Protection of Future Power Systems

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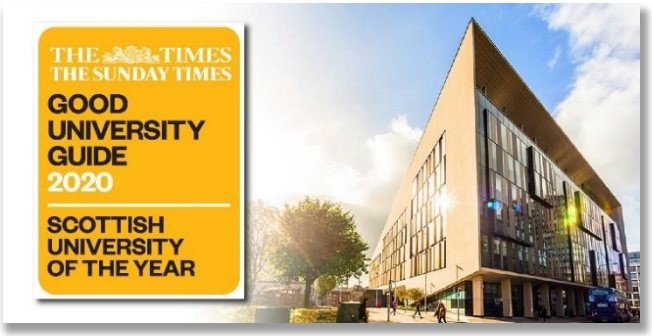





IEEE Workshop on Representations of Power Electronics for Grid Dynamic (PEGD) Studies
Imperial College London, 5th December 2019

Overview

- Who am I, where do I come from?
- The changing power system:
  - impact of increasing penetration of converter-interfaced renewable generation – challenges and opportunities
  - electrification of heat and transport
- Overview of potential solutions:
  - on-going work at Strathclyde and partners on protection (+ monitoring and control)
- Conclusions and discussion

Who is Campbell Booth?

1987 – present: University of Strathclyde

BEng and PhD: power system protection and monitoring, then post-doctoral researcher (Rolls-Royce)

Member of academic staff: projects with a range of government, industry and academic partners

Now head of EEE department at Strathclyde

2014 – present: Synaptec (Strathclyde spinout)

Distributed optical sensing (voltage, current, temperature, vibration) for power system protection, control and monitoring

www.synapt.ec

University of Strathclyde, Glasgow, Scotland

- Core strengths in engineering, science, and business - 22,000 students
- Electronic and Electrical Engineering
  - 500 academic/research plus support staff and PhD students
  - 1,000 undergraduate and MSc students
  - One of the largest European power systems research institutes

