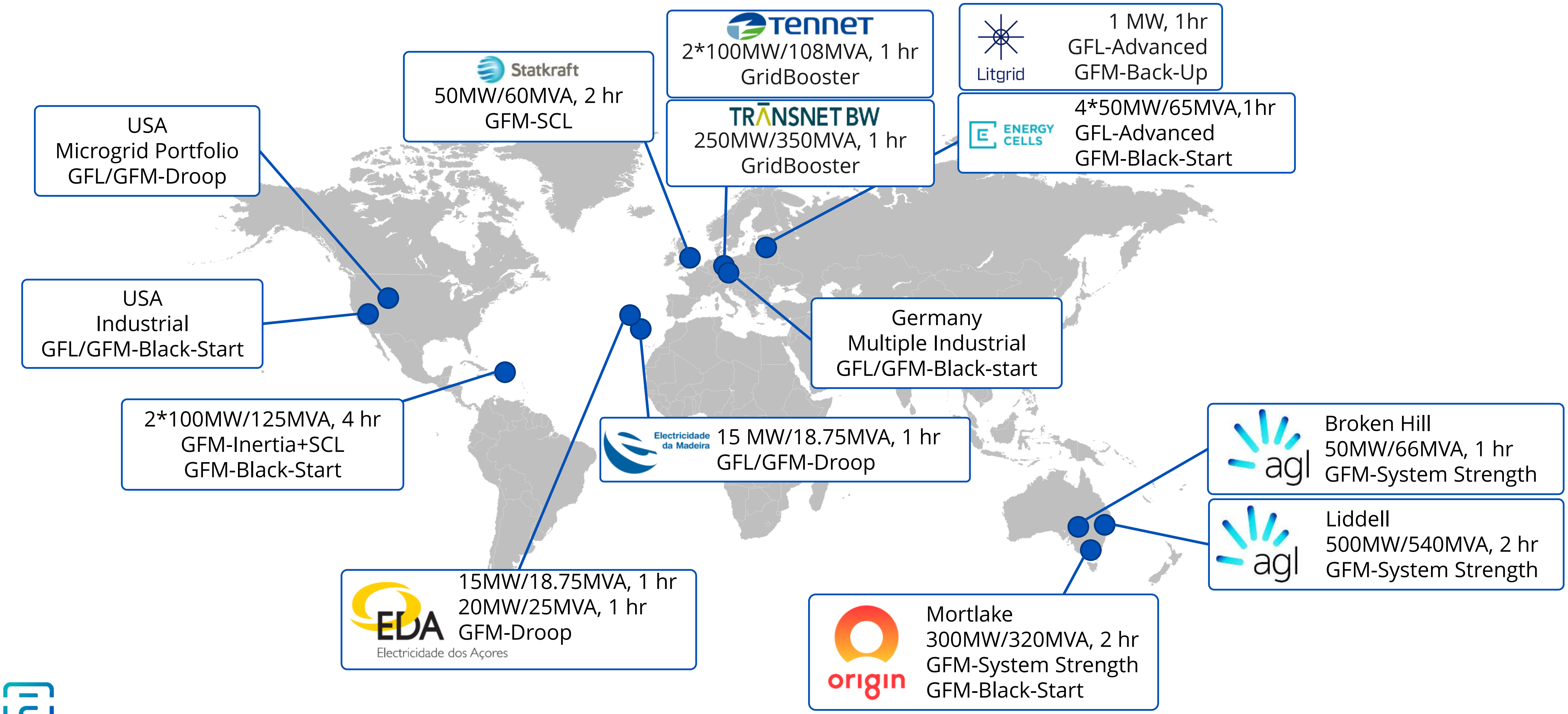
17JAN25 ERCOT IBRWG

ERCOT's Advanced Grid Support Proposal

Techno-economic Impact to Energy Storage Resources

Grid-Forming Projects Increase in Size and Number

Fluence Contracted Projects Exceed 2000 MVA



System Strength: Compensate vs. Compel vs. Cost-Out?

ercot

NESO National Energy System Operator | amprion | 50hertz | Tennet | TRANSNET BW | entsoe | MISO | AEMO

STABILITY PATHFINDER 2

- Identified weak points in grid
- Focused on SC levels
- Defined technology agnostic requirements
- Public tender to incentivise grid strength
  - Fault power (MVA)
  - Upside for Inertia (MVA.s)
  - Allows Parallel Services

	Effective SCL in MVA at 100ms for a fault at Blackhillock 400kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Eccles 400kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Hunterston 400kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Loangannet 275kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Peterhead 275kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Spittal 275kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Mark Hill/ Coylton 275kV (from Test 1 Step 3).	Effective SCL in MVA at 100ms for a fault at Moffat/Elvanfoot 400kV (from Test 1 Step 3)	Inertia x Inertia availability (MVA.s)
Technology Type	**SCL Blackhillock**	**SCL Eccles**	**SCL Hunterston**	**SCL Logannet**	**SCL Peterhead**	**SCL Spittal**	**SCL Mark Hill**	**SCL Moffatt**	**Inertia Derated**
Grid Forming Battery Storage	8	22	74	41	7	0	125	68	0
Grid Forming Battery Storage	19	21	79	56	13	1	25	55	0
Synchronous Condenser	1918	32	70	476	574	13	18	66	549
Grid Forming Battery Storage	84	4	10	49	51	1	2	9	333
Grid Forming Battery Storage	1	44	249	95	1	1	114	211	1341
Grid Forming Battery Storage	5	936	22	41	4	1	4	57	2686

RFG2.0

- Identified weak scenarios (EU Grid Split)
- Focused on Inertia Needs
- Defined requirements more flexible for renewables (Asymmetric Inertia)
- Public Consultation to review
- Effectively compels all BESS to be GFM in ~3years
- Triggered Bundesnetzagentur to initiate a "Bonus" scheme which will compensate early adapters!

