The Enhanced Frequency Control Capability (EFCC) Network Innovation Competition Project

01/05/19

Thank you for joining our webinar.

You are on mute and will remain muted.

Email questions to **box.EFCC@nationalgrid.com** or use the **chat** function on Webex.

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Contents

Project overview

Lilian Macleod

National Grid ESO

How can EFCC resolve the system operability challenges?

Reduction in system inertia, making system frequency more volatile

- System inertia is the aggregated inertia of all rotating machines that are coupled to the system
- Frequency is more volatile when system inertia is low

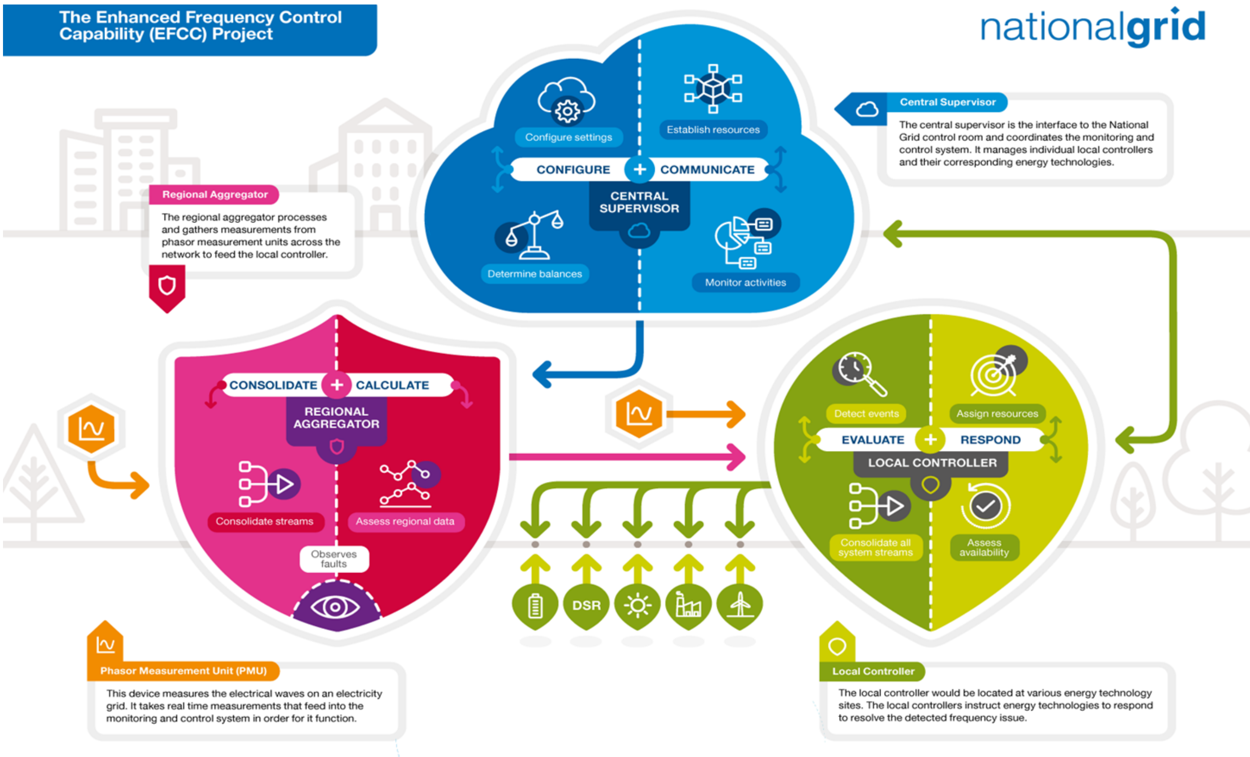
Rate of Change of Frequency (RoCoF) is increasing, faster response capability is required

- RoCoF depends on the total amount of energy stored in the rotating masses which are synchronised to the system
- Reducing system inertia requires faster delivery of response

Regional vs National Frequency: frequency differs across the system immediately after an event

- Requires proportional response to frequency events

The MCS detects and verifies frequency events, providing a targeted, proportional response



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EFCC – the future of frequency control

MSC Testing

- Frequency event caused by the system load increment/decrement in the low system inertia conditions can be successfully detected
- Event detection and resource allocation modules respond within the designed time
- Wide-area based RoCoF calculation and loss of generation estimation are accurate.
- Size of data buffering window directly determines EFCC's capability to handle degraded communication performance
- Increasing buffering window can mitigate the risk of losing packets, but can compromise the response speed

Wind
Ørsted and Siemens

- Wind - demonstrated capabilities of wind power plants to participate in fast frequency control (target time of 0.5 seconds is achievable).
- Tests combined with portfolio analysis showed the potential to harness inertial response that can increase wind turbine generation for a short period without prior curtailment.
- There is a wind speed-dependent recovery period so it is important to consider any potential second frequency dip.
- The optimisation functionality in the MCS allows the response from other service providers to be coordinated to compensate for the wind recovery period.

