On Advanced Wide Area Control of Future Low Inertia Power Systems

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Presentation Outline

- Challenges of frequency control in low inertia power systems
- EFCC scheme – a wide-area monitoring and control system for enhanced frequency control
- Hardware-in-the-loop (RTDS) validation of the EFCC scheme
- Conclusions

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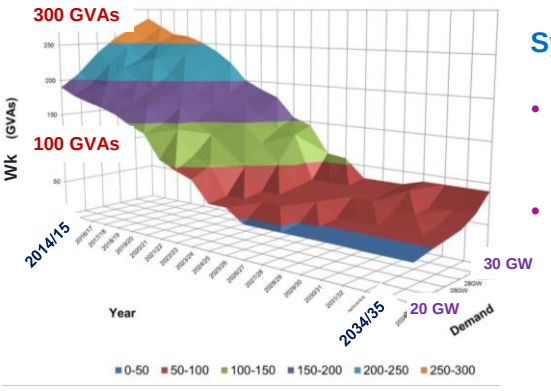
Challenges with increasing penetration of renewables



System inertia is decreasing

- **Higher RoCoF after power imbalance events -> more sensitive to disturbances**
- **Larger volume of response reserve (under Gone Green, potential additional cost of ~£200m)**

System Inertia Changes for Gone Green Scenario

http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

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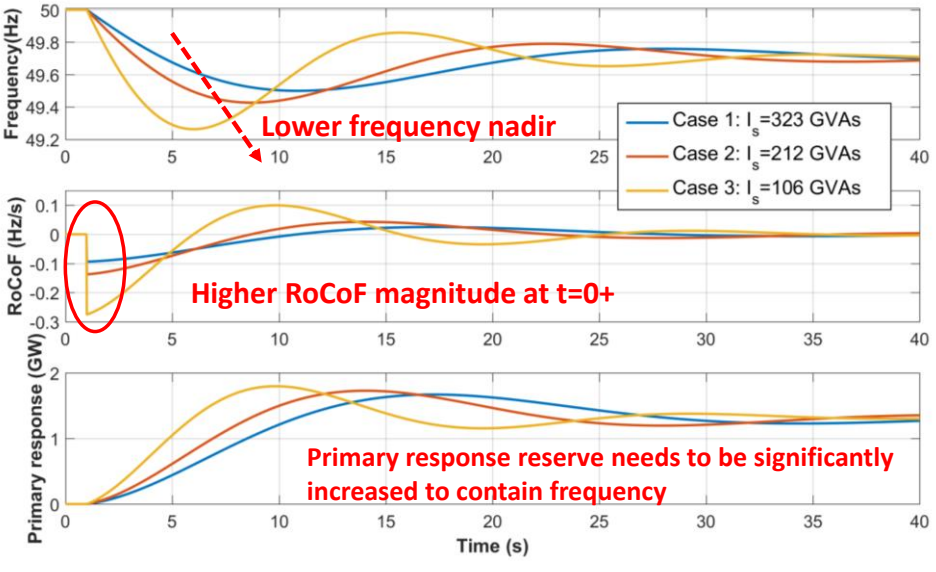
Impact of reduced inertia on frequency control - loss of 1.32 GW generation



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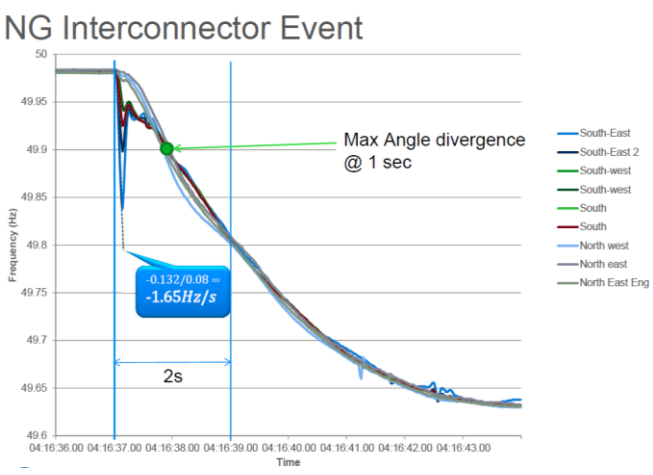
Challenges with increased penetration of nonsynchronous generation



System frequency response (source GE)

- ROCOF not equal across the system (regional inertia)
- Resource should be deployed in appropriate locations
- ROCOF depends on the disturbance location

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Proposed wide area control solution:

Enhanced Frequency Control Capability (EFCC) project

- £9m+ NIC project led by National Grid
- Fast frequency response using Synchronized Measurement Technology (SMT) - PMUs
- Locational impact of disturbance is considered for resource deployment
- Coordinated response from a variety of resources, e.g. energy storage, demand side, wind, etc.

