Design and Validation of a Wide Area Monitoring and Control System for Fast Frequency Response in future Low Inertia Systems

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nationalgridESO

GE ●BELECTRIC centrica Flexitricity MANCHESTER 1824 The University of Manchester University of Strathclyde Ørsted SIEMENS Gamesa RENEWABLE ENERGY

USER SPOTLIGHT SERIES BY RTDS Technologies

Overview

- Motivation of fast frequency control
- Introduction of EFCC – the fast frequency control scheme
- Testing configurations and test results
  - Implementation of Power-Hardware-in-the-Loop (P-HiL) testbed using Motor-Generator (MG) Set
  - Application of PHiL testbed for validating the EFCC scheme
- Conclusions

The changing power system

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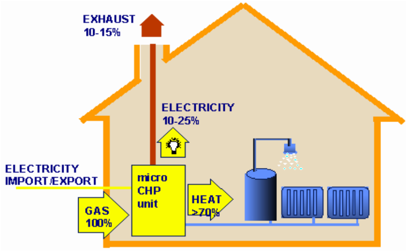

GB Power System

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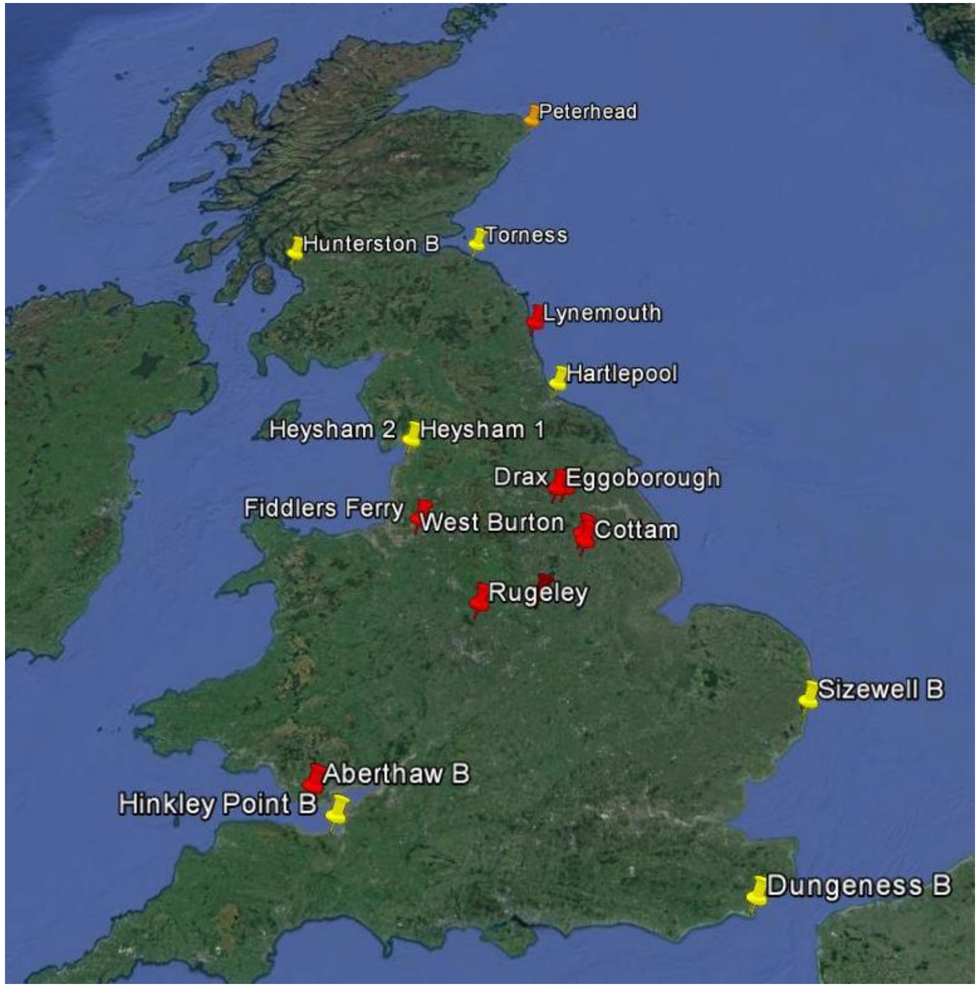
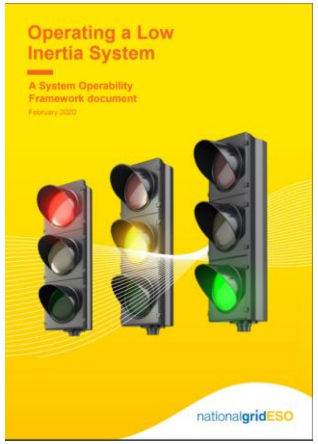


Current Coal & Nuclear Power Stations

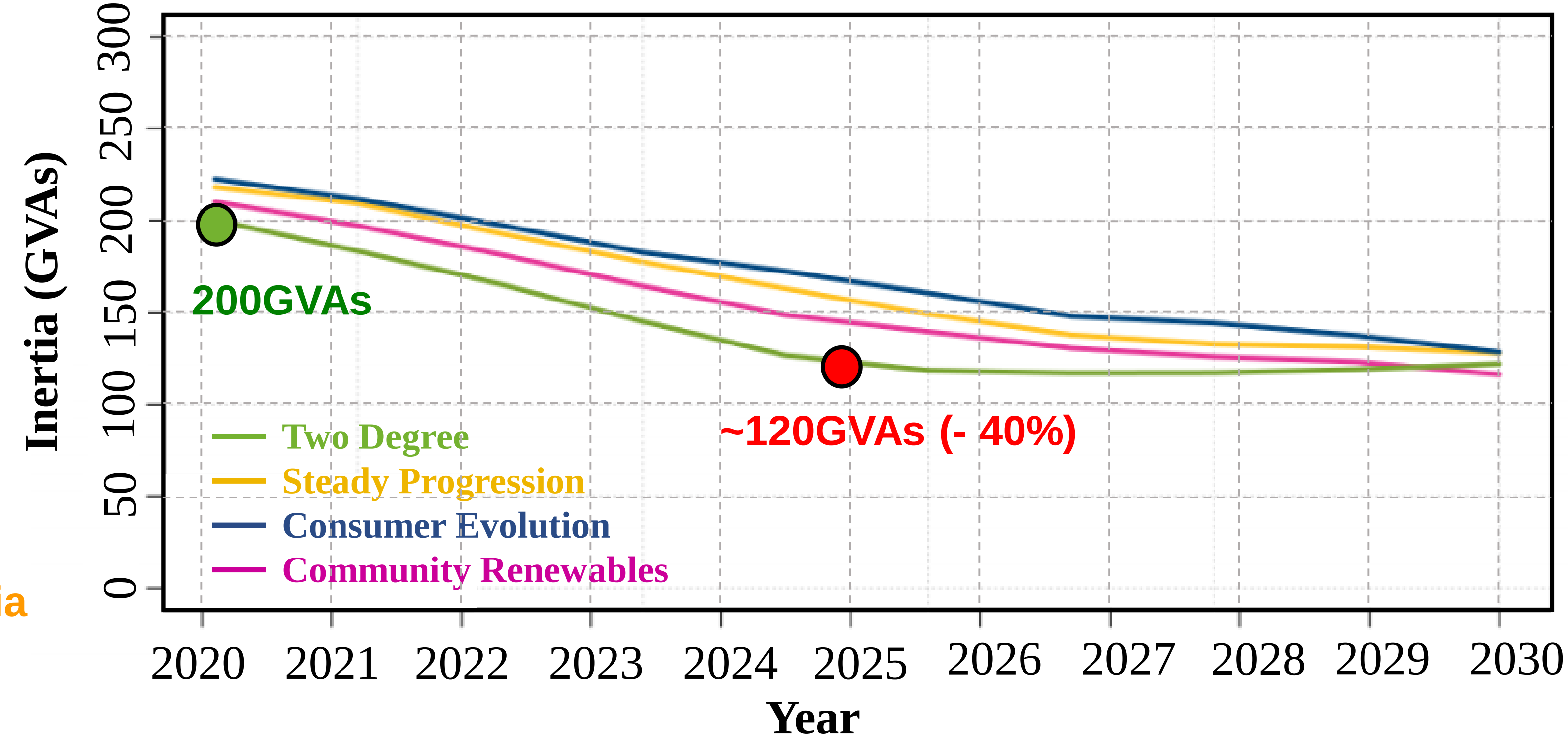
Post 2025 Coal & Nuclear Power Stations

Challenges resulted from changing generation:

- **Reduced inertia**
  - Higher RoCoF – faster frequency deviation
  - Frequency control challenges – increased operational cost