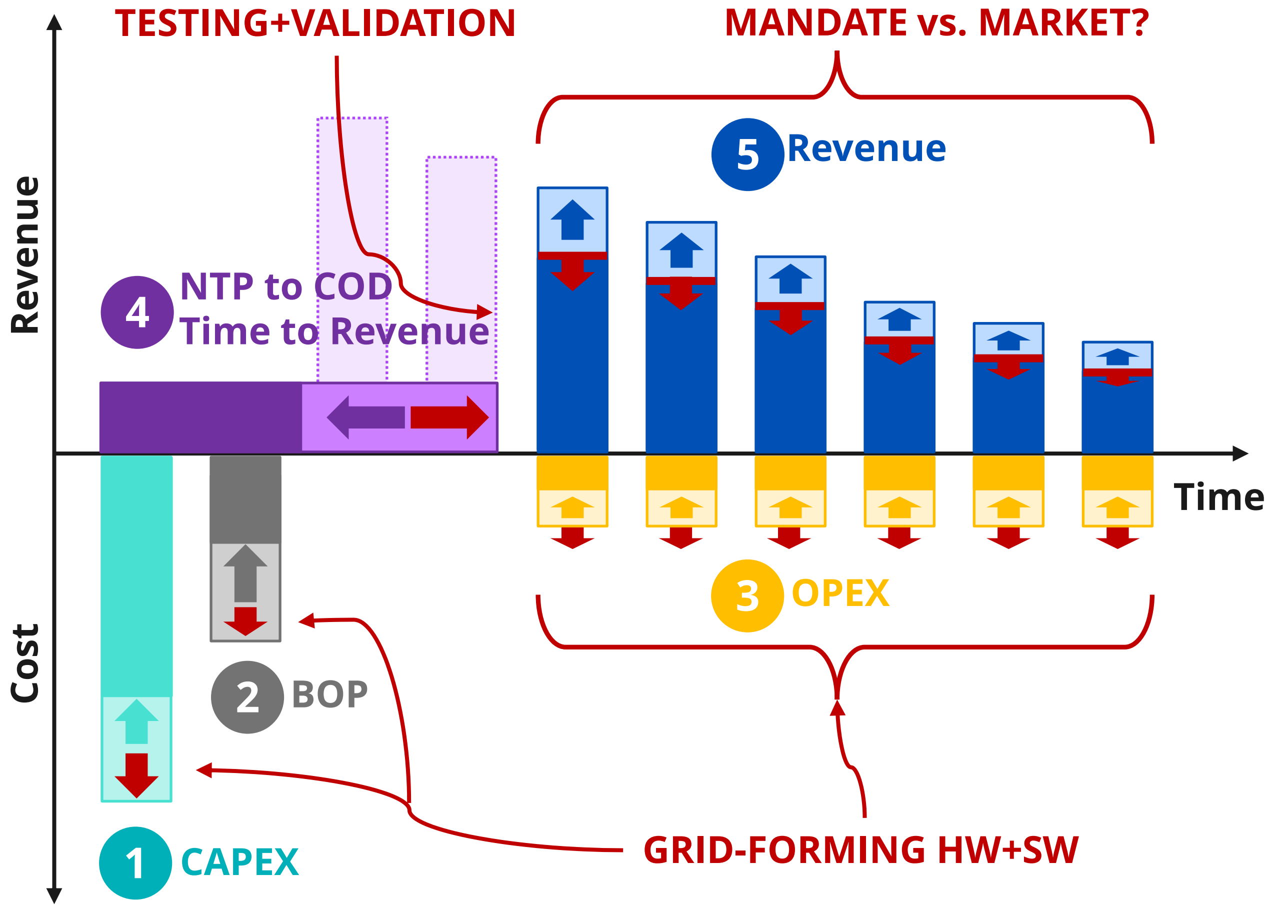
SYSTEM STRENGTH CHARGE

- Identified weak points in grid
- Focused on SC ratios
- Defined technology agnostic evaluation tests
- Charging mechanism to promote
  - Siting to strength
  - Improved GFL controls (lower SCR)
  - GFM controls
  - Synchronous Condenser/Generator

$$\Delta AFL_{IBR1} = (-\mathrm{SCR}_{\mathrm{withstand}} + \alpha) \times \mathrm{P}_{\mathrm{rated}}$$

GFM is free right? Right…?

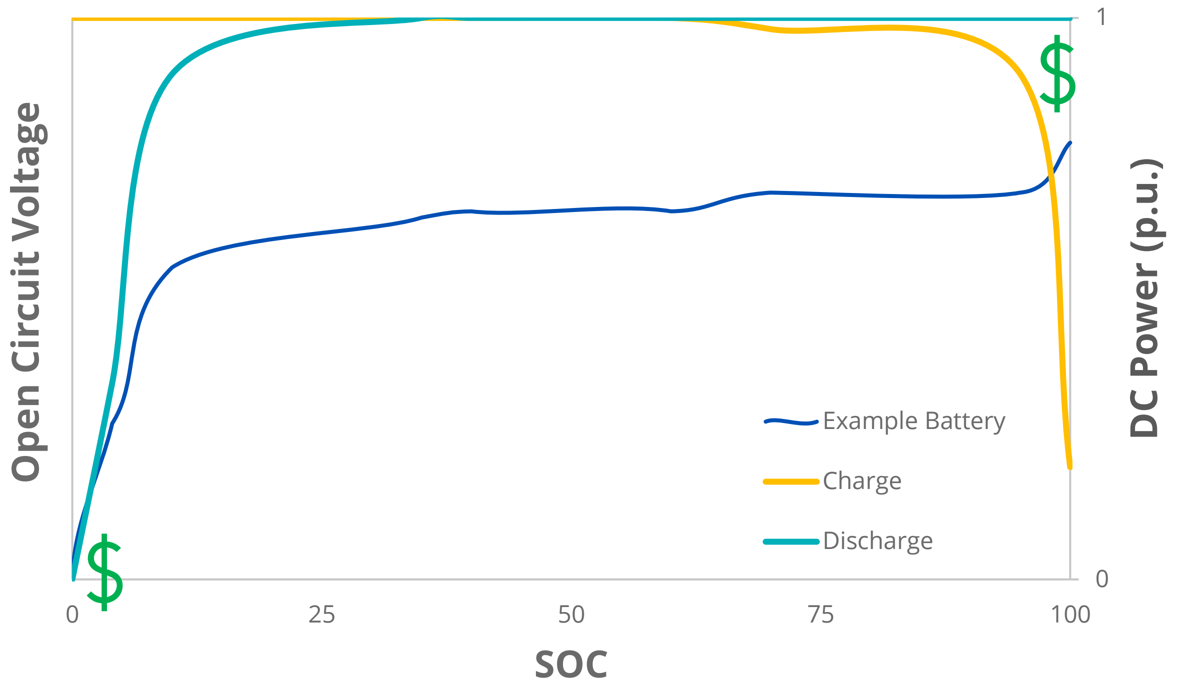
1. CAPEX
   - Controls Cost
   - $S_{R,GFM}/S_{R,GFL}$ Power Stability Buffer
2. Balance of Plant
   - MV/LV Transformer Sharing
   - Advanced Metering
   - Aux Resiliency and Robustness
3. OPEX
   - SOC (in)Accuracy → Recalibration
   - GFM Troubleshooting Complexity
   - Advanced Monitoring
   - Limited freedom to optimize plant losses
4. Time to Revenue
   - Testing, testing, testing
   - Simulations and validation
   - Certification
5. Revenue
   1. No upside without market
   2. Potential penalties



