



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 CO₂ emissions per year in over 190 countries and are proof of SMA's strong market position over many years.

... 1,700 patents and utility models

granted worldwide prove our high innovative strength.

1. Calculation: 113 GW accumulated installed SMA inverter capacity x 1,512 kWh power generation/year/kW x 0,475 kg prevented CO₂ emissions/kWh

SMA Solar Technology

... 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.

... 3,500 SMA employees

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

Key financials 2021 (prelim.)

Sales: MEUR984

EBITDA: MEUR9

Inverter power sold: 13.6 GW

Guidance 2022

Sales: MEUR900 to MEUR1,050

EBITDA: MEUR10 to MEUR60





Agenda



Stability needs

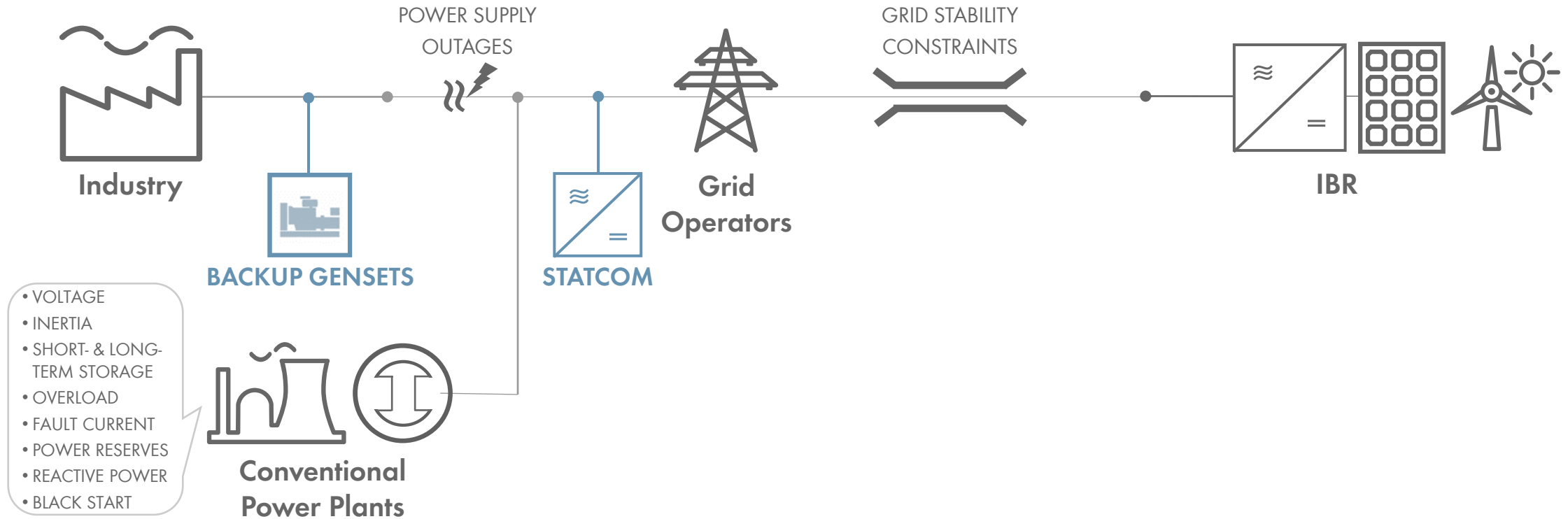
Technical Performance

Experience and Markets

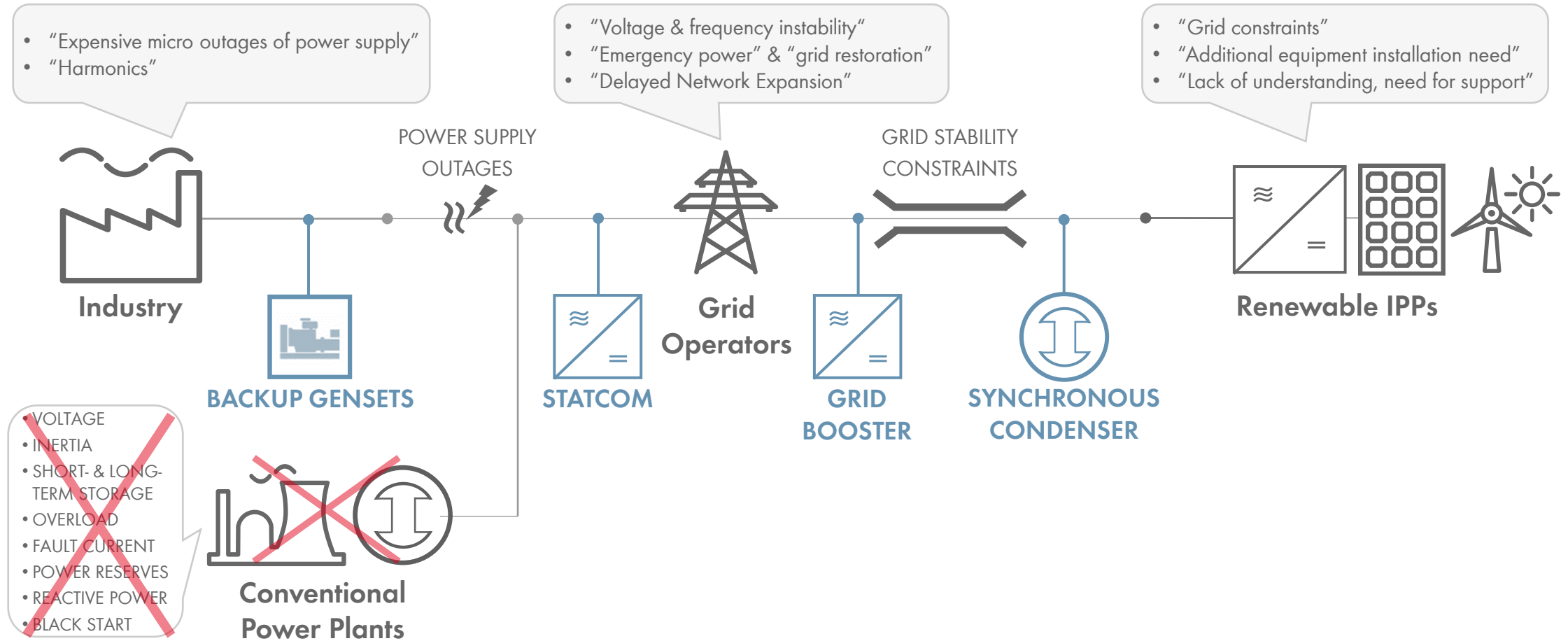
Power system operators and regulators globally are working on solutions to guarantee grid stability as IBR penetration increases



