

CHIMERA: From Grid Code Compliance Testing to Large-Scale Real-Time Simulation of Grid-Forming Hybrid Power Plants

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Agenda

1. Grid Requirements
2. Grid-Forming Hybrid Power Plants
3. CHiL Tests of DC Hybrid Power Plants
4. From Plant Level to System Level
5. Flagship Research Project: CHIMERA



Grid Requirements

Grid Requirements

*“Therefore, [...] **all generation facilities** connected to the grid (wind, PV, and energy storage systems) must be upgraded as soon as possible so that they can also **contribute to the inertia reserve**.*

*[...] In addition, it is necessary to establish the necessary grid connection requirements for **electrolyzers** and to ensure their grid-supportive operation **in combination with large-scale battery energy storage systems**.”*

Source: 4 German TSOs, “Assessment of System Stability, Supporting Document to the Grid Development Plan for Electricity 2037/2045,” 2023 Version, Second Draft, 2023.

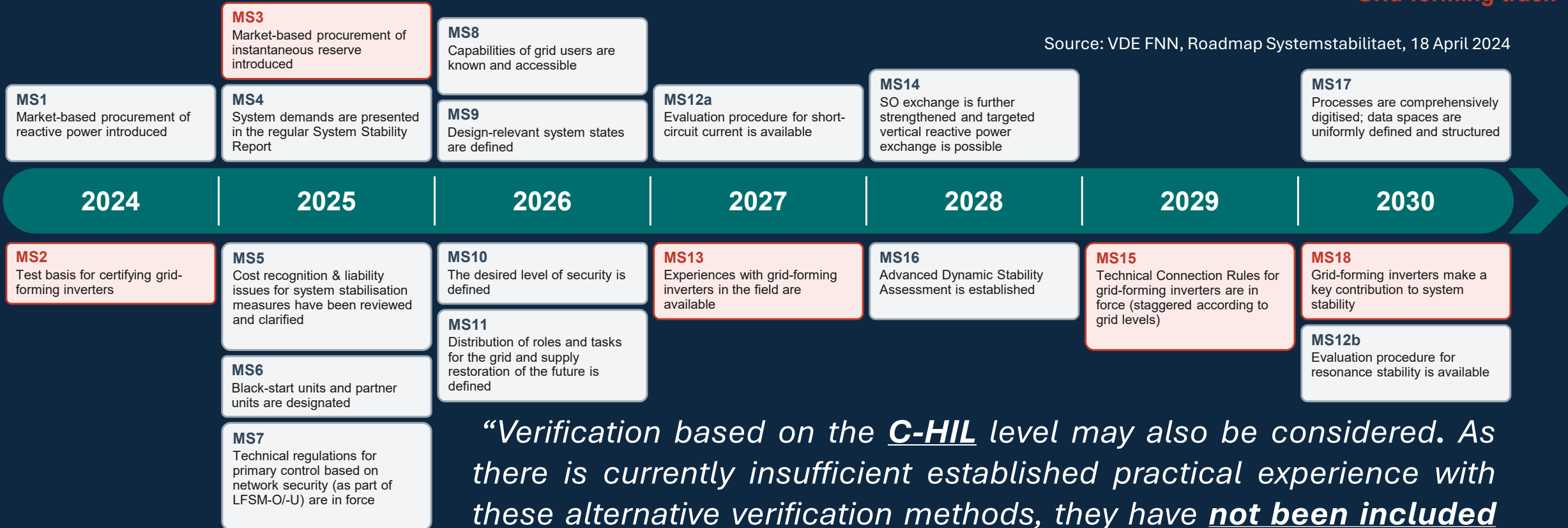
*“[...] there is already a need for instantaneous reserve capacity in Germany today, [...] Without additional countermeasures, the NEP 2037 / 2045 (2023) scenario will result in frequency gradients of more than +10 Hz/s and up to –3 Hz/s, which would make **system splits unmanageable for over 3,000 hours of the year**.”*

Source: 4 German TSOs, “System Stability Report,” 2025.

