CESI National Centre for Energy Systems Integration

Frequency Response Services Designed for Energy Storage

David Greenwood[1], Khim Yan Lim[2], Haris Patsios[1], Padraig Lyons[1], Yun Seng Lim[2], Phil Taylor[1]

[1]Newcastle University, UK

[2] University Tunku Abdul Rahman, Malaysia

EPSRC Engineering and Physical Sciences Research Council

Newcastle University

UTAR UNIVERSITI TUNKU ABDUL RAHMAN

Newton Fund

Skoltech Skolkovo Institute of Science and Technology

Overview

- What is frequency response, and why do we need it? Why should we use Energy Storage?
- What is *Enhanced* Frequency Response (EFR)
- Analysis of historical frequency data
- Experiment 1: Response to historical frequency data
- Experiment 2: Response to simulated frequency events
- Conclusions

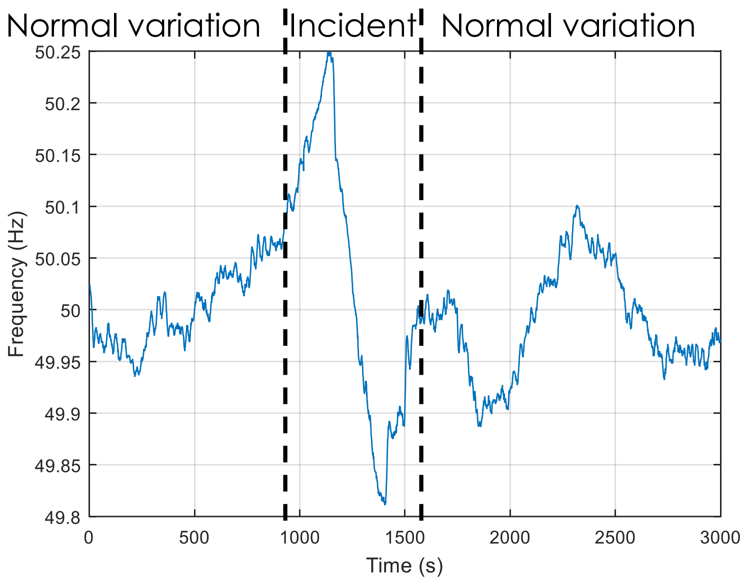
National Centre for Energy Systems Integration
EPSRC Engineering and Physical Sciences Research Council
Skoltech Skolkovo Institute of Science and Technology

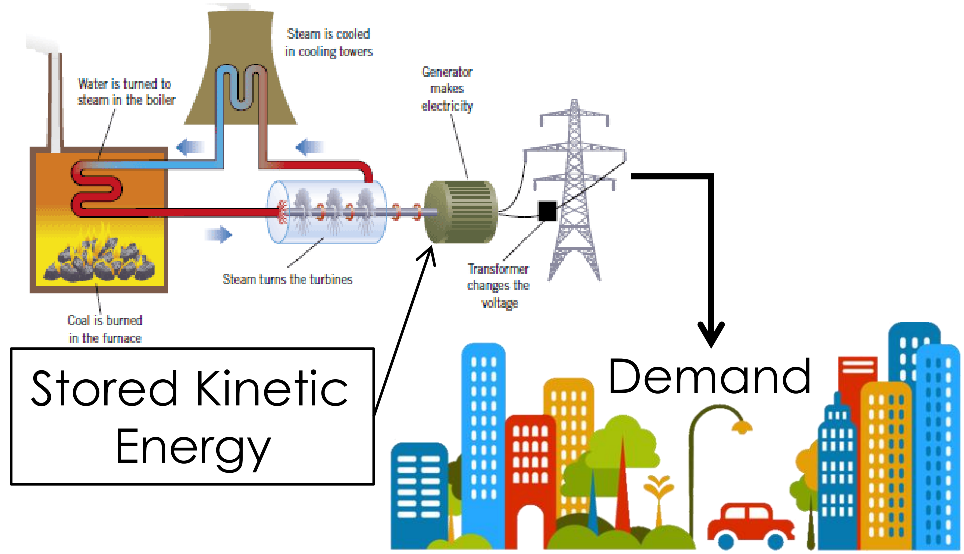
What is frequency response, and why do we need it?

National Centre for Energy Systems Integration
Engineering and Physical Sciences Research Council
Skolkovo Institute of Science and Technology

Why does the frequency vary?

