

Grid-forming technology Ensuring stability and enhancing BESS revenue

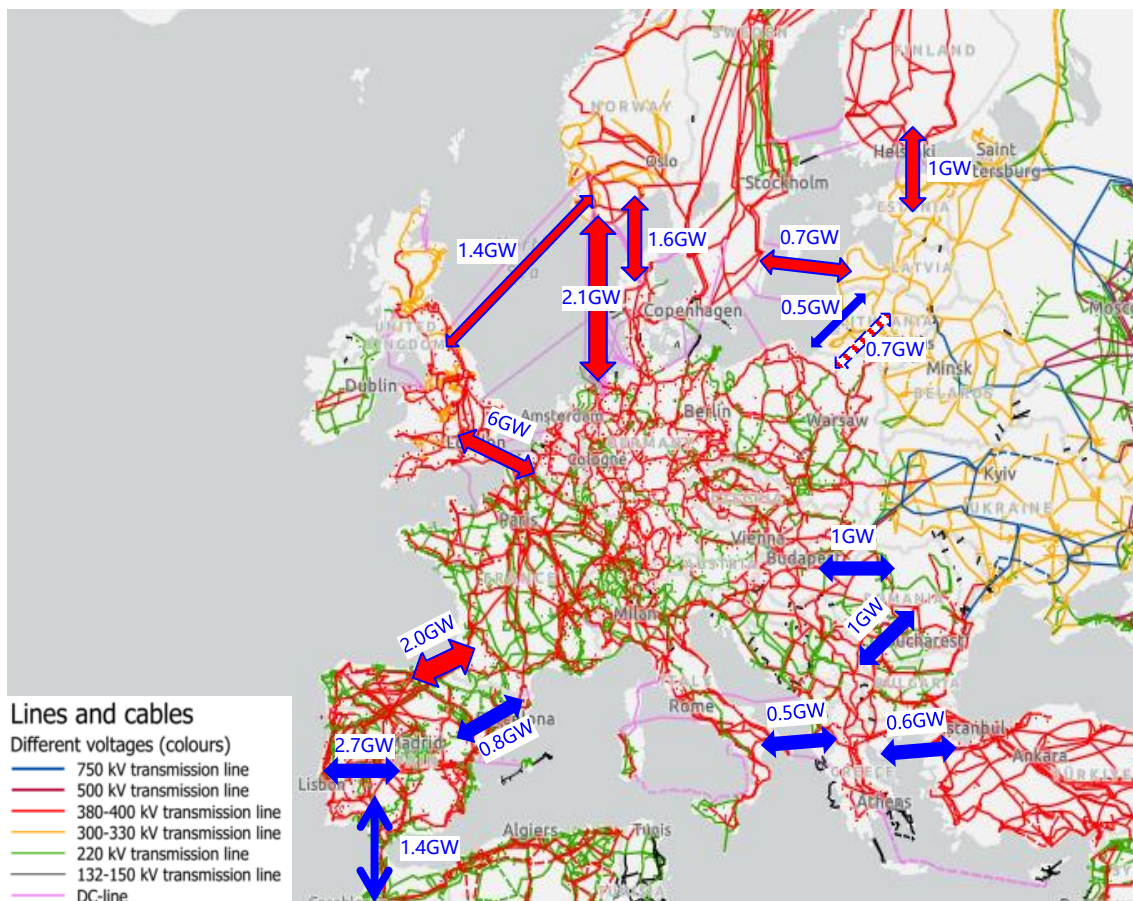
Dr. Raven Liu
Huawei European Digital Power

