Enhanced Frequency Control Capability Project Dissemination Event



25th February 2016

Operability Challenges and Innovation
SOF Relationship to the Future of Energy

nationalgrid

Future Energy Landscape

Performance Requirements

Operational Challenges

Solutions and Opportunities

Operability Challenges and Innovation
SOF 2015 – Three Strategic Themes

nationalgrid

1

Services and Capabilities

It is essential that **new system services** are developed to access existing and new capabilities from both synchronous and asynchronous generation

2

Whole System Solutions

Transmission and distribution companies must consider the **whole system** impact of technologies and enable access to demand side resources

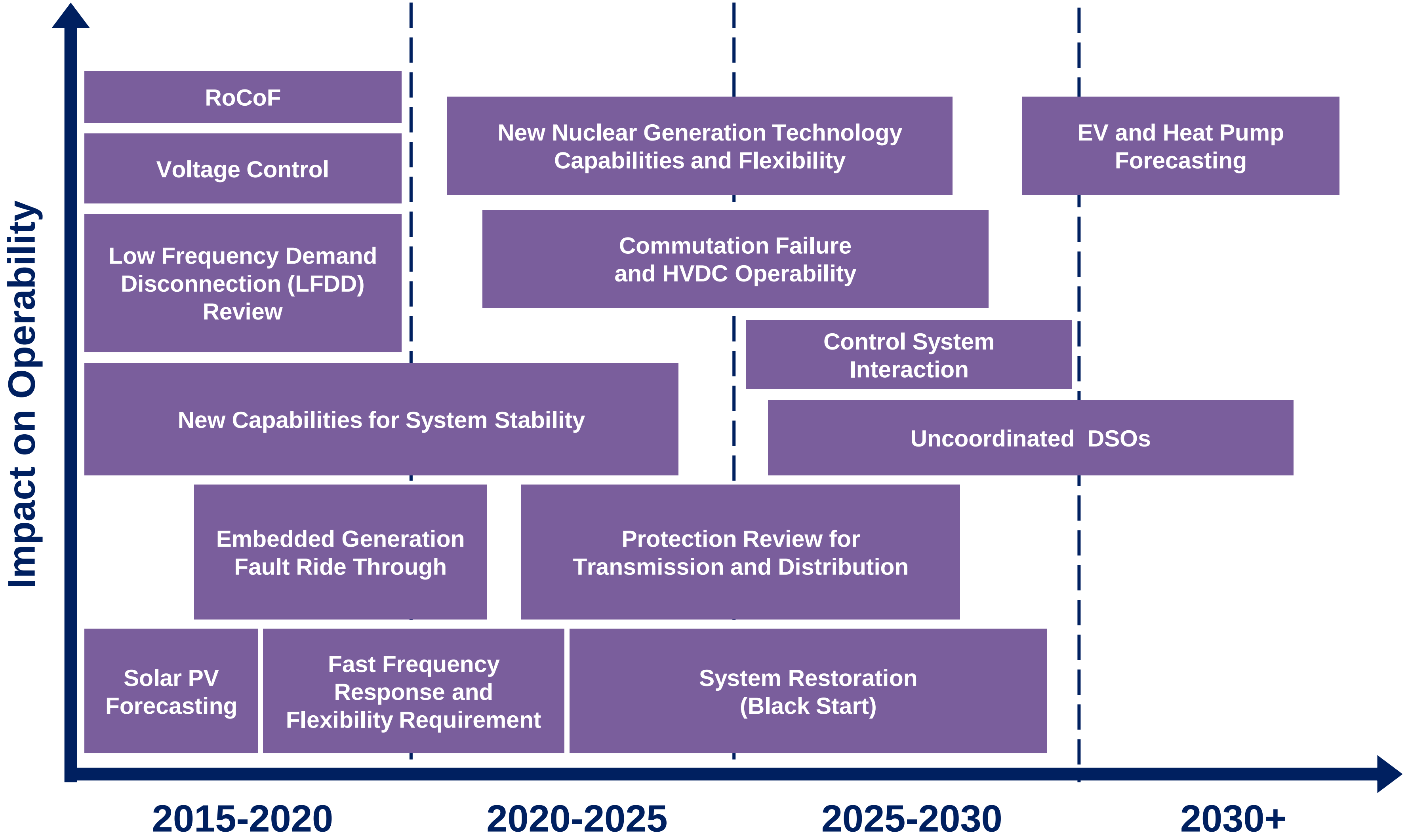
3

Increased Flexibility

The **value** of new system services, in particular **flexibility,** must be considered at the design stage by manufacturers and developers for future revenue streams

