Global Experience in the Stability Segment

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October 20th 2022 - Webinar 2: Caracterizar la Integración de los Inversores tipo Grid Forming

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Agenda

1 Company Introduction

2 Global Energy Transition Next Step: System Strength

3 Global experience in the stability segment

4 Overview of currently developed projects

5 Summary

YEARS POWERFUL PERSPECTIVES

1981. Drei junge Wissenschaftler an der Universität Kassel haben eine nachhaltige Vision für die Zukunft: die Welt dezentral mit erneuerbaren Energien zu versorgen. Von vielen belächelt, gründen sie SMA – und werden gemeinsam mit ihren Mitstreiter:innen zu **Pionieren** der globalen Energiewende.

40 Jahre später hat sich die Sicht auf die Photovoltaik entscheidend gewandelt. Sie ist weltweit anerkannt und etabliert. Geblieben sind die Leidenschaft, der Innovationsgeist und die Begeisterung der SMA Mitarbeiter:innen für die nachhaltige Energieversorgung der Zukunft.

Zeit zurückzuschauen. Und nach vorn. **Auf die Vergangenheit, die Gegenwart, die Zukunft**. Unterschiedliche Sichtweisen und Perspektiven einzunehmen. Aus Sicht unserer Mitarbeiter:innen, unserer Partner:innen, unserer Kund:innen und der jungen Generation.

Powerful Perspectives.

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		

A pioneer in PV and storage system technology for over 40 years...

1987
SMA develops the first transistor inverter for photovoltaics.

2001
Sunny Island with grid forming capability to supply off-grid areas and islands.

2011
Sunny Tripower is the first inverter to achieve 99% efficiency.

2015
For the first time, the Sunny Home Manager integrates household appliances into the energy management system via EEBUS.

2017
Sunny Tripower CORE1 is the first free-standing string inverter.

2018 ennexOS CROSS-SECTOR ENERGY MANAGEMENT
With ennexOS, SMA establishes the first IoT platform for cross-sector energy management.

2020
SMA 360° is the most comprehensive installer App on the market.

2020
The SMA EV Charger enables fast, intelligent and cost-efficient EV-charging.

1995
With the development of string technology, SMA paves the way for the mass distribution of photovoltaics.

2007
SMA is bringing the first large scale central inverter series to the market - the Sunny Central 100 NG.

2010
Market launch next generation of central inverters - Sunny Central CP.

2016
Sunny Boy Storage is the first AC-coupled system to integrate high-voltage batteries.

2019
Sunny Central UP delivers 50% more power than its predecessor and integrates large storage systems.

2020
The SMA Power Plant Manager optimally integrates decentral energy sources into the grid.

SMA core business in 3 segments: SMA Energy Systems for all customer groups

Focus today: Large scale projects

Home Solutions

The SMA Energy System Home enables private households to generate, store and manage solar energy.

Business Solutions

With the SMA Energy System Business, companies can substantially reduce their energy bills.

Large Scale & Project Solutions

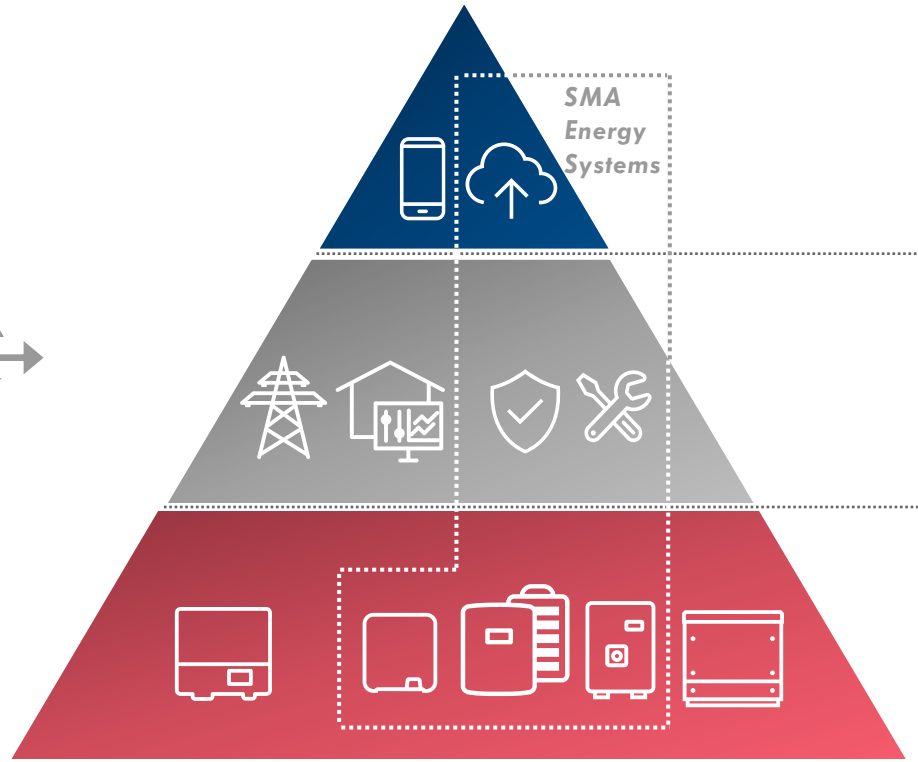
The SMA Energy System Large Scale secures future-proof investments for project developers, investors and plant operators.

Our perfectly matched hardware, software and services enable our customers to participate in the energy system of tomorrow, today

Market trend

Demand for dedicated solutions is rising – SMA offers future-proof system packages.

SMA offering



Software & Digital Services – added value for all customer groups

With software like **ennexOS** and **digital services,** SMA is an innovator in the digital energy market and opens up new possibilities for all customer groups.

Service products – basis for long-term customer relationships

With service products such as monitoring, Engineering Service, Operation & Maintenance, etc., SMA is reliable long-term partner of its customers.

Components – SMA's core business

With innovative and high-quality solar & battery inverters and system components, SMA forms the core of every solar or storage power plant.

