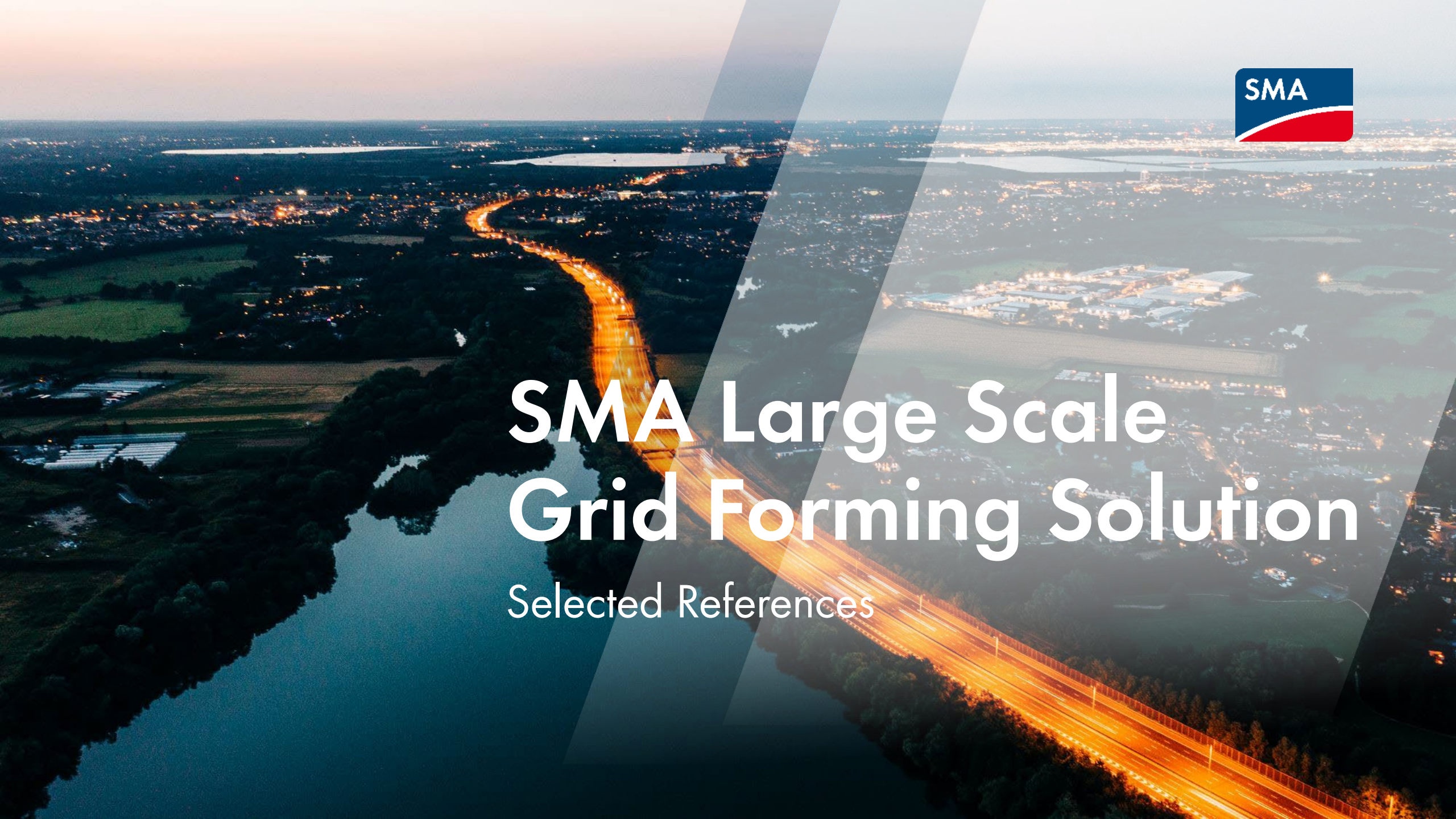
