Welcome to

The DRZC Independent System Testing Report

GE VERNOVA

The National HVDC Centre

An interactive webinar event
19 April 2023

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Distributed ReStart

Energy restoration for tomorrow

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Agenda

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- **Introduction and project overview**
  Michael Kenny – Distributed ReStart
- **An overview of the DRZC control scheme**
  Douglas Wilson and Marta Laterza – GE
- **HVDC Centre communications testing**
  Fabian Moore – The National HVDC Centre
- **Conclusions and improvements**
  Douglas Wilson and Marta Laterza – GE
  Fabian Moore – The National HVDC Centre
- **Redhouse live trial update**
  Jack Haynes – Distributed ReStart
- **Q&A**
  Colin Foote – The National HVDC Centre
- **Final thoughts**
  Colin Foote – The National HVDC Centre

Introduction and project overview

Michael Kenny – Distributed ReStart

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Introduction and project overview

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Power Engineering and (live) Trials (PET):

- Demonstration of black start from DER
- **Defined the functional Specification for a DRZ Controller (GE prototype, designed, built and tested)**
- Defined all required DER and DNO network protection settings and equipment

Organisation, Systems and Telecoms (OST):

- Demonstration of black start from DER via live desk-top exercises – new 'bottom-up' restoration process validated by industry
- **Defined the functional specification for a resilient system and comms infrastructure**
- Defined all required DER, DNO, TO and ESO change impacts

Procurement and Compliance (P&C):

- Demonstration of black start from DER procurement via a mock tender
- Defined the Grid Code changes and modifications required to support the ESRS and distribution restoration
- Defined and agreed with Ofgem, the new funding mechanisms to allow DERs to tender for the new services (South East and Northern Tenders in progress towards BAU)

27 Reports and briefs, 10 Engagement events, 4 DRZC Functional Design Specs, 6 live trials stage podcasts during Covid-19, 6 Stakeholder Advisory Panel quarterly sessions, start and end of project animation videos, and counting!

Knowledge and Dissemination (K&D)

An overview of the DRZC control scheme

Douglas Wilson and Marta Laterza – GE

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An overview of the DRZC control scheme

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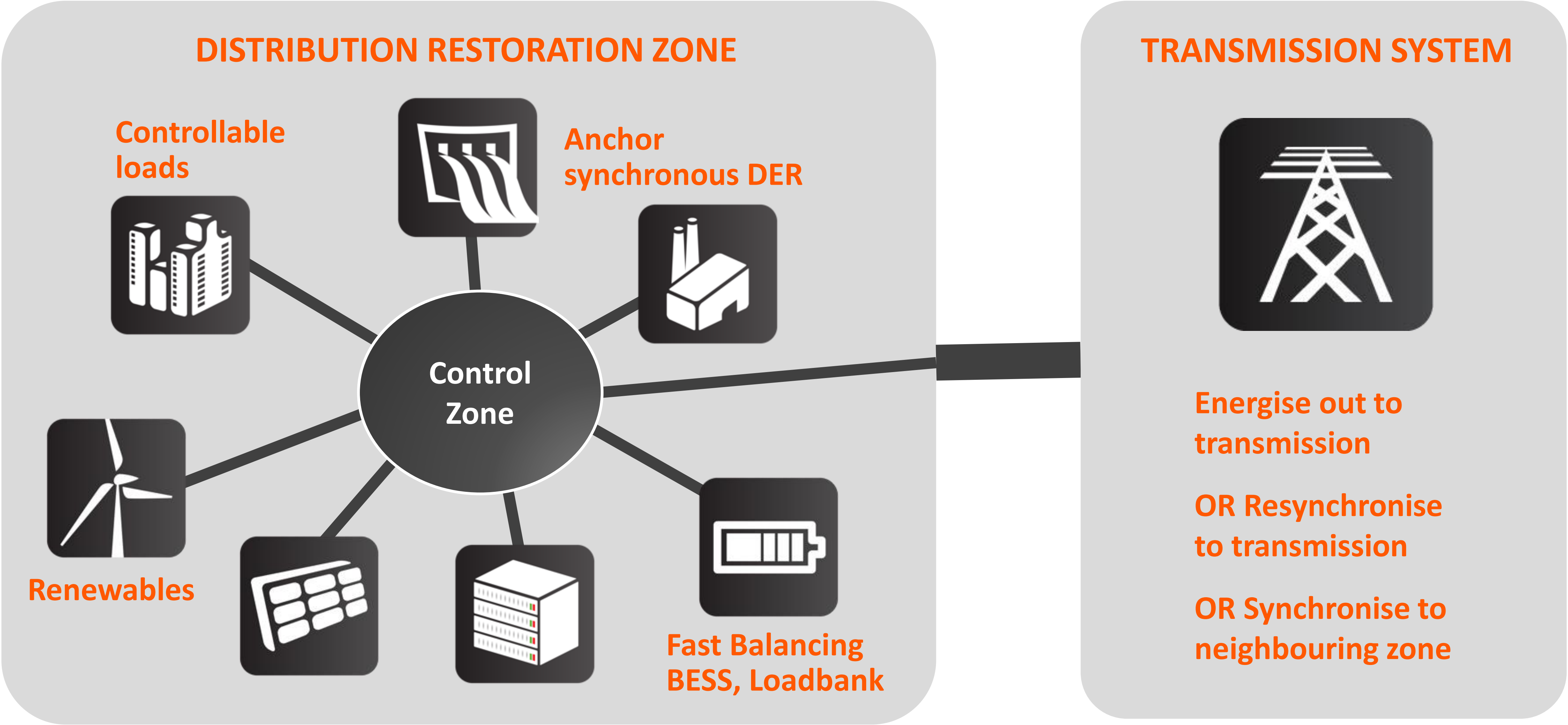

