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SYSTEM RESTORATION AND OTHER GRID SERVICES

Power Systems Protection Centre Workshop

7th Feb 2024

Services implemented with wide area control

Manage a co-ordinated distribution-based system restoration zone

→ **GB Electricity System Restoration Standard** implemented regionally, with an interim target of **60%** of **regional** demand to be restored within **24 hours**.

Using same infrastructure, provide an aggregated fast response service for network disturbances.

→ Basis for distribution providing regional disturbance response service. Improving system stability while reducing cost of ancillary services.

Design, implement and demonstrate a control system to achieve these goals

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INNOVATION CENTRE

ELECTRICITY SYSTEM RESTORATION SERVICE

ESRS:
ZERO CARBON
RESTORATION
USING DER

Control Zone with Diverse Resources

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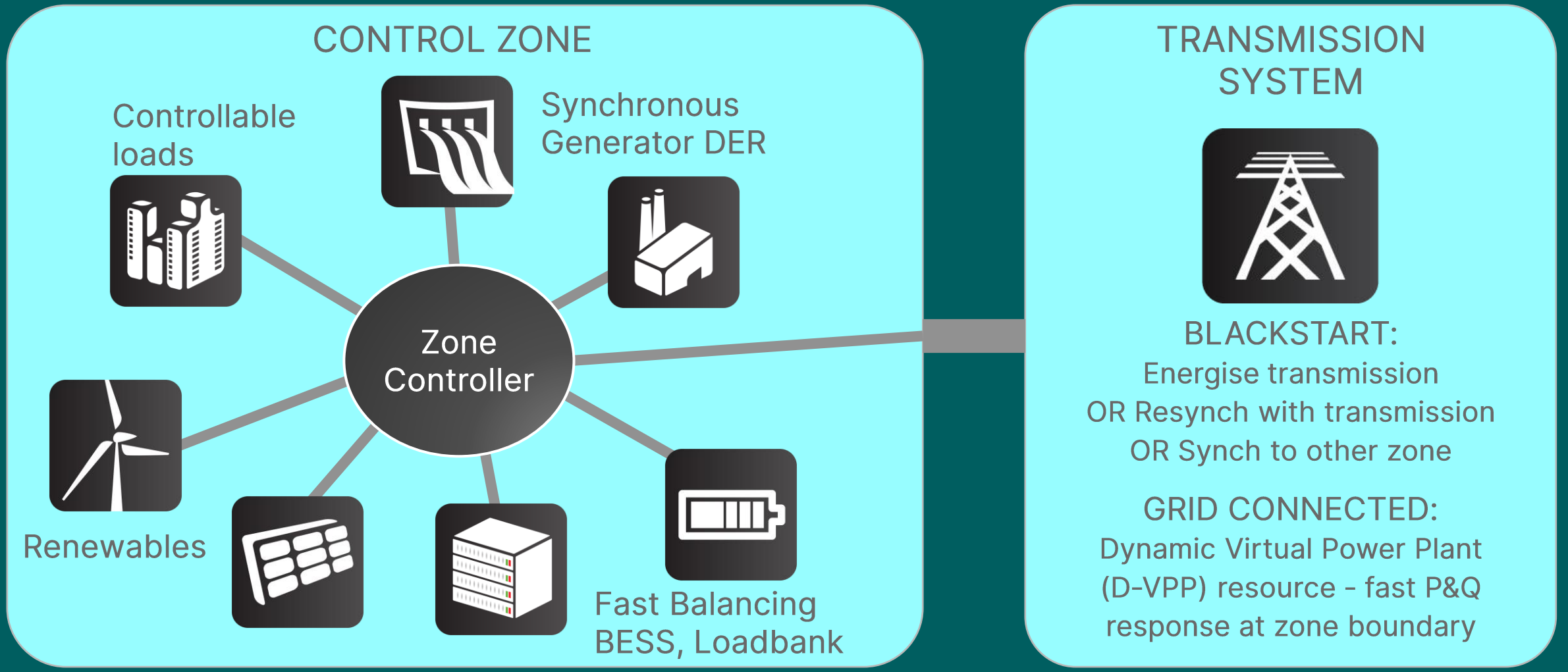

Pathway to ESRS System Deployment

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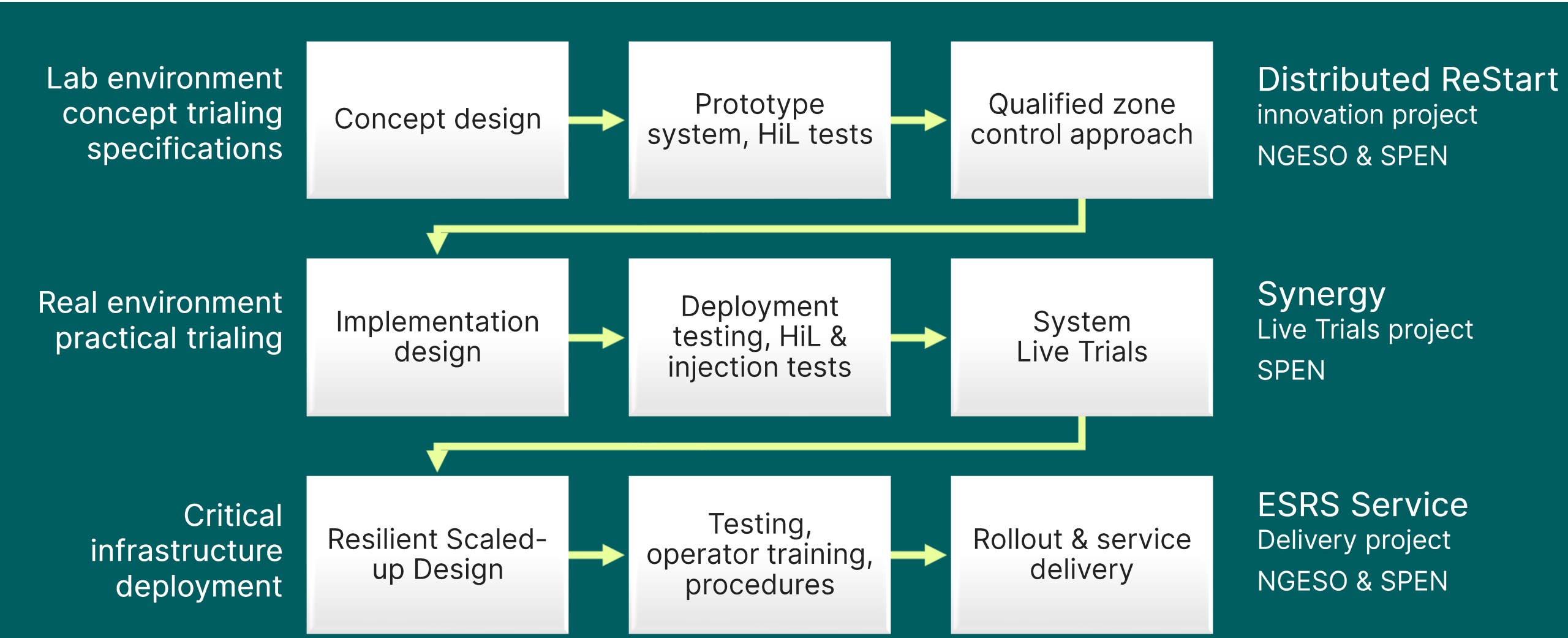
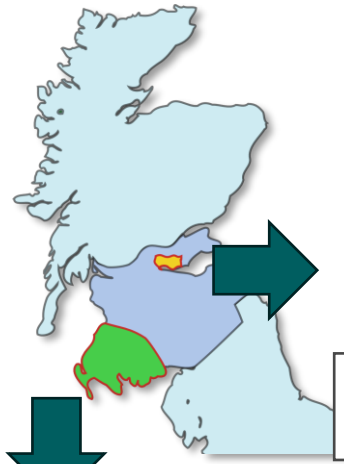