CCGT
Centrica

- Demonstrated that a CCGT can respond more quickly to rapidly falling network frequency by responding to RoCoF instead of deviation in frequency from a set point (normally 50.0 Hz).
- Determined that a new type of frequency response from large thermal plant is achievable and that a conventional primary response delivered at 10 seconds could be delivered approximately 3 seconds quicker and can be sustained for as long as dictated by network requirements.

EFCC – the future of frequency control

Solar Belectric

- Demonstrated that the provision of +/-frequency response services from central inverter-based solar PV plant is possible.
- Limitations include curtailment for the provision of positive frequency response, day/night availability, asymmetric response time of inverters, flat ramp rates and the volatility of available power, resulting in slow response time.
- For 2014 central converter-based solar farms, an update of the communication system and a retrofitting of the PV farm with a good network design and fast switches is necessary to provide fast frequency response

Solar and Battery Hybrid

- Hybrid solar PV and battery unit can provide additional frequency response support.
- A potential combined operating regime between solar PV and battery could have the battery providing the fast reaction part of an overall response.

System requirement for fast, coordinated frequency response

Ben Marshall

National Grid ESO

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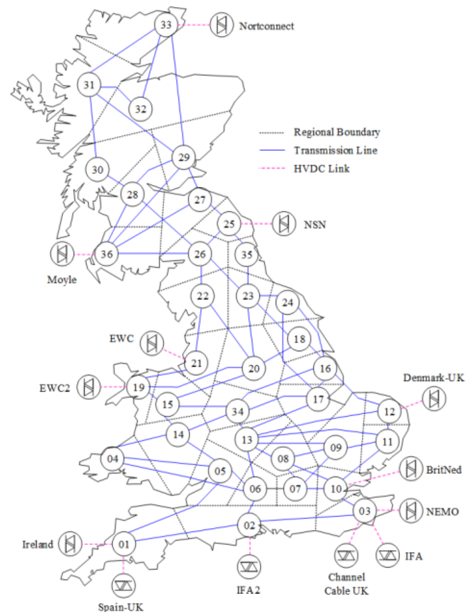
System need for fast, coordinated frequency response

Review of the system need for fast coordinated frequency response was required and techniques used

What did we do?

- Used a 36-bus reduced model of the GB electricity transmission system in DIgSILENT PowerFactory
- The inertia of the system was distributed within the model based on FES backgrounds
- Within the model, different generation/demand loss and electrical faults were tested at different GB locations.
- Developed three different wide area control methods to simulate fast, coordinated frequency response to evaluate their benefit to operational control
- The control models developed allowed the effect of wide area techniques for frequency control to be compared against the static and dynamic responses used today.
- The analysis simulated the loss of generation from different network locations to identify the effectiveness of the control methods in containing frequency.
- Further analysis investigated the impact of different service provider availability, communication delays and the time taken to measure RoCoF.



36-bus reduced model of the GB electricity system

System need for fast, coordinated frequency response

Wide area control methods were developed

How did we do it?

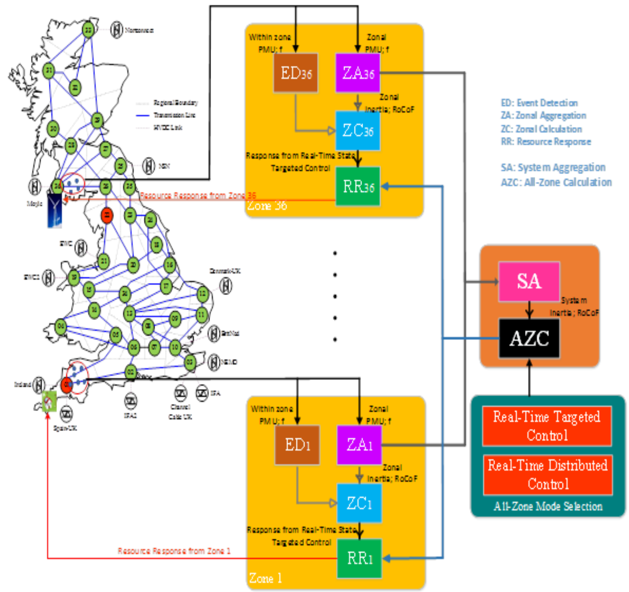
DIgSILENT programming language was used to simulate a wide area control system that would

- Measure and identify a RoCoF
- Calculate the energy imbalance during a system frequency event
- Modify the output of service providers and
- Manage the frequency deviation after a system frequency event

Control methods developed and compared

- **real-time targeted control** which approximates the operation and performance of the MCS developed GE Renewable Energy
- **real-time distributed control** where resources are deployed evenly across the network irrespective of the location of the frequency event
- **system state targeted control** where a “picture” of system inertia **prior** the event is used to provide coordination across service providers within an area based on the system frequency and RoCoF **during** the event. Though system inertia will differ before and during an event, however, this method relies on the difference being small enough to still effectively deploy response