National Grid ESO, Operability a Low Inertia System



Impact of reduced inertia on frequency control - loss of 1.32 GW generation

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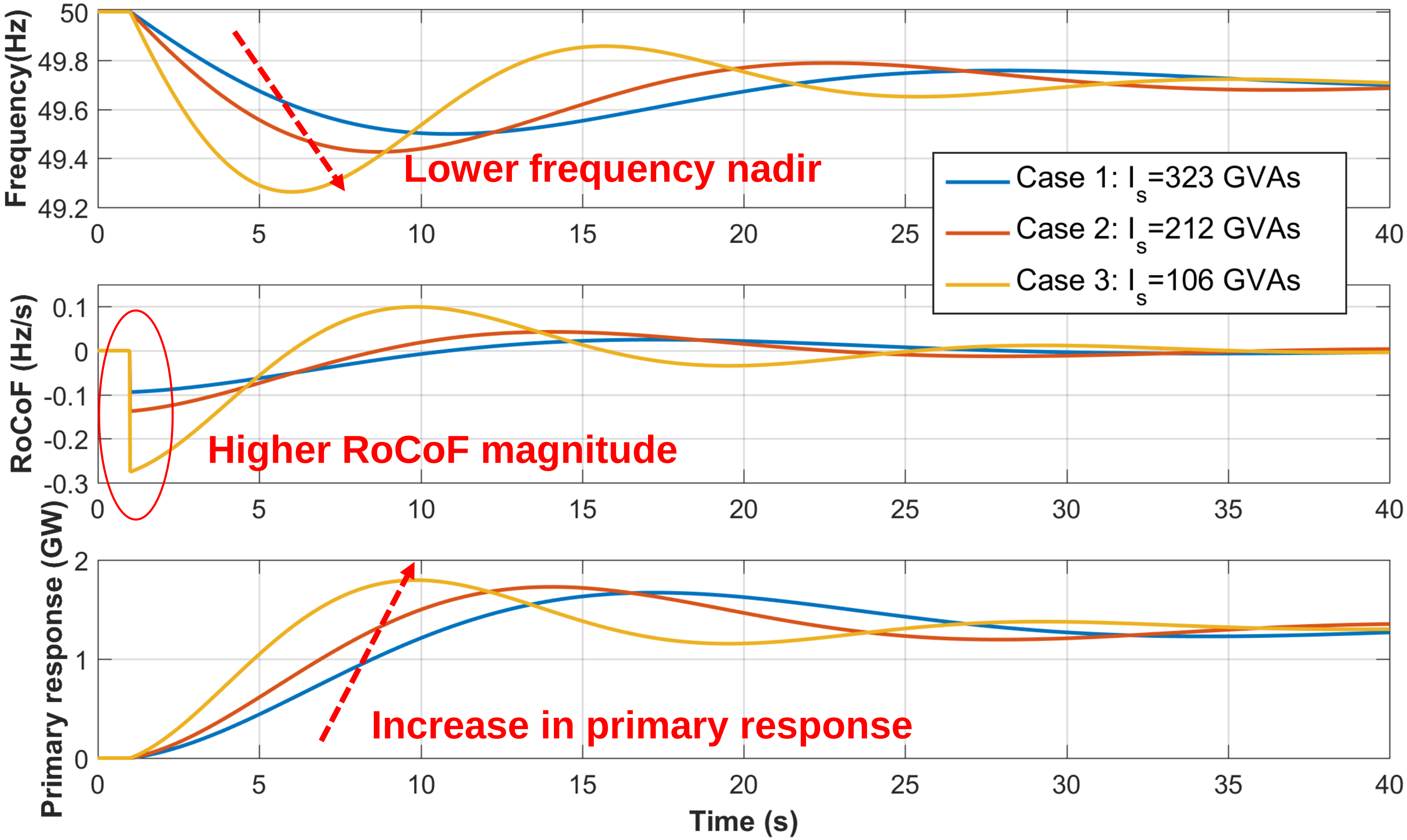

Challenges with increasing penetration of renewables

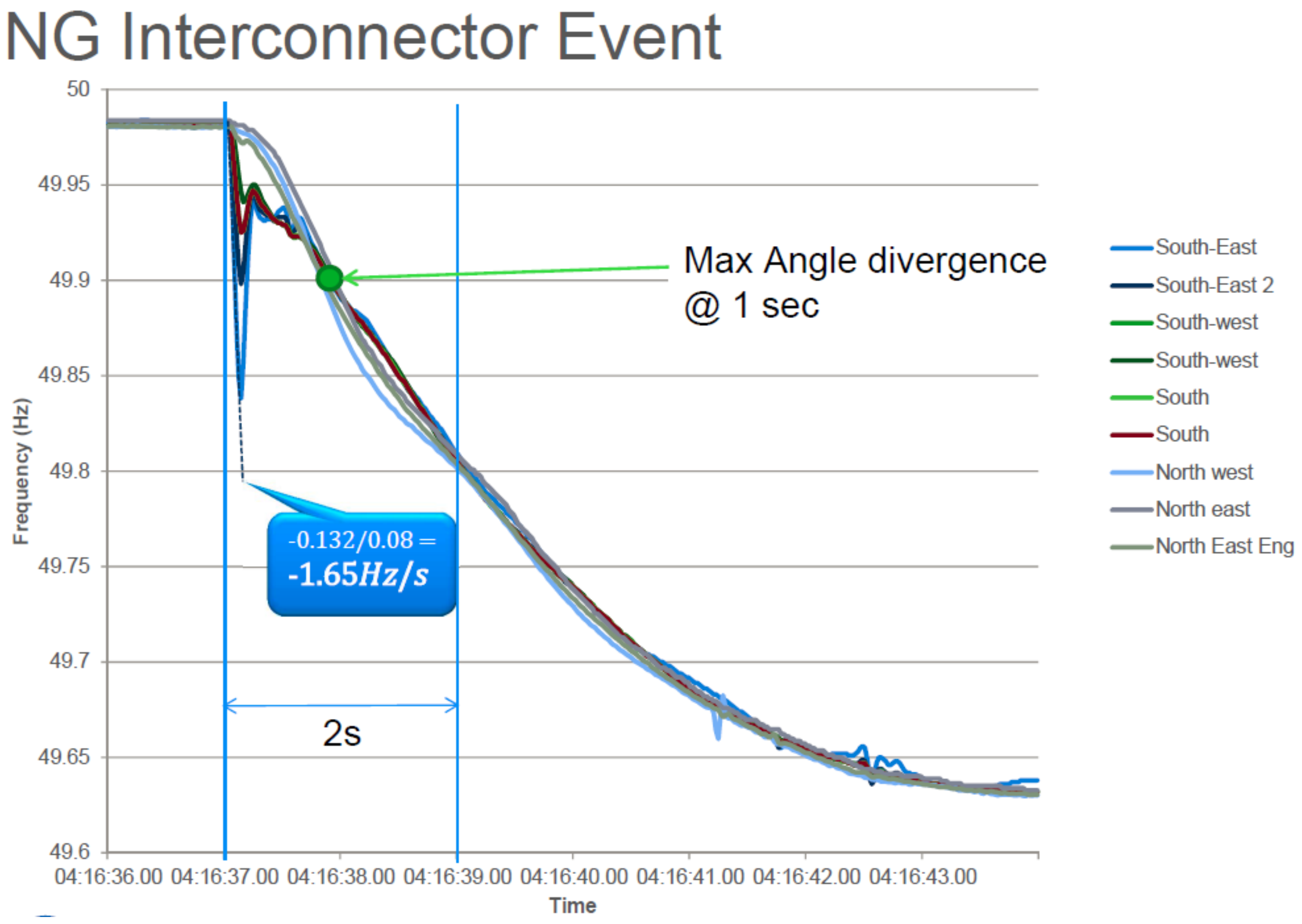

Diagram from GE slides provided by Douglas Wilson

- **Increasing variability of system inertia**
- **ROCOF not equal across system (regional variation)**
- **Need for locational consideration for fast frequency response**

Challenges with increasing penetration of renewables

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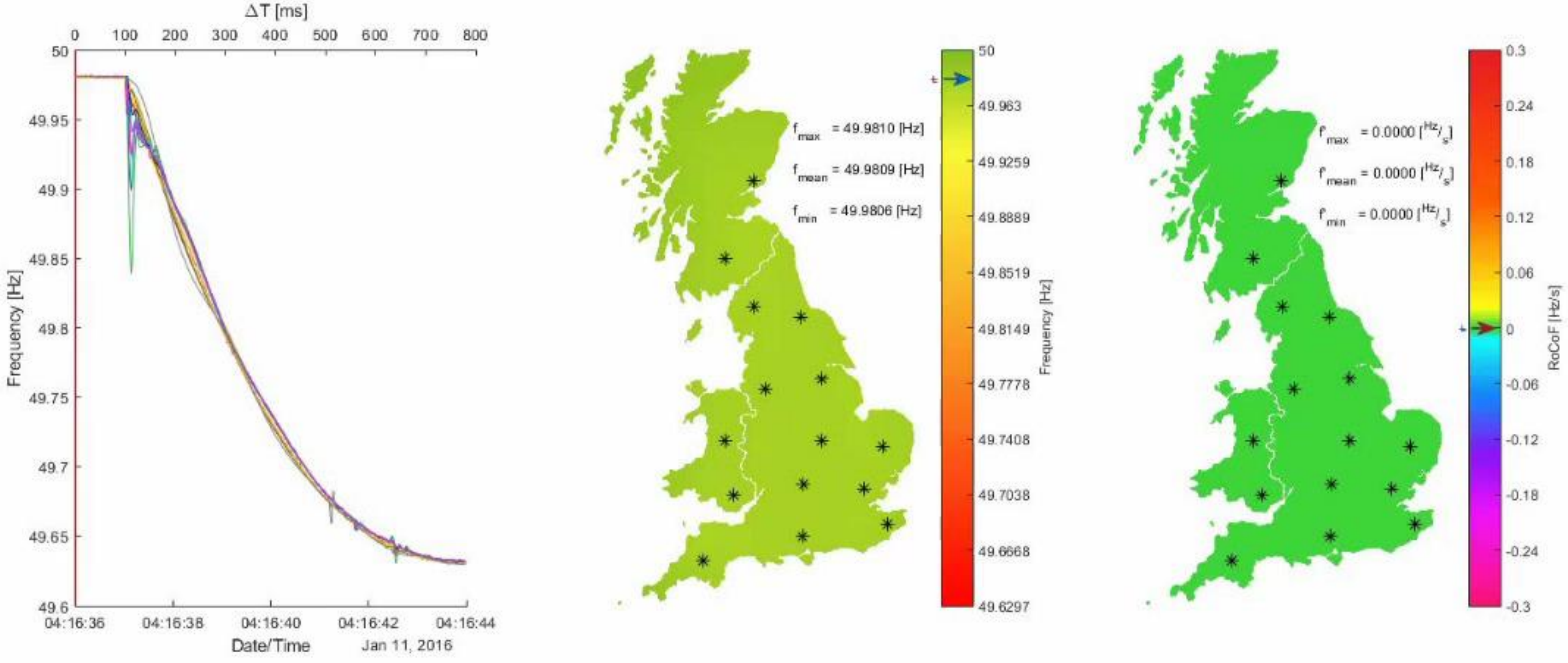