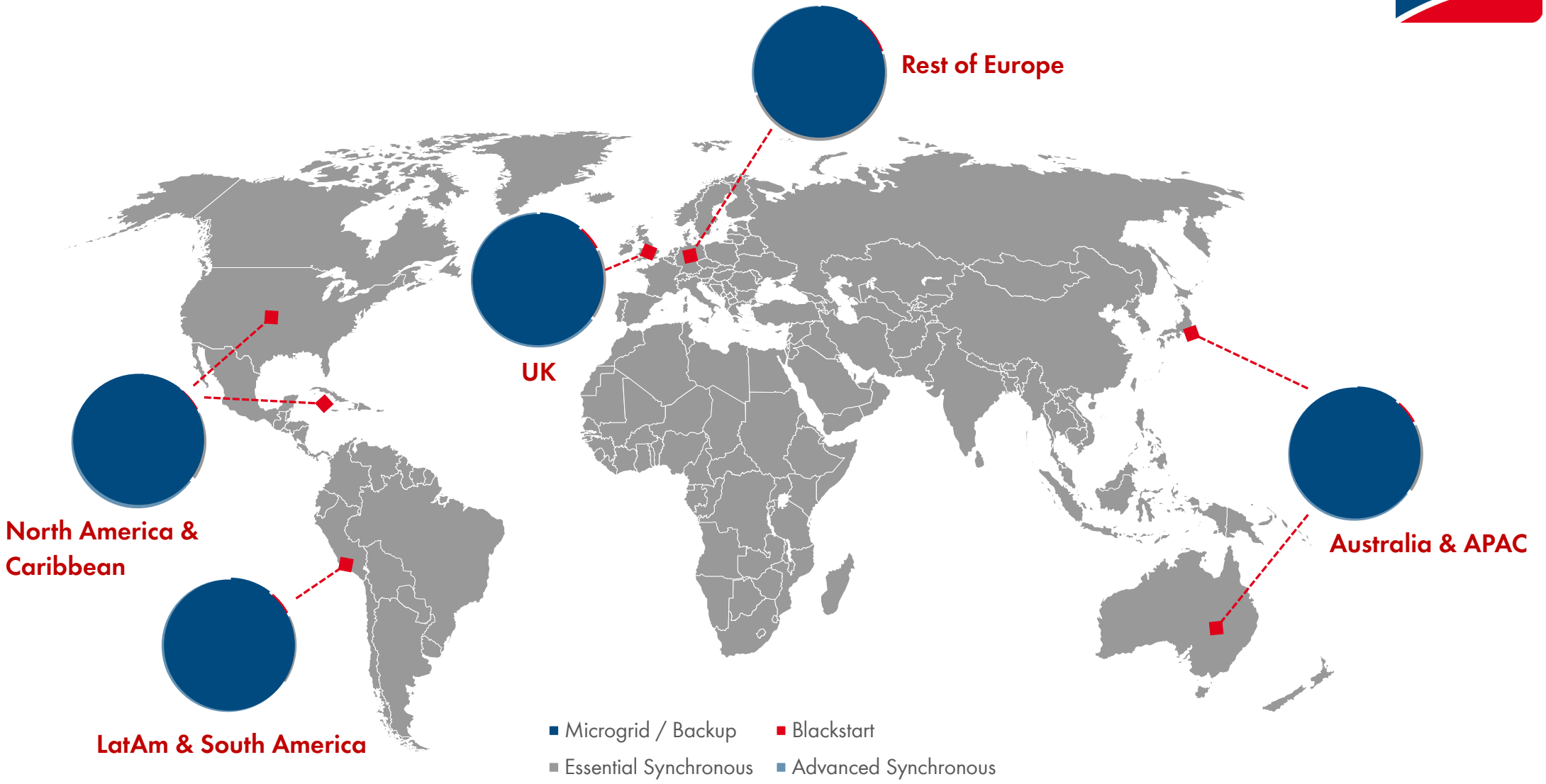