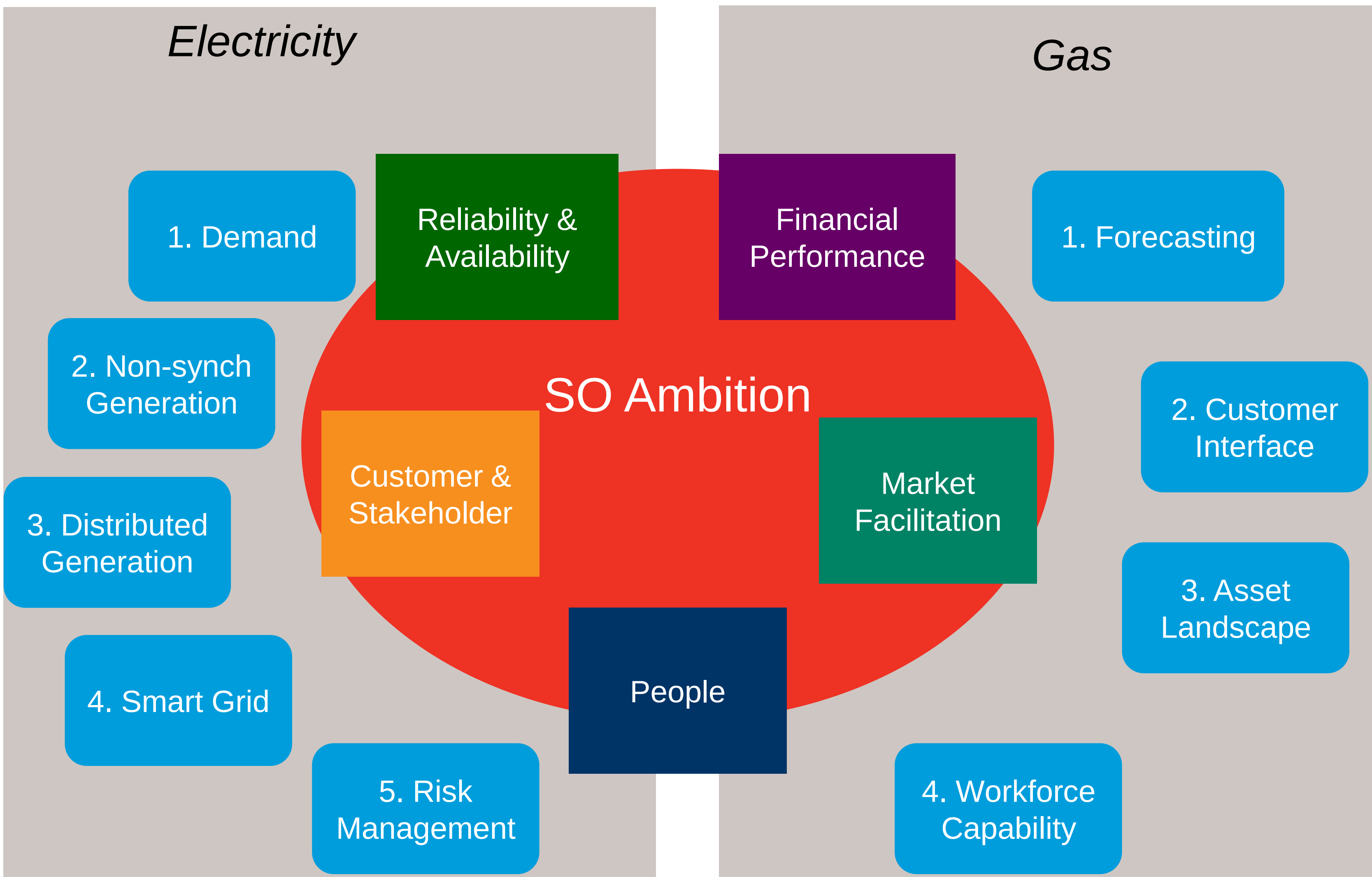
Operability Challenges and Innovation
Timeline of Operability Challenges