EEE at Strathclyde

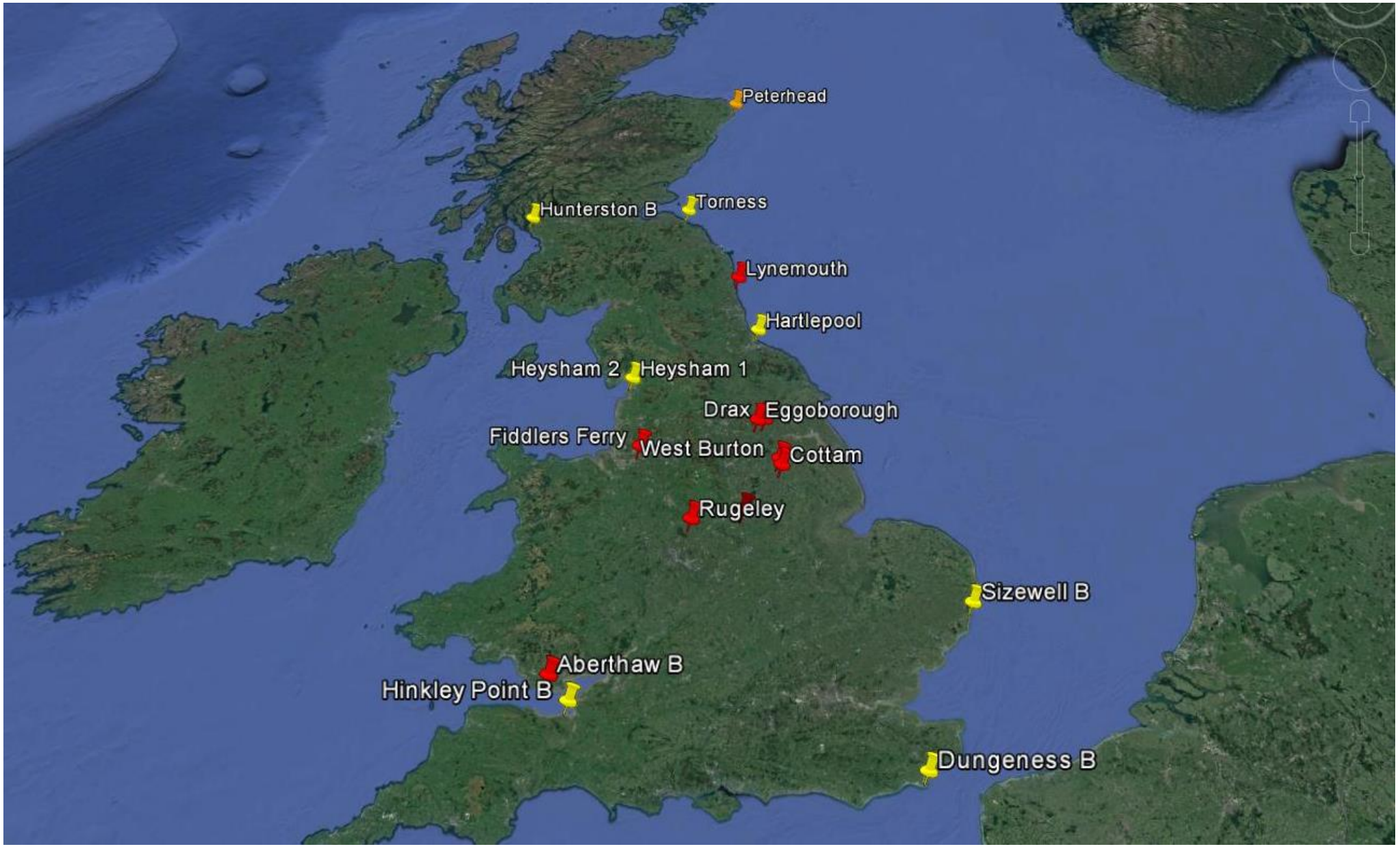
~1,500

Academic/Teaching, Research/KE Staff,
PhD, MSc, Undergraduate
+ support staff

The changing power system

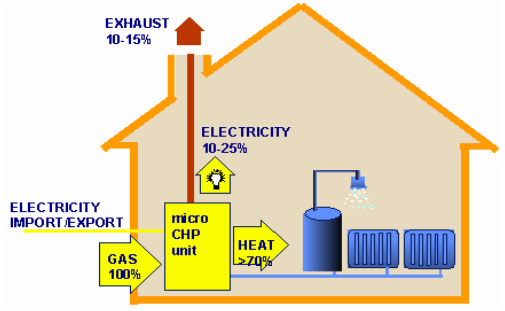
The changing power system

GB: Current Coal & Nuclear Power Stations

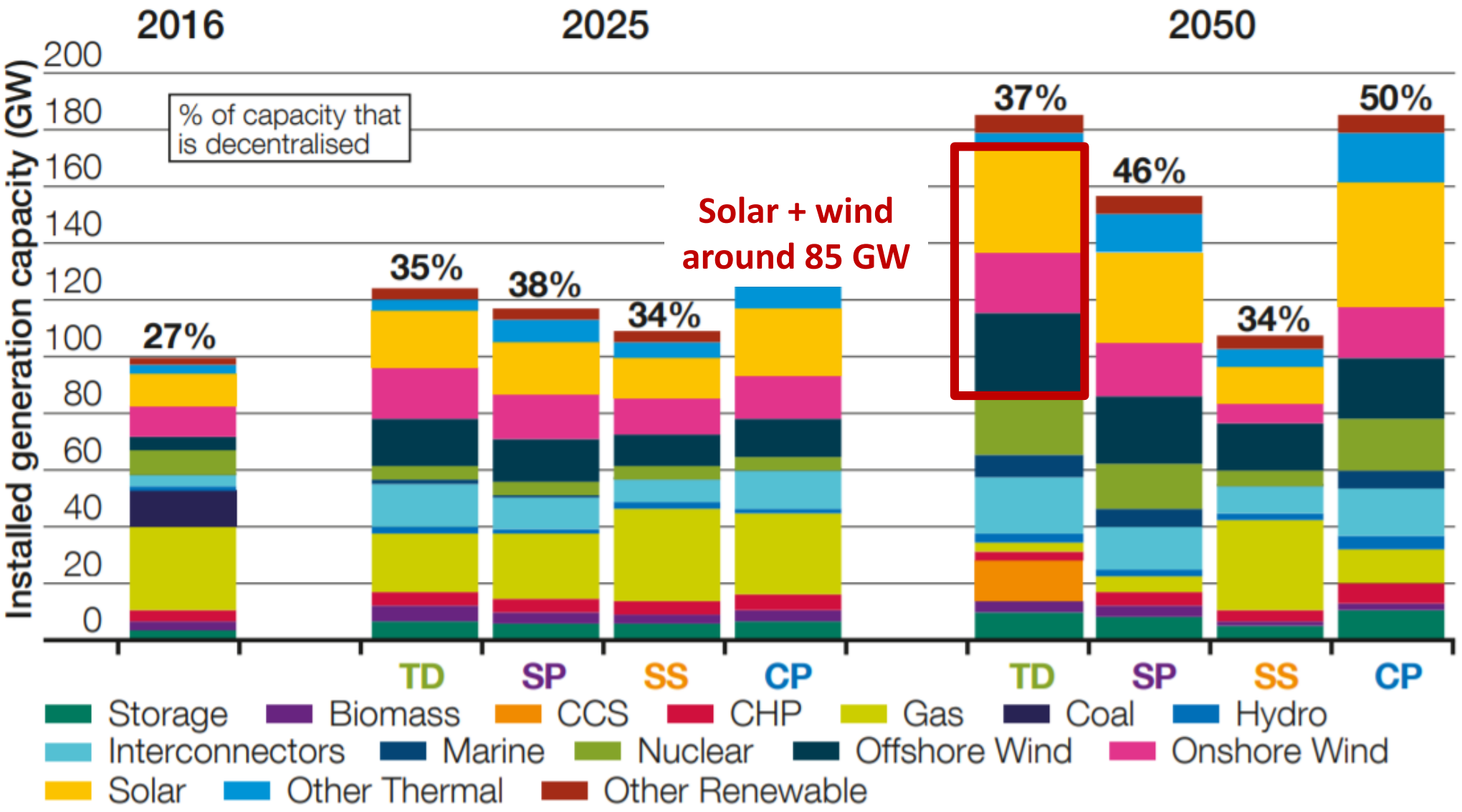


GB: Post 2025 Coal & Nuclear Power Stations?

The changing power system



Changing generation

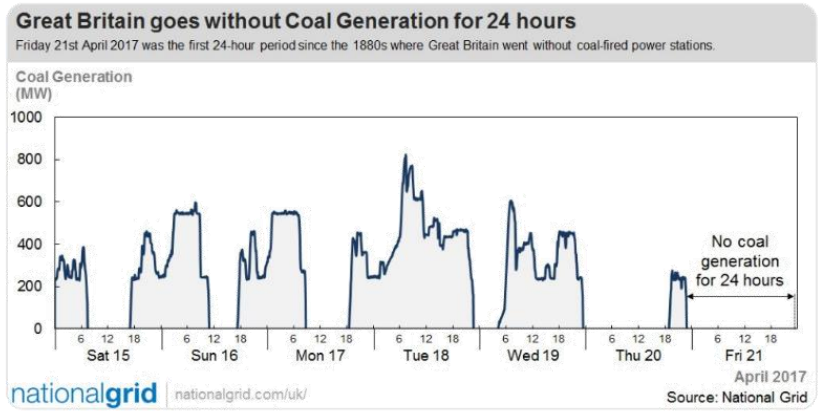


http://fes.nationalgrid.com/media/1253/final-fes-2017-updated-interactive-pdf-44-amended.pdf