Controlled Zones for Live Trials



Transmission
132 & 275 kV

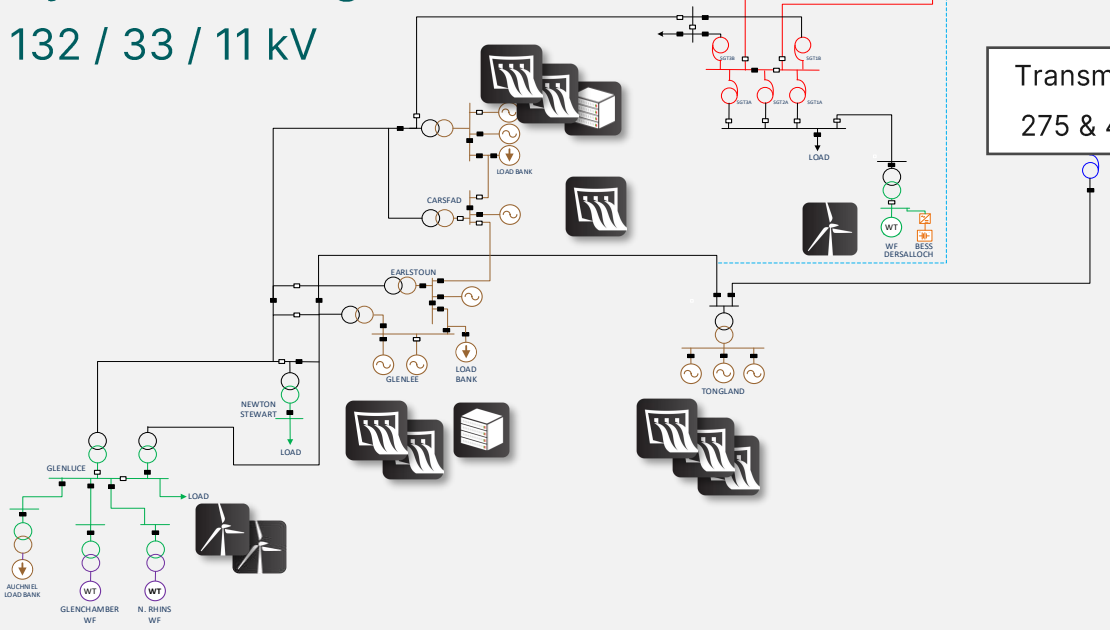
Control Zone #1

Hydro & wind generation

132 / 33 / 11 kV

Transmission
275 & 400kV

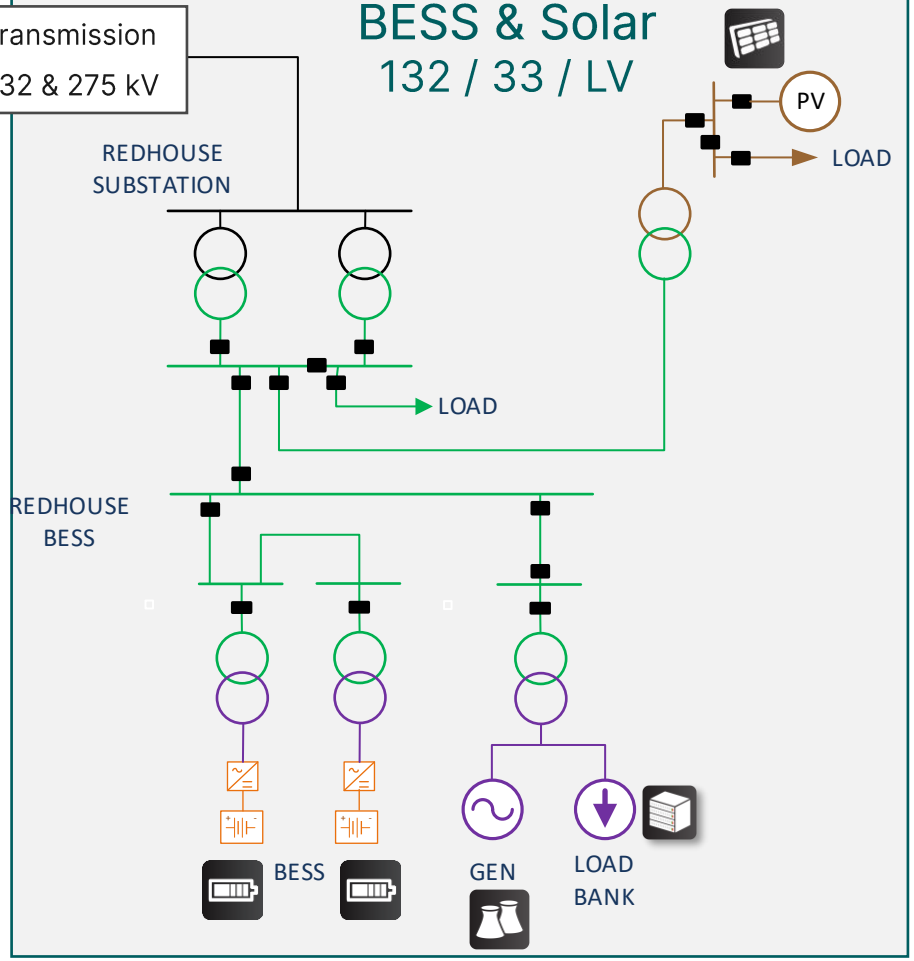
Transmission
275 & 400kV



Control Zone #2

BESS & Solar

132 / 33 / LV



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CONTROL SCHEME DESIGN

Control Hierarchy

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Operational Control Centre

ADMS Operator Dashboard

CENTRAL CONTROLLER

Central Wide Area Control
Co-ordinating Regions & Services

WAMS Dynamics Views

Measurement C37.118

Control IEC104

Zone Control
e.g. Anchor generator of restoration service

DRZC

DISTRIBUTION RESTORATION ZONE CONTROLLER #1

Logic for controlling & co-ordinating services delivered by the zone

ZONE #*N*

Etc.

PMU

Measurement C37.118

Control IEC104

Measurement C37.118

Edge Control
e.g. Other controlled DER, storage etc

FIELD INTERFACE UNIT #1

Local failsafe logic, interface to plant, data aggregation & encryption

FIU #*N*

Etc.

Modbus / DNP

C37.118