Energy/SOC in GFM

- **Energy** for Inertial Response does <u>not</u> guarantee **Power** for Inertial Response
- Estimation of BESS Energy/SOC is impacted by use case and cell chemistry.
- Operation in GFM results in continuous low level power which is difficult to accurately measure.
- System BMS's SOC estimation and calibration can be limited to certain ranges and conditions.
- PPC needs to monitor and mitigate inaccurate SOC.

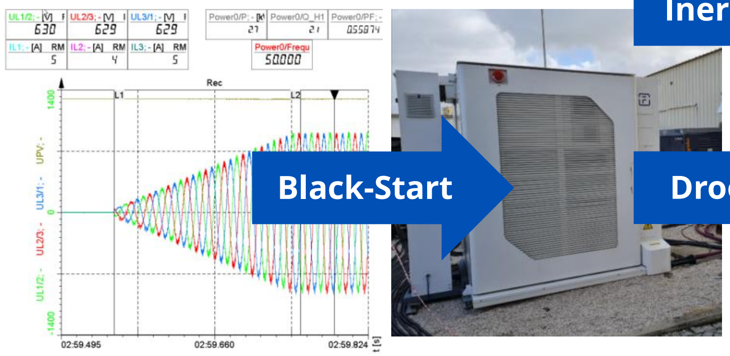
ESR Operators can and do use full SoC for revenue.

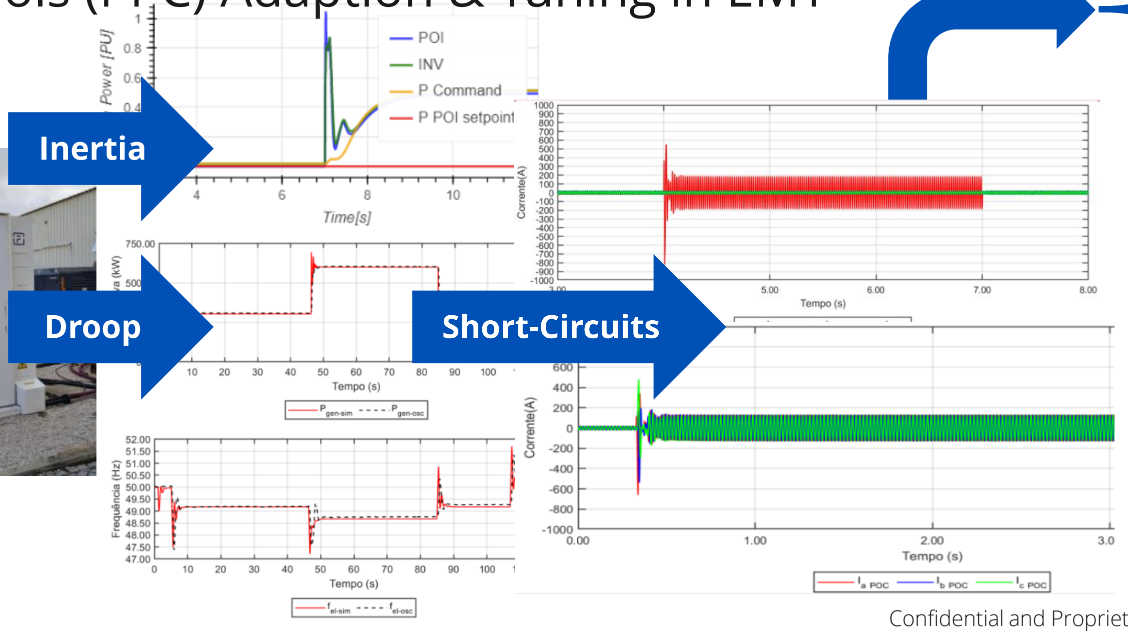


Fluence PCS: Qualification & Integration

Picking Apart the PCS

- Documentation Diligence
- EMT Simulations (PSCAD, PF, PSSE, HiL)
- Factory Witnessed Test
  Direct Controls/Sequences, Accuracy, Speed, CMV, Black-Start, Short-time >>I
- Core Lab(s): Simulation & Validation
  Fluence PPC/Cube, 1..2xPCS, MV Trafo, Grid and/or Grid Emulators, Load banks
- Power Plant Controls (PPC) Adaption & Tuning in EMT
- Project Execution