Historical Event

Potential solution: EFCC project

- £9m+ project led by National Grid
- Fast frequency response using wide area monitoring and control techniques
- Locational impact of disturbance is considered for resource deployment
- Coordinated response from a variety of types, e.g. energy storage, demand side, wind, etc.

The EFCC scheme

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Central Supervisor (CS)

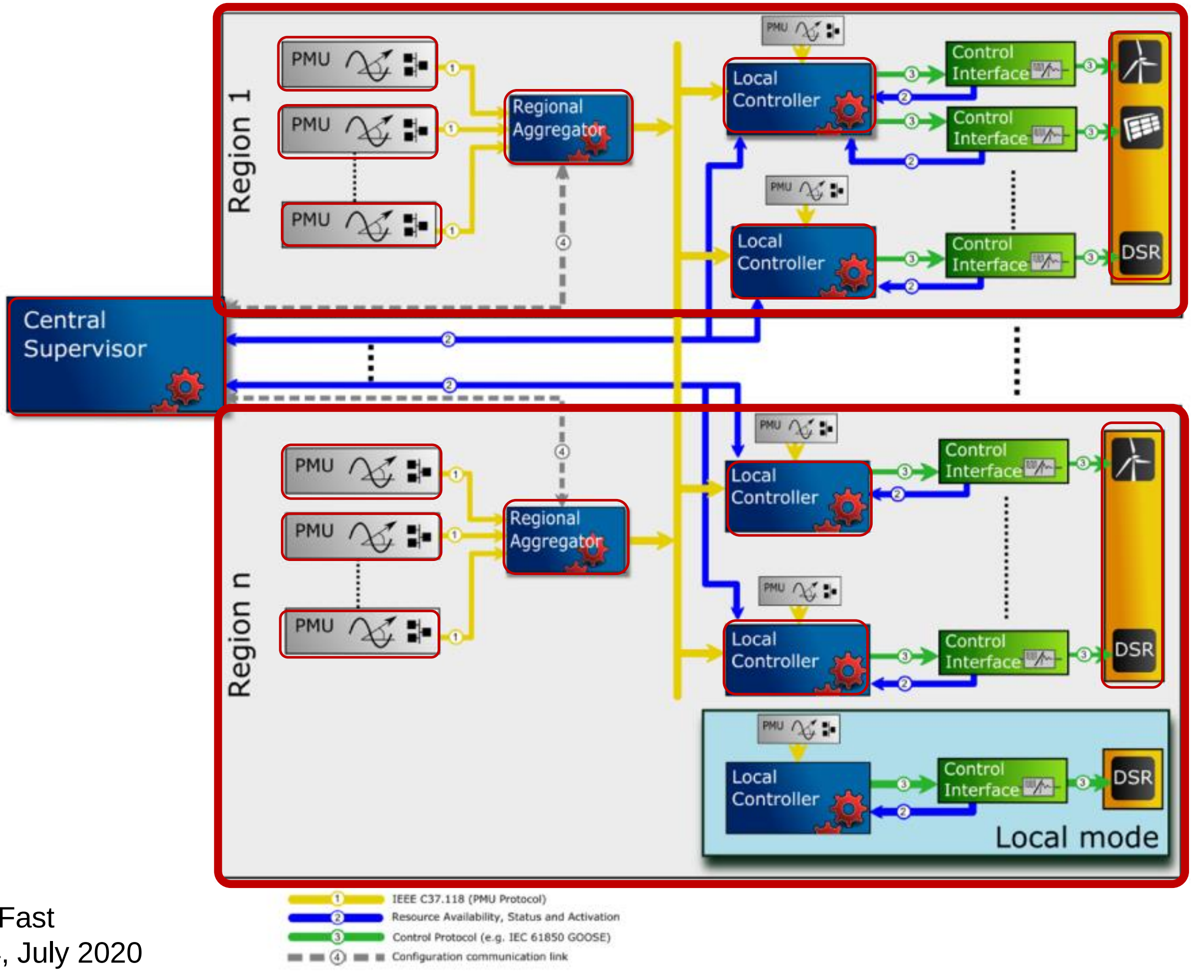
- Only one for the whole system
- Updates of resource information (availability, duration , etc.)

Regional Aggregators (RAs)

- Aggregating PMU measurements
- One per region

Local Controllers (LCs)

- Real-time monitoring and detection of events
- Control resource to deploy response
- One per resource



Q. Hong et al., "Design and Validation of a Wide Area Monitoring and Control System for Fast Frequency Response," in *IEEE Transactions on Smart Grid*, vol. 11, no. 4, pp. 3394-3404, July 2020

Power Networks Demonstration Centre

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HV Network (11kV)

- 3 x underground feeders for a total equivalent length of 6km.
- 1 x overhead feeder for a total equivalent length of 60km
- 11kV/400V transformers from 0.5 MVA to 25kVA
- Pole mounted auto reclosers
- Series voltage regulator

Power Supplies

- On Grid : 11kV 2MVA connection
- Off Grid : 5MVA MG Set
- 540kVA Bidirectional Triphase Converter (0-1300Vdc, 480Vac)

Power Hardware In the Loop

- Hardware in the Loop Simulation with 6 x racks of RTDS hardware
- Optical interface for interaction with both MG Set and TriPhase Converter
- 3-50µs simulation time-step

LV Network

- LV Fed from HV Network
- Mock impedances ~ 0.6 km
- Load banks total ~ 600 kVA
- Indoor and outdoor test connection points

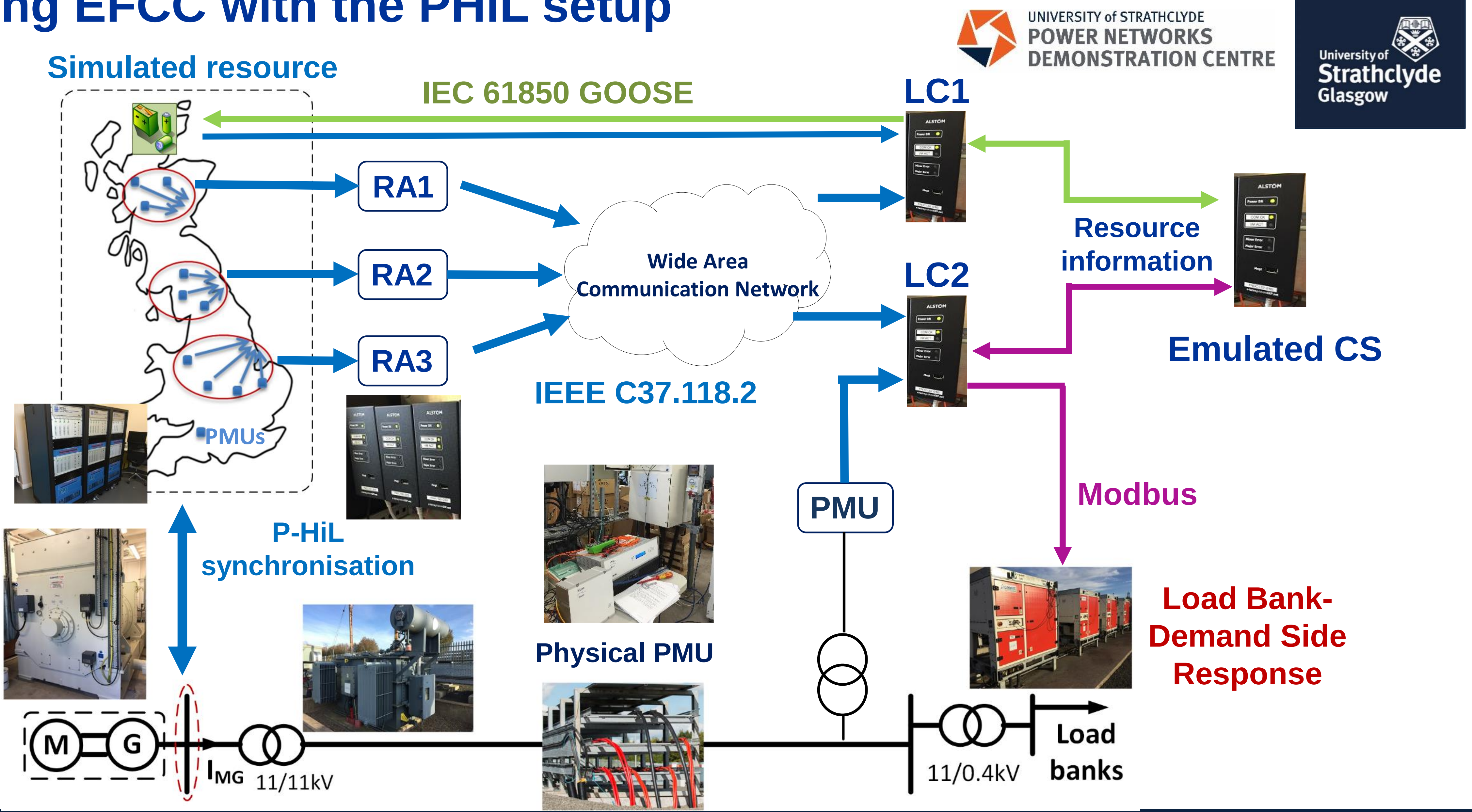
Industry Standard DMS/SCADA/Historian

- PowerOn Fusion monitoring control and switching management
- OSISoft PI Historian connected to SCADA
- Fast Data Acquisition System