DIgSILENT simulation environment of the control techniques



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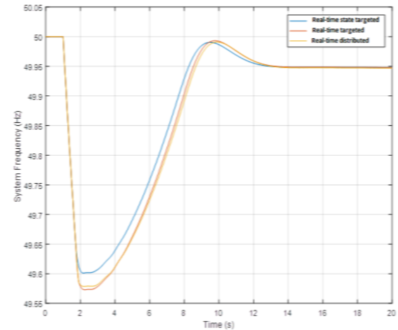
System need for fast, coordinated frequency response

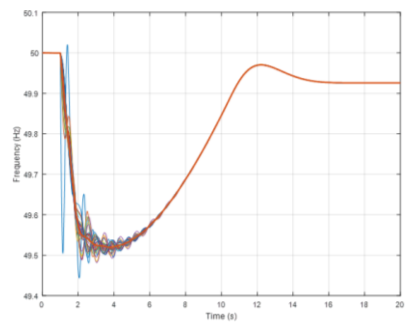
What did we learn?

- In low inertia scenarios, fast response is not enough as regional variations in frequency are more apparent.
- Control methods allowed the largest loss on the network to be increased from 550MW – 800MW which could allow more renewable generation to be accommodated.
- Up to a rate of change of frequency (RoCoF) of 0.6Hz/s, if there was sufficiently fast frequency response available evenly distributed across the network, a real-time targeted wide area control method was not needed.
- Balance between a long RoCoF measurement time and delayed response deployment. If the sample time is too short, this will give inaccurate measurements and inaccurate response.
- System state targeted control (SSTC) method can operate up to RoCoF levels of 0.6Hz/s and requires less measurement infrastructure compared to the GE Renewable Energy MCS
- SSTC method is a potential initial stage for MCS implementation because it uses less infrastructure whilst delivering equivalent system benefit in the medium term

Comparison of the control methods for max. loss in SW England (real time targeted=blue, real-time distributed=yellow, SSTC=orange)



Simulation of 2020/21 max. loss in SW England
(national frequency=orange, SW frequency= blue, SSTC mode)



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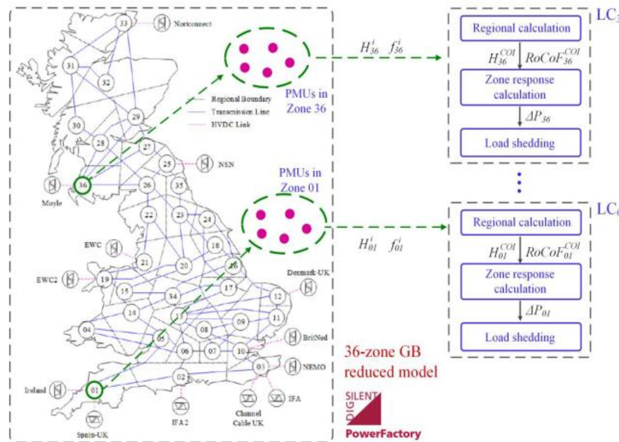
System need for fast, coordinated frequency response

System State Targeted Control (STTC) method

A potential methodology for prototyping and testing of the STTC method is needed before implementation within the MCS.

- We have confirmed that based on the SSTC mode, there would not be a need for wide area communication during a frequency event.
- This means that no regional PMUs, Regional Aggregation and fast communications infrastructure would be required in comparison to the full MCS.
- SSTC continues to require inertia information and resource information ahead of real-time, so that each local controller can be primed to behave effectively during a frequency disturbance. This slower communications infrastructure and interfacing with existing electricity control room systems is still required.
- We do not preclude full MCS roll-out in time. As RoCoF continues to rise, and where generation loss reduces system inertia significantly, SSTC becomes less accurate.
- We have confirmed that SSTC mode can in principle be delivered via a staged deployment of the MCS, and does not lead to redundant infrastructure.

Schematic of System State Targeted Control



How the analysis feeds into other frequency control work

Response holding requirements

Using the reduced GB model, examined how fast coordinated frequency service impacts frequency response holding at different levels of future inertia and maximum loss.

This network modelling approach, developed by EFCC Project, also has the potential to support the evaluation of regional and national frequency performance of new response products & services being developed under the Frequency Response Roadmap.

Detailed GB frequency and voltage modelling

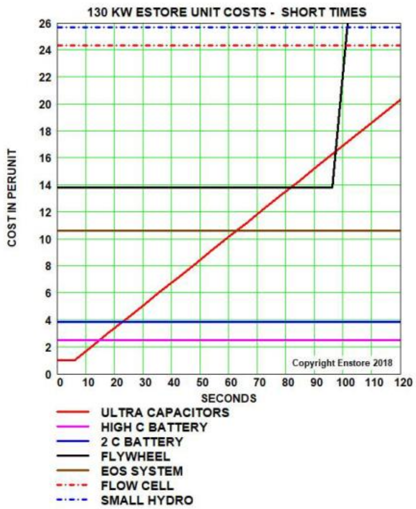
The EFCC project has developed a plan for the delivery of a full GB transmission scale planning model. The experience of developing this model has fed into the development of GB transmission and distribution dynamic modelling supporting analysis of our Stability Pathfinder and the NIC project Phoenix.