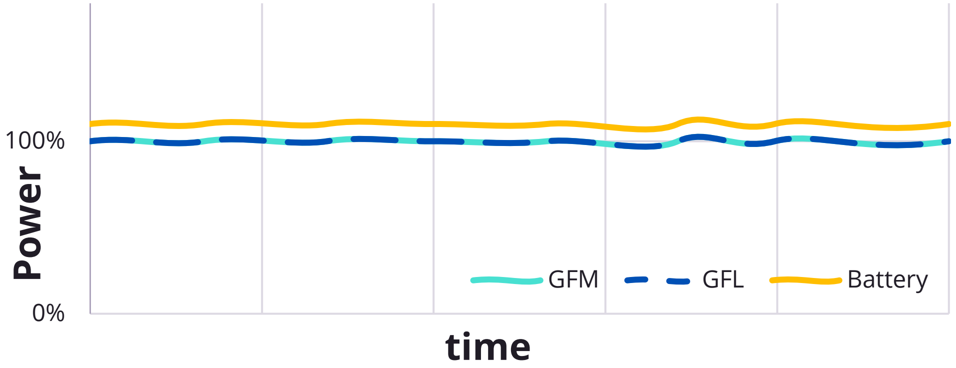




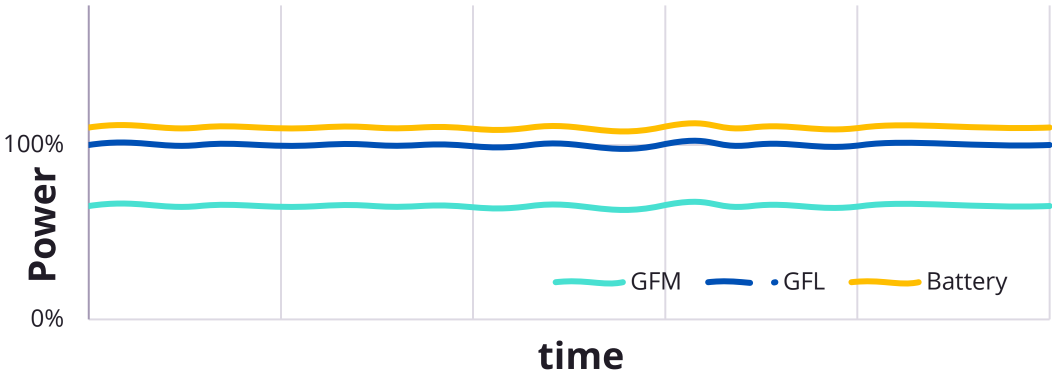
Knowing your Limits

Short-term overload requires careful consideration, and constant dynamic re-assesment