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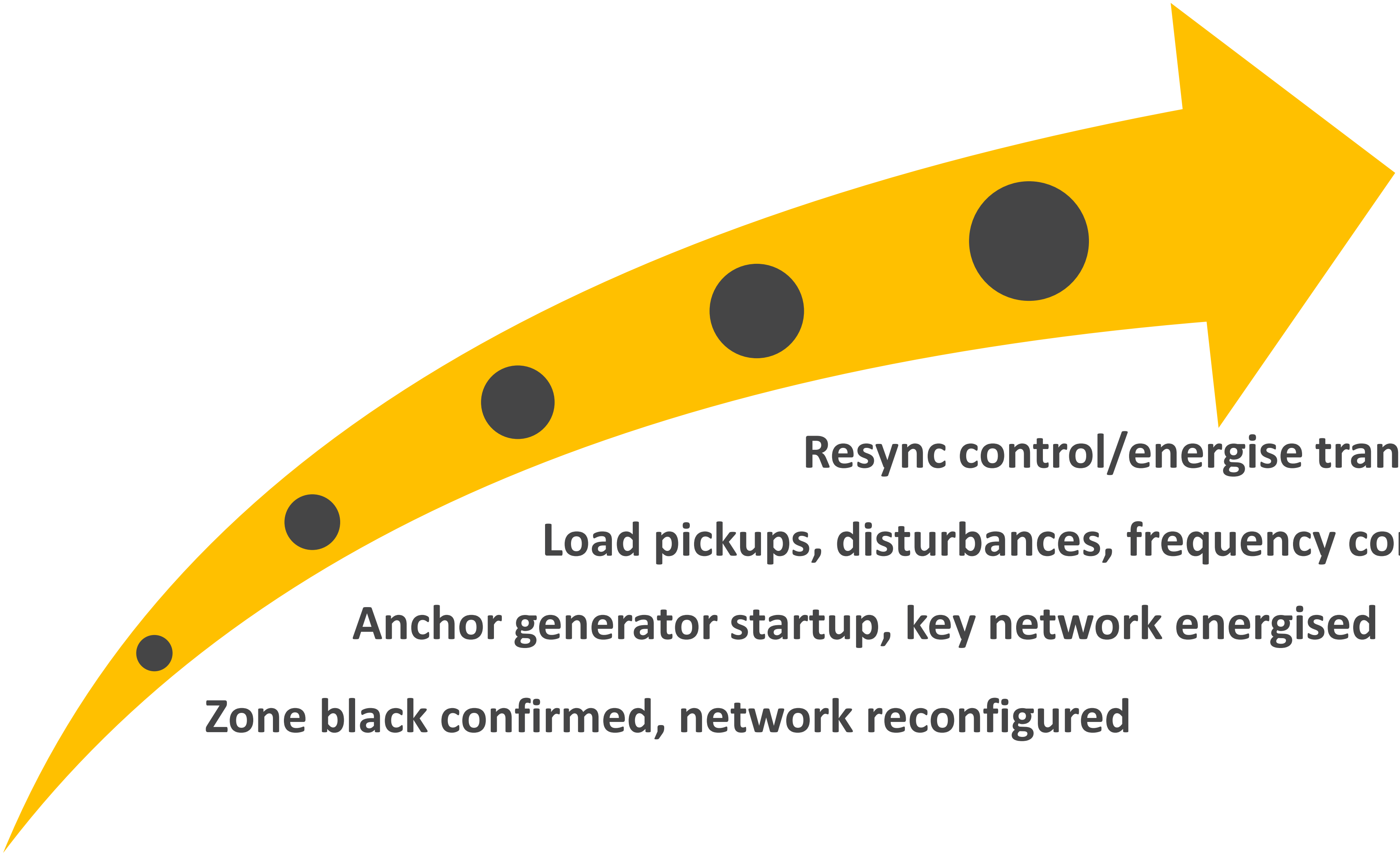
Continued zonal rapid dispatchable resource
Resync control/energise transmission
Load pickups, disturbances, frequency control
Anchor generator startup, key network energised
Zone black confirmed, network reconfigured

Types of response and thresholds

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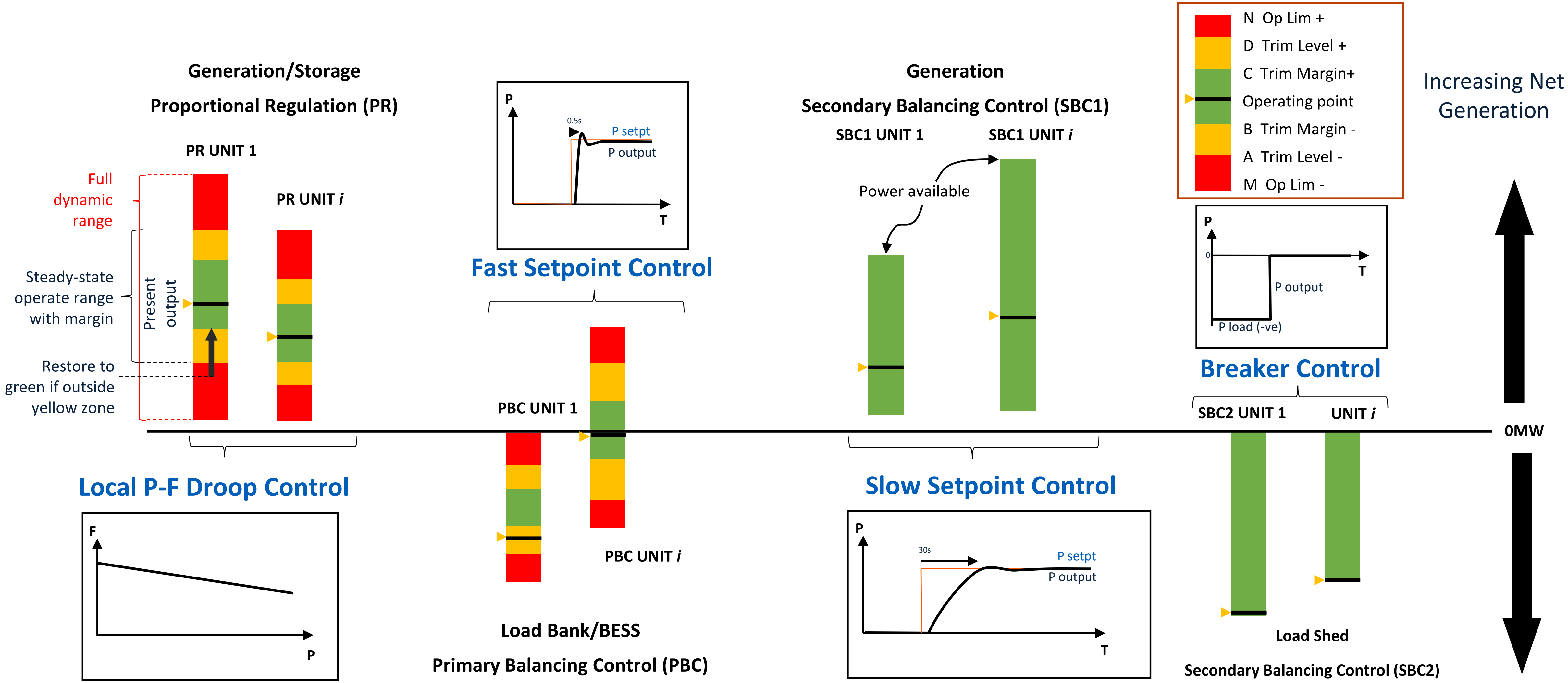

Several units of each response type can be configured. Shown here with two of each type.