Fault Throwing

- High Voltage Fault Throwing
- Low Voltage Fault Throwing

Testing EFCC with the PHiL setup



Power-Hardware-in-the-Loop (PHiL) testbed

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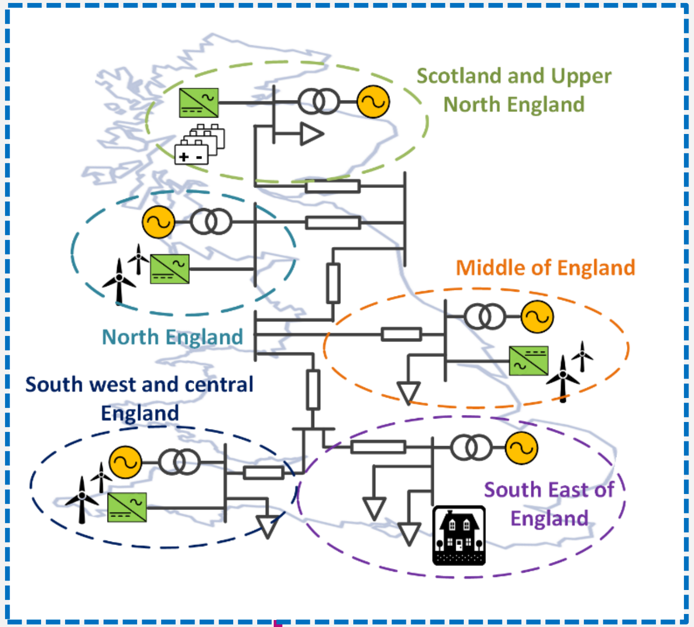
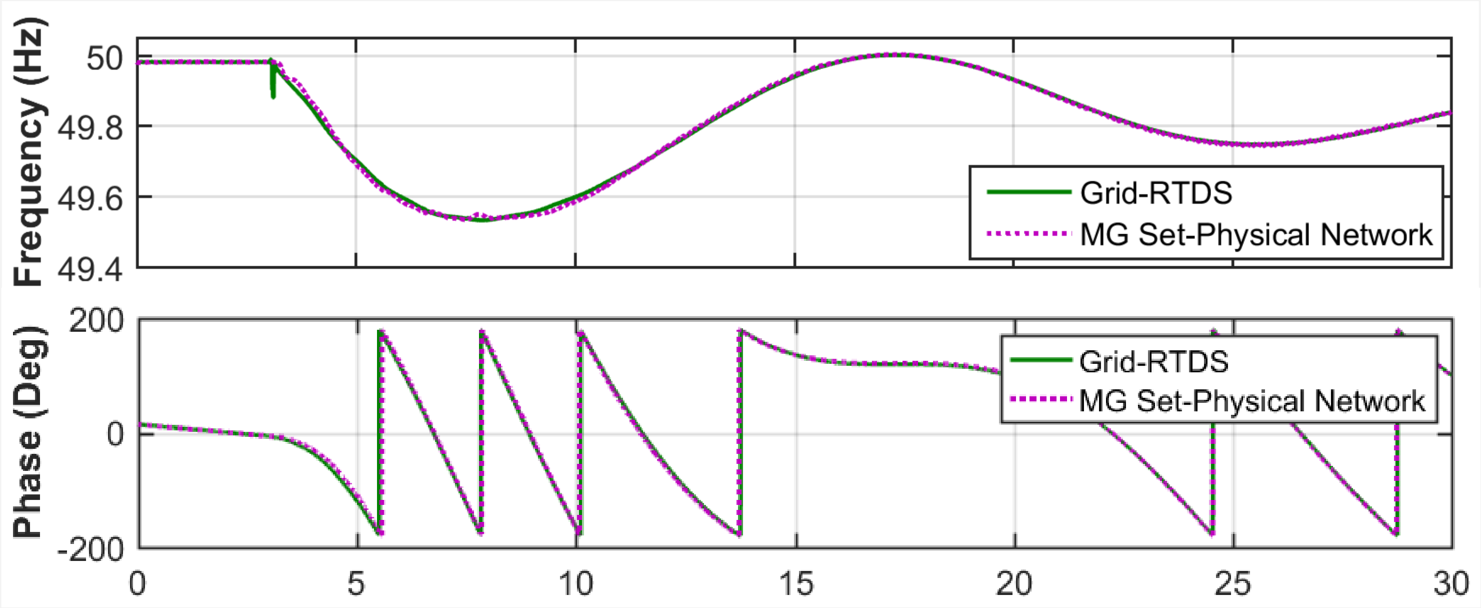
Reduced GB transmission network RTDS model



P-HiL testbed validation



Control MG set to sync with the model

Feedback scaled current to “close the loop”

Power-Hardware-in-the-Loop (PHiL) testbed

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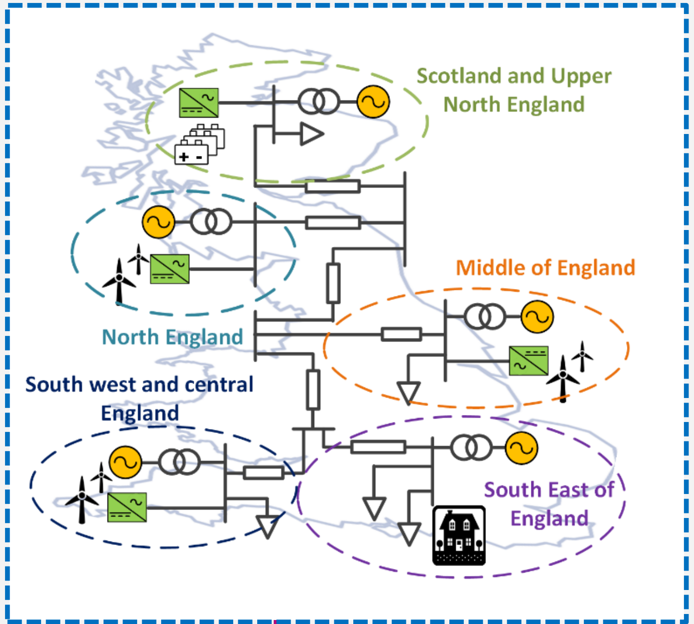
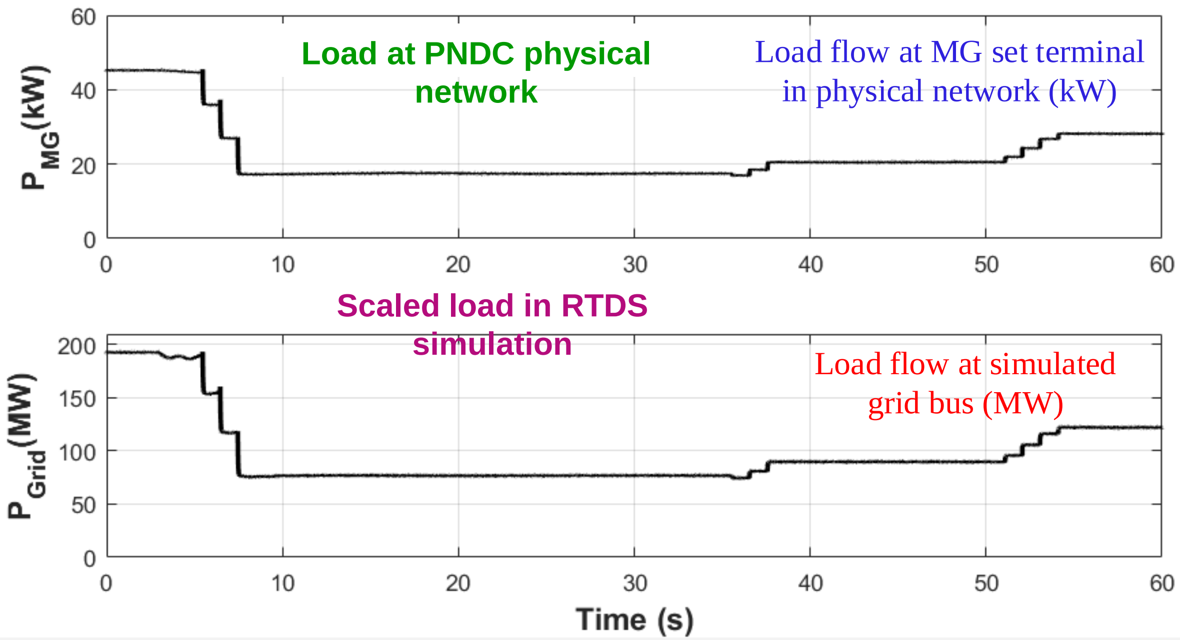