get inspired @ 10th Sep, Berlin



Cross-border connection bottlenecks threatens stability of European power system

Limited cross-border transmission capacity



Source: ENTSO-E

Changing generation distribution patterns

In the past



Now



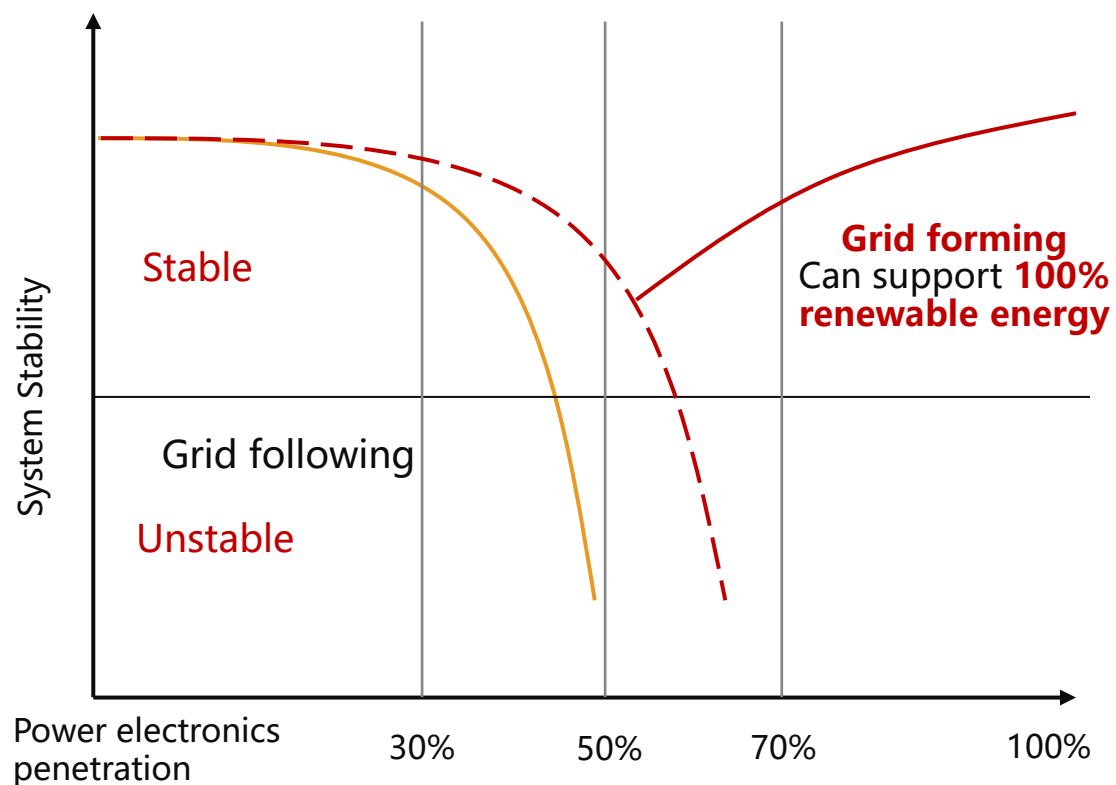
Traditional synchronous generators were usually geographically **evenly widespread**.



Renewable generation is **highly concentrated**, creating regional imbalances.

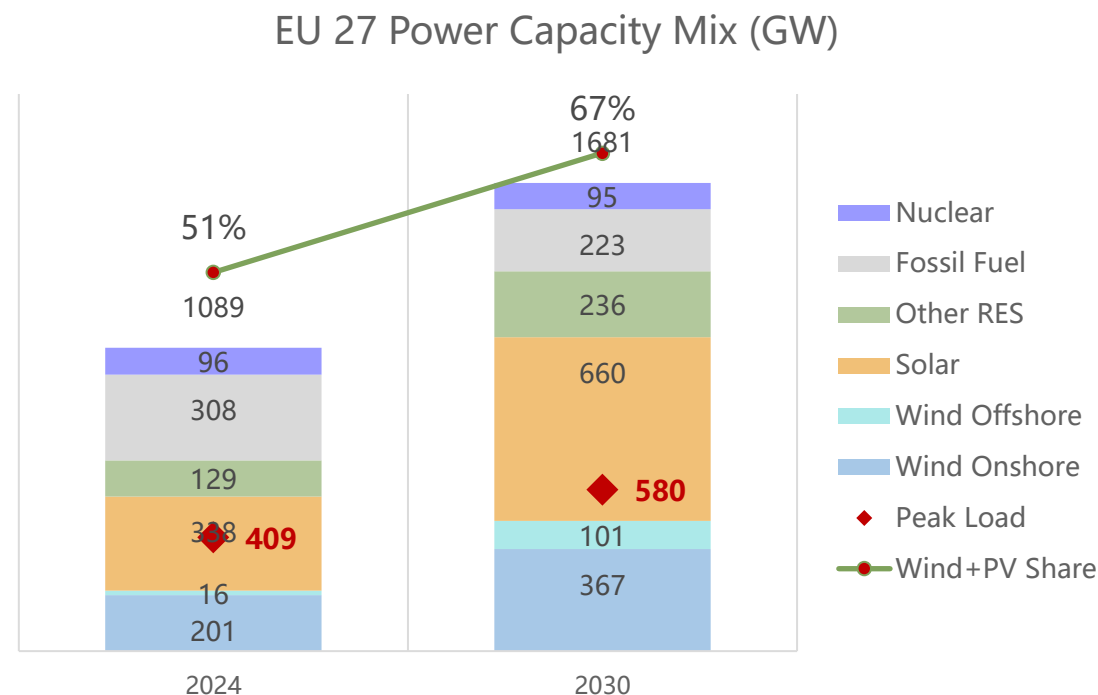
The high inverter-based resources requires grid-forming to strengthen the grid