Informing future Performance requirements.

Grid Code Expert Working Group is exploring the specification of Virtual Synchronous Machine or equivalent performance from Non-Synchronous Generation. Specifying a “handshake“ between VSM energy storage and conventional frequency response that would need to occur across 20s.

Were an ‘EFCC’ equivalent frequency response available a future “handshake” could occur within 500-700ms of an event. Use of ‘EFCC’ in combination with conventional response potentially enables a greater range of effective technology solutions.

Energy store options, as reported to VSM Expert Group.



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Fast frequency response technical assessment

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Powering the future – demand side response

Dr Alastair Martin

Chief Strategy Officer

Flexitricity

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Demand Side Response in EFCC

The next steps

EFCC Project Webinar

1st May 2019

Flexitricity

Flexitricity – EFCC Trial Overview

For EFCC project, Flexitricity operated 3 services across 6 partner sites.

- **Static RoCoF** – electric load switched off in response to RoCoF breaching a certain limit.
- **Spinning Inertia** – operating synchronous generator at full load and monitoring response.
- **Dynamic RoCoF** – adjusting flexible loads in response to locally measured RoCoF.

Trials operated between May 2017 and October 2018.

RoCoF = Rate of Change of Frequency

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Static RoCoF

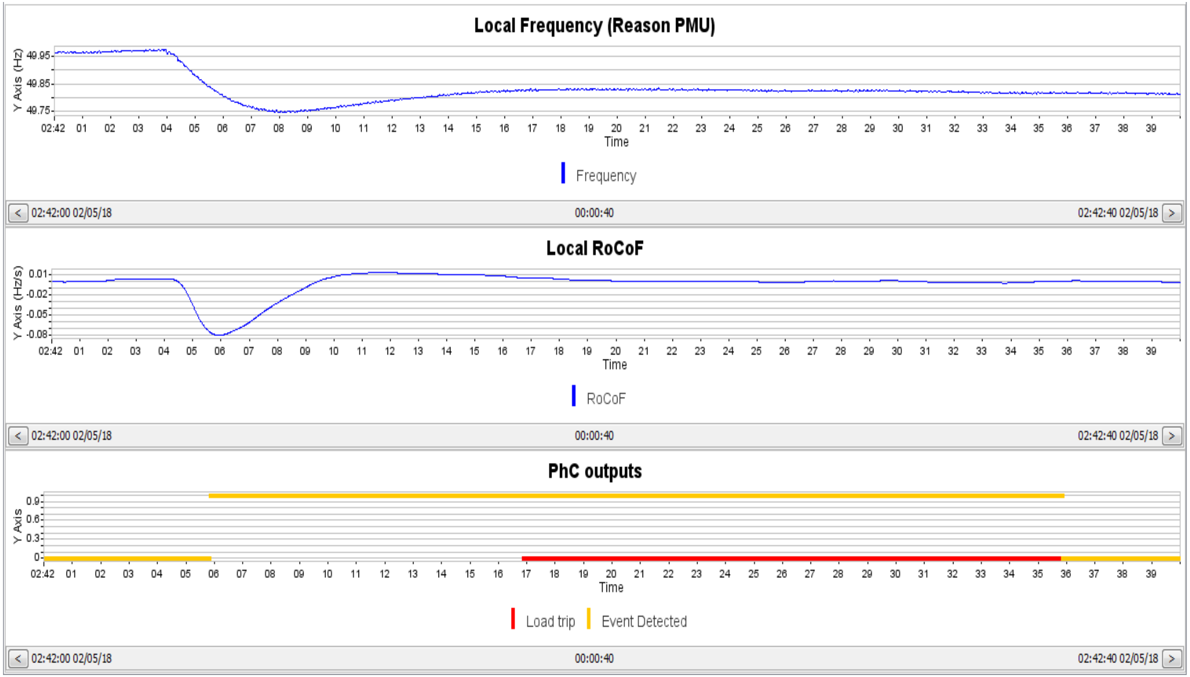
Test question:

- **Can we trip large industrial load in response to locally-measured RoCoF?**

Results:

- Positive
- From event to load drop: ~0.75s
- Local RoCoF detection requires site tuning
  - Also observed consistently on other sites