GOOSE

Plant Ctrl

PMU & IO

CB Ctrl

Control Hierarchy Implementation

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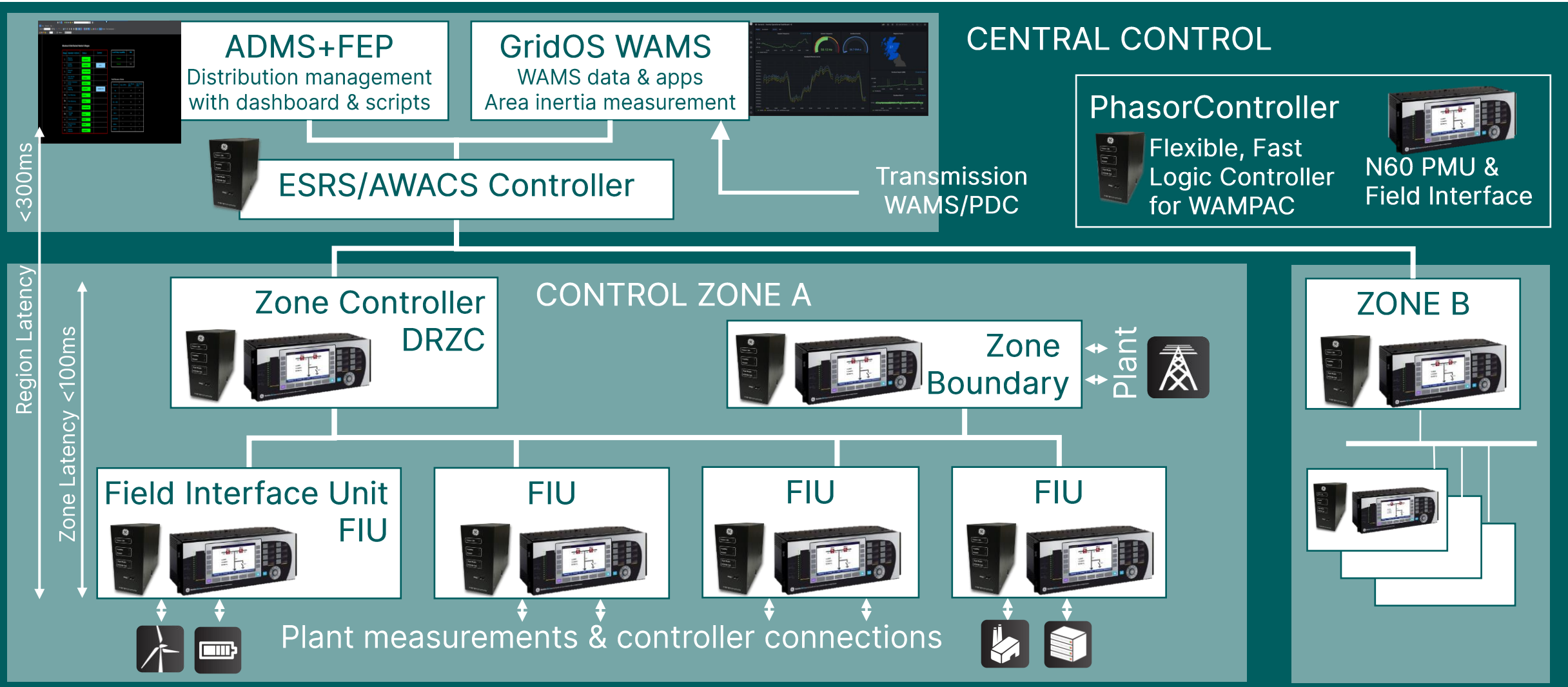
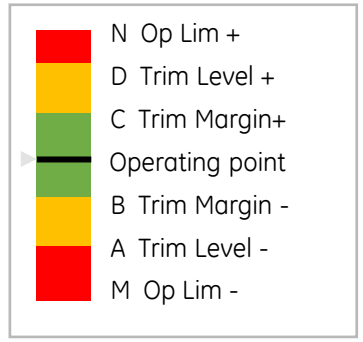


DRZC Balancing Control Processes

Process	Description
Proportional Regulation e.g. BESS, Hydro	Conventional **local droop frequency & voltage control**; Wide Area Control (WAC) may adapt setpoints.
Fast Balancing e.g. BESS, Load bank	Sub-second WAC control to **rebalance load pickup or load/gen trip.** Response proportional to power gain/loss, using multiple resources.
Slow Balancing e.g. Wind, solar, load	WAC re-dispatch of slow responses **so fast balancing units maintain control margins**
Priming	Biasing fast response units for **maximising load pickup** capability
Resynchronisation Control	**Aligning the island's frequency and voltage with grid** across resync boundary. Followed by synchrocheck relay arming.
Dynamic Virtual Power Plant	Once resynchronised, **zonal P & Q setpoints** can be applied to the total export which can change by manual dispatch or auto trigger.