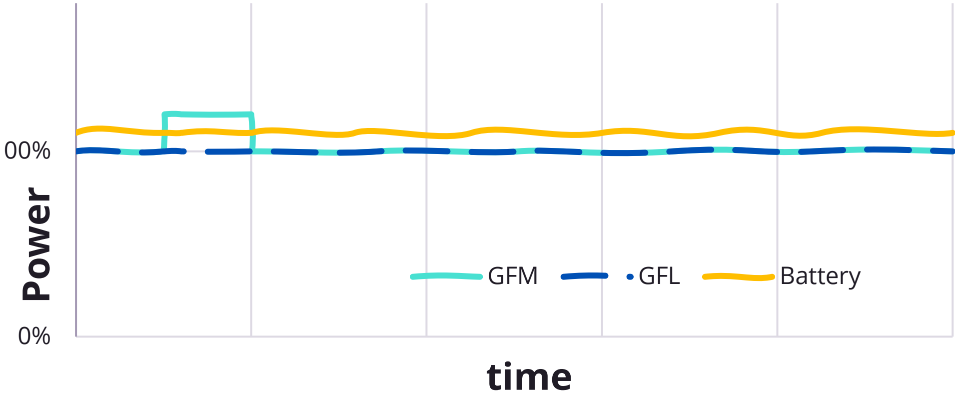
Initial Expectations



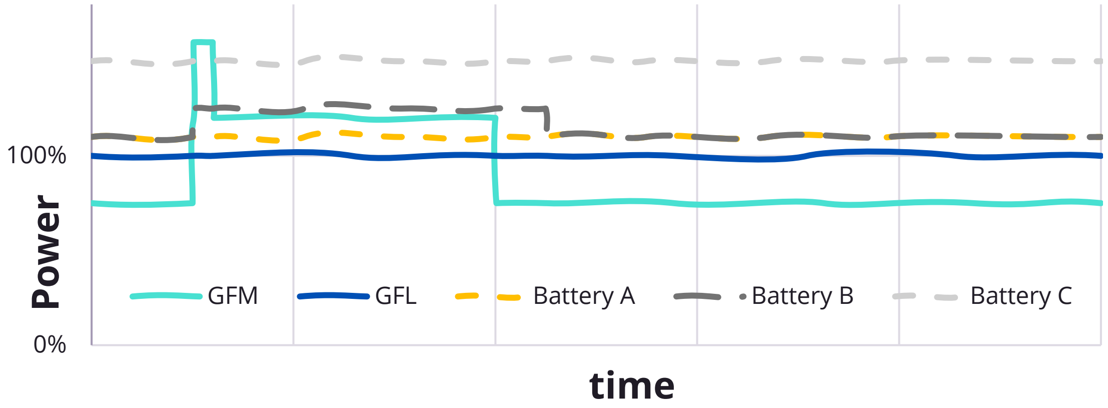
Conservative



Status Quo



Trade-Off



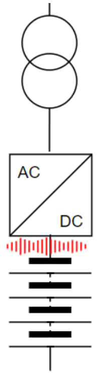
Conventional Hardware Configurations

Single Winding

Single GFM Controller

Multi-Synched-Stack

Single-DC-Bus

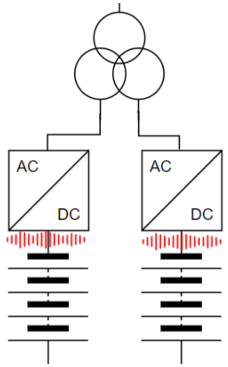


Multi Winding

Multi GFM Controller

Multi-Synched-Stack

Single-DC-Bus

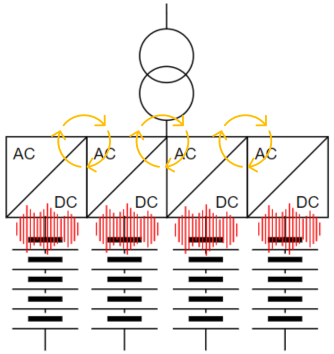


Single Winding

Single GFM Controller

Multi-Synched-Stack

Multi-DC-Bus

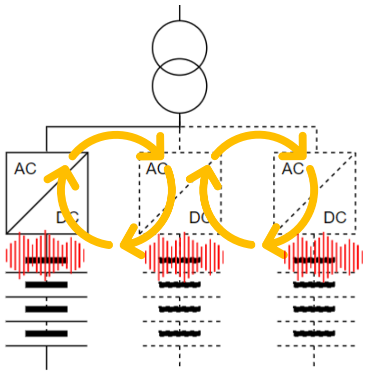


Shared Winding

Multi GFM Controller

Multi-PCS-Pseudo-Synch

Multi-DC-Bus



Common Mode Voltage (CMV) Circulating Current (CC)

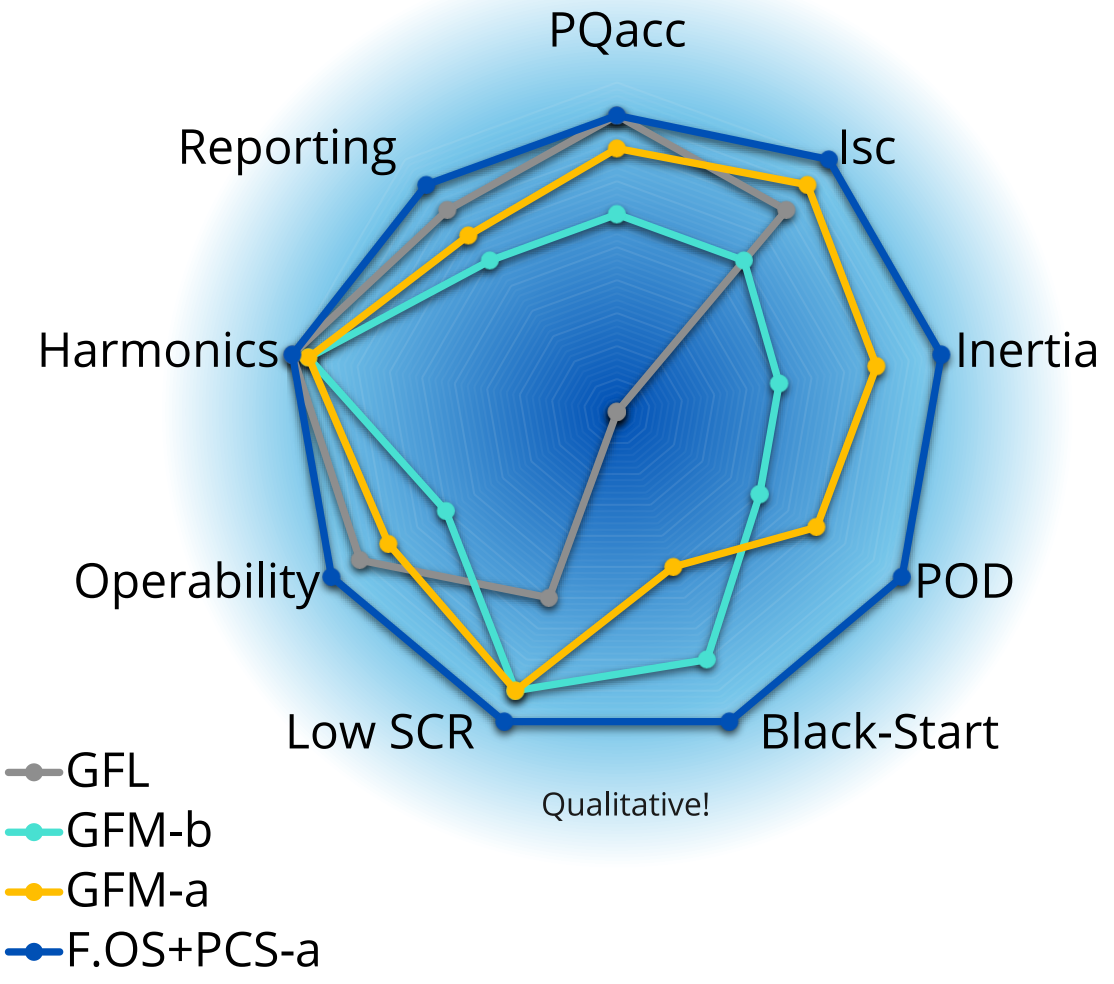
PPC's Coordinating Roles

Turning GFM Controls of PCS into Standardized Plant Products

How do we meet the needs of the many, while respecting the limits of all?

- Coordinate Plant Performance
    - Accurate P/Q, Energy
    - GFM-Droop/Inertia
- Increase plant stability
    - Balance Asymmetry
    - Outages
    - Oscillation damping
- Process and Report Total Plant Metrics
    - P, Q, MWh, Isc, MWs, Droop
    - "Re-Dispatch" GFM-Parameters
- Coordinate Sequences/Switches
    - MV/HVSG
    - Auxiliary
    - Self-Supply/Black-Start/Grid-Restoration

Fluence PPC (F.OS) Improves and Expands PCS Grid-Forming



Comments to ERCOT's Test Framework

General

- 1.3b) ESR frequently do operate at or very near maximum limits, in particular for power
- Unclear if plant controls are to be considered or not
- No tests at full charge power, nor with reactive power
- No reactive step tests (e.g. Series Compensation)
- Extra Electranix tests: Without data how will procedures evolve?
- No consideration for DC source limiting convertor active limits

Test 2: Phase Angle Jump

- Only Discharge
- No reactive power despite GFM inherently providing Q
- ERCOT does not require overbuild, so no response will be provided for +Angle Jumps. Testing controls ability to limit is sensible but additional test showing symmetrical response from P=0 setpoint or P=-1p.u. are needed.
- B. Justification for 1 and 3 Cycles in Electranix slides