National Centre for Energy Systems Integration





- Frequency variation is a result of power mismatches between supply and demand
- Frequency varies continuously, but sudden mismatches (often caused by disconnections) can create sudden large deviations

- Kinetic Energy stored in the rotating masses; this is the system inertia
- Energy is transferred to or from the rotating mass to instantaneously balance supply and demand, causing changes in frequency
- But we anticipate future power systems having less inertia…

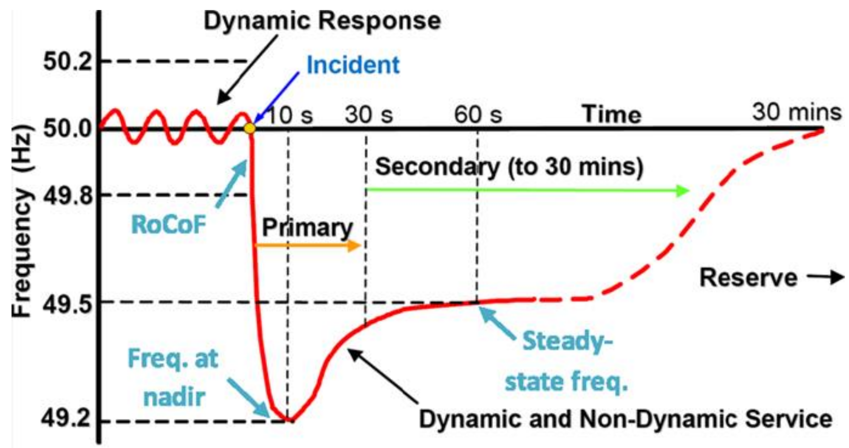
EPSRC
Engineering and Physical Sciences Research Council

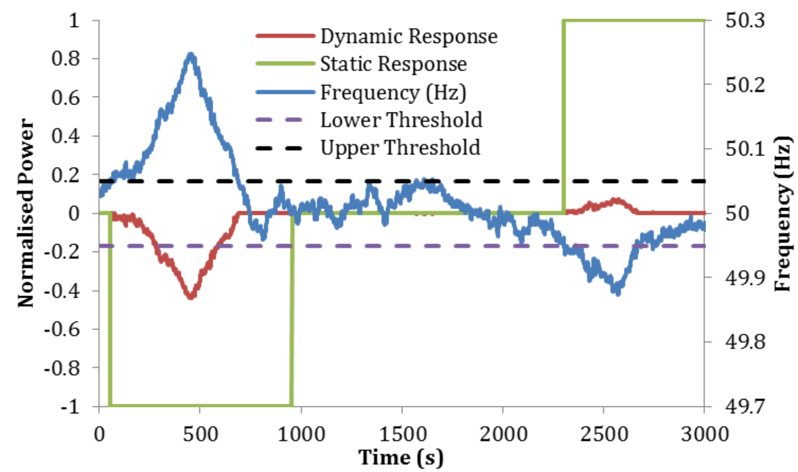
Skoltech
Skolkovo Institute of Science and Technology

What is Frequency Response?

National Centre for Energy Systems Integration

- When the frequency starts to change, the system operator acts quickly to restore it to its nominal value
- Primary frequency response providers will *supply* or *absorb* real power within 10s
- Secondary frequency response providers will *supply* or *absorb* real power within 30s
- But will this be quick enough in a *low inertia* system with *unpredictable* demand and generation?





EPSRC
Engineering and Physical Sciences Research Council

Skoltech
Skolkovo Institute of Science and Technology

Why Energy Storage?

Benefits

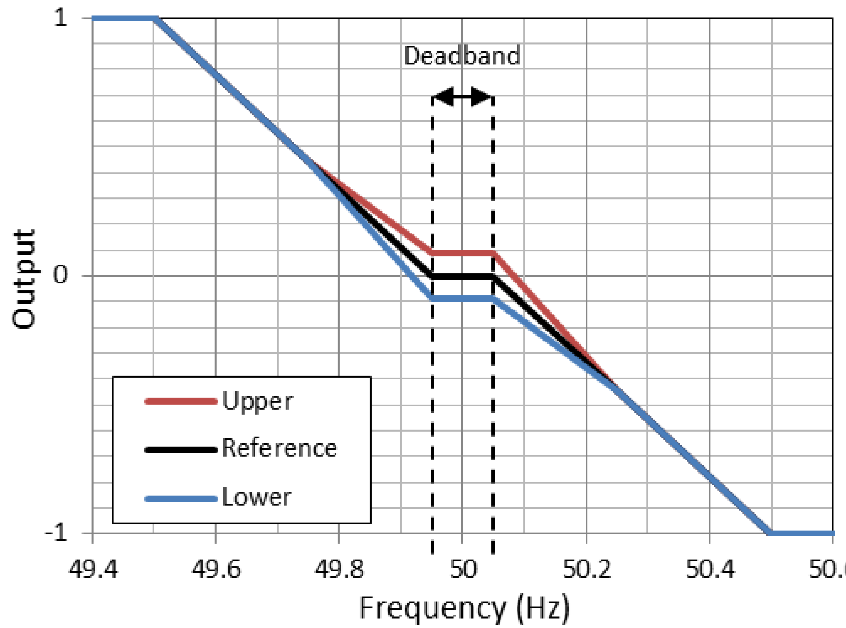
- Energy Storage can provide a power response much faster than conventional power sources
- Primary Response requires high power, but only for a few minutes

Challenges

- Energy Storage needs to manage its state of charge to remain available
- Existing markets are designed for conventional power sources
- Energy Storage is not well defined in the regulations in most countries

Enhanced Frequency Response (EFR)