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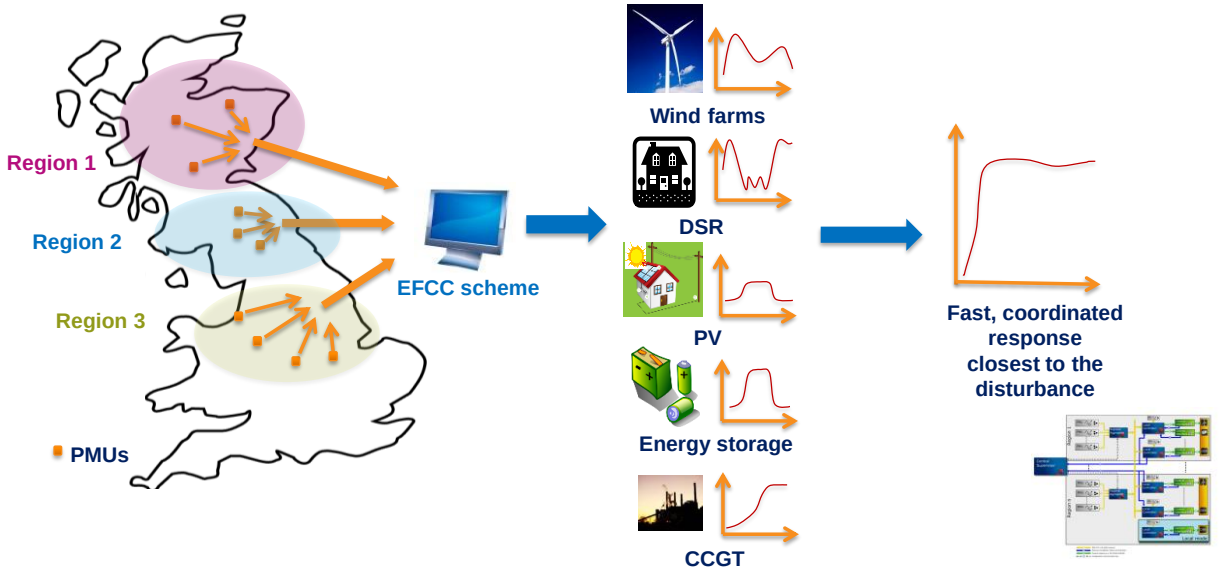
Overview of the EFCC scheme



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Active power imbalance estimation

V.V. Terzija, "Adaptive Underfrequency Load Shedding Based on the Magnitude of the Disturbance Estimation", IEEE Transactions on Power Systems, Vol. 21, No. 3, August 2006, Page(s): 1260- 1266

$$\frac{2H_i}{f_n}\frac{df_i}{dt} = p_{mi} - p_{ei} = \Delta p_i$$

Swing equation for a single generator

$$\Delta p = \sum_{i=1}^{N} \Delta p_i = \frac{2\sum_{i=1}^{N} H_i}{f_n}\frac{df_c}{dt} = \xi \frac{df_c}{dt}$$