Changing generation

ESO Control Room @NGControlRoom — Follow

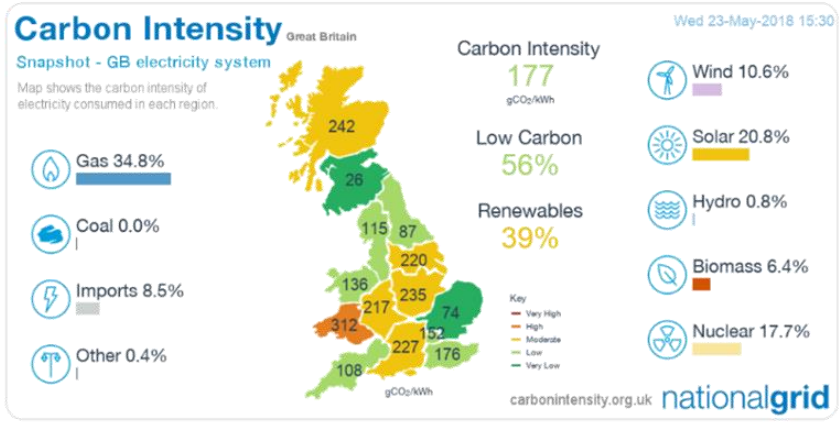
National Grid can confirm that for the past 24 hours, it has supplied GB's electricity demand without the need for #coal generation.



3:11 PM - 21 Apr 2017

ESO Control Room @NGControlRoom — Follow

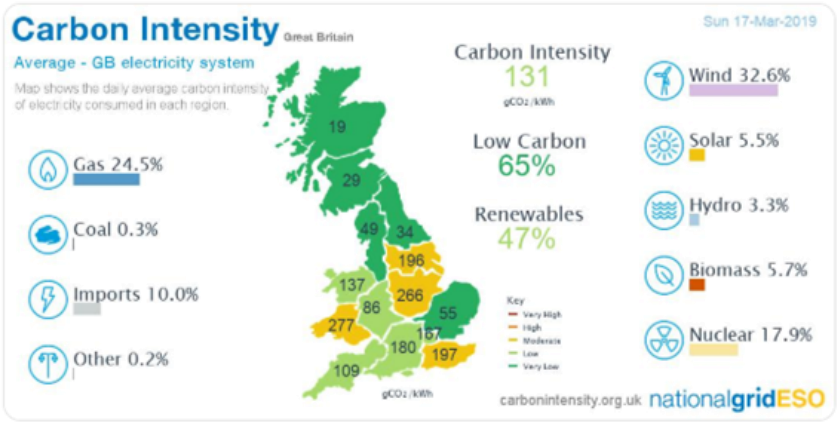
56% low carbon and no coal generation.



7:57 AM - 23 May 2018

ESO Control Room @NGControlRoom — Follow

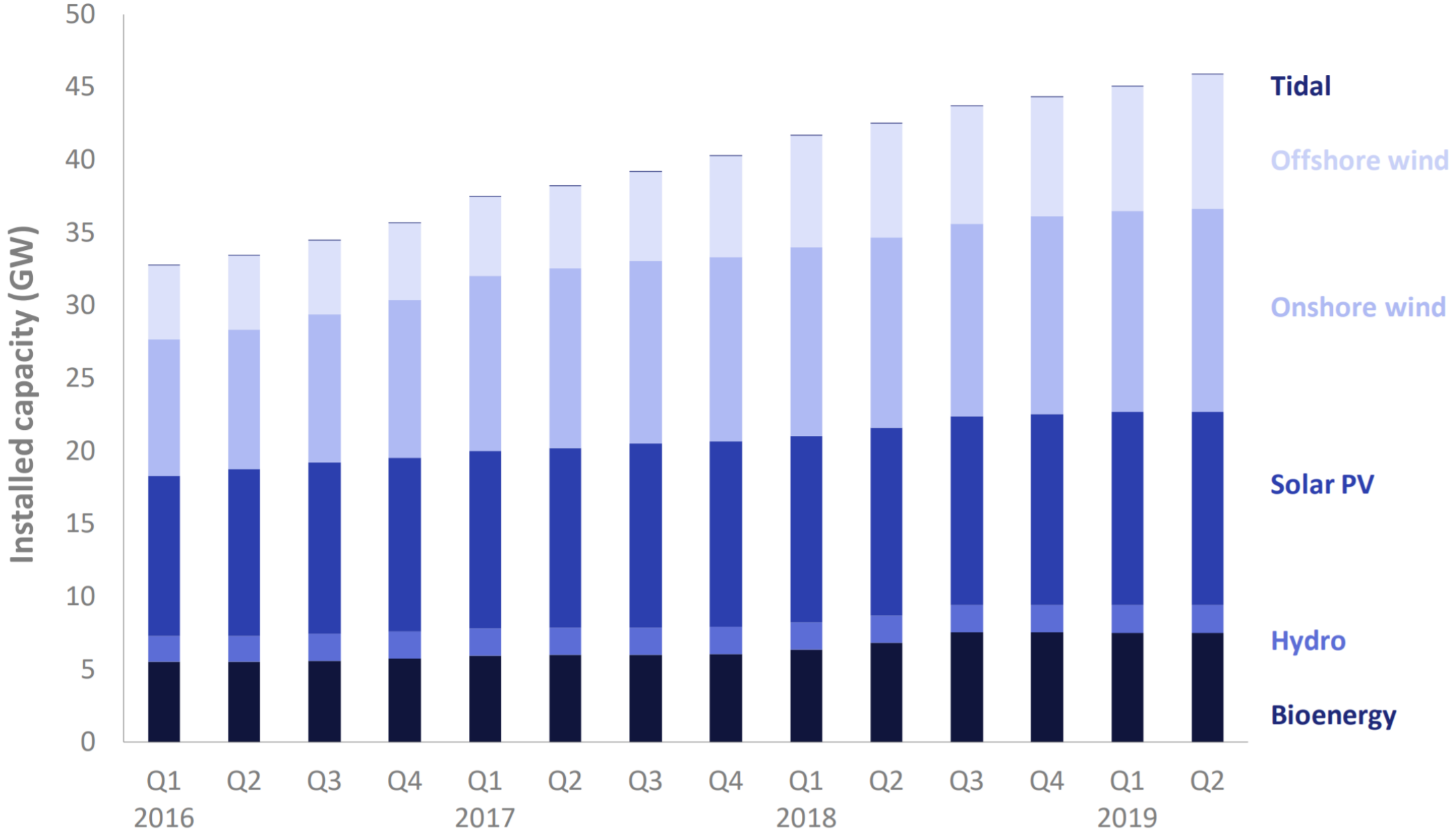
Yesterday #wind generated 32.6% of GB electricity, more than gas 24.5%, nuclear 17.9%, imports 9.9%, biomass 5.7%, solar 5.6%, hydro 3.3%, coal 0.3%, other 0.2% *excl. non-renewable distributed generation