Test 3: Small Voltage Disturbance

- Only Discharge and no reactive (Apply +-0.95 from DWG?)
- Performance indicates very tight V(Q) droop and/or closed loop plant controls
- Behavior beyond +-3% not probed. Test 6 jumps to e.g. >+-10% voltage events. Experience shows some GFM controls fail on shallow faults.
- Justification for 3MVar/3%Voltage behavior – may drive overbuild of converters
- Justification for 6 cycles from Electranix slides

Test 4: Frequency Change and Inertia Response

- Only tested at ZERO active/reactive, ERCOT will have no indication how much/quickly GFM capabilities degrade across plants power
- Required behavior beyond 1Hz/s? No tests for >60Hz – Is this intentional?
- How realistic is an instantaneous frequency step of 0.3Hz? Effectively infinite RoCof
- No performance criteria for instantaneous provision of active current. Passing Criteria could be met with a fast Grid-Follower but which brings inherent dead time from metering, controls delays and comms latency.
- A. "voltage should not… deviate from steady state… for any significant amount of time" Inertial P through plant impedance -> voltage deviation, vague time criteria
- C. Delta_E can be impacted by plant controls, shall PPC be activated or deactivated?
- D. Does this imply GFM-Droop is required on convertor or Plant level FR controls?

Comments to ERCOT's Test Framework

Test 5: System Strength

- Only Discharge
- No reactive power despite GFM inherently providing Q
- Experience shows GFM controls most often fail on asymmetrical faults, particularly with phase C-GND. Recommend considering all 11 fault types.

Test 7: Loss of Synchronous Machine Test

- If there is concern of Plant-Plant oscillations (of the same type) should it not first be tested within a plant (Block-Block) or with more onerous tests?
- No special performance criteria for Scenario 3 mentioned.
- A. Justification for 5..10s?
- B. Add check to ensure no opposing P nor Q between the 2 plants
- C. Implies f(P) and V(Q) droop controls are required on converter level – is this intentional?

5 Appendixes

ΔE Criteria exposes ERCOT to Grid-Following controls with inherent deadtime from metering/controls/communications, which in turn lead to stability risks.

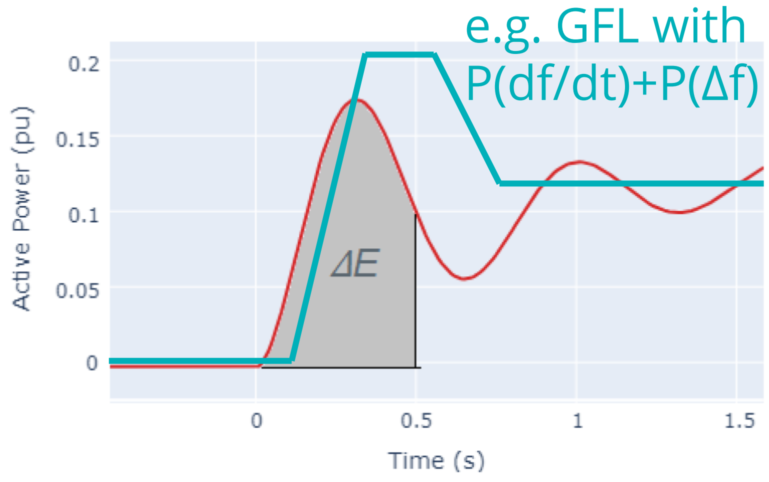


Figure 4. The output active power of the resource and illustration of ΔE

Source: **Advanced Grid Support Energy Storage Resource (AGS-ESR) Functional Specification and Test Framework for the ERCOT Grid Version 1.0 September 2024**