- EFR is a new frequency response service in the UK
- It is explicitly designed to be fulfilled by energy storage systems
- Response is required within 1s of a frequency deviation
- Suppliers must be able to deliver rated power for 15 mins
- Envelope allows state of charge adjustment while frequency is within the deadband close to 50Hz



Service	Deadband
1 (wide)	50±0.05 Hz
2 (narrow)	50±0.015 Hz

National Centre for Energy Systems Integration

EPSRC Engineering and Physical Sciences Research Council

Skoltech Skolkovo Institute of Science and Technology

CESI National Centre for Energy Systems Integration

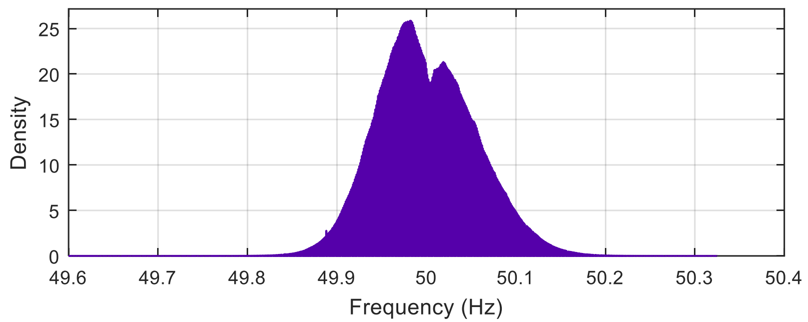
Analysis of historical frequency data

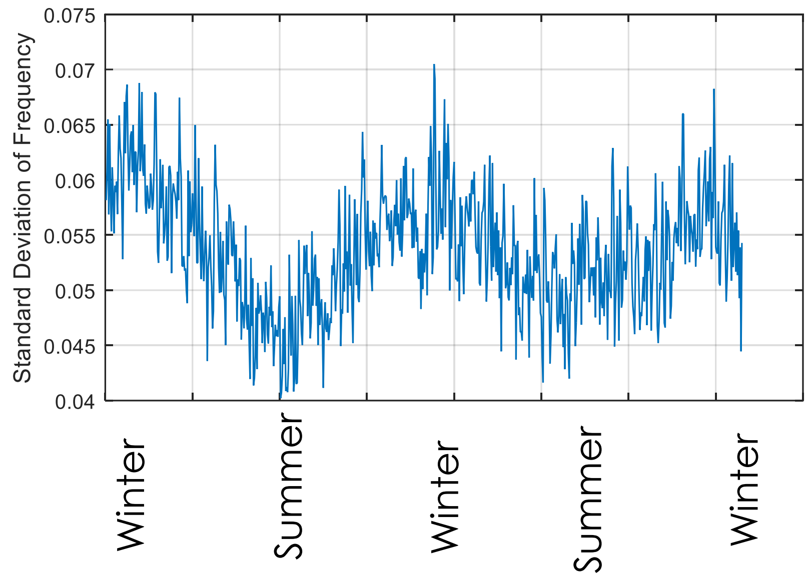
EPSRC Engineering and Physical Sciences Research Council