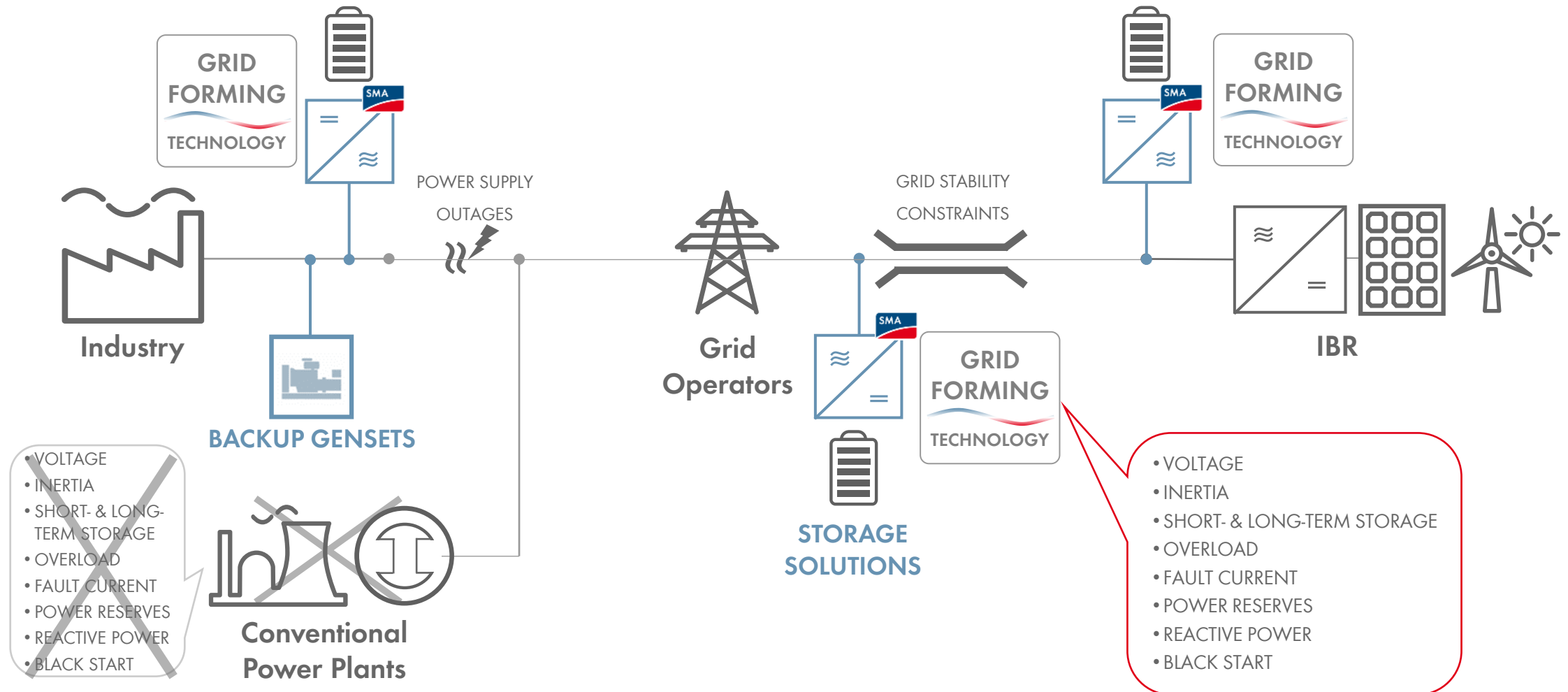
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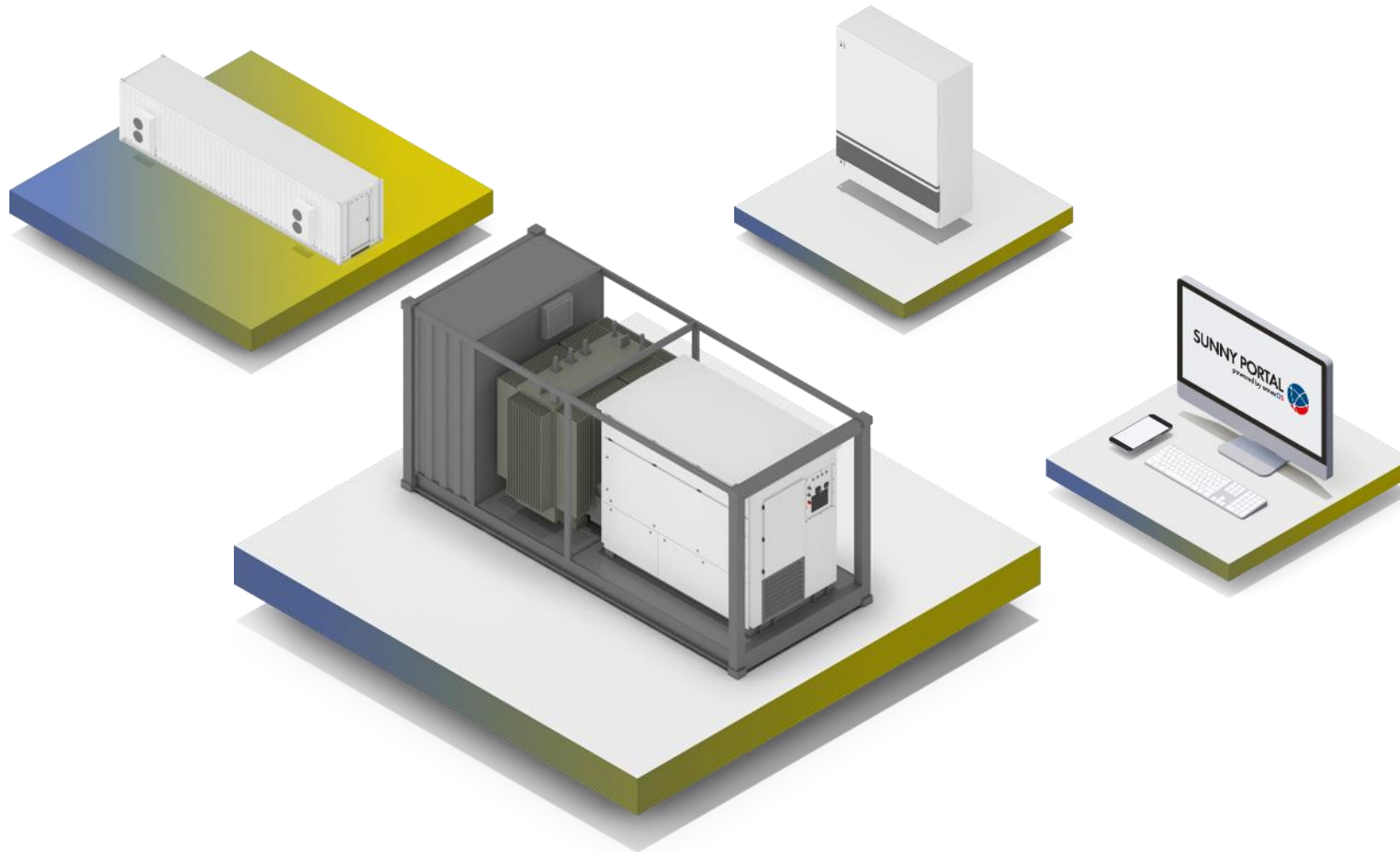
Challenges