Grid Requirements

Grid-forming track

Source: VDE FNN, Roadmap Systemstabilität, 18 April 2024

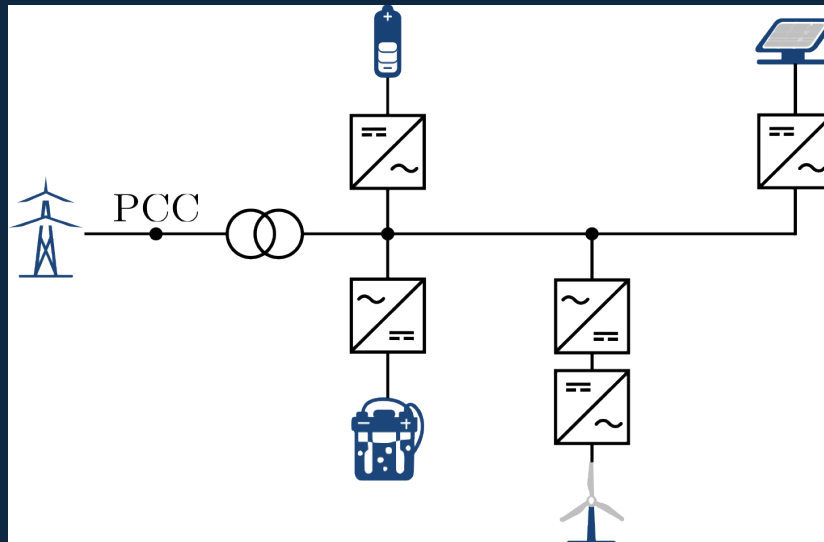


*“Verification based on the **C-HIL** level may also be considered. As there is currently insufficient established practical experience with these alternative verification methods, they have **not been included in the current version of the FNN technical note.**”*

Source: VDE FNN, FNN Technical Note: Technical Requirements for Grid-Forming Properties, Including the Provision of Inertial Response, Version 2.0, 2025.