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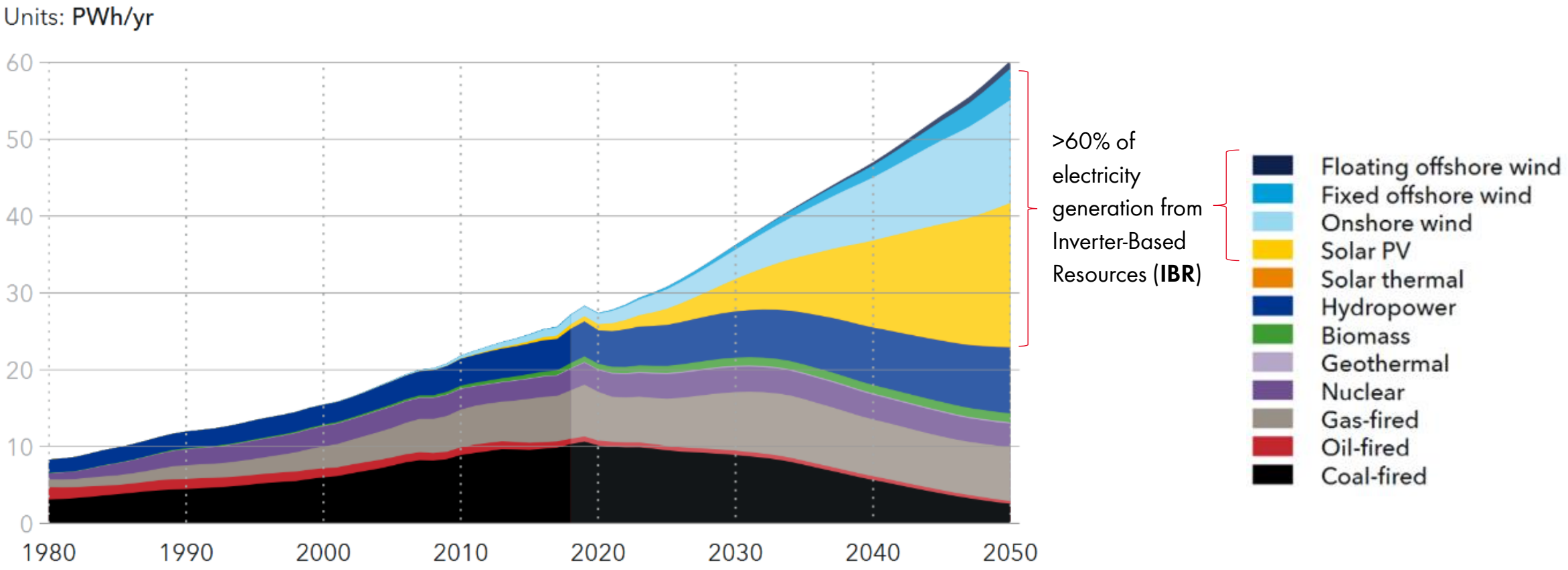
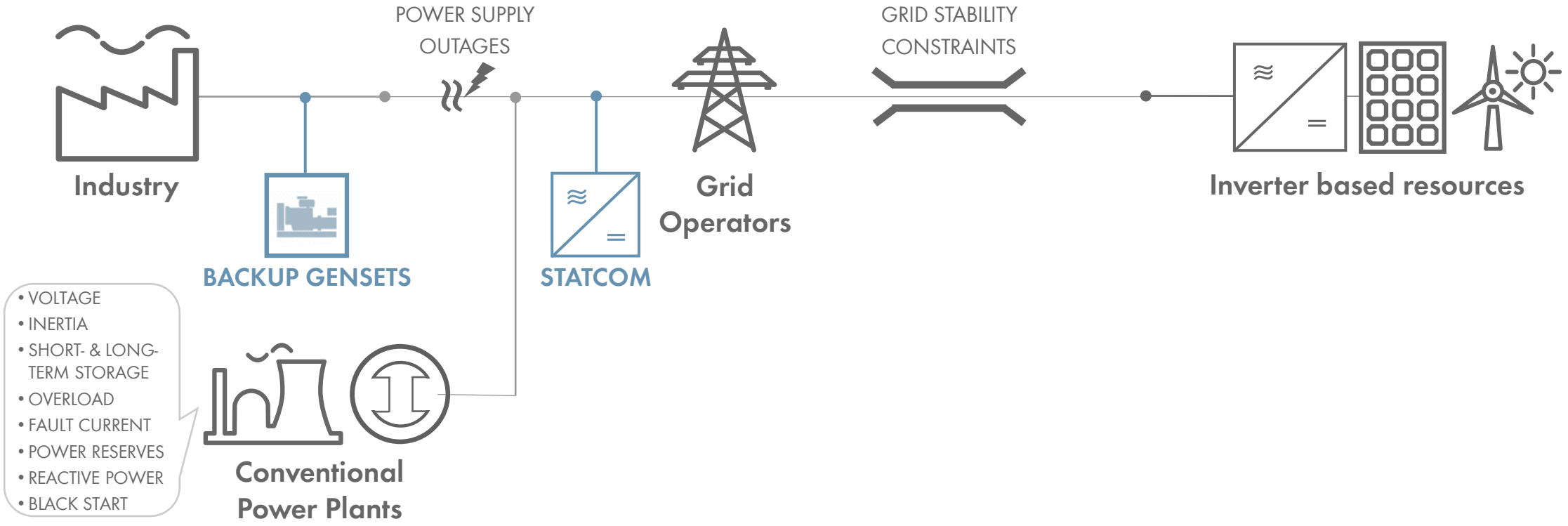
Energy generation transformation: increasing RES with decreasing share of rotating masses to provide grid stability.