nationalgrid



Operability Challenges and Innovation
National Grid SO Innovation Themes

nationalgrid



Operability Challenges and Innovation
Examples of Ongoing Innovation Projects

nationalgrid

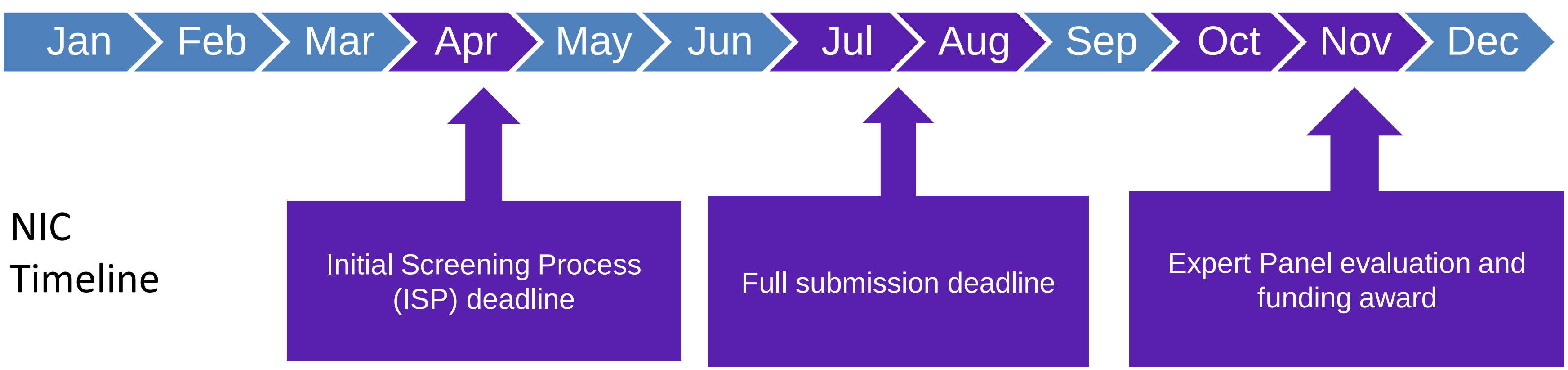
- Following the SOF 2014 we identified 2 major innovation projects:
  - Enhanced Frequency Control Capability Project (Non-Synch Generation)
  - South East Smart Grid (Smart Grid)

- Other ongoing projects include:
  - DIVIDE Voltage Dependent Load Behaviour (Demand)
  - Control & Protection Challenges in Power Systems (Non-Synch Generation)
  - PV Monitoring & Forecasting (Distributed Generation)
  - Detection and Control of Inter Area Oscillations (Non-Synch Generation)

Operability Challenges and Innovation
Support for Innovation Projects

nationalgrid

- As in other areas, innovation is key to meeting network challenges.
- We already work with many partners nationally and internationally (e.g. DS3) on operability challenges and to identify innovation needs
- Innovation funding is available including our Network Innovation Allowance (NIA) and the Network Innovation Competition (NIC)
- We'd like ideas and support to develop further innovation projects.



Operability Challenges and Innovation
SOF 2015 Future Innovation Areas

nationalgrid

Topics	SOF 2015 Strategy Recommendations	Future Innovation Areas		SO Innovation Themes
	Services and Capabilities	Energy Storage	Support from Embedded Generation	1. Demand
				2. Non-sync Generation
	Whole System Solutions	DSO Services and Co-ordination	Support from Demand Customers	3. Distributed Generation
				4. Smart Grid
	Increased Flexibility	Flexible Non-Synchronous Generation	Flexible Synchronous Generation	5. Risk Management

Future Operability Strategy

Operability Challenges and Innovation
Smart Frequency Control Project

nationalgrid

- Enhanced Frequency Control Capability Project
  - Addresses key operability challenges.
  - Fits with our SOF 2015 Recommendations
  - Is a key part of our current innovation project portfolio.
  - Will develop the frequency services that we are going to need.
- The project has been running for around 12 months and we are starting to see tangible progress and outputs.