DRZC Balancing Controls

Merging resource capabilities in co-ordinated zone balancing



Generation / Storage

Proportional Regulation (PR)

PR UNIT 1

PR UNIT *i*

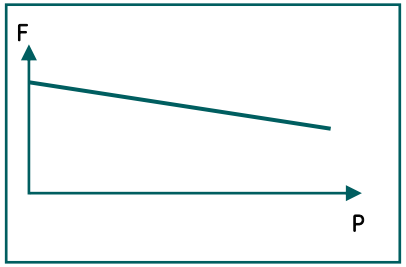
Full dynamic range

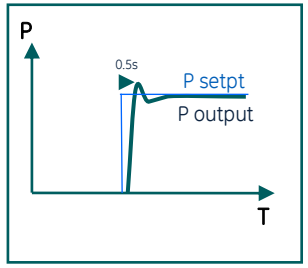
Steady-state operate range with margin

Present output

Restore to green if outside yellow zone

Local P-F Droop Control





Fast Setpoint Control

PBC UNIT 1

PBC UNIT *i*

Load Bank / BESS

Primary Balancing Control (PBC)

Generation

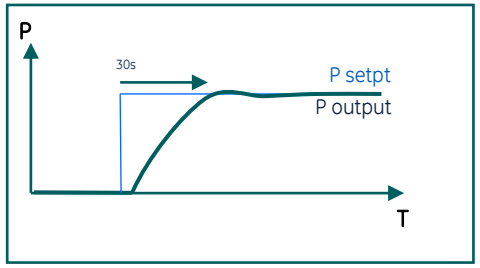
Secondary Balancing Control (SBC1)

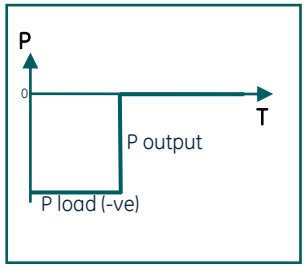
SBC1 UNIT 1

SBC1 UNIT *i*

Power available

Slow Setpoint Control





Breaker Control

SBC2 UNIT 1

UNIT *i*

Load Shed

Secondary Balancing Control (SBC2)

Increasing Net Generation

0MW

Increasing Net Load

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

ADMS Network Control & Supervision Processes

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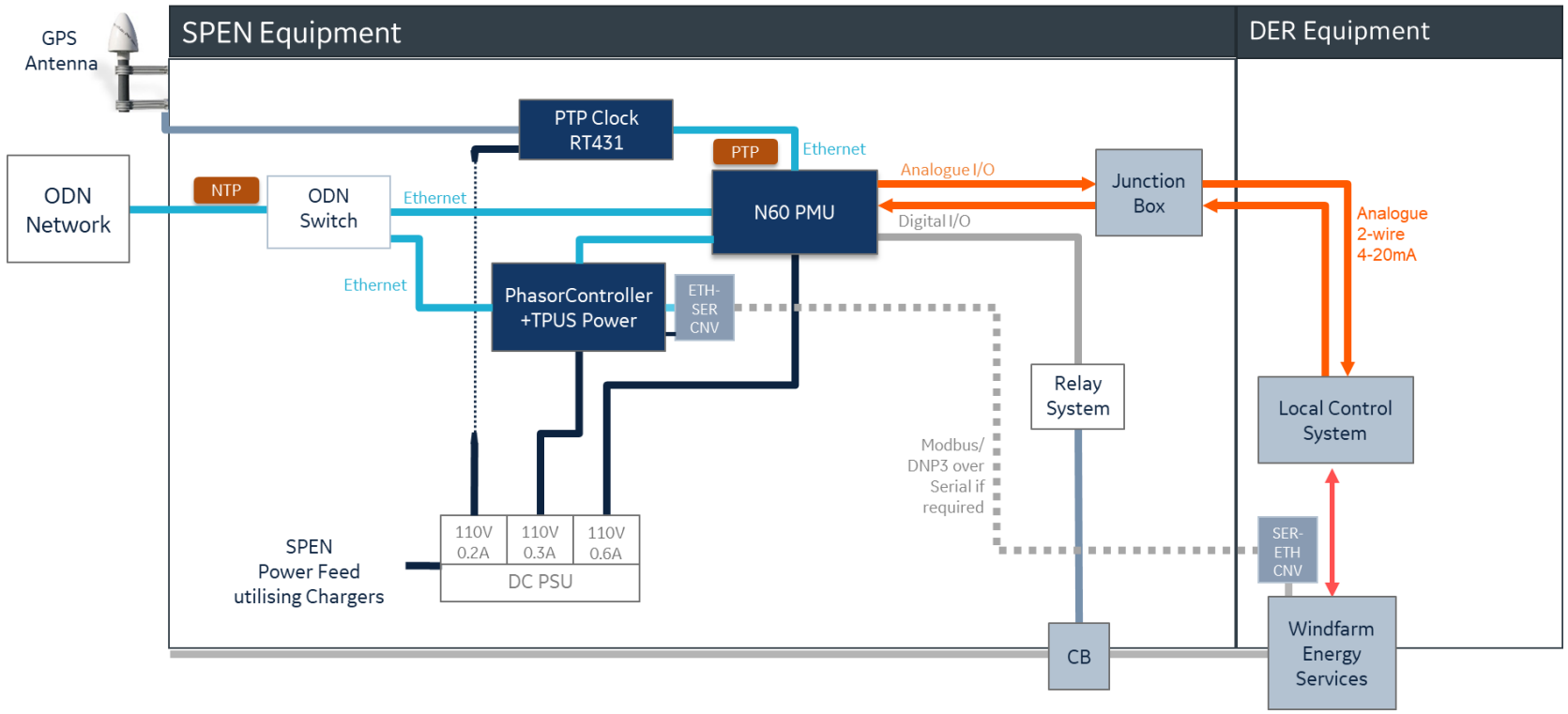
Process	Description
Network Initialisation	Sets all CBs to known starting point for island
Enable/disable units	Manage which units are participating in the zone control
Enable/disable control processes	Manage which control processes are active in the zone control
Energise network	Switching sequences to energise network sections, simplifying procedure
Observe zone state	Zone black, zone islanded, unit operating point vs limits etc.
Initiate resync control	Zone starts follows the frequency and voltage across the resync boundary
Synchrocheck arming	Once F & V aligned, arm the synchrocheck relay, observe closing
Dynamic VPP settings	Enable and apply zone boundary P&Q setpoints to Dynamic VPP function