World electricity generation by power station type

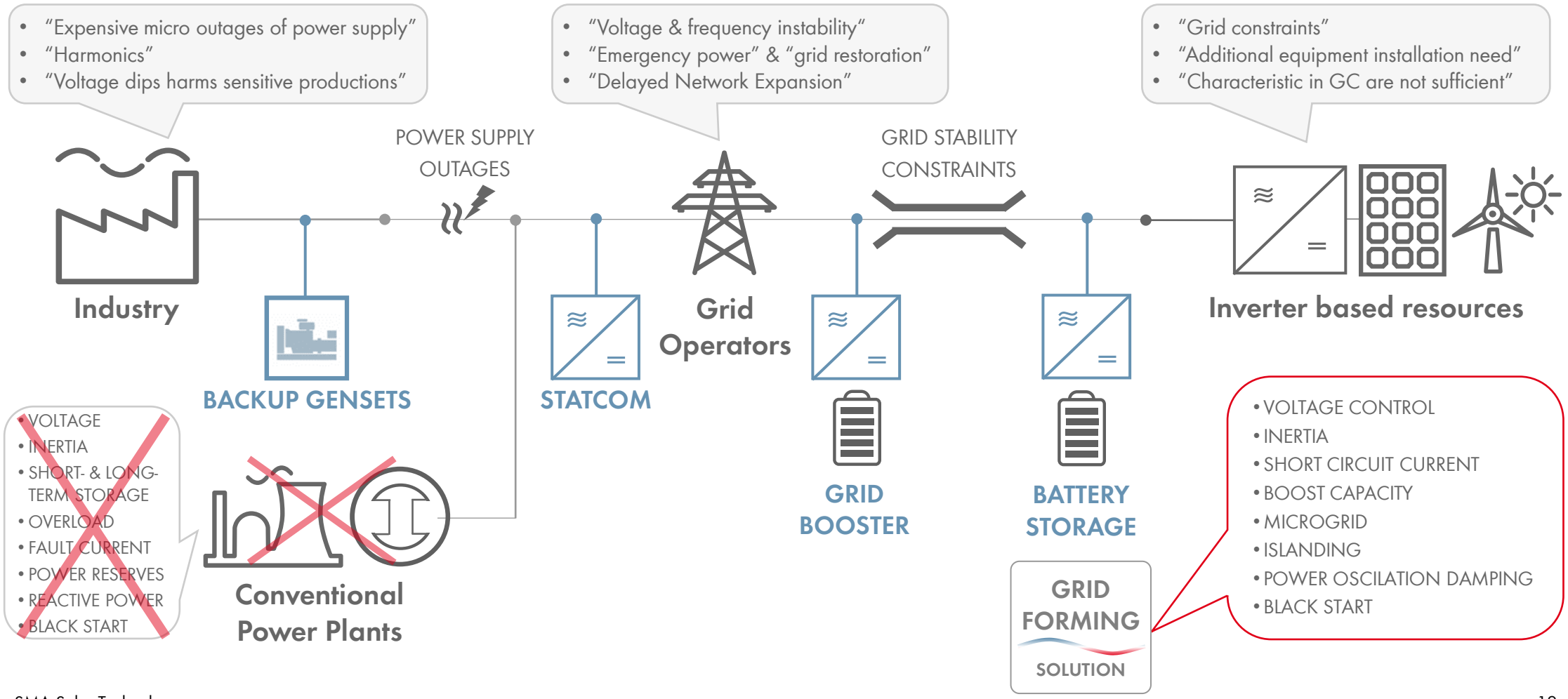


Historical data source: IEA WEB (2019), IRENA (2019)

Today topology of the existing power grid



What is the challenge we are facing now?
And what has to be implemented for a successful energy transition?



What is system stability and what are the most relevant grid services provided by Grid Forming Solutions

CIGRE Definition of power system stability:

The ability of power system equipment to operate in a **stable manner** and for the system as a whole **to recover intact from major disturbances**, is influenced by the electrical 'strength' of the system at the point where equipment connects.

Inertia

The ability to instantaneously support frequency deviations during i.e. phase jumps or RoCoF events

Short Circuit Current

The ability to clear system faults and increase system strength by increasing the SCR at point of interconnect

Island capability

The ability to continue operation when public grid is not available

System Restoration

Blackstart – The ability of the plant to start itself and serve system restoration

How much Grid Forming is needed in the system?
… it depends…

1. **Network system strength analysis**
   - Definition of design incidents in a 10 year prospect
   - Evaluation of voltage stability threats (e.g. SCR > 2 … 2,5)
   - Evaluation of frequency stability threats (e.g. RoCoF < 1 Hz/s)
2. **Derive potential counter measures in terms of**

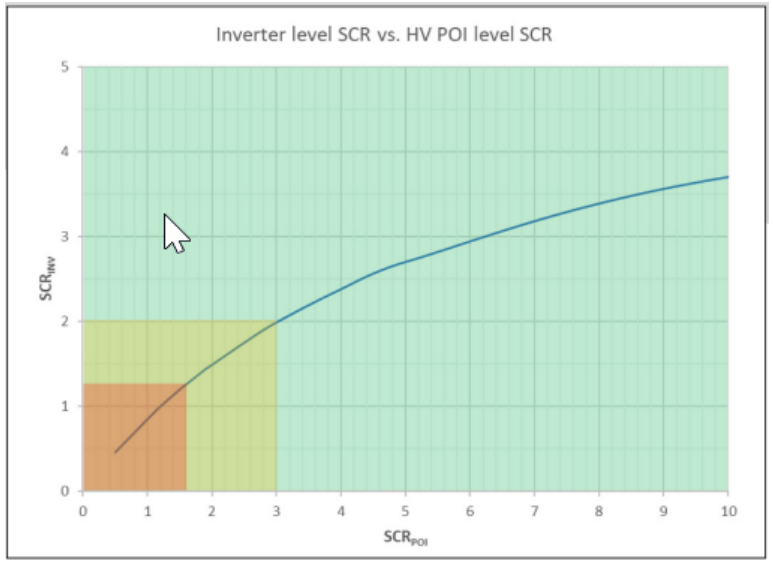


Figure 3 - Impact of range of system strength on complexity of IBR connection

Source: CIGRE Science & Engineering Vol. 20 February 2021

- **Green**
  - Standalone tuning of IBR control system is often sufficient to achieve satisfactory outcomes.
  - Standard control system parameters are likely to work.
- **Yellow**
  - Standalone tuning of IBR control system is not sufficient due to increased risk of interactions with other nearby IBR.
  - Site-specific control system tuning is likely to be required.
- **Orange**
  - Control system tuning by itself may not be sufficient.
  - Additional equipment such as SynCons and grid-forming inverters will likely be required to achieve an acceptable outcome.

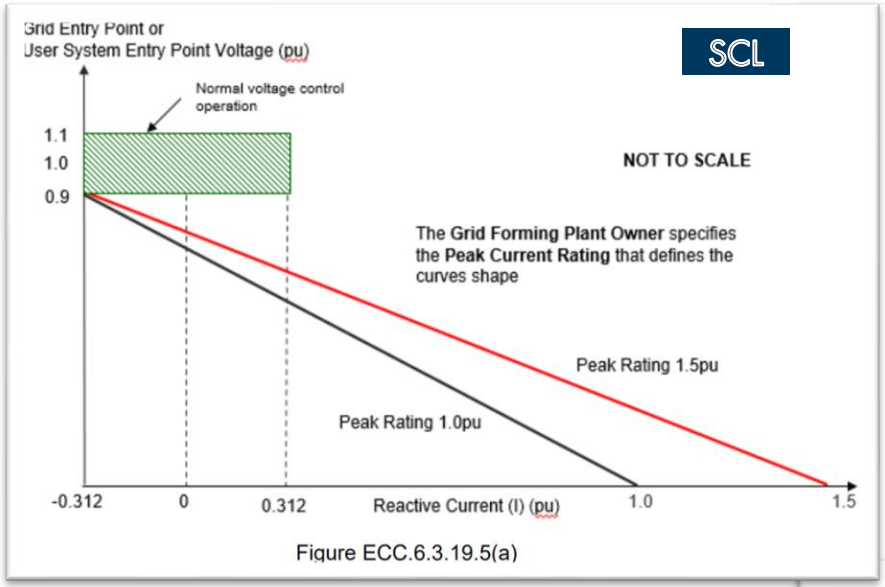
Grid Supporting

Fast Frequency Response (P/f)
Voltage control (Q/U)
Fast fault current (FRT)