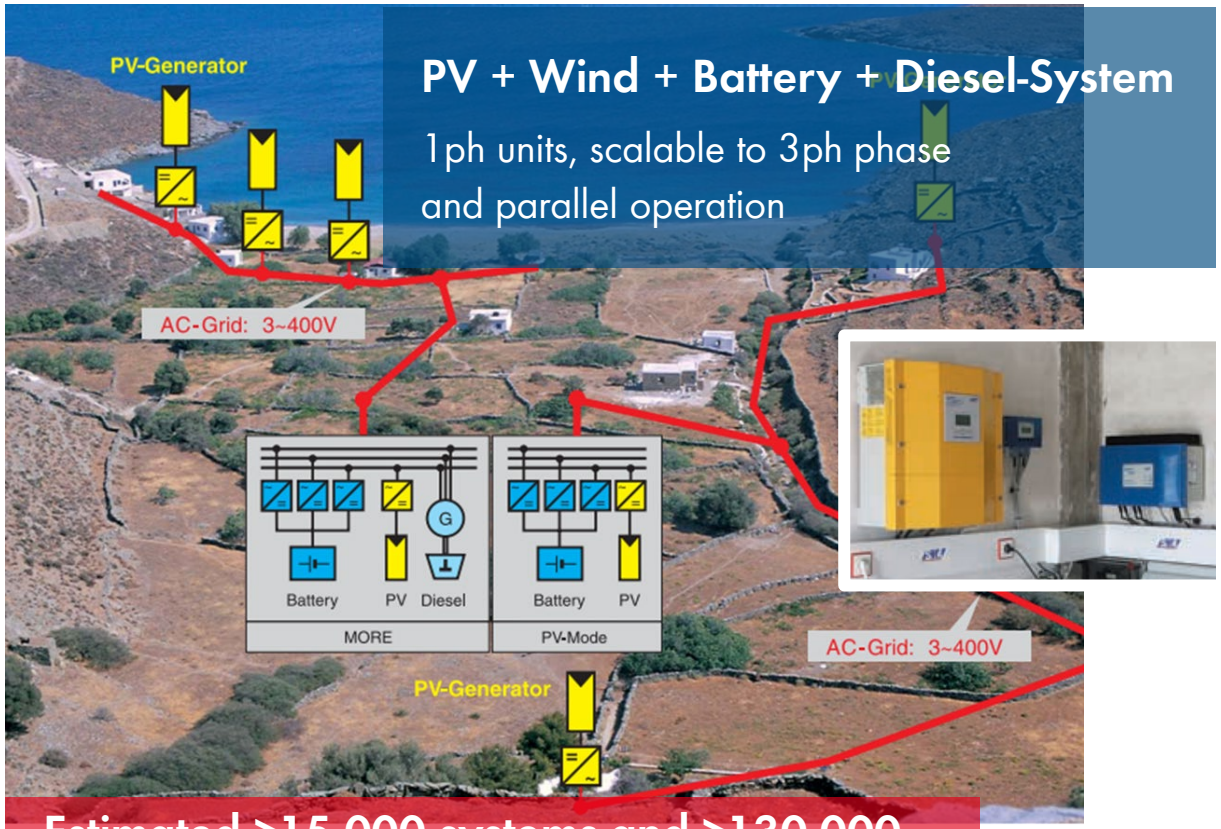
SMA Large Scale Grid Forming Solution

Selected References

Grid Forming Projects – *Deployment is Global, and Growing*

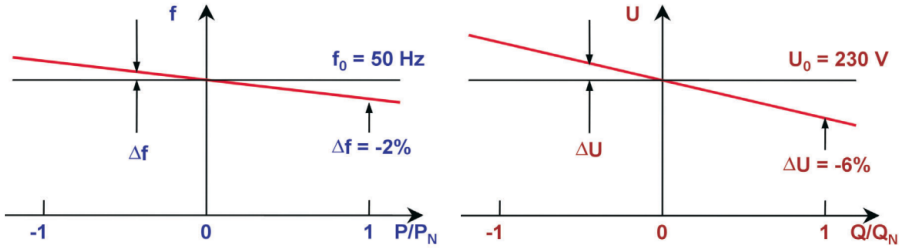


Pioneering Grid Stability: Modular Grid Forming Hybrid-Power Supply based on AC-coupling - Kythnos Island in Greece 1982 - 2001



Estimated >15,000 systems and >130,000 Sunny Island Battery Inverters have been installed in Grid-Forming mode since 2001.

Kythnos Island – 20 Years' Experience of System Technology for Renewable Energies (sma.de)



- **First wind-diesel hybrid system in Europe** featuring a central control unit built by SMA goes into operation.
- **kW showcase for high renewable grid integration**.
- **Droop-based Grid Forming control** of Sunny Island battery storage inverters enables simple design and stabilization of island grids due to connection of all components on the AC side.

