Grid Forming – Stability Solutions

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ESIG Special Topic Workshop: Grid-Forming IBRs - Session 3: Grid Forming Capabilities and Challenges (specifications, requirements and cost)

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Why SMA?

Because ...

... 113 GW of installed SMA inverter power

help to prevent almost 76 million tons of CO_2 emissions per year in over 190 countries and are proof of SMA's strong market position over many years.

... more than 4 GW of SMA battery inverter power

ensure round-the-clock sustainable electricity supply worldwide and make us a global leader in battery system technology.

... 1,700 patents and utility models

granted worldwide prove our high innovative strength.

... 3,500 SMA employees

are working with our partners and customers to pave the way for the energy supply of tomorrow, today.

1. Calculation: 113 GW accumulated installed SMA inverter capacity x 1,512 kWh power generaton/year/kW x 0,475 kg prevented CO_2 emissions/kWh

Key financials 2021 (prelim.)		**Guidance 2022**	
Sales:	MEUR984	Sales:	MEUR900 to MEUR1,050
EBITDA:	MEUR9	EBITDA:	MEUR10 to MEUR60
Inverter power sold:	13.6 GW		

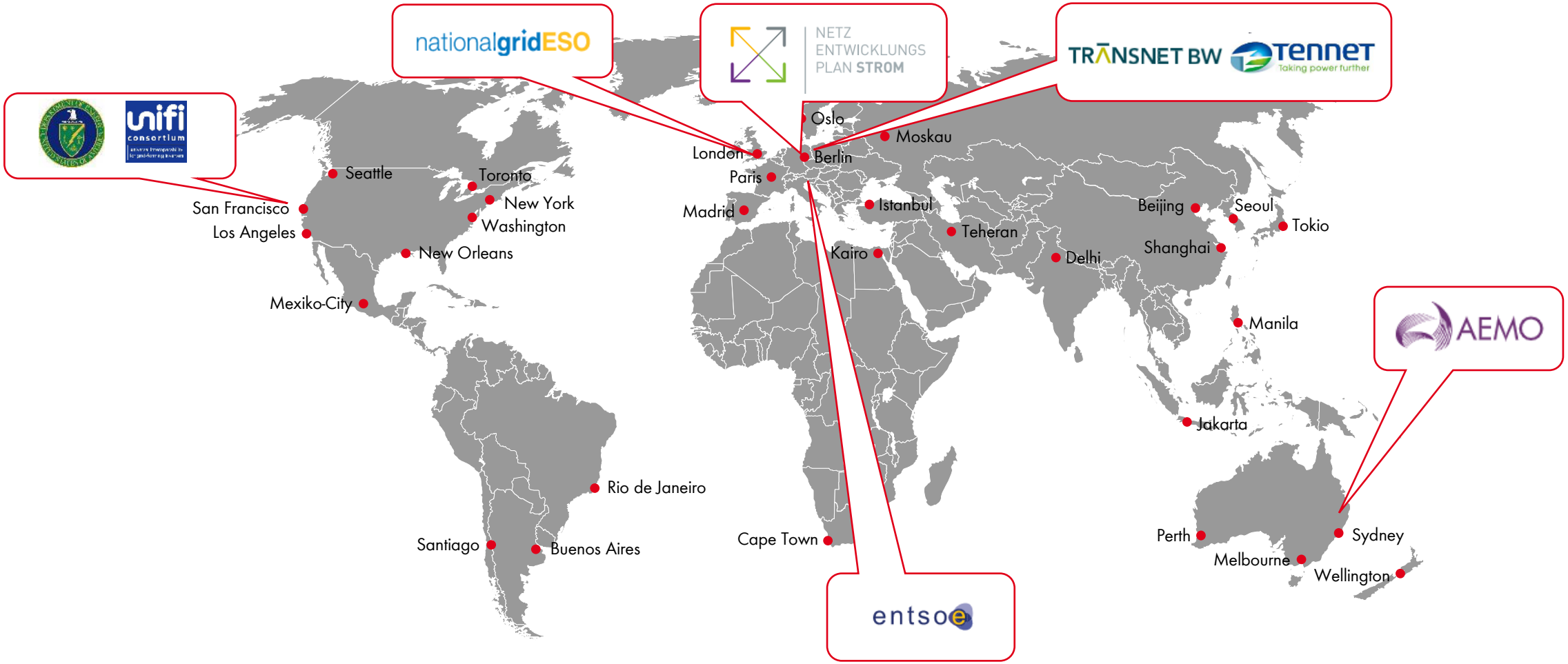
Agenda

Stability needs

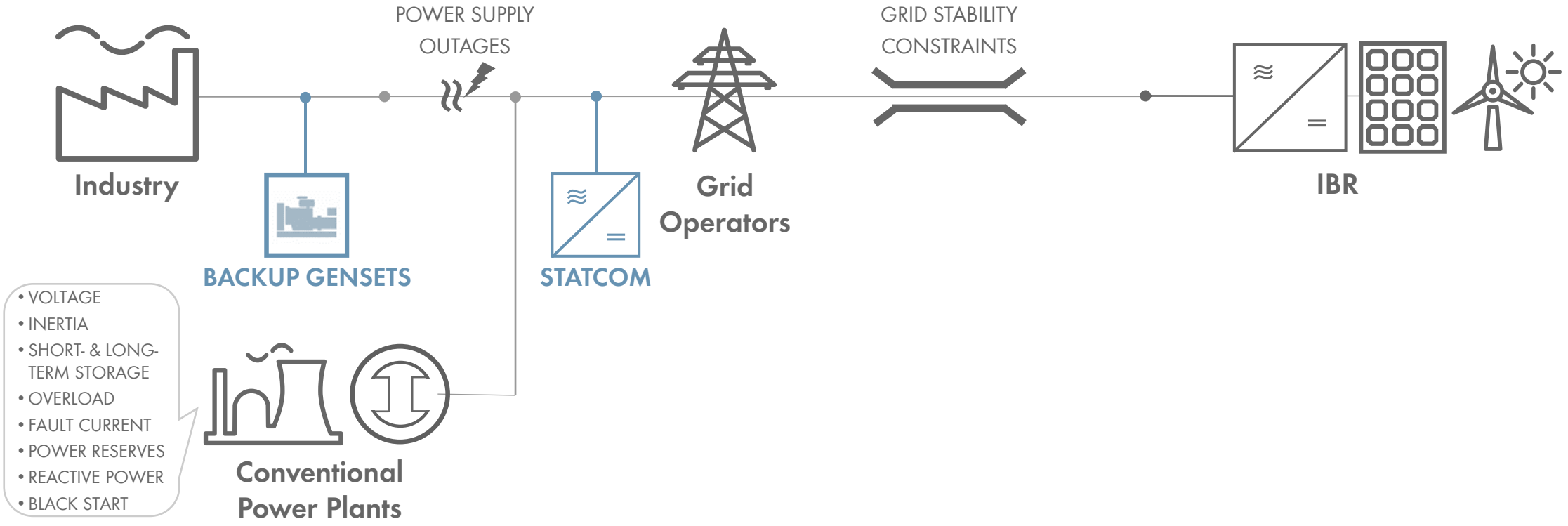
Technical Performance

Experience and Markets

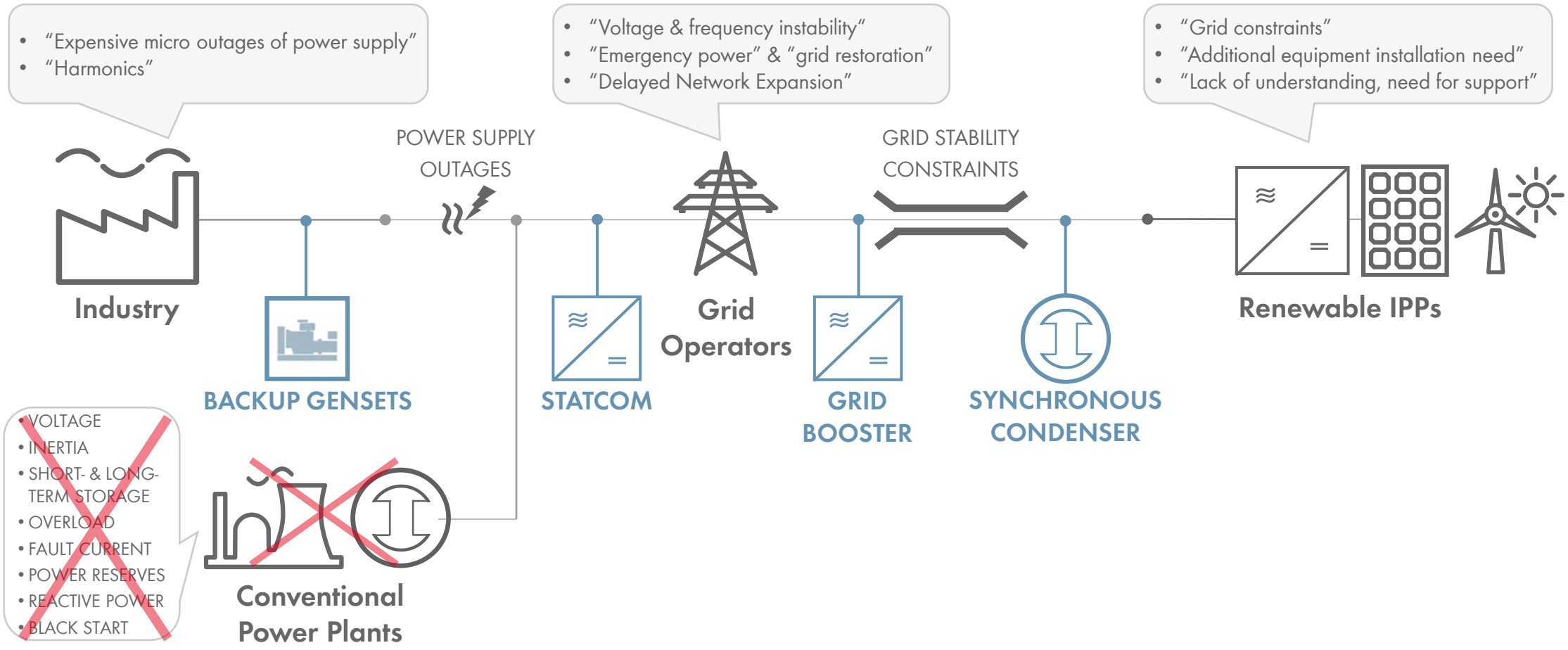
Power system operators and regulators globally are working on solutions to guarantee grid stability as IBR penetration increases