Distributed ReStart HiL test system

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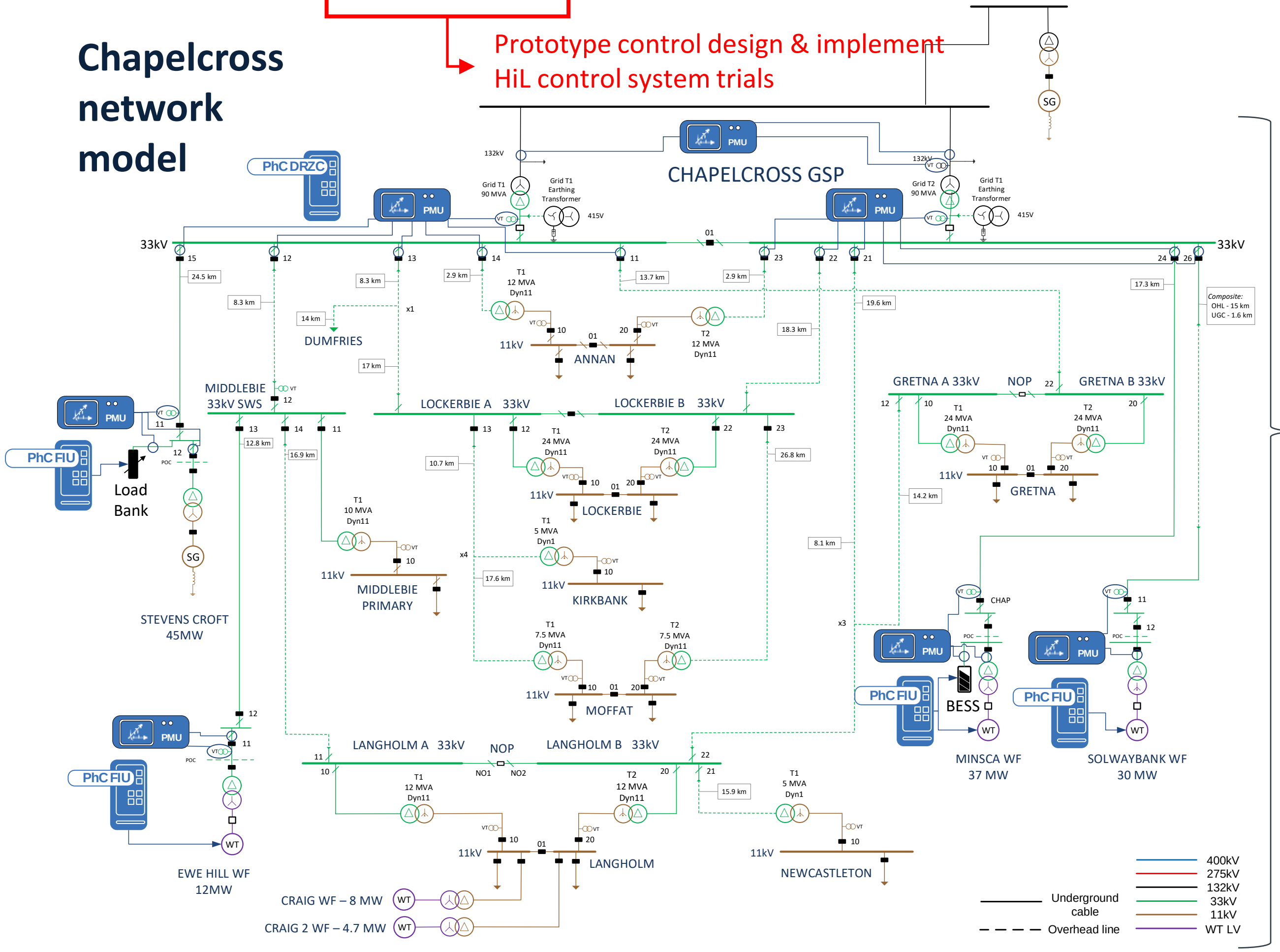
Project Direction	Power Engineering & Trials	Organisational, Systems & Telecoms	Procurement & Compliance	Knowledge & Dissemination

Prototype control design & implement
HiL control system trials

Chapelcross network model

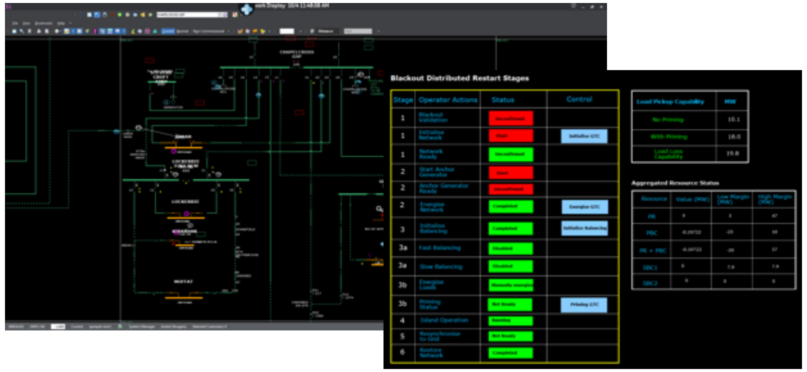


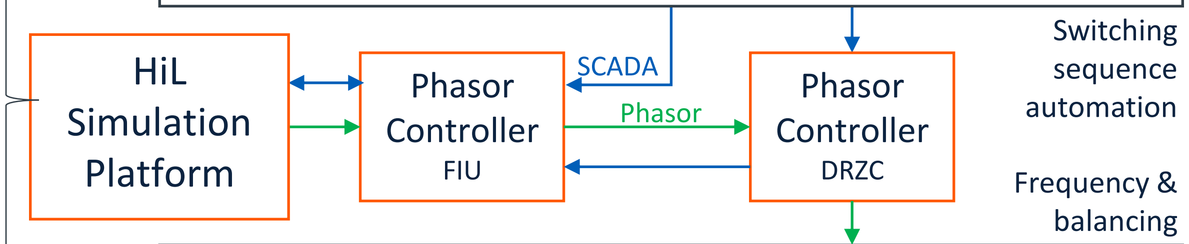
Prototype Distribution Restoration Zone Controller (DRZC)

ADMS

Dashboard & controls

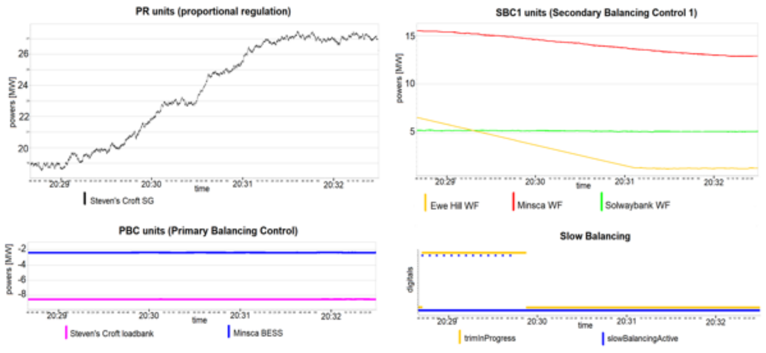
Front End Processor





WAMS

Dynamic display for balancing & stability



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Example response for 20 MW cold load pickup