Grid-Forming Hybrid Power Plants

Grid-Forming Hybrid Power Plants



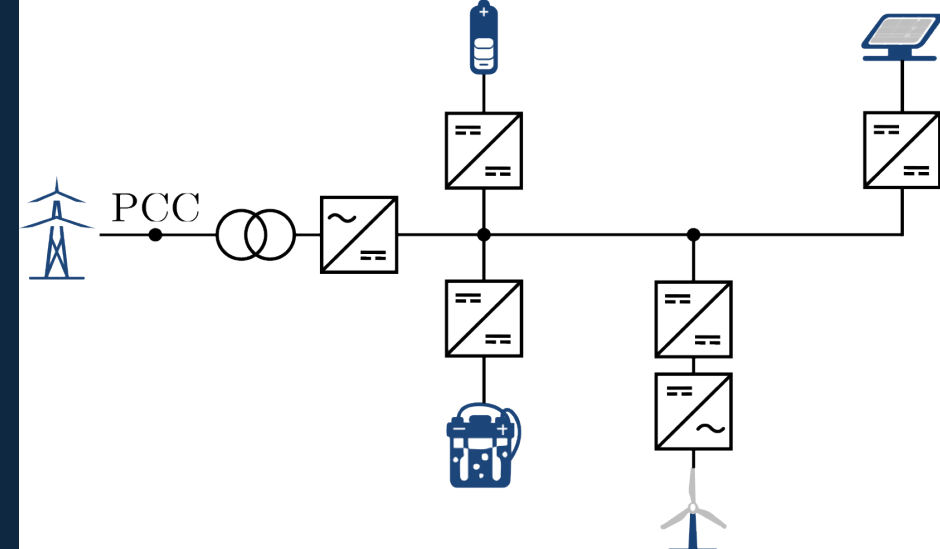
AC – BESS is GFM

On going



Short-mid term solution

Complex Control strategy



DC - Head Station is GFM

10-15 years in future



Long-term solution

Advantageous Control strategy

Grid-Forming Hybrid Power Plants

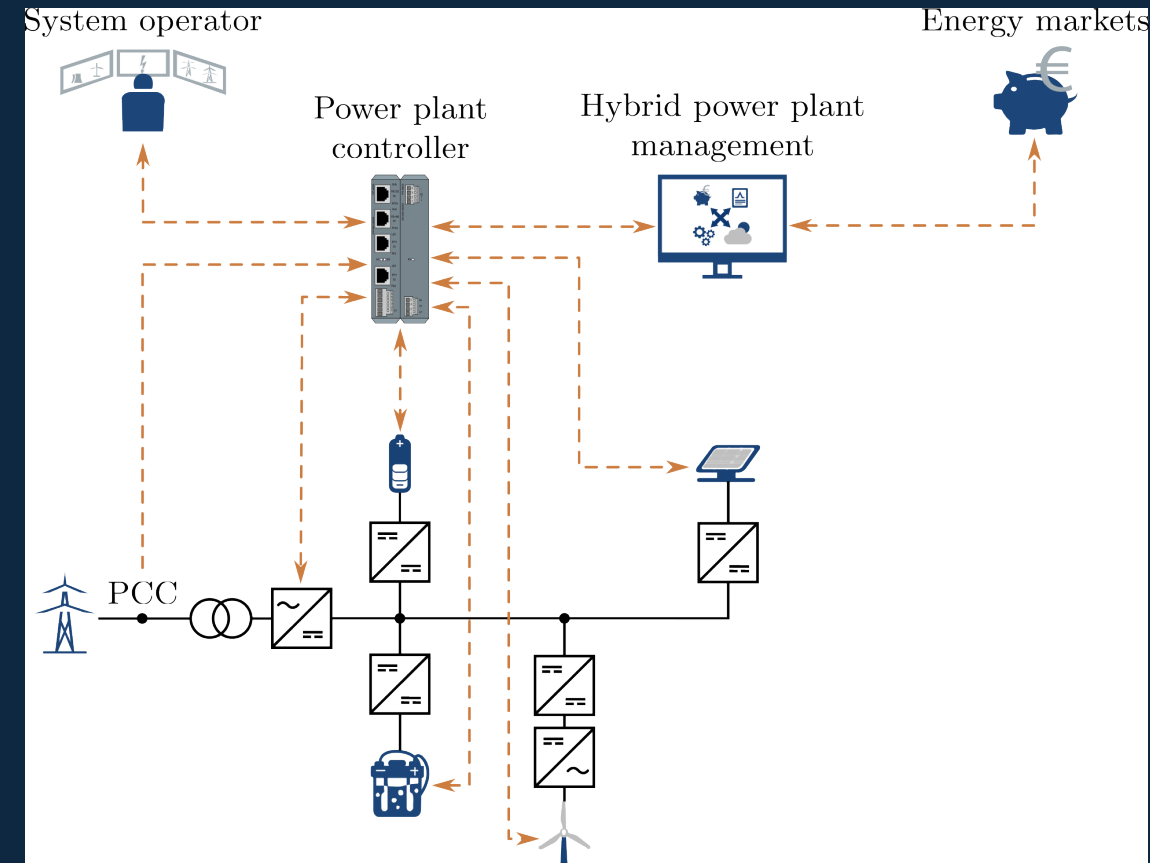
- A hybrid power plant (HPP) is the combination of renewable energy facilities (Wind, PV, BESS, electrolysis, etc.) at one grid connection point
- Grid-forming HPP are a key technology for large-scale green hydrogen production and power system stability
- GFM HPP increase the base-load capacity of renewables, provide black-start capability and system services
- HPPs are physical plants, not virtual plants