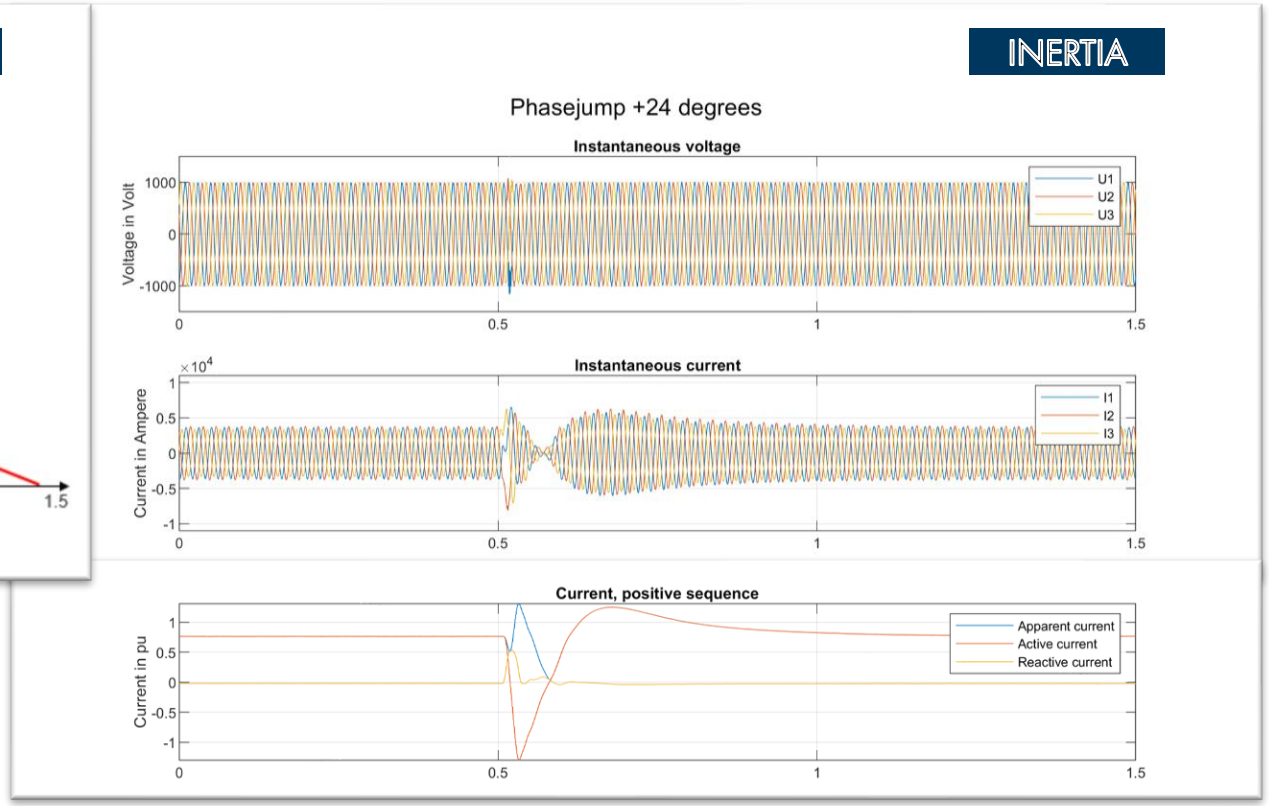
Grid Forming

Inertia needed
Short-Circuit-Level needed
Islanding capability
System restoration

Which application contributes most?
… Short Circuit Current and Inertia characteristic as an example



Source: The Grid Code, ECC (nationalgrid UK)



SMA Test Center Large Scale: Test Report

Available today

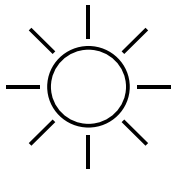
STORAGE SOLUTIONS

SYNCHRONOUS CONDENSERS

Grid Forming provides instantaneous performance and is not responding on setpoints from PPC