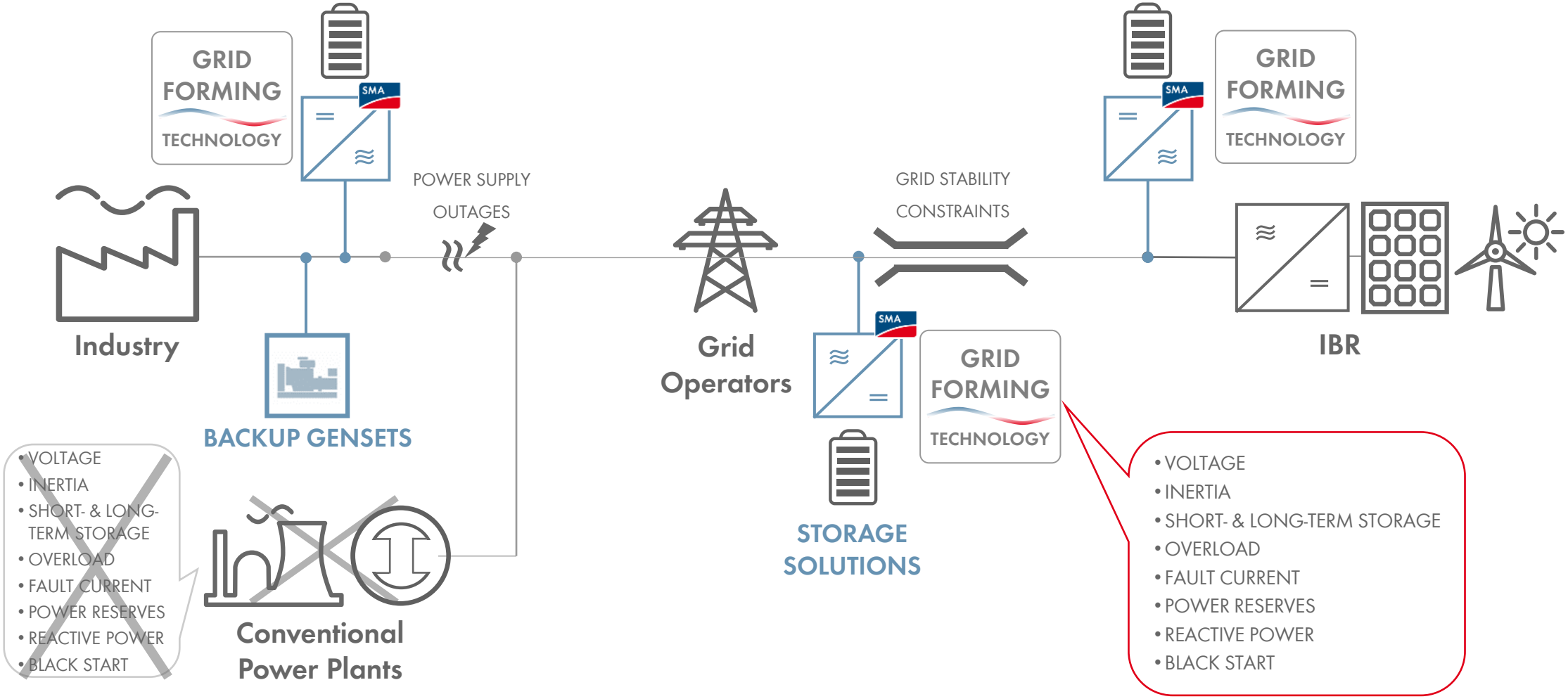
Topology of the existing power grid



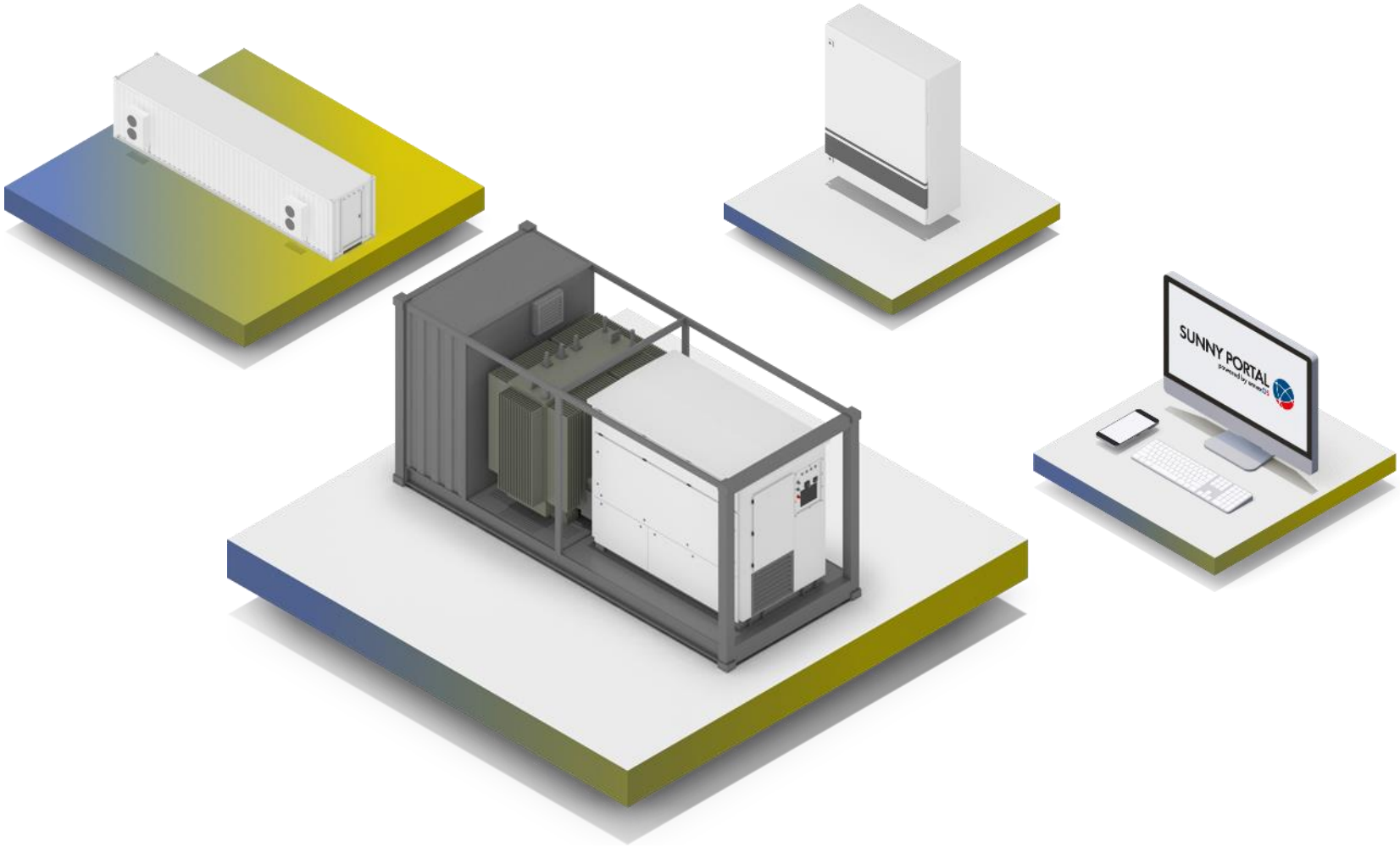
Challenges


• "Expensive micro outages of power supply"
• "Harmonics"
• "Voltage & frequency instability"
• "Emergency power" & "grid restoration"
• "Delayed Network Expansion"
• "Grid constraints"
• "Additional equipment installation need"
• "Lack of understanding, need for support"
POWER SUPPLY OUTAGES
GRID STABILITY CONSTRAINTS
Industry
BACKUP GENSETS
STATCOM
Grid Operators
GRID BOOSTER
SYNCHRONOUS CONDENSER
Renewable IPPs
• VOLTAGE
• INERTIA
• SHORT- & LONG-TERM STORAGE
• OVERLOAD
• FAULT CURRENT
• POWER RESERVES
• REACTIVE POWER
• BLACK START
Conventional Power Plants

Advanced grid-forming functions in inverters not only can substitute, but improve on the existing technologies



Select the SMA Large Scale Energy System that fits your need!



Grid Forming

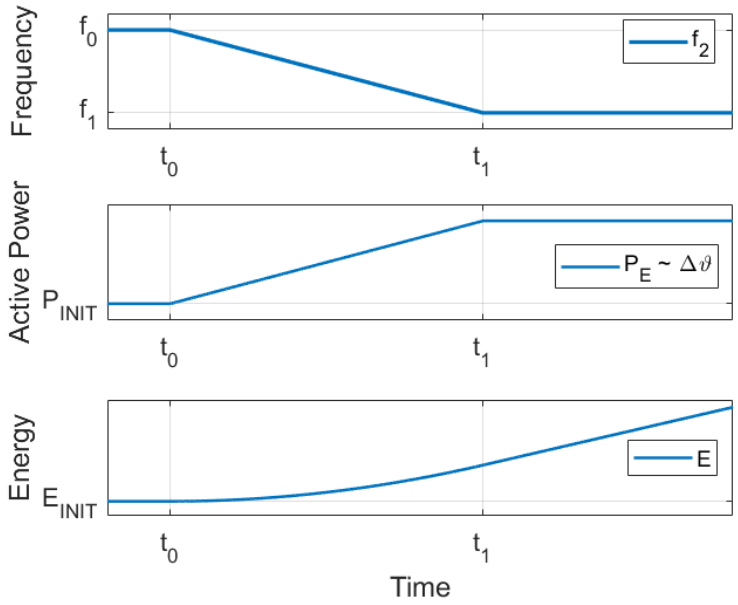
Technical performance – selected examples