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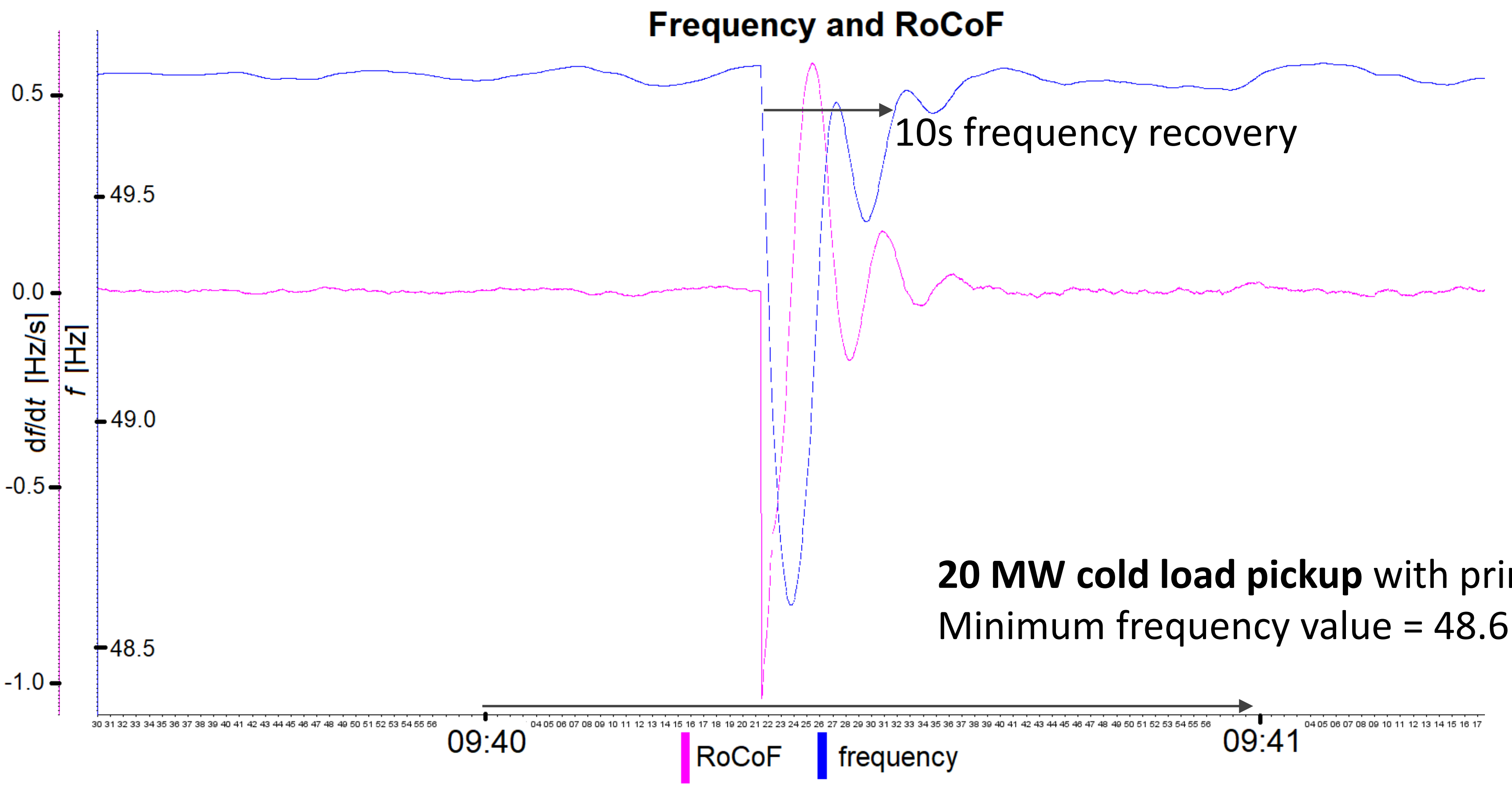

20 MW cold load pickup with priming

Minimum frequency value = 48.6 Hz; Minimum RoCoF = -1.0 Hz/s

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Example response with fast and slow balancing control

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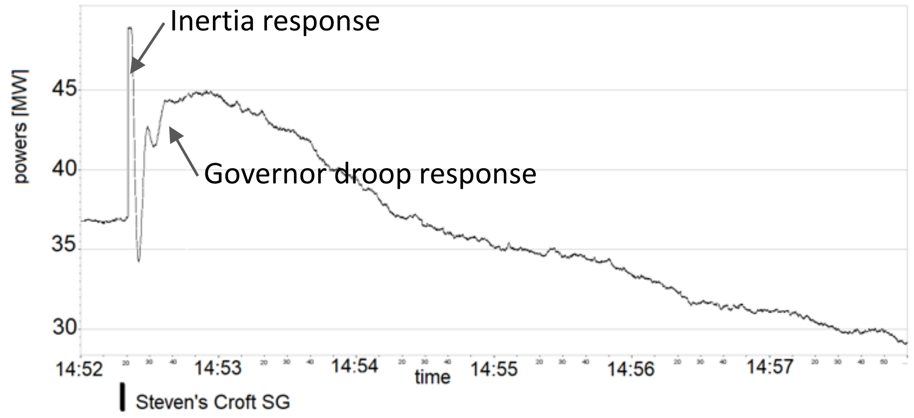
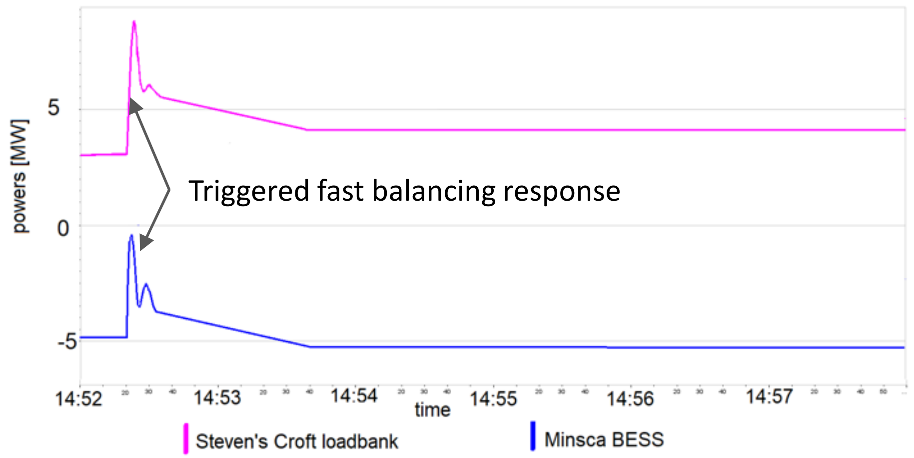
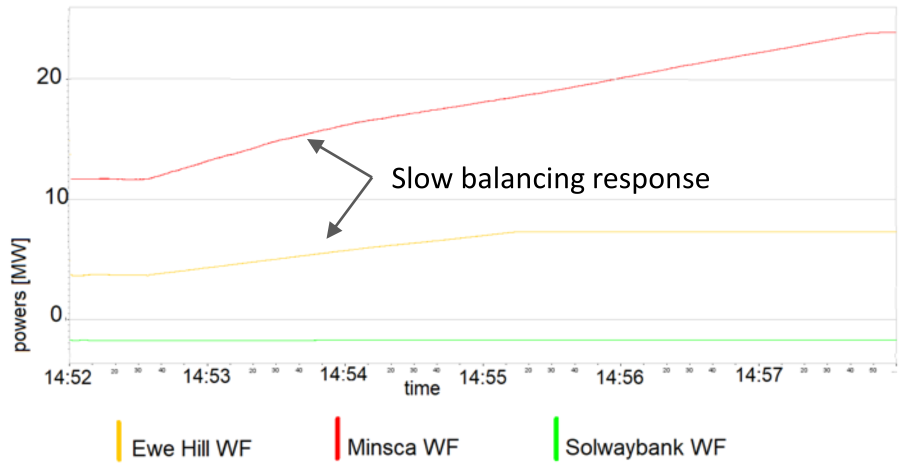
PR units (proportional regulation)