Network Innovation Competition:
Enhanced Frequency Control Capability, EFCC
(SMART Frequency Control)



Charlotte Grant
Technical Project Manager

Network Innovation Competition:
Enhanced Frequency Control Capability, EFCC
(SMART Frequency Control)

Video here

Frequency Limits

Generation

Demand

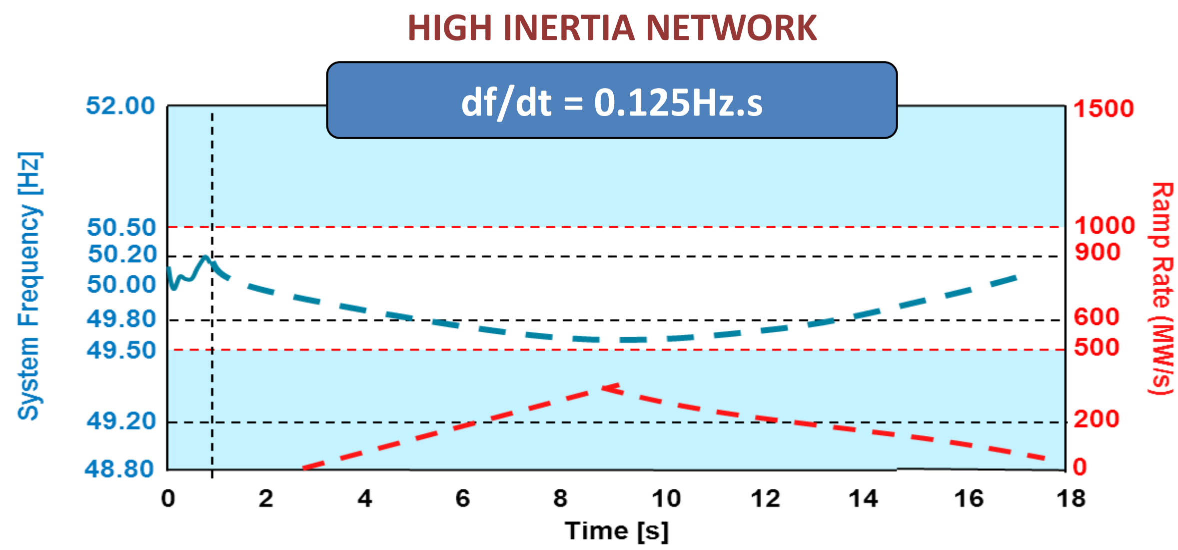
50.0 Hz

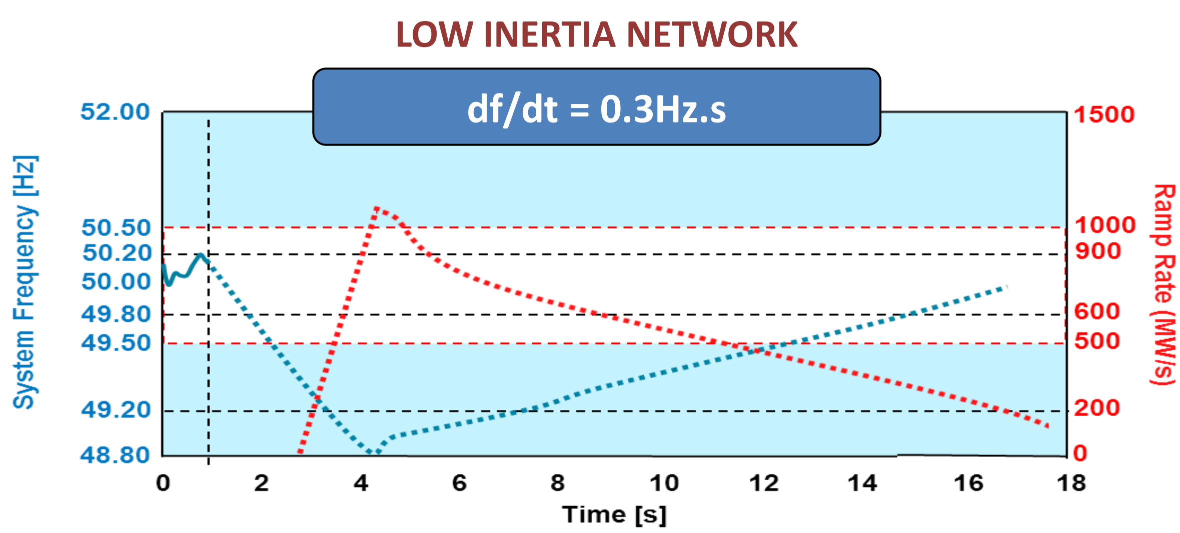
50.0	Normal operating frequency
50.5	Upper statutory limit
52.0	Generators tripping
49.5	Lower statutory limit
48.8	Demand disconnection starts
47.8	Demand disconnection complete