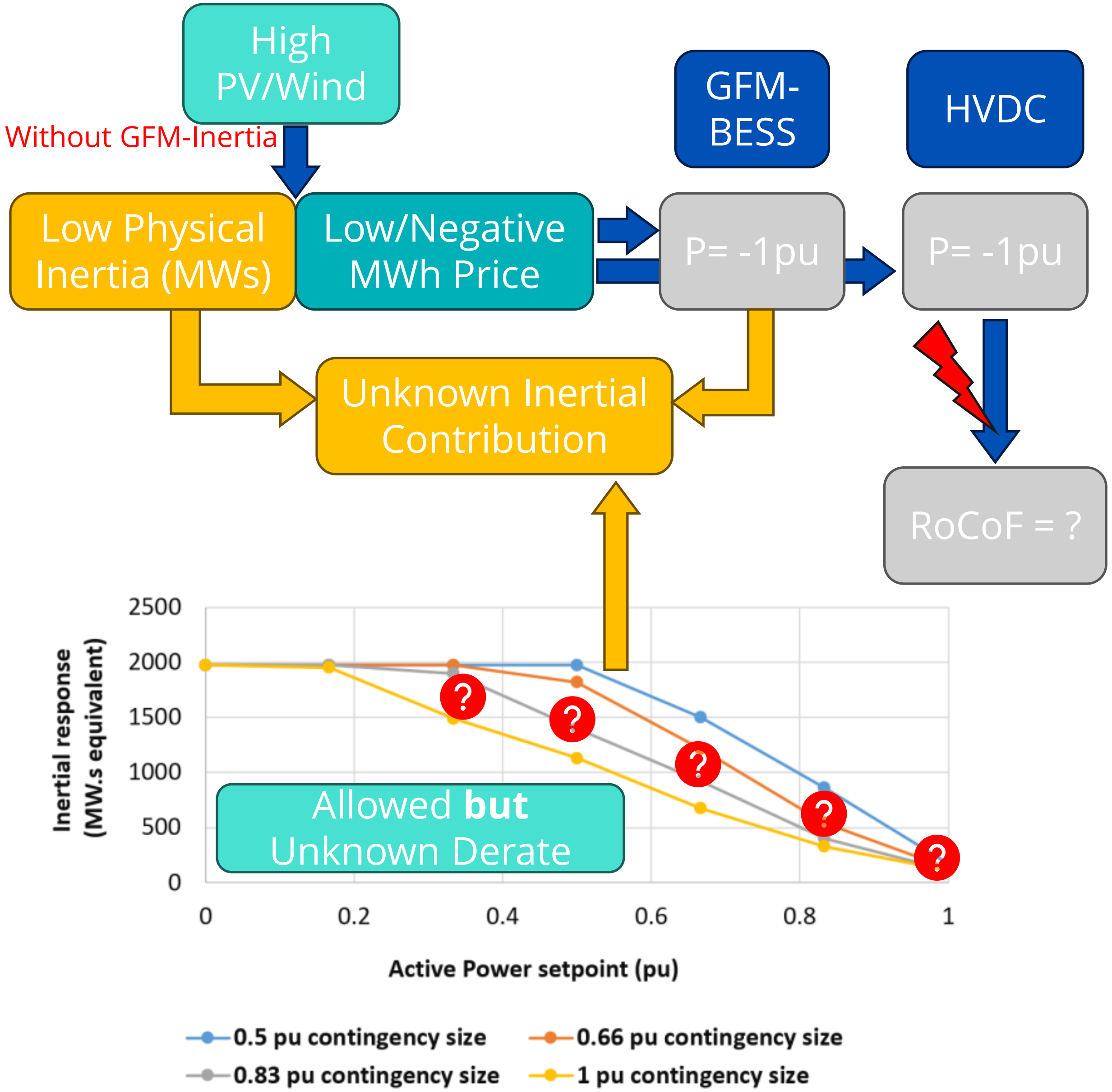
Controlling Compliance

- “No overbuild“ Requirements only ensure GFM behaviour when not at design limit
  (AEMO, Fingrid, MISO, ERCOT, etc.)

- Project economics design strive for:
  $P_{nom} \approx P_{max} \approx P_{op}$
  $Q_{nom} \approx Q_{max}$

- High renewable (low physical inertia) future requires more visibility
  - Prove overbuild for compensated
  - Detail derate for mandated

- Defined Monitoring and Controlling



Modified from: © AEMO 2023 | Voluntary Specification for Grid-forming Inverters

Thank you!

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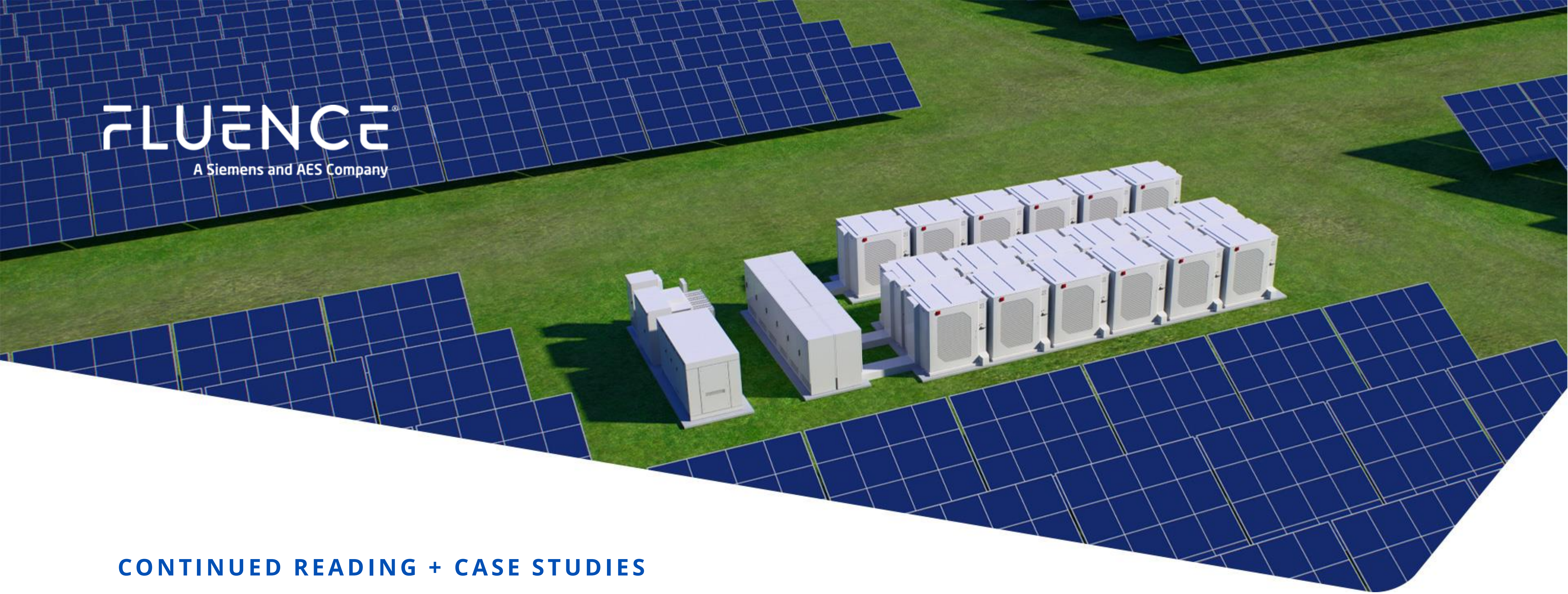


CONTINUED READING + CASE STUDIES

Want to know more about Fluence?