When power electronics penetration exceed 50%, grid forming become a Necessity



Source: EU MIGRATE Project

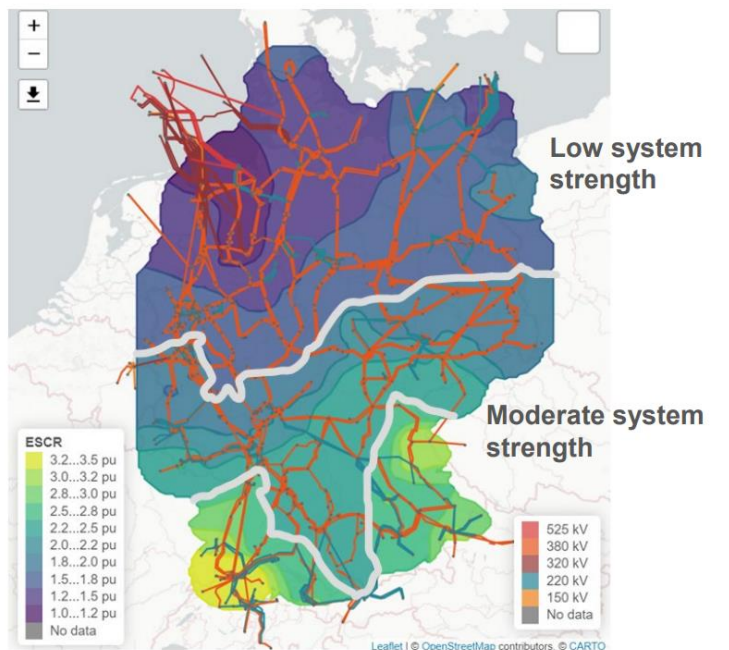
Wind + Solar share exceeded 50% in 2024, will reach 67% by 2030



Data: ENTSO-E TYNDP 2024

Grid stability challenges create a high risk of major blackouts

Reduced grid strength

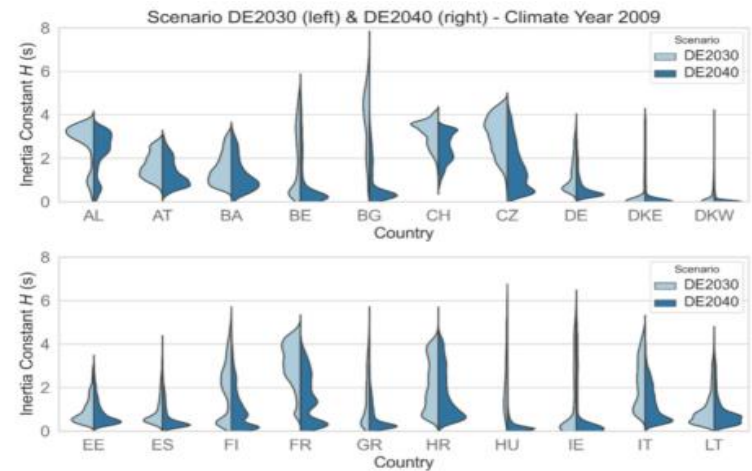


$$ESCR = \frac{\text{Short-Circuit Power at the connection point (MVA)}}{\text{Inverter-Based Generation Capacity (MW)} + \text{Reactive Power Compensation (MVAR)}}$$

Source: VDE FNN

- Regional short-circuit levels are falling; northern Germany shows very **low grid strength (ESCR ≤ 2)**.