Skoltech Skolkovo Institute of Science and Technology

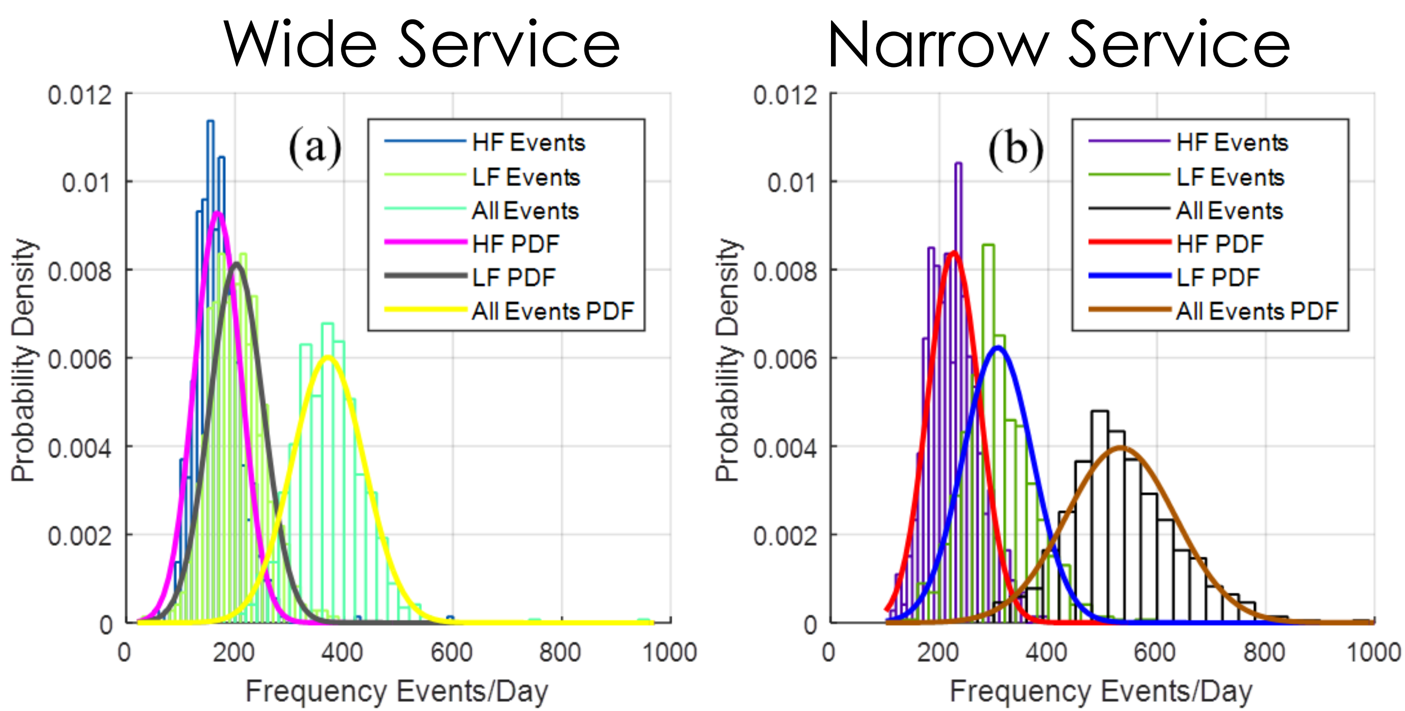
Data Description

- National Grid have made frequency data available at 1s resolution for 2014-15
- This data allows us to see what EFR operation would look like
- Results presented use upper/lower deadband values of 50.05 and 49.95 Hz





Data Analysis: Results

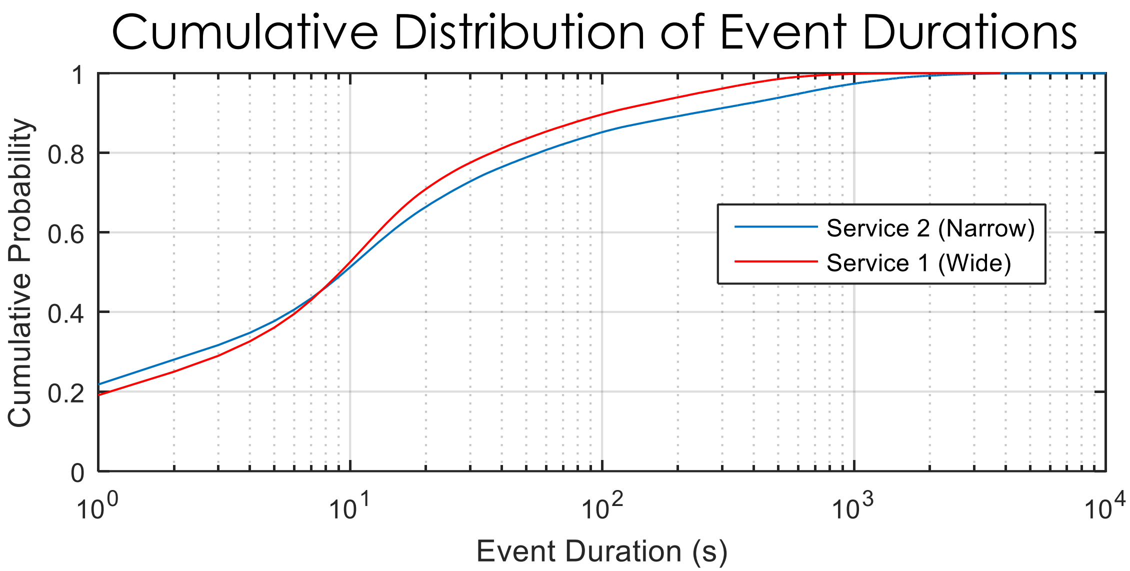


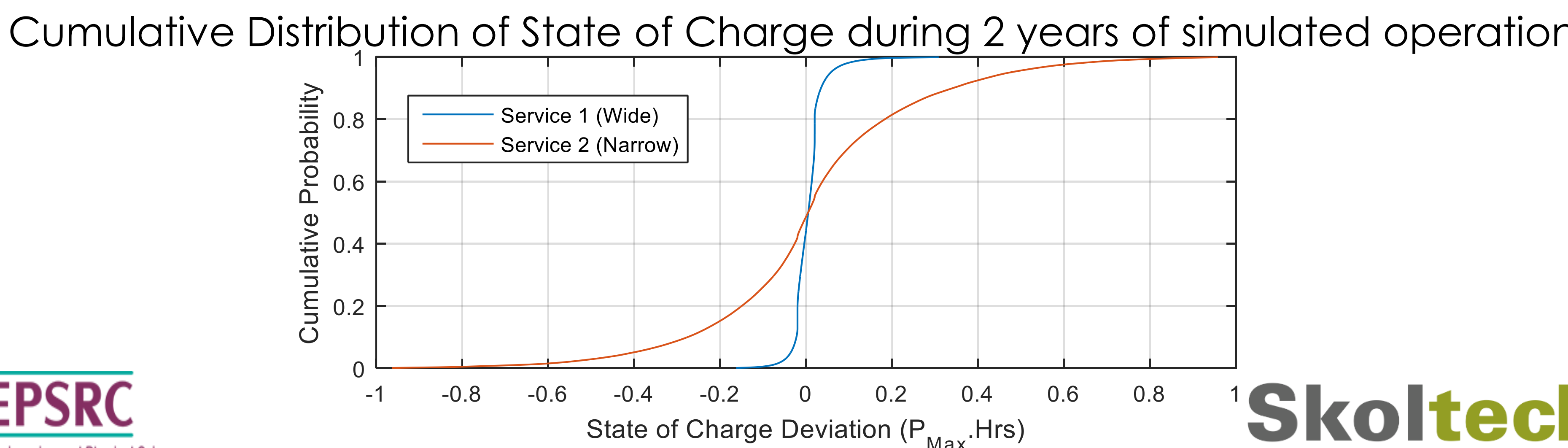
National Centre for Energy Systems Integration