Typical Field Installation



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HARDWARE-IN-THE-LOOP TESTING

Hardware-in-the-Loop Test Setup

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OPAL-RT TECHNOLOGIES

Hardware in the loop digital simulator

Synchrophasor measurements & GOOSE control

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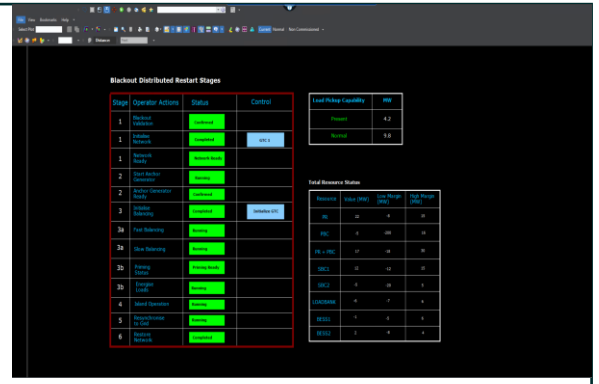
SCADA IEC104



Network View
ADMS+FEP configured for restoration zone control

Dynamics View
WAMS PDC, applications & visualisation of system dynamics

Synchrophasor IEEE C37.118

Real-time control
Bank of virtualised PhasorControllers

SERVER WITH VMs WITH GE's SYNERGY MONITORING & CONTROL

Hardware-in-the-Loop

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Functions

Testing scheme logic & performance

Demonstrations & acceptance tests

Operator training simulator

Challenges

Dynamic model validation

Creating representative comms

Performance in real-time simulation

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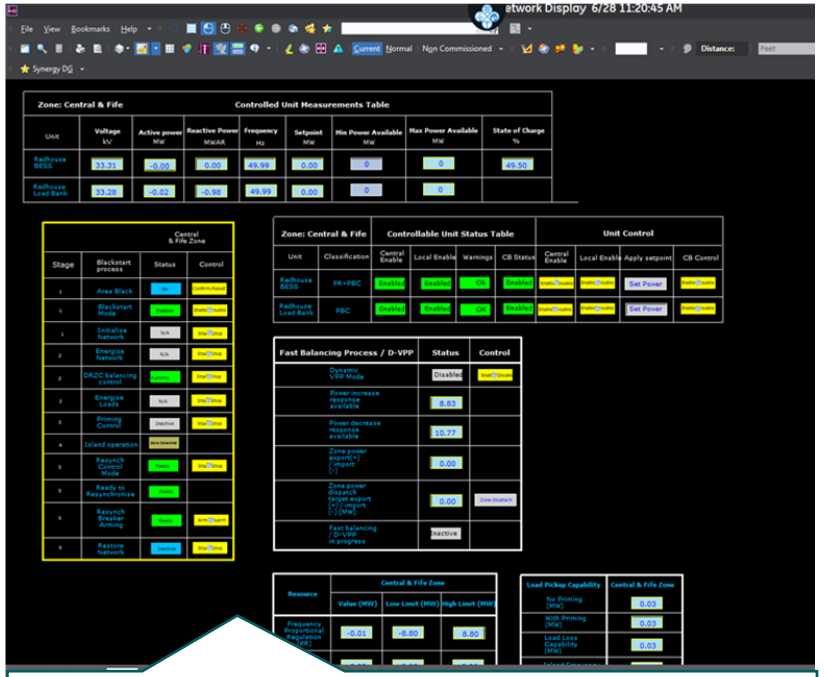
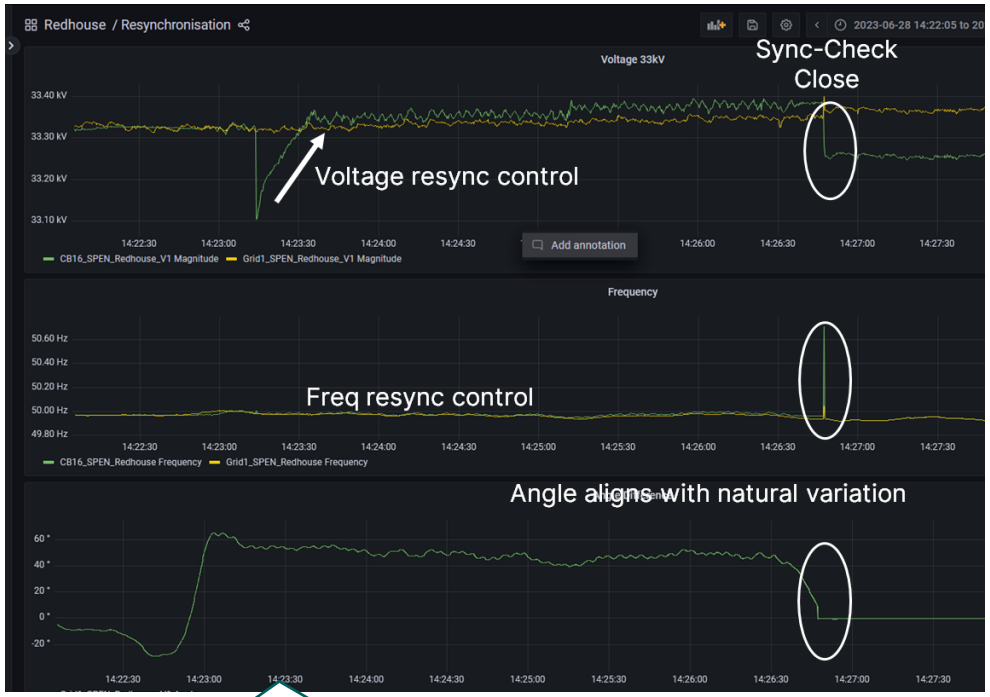
LIVE TRIALS