4:37 PM - 18 Mar 2019

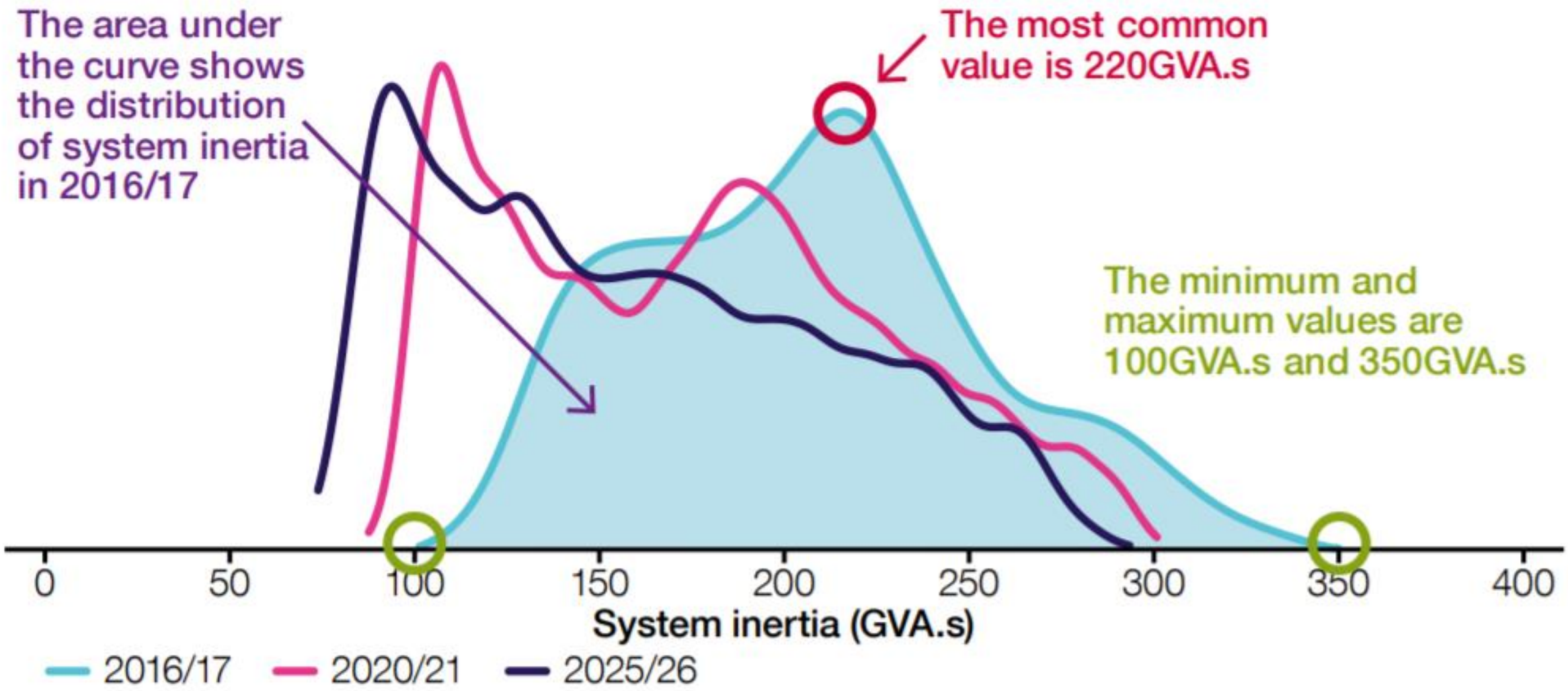
April 2017	April 2018	March 2019
First no-coal day since late 1800s	Three consecutive no-coal days	33% wind contribution – common throughout March

Chart 6.3 Renewable electricity capacity (as at end of quarter) (Table 6.1)



https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835114/Renewables_September_2019.pdf