Applications with grid forming available today

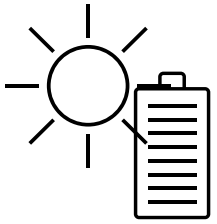
Grid Supporting



PV only

Grid Forming

Battery Storage

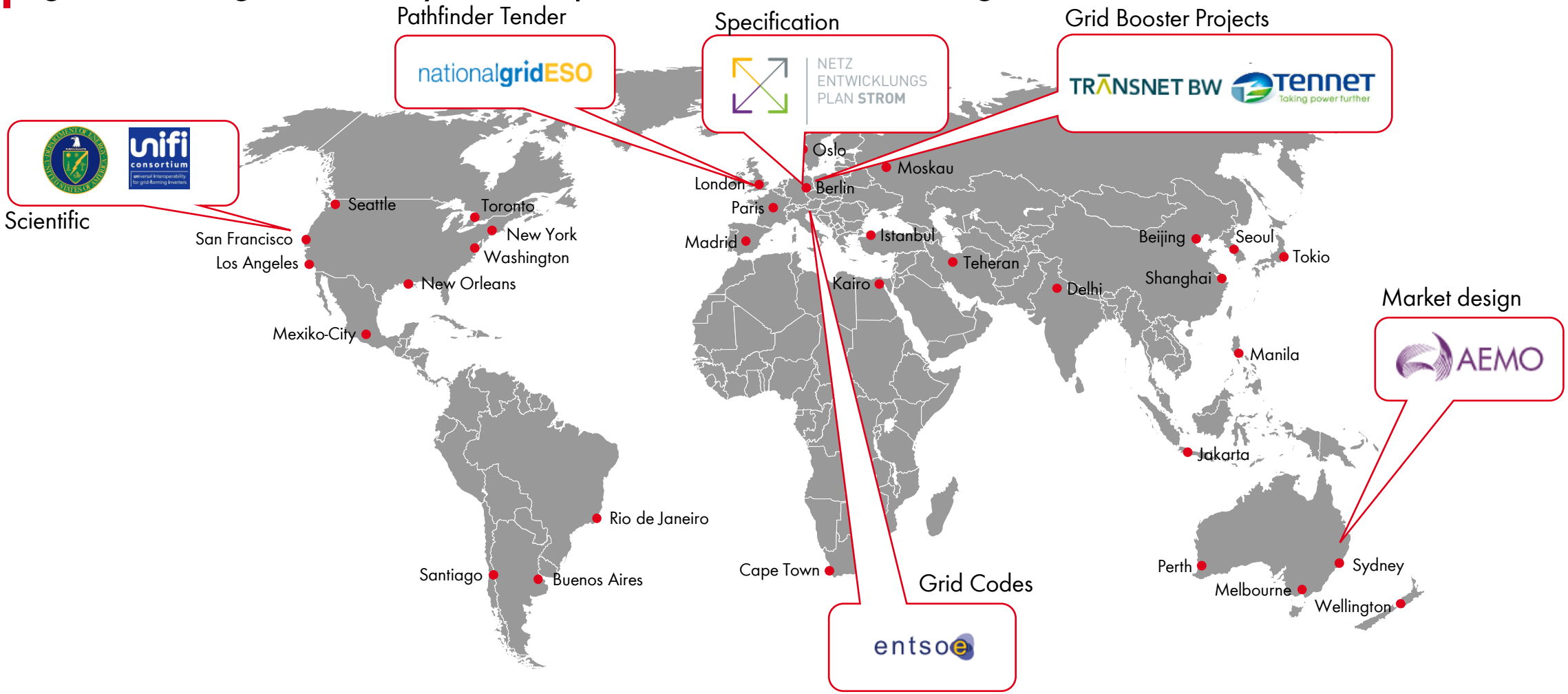


PV+Battery

Retrofit GFM Battery

Other application are in research projects

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



Three ways of establishing new technologies to tackle the stability challenges in the next years

Grid Codes / Connection Rules

Use Gridcodes to force new capabilities

- Technical risks in Wind and PV Applications result in longer implementation / Time to market
- Grid Code Development Processes take years
- Definition of characteristic might notbe suitable for all network regions

New Grid Operator's Assets

Grid operator uses and owns new dedicated assets to provide e.g. Stability / Inertia / Dynamic Reactive Power

- Can be useful to gain experiences with new technologies to provide new services as a role model for other approaches (e.g. market based / Grid Codes)
- Separation of Grid Stabilization functionality and Energy Provision

Market based approaches

Define new system services and provide incentives / tenders

- Stimulates positive dynamics / competition and constructive attitude of developers in terms of new capabilities
- relatively short implementation time
- Examples:
  - UK (Stability) Pathfinder Program by NGESO
  - AEMO System Strength Services

Grid Services should be specified technology agnostic and sourced market based!

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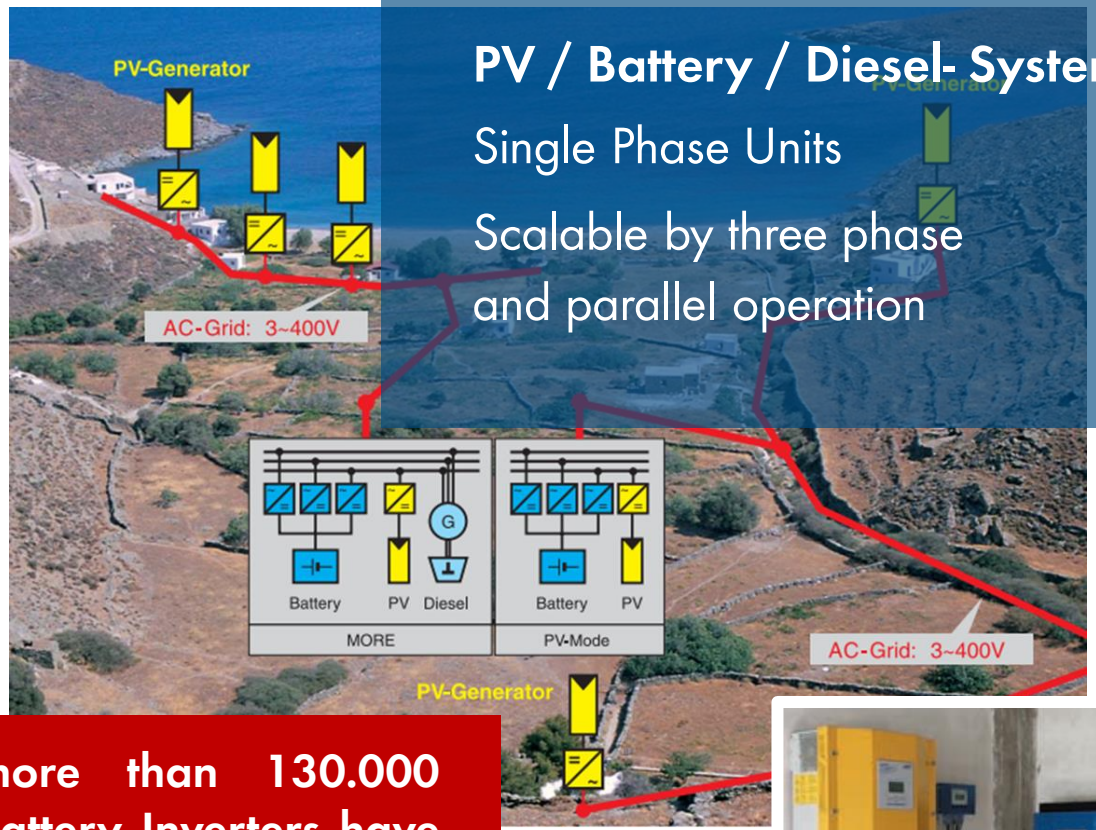
Grid Forming Hybrid-Power Supply in Greece 2001: Pioneering Grid Stability