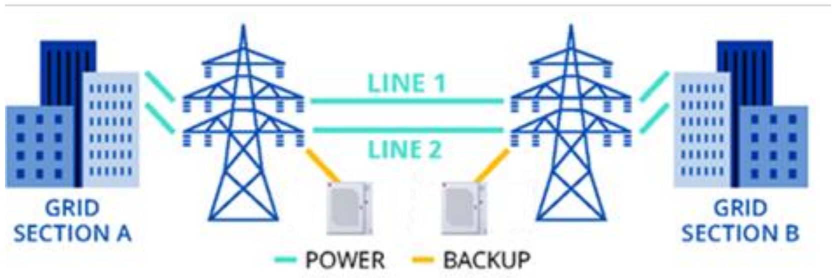
Changing conditions create new challenges for grid operators

Storage is emerging as a valuable resource in this transition

Network Utilization

Changing generation resources and renewable intermittency causes transmission line congestion, which results in asset curtailment and re-dispatching

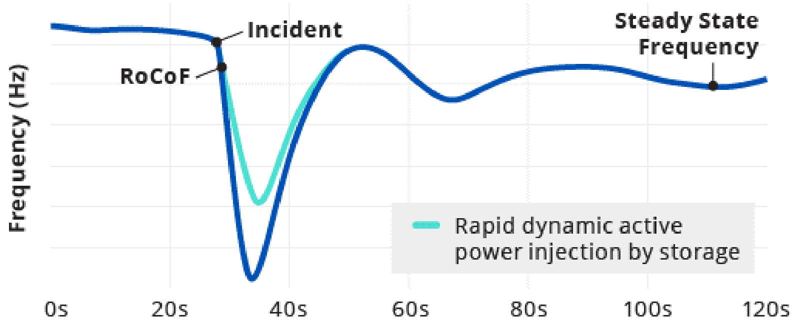
Energy storage can be deployed quickly on the grid to increase capacity on transmission lines through energy shifting or n-1 contingency reserves



System Stabilization

A growing share of inverter fed resources and changing load profiles create new system stability issues for grid operators

Energy storage with advanced grid forming controls supports grid stability and power system operation with complex applications, such as inertia, black start, oscillation damping control, and more



Fluence Ultrastack

Purpose built to meet the unique operational needs and technology requirements of T&D asset owners

Flexibility
Cost effective solution with rapid installation compared to alternatives

Scalability
Supports 50MW+ system sizes and complex grid requirements

Technology
Advanced grid services and critical asset IT security

Architecture
Fast system response and redundant controls

Availability
99%+ asset uptime and availability

Sustainable
Supports rapid grid transition to renewables

CASE STUDY

A powerful asset for European grid interconnection and renewables transition

EPSO-G (Lithuania)

Energy Cells – 200 MW / 200 MWh (50 MW per site)

SERVICES

- Inertia Contribution
- Renewable Integration
- Grid Restoration

IMPACTS

- Increase Grid Resilience today
- Ensure stable operation during synchronization with European Grid
- One of the largest energy storage project of its kind

CASE STUDY

Strengthening energy security and renewable integration in Germany

TransnetBW (Germany)
250 MW / 250 MWh

SERVICES

- Grid stability
- Congestion relief

IMPACTS

- Ease bottlenecks transporting wind energy from northern Germany
- Avoids derating of lines
- Reduces redispatch cost & lowers end user energy cost

 |

CASE STUDY

Better utilisation of existing power lines and lower cost for customers in Germany

TenneT TSO (Germany)

2 x 100 MW / total 200 MWh across two strategically positioned sites in the North and in the South

SERVICES

- Grid stability & increase utilisation
- Congestion relief

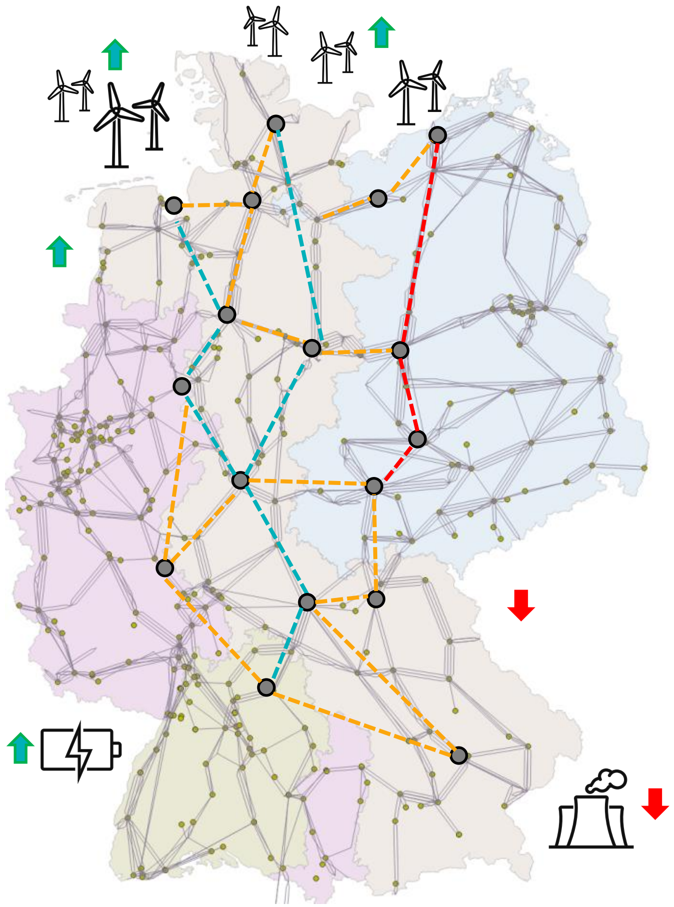
IMPACTS

- Ease bottlenecks transporting wind energy from northern Germany
- Reduces redispatch cost & lowers end user energy cost
- Reducing the need for grid expansion measures

Background

GRID BOOSTER PILOT PROJECT KUPFERZELL

Rising costs for transmission system operation triggers innovative grid solutions



Energy Policy Goals

- **04/23**: phase-out of nuclear power plants
- **2038**: phase-out of coal power plants (minus >30GW)
- **2030**: 80% RE-share in energy consumption

  e.g. >30GW offshore

  e.g. >115GW onshore

Consequences

- Growing imports to Baden-Württemberg
- Growing difference in generation & load (north – south)
- Growing costs for curtailment, redispatch and system operation

Solutions

- Accelerate grid expansion for large grid projects through changes in regulation
- Optimize utilisation of & load factor for existing lines through innovative solutions

***2018**: **first concept idea** for grid boosters, **2019**: **confirmation of TransnetBW** Grid Booster project in national Grid Development Plan*