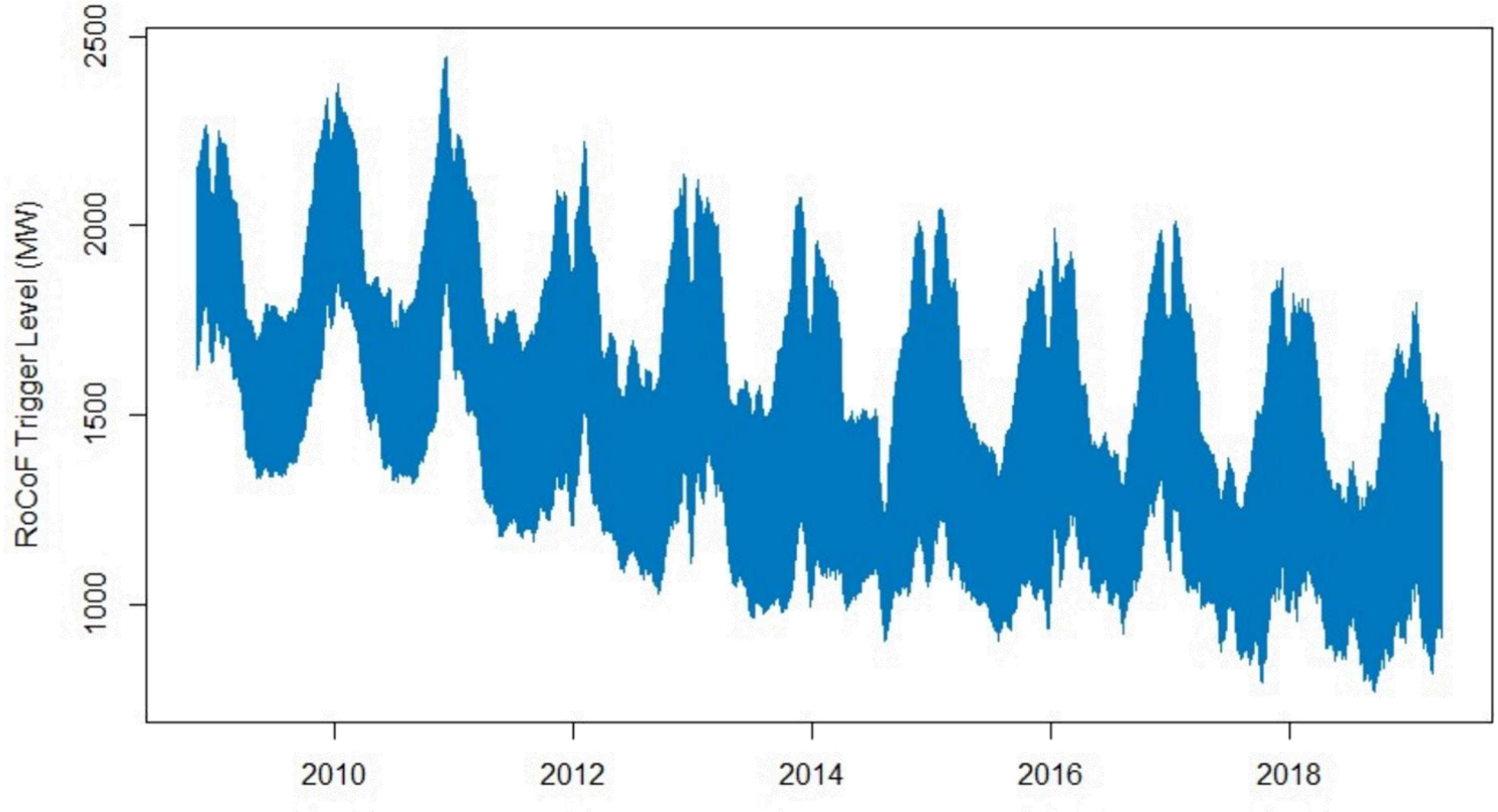
Reducing system inertia



From National Grid System Operability Framework 2016

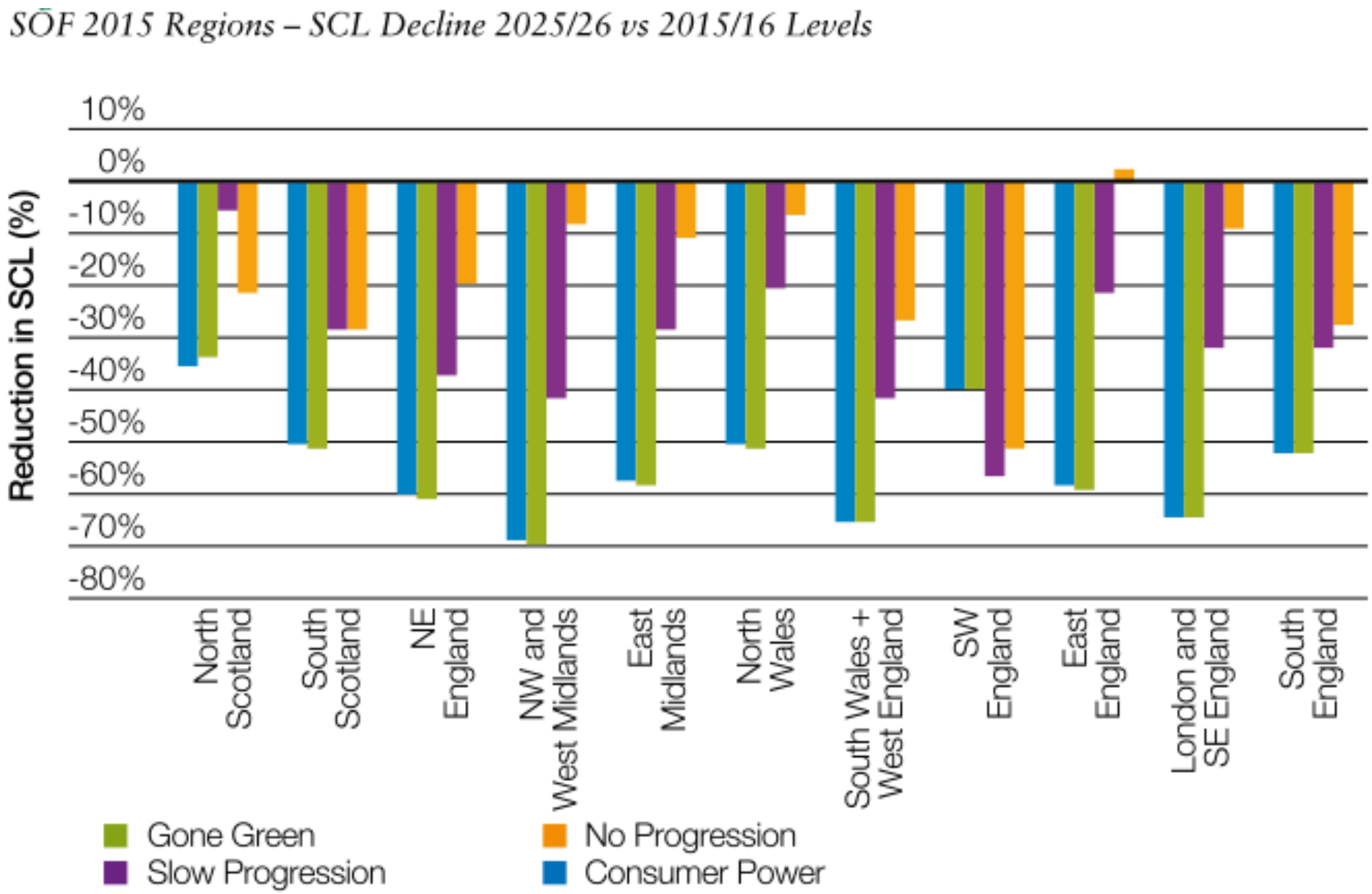
Reducing system inertia

Declining System Inertia



From National Grid ESO, 2019

Reducing fault levels



UK: growth in controllable resources (and complexity)

- Massive increase in:
  - Monitoring data
  - Controllable units (generators, energy storage, etc.)
- Needs breakthrough in ICT infrastructure and security
- New monitoring, control and protection functions
- Opportunity to learn a lot from the explosion in data