Insufficient system inertia



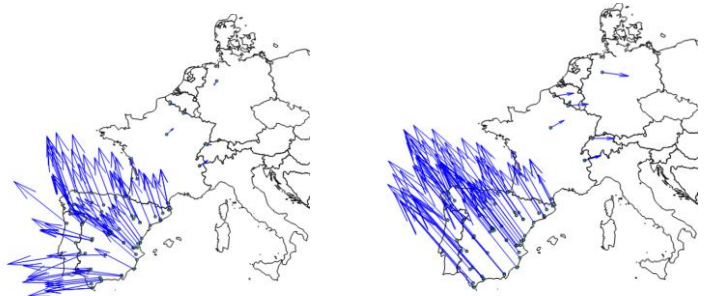
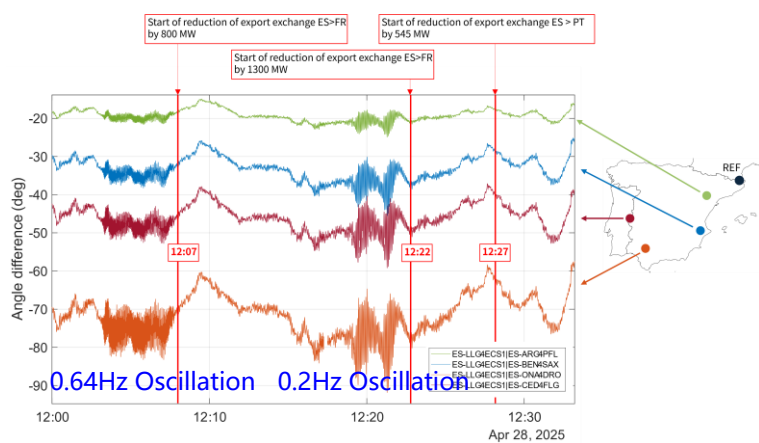
Source: ENTSO-E

TSO	Required Inertia in 2030 (GVA.s)	Current confirmed inertia (GVA.s)
50Hertz	448	17
Amprion	308	23
TenneT	568	99
TransnetBW	14	6
Total	1338	145

Source: Network Development Plan 2037/2045 (2023)

- By 2030, system inertia will **be below 2s** in most countries, with Germany requiring **1338 GVA.s** to ensure stability.

Increased power oscillations



- The grid experienced **significant power oscillations**, which directly caused the major blackout in Spain.

What is grid-forming?

ENTSO-E defined grid forming capabilities



Creating (forming) system voltage.

Contributing to fault level (short circuit power).

Contributing to total system inertia

Supporting system survival to enable the effective operation of low frequency demand disconnection for rare system splits.

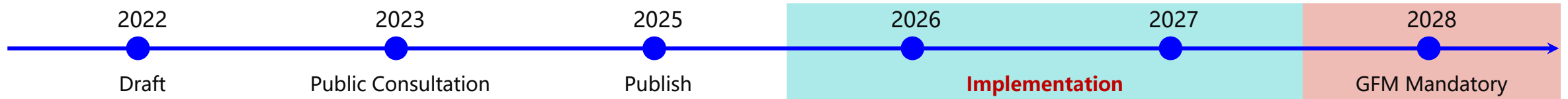
Acting as a sink to counter harmonics and inter-harmonics in system voltage.

Acting as a sink to counter any unbalance in system voltage.

Preventing adverse control system interactions.

Grid-forming requirements are being established across Europe and member states

RfG2.0 will be published in 2025, and GFM requirements will be implemented in member states by 2028



Countries already published or drafted grid-forming requirements



UK



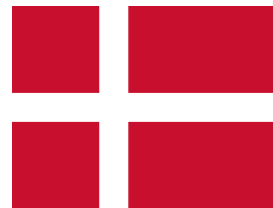
Germany



Italy



Finland



Denmark



Netherlands

UK stability market: moving beyond pilot tender to full operation

Skeleton of stability market design



To slow down the **rate of change of frequency (RoCoF)**

$$Inertia = \frac{\Delta P f_0}{2 \times RoCoF}$$



To help maintain **system voltage** during a fault.

$$Short\ Circuit\ Level\ (MVA) = \sqrt{3} \times Rated\ Voltage\ (kV) \times Fault\ Current\ (kA)$$