Active power imbalance

$$f_c = \sum_{i=1}^{N} H_i f_i \Big/ \sum_{i=1}^{N} H_i$$

$$\xi = \frac{2}{f_n}\sum_{i=1}^{N} H_i$$

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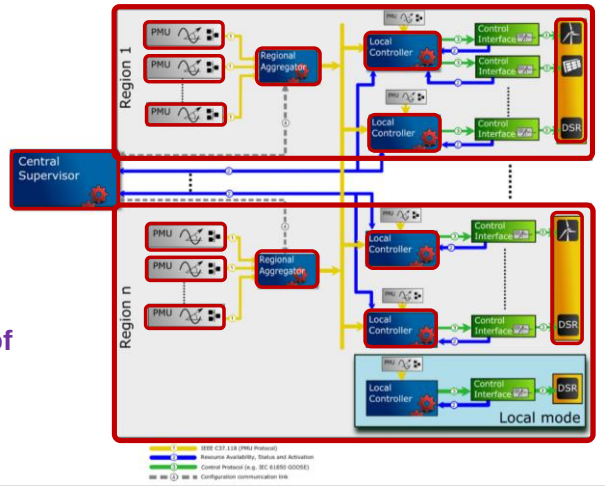
The EFCC scheme

Central Supervisor
- One for the whole system
- Updates of resource information (availability, duration , etc.)

Regional Aggregators
- Aggregating PMU measurements
- One per region

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



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Hardware in the Loop tests of EFCC

The Manchester RTDS (30 PB5 Processor Cards)

EFCC controllers

Admin PC to control simulation runs and visualise the results

RTDS to perform flexible HiL tests

Communication Infrastructure

Evaluating **EFCC** hardware components:

a) Regional Aggregators (x2)
b) Local Controllers (x4)
c) Central Supervisor (x1)

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Hardware in the Loop tests of EFCC

- Using **hardware-in-the-loop (HiL)** simulation to assess the GE-MCS for a range of system cases and operational conditions
- Simulating future power networks with high penetration of Non-Synchronous Generation (NSG) and **variable/reduced system inertia** (expressed in GVAs)
- Modelling virtual phasor measurement units (**PMUs**) and Information and Communications Technology (**ICT**)
- Rigorous testing of resilience and robustness of the **GE-MCS** connected to the primary plant for a broad range of scenarios

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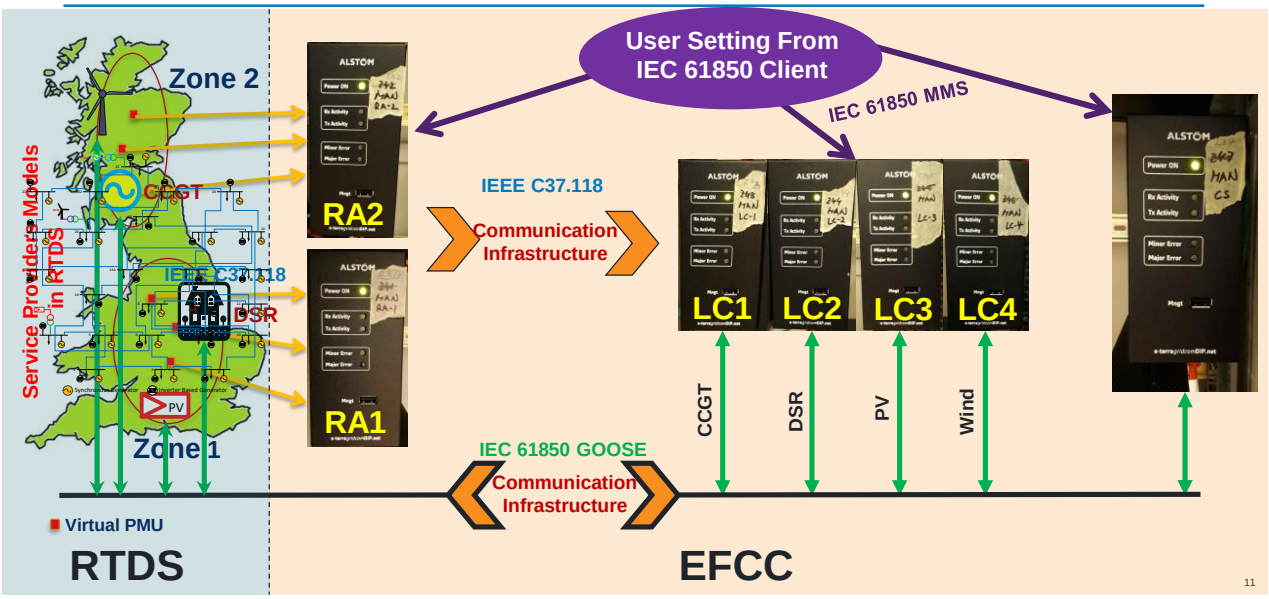
EFCC Hardware Connected to the RTDS GB Model