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

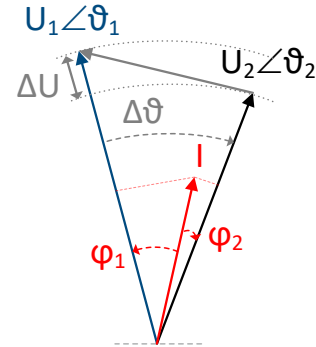
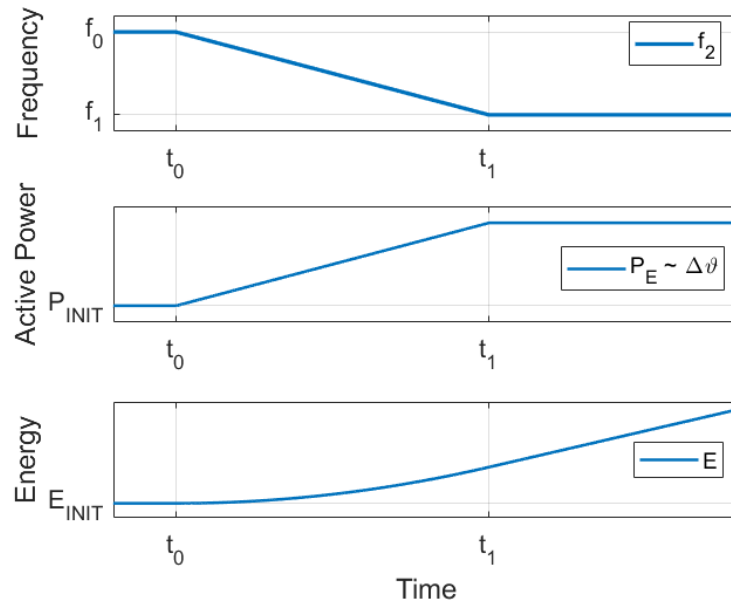
Synchronous operation of IBR with static or transient type of instantaneous response to voltage & frequency disturbances