Balancing Services Types

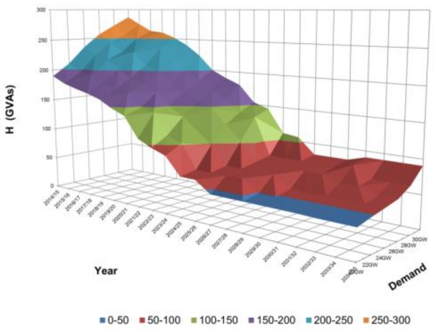
- Increase in demand (Primary Response)
- Decrease in demand (High Response)
- Recovering system frequency (Secondary Response)

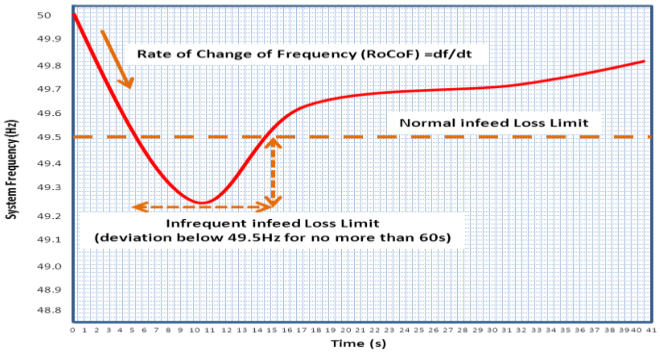
Reduction of System Inertia & Frequency Containment