Static RoCoF response during RoCoF event - 2nd May 2018



Spinning inertia

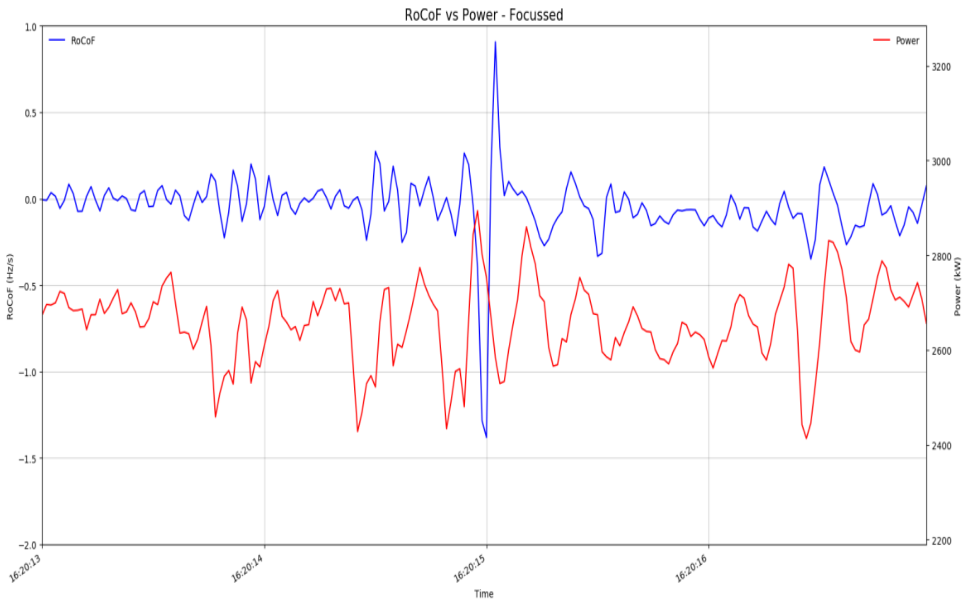
Test question:

- **Do embedded synchronous generators provide "free" inertia services already?**

Results:

- Negative
- Oscillation does occur
  - Similar to large power stations
- Not consistent
- Other factors contaminate

Spinning Inertia response at Greenhouse during RoCoF event – 13th July 2018



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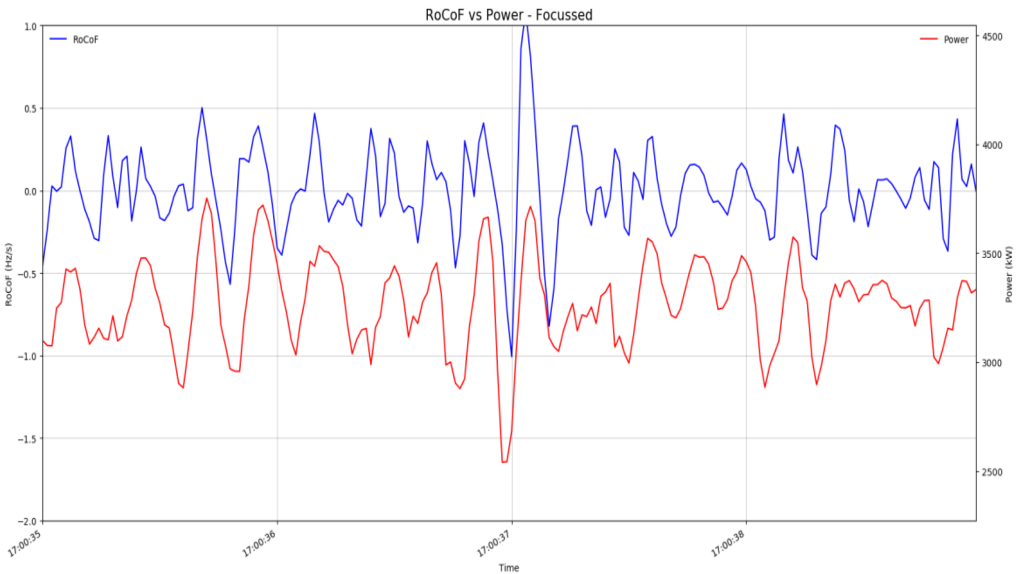
Spinning Inertia response at Greenhouse during RoCoF event – 30th October 2018



Spinning inertia – what's going on?

Factors involved:

- Gain and damping settings optimised for core CHP role
  - Controlling output power, not frequency
  - Slightly underdamped response delivers overshoot?
- Speed of action
  - 16 cylinder 1500rpm engine = 200 ignitions per second
  - Electronic engines
  - Governor response ~80ms
  - Governors just too quick?
- Next steps
  - Apply dynamic RoCoF to embedded synchronous plant

Dynamic RoCoF

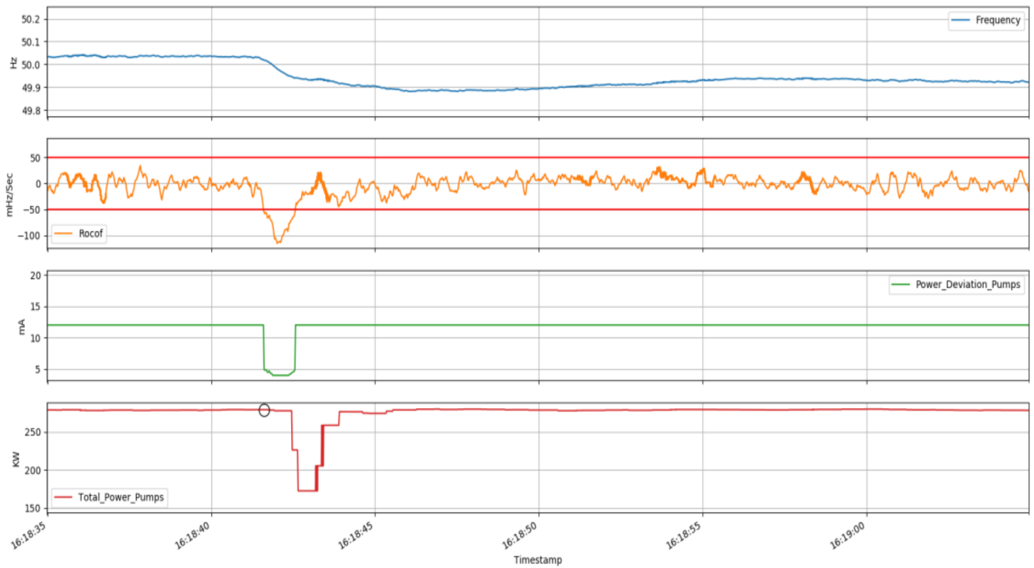
Test questions:

