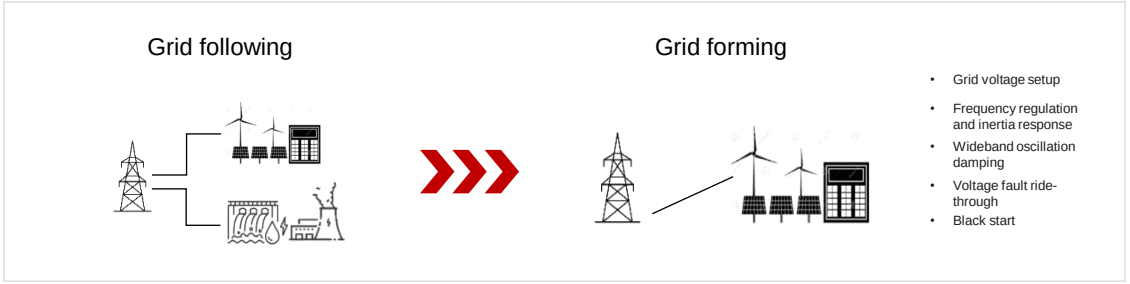


High-voltage connection

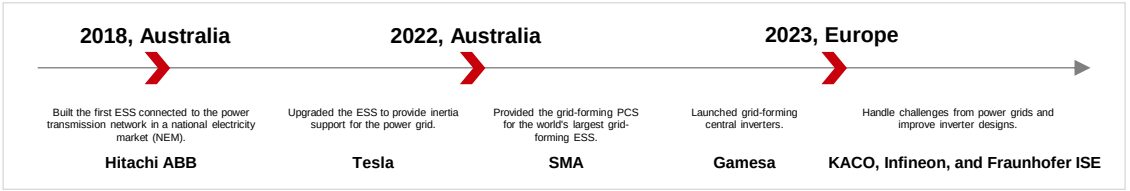
- No step-up transformer required, reducing system loss
- High efficiency and energy density
- No circulating current

Grid ESS | Peak shaving and frequency regulation | Load-side high-voltage scenarios (such as mining areas)

Grid forming technology: wide applicability, evolving standards and business models



International inverter vendors have stepped up research on grid forming technology.



Global efforts to develop grid forming standards and business models

Country/Region	Policy/Standard	Business Model
	National Energy Administration: Carry out the demonstration of renewables-based grid forming technology.	National Development and Reform Commission: Strengthen the stability of power systems in new situations.
	National grid electricity system operators (NGESOs) have implemented grid code revisions to introduce minimum specifications required to provide grid forming capabilities.	Released numerous bidding projects for power system inertia and short-circuit power services.
	The European Network of Transmission System Operators for Electricity (ENTSO-E) has defined the connection network codes (CNCs) for grid-forming inverters (GFIs) to ensure the standardization of EU requirements.	The EU is establishing a new "non-frequency ancillary service" market. Germany is expected to become the first power system inertia market in the European continent.
	The Renewable Energy Agency (ARENA) funded eight grid-scale battery projects, which will run in grid forming mode by 2026.	Bidding for power system inertial support, usually region-level

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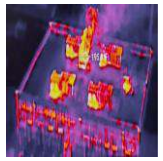
PV+Wind+ESS convergence, active safety, and comprehensive intelligence to develop renewables as the main source of electricity

Security Challenges

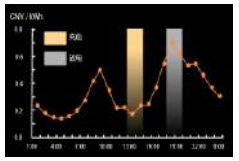





PV: Insulation faults caused by environment, high humidity, and high salt

ESS: Risks caused by insulation failure, overcharge, internal short circuit

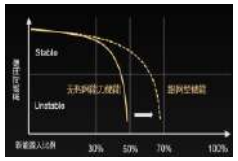
Benefits Challenges



PV: The actual PR is lower than the theoretical PR

ESS: Single revenue model and low IRR revenue

On-Grid Challenges

PV: The grid strength becomes weak, and the grid connection requirements are strict.

ESS: The GFL ESS capability is weak to support the grid

O&M Challenges


PV：2 million+ modules / GW

ESS：1 million+ cells / GWh

Digital Technology + Electronics Technology

Higher PR, higher RTE,
Intelligent power prediction, GFM, and multiple auxiliary services

@Higher Revenue

From Cells to Grid and intelligent health diagnosis
Ensure lifecycle security

@ Proactive Security

Unattended
Few O&M personnel

@Smart O&M

Digitalization

Intelligent

Auto O&M

Smart String ESS Platform, safe, stable, efficient, and intelligent throughout the lifecycle from cells to grids

Smart String ESS Platform

Smart String Grid-Forming ESS

Smart Power Conversion System (PCS)

Smart Array Controller (SACU)