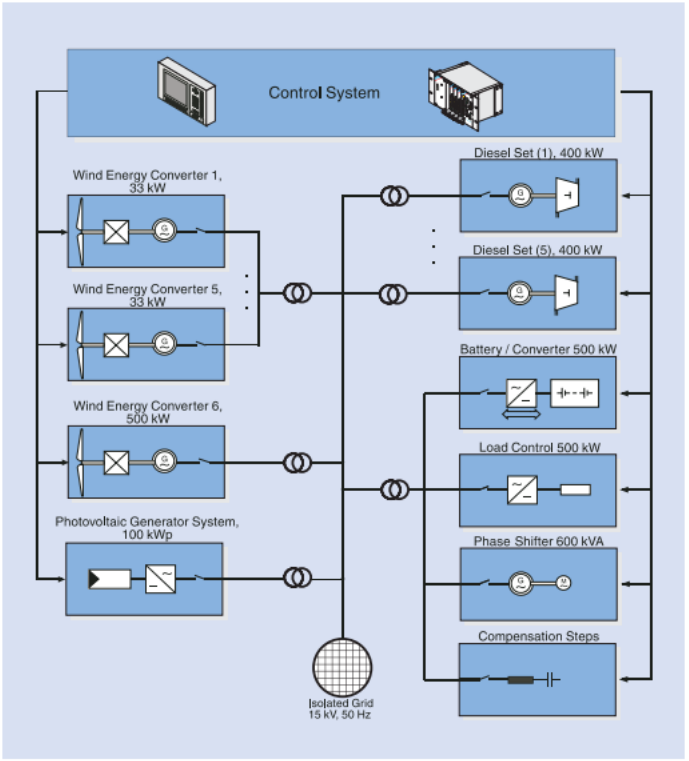
PV / Battery / Diesel- Systems

Single Phase Units

Scalable by three phase and parallel operation

Since then more than 130.000 Sunny Island Battery Inverters have been installed in Grid-Forming mode

Control system of the island power supply



Island electrification by combining PV, batteries and diesel

Saba, NL Antilles in 2017

The PV-diesel-battery plant is located on the island of Saba, located in the Caribbean. The power application battery plant is designed for the ramp rate control for the 1,142 MWp PV plant.

Project

- Location: Saba, Caribbean NL
- Commissioning: November 2017

Plant information

- Installed PV power: 1,142 MWp
- Installed battery power: 800 kW
- Installed battery storage: 393 kWh

SMA System Technology

- SMA Fuel Save Controller
- 1 SMA Sunny Central Storage 800
- 34 Sunny Tripower 25000TL-30

MW-Scale Grid Forming Hybrid System - St. Eustatius Island, 2017

Project

- Location: St. Eustatius, Caribbean
- Commissioning: November 2017
- Requirements: Grid forming inverters, overall power and energy management system

Plant information

- Installed PV power: 4.15 MWp
- Installed Storage capacity: 5.9 MWh
- Diesel capacity: 4 MVA
- Annual energy yield: 6,400 MWh
- Annual diesel savings: > 1,700,000 liters
- Island Load: ~2MW

System Technology

- Battery: 2 x SCS 2200 Grid Forming in 2 x MVPS 2200 and 1xSCS 1000 in MVPS 1000
- PV: 2xSC CP XT1000 in 1xMVPS 2000 and 74 SMA Sunny Tripower 25000TL-30
- Control: FSC 2.0 with Automatic Genset Shutdown

Today, solar energy covers 46% of St. Eustatius' total electricity need. Grid Forming SCS 2200 inverters allow to operate the island grid for 10.5 hours in Diesel Off-Mode operation with 100% Solar Power Fraction. In total a 5.9MWh Li-Ion storage facility has been integrated for energy shifting and grid services. Thanks to the SMA Fuel Solution about 4,560 tons CO2 per year can be saved. The project has been designed, and implemented by the SMA Sunbelt Energy GmbH.

St. Eustatius: 100 Percent Caribbean Solar Power - YouTube

Utility PV Solar Power Plant – West Murray Region, Australia, 2019

[System Strength: Our technologies ensure grid stability - YouTube]

Image: Wirsol Energy Pty Ltd.

Image: https://www.wemensolarfarm.com.au

Project

- Location: Wemen, Australia
- Commissioning: March 2019
- Challenges: Low level system capability restrictions – Creating software components to release restrictions.

Plant information

- Nominal PV power: 97.5 MWp
- Annual energy yield: 220 GWh
- 319,000 solar-modules

SMA System Technology

- 39 × SC 2500-EV
- 19 × MVPS 5000
- 1 × MVPS 2500
- 1 × Power Plant Controller

Wemen Solar Farm is considered one of the largest solar operations in the West Murray Zone, Victoria, Australia. In addition to equipment supply and service support, SMA also provided innovative software setting solutions to solve low level system capabilities and release electrical output to the grid system. These software solutions were effectively applied to several major plant operations in the West Murray Zone.

SMA Energy System Large Scale and enhanced plant performance for system strength

Large Scale BESS with ancillary services, Grid Forming and Blackstart
Bordesholm, Germany in 2019

[The Bordesholm stand-alone grid ensures power supply even in the event of a grid failure - YouTube]

Made possible with a storage system from SMA, Bordesholm became the first ever town in Germany to be disconnected from the utility grid and supplied exclusively with renewable energy (solar, wind, biomass) for an hour, before being discreetly reconnected to the transmission line.In addition to a grid formation function, the SMA battery inverters are also equipped with an optional "black start" function, which allows the entire electricity supply to be restarted after a power outage.

Project

- Location: Bordersholm, Germany
- Commissioning: May 2019
- Requirements: Design study, retrofit, resilience, grid quality improvement, automation, integration to existing infrastructure, respecting logistic limitations

Plant information

- Installed Storage capacity: 15 MWh
- The storage system supplies primary control energy or energy for intraday trading or direct marketing. In addition, it secures the power supply in the event of power outages.

Integrated System Technology

- 7 x SMA SCS 2200 Blackstart Grid Forming MVPS
- Battery storage with 15 MWh Li-Ion (NCM) cells from Samsung SDI (48.000 cells)
- Energy and Power Management System with SMA's Hybrid Controller

Installed Base till 2021 and deployment in 2022/2023:
SMA Energy System Large Scale with Grid Forming

More than 130 Sunny Central Storage with Grid Forming installed around the globe totalling 450 MW

The Torrens Island power station owned by AGL. *(ABC News: Carl Saville)*

... and another 400 MW right now in deployment

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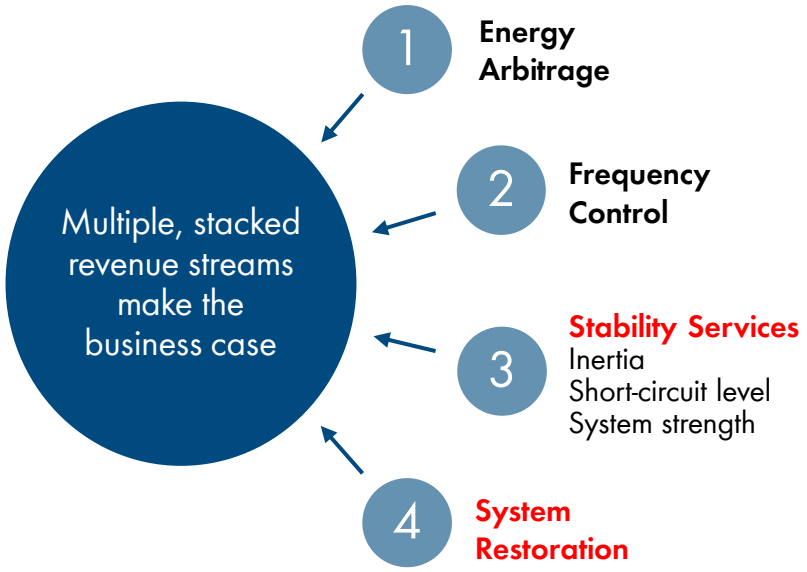
Recap