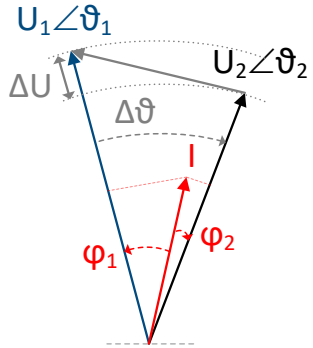
Synchronous operation of IBR with static or transient type of instantaneous response to voltage & frequency disturbances

Grid Forming Droop Control

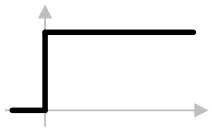
$$\frac{\Delta P}{S_N} \cong \frac{1}{k_f} \cdot \frac{\Delta f}{f_N}$$

$$\frac{\Delta Q}{S_N} \cong \frac{1}{k_U} \cdot \frac{\Delta U}{U_N}$$

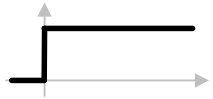




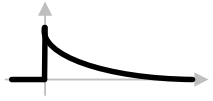
DISTURBANCE



STATIC RESPONSE



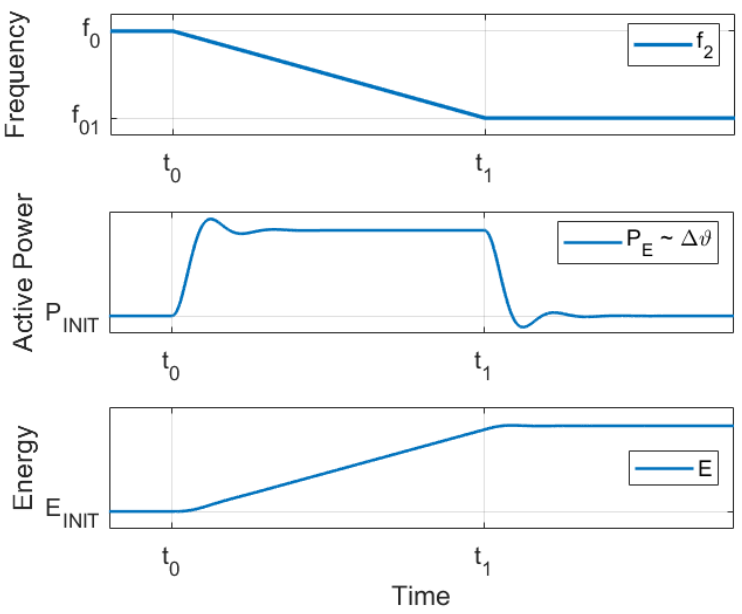
TRANSIENT RESPONSE



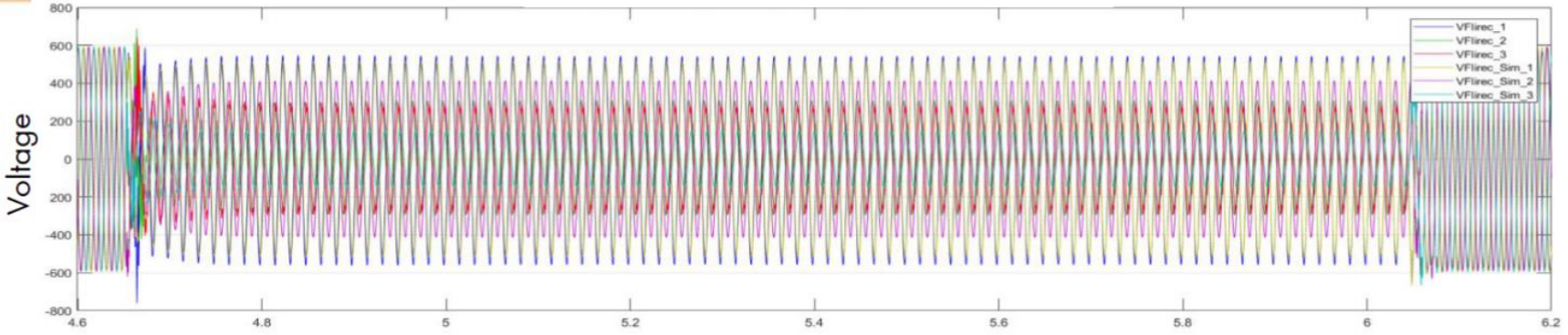
Grid Forming Inertia Control

$$\frac{\Delta P}{S_N} \cong -2 \cdot H_\vartheta \cdot \frac{\Delta f/\Delta t}{f_N}$$

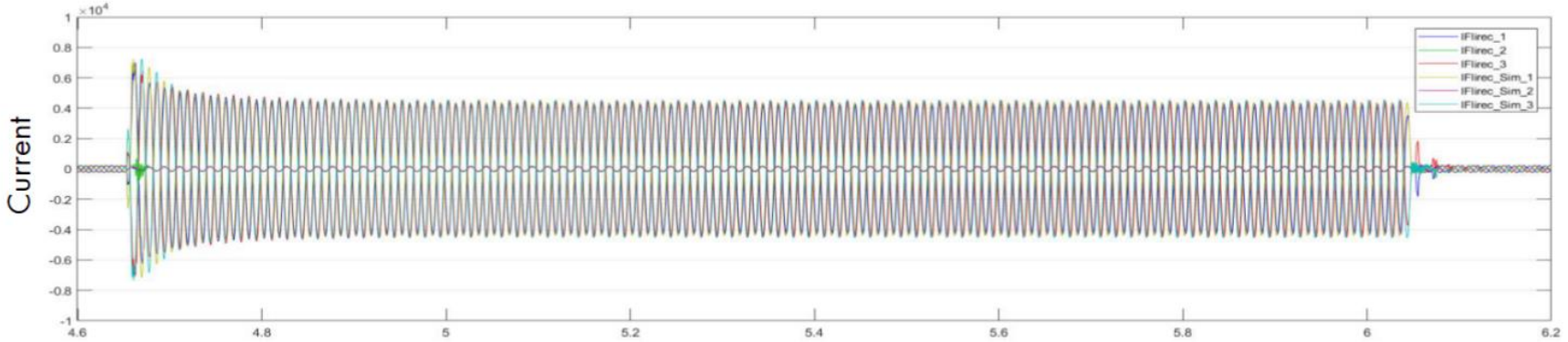
$$\frac{\Delta Q}{S_N} \cong -2 \cdot H_U \cdot \frac{\Delta U/\Delta t}{U_N}$$