Smart Power Plant Controller (SPPC)

Smart Transformer Station (STS)

Distribution Transformer (DTS)

Smart Energy Management System (EMS)

All-architecture safety

Energy storage safety is not only cell safety And full-architecture security of electromechanical/thermal/environment/system/grid

All-scenario grid forming

Full-lifecycle and full-grid environment Proactive support the grid

Full-lifecycle cost-effectiveness

Full business model application Better performance and configuration over the life cycle

Full-link digitalization

Energy storage security guard, real-time monitoring of security status, and Reduced O&M costs

All-architecture safety: multi-level safety designs from DC to AC and from cells to power grids to ensure system reliability

Full-architecture security key

Cell level: thermal runaway warning

- Joint development, dedicated line production, total quality management, and full-lifecycle tracing
- 5 + Stricter than industry test standards: no fire, explosion, and liquid leakage
- CPK Grade A+ > 1.67

Drops

acupuncture

squeezing

Pack level: preventing thermal runaway spreading

- High-strength design with high temperature resistance of 1500°C
- Ultra-long 1000+ hours electrolyte corrosion resistance
- positive pressure oxygen barrier
- Pack of smoke

Battery Pack Soaking
in Salt Water
Brine 72 h, 100% SOC

Pack of smoke
99.9% of combustible gas rapid emission

System level: multi-level safety design

- thermal runaway active explosion discharge
- Minute-level fire extinguishing

Thermal runaway
active explosion discharge
Quick pressure relief to ensure personal safety

Battery pack-level thermal runaway and non-diffusion
Minute-level water spray quick fire extinguishing

Grid level: operating reliably in various complex grid environments

- The energy storage system is absolutely safe under high and low voltages of the power grid.

Absolute security for any SOC

Two-stage PCS

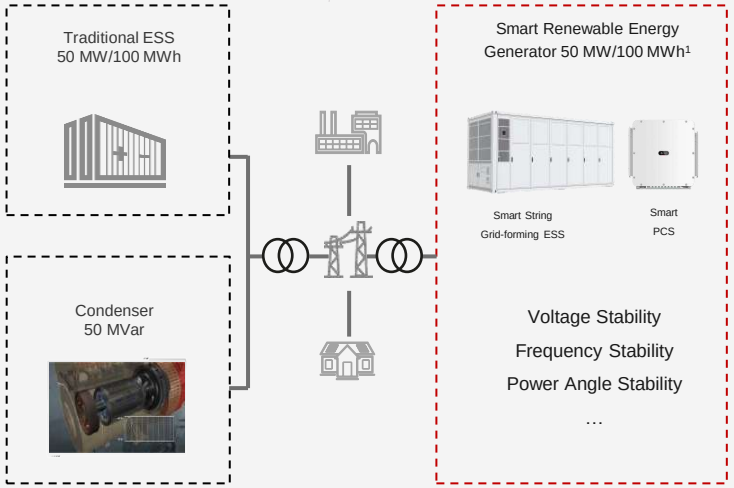
high voltage

All-scenario grid forming: Smart Renewable Energy Generator, redefining stability, extending grid forming from ESS to PV+ESS

Technical capabilities

Equivalent condenser + + traditional ESS, improving renewables integration

Condenser + traditional ESS VS **Smart Renewable Energy Generator**



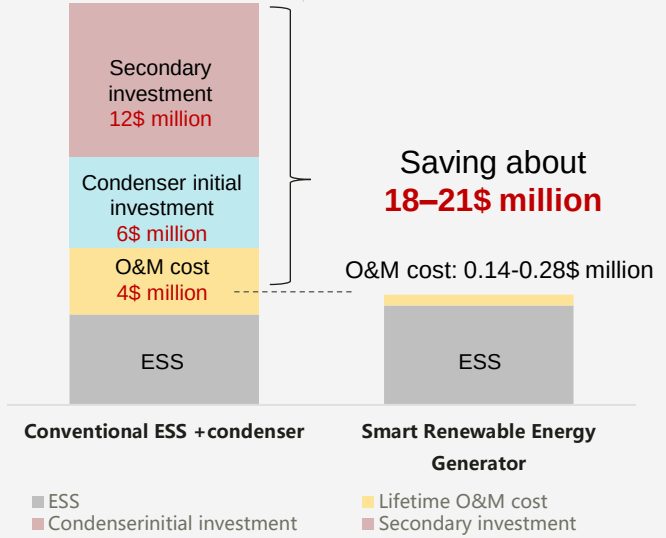
100 MWh Smart String Grid-Forming ESS

≈ 100 MWh conventional ESS + 50 MVar condenser

Business value

Saving about 0.2$ per Wh throughout the lifetime

Condenser + traditional ESS VS **Smart Renewable Energy Generator**



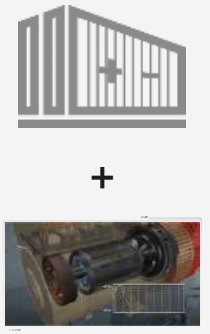
Calculation model:

ESS capacity: 100 MWh; active power: 50 MW; condenser power: 50 MVar; requirements: 3 to 6 times the reactive current; lifetime: 25 years

Evolution capability

One matches all, ready for grid forming, ESS → PV+ESS grid forming

Condenser + traditional ESS VS **Smart Renewable Energy Generator**



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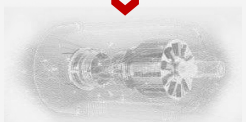
Capacity expansion not supported

ESS grid forming
40%–100% renewables integration

1–n Smart PCSs



PV+ESS grid forming

- **Stronger voltage support capability** (higher reactive overcurrent tolerance)
- **Stronger frequency support capability** (larger inertia)
- **Stronger power angle stability** (wider-range oscillation damping)

1：.ESS backup time: 2 hours.

2：Boundary conditions: ESS capacity 100 MWh, active power 50 MW, condenser power 50 MVar, and 3 to 6 times the reactive current; discount rate 5%; lifetime 25 years, including one augmentation. SOC balancing once a year for the conventional ESS, 3 person-days/MWh each time, labor cost CNY950/person-day, and round-trip cost CNY1000/time.

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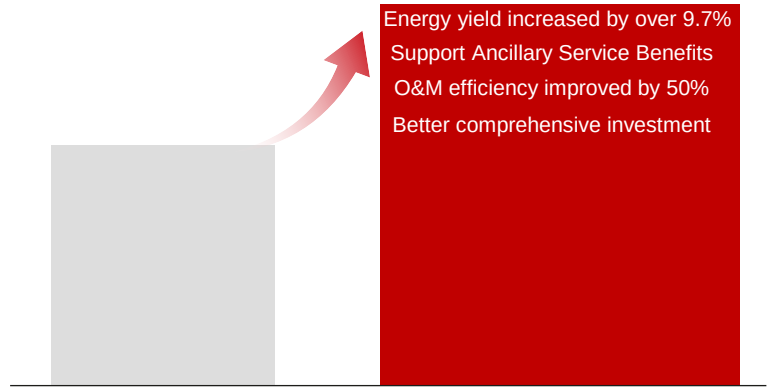
Full-lifecycle economy: better comprehensive investment, ROI increased by 3% to 8%, and discharge capacity increased by more than 9.7% over the life cycle.

Eight core indicators of discharge capacity

- Higher available capacity: One Rack, one management, supporting full-lifecycle power improvement by 7.23%@12 clusters
- One Pack, one optimization: 1.7% higher battery life cycle
- Increased RTE efficiency 91.5% *
- Higher discharge efficiency 95.7%
- SOC accuracy < 3%*
- Constant power range 0 to 100%
- Availability > 99.9%
- 2015 to 20-year SOH performance assurance

Note: 91.5% RTE 0.25C measurement point is the AC low-voltage side, including the auxiliary power supply. The warranty period is 20 years and the SOH period is less than 60%.

ROI increase by 3% to 8%



$$ROI = \frac{\text{20-year total power generation revenue + 20-year power grid auxiliary service revenue}}{\text{Initial investment – Residual value of fixed assets + 20-year O\&M cost}}$$

One platform, compatible with all business models, and higher revenue in the lifecycle

Energy market | Capacity market | Frequency modulation Market | GFM Market | PV + Wind + ESS PPA | Long-term power supply PV + Wind + ESS | Microgrid

Short circuit capacity	inertia	Black Start	Wideband oscillation suppression	One, two, three frequency modulation	reactive overload capacity	constant power capability	SOC precision	Availability	Concurrent and deregistered applications
1.5/3/6x vs. 3x	3-20s VS 20s	Minute-level vs. day-level	0.1-100HZ VS 0.2-2.5HZ	< 100 ms VS >200ms	1.5x vs 1.2x	0 - 100% VS 0-94%	3% VS 5%	99.9% VS 98%	A platform

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Full-link Digitalization: Digital technologies help power plants change from fewer people to unmanned, achieving "driverless" throughout the life cycle.