CHiL Tests of DC Hybrid Power Plants

CHiL Tests of DC Hybrid Power Plants

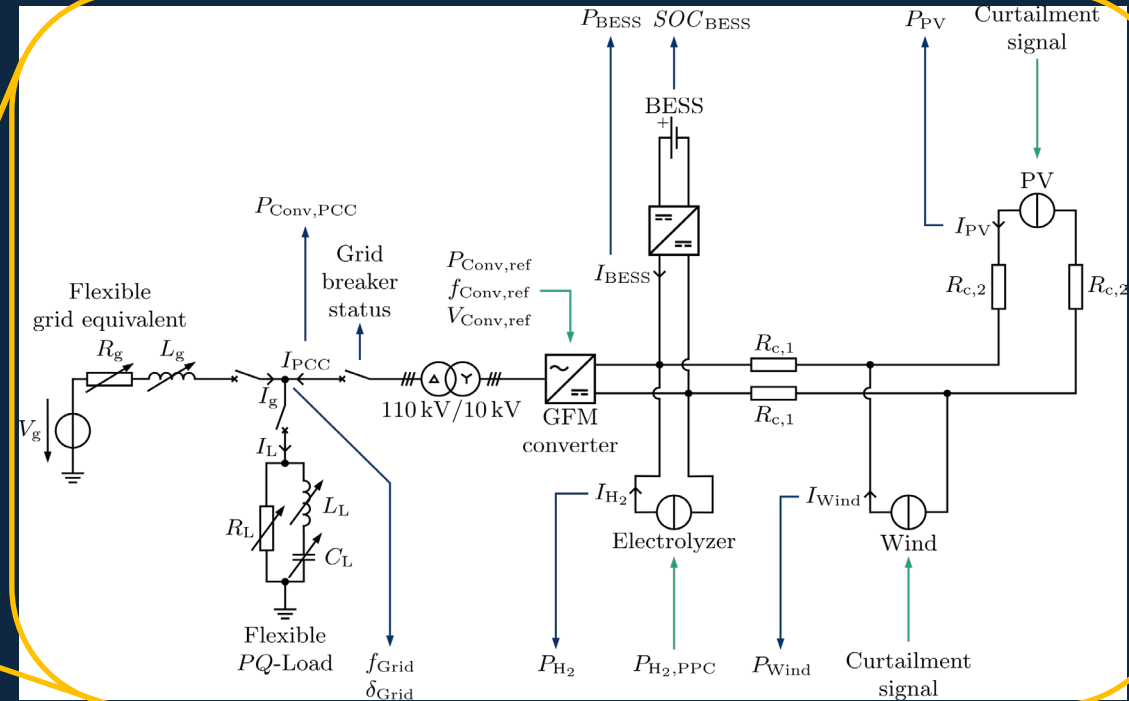
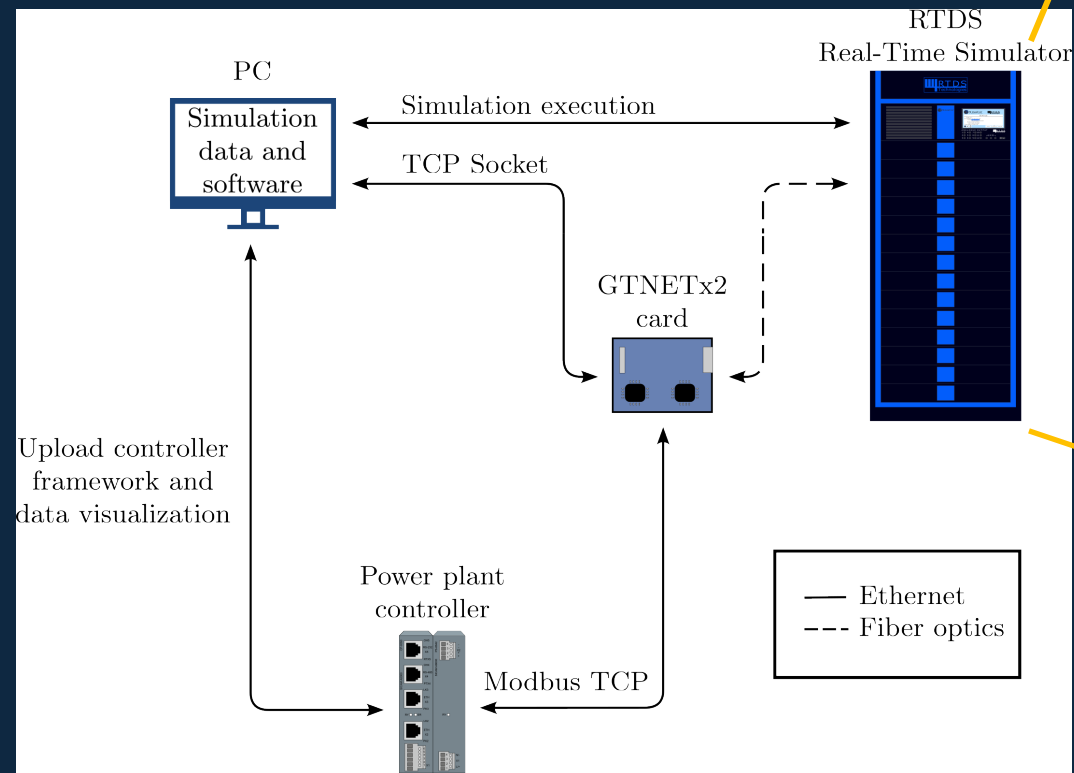
Power Plant Controller - PPC