Fault Current Provision – 1 phase Fault Model Validation

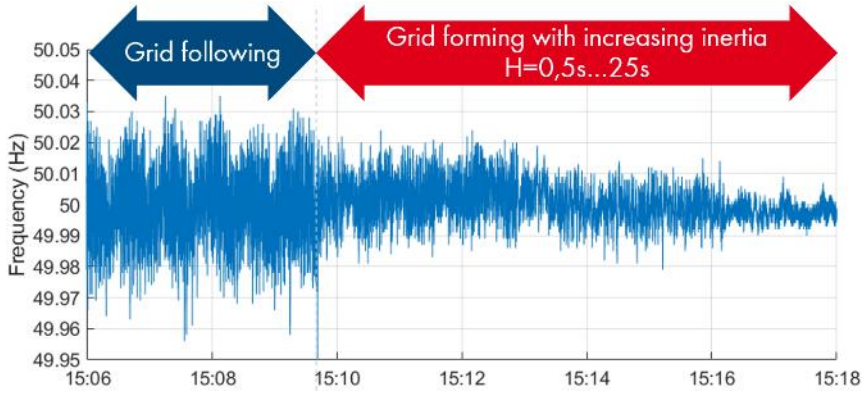


- Fault current testing: example 1phase → GND
- Very good match between lab measurements and EMT model results (PSCAD)