Reduction of System Inertia & Cost of Frequency Control

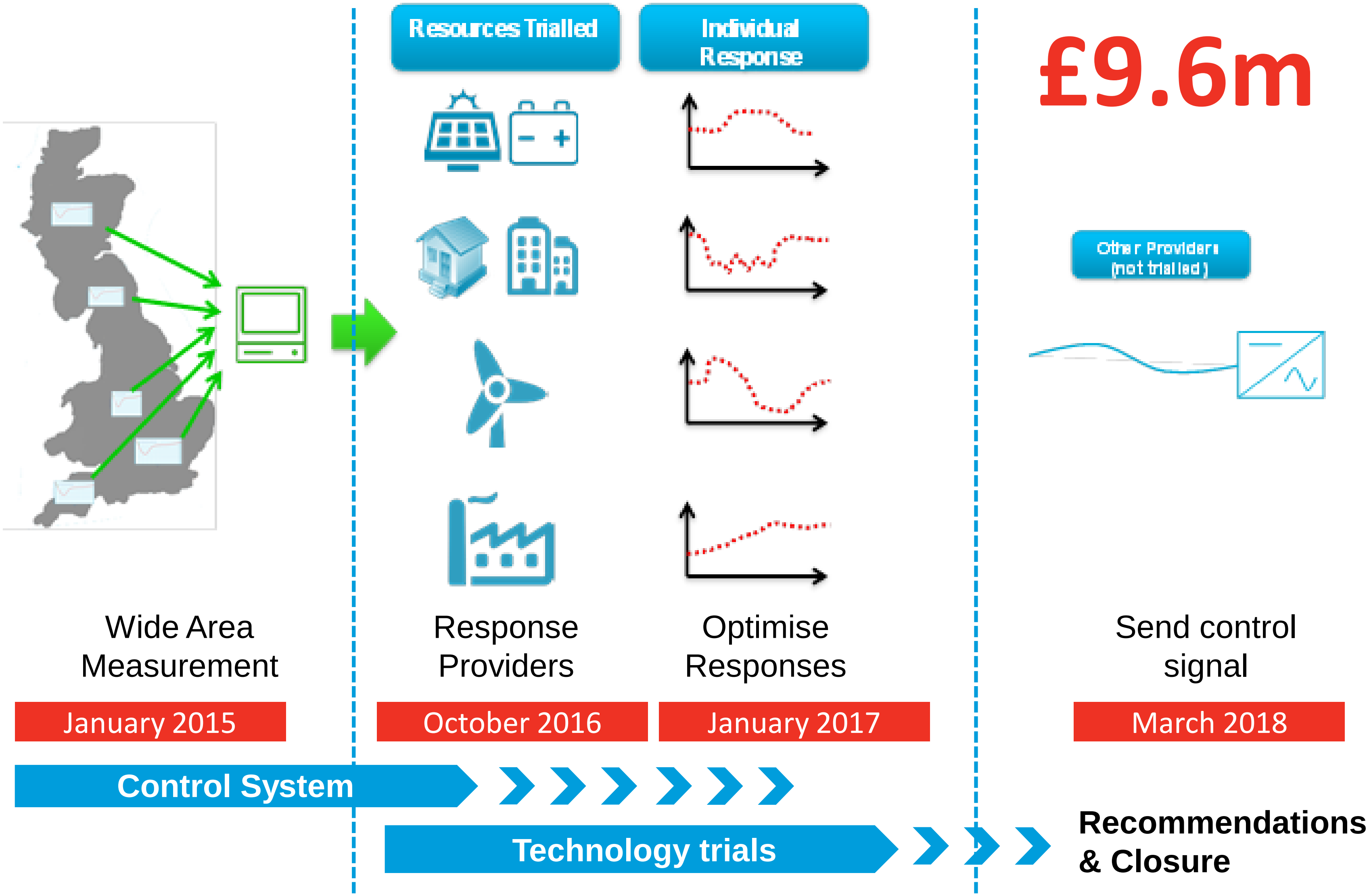




Cost Benefit Analysis 2014

	Solution	Cost (2020 Gone Green)
Balancing Services Methods	Constrain generators	Extra £600m
	Constrain largest infeed/outfeed	Extra £130m-£270m (depending when the large infeeds are connected)
	Carry larger volumes of response	Extra £210m

Enhanced Frequency Control Capability, EFCC (SMART Frequency Control Project)

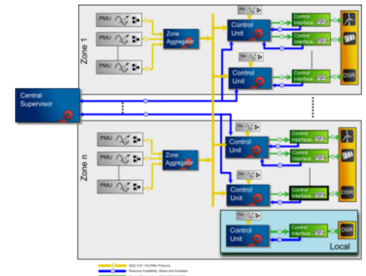


Enhanced Frequency Control Capability, EFCC (SMART Frequency Control Project)

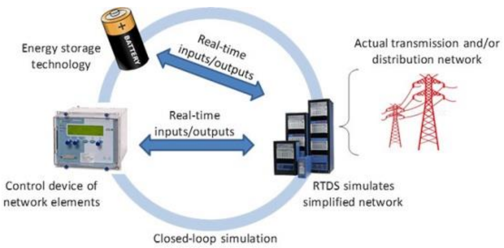
RIIO NIC NETWORK INNOVATION COMPETITION

University of Strathclyde Glasgow

GE Grid Solutions formerly Alstom



MANCHESTER 1824 The University of Manchester



SMART Frequency Control

centrica

BELECTRIC™

Flexitricity

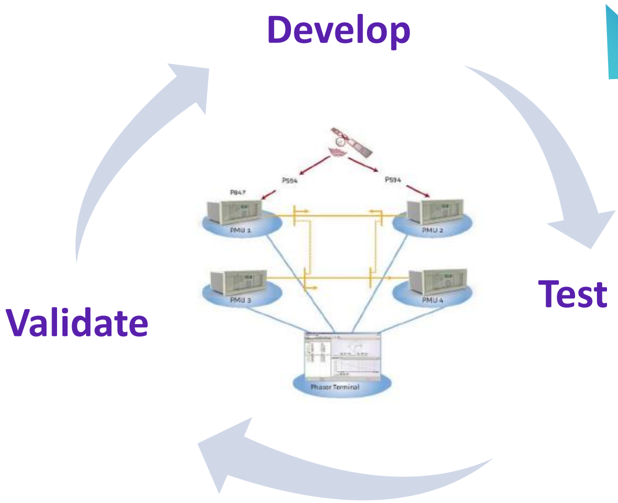
Enhanced Frequency Control Capability, EFCC (SMART Frequency Control Project)