- **Can electricity consumers respond dynamically to RoCoF?**
- **Can we detect RoCoF cheaply?**

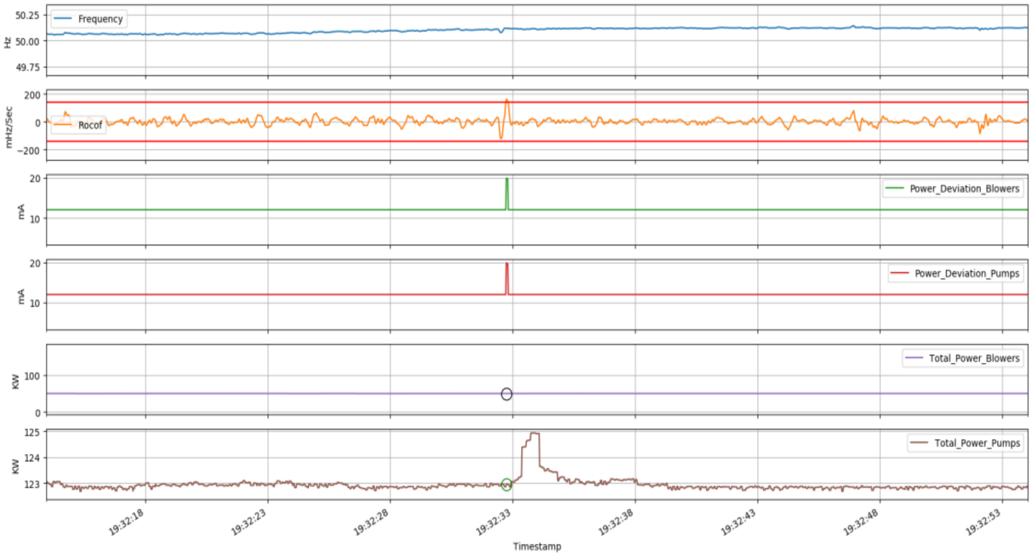
Results:

- Both positive
- From event to load response: <<1s
- Response time depends on local control system setup
  - For the trial, we approached local controls “as is”
  - This can be altered
- Electrical response before mechanical
  - That’s what we want
  - Consider load curves
- Local RoCoF detection requires site tuning

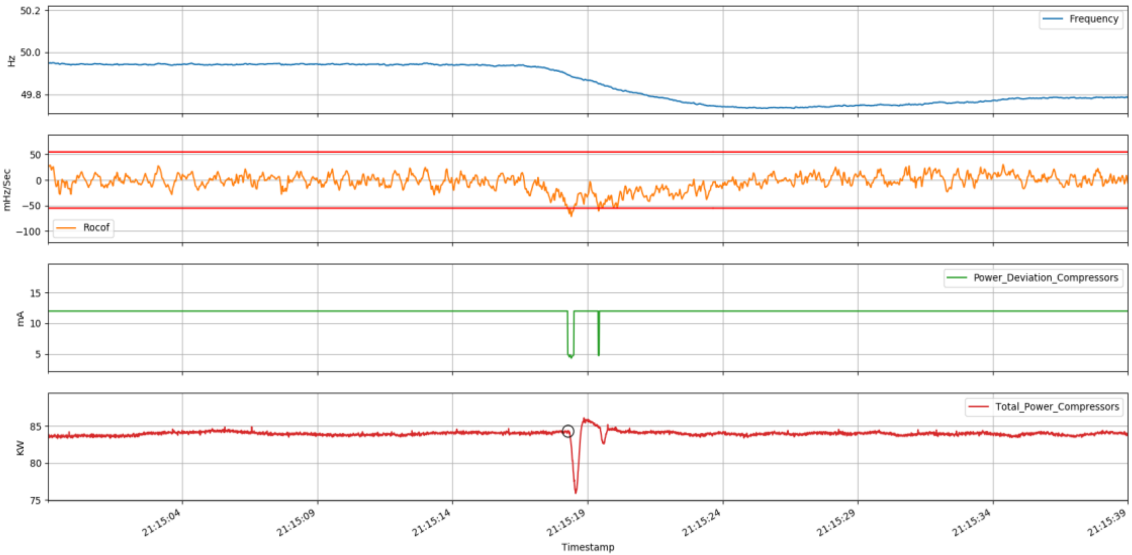
Negative Dynamic RoCoF response at Pumping Station – 7th March 2018