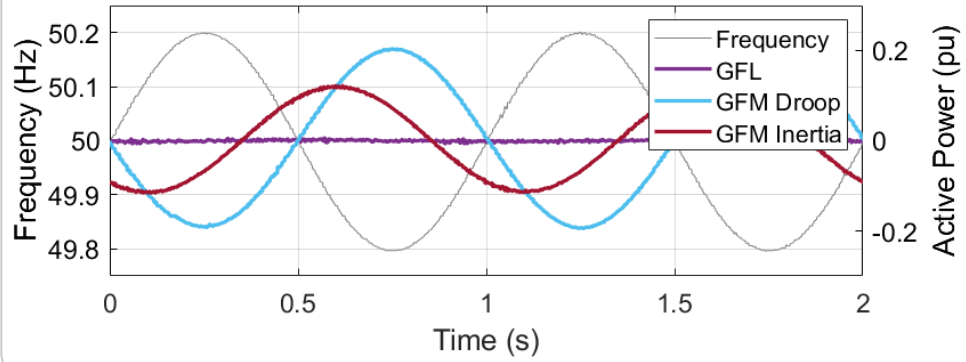


System Strength/ Power Quality
Measurements with Grid Forming Storage System

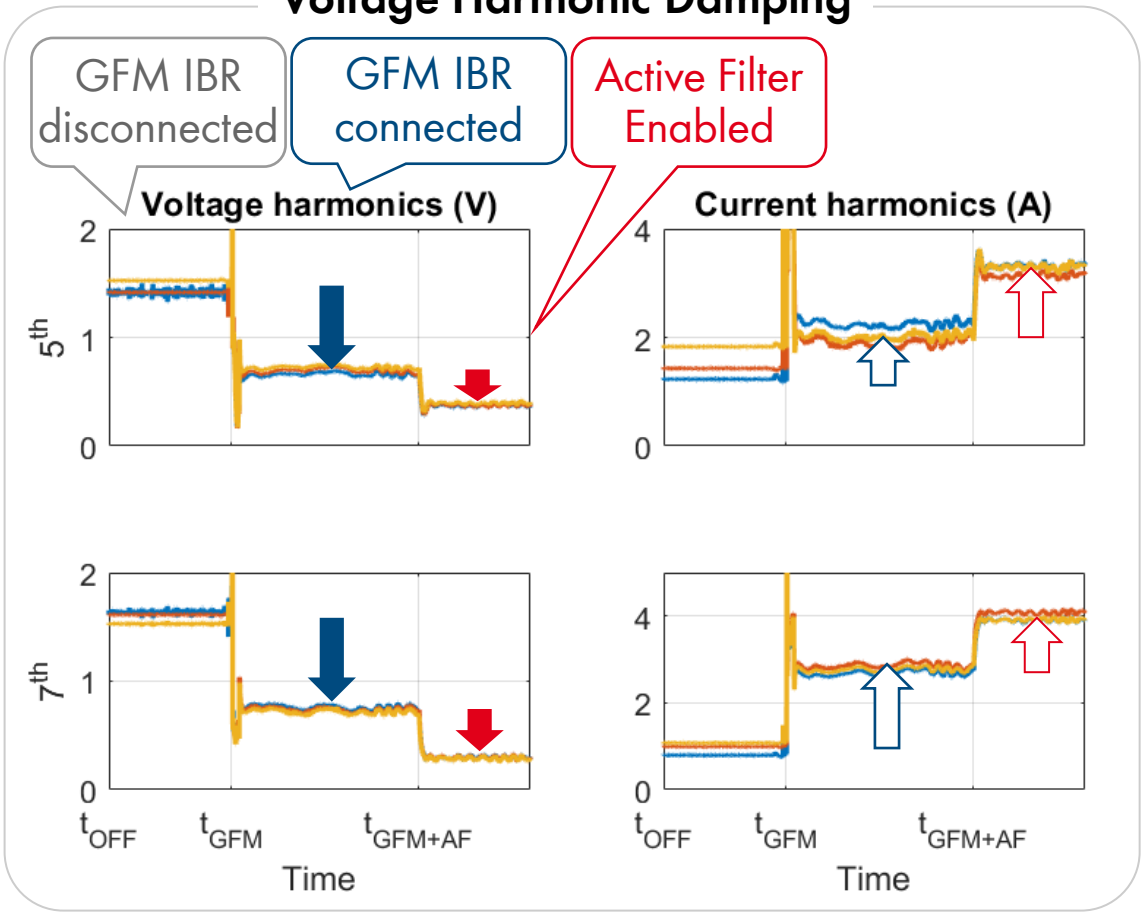
System Strength Improvement



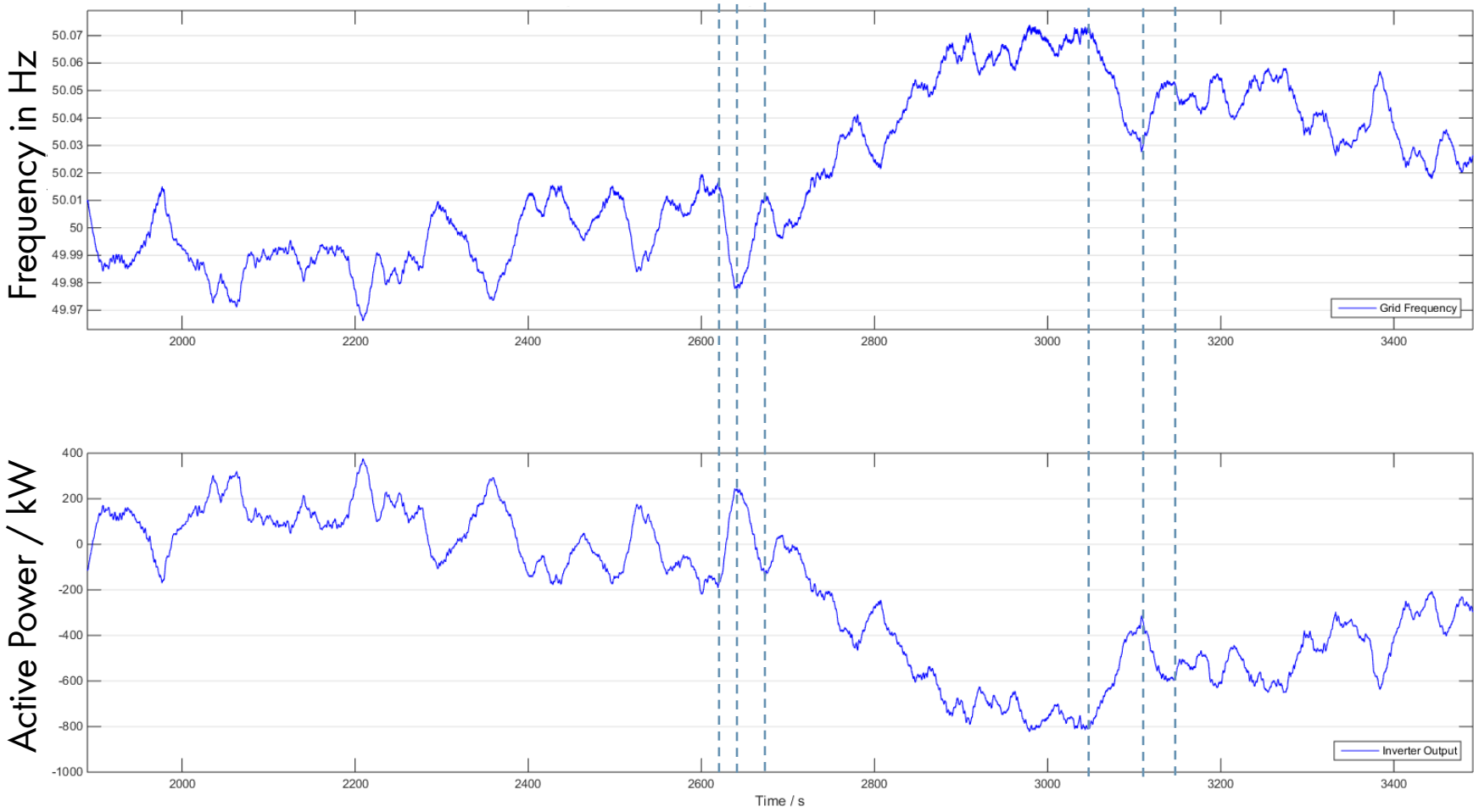
Sub-synchronous oscillation response



Voltage Harmonic Damping



Example: Grid-Forming in Grid-Parallel Operation



- Grid-parallel operation of grid-forming Plant