Engler, A. et al: „Next Generation of AC Coupled Hybrid Systems – 3 Phase Parallel Operation of Grid Forming Battery Inverters", 2nd European PV-Hybrid and Mini-Grid Conference, Kassel, Germany, September 2003

Hybrid Energy System – NL Antilles, 2017

Large-Scale Island Electrification, St. Eustatius – 5MW (Grid Forming Droop)

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 Solution, about 4,560 tons CO2 per year can be saved. The project has been designed and implemented by the SMA Sunbelt Energy GmbH.

Project "St. Eustatius Phase 1+2"

- 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: ~2 MW

SMA System Technology

- Battery: 2 x SCS 2200 grid forming in 2 x MVPS 2200 and 1 x SCS 1000 in MVPS 1000
- PV: 2 x SC CP XT1000 in 1 x MVPS 2000 and 74 SMA Sunny Tripower 25000TL-30

St. Eustatius: 100 Percent Caribbean Solar Power - YouTube

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

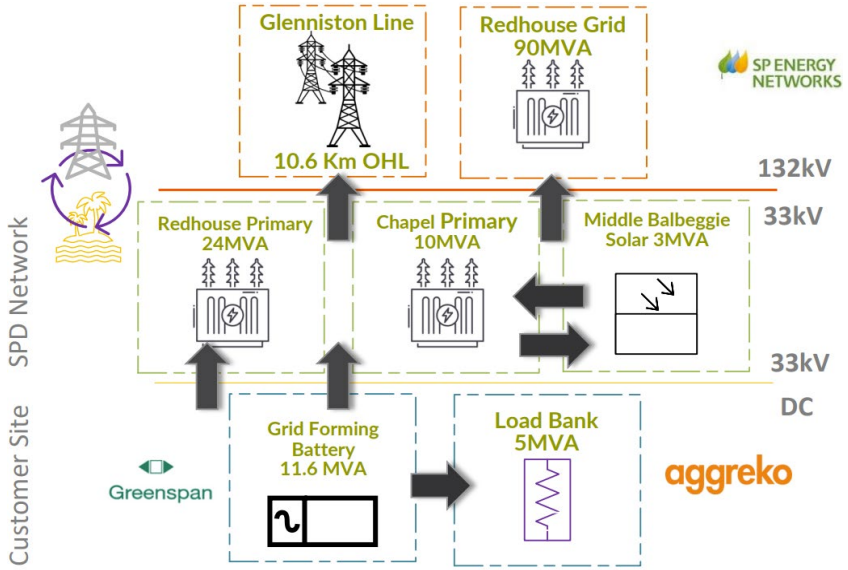
Plant information

- 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

"Distributed ReStart": World's first live trial of utility-scale battery for system restoration (black start) of T&D grid in practice - Redhouse, Scotland, 2023



4MW Instantaneous load step (Approx. 2000-3000 homes)

8MW BESS Capacity

Operational limits observed with 1% droop control

Far superior to synch machines of same capacity (500%+ better)

Technical project:

Demonstrate a "non-synchronous" BESS to restart the distribution restoration zone (DRZ).

Reduce grid restoration timeframe from days to hours.

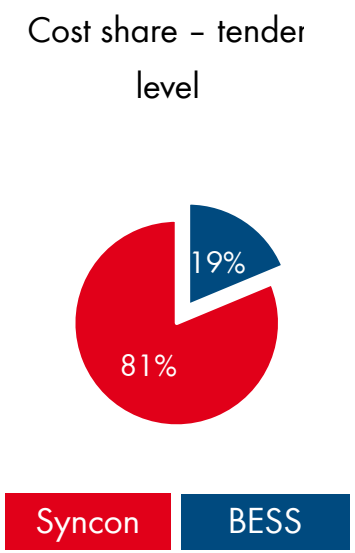
Key findings:

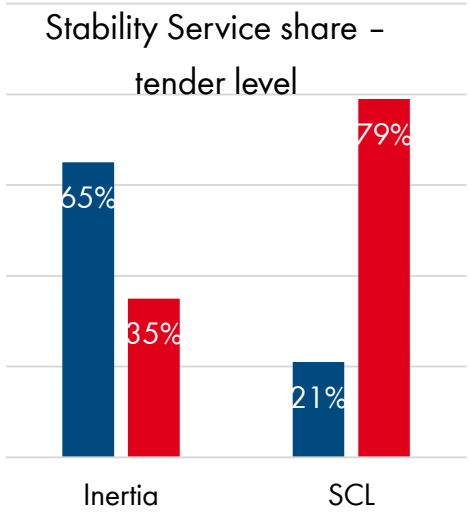
- BESS can blackstart itself. BESS can be used as anchor to start, maintain and control power islands with or without diesel.
- BESS can energize distribution & transmission transformers & lines (Point on Wave switching recommended)
- Block load pickup capability of BESS is far superior compared to synchronous generators (no must-run).