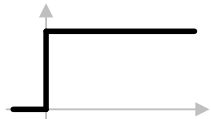
Grid Forming Droop Control

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

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



DISTURBANCE



STATIC
RESPONSE



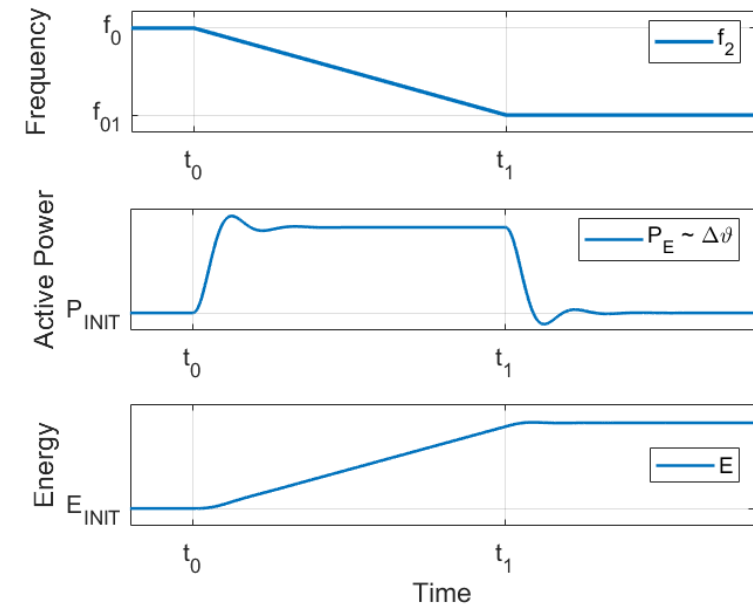
TRANSIENT
RESPONSE



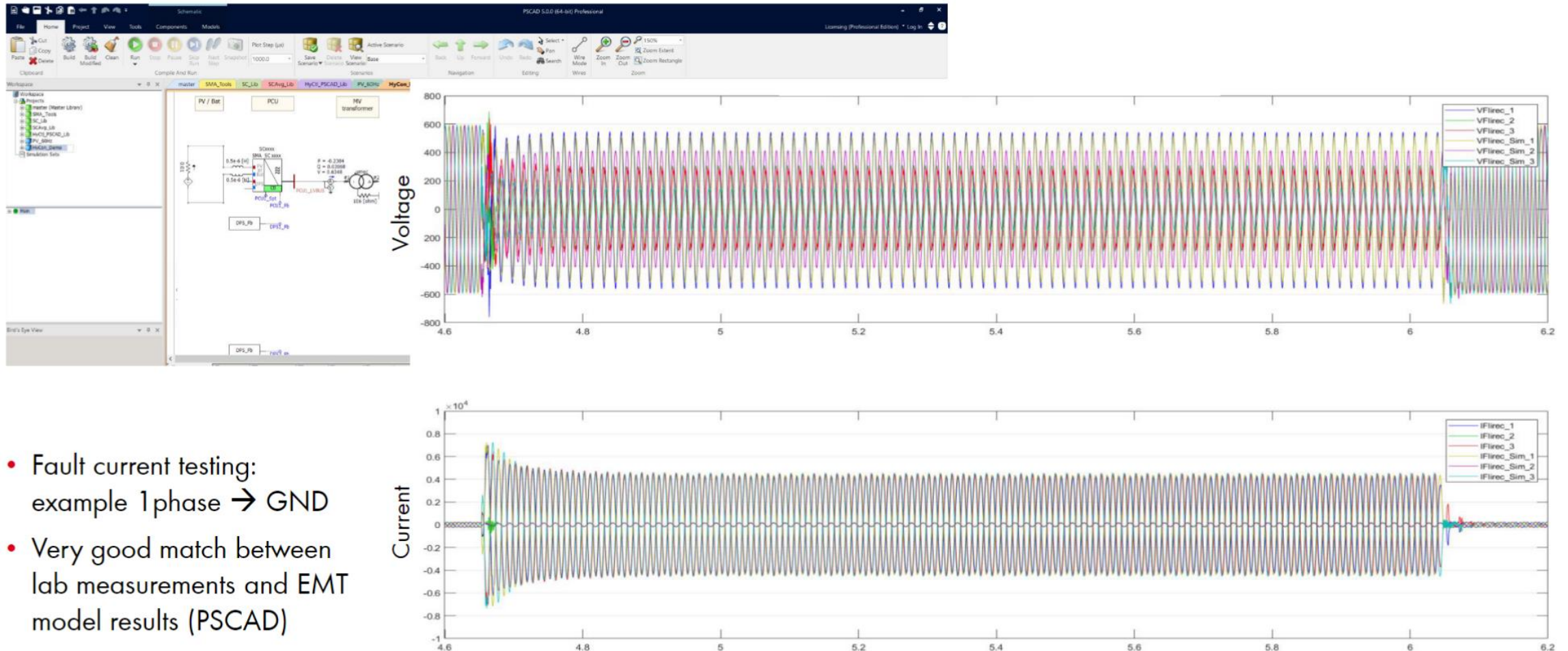
Grid Forming Inertia Control

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

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



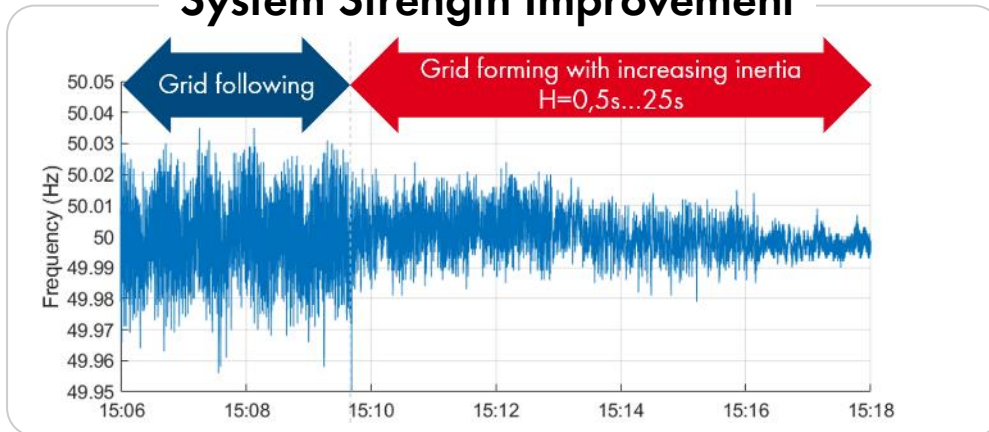
Fault Current Provision – 1 phase Fault Model Validation



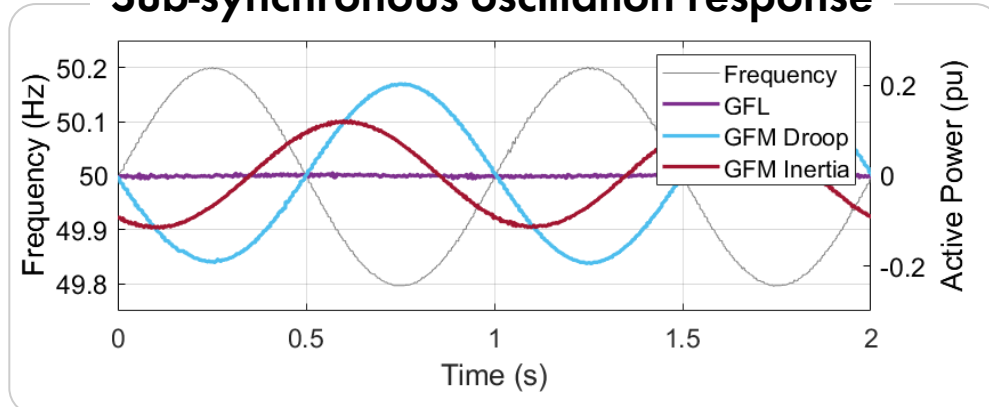
System Strength/ Power Quality Measurements with Grid Forming Storage System