	Long-term (Y-4)	Mid-term (Y-1)	Short-term (D-1)
Eligibility	New build Enhanced capability	Existing capability	
Lead time	Y-4	Y-1	D-1
Contract	10y for new build 3y for enhanced capability	1y	Service Windows
Block	Baseload availability	Baseload availability	4 h (EFA blocks)
Availability	90%	90%	100%
Payment	Availability Delivery	Availability Delivery	Delivery
Price	Pay-as-bid	Pay-as-bid	Pay-as-clear

The upcoming LT and MT market with well-defined needs

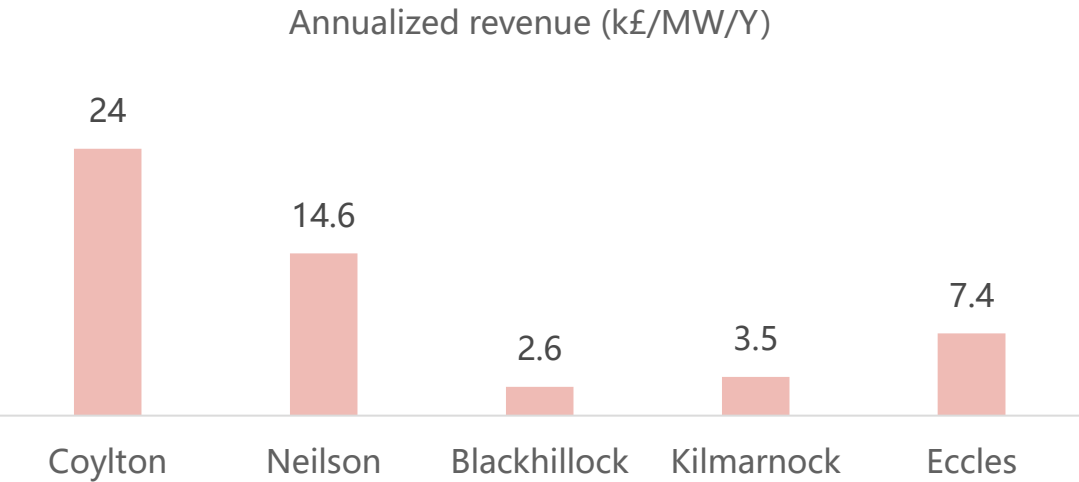
		2019	2021	2022	2024	2025	2026
Pathfinder Inertia+SCL	Phase	Phase 1	Phase 2	Phase 3			
	Contract (Years)	6	10	10			
	Inertia (GVA.s)	12.5	6.7	17.1			
	SCL (GVA)		11.5	12.7			
	Awarded	12 Sync Comps	5 Sync Comps 5 GFC BESS	29 Sync Comps			
Long-term Inertia+SCL	Inertia (GVA.s)					10	
	SCL (GVA)					31.1	
Mid-term Inertia Only	Inertia (GVA.s)				5	10-15	11+
	Awarded					5 Sync Comps	

Grid-forming BESS became competitive solution in second phase pathfinder

Five GFM BESS secure part of revenue for 10 years

Company	Project	SCL (MVA)	Inertia Derated (MVA.s)	Capacity (MW/MWh)	Start Date
STATKRAFT	Coylton	345	0	50	2025/4/30
STATKRAFT	Neilson	269	0	50	2024/4/29
Zenobe	Blackhillock	210	333	300/600	2024/3/31
Zenobe	Kilmarnock	716	1341	300/600	2024/10/25
Zenobe	Eccles	1070	2686	400/800	2026/4/30
Total		2610	4360		

For the 2 hours BESS projects, the average annualized revenue will be **£4.5k/MW/Y**, accounting for around **6.8%** of market average revenue.



1st round LT market bundling reactive power and restoration

Reactive Power	Stability	Restoration
90% availability	90% availability	80% availability
Dynamic reactive power: -2185/+600	Short Circuit Level (SCL): 31150 MVA	Anchor (primary) service, and
Static reactive power: -515/+1100	Inertia: 10 GVA.s	Top-up service
Injection and absorption services		
Dynamic reactive power distribution	SCL distribution	