What could go wrong

Power goes out. People have enough food and water in their homes for only the first day or so. Key installations rely on generators at first.

Government cannot communicate with people. Few have battery powered radios. No phones, no internet, no television. No one knows what's going on.

Water goes and people cannot flush their toilets or get drinking water. Hygiene plummets quickly.

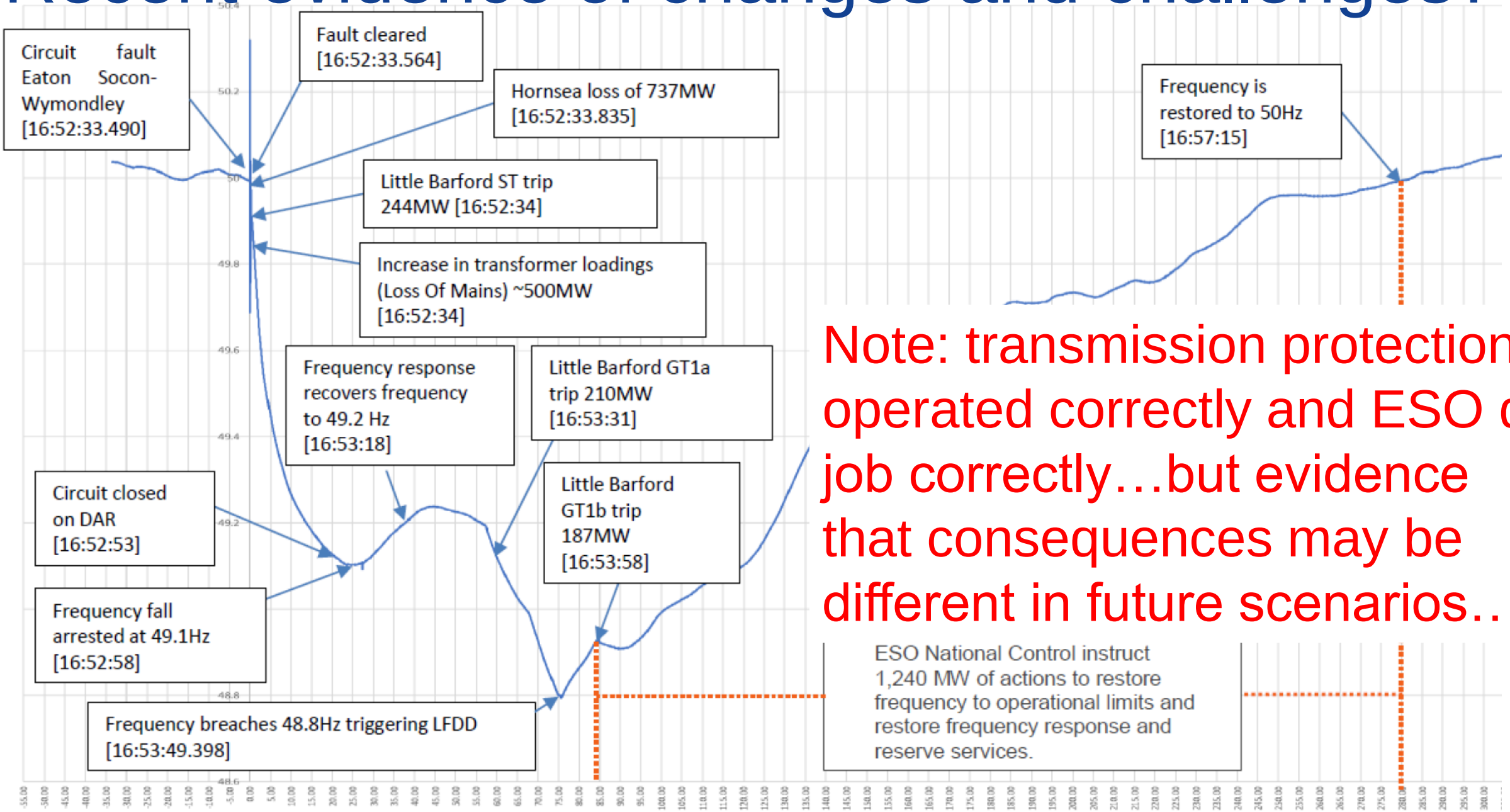
Initial fuel reserves run out. More fuel cannot be fetched from storage tanks without electricity. Lorries cannot run for deliveries. Generators cannot run.