SMA Large Scale Storage Solution (Grid connected grid forming)

NationalGrid ESO: „Distributed ReStart – Energy restoration for tomorrow: Final Findings and Proposals for Electricity System Restoration from DERs", October 2023

WORLD'S FIRST transmission connected Multi-Purpose Storage Asset - Blackhillock, Scotland, UK - 2023





When fully built, Blackhillock will be a 300MW / 600MWh project. It will be the first to provide the full suite of active and reactive power services in the world and will be the largest transmission connected battery in Europe when commissioned. The gigawatt of batteries should provide 4.4 GVAs (gigavolt ampere seconds) of inertia – 5% to 10% of Britain's requirement..

Project

- Location: Blackhillock, Scotland, UK
- Commissioning: 2023

Project information

- 200 MW / 400 MWh (Phase 1)
- Winner of first batch Stability Pathfinder UK
- Inertia: 333 MWs | Short Circuit Level: 84 MVA
- 10 years contract

System Technology

- 62x Medium Voltage Power Stations
- Grid Forming Solution
- Current Boost
- Engineering Service

SMA Large Scale Storage Solution (Grid connected grid forming)

WORLD'S SECOND Transmission connected Multi-Purpose Storage Asset - Kilmarnock, Scotland, UK - 2024

Kilmarnock South battery project reduces the waste of wind energy. It is the second multi-purpose asset in the world following a multi-market trading strategy. The plant design is optimized for participation in wholesale market, ancillary services and stability services – all at the same time.

Project

- Location: Kilmarnock, Scotland, UK
- Commissioning: 2025

Project information

- 300MW / 600MWh
- Winner of first batch Stability Pathfinder UK
- Inertia: 1341 MWs | Short Circuit Level: 249 MVA
- 10 years contract

System Technology

- 126 Medium Voltage Power Stations
- Grid Forming Solution
- Current Boost
- Engineering Service

SMA Large Scale Storage Solution (Grid connected grid forming)

Installed Base till 2022 and deployment in 2023/2024/2025:
SMA Large Scale Energy System with Grid Forming

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

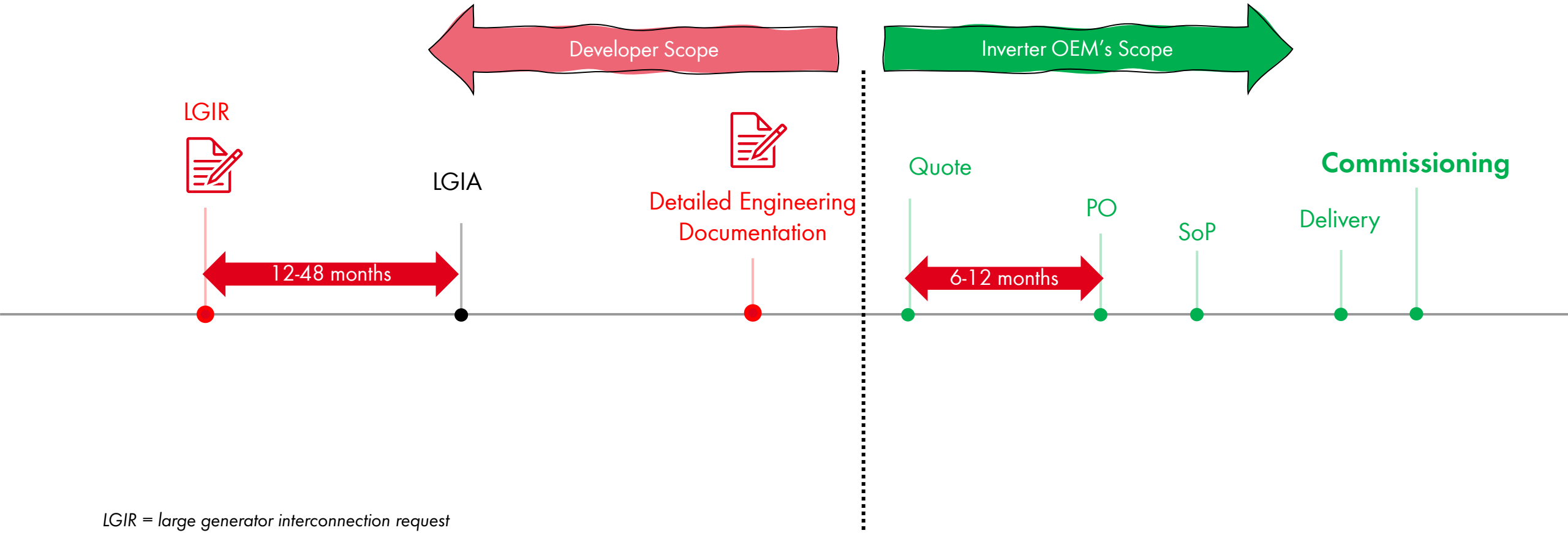
More than 130 Sunny Central Storage with Grid Forming installed around the globe totalling 450 MW