Live Trial Visualisation of Blackstart & Islanding



ADMS Dashboard

- Controlled unit measurements PQV, setpoints, min/max available
- Control status and user interaction
- Workflow including DRZC zone automation processes



WAMS Dashboard

- Dynamic trend charts
- Controlled unit PQV, frequency
- Resync boundary VFδ differences to align
- Zone control activity status

Zone Dashboard Overview

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Dashboard for each Zone

ESRS Workflow

Measurements Table

Unit Status and Control

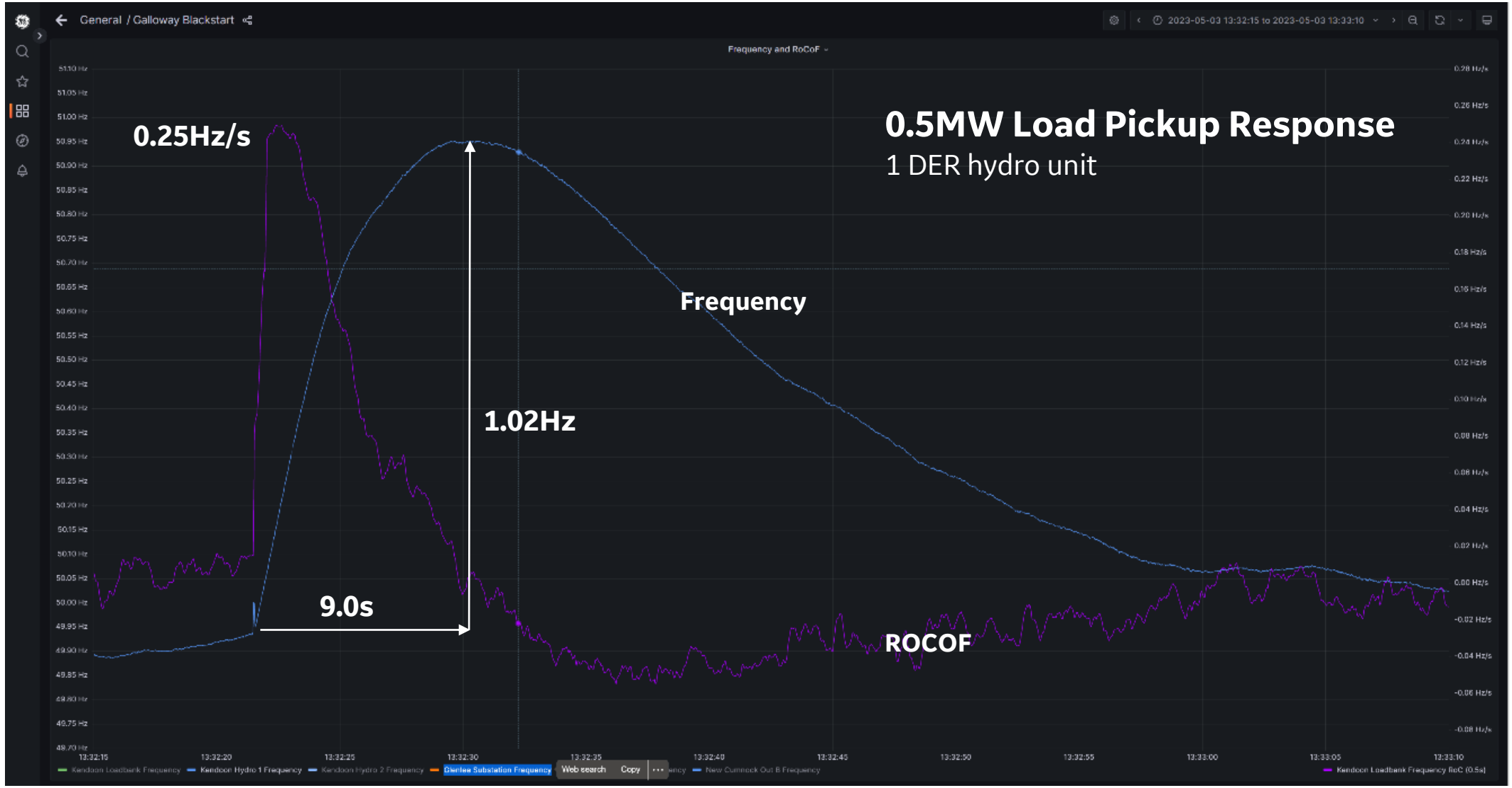
Dynamic VPP

Load Pickup Capability in zone

Zone resources by category

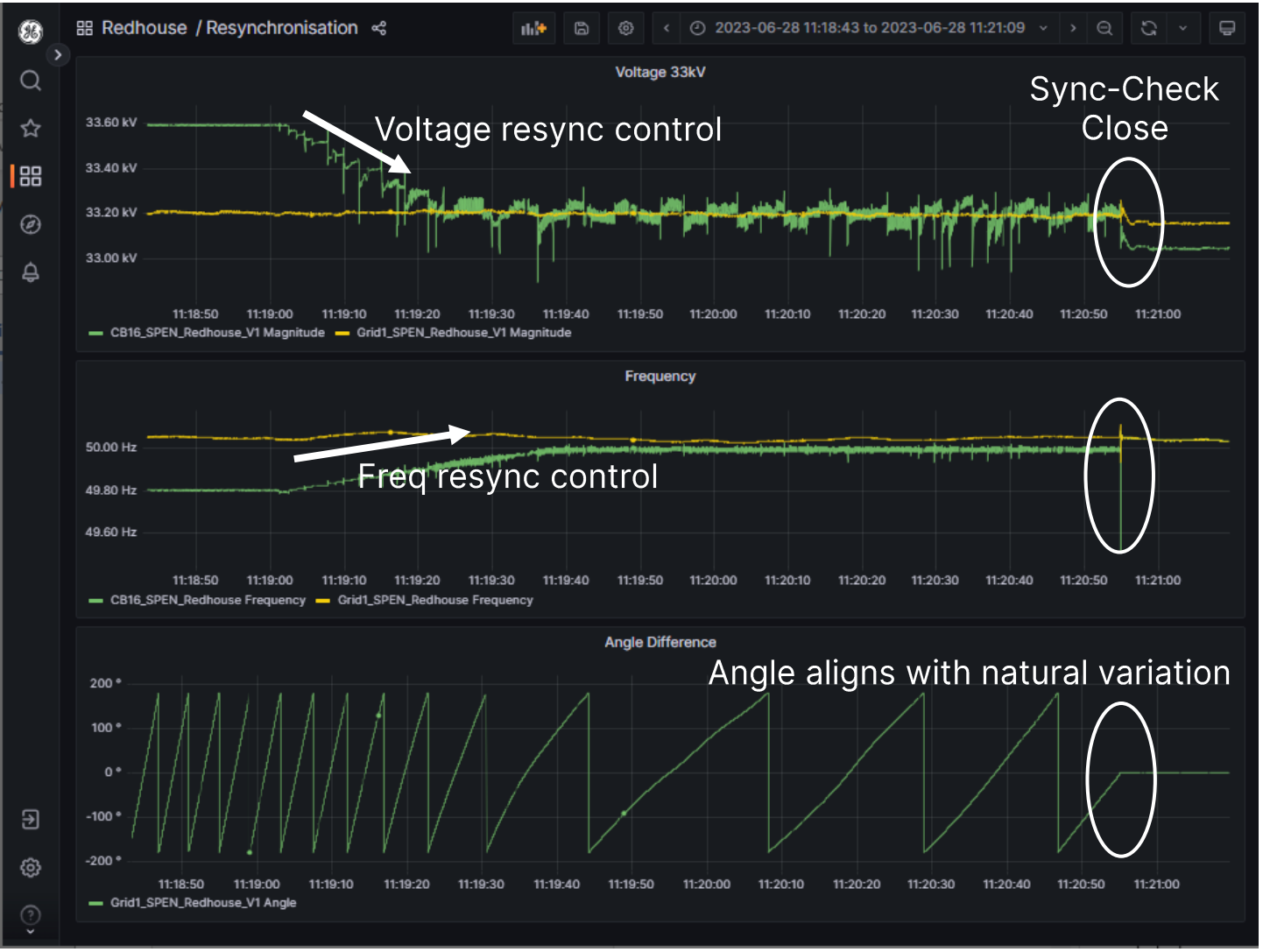
Example Fast Balancing Trial Response (BESS anchor)

Contrast Hydro Anchor Droop Response (1-unit)



Example Slow Balancing Trial Response

Resynchronisation Control and Relay Closure



Resync Control Mode brings zone voltage and frequency into alignment with external grid through P&Q setpoint control, shifting position on droop line.

Resync Boundary can be remote from anchor generator.

Sync-Check Relay function on N60 PMU armed from ADMS