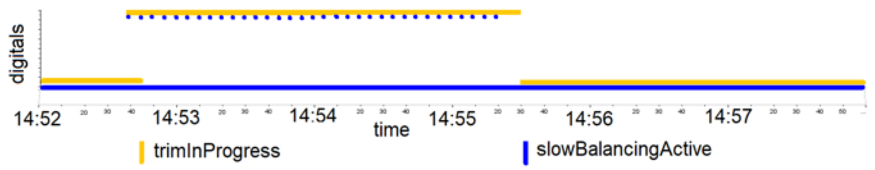
PBC units (Primary Balancing Control)



SBC1 units (Secondary Balancing Control 1)



Slow Balancing



14 MW load pickup with PR and PBC close to upper margins (case 4.b)

Fast and slow balancing response together with proportional governor frequency droop

System latency budget

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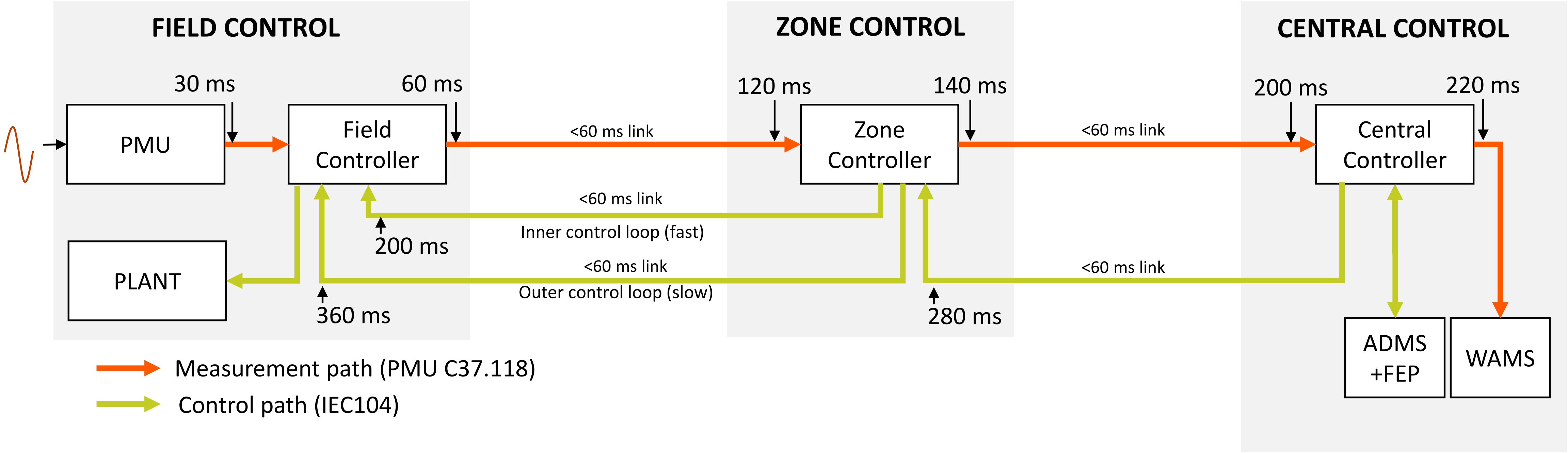

200 ms inner loop round-trip latency with 60 ms comms link latencies as shown

Scheme can be tuned to ~ **140 ms** inner loop latency with 40 ms link latency and controller configuration

Use cases of HiL testing

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- Development and testing of all DRZC components and functions (ADMS, WAMS, DRZC)
- Creation of scenarios to prove each stage of island and resync behaviour
- Creation of complex planned and unplanned scenarios for robustness testing
- Investigate and tune aspects of behaviour
- Sensitivities to behaviour of plant and system, including communications
- Validation and acceptance testing of control system
- Demonstration and stakeholder workshops
- Future use in operator training

HVDC Centre communications testing

Fabian Moore – The National HVDC Centre

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Hardware-in-loop test environment