- **Central Communication and Data Hub:** Bidirectional exchange of measured values and setpoints between all units of the hybrid power plant and the Point of Common Coupling (PCC).
- **Internal energy management during grid-connected and off-grid operation:** Implementation of setpoints, output curtailment, and intervention in response to short-term power changes to ensure compliance with operating limits during normal operation, as well as self-sufficient emergency energy management in the event of a grid or communication failure, including automated synchronization, black start, and grid restoration.
- **Interface to the hybrid power plant management system:** Forwarding of measurement data and receipt of schedules and setpoints.
- **Connection to the grid control center:** Provision of current grid feed-in data and implementation of external specifications for congestion management as well as secondary and tertiary control.



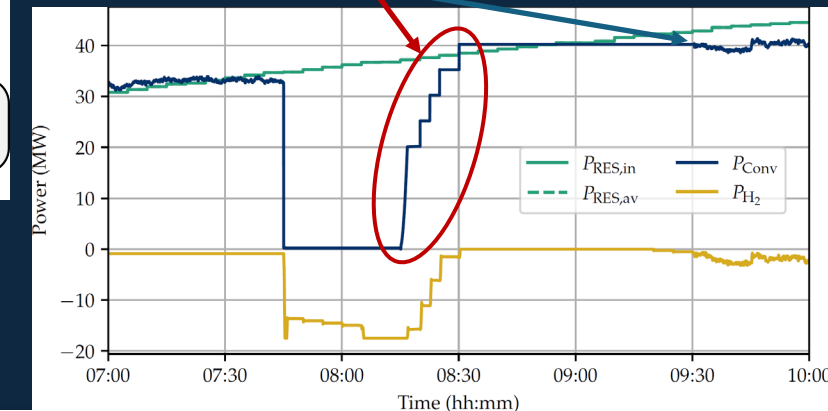
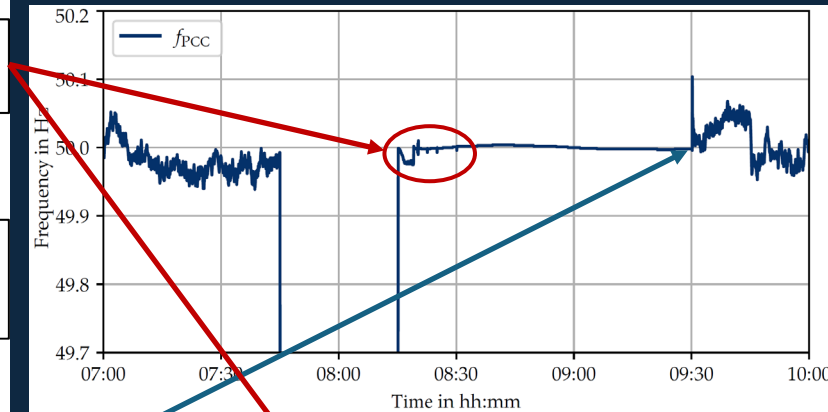
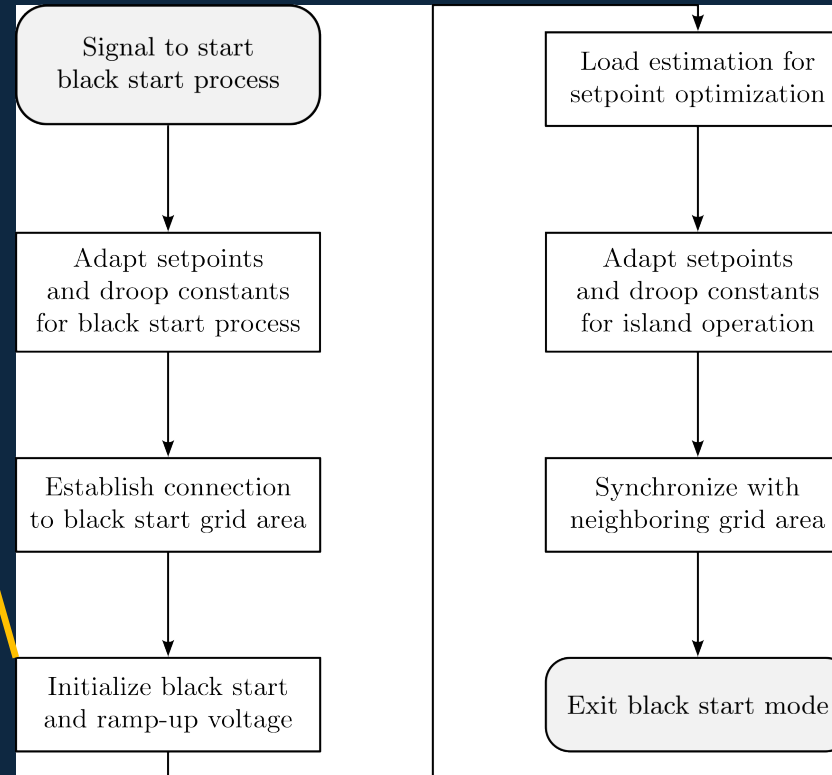
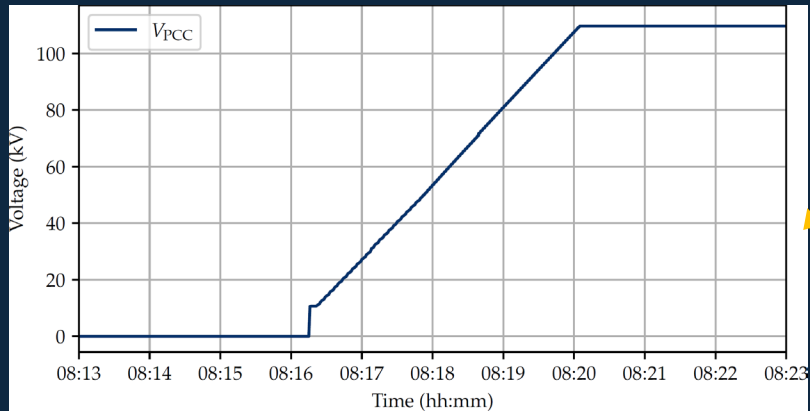
CHiL Tests of DC Hybrid Power Plants

Lab set-up



CHiL Tests of DC Hybrid Power Plants

Example: Blackstart



J. Richter, C. Wiesnet, G. Mehlmann, M. Luther, „Provision of black start and system services by sector-coupled hybrid power plants: A real-time validated power plant controller framework,“ Energy Reports, Volume 16, 2026, ISSN 2352-4847, <https://doi.org/10.1016/j.egyr.2026.109482>.