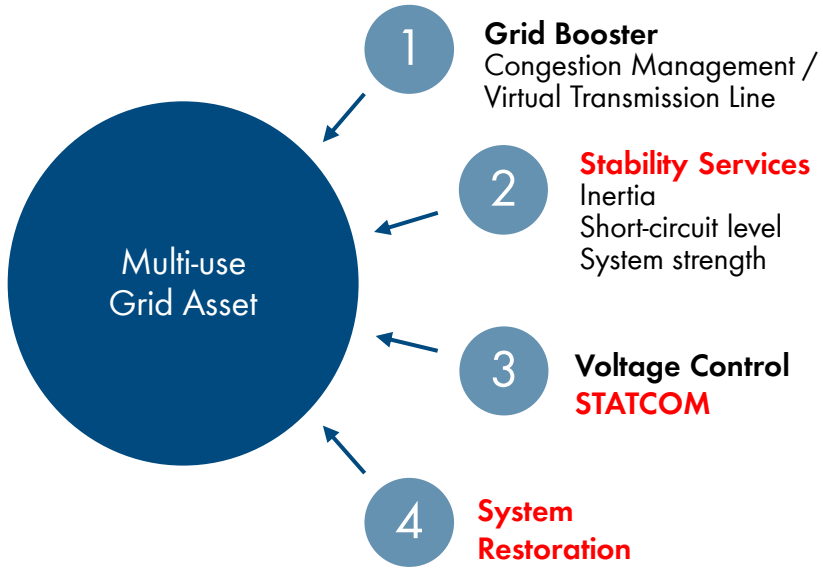
Battery Storage applications are the most economic and mature applications to incorporate Grid Forming Solutions and therefore provide system stability <u>short-term</u>

Multi-use of battery storage
Grid Forming Solutions

Market-oriented Battery Storage Plant

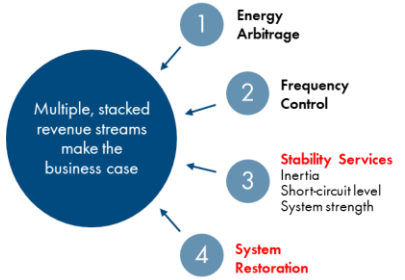


Grid Asset based on Battery Storage Plant



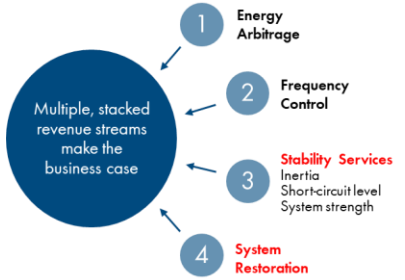
For the red marked services the plant has to incorporate a Grid Forming Solution

National Grid ESO in UK Stability Pathfinder Tender



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)

National Grid ESO in UK Stability Pathfinder Tender



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

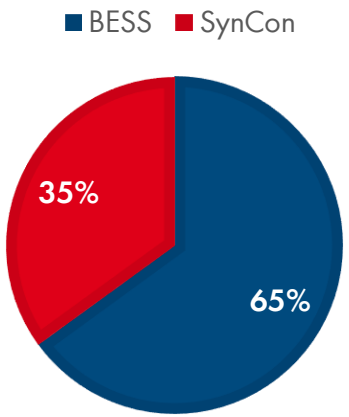
NOA Stability Pathfinder - Phase 2 results