People need food and water, but no shops, no money, ATMs, banking or contactless payments. Looting starts in some places and order breaks down. Lack of communication means people still do not know what's happening and distrust of the government festers.

Cities uninhabitable within days if sanitation not up and running, particularly in hot weather. Possible disease outbreaks. May need evacuating.

Grid eventually restarted, but removing contamination from water supply may take months.

Recent evidence of changes and challenges?



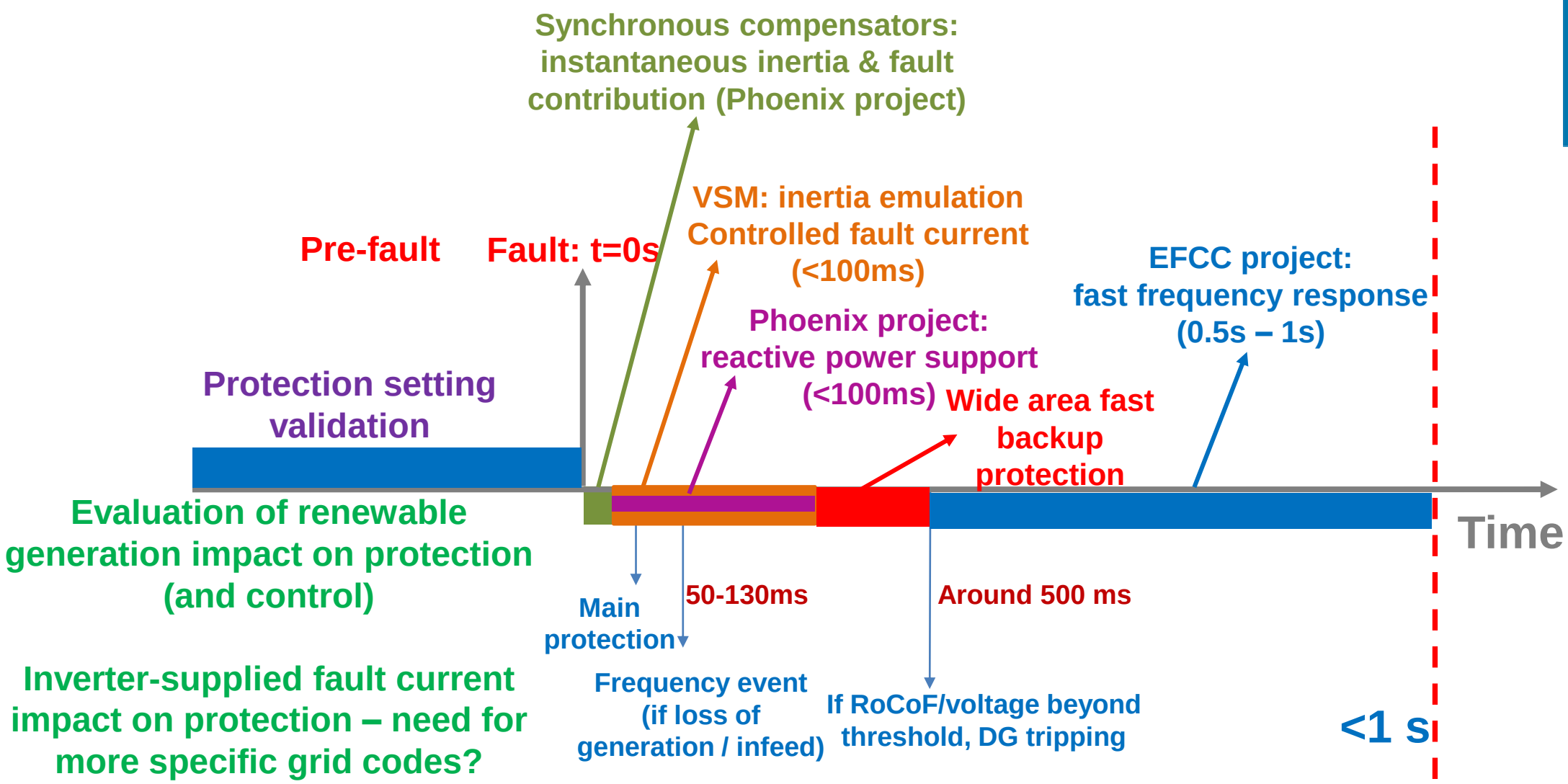
Note: transmission protection operated correctly and ESO did job correctly…but evidence that consequences may be different in future scenarios…

Recent evidence of changes and challenges?