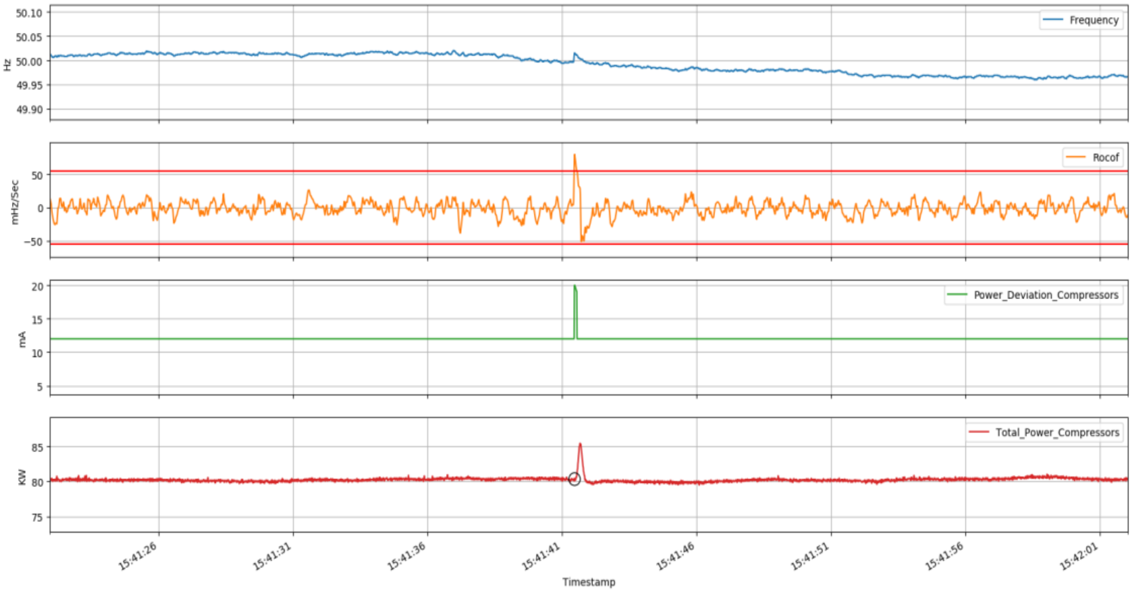
Positive Dynamic RoCoF response from RAS Pumps at WwTW – 20th April 2018



Negative Dynamic RoCoF response at Cold Store – 29th January 2018

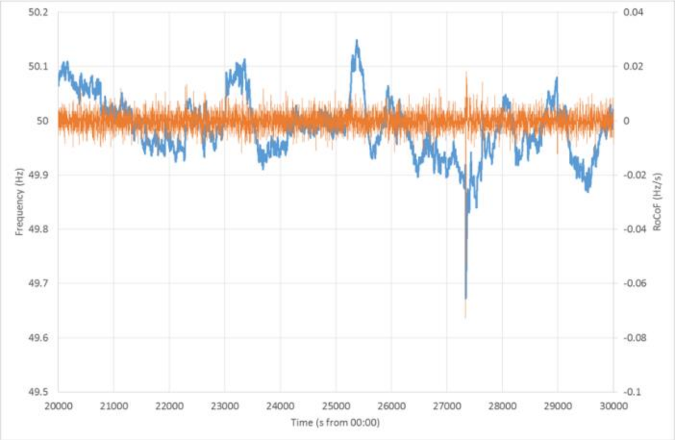


Positive Dynamic RoCoF response at Cold Store – 4th February 2018



Frequency or RoCoF?

- RoCoF
  - Happens first
  - Incurs processing time
  - Dirty
  - Local detection needs local tuning
- Frequency
  - Takes time to change
  - Shorter processing time
  - Local tuning not required
- What does DSR think?
  - DSR doesn't mind
  - DSR doesn't like false positives



Didcot B trip from 660MW – 14th March 2017

New SNaPS, new DSR approach

- Dynamic response is central
  - RoCoF or rapid frequency response
- Site controls are involved
  - Open up the black box
  - Take the handbrake off
  - Find the full range of the equipment
  - Stay within process constraints
- Choose the activity
  - Regulation: continuous, small variations over several seconds
  - Moderation: sub-second, regular
  - Containment: sub-second, occasional
  - Static containment: sub-second, rare
- True RoCoF response?
  - DSR can do it, but frequency might be enough