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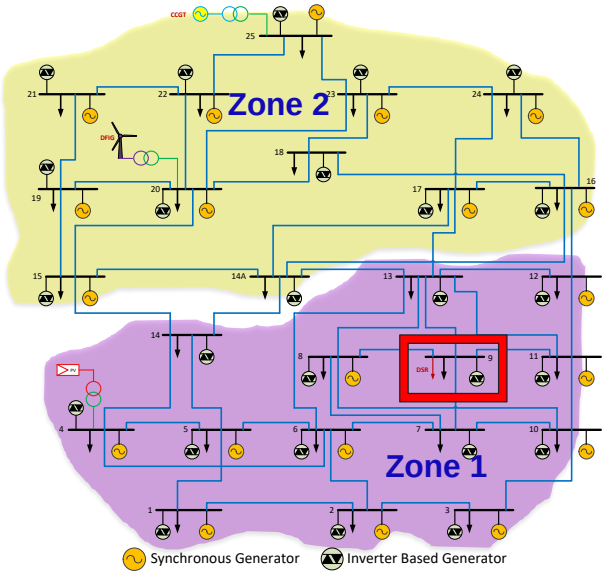
Case 1: HiL validation of EFCC

- **Demand: 42 GW**
- **Inertia: 82 GVA.s**
- **Event: Sudden load connection**
- **Size: 1000 MW**
- **Location: Bus 9**
- **Available Power in zone 1: 1500 MW**



Service Provider	Available Power (MW)
DSR	200
PV	1300
CCGT	200
Wind	300

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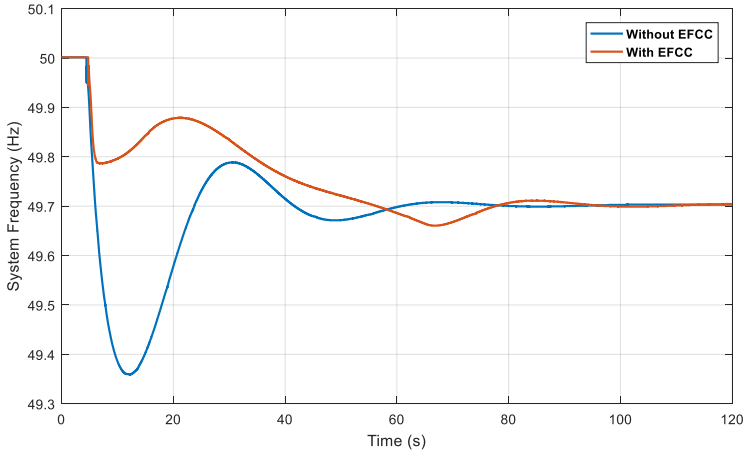
Case 1: HiL validation of EFCC



- EFCC delivers a faster and more effective frequency response (Lowest frequency is improved from 49.37Hz to 49.66Hz).

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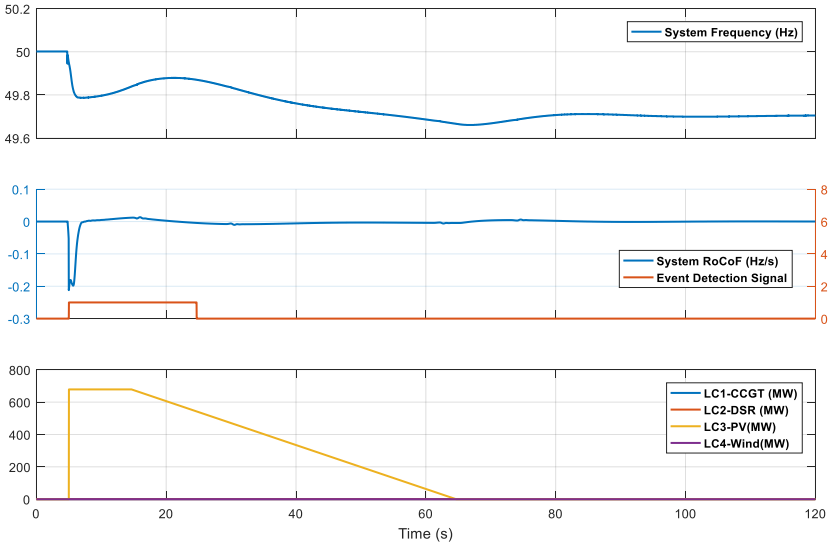
Case 1: HiL validation of EFCC