P-HiL testbed validation



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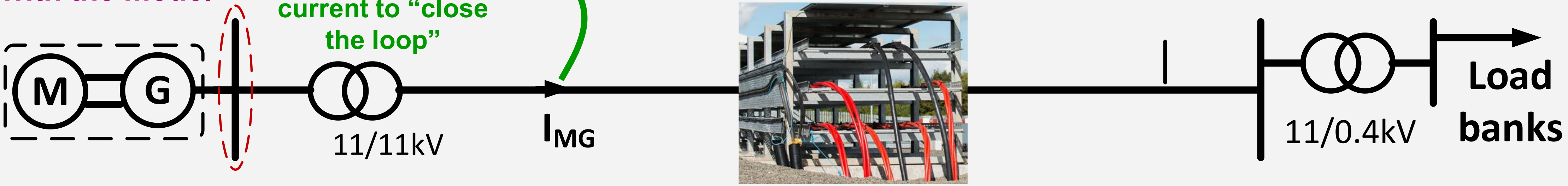

Implementation of the MG set’s controller for PHiL

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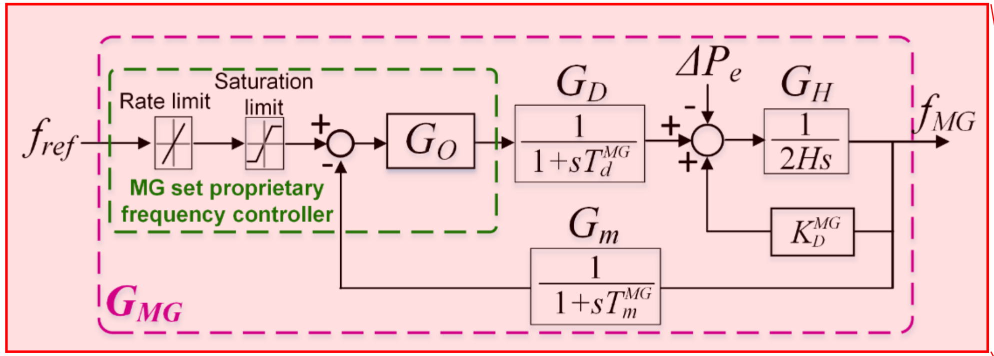
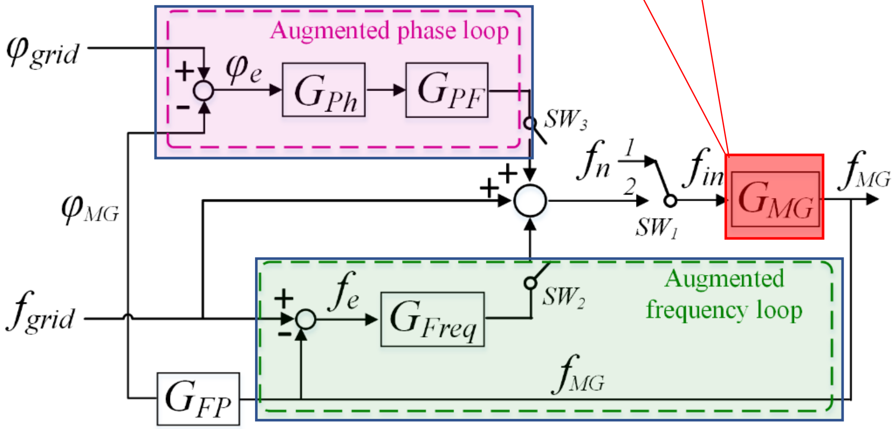
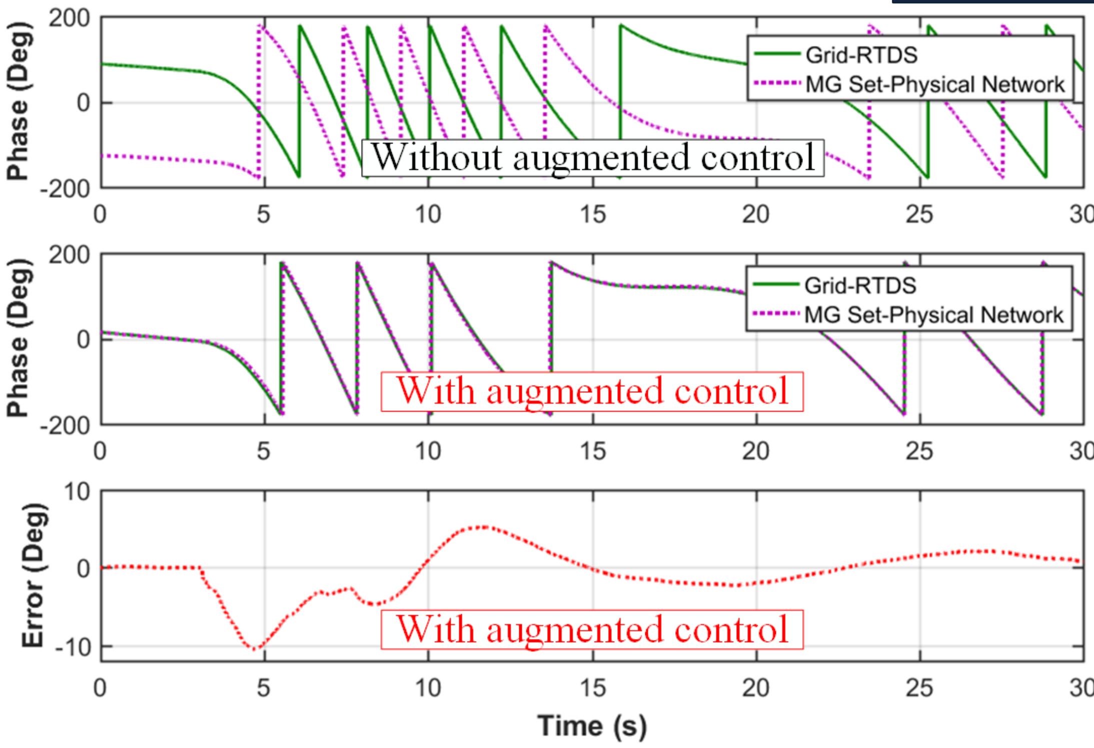
- MW scale Motor-Generator (MG) set
- With proprietary frequency controller
- Augmented frequency and phase loop developed
- Internal Model Control used for tuning