- Naturally providing inertia and primary control reserve

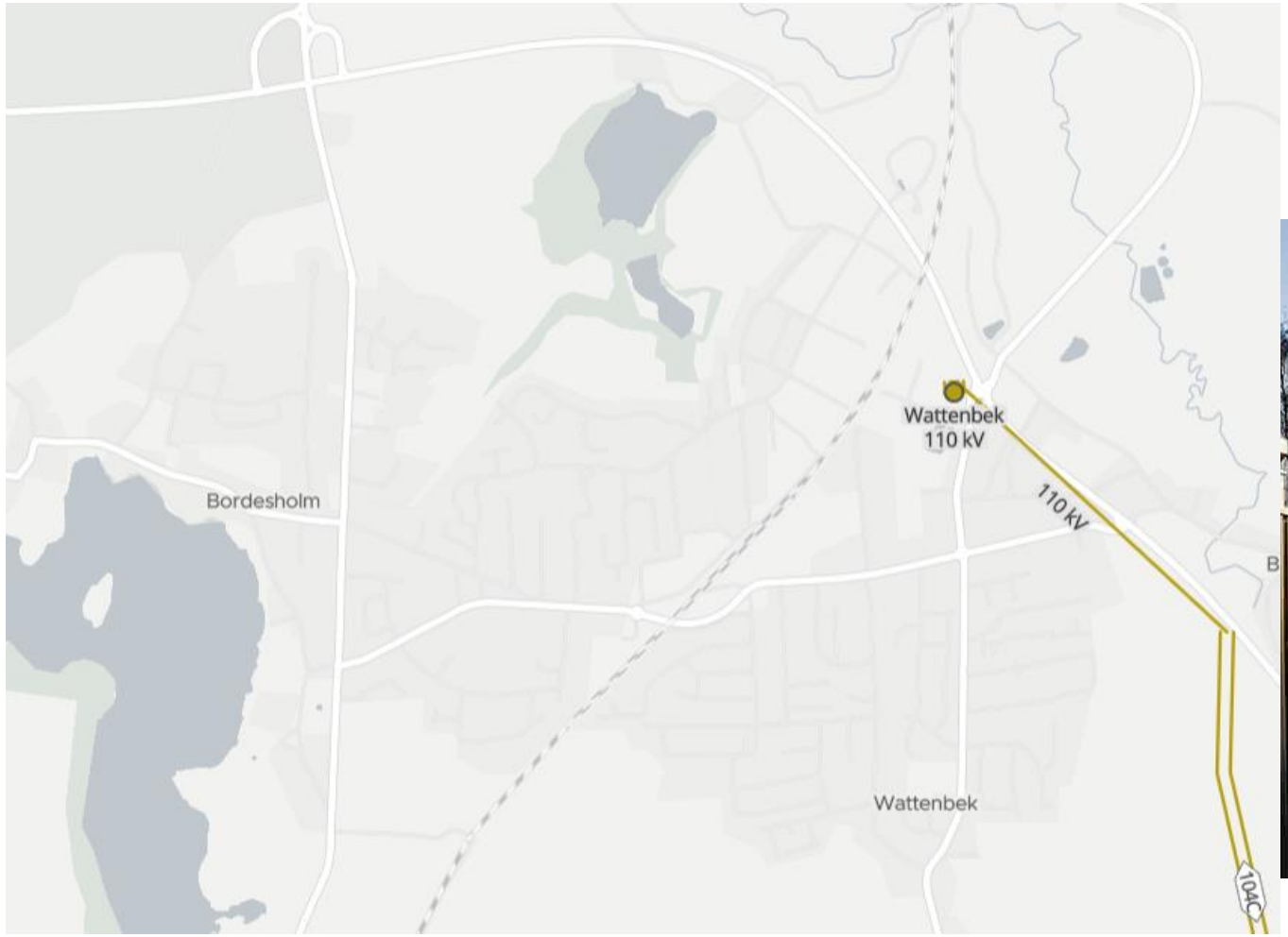
Publications

A. Knobloch *et al*., "**Synchronous energy storage system with inertia capabilities for angle, voltage and frequency stabilization in power grids**," *11th Solar & Storage Power System Integration Workshop (SIW 2021)*, 2021, pp. 71-78, https://doi.org/10.1049/icp.2021.2486 .