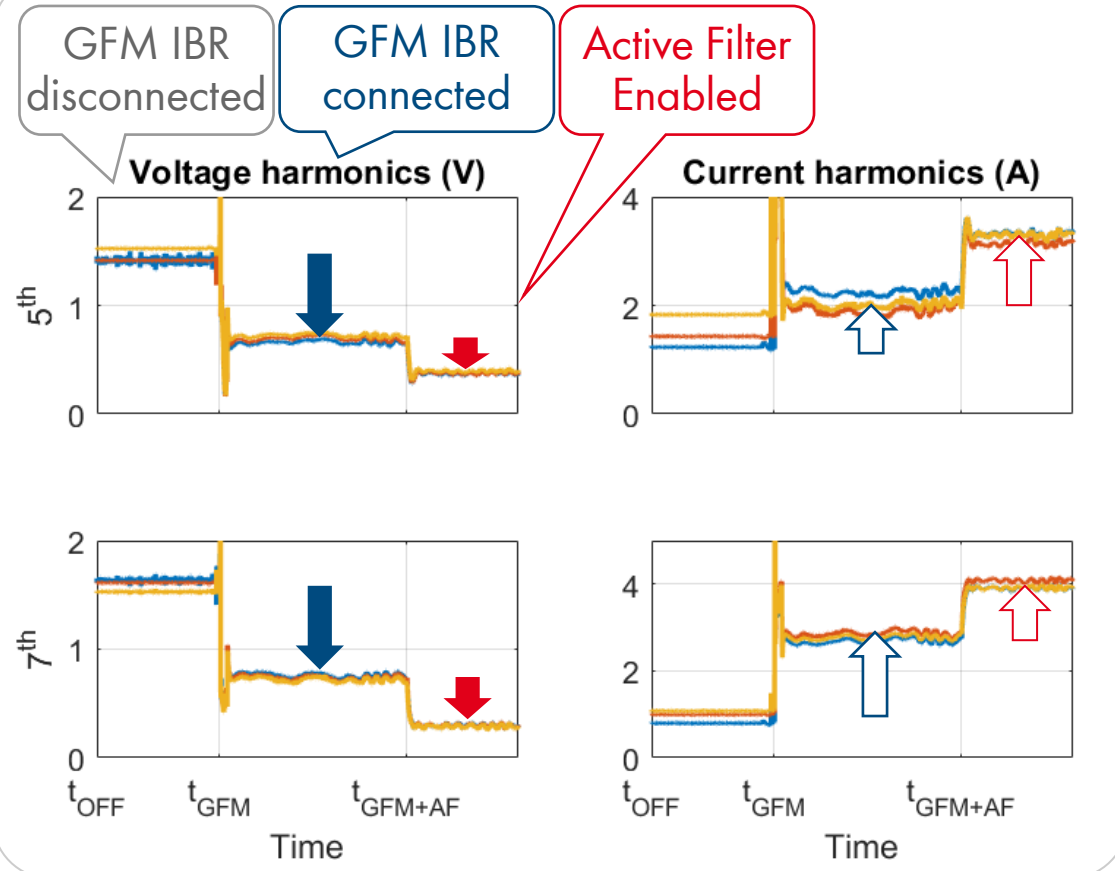
System Strength Improvement



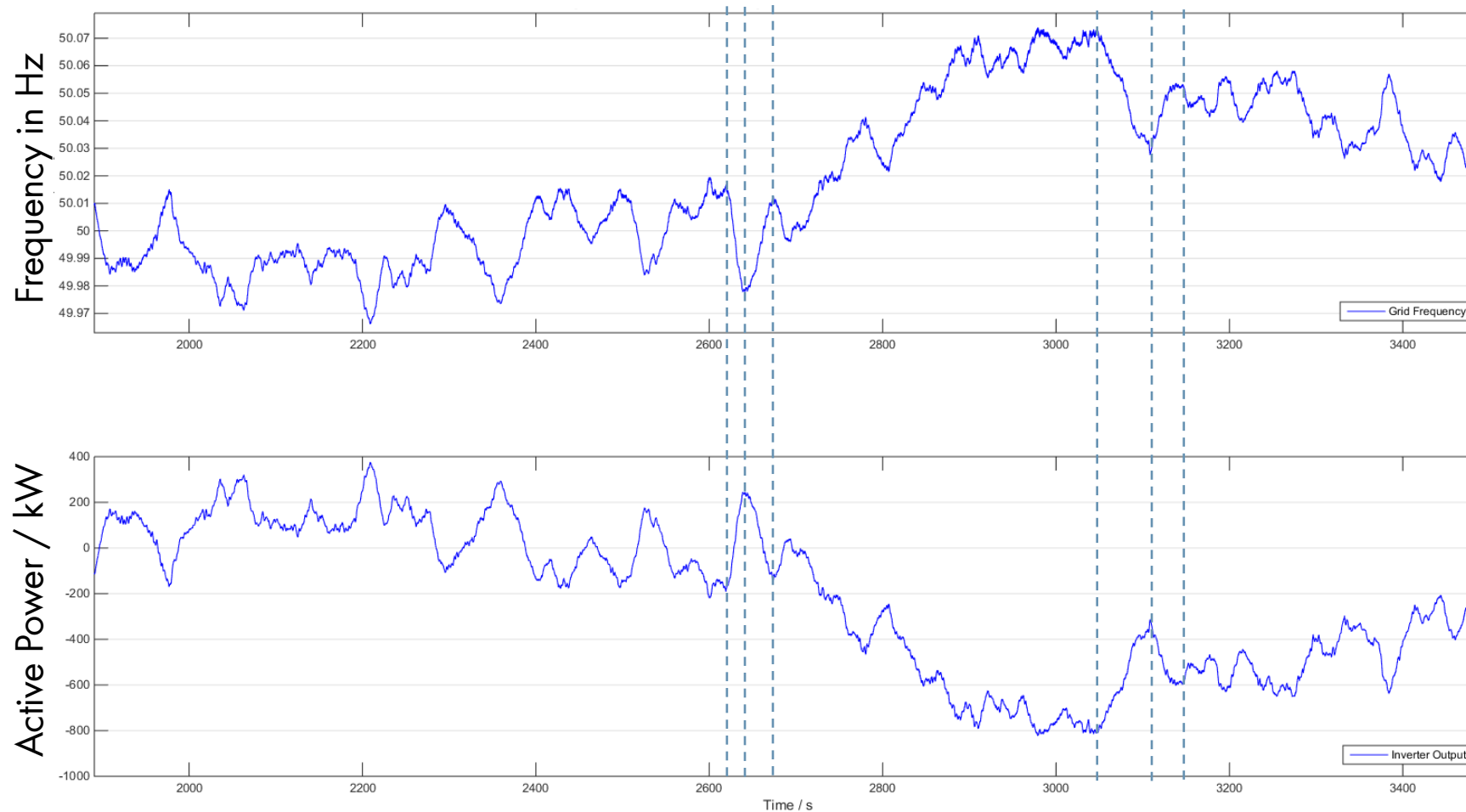
Sub-synchronous oscillation response



Voltage Harmonic Damping



Example: Grid-Forming in Grid-Parallel Operation



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

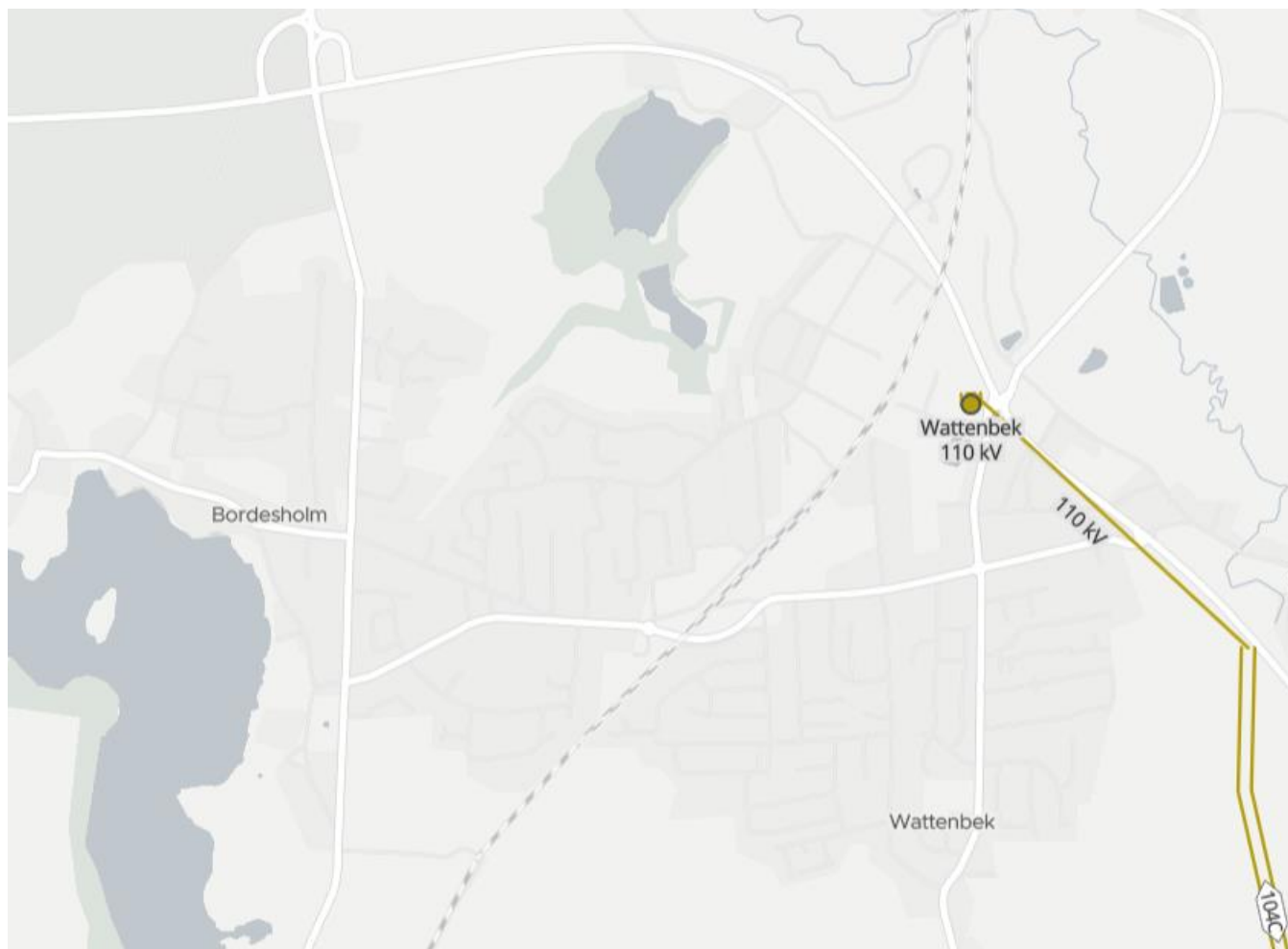
A. Knobloch *et al.*, "**Synchronous energy storage system with inertia capabilities for angle, voltage