From Plant Level to System Level

From Plant Level to System Level

Neilston Greener Grid Park ©Statkraft

- First Grid Code requirements for GFM are in the making but CHiL is handled differently
- CHiL tests are important to accelerate and de-risk large HPP projects
- International GFM-BESS pioneering projects emphasize the need for CHiL test campaigns, e.g. Neilston Greener Grid Park and Blackhillock, UK



A. Bammes, et al., "De-Risking Grid Forming Battery Energy Storage Projects - Grid Code Compliance testing of a 50MW Storage System using Control-Hardware-in-the-Loop," in: CIGRÉ 2025 International Symposium, Montreal, Canada, 2025.

X. Li, A. Knobloch, M. Mojtaba Dadashi, et al., "Experience with Commercial Stability Service Provision of the UK Blackhillock Large Scale Grid-forming BESS," in: CIGRÉ 2026 Paris Session, Paris, France, 2026.

From Plant Level to System Level

- **20 January 2026:**
During field commissioning of the 100 MW Kiisa BESS (Estonia) both HVDC interconnectors EstLink 1 and 2 to Finland tripped, disconnecting nearly 1 GW.



©FINGrid

Such events raise a key question regarding CHiL-testing:

Could the BESS-induced oscillations have been identified through a CHiL test campaign prior to field commissioning? If so, what scope and capabilities are required?

1. CHiL studies to represent the grid using only Thévenin equivalents are not sufficient in converter-dominated grids
2. Interacting neighboring controllers (here HVDC) have to be included in CHiL setups
3. Cross-border real-time models can be sensitive to capture such interactions adequately, especially if HVDC are involved

Flagship Research Project : CHIMERA

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Flagship research project CHIMERA on grid-forming hybrid power plants

11 full partners, 5 associated partners (project lead: FAU-LEES, co-lead: Siemens Energy)

With funding from the:



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Plant-level grid-forming control

A central plant controller delivers synthetic inertia and rapid primary frequency response from the aggregated hybrid plant, allowing individual units (except storage) to remain in grid-following mode and avoiding the rollout of grid-forming control to every unit.

HiL-validation and large-scale demonstration

The Kopernikus ENSURE Co-demonstration platform tests the concept under realistic conditions, covering both grid code compliance and systemic behaviour via a European real-time grid model (NEP 2035) for scaling and instantaneous reserve in system-split scenarios.

Regulatory and market alignment

The work supports the German System Stability Roadmap, incorporates the revised Requirements for Generators 2.0 (RfG 2.0) into compliance assessments, and addresses market-based procurement of instantaneous reserve.

Configuration and control optimization

The project evaluates hybrid configurations (BESS, electrolyser, wind, PV) with optimised control (reduced latency, forecast integration) and integrates fast power-electronic tap changers that enable millisecond voltage regulation and potential STATCOM downsizing or elimination..

Platform advancement

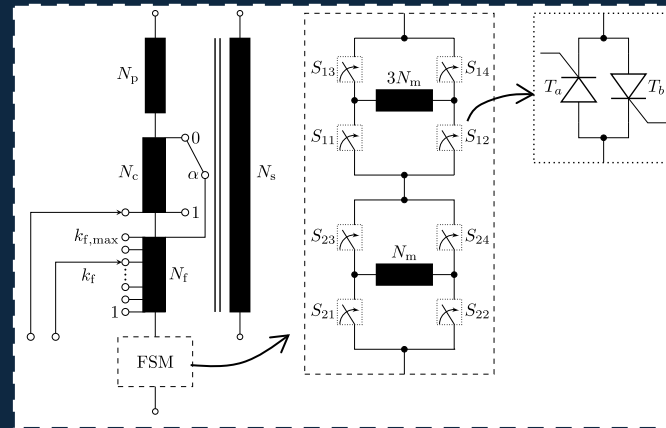
Ongoing development focuses on increased automation, protection of proprietary models, assured model quality, and dynamic phasor modelling rather than RMS modelling for large-scale grids.