- Measured RoCoF: -0.21 Hz/s
- The event is detected within 500ms in Zone 1.
- Requested response is 600 MW which is calculated based on the measured system RoCoF and system inertia

(see V.V. Terzija, "Adaptive Underfrequency Load Shedding Based on the Magnitude of the Disturbance Estimation", IEEE Transactions on Power Systems, Vol. 21, No. 3, August 2006, Page(s): 1260- 1266.)

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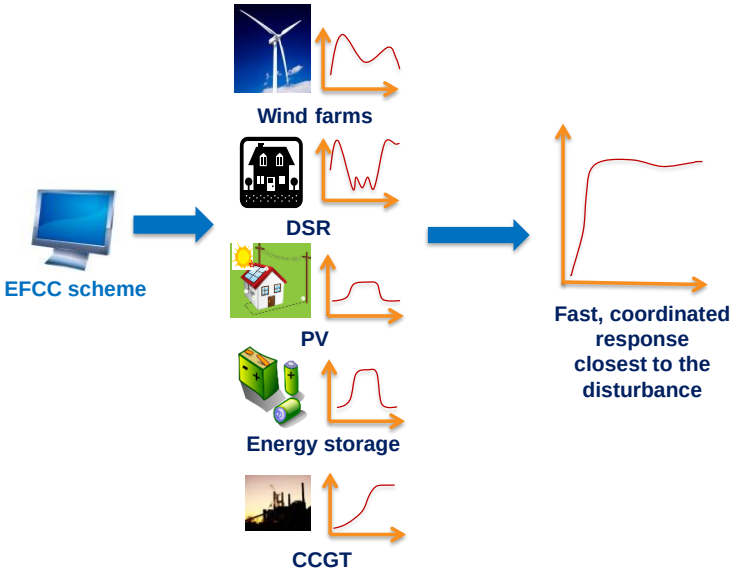
Discussion on the EFCC scheme



Who is missing?

1) **Interconnector**
2) **Synchronous Condenser**
3) **Other…**

A move towards a coordinated response of all possible active components?

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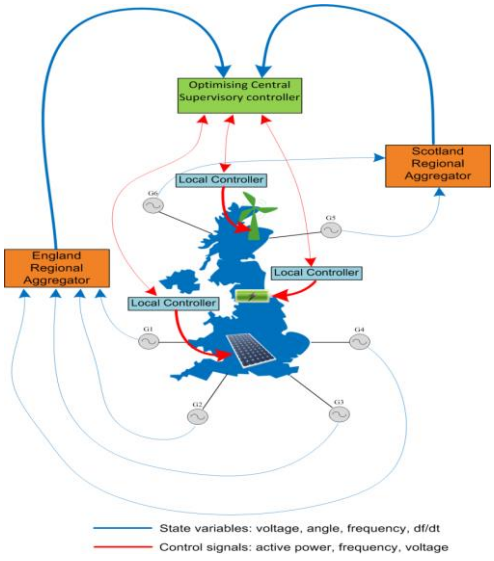
Supervisory Control Scheme - LQGC



Application of a Linear Quadratic Gaussian Controller

- ***Faster response?***
- ***Optimized response?***
- ***ICT requirements?***
- ***Robustness and flexibility?***

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Conclusions

- Significant challenges in power system frequency control resulted from increasing converter-interfaced generation
- Fast frequency response using wide area and monitoring techniques offers a promising solution for future frequency control
- The EFCC scheme has been developed and tested - it is capable of instructing fast and coordinated response to enhance frequency control in low-inertia systems
- Integration of other system components for EFCC?

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Thank you !!

More information:

http://www.nationalgridconnecting.com/The_balance_of_power/the-project.html

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