and frequency stabilization in power grids**," *11th Solar & Storage Power System Integration Workshop (SIW 2021)*, 2021, pp. 71-78, <https://doi.org/10.1049/icp.2021.2486> .

P. Mayer *et al.*, „**Improving grid strength 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

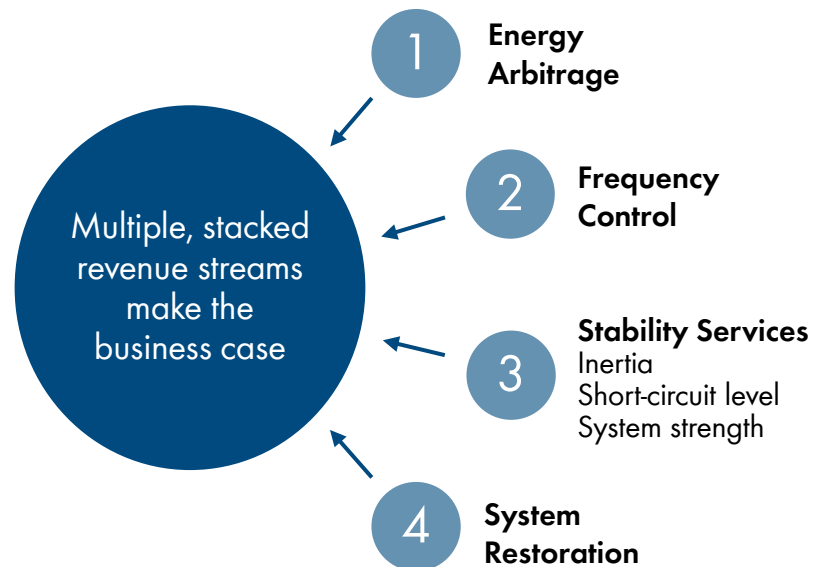


15 MW

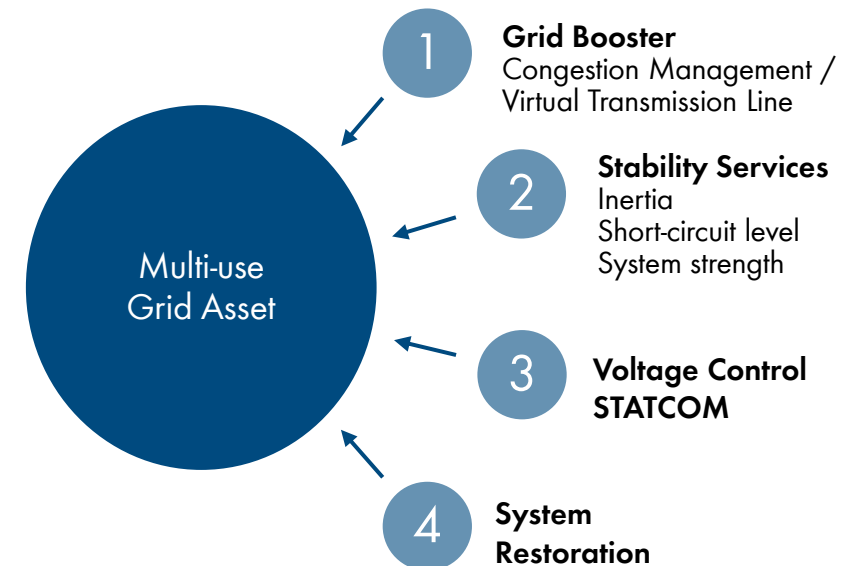
Multi-use of battery storage Grid Forming Solutions