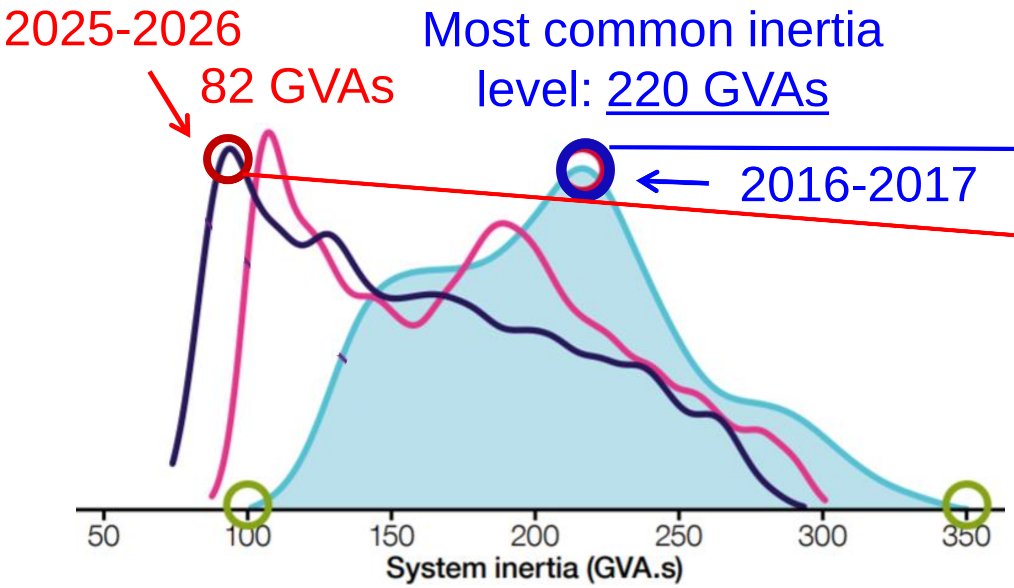


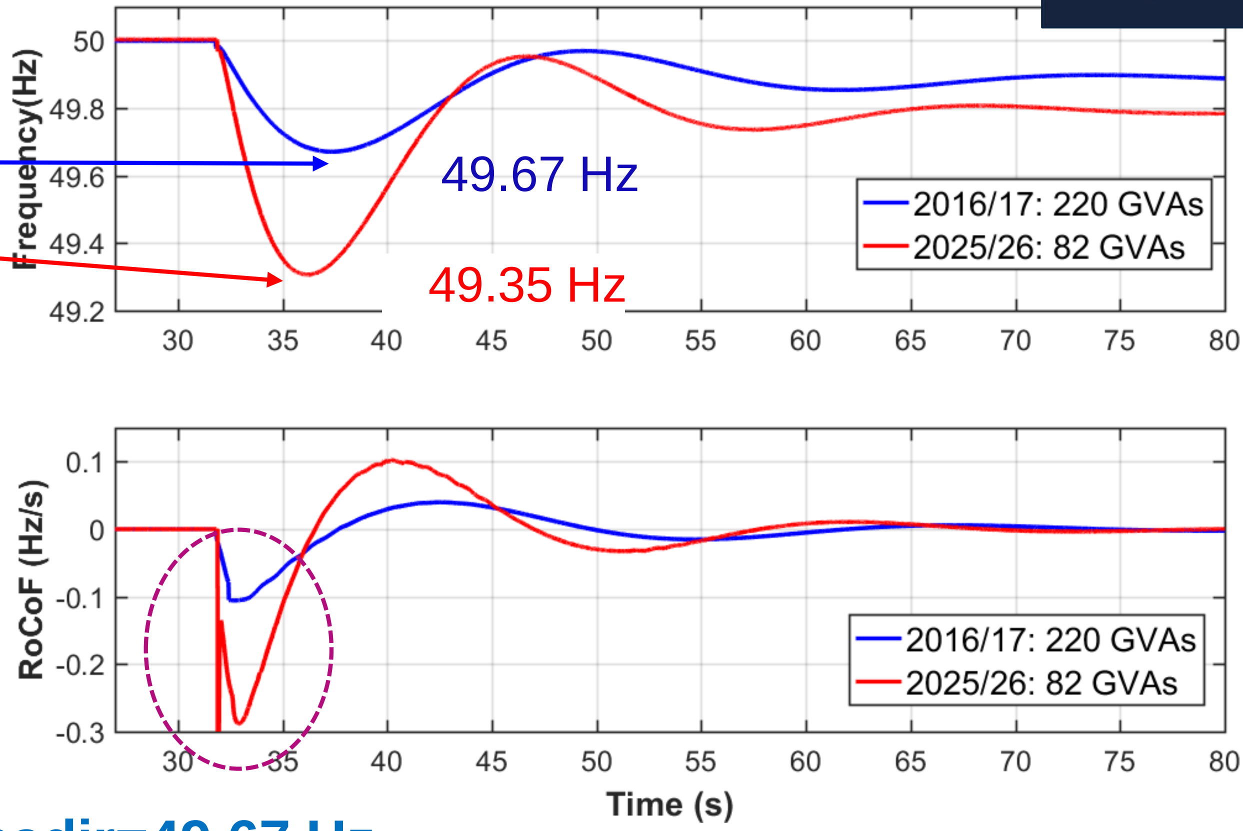


Frequency Tracking
Phase Tracking

Q. Hong, I. Abdulhadi, *et al.*, "Realization of High Fidelity Power-Hardware-in-the-Loop Capability Using a MW-Scale Motor-Generator Set," *in IEEE Transactions on Industrial Electronics*, vol. 67, no. 8, pp. 6835-6844, Aug. 2020

Testing of the EFCC system



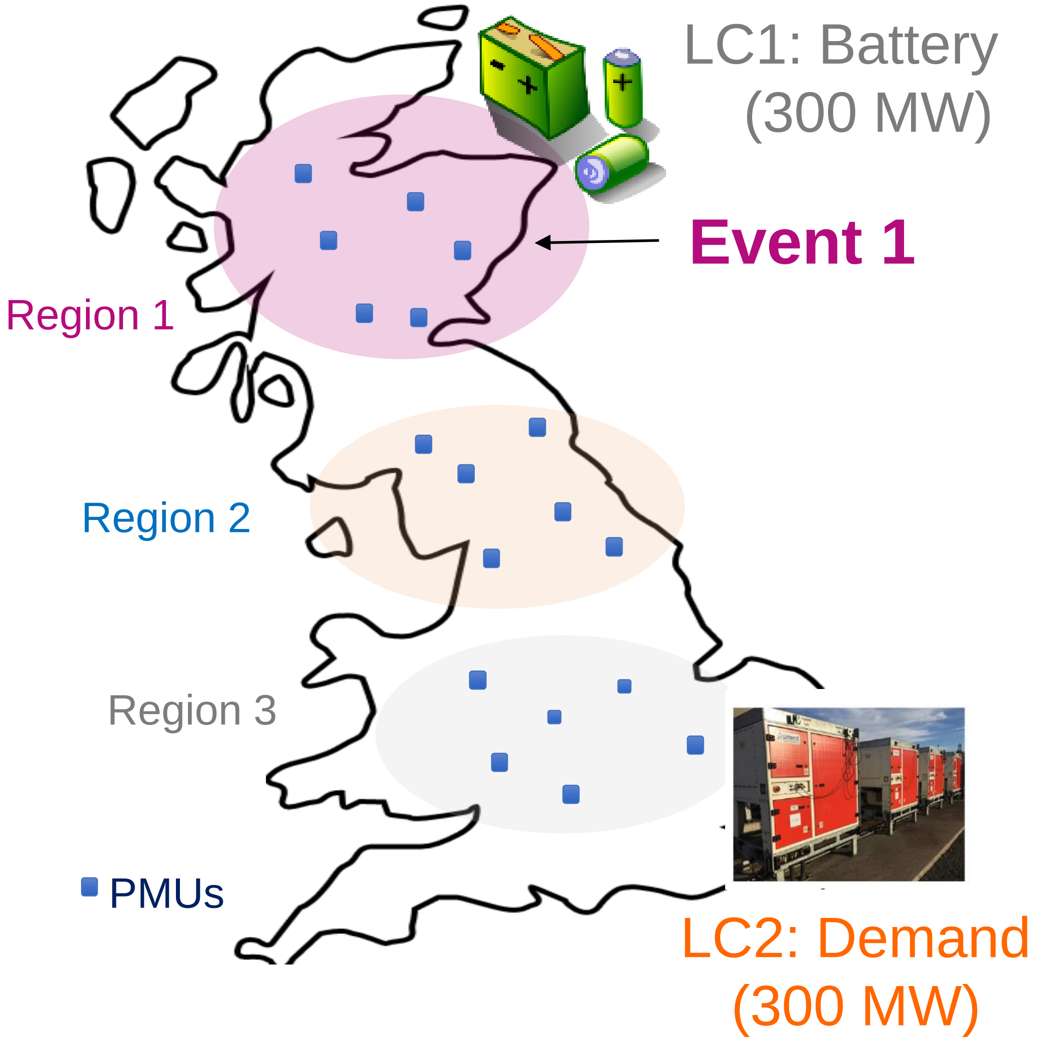


Without EFCC (1 GW loss)

- Inertia = 220 GVAs (now), frequency nadir=49.67 Hz
- Inertia = 82 GVAs (2025/26), frequency nadir=49.35 Hz

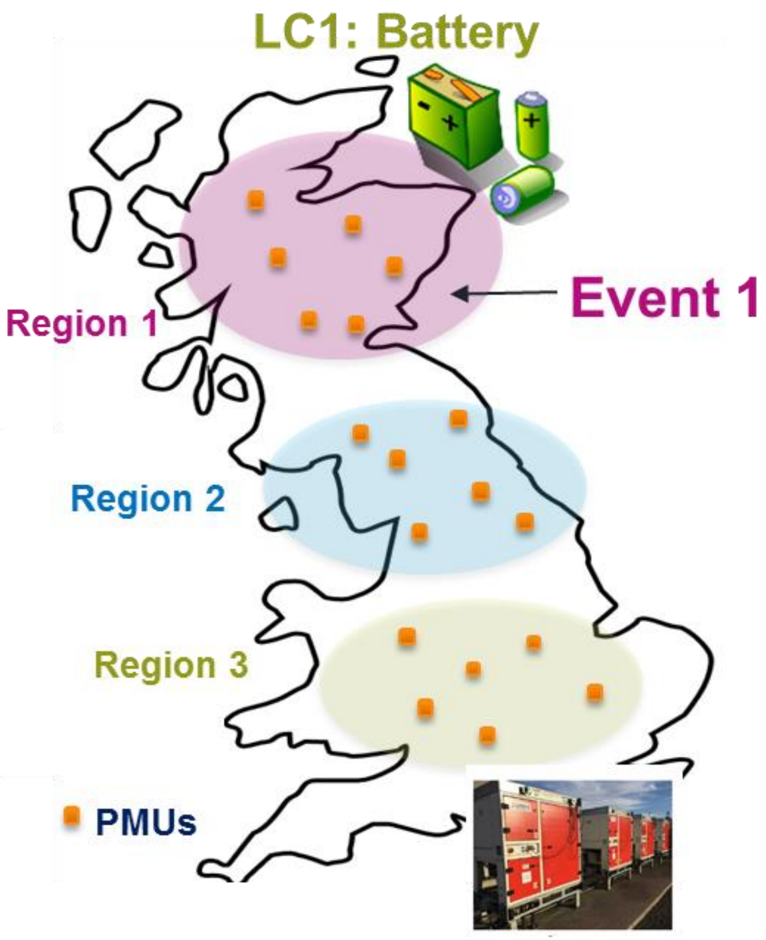
How can EFCC help and how did we validate its performance?