Proactive diagnosis by AI and accurate warning in days

More fields and longer-term training, accurately locating 10+ cell/module faults

Model training duration > 3 years, sample quantity > 10 GWh

Huawei new energy vehicles, data centers, optical storage, and other fields

Second-level data collection

> 1 billion data/day*

Hour-level proactive diagnosis

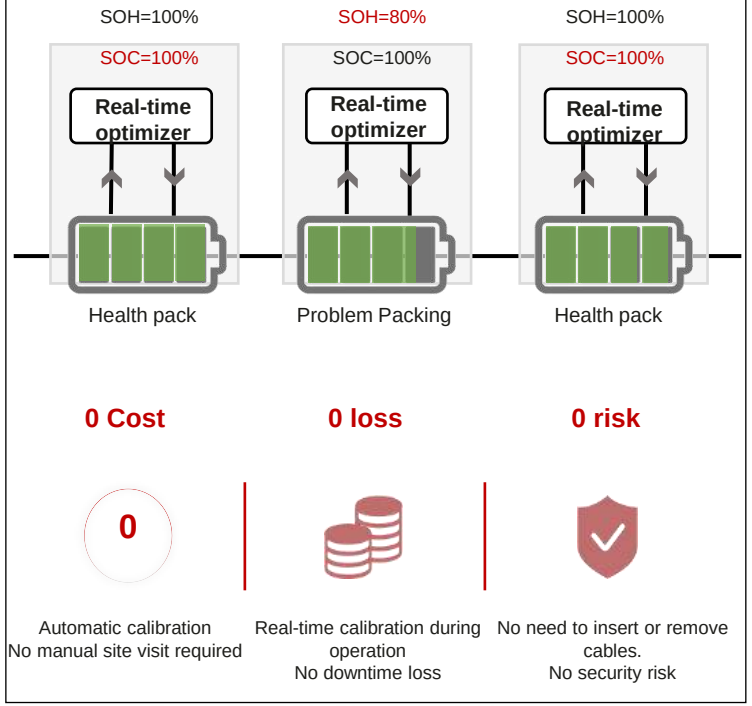
24-hour uninterrupted security protection

Daily risk warning

10+ electrochemical cell security risks are known in advance.

Automatic SOC calibration, improving the battery discharge rate

Save experts on-site visits by up to 480,000 RMB/time/100 MWh.



Precise Smart Grid Detection and Fault ride through

Stable operation of the entire power grid

High and low voltage ride-through
Weak power grid response in milliseconds
→ Two-level architecture
Secure fail-through

Power grid voltage is abnormal.
Precise detection of voltage exceptions < 1%
→ Reconstructed voltage stability
Rapid support voltage change

Power grid frequency is abnormal.
Precise detection of frequency exceptions < 1%
→ Reconstruction frequency
Fast support frequency change

frequency oscillation
0.1–100 Hz suppression
→ Reconstruction angle stability
Rapidly suppress system oscillation

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* 1 GWh energy storage plant contains about 10,000+ battery packs and 1.1+ million electrochemical cells.

Digital, intelligent, full-lifecycle "driverless"

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All Business Model Applications References - Globally 25GWh+, Europe 4.5GWh+

App① *Nordic 400MWh+* (Frequency Modulation Market)
Customer S×, E×
200ms Fastest Response & Modulation

App② *Germany 360MWh+* (Innovation Market +Trading)
Customer A×, E×
One-stop solution instead of patchwork

App③ *France 330MWh+* (Auxiliary Market)
*Customer **GAZEL***
Reliable Grid Connection Capability

App④ *Bulgaria 1.4GWh+* (Arbitrary Market)
Customer S×, B×
Dedicated Localized Service Save Huge O&M Labor Cost

App⑤ *Greece 800 MWh+* (Subsidy Market)
Customer P×, F×
Dedicated Localized Service & One stop solution

App⑥ *Romania 260MWh* (Capacity + FM market)
Customer E×
Quick: 50MWh @ 30 working days

App⑦ *Hungary 200MWh+* (Subsidy Market)
Customer M×
One-stop solution instead of patchwork

App① *Middle East Saudi 1.3GWh+* (Grid Forming Market Off Grid)
World's Largest 100% RE City
>1 year Steady operation under strictest power grid

App② *China Qinghai 100MWh+* (Grid Forming Market On Grid)
World's 1st 100 MWh Complementary ESS power station

App③ *Philippines 4.5GWh+* (PV & ESS Combination)
Reliable Grid Connection Capability and One-Stop Solution

App④ *Singapore 116MWh+* (Auxiliary Market)
Customer S×
Fastest (6 months) Hundred MWh ESS Construction
Long consistent power→Higher Revenue

App⑤ *Uzbekistan 300MWh+* (Capacity Market)
Customer H×
Largest ESS Project in Central Asia
Grid Forming Ready + Local Service Ability

5 Months To Complete 60MWh BESS Project

Contract Signed	1st Batch BESS	2nd Batch BESS	STS Delivery	Grid Connection	TSO Certificate
Feb 2024	**May 2024**	**June 2024**	**June 2024**	**July 2024**	**August 2024**

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