Market-oriented Battery Storage Plant

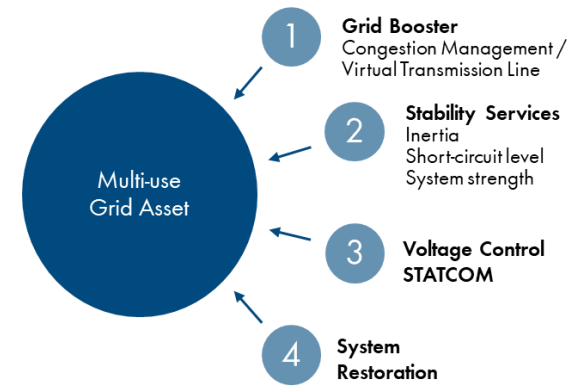


Grid Asset based on Battery Storage Plant



German TSOs: Grid Booster Tender

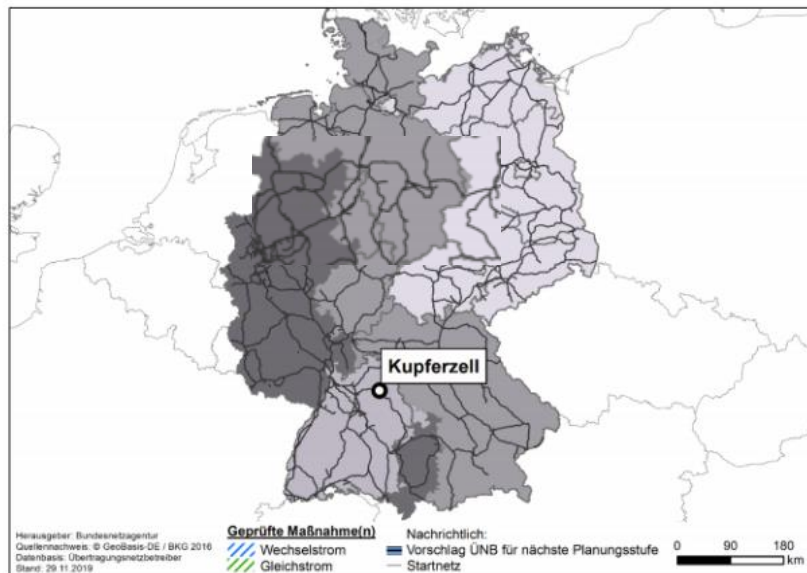
Source: German Grid Development Plan <https://www.netzentwicklungsplan.de>



TransnetBW Grid Booster

- 354 MVA in Kupferzell

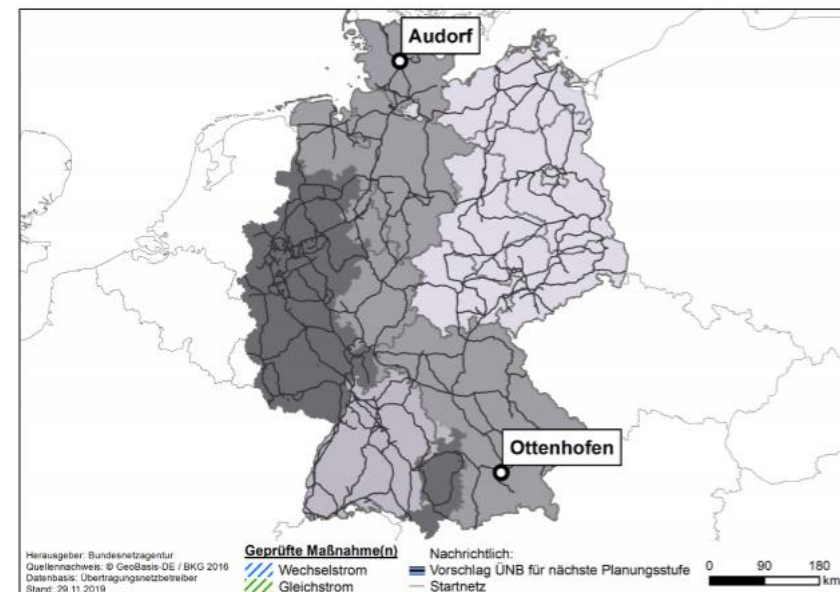
P430: Netzbooster-Pilotanlage Wehrendorf-Kupferzell



Tennet Grid Booster

- 2 times 100 MW Ottenhofen and Audorf Süd

P365: Netzbooster-Pilotanlage Audorf/Süd-Ottenhofen





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

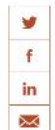


Phase 1 – GB wide	Phase 2 - Scotland	Phase 3 – England / Wales
Synchronous Machines only	Synchronous Machines or Inverter-based Solutions → Multi-Use ✓	
<ul style="list-style-type: none">• Tender 2019• Service start 2020/2021• 5 years	<ul style="list-style-type: none">• Tender closed Jan 2022• Service start 2024• 10 years	<ul style="list-style-type: none">• 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



Scotland's wind success
story bolstered by £323m
stability investment



6th April 2022 - Future of energy

- Ten contracts awarded to improve long-term stability of electricity system
- World-first large-scale use of grid forming converters to support increasing wind farm energy generation
- 'Fossil fuel-free power stations' to provide cheaper, greener way of boosting stability