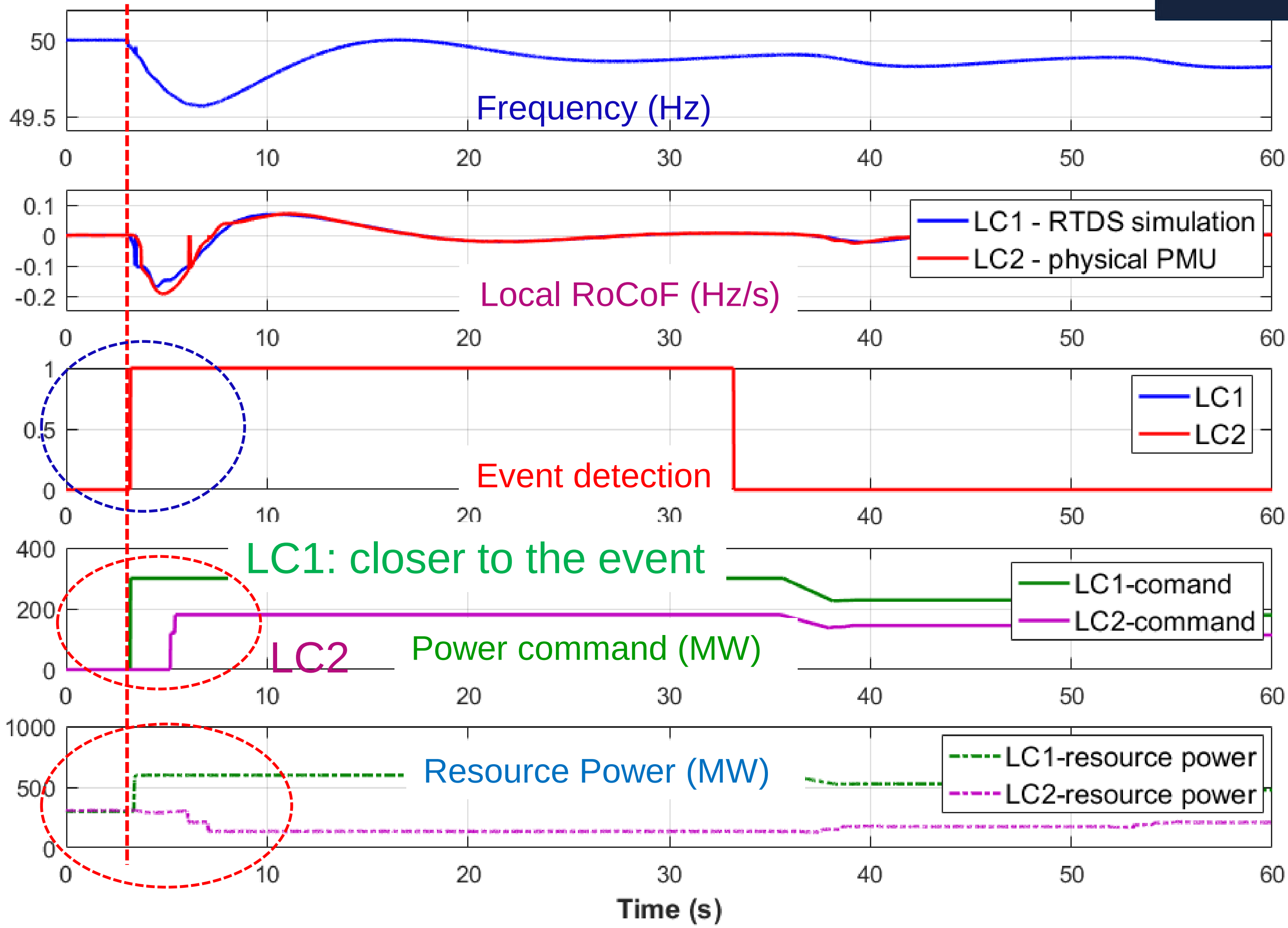
Case study: loss of generation event in Scotland



- Inertia level: 82 GVAs
- Event: loss of generation
- Size: 1000 MW
- Testing effectiveness of fast frequency response from EFCC

Case study: 1 GW loss, Region 1 (LC1 location), 82 GVAs





Case study: 1 GW loss, Region 1 (LC1 location

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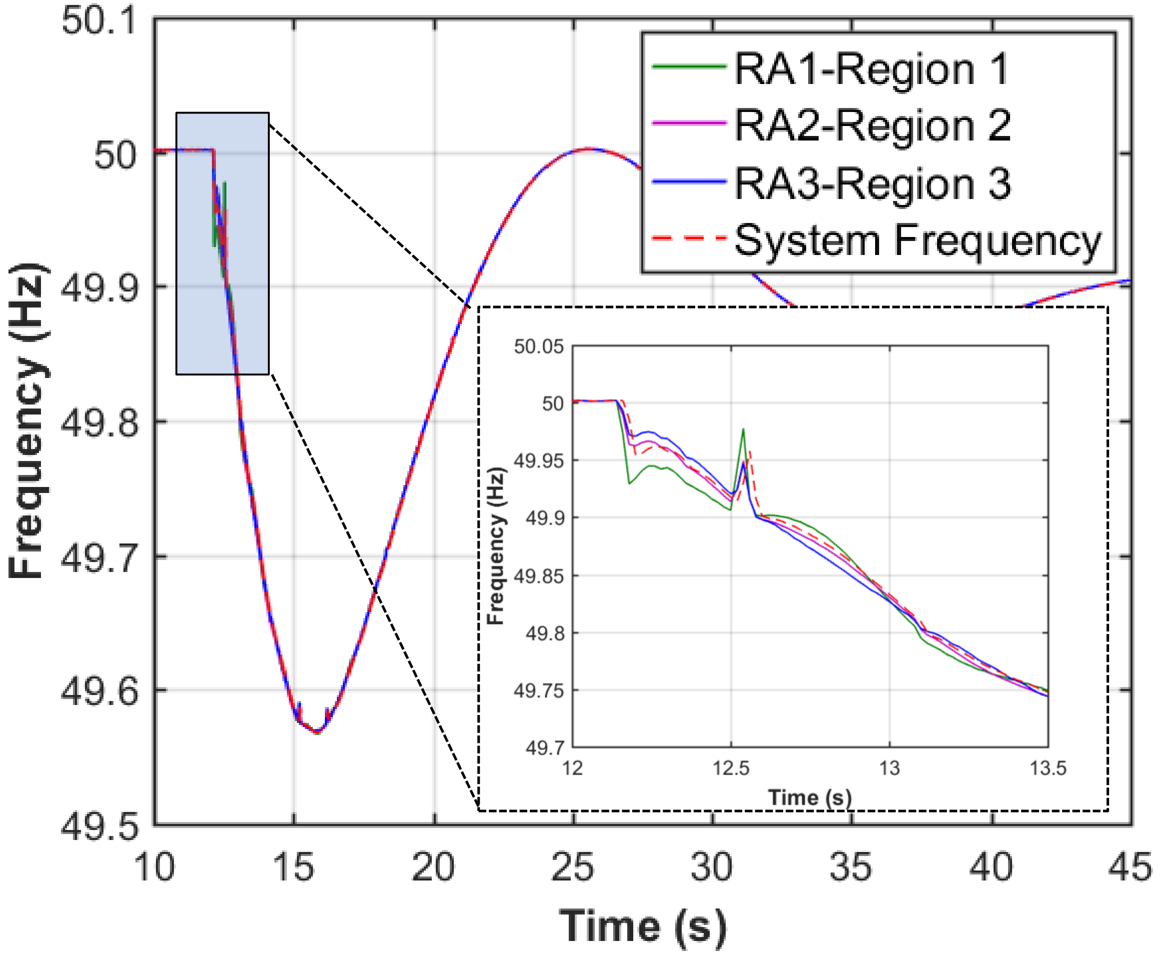
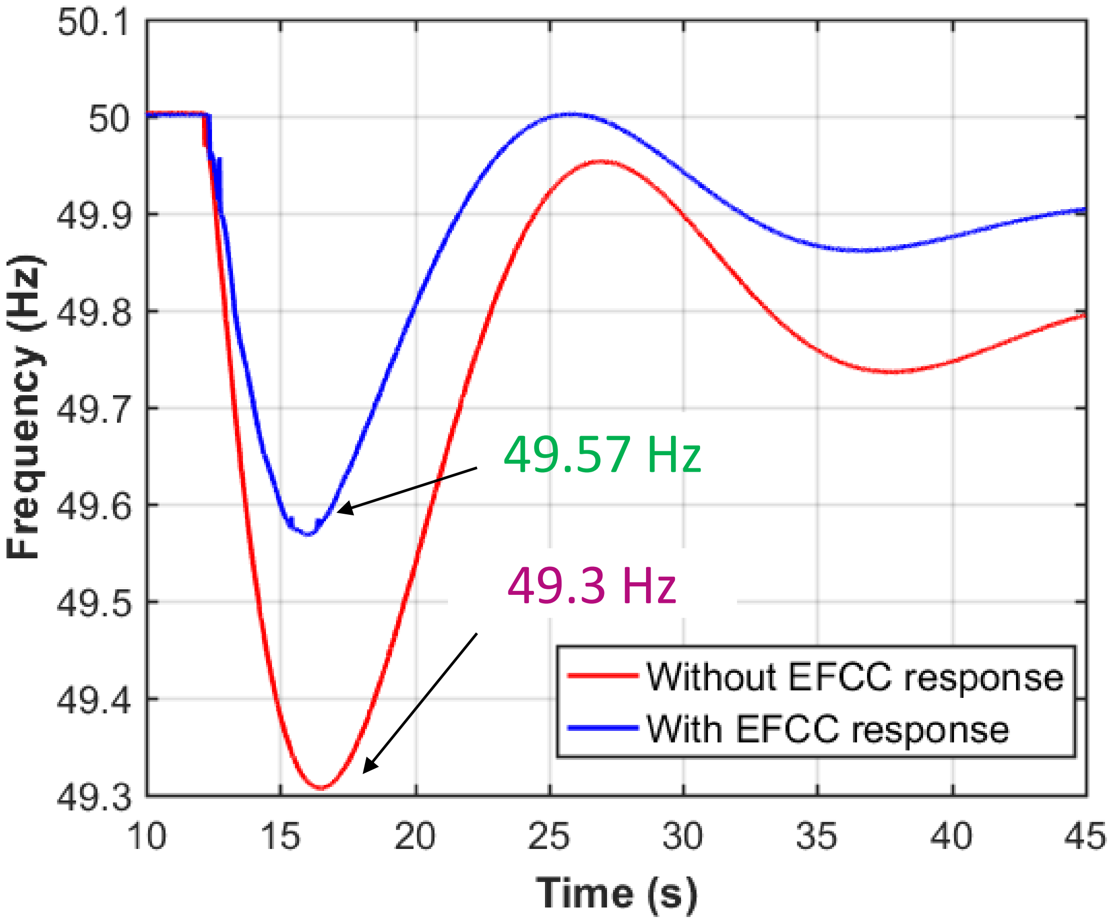