EPSRC Engineering and Physical Sciences Research Council

Skoltech Skolkovo Institute of Science and Technology

Data Analysis: Results





CESI National Centre for Energy Systems Integration

EPSRC Engineering and Physical Sciences Research Council

Skoltech Skolkovo Institute of Science and Technology

National Centre for Energy Systems Integration

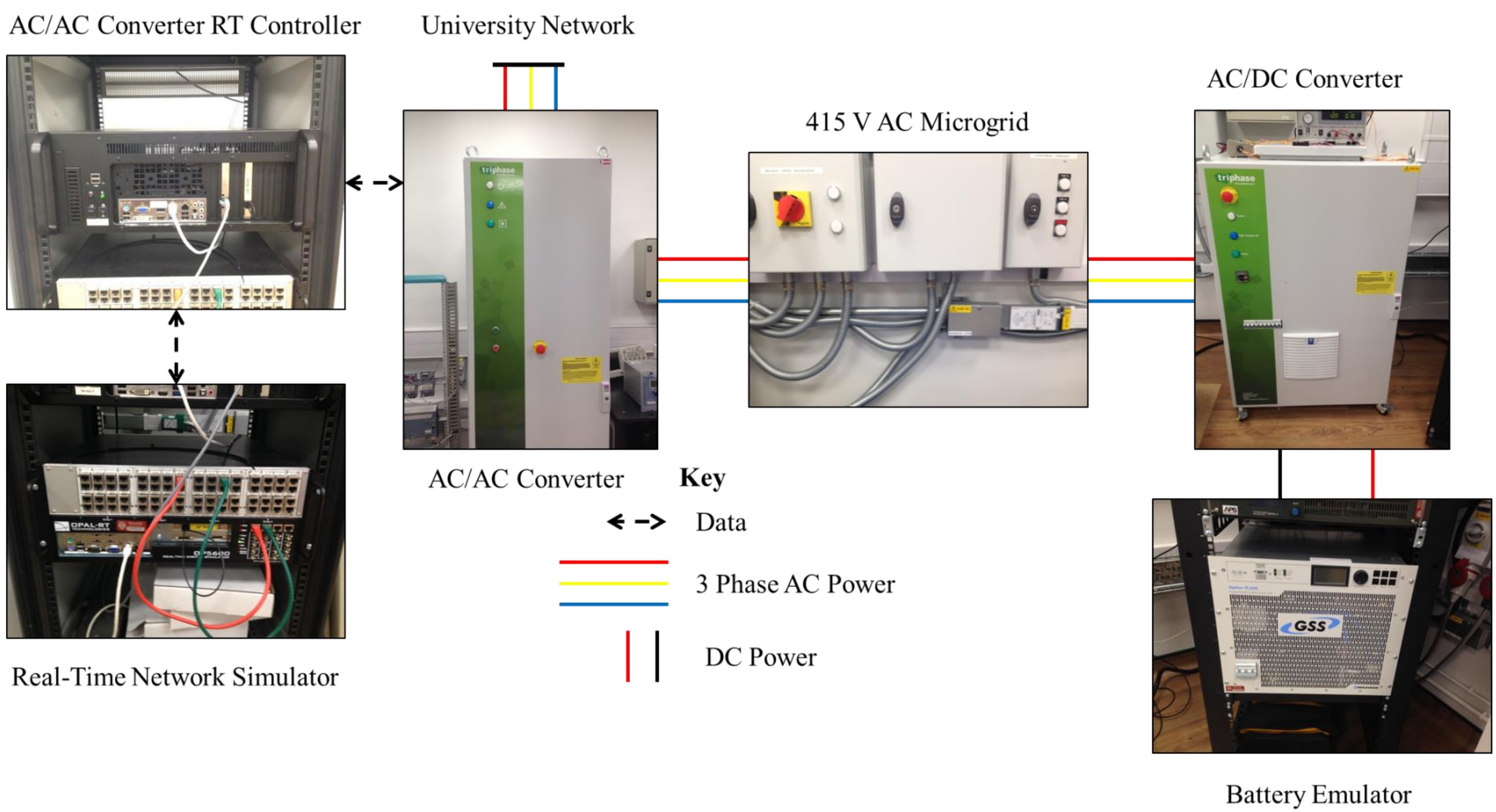
Experimental Set-Up

EPSRC
Engineering and Physical Sciences Research Council

Skoltech
Skolkovo Institute of Science and Technology

Lab Overview