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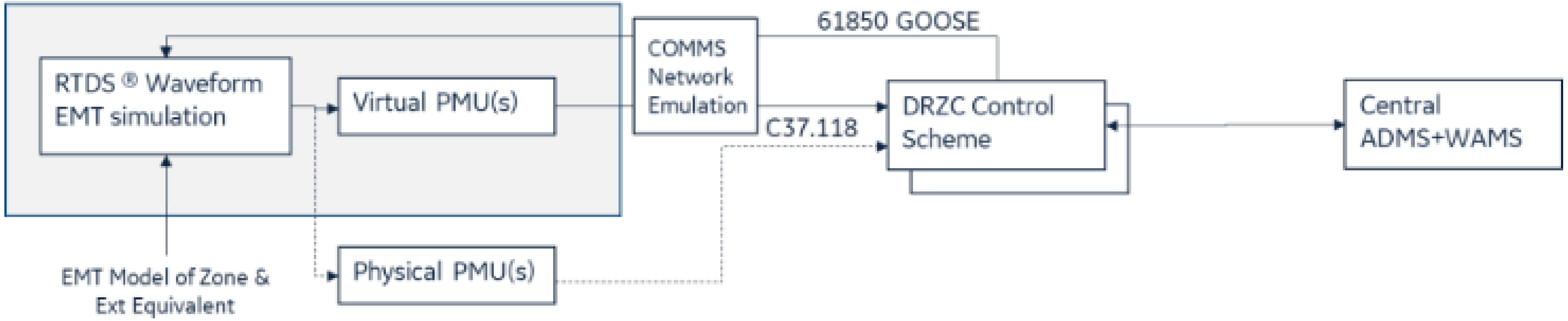
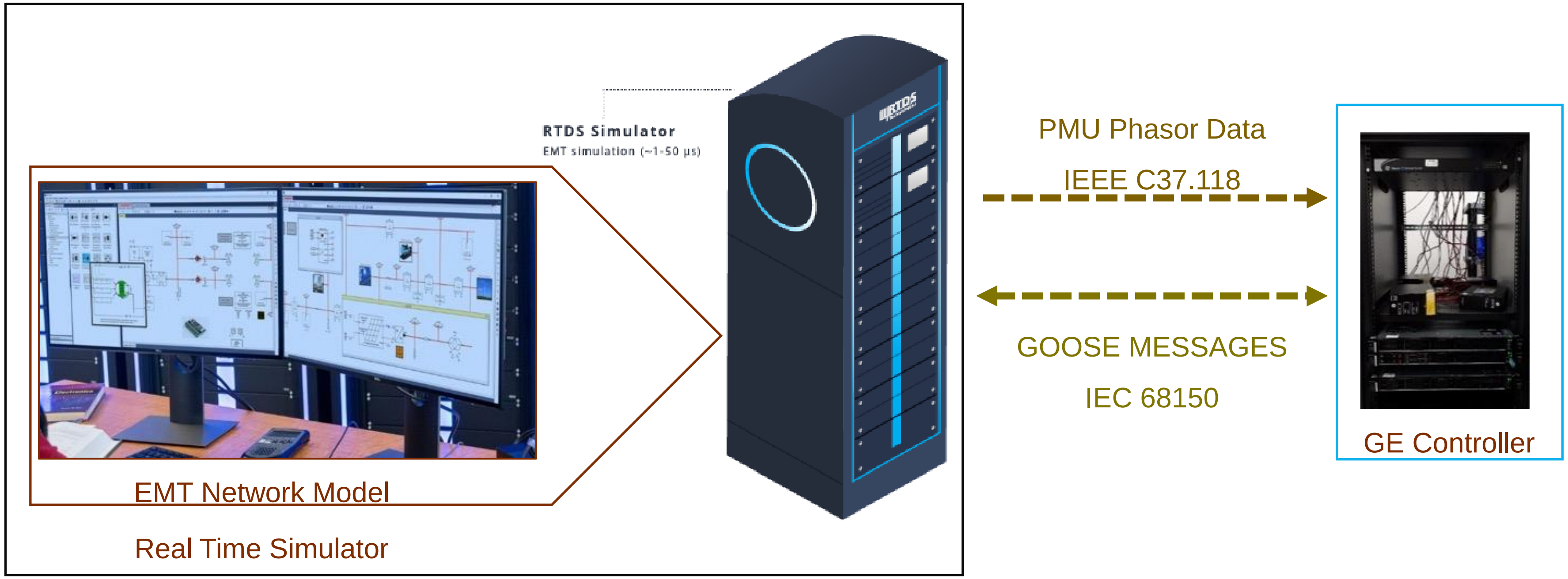
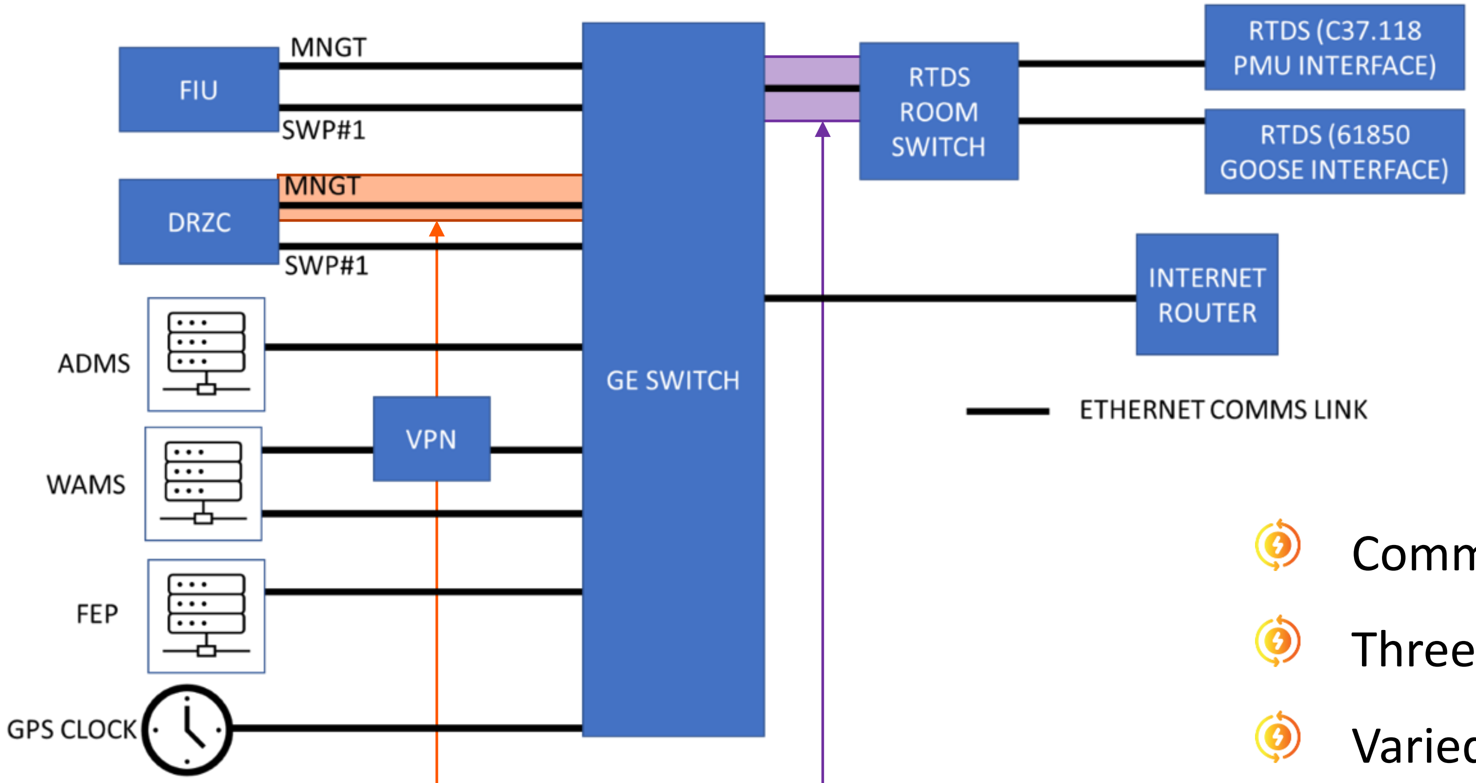
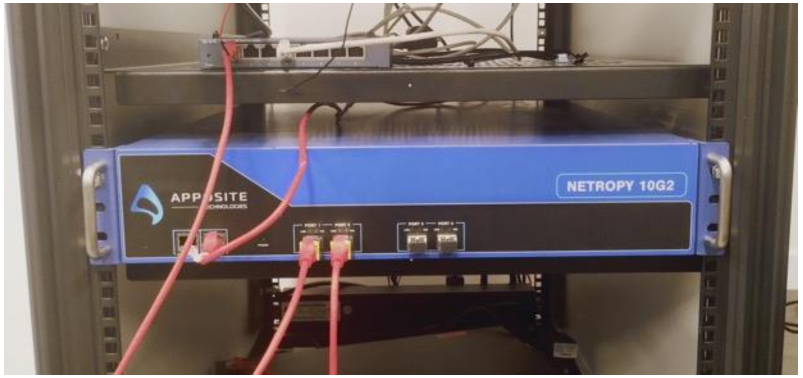




- DRZC hardware-in-loop test environment with RTDS
- RTDS model included:
  - Anchor generator
  - 33 kV network and load
  - Controllable load bank
  - BESS
  - Several wind farms
- Testing focused on impact of comms delays on fast-balancing control