... and more than 1 GW right now in deployment

Incl. Grid Booster, Pathfinder and others

Let's Talk Commissioning

Typical Project – Early Development to Delivery



LGIR = large generator interconnection request

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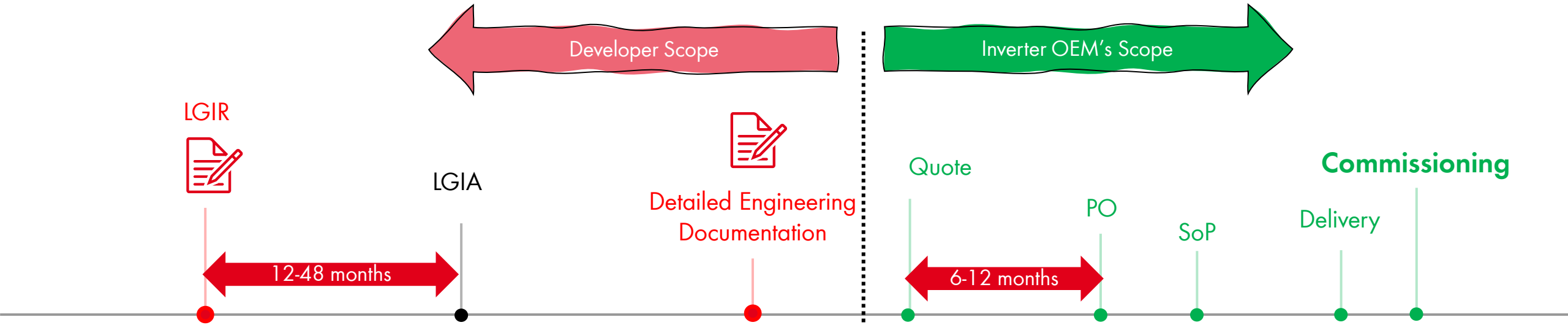


Grid Following

- ✓ Generic Models
- ✓ Default Parameters
- ✓ *Minimal OEM involvement*

Grid Forming

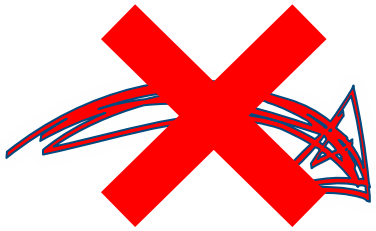
- ✓ *Deep OEM involvement*
- ✓ Detailed, specific parameter set
- ✓ Project Specific, User Defined Models
- ✓ Factory Integration Testing (optional but common)

..... **Commissioning**

The actions within "commissioning" are basically the same whether GFL or GFM

Commissioning of an Inverter

BUT, what is very different...



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..... **Commissioning**

The actions within "commissioning" are basically the same whether GFL or GFM

...is WHERE the parameter set is coming from.

Real World Feedback – **December, 2024**

The Blackhillock site in Scotland is being commissioned right now, and although the details are under NDA, the biggest commissioning challenges there are related to **heavy rain**, **nesting birds and "typical" construction time schedules.**

Product Manager, SMA