Process view & success observed by WAMS, next actions can be initiated (automated if required) e.g. back to grid-following, frequency droop control off, local earth removed

Resynchronisation Control and Relay Closure

As previous, with BESS P & Q control in place of load bank P & Q

Dynamic Virtual Power Plant

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SUMMARY OF EXPERIENCE

Experience from Live Trials (1)

Galloway Live Trials – Hydro-anchor Zone Blackstart & Island Run

- Frequency control is possible with one 12MW hydro unit with ≤1MW load pickup. Load pickup increased by fast balancing and multiple hydro units (more inertia).
- Energisation of 132kV transformers and lines from hydro unit is well controlled using Point on Wave switching
- WAMS dynamic observability is critical for running a blackstart process
- Modbus issues for co-ordination with loadbank affected island stability

Aggreko Mini-Grid Tests (2x Genset 2x Load Bank + WAMS/DRZC)

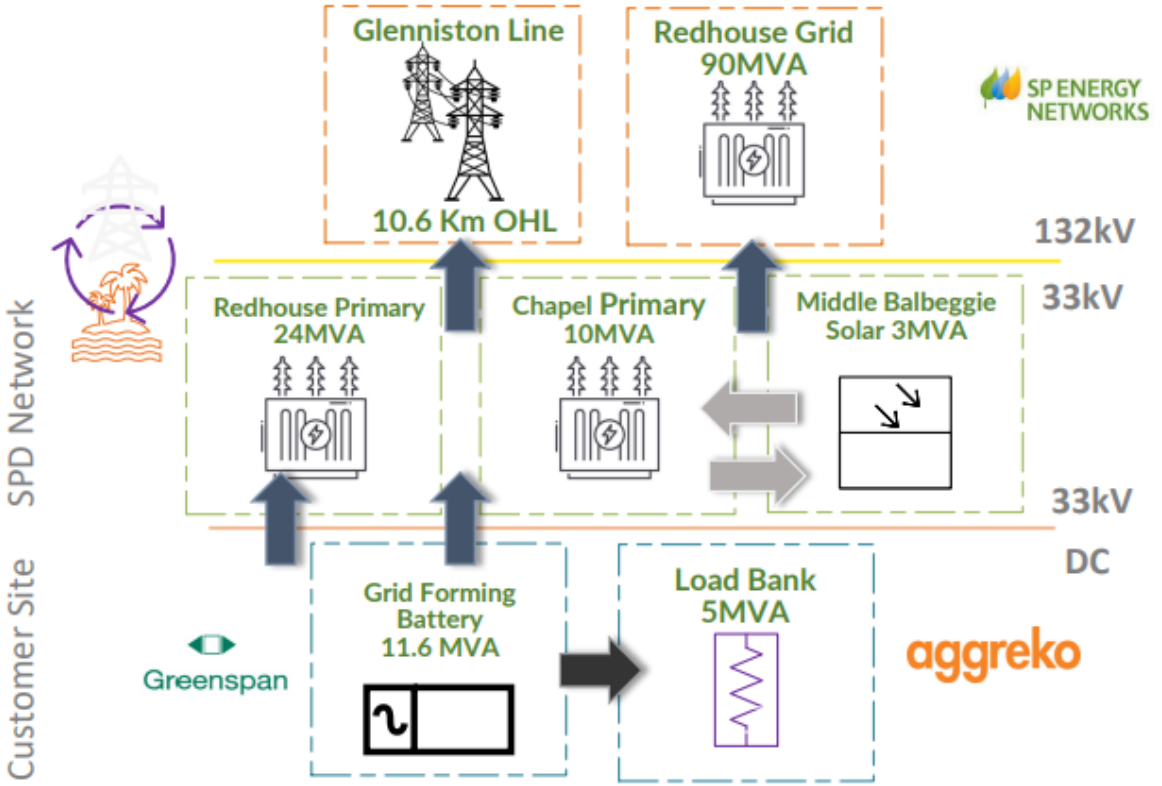
- Modbus fast balancing control issue resolved and tuned
- Fast balancing process proven, allowing load disturbance up to 67% of rated capacity of the frequency regulating generator