- Transmission protection operation, followed by rapid overall loss of 2,100 MW of generation
- Frequency dropped to 48.8 Hz
- Initial RoCoF was fast
- LFDD removed almost 970 MW of demand
- Approx 500-600 MW of DG also disconnected
- Frequency restored quickly (5 mins), all supplies within 45 mins
- But, large and sustained disruption, investigations on-going…

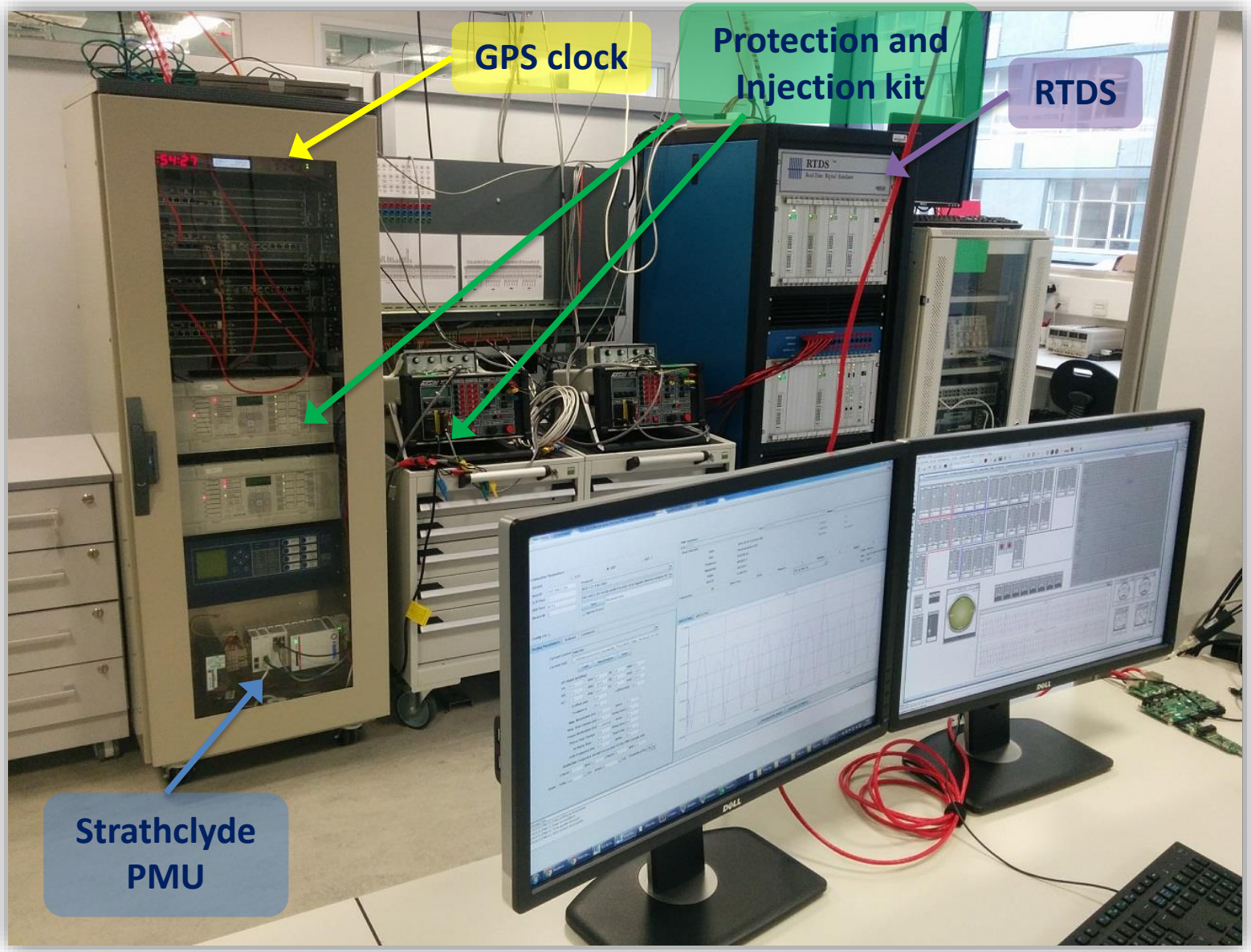
References:
1. Energy Emergencies Executive Committee: Interim Report on GB Power System Disruption – 9th August 2019
2. NGESO Final Technical Report into Friday 9 August Power Outage, https://www.nationalgrideso.com/information-about-great-britains-energy-system-and-electricity-system-operator-eso

Potential solutions: some things we are working on



The resilient distributed power system – using storage (and other vectors) to support system operation – protection/automation research required

Strathclyde facilities: protection and automation



- Automated real-time test suite
- Investigate future power system and measurement, monitoring, protection, communications, control performance…
- Plus PNDC for large scale power-in-loop…

PNDC project – PV inverter protection sensitivity and stability evaluation

https://pndc.co.uk/

- Risks of sustaining islands or spurious tripping of PV inverters.
- PNDC testing to evaluate PV inverter performance during islands and frequency disturbances up to 1 Hz/s.
- Work informs ENA sponsored joint UK distribution and grid code working group (GC0079).

Overhead Lines

Strathclyde facilities: large-scale PMU testbed

- RTDS GTFPGA
- 16x Raspberry Pis
- Strathclyde PMU algorithm
  - Adaptive filter window

- **64 PMUs in real-time**

- Dynamically change reporting rate, M or P class

University of Strathclyde Engineering

In the future, protection and automation systems will face more challenges than in the past

Investigation into future solutions still requires a lot of research, development and demonstration

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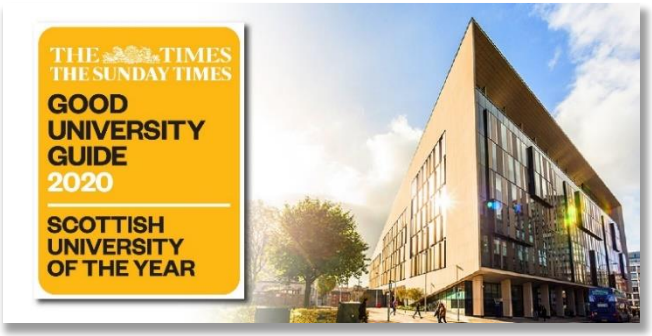




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