Source National Grid ESO

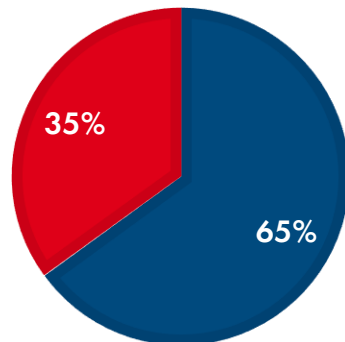
224 projects proposals
10 winners

5 projects Grid Forming Battery

5 projects Synchronous Condenser

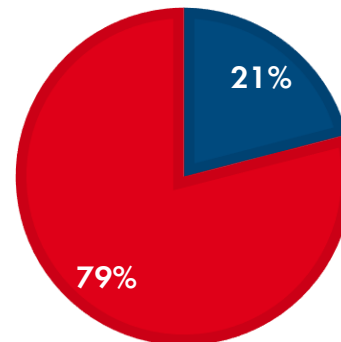
6.7 GVA_s INERTIA

■ BESS ■ SynCon



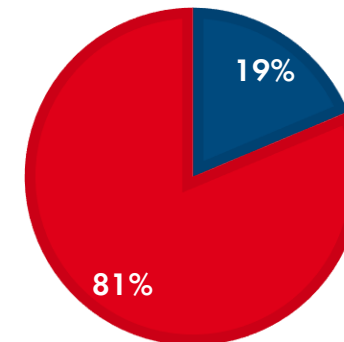
11.5 GVA SCL

■ BESS ■ SynCon



ANNUAL COST

■ BESS ■ SynCon



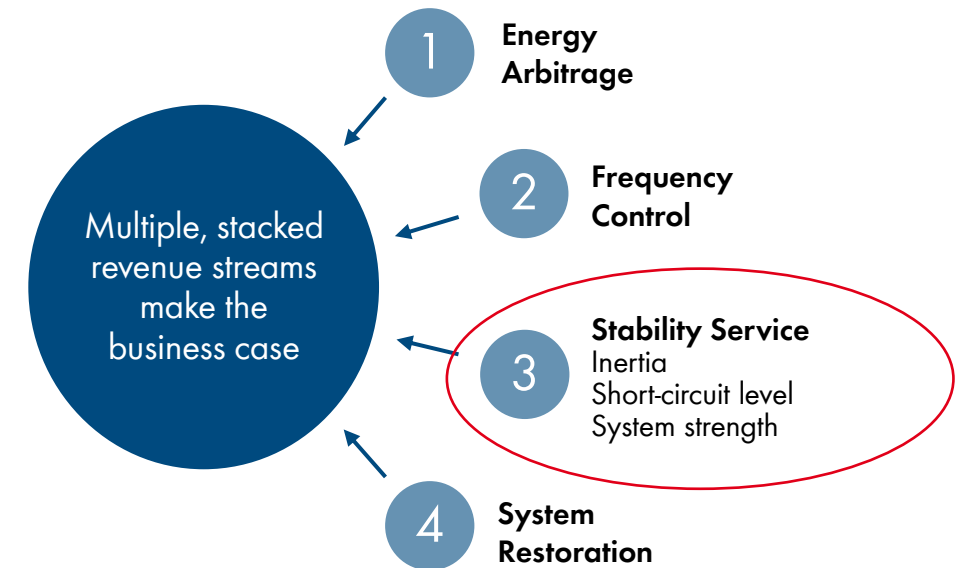
[Shares derived from Tender Results from
Source National Grid ESO](#)

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 $H = 25s \rightarrow 1.25 \text{ GWs}$
- 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)

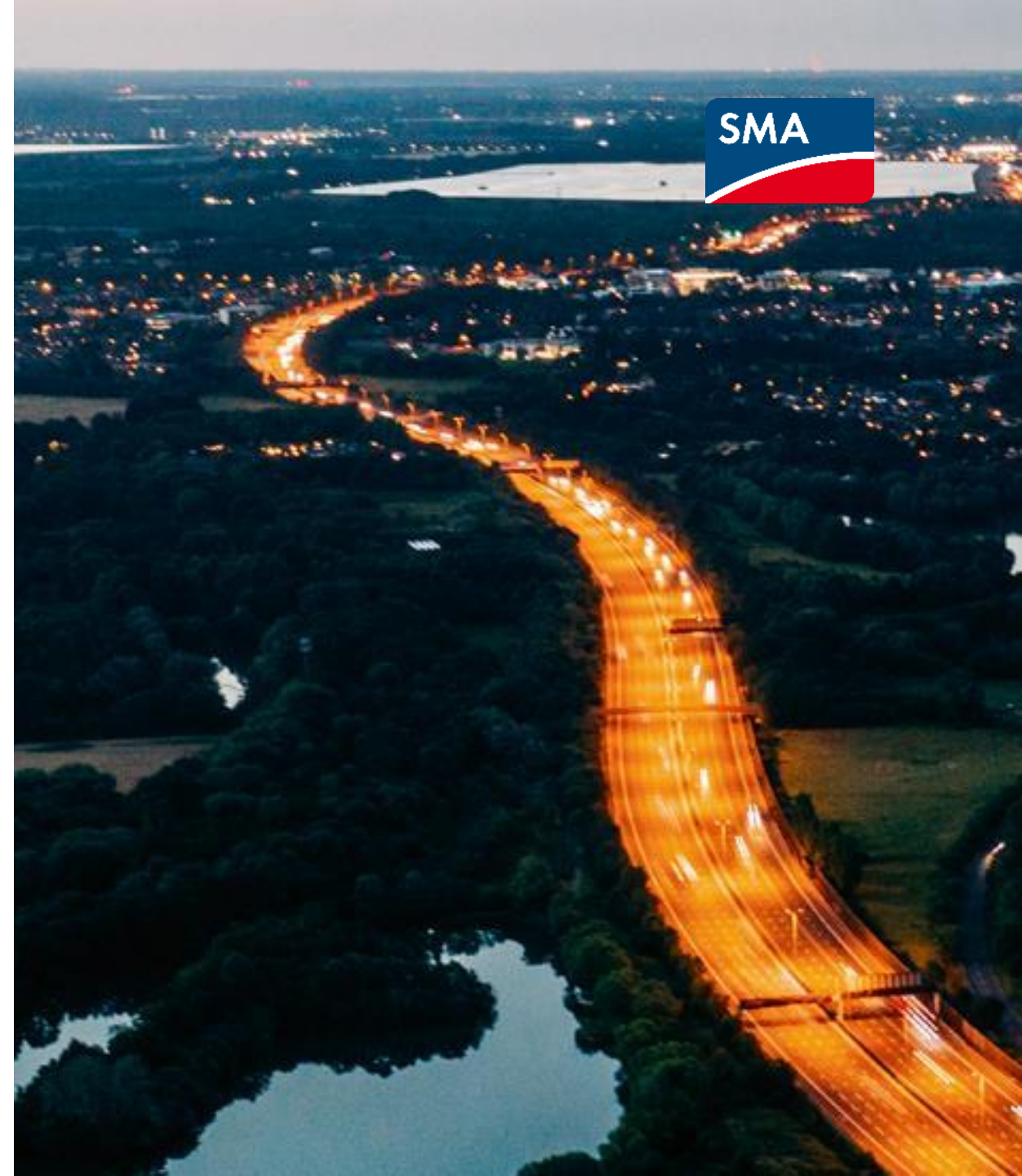
Ancillary service markets as drivers (e.g. UK)

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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