Comms network emulator





- Comms network emulator used to insert delays
- Three test paths
- Varied delays from 0 ms to 90 ms

Test	Link (Bidirectional)		Protocol
1	DRZC	FIU	IEC 104 encrypted
2	WAMS	DRZC	IEEE C37.118 with TLS
3	WAMS	RTDS	IEEE C37.118

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Test 1 – results

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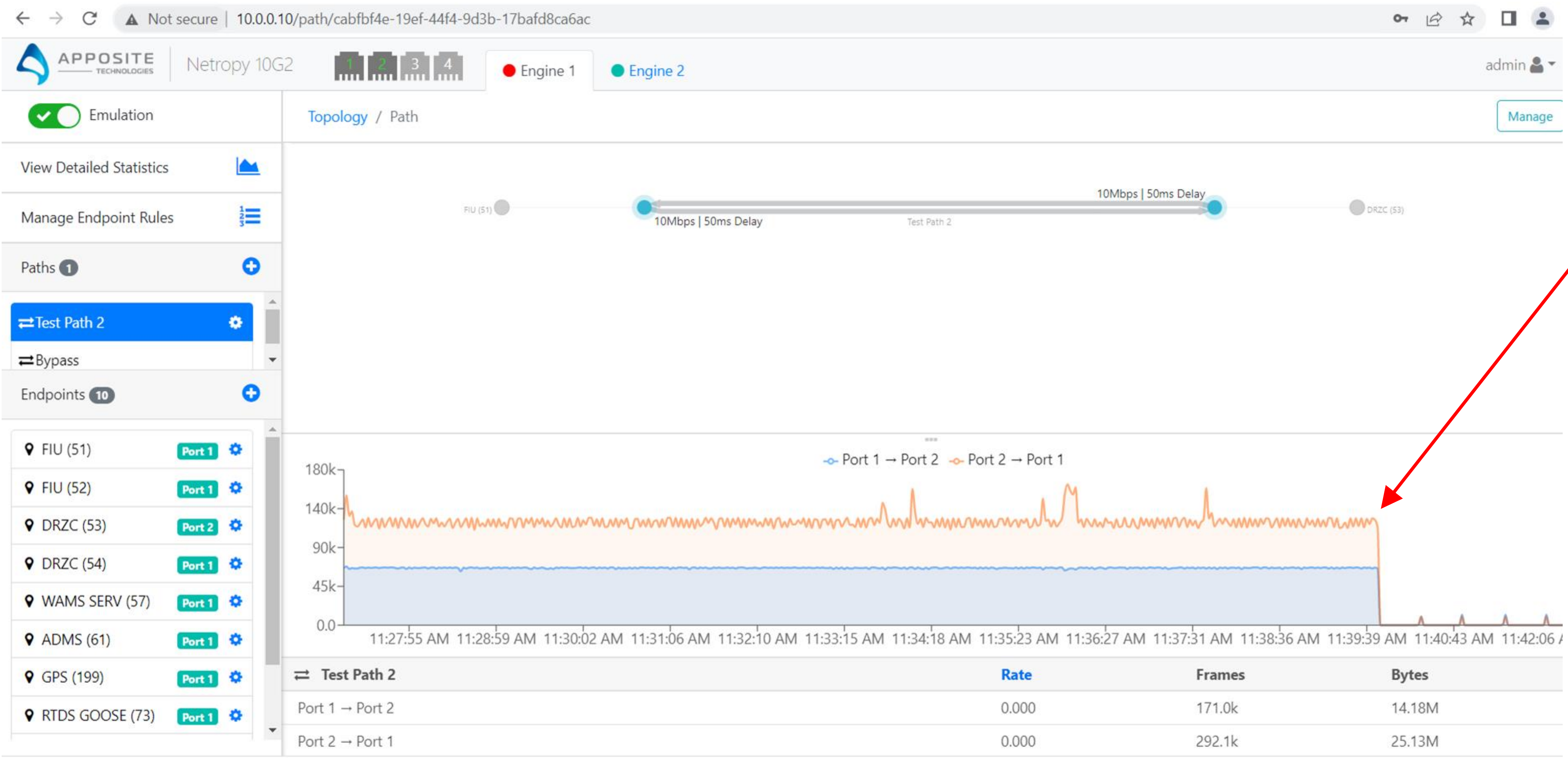


IEC 104 data between the DRZC and the FIU

Comms delay increased from 0 ms to 50 ms at 11:39:39

Resulted in failure in communication (traffic drops)

With no comms between FIU and DRZC, DRZC cannot take any control action

Delays of 11 ms or more would cause similar communication failures

Test 2 and 3 – results

Comms Delay Test Setup	Delay (ms)	Minimum Frequency (During +10 MW step)	Maximum Frequency (During -10 MW step)
2	0	48.8	51.2
3	0	48.8	51.2
2	50	48.9	51.2
3	50	48.8	51.2
2	60	48.8	52.7
3	60	49.4	53.1
2	70	47.2	53.5
3	70	47.2	53.4
2	80	46.5	53.5
3	80	46.8	53.1
2	90	46.5	53.3
3	90	46.5	53.5

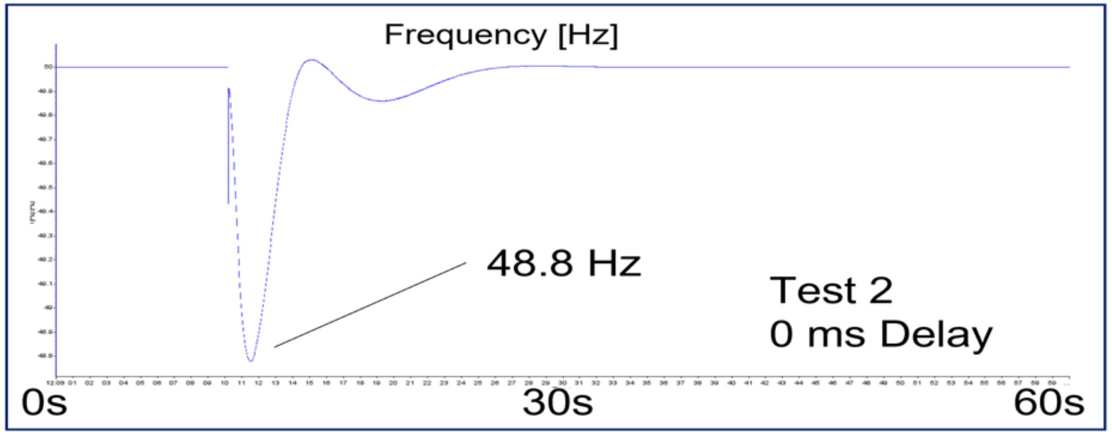
Frequency deviation for +10 MW and -10 MW load steps