P. Mayer et al., „**Improving grid strengh in a wide-area transmission system with grid forming inverters**“, IET Generation, Transmission & Distribution, May 3, 2022 (early access), https://doi.org/10.1049/gtd2.12498 .

Grid Forming
Experience and Markets

Grid Forming Project: Bordesholm, Germany 2019



Battery Storage Application

Frequency Containment Reserve

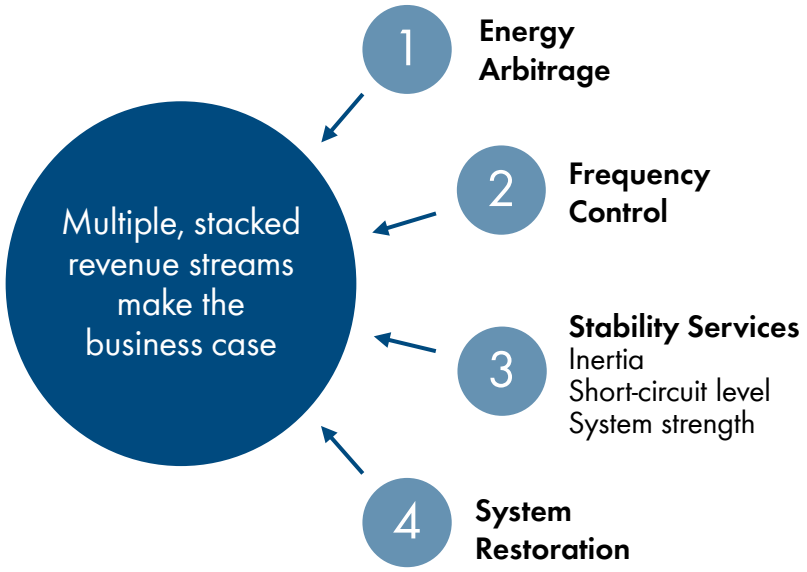
Backup Islanding for 8000 inhabitants

15 MW

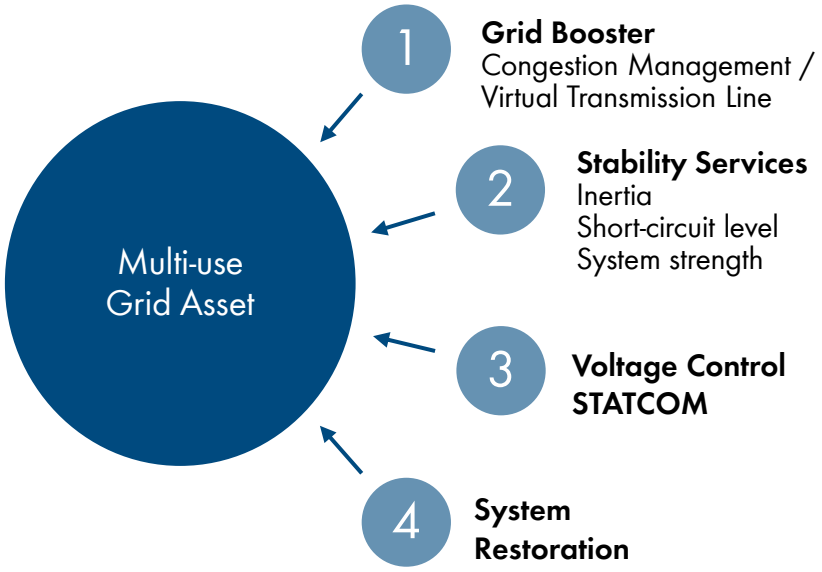
https://youtu.be/y9wp53WfROM

Multi-use of battery storage
Grid Forming Solutions

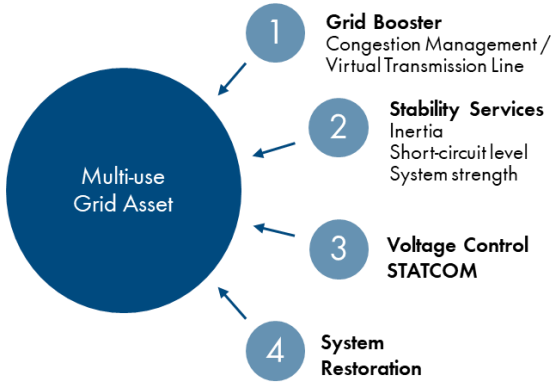
Market-oriented Battery Storage Plant



Grid Asset based on Battery Storage Plant



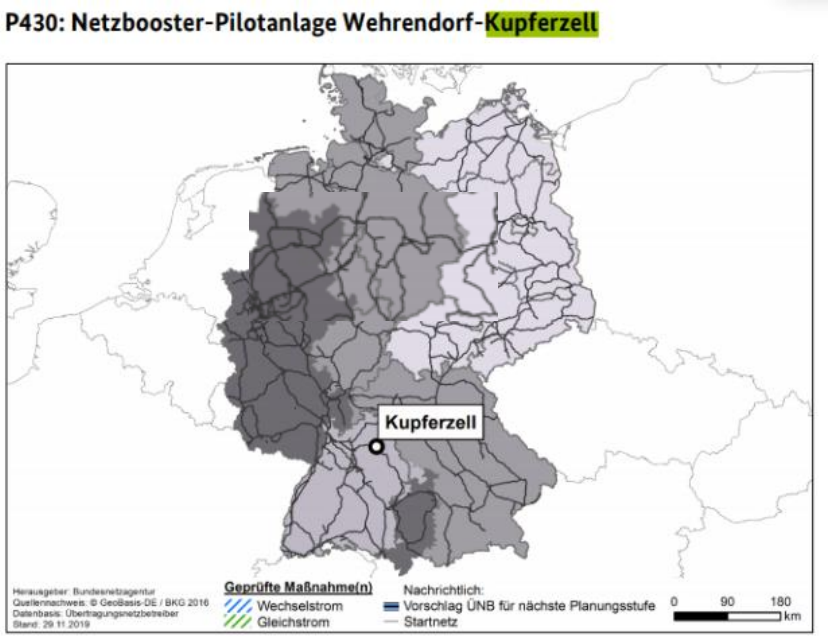
German TSOs:
Grid Booster Tender



Source: German Grid Development Plan https://www.netzentwicklungsplan.de

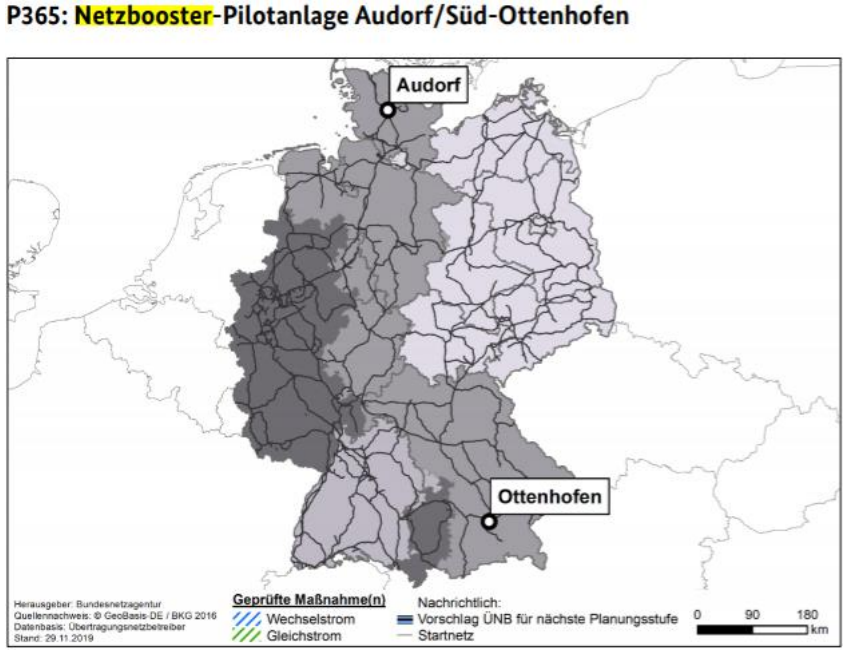
TransnetBW Grid Booster

- 354 MVA in Kupferzell



Tennet Grid Booster

- 2 times 100 MW Ottenhofen and Audorf Süd



nationalgrid UK Stability Pathfinder

UK power system:

➔ low share of synchronous generation

➔ stability at risk (frequency, voltage)

nationalgrid tenders „Stability Service Provision“

➔ Increase Inertia and Short-Circuit Level,

➔ To maintain stability and resiliency.

Stability Pathfinder Phases

Phase 1 – GB wide	Phase 2 - Scotland	Phase 3 – England / Wales
Synchronous Machines only	**Synchronous Machines** or **Inverter-based Solutions** → Multi-Use ✔	