224 projects proposals
10 winners

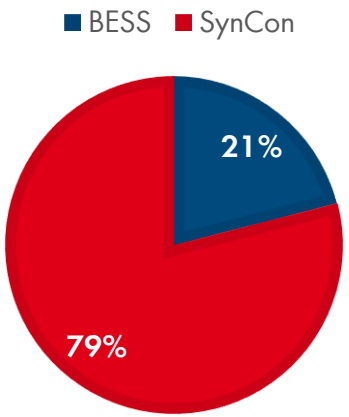
5 Battery plants with inertia and SCL

5 SynCon plants

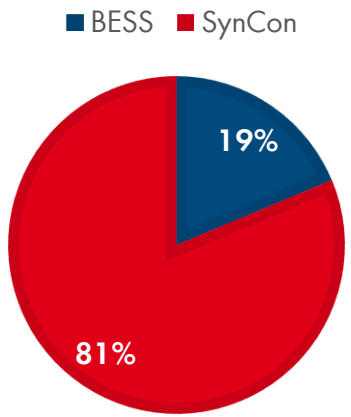
6.7 GVAs INERTIA



11.5 GVA SCL

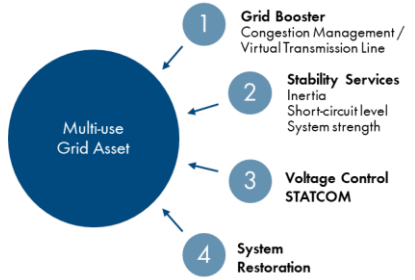


ANNUAL COST



Shares derived from Tender Results from Source National Grid ESO

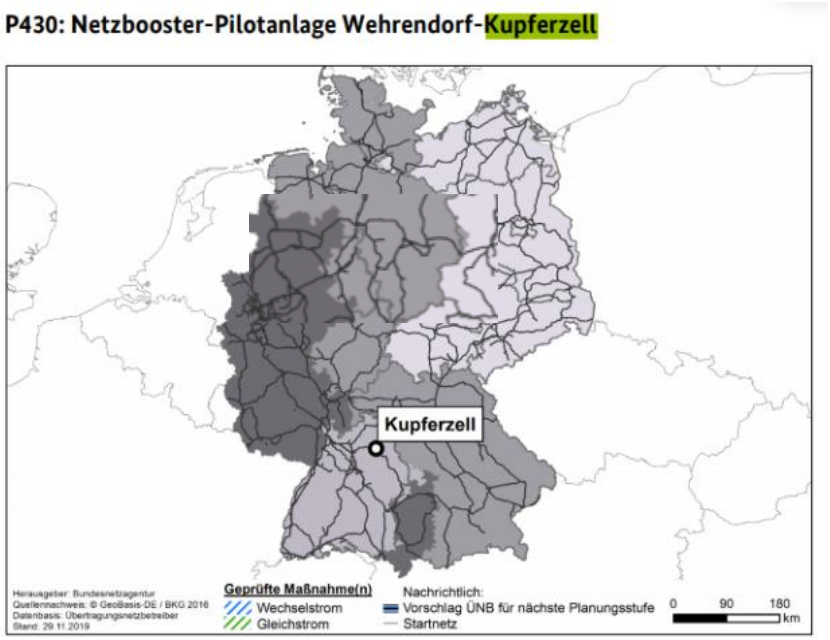
German TSOs: Grid Booster Tender



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

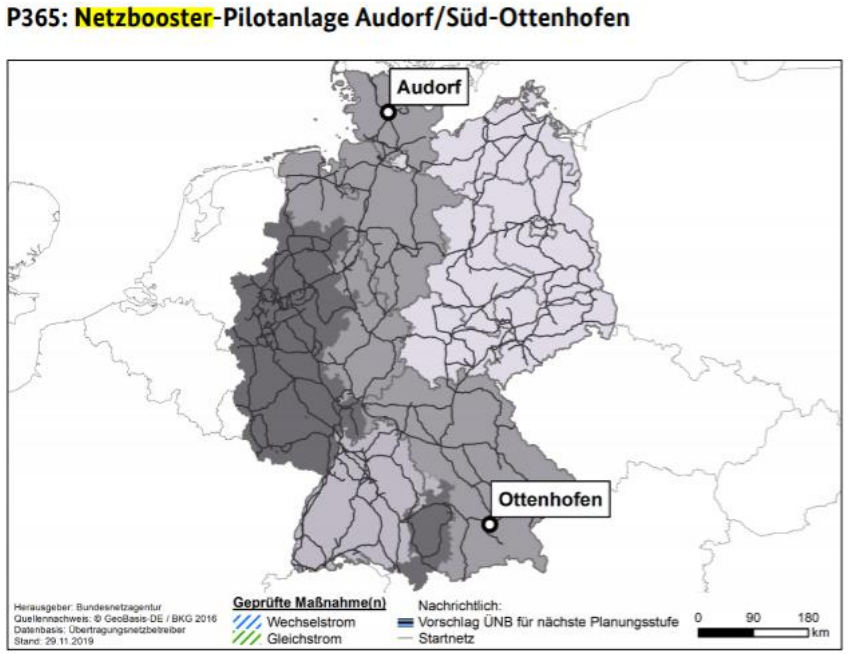
TransnetBW Grid Booster

- 354 MVA in Kupferzell

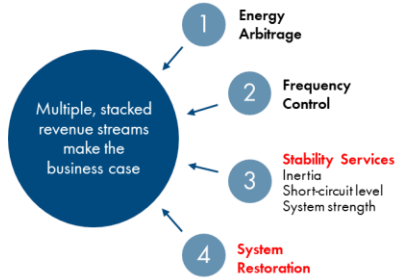


Tennet Grid Booster

- 2 times 100 MW Ottenhofen and Audorf Süd



AEMO Specs and ARENA Australia Large Scale Battery Storage Funding



Source: AEMO | Engineering the future – application of advanced grid-scale inverters

Application of Advanced Grid-scale Inverters in the NEM

August 2021

An Engineering Framework report on de

Table 1 Power system capabilities relevant to advanced inverters

Capability	Description	Purpose
System strength[A]	The ability to generate, maintain, and control the voltage waveform.	Support maintaining network synchronism during steady state operation, disturbances, and recovery after disturbances and supply enough fault current to ensure correct operation of network protection systems.
Disturbance withstand	Defined responses and ability to maintain stable operation during voltage, frequency, phase disturbances (fault ride-through), and to damp active power oscillations after a disturbance.	Maintain supply resources operating during and following a disturbance, to support power system recovery and stabilisation.
Inertia[C]	Instantaneous and inherent active power response, not dependant on measurement, to rapid changes in frequency.	Impede the system's rate of change of frequency (RoCoF) as a response to frequency disturbances.
Primary frequency response[C]	Locally controlled active power response to frequency change. Can include Fast Frequency Response (FFR)[E].	Maintain the network within a tight frequency band, manage intra-dispatch supply and demand variations, and arrest changes in power system frequency. In some cases, FFR can reduce system inertia requirements.
Support power system island	Manage active power output to support island operation over dispatch timescale.	Provide sufficient energy resources (dispatchability, ramp rate, and secondary frequency response) to maintain supply-demand balance within island boundaries.
Initiate or support system restoration	Bring plant online during system restoration process, including provision of necessary surge current and capability to remain online under adverse conditions.	Provision of SRAS during black start.

Source: ARENA funding to address emerging system strength challenges - Australian Renewable Energy Agency (ARENA)

SCOPE OF ACTIVITY

The Funding Round is open to Proposals that demonstrate the use of advanced inverter technologies on LSBS projects at scale. Proposals must comply with the following parameters:

a. Projects must be grid-connected and operate in the National Electricity Market (NEM) or the Western Australia Wholesale Electricity Market (WEM).
b. Projects must use advanced inverter technology.
c. Projects must meet or exceed the minimum LSBS size of 70 MW (nameplate inverter rating). There is no maximum size limit.
d. Projects must be located at a single site.
e. The maximum grant available to a single project is $35 million.
f. Projects must reach financial close no later than 31 December 2023.

A project is required to satisfy the above conditions as part of either a brownfield or greenfield project. The project may be co-located with other generators or loads; however, ARENA Funding will only support the LSBS scope (including balance of plant and connection costs).

Projects that do not fit within these parameters are unlikely to be assessed as high merit under the Funding Round.

Agenda

1 Company Introduction

2 Global Energy Transition Next Step: System Strength

3 Global experience in the stability segment

4 Overview of currently developed projects

5 Summary

Summary

The whole industry needs possibilities to gain experience in real projects

- Market based incentives (UK Stability Pathfinder)
- Grid asset tenders (German TSOs)

Inverter based Grid-Forming is a well-known technology

- SMA Energy System Large Scale with Battery Storage ready to be deployed

Technical specification of a Grid-forming plant

- Technology agnostic approach to get a technically sound and economically viable solution

Percentage of Grid-Forming plants in the power system

- It has to be evaluated on specific design incidents which may cause threats to the system (i.e. 1 Hz/s)

Overall cost for a Grid Forming Solution

- Multi-use of battery storage plants enables investment security and a much faster Return on Invest

EMERGING TECHNOLOGIES NEED PIONEERS WHO SET THE STANDARD

THANK YOU

Questions, Comments and Ideas?

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