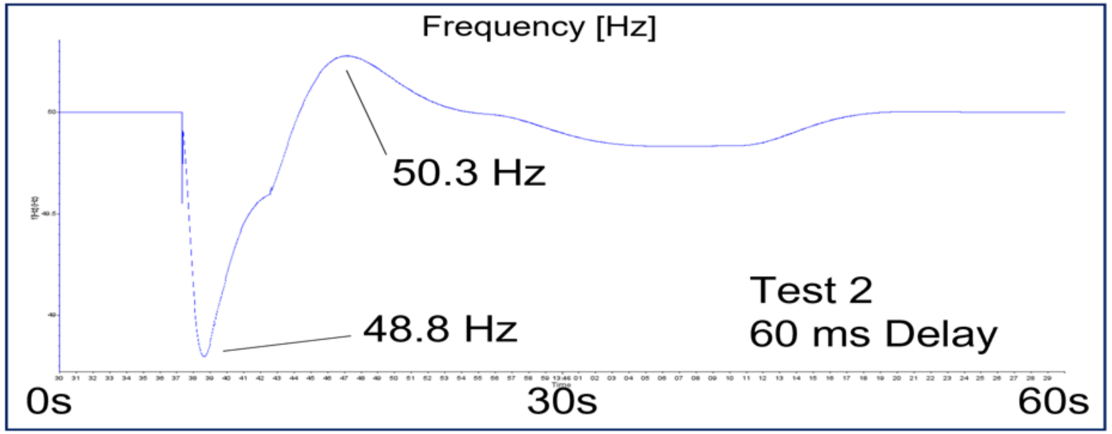
Tests affected how PMU C37 data arrives at DRZC

Comms delay varied from 0 ms to 90 ms

Results similar for +/- load steps

- Delay <50 ms did not impact the performance of the fast-balancing control significantly
- Delays of 60-80 ms showed deterioration
- For delays 90 ms or longer the DRZC would reject PMU data measurements and stop taking control actions





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Conclusions and improvements

Douglas Wilson and Marta Laterza – GE

Fabian Moore – The National HVDC Centre

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Comms testing conclusions and improvements

- Independent system testing conducted in EMT-based simulation environment
  - effort resulted in significant number of incremental improvements to the controller, including Integration improvement in how set points are issued to reduce risk of instability caused by gaps in data

- Testing focused on impact of communications delays – using network emulation equipment
  - revealed a vulnerability in the IEC 104 comms (since fixed by GE)
  - showed how delays in C37 PMU data caused degradation in fast-balancing control
    - will inform specification of comms network
    - identified opportunity to reduce “built-in” delay caused by the PMU measurement, aggregation and forwarding through the WAMS server

Overall conclusions and recommendations

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Overall learning

- HiL testing recommended for BAU DRZC deployment process
- Enabled project collaborators to experience and provide insights in development
- Steep development learning curve to develop integrated HiL, DRZC and central systems

Vendor and third party HiL testing

- Vendor HiL testing useful for system development and rolling out scheme
- Third Party HiL Testing useful for type testing, reference networks, vendor qualification
- Third Party HiL Testing must be collaborative with vendor

Different HiL environments

- RMS (50 Hz) simulation simpler, faster turnaround, less processing power; OK for most DRZC control
- EMT (~6 kHz) simulation models required for protection and power electronic control stability
- Comms emulation valuable for DRZC configuration and defining comms specifications

Redhouse live trial update

Jack Haynes – Distributed ReStart

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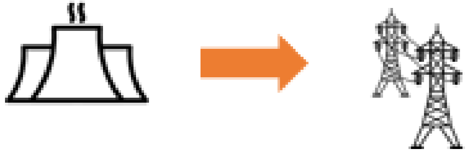
Project motivation

Today | 5-7 days for restoration using traditional methods *



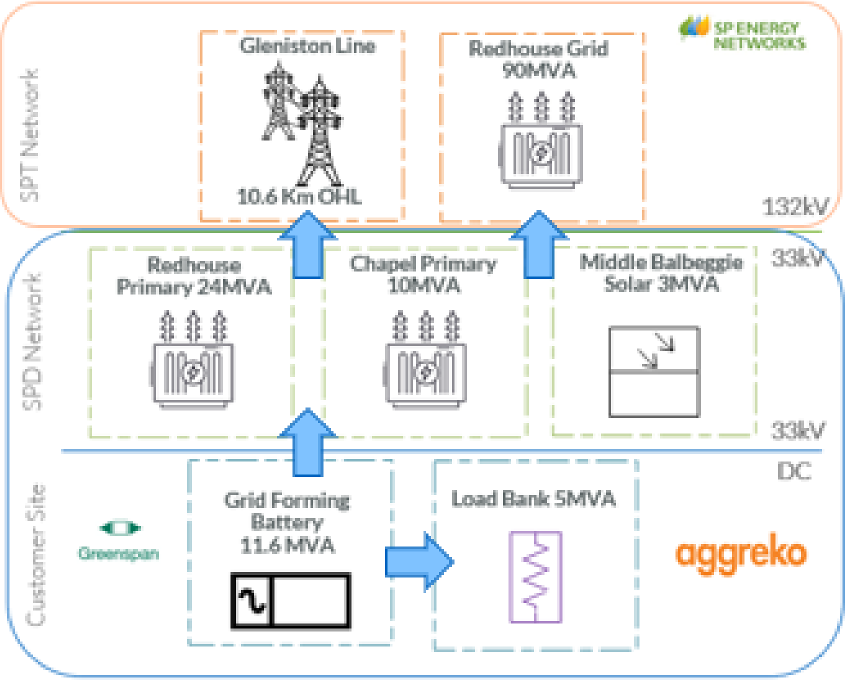
- Closing of coal/ gas stations means need to rely on renewables for restoration
- Need to tap into distributed generator resource of which there are 1000s connected in the U.K
- Reduce restoration timeframe and monetise availability

** Restoration timeframes are indicative only and we aim to improve the existing plans for restoration to be able to meet the new ESRS standard set by DESNZ by 2026*

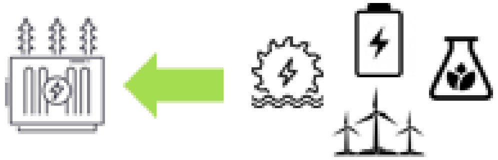
Live Trial Demonstration (Q2 2023)

Simulate blackstart scenario and demonstrate journey from completely 'failed' grid to fully operational network without affecting any real customers

1) Use Grid Forming Battery Generator as anchor to start power island
2) Simulate customer demand using temporary load bank
3) Energise Distribution transformers at two local primary substations
4) Add additional DER to island mix (Solar farm) to provide top-up service
5) Energise Grid transformer and 132kV OHL from battery source
6) Resynchronise battery generated power island with intact grid network



Global Benefits



After D-Restart | <1-3 days for restoration using DRZs

1) Demonstrate ability of DERs such as wind, hydro, biomass or batteries to start and maintain power islands
2) Increase number of revenue streams generation owners via commercialisation of restoration availability
3) Reduce blackstart restoration timeframe from 5-7 days to potentially hours – 3 days subject to rollout *
4) Set global benchmark / template for distributed restoration zones (DRZs) through world first testing
5) Further expand the portfolio of renewable generation benefits in pursuit of Net-Zero

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Q&A

Colin Foote – The National HVDC Centre

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Final thoughts

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Thank you for joining us.

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