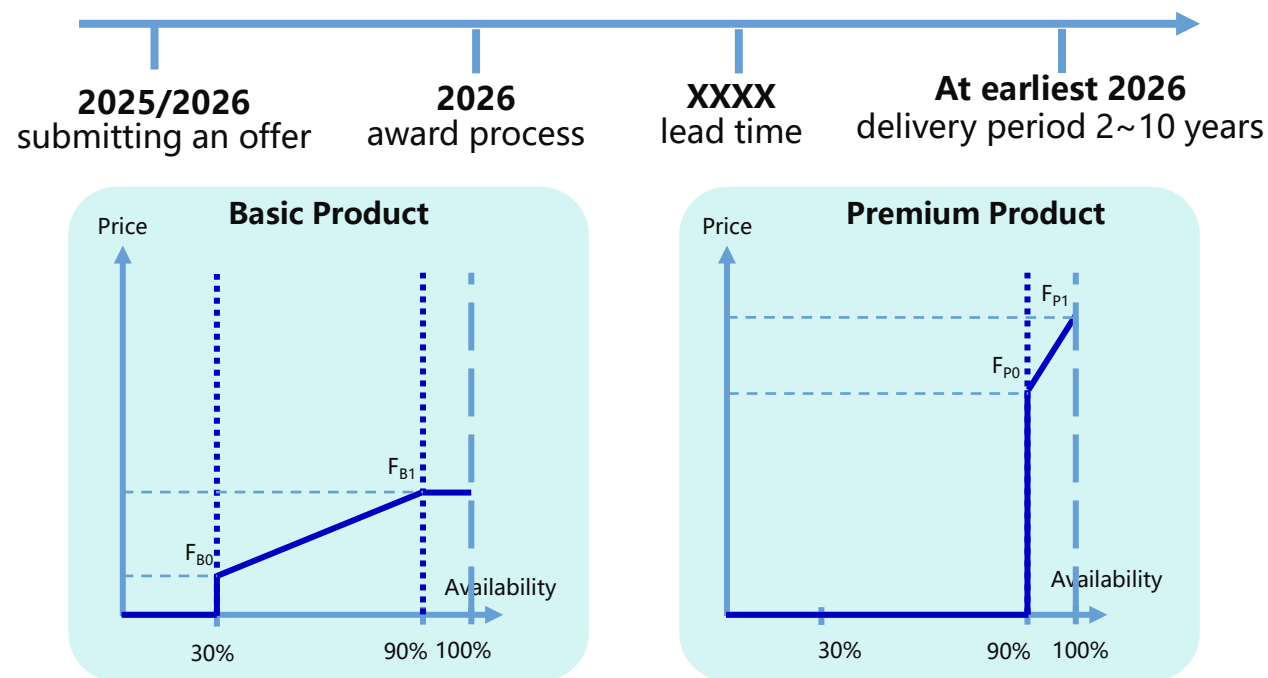
Germany inertia market provides a bonus mechanism for service providers

The definition of inertia products

	Basic (availability $\geq 30\%$)	Premium (availability $\geq 90\%$)
Positive	Loads Battery Synchronize Machines	Battery Synchronize Machines
Negative	Wind and PV Battery Synchronize Machines	Battery Synchronize Machines

- Battery can be applicable for all of the **4 products**.
- The provider need to do the proof of **technical capability and the start-up time of the specific unit** through certification according to **FNN note**.
- The provider should be **always on** and may not deactivate the instantaneous reserve capability.

The procurement process and price setting



- There will be **fixed price** compensation, and the price level is related to the availability.
- The offered quantity and product is determined by provider.
- The price per product and region is determined by TSO and there will be a publication of price developments for **the following 2 years**. The **price at earlier stage is expected to be higher** than later.