Co-ordinated wide area control service is a viable replacement for conventional blackstart

Redhouse Grid-forming BESS Anchor

The goal and scope of the world-first Redhouse live trial

- The project's two previous live trials had proven the concept of using **biomass** and **hydro** to start-up and control a power island or 'distribution restoration zone' (DRZ).
- The goal of this trial was to use **a non-synchronous converter-connected battery energy storage system (BESS** to restart the DRZ.



DRZ Control for Redhouse using Synergy project infrastructure for control, monitoring & comms (WAMS, ADMS, field intelligence).

Source: NGESO & SPEN presentation ESO Operational Transparency Forum, 26 July 2023

Experience from Live Trials (2)

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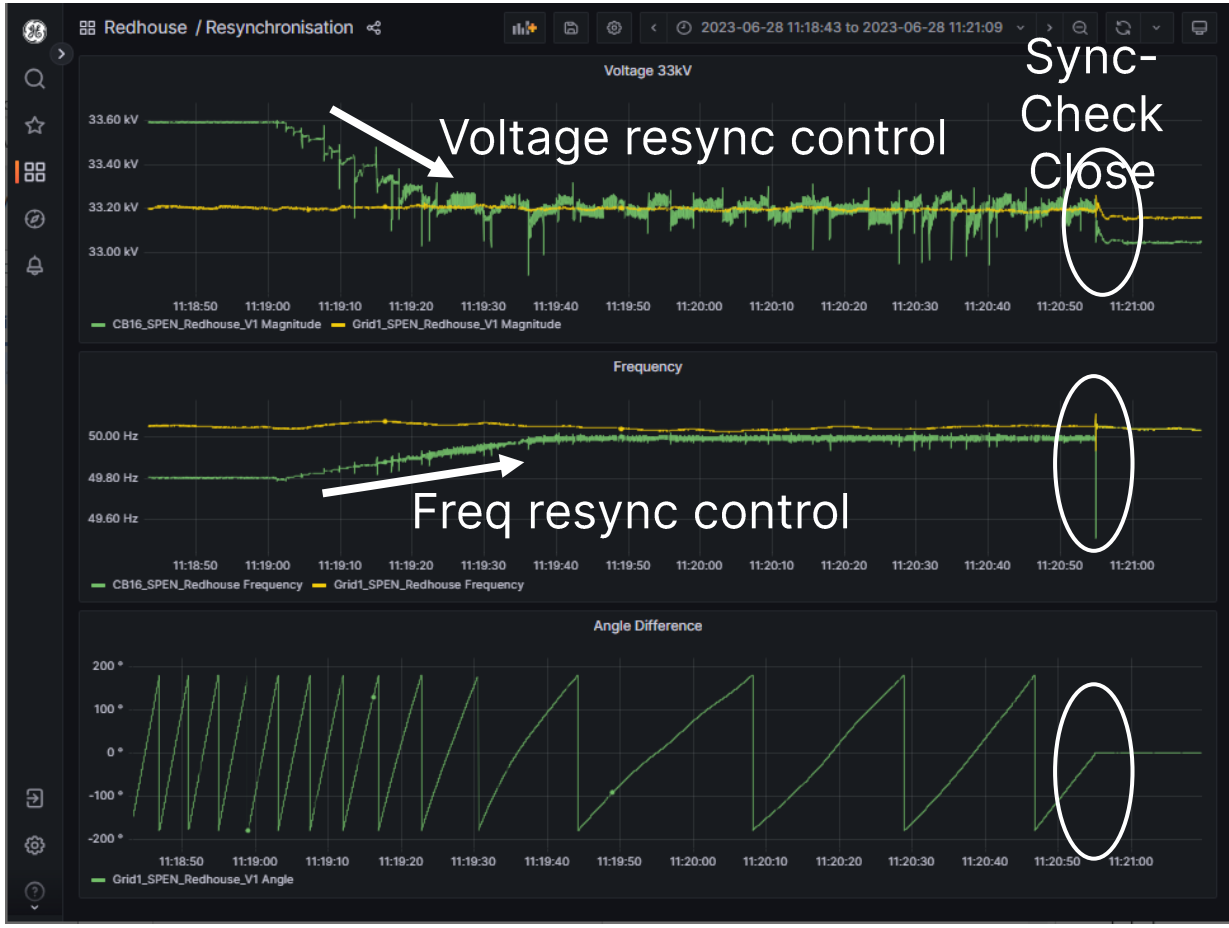
Live Trials of BESS-anchor Zone Blackstart, Island Run, Resynchronisation

- Grid-forming BESS startup & transformer energization (33/11kV & 132/33kV), demonstrated value of Point-on-Wave switching. Block load pickup observed in WAMS.
- Balancing control of island by DRZC demonstrated as power balance drift and disturbances introduced in island.
- Resync control aligned frequency and voltage across resync boundary so remote network synchrocheck closure can be applied.
- Dynamic Virtual Power Plant (D-VPP) controlled zone boundary power setpoint while internal loading varies. Setpoint changes proven



Collaboration: SPEN Synergy & NGESO/SPEN Distributed ReStart

Grid-forming BESS is viable anchor; DRZC is important to expand & automate island

Conclusion and Next Steps

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Technically proven for progressing to BaU implementation

E.g. Scaling up to larger zones

Resilient implementation

Manage stored energy in zones

Operator training and procedure development

Use of infrastructure for other aggregated services

E.g. Dynamic containment (fast frequency control)

Slow reserve balancing

Constraint management (T&D)

Locational fast balancing


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