Flagship Research Project: CHIMERA

With funding from the:

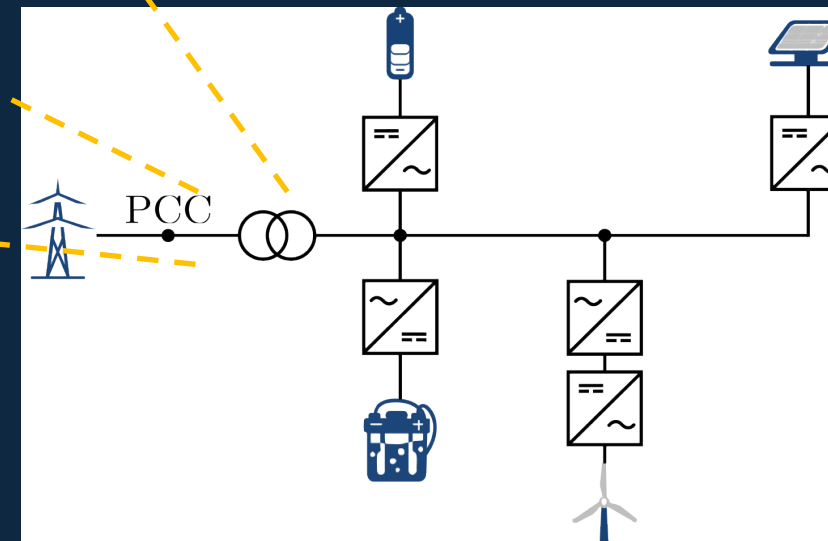


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Tap Changer in Hybrid Power Plant

- Grid Forming Capability requires Apparent Power of the Converter
- P/Q Capability of Converters depends on applied voltage to the converter. Tap Changers can improve this stationary (conventional tap changers) / and dynamical (hybrid tap changers)

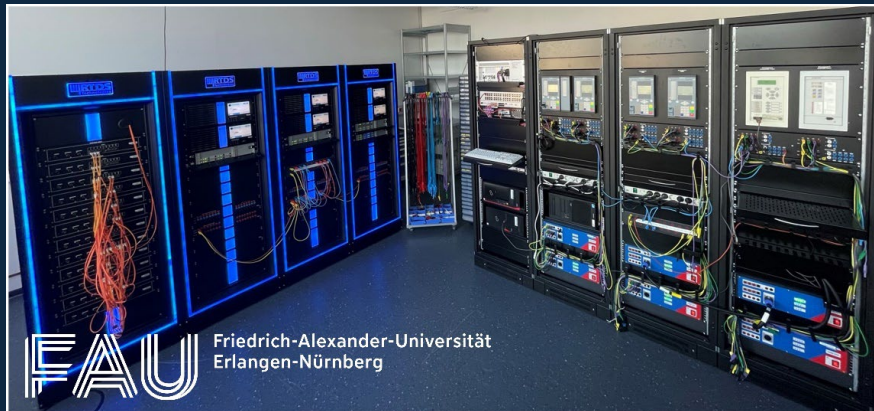


I. Burlakin et al., "Enhanced voltage control in offshore wind farms with fast-tapping on-load tap-changers," 23rd Wind & Solar Integration Workshop (WIW 2024), Hybrid Conference, Helsinki, Finland, 2024, pp. 931-938, doi: 10.1049/icp.2024.3896.

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