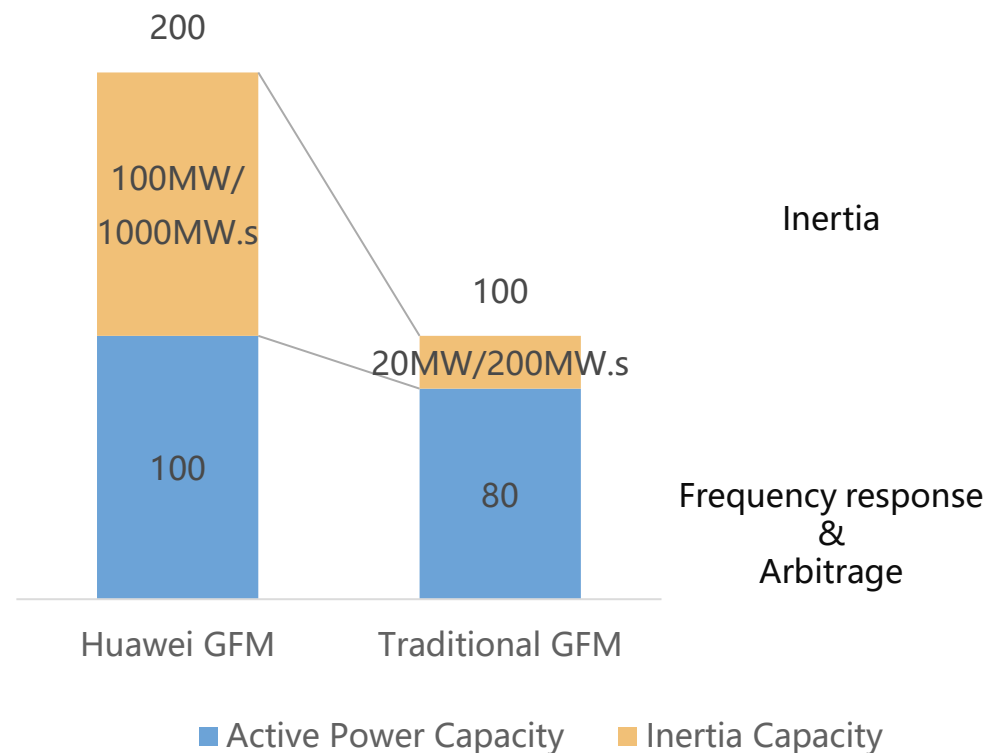
Better performance above market requirements unlock more potential revenue

GFM key performance

	Traditional GFM	Huawei GFM
Short-circuit capacity	1p.u.	3p.u.
Active Power overload	1.1p.u.	1.25p.u.
Inertia constant H	~10s	0~20s
Intentional Islanding	Y	Y
SCR Adaptability	> 1.2	> 1.0
Power Oscillation Damping	0.1~2.5Hz	0.1~100Hz
Positive impedance characteristics	0.1-500Hz	0.1-2500Hz
Black Start	Hours	≤ 10min

Enhance capability to provide inertia

Huawei GFM vs Traditional GFM



Global projects have demonstrated Grid-Forming from MW to GW scale

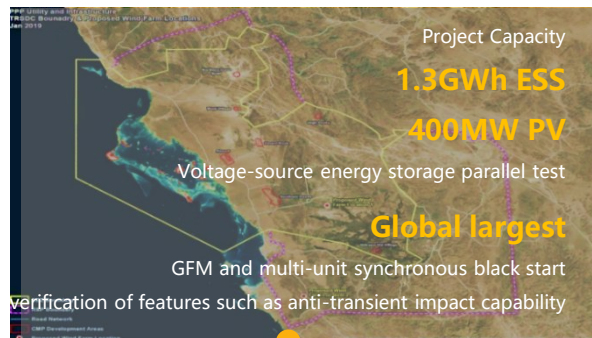
Qinghai Huarun Poverty Alleviation



Sep, 2022

First GFM Solar ESS (2MWh) Test

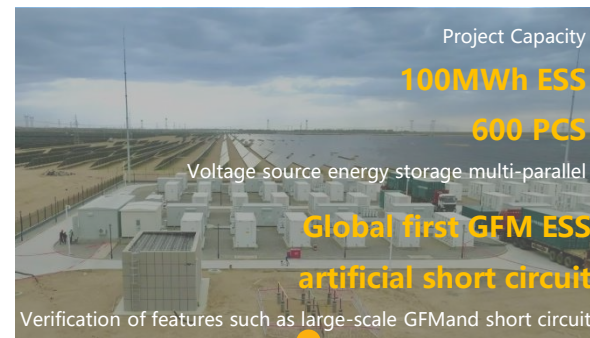
Saudi Arabia Red Sea Power Plant



Sep, 2023

100% Renewable

Qinghai Golmud



Jun, 2024

PV+100MWh Scenario at DC Near-Zone

Complex & harsh
environment
conditions

Deserts
Extreme cold
High humidity
High temp.
High salt content
High altitude

Jan, 2023

Weak Grid Solar ESS (2MWh)