National Centre for Energy Systems Integration

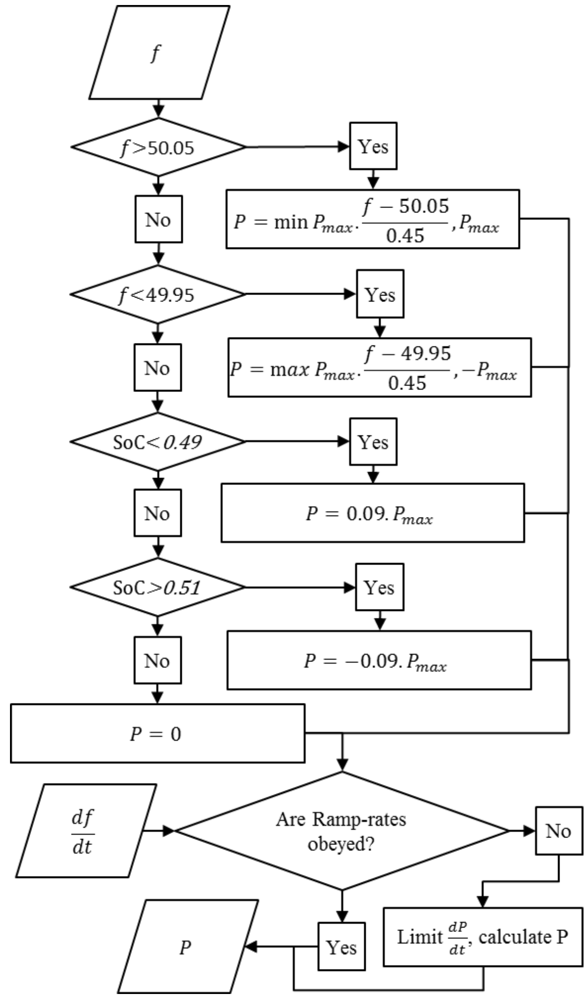


EPSRC
Engineering and Physical Sciences Research Council

Skoltech
Skolkovo Institute of Science and Technology

Control Implementation

- Low-level control built in to DC/AC Converter
- High level control implemented on real-time target PC
- Controller:
  - calculates set-point
  - checks ramp-rate limitations
  - manages State of Charge



Experiment 1: Response to historical frequency data

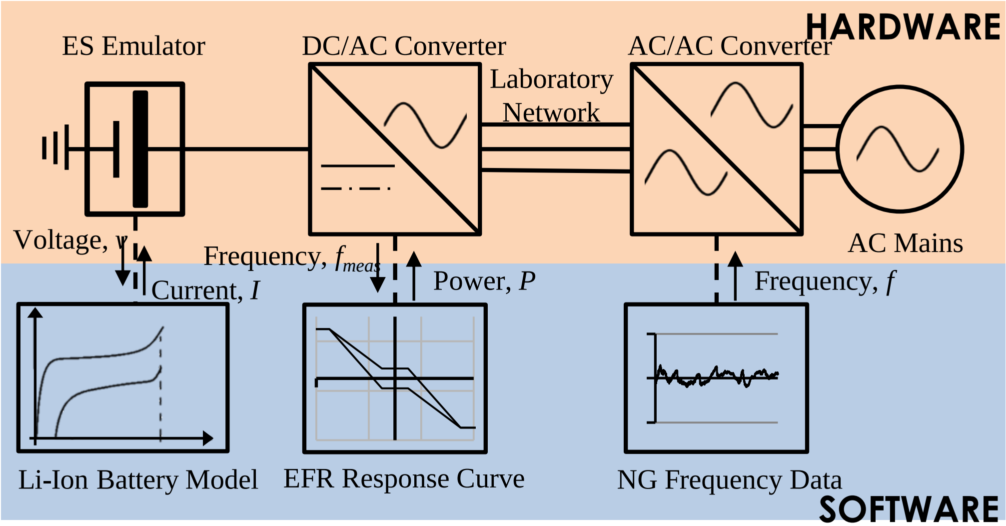
National Centre for Energy Systems Integration