Flexitricity

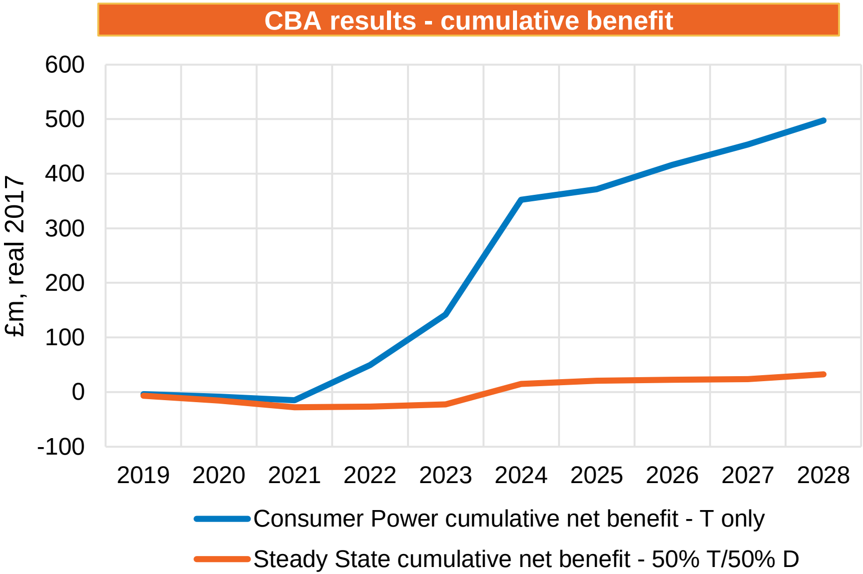
Cost Benefit Analysis

Lilian Macleod

National Grid ESO

Cost benefit analysis – updated

The cost benefit analysis (CBA) identified potential savings in both Steady State and Consumer Power Future Energy Scenarios



What did we learn?

- CBA identified savings in both Steady State and Consumer Power Future Energy Scenarios
- Saving achieved reducing the amount of market invention required balance frequency response in low inertia systems
- Savings will be offset by the costs of implementing and maintaining the MCS
- Accessing the potential benefits will require enhancements to the MCS and development of the appropriate commercial framework and IS interfaces

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Implementation

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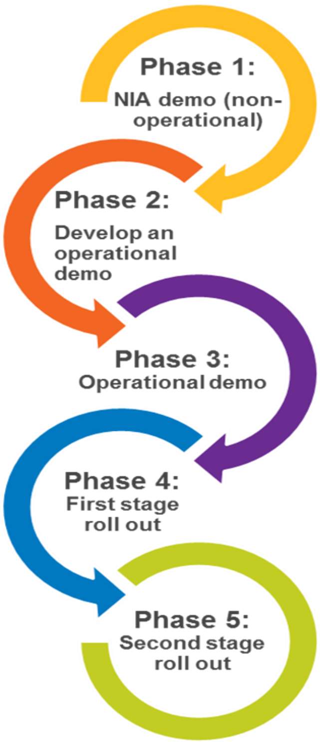
MCS Implementation – potential staged approach

Approach to implement the MCS that is conditional on sanction

A phased approach is needed to fully assess how the MCS will operate on the electricity system before any potential roll-out, and consider the new commercial frameworks and IS interfaces with balancing systems



- NIA funding being sought for a limited installation of the MCS
- Connectivity to 3rd party service provider
- 2019 - 2020

- Define wider trial and PMU installation strategy and Determine terms and conditions for service providers Incorporate system state targeted control method into the MCS and interface with commercial and operational systems
- 2019 - 2021

- NGESO directly instructs service providers via the MCS
- Definition of service technical compliance requirements
- 2021 - 2022

- System state targeted control in operation
- Dynamic system modelling, real-time system measurements across the GB electricity network and commercial frameworks in place
- 2022 - 2025

- Full MCS in operation; Central Supervisor, Regional Aggregators and Local Controllers
- From 2025 onwards

These implementation phases are subject to business approval and are dependent upon other business requirements to support roll-out

MCS Implementation – business requirements

The implementation of the MCS depends on changes to business processes and frameworks

Some of these business process requirements are currently being developed by NGESO through separate initiatives that require industry stakeholder engagement , and principally include:

Network Studies and frequency response planning

- System modelling to inform control engineer of the response expected from the MCS, simulate and plan how to coordinate with all frequency response services
- DIgSILENT PowerFactory developed by the University of Manchester to simulate different wide area control systems, can be utilised to assess the impact of fast response on the network
- Improved system dynamic models are needed to fully simulate the behaviour of lower inertia networks to give a comprehensive view on how to operate the electricity system

Commercial and operational requirements

- Interaction with new commercial applications, real-time operational interfacing and coordination with market mechanisms:
  - frequency response auction platform
  - Real-time system inertia measurement tool
  - System performance monitoring and phasor measurement devices
- Improved forecasting of availability for renewable generation
- access to better settlement metering data to capture real-time response delivery.

Conclusions

Key findings

Enhanced system modelling capability

Phased implementation approach

Shared learning and insights can benefit other areas of industry activity

Confirmed the benefit of fast coordinated frequency response

Next Steps

Publication of Closing Down Report

Publication of Technical Reports

Installation of MCS on the system – testing communications network

Questions

Email questions to:
box.EFCC@nationalgrid.com
Or use Chat on Webex

Presentation will be available on EFCC website:
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