May, 2024

Wind + 100MWh Scenario

Jul, 2024

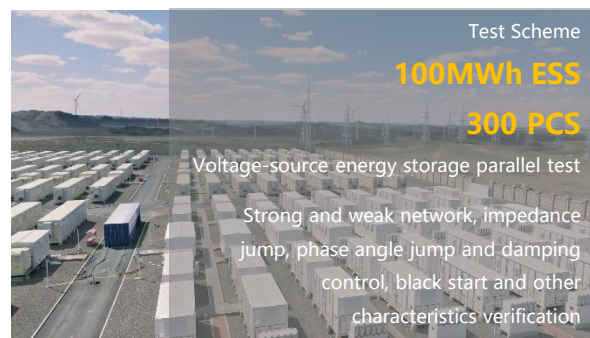
Extremely Weak Grid Terminal

On-grid / offgrid
strong grid /
extremely weak grid
Wind/Solar/BESS
DC transmission
terminal

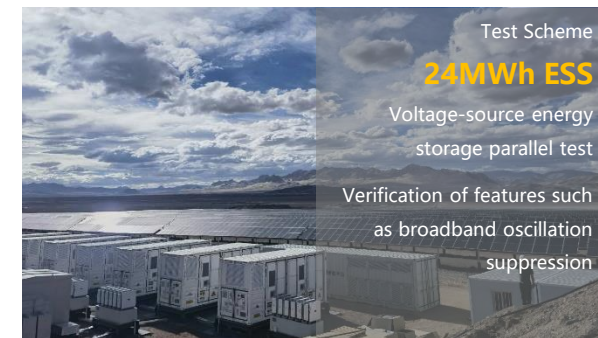
Complex power
system scenarios



Qinghai Guoneng Zhou Liang

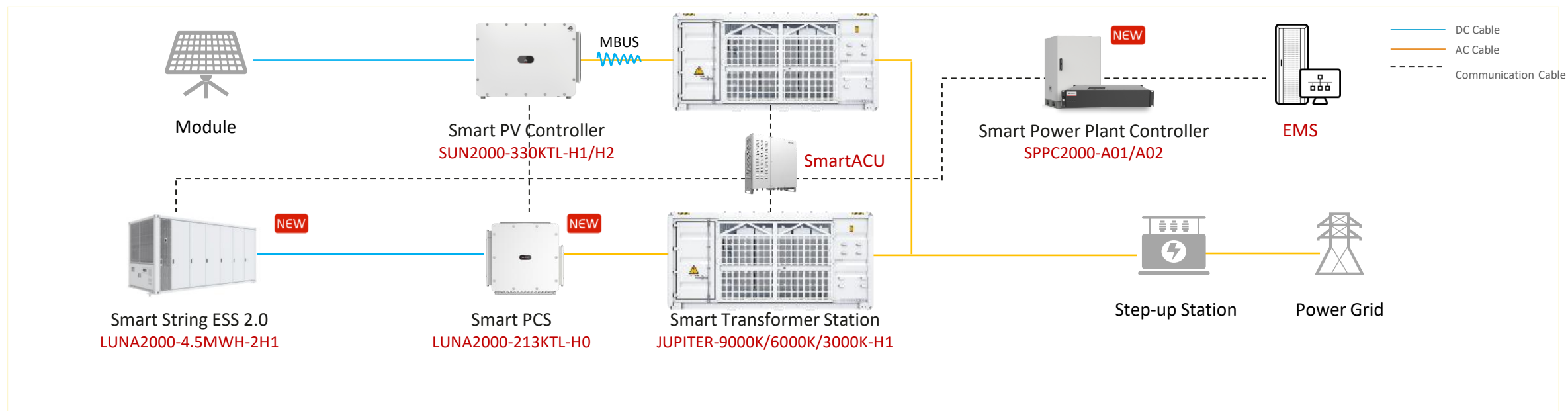


Huarun Salt Water Spring in Hami, Xinjiang



Xizang Zangkaitou Ali

Smart String Grid Forming ESS: High safety and reliability, all-scenario grid-forming



Optimal LCOS

Ultimate Safety

Smart O&M

Grid Forming

Conclusion

- Wind and solar penetration in the EU is approaching 50%, creating major challenges due to low inertia and limited POD resources.
- Increasingly, countries are drafting **GFM grid codes** and designing **market mechanisms**.
- Inertia and short-circuit strength are already being procured through **markets in Germany and the UK**.
- Advanced grid-forming technology can **unlock higher revenue** potential in these markets.
- Huawei' s state-of-the-art GFM technology has been validated through extensive field testing.

Thank You !

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