EPSRC
Engineering and Physical Sciences Research Council

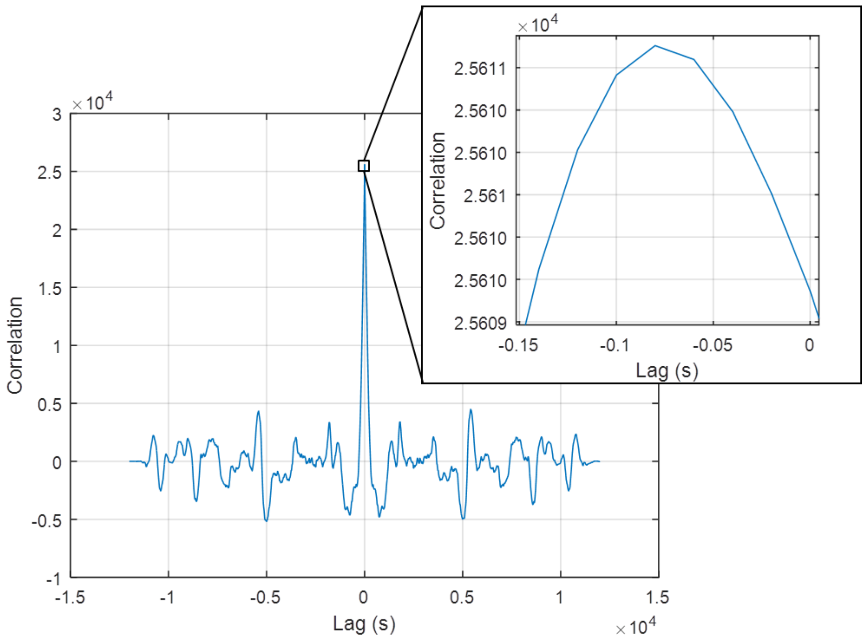
Skoltech
Skolkovo Institute of Science and Technology

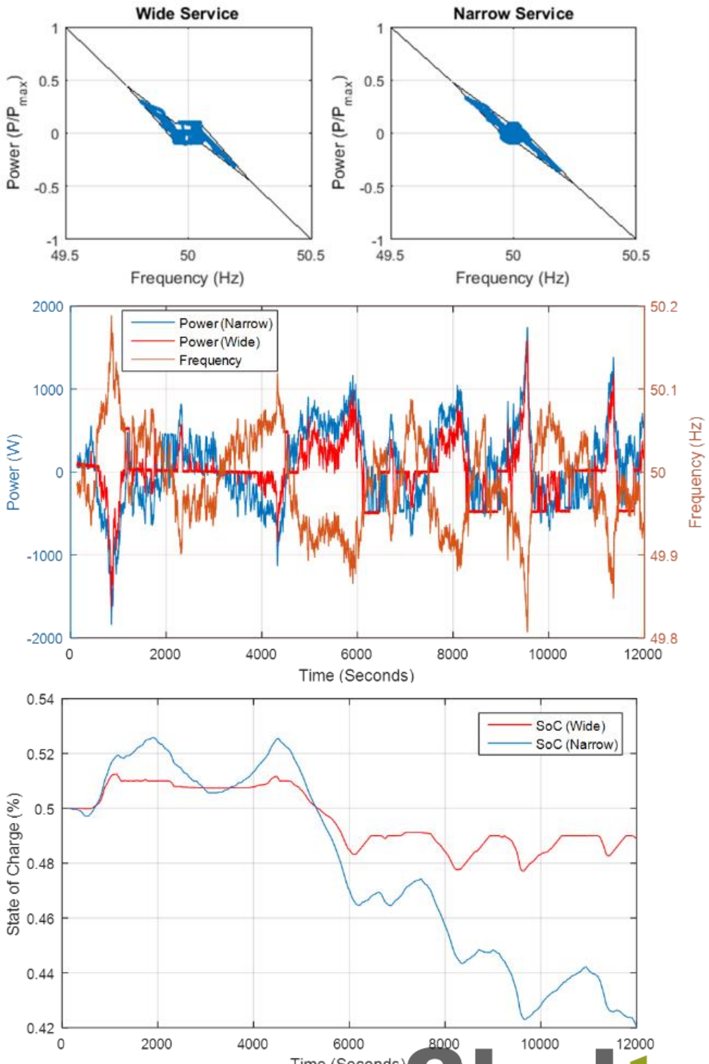
Experiment 1: Aims and setup

- Historical frequency data was reproduced on the laboratory LV network
- The ESS responded according to the EFR response curve, and managed its state of charge between responses.