Frequency measured in RAs



Comparison: with and without EFCC response

What if we increase the resource size?

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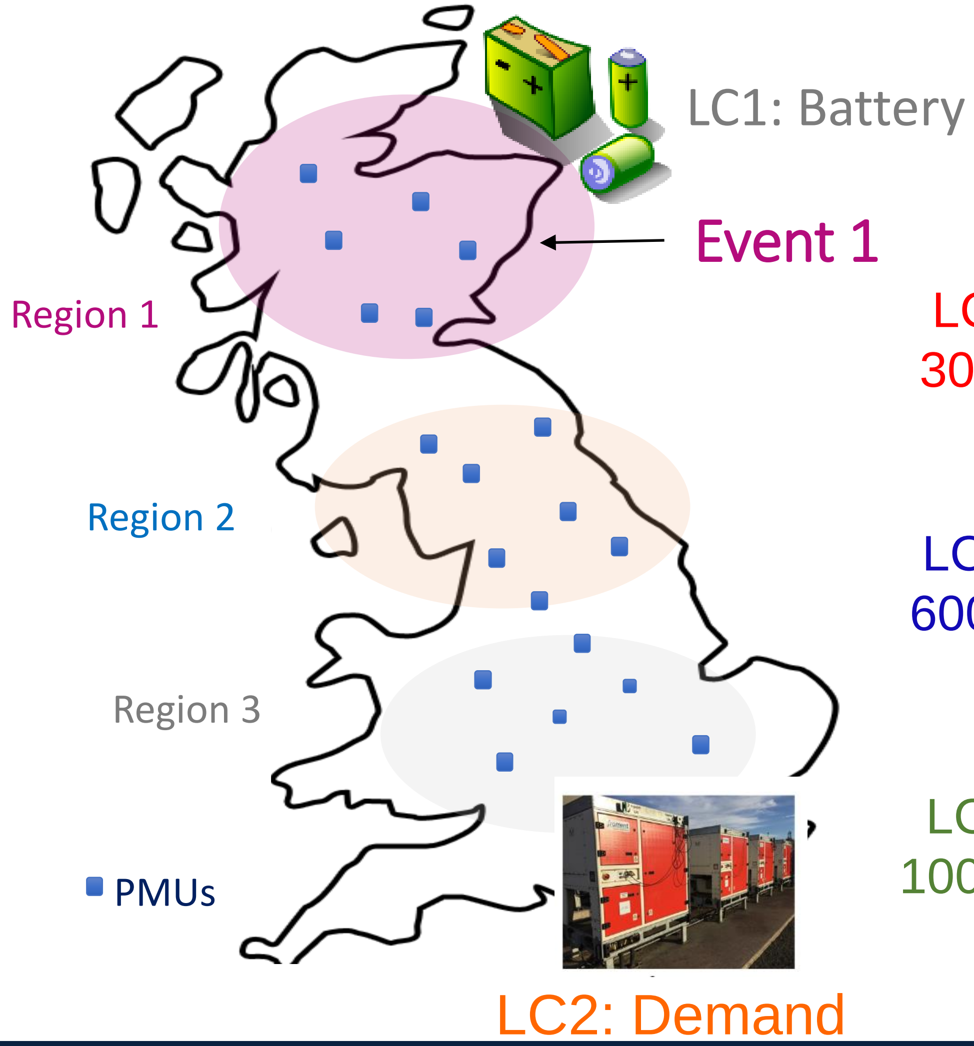

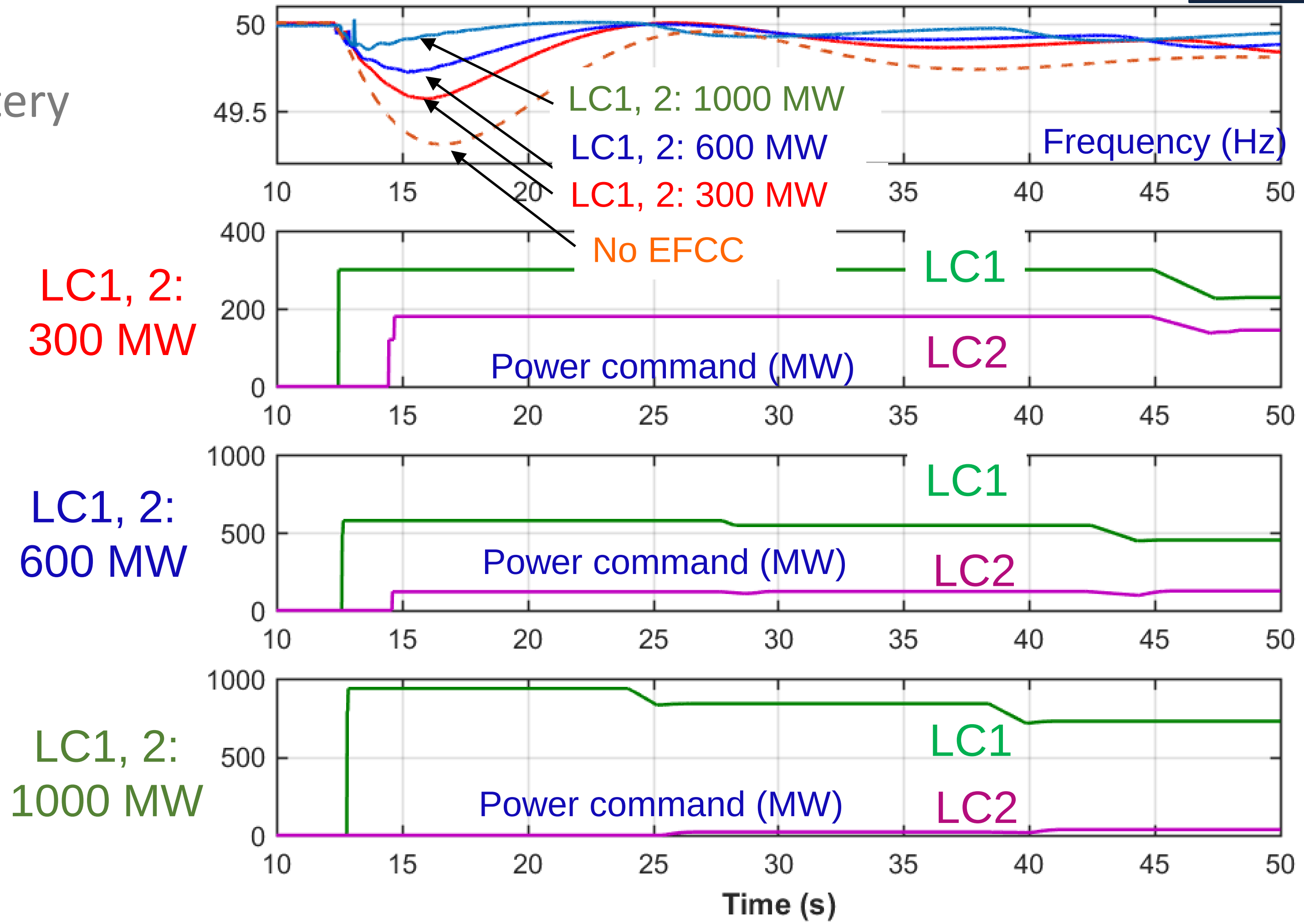

Conclusions

- Future power network faces significant challenges associated with frequency control
- Distributed energy resources (DERs) show great potential in supporting future frequency control
- EFCC scheme offers one of the frequency control solutions using wide-area monitoring and control techniques
- The P-HiL testbed provides ideal test environment for evaluating novel frequency control solutions and DER capabilities in supporting frequency control



Thank you!

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