• **Tender 2019** • **Service start 2020/2021** • **5 years**	• **Tender closed Jan 2022** • **Service start 2024** • **10 years**	• **Tender to close soon (Summer 2022)** • **Service start 2025** • **10 years** • Short Circuit Level – 7.5 GVA (region specific) • Inertia – 15 GWs (non-regional)

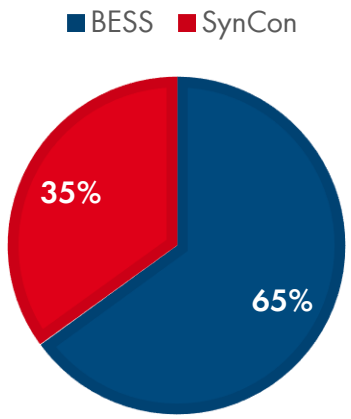
UK Stability Pathfinder 2 (Scotland)
Tender results

Source National Grid ESO

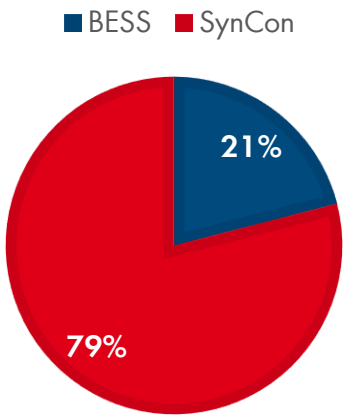
224 projects proposals
10 winners

- **5 projects Grid Forming Battery**
- **5 projects Synchronous Condenser**

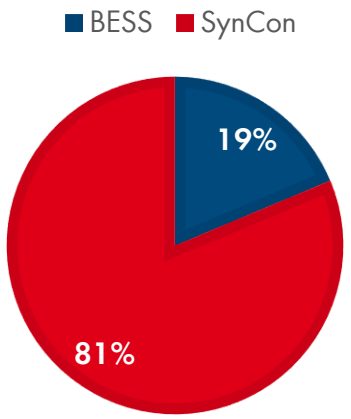
6.7 GVAs INERTIA



11.5 GVA SCL



ANNUAL COST

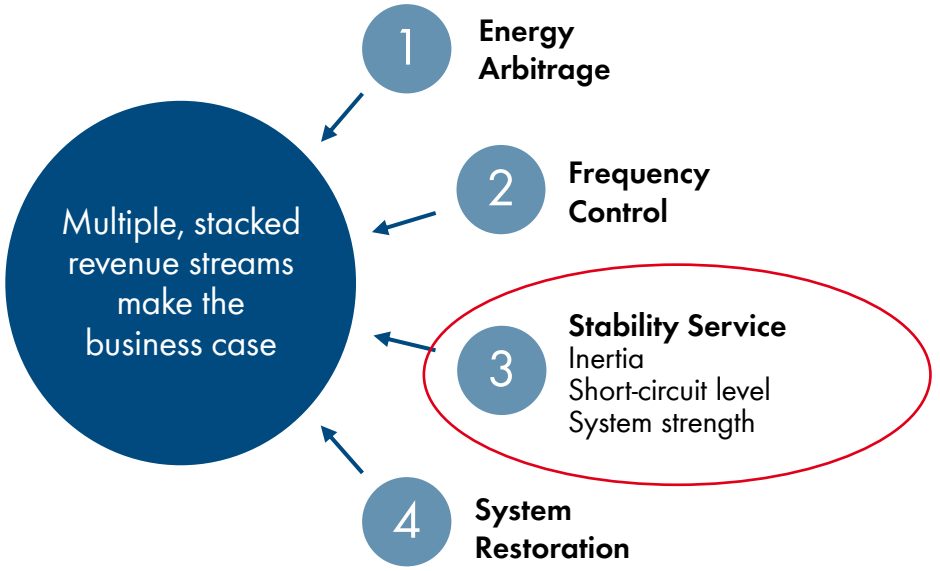


Shares derived from Tender Results from Source National Grid ESO

Multi-Use of Battery Storage important for business case

Example Battery Storage Solution based on SMA technology

- **100 MW** continuous power (1,2 or 4 h duration)
- **50 MW / 5s** reserve on top for inertia; at H = 25s ➔ 1.25 GWs
- Additional short-circuit level (peak current for 140 ms)



Status / Outlook

250 MW-class grid-forming storage projects as new standard

More standardization (requirements, new ancillary services)

Ancillary service markets as drivers (e.g. UK)

Grid integration studies

Summary

SMA Grid Forming Solutions

- Key to a 100% green, **stable and resilient** power supply
- Basis for Frequency and Voltage stability: Inertia and Short-Circuit Level
- GER example: Grid Booster as TSO asset
- UK example: market-based procurement of Stability Service

Thank you!

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