Experiment 1: Results

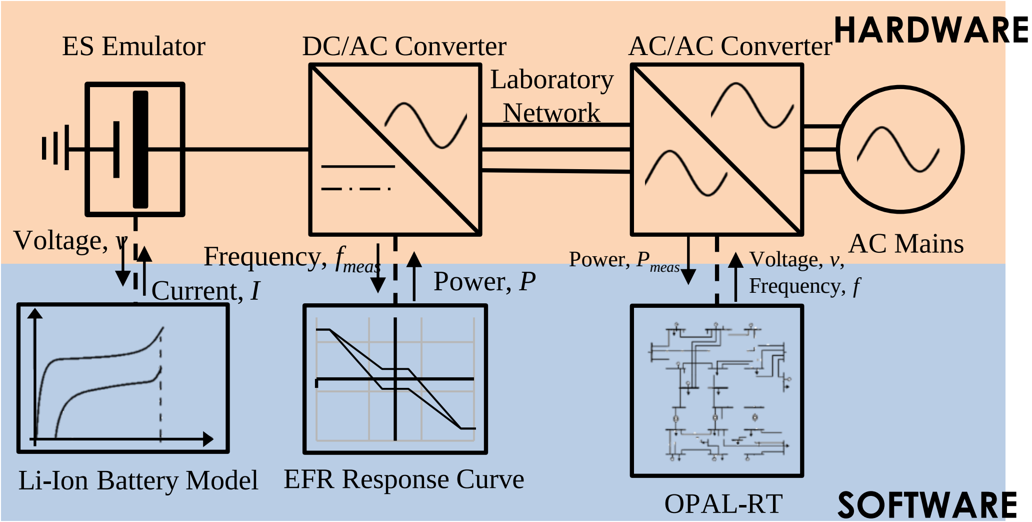




Experiment 2: Response to simulated frequency events

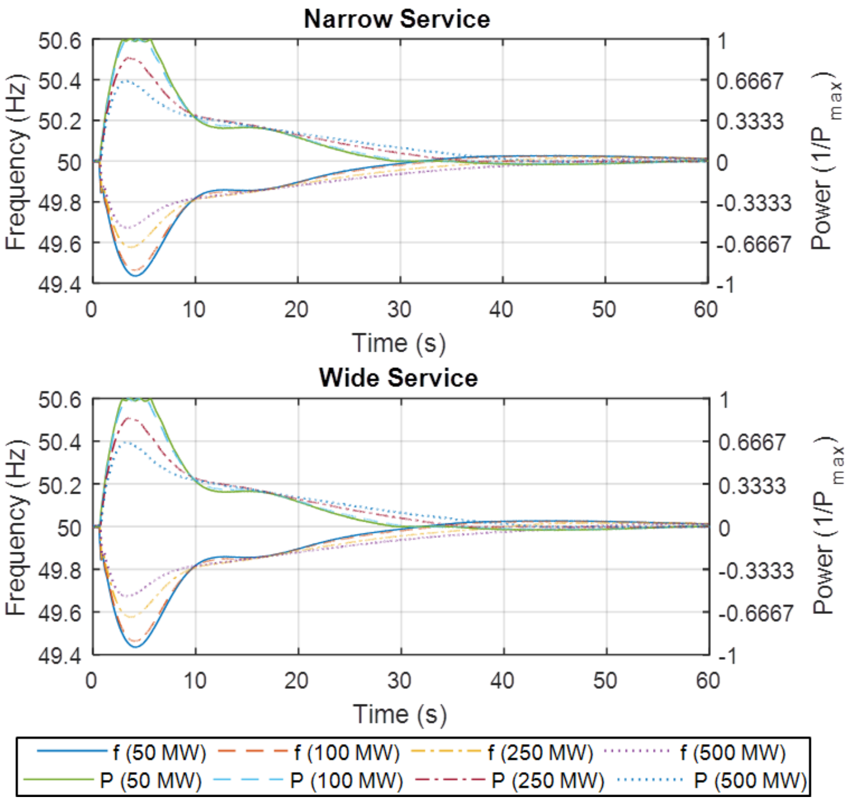
Experiment 2: Aims and setup

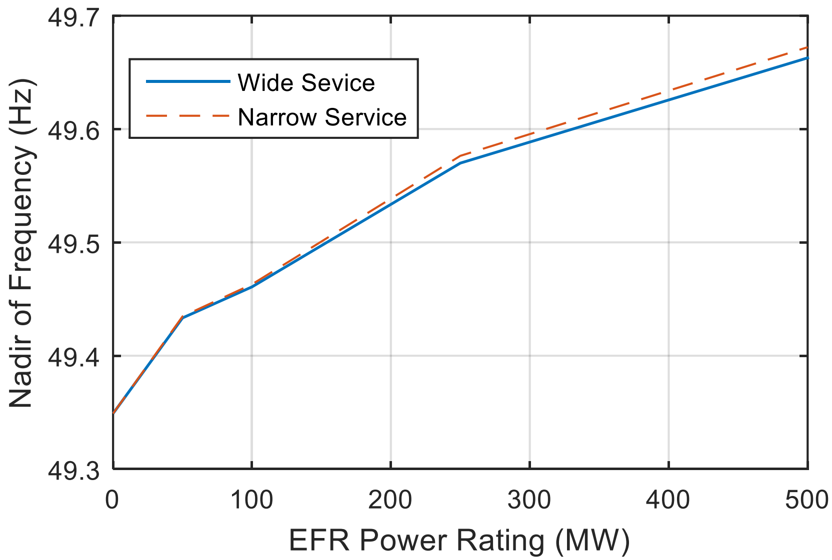
- The IEEE 24-bus test network was simulated in the OPAL-RT
- Frequency events were created in the simulation, resulting in frequency changes on the laboratory network
- The ESS responded to the frequency change; the resulting power signal was measured and fed back into the simulated network
- The ESS response was scaled up, representing different ESS penetration levels



Experiment 2: Results

Experimental Investigation





Conclusions

- Less predictable generation and lower system inertia necessitate a new approach to frequency regulation
- Enhance Frequency Response (EFR) is a sub-second frequency service designed for energy storage systems
- We have demonstrated that the EFR requirements can be fulfilled
- Some aspects of the service could be redesigned to make better use of the ESS
- EFR will be more effective in conjunction with conventional, less costly frequency response providers

Thanks for your attention, I will now take any questions