RIIO NIC NETWORK INNOVATION COMPETITION

VISOR Visualisation of Real Time System Dynamics using Enhanced Monitoring

RIIO NIC NETWORK INNOVATION COMPETITION

SMART Frequency Control



Commercial Development

Technical Developments

Interaction with existing services (i.e. STOR, Primary Response etc.)

Evaluation of Communication and compliance requirement

Package of new services

July 2015

March 2018

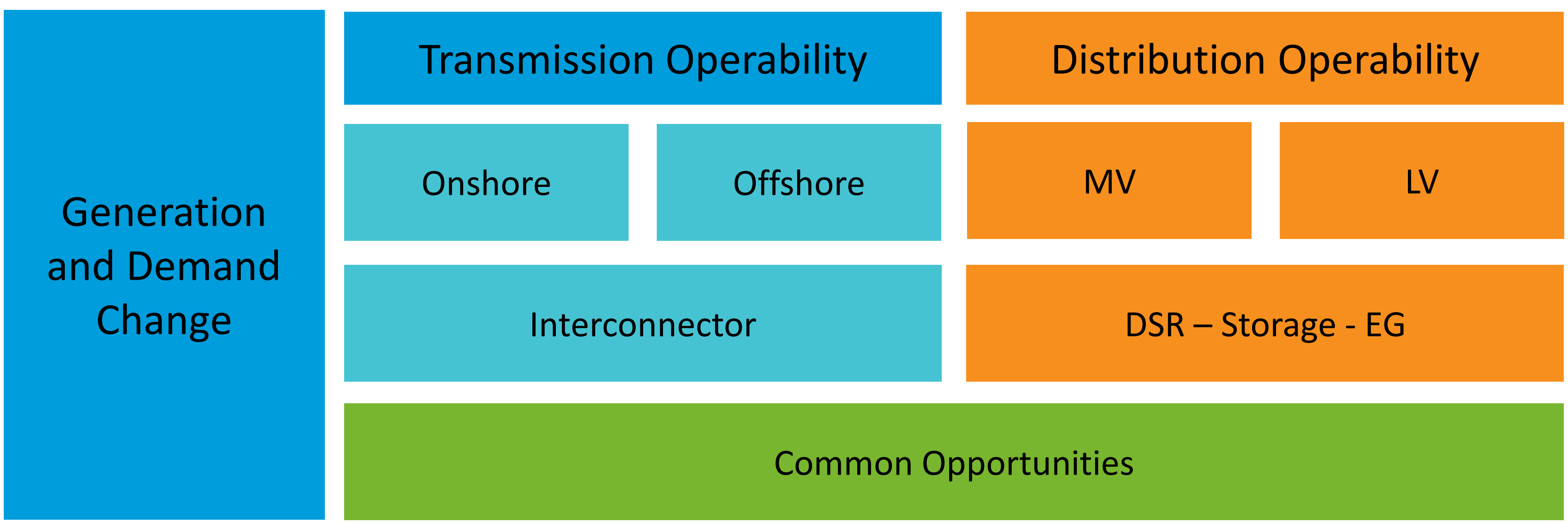
Commercial Service and IS Comms

Recommendations & Closure

Enhanced Frequency Control Capability, EFCC (SMART Frequency Control Project)

SMART Frequency Control

GB Power System Operability



Wide-Area Frequency Control Scheme
Smart Frequency Control

Douglas Wilson & Seán Norris

25/02/2016

Contents

1. SFC Technical Challenge
2. Control Scheme
3. Applications
4. Perspective of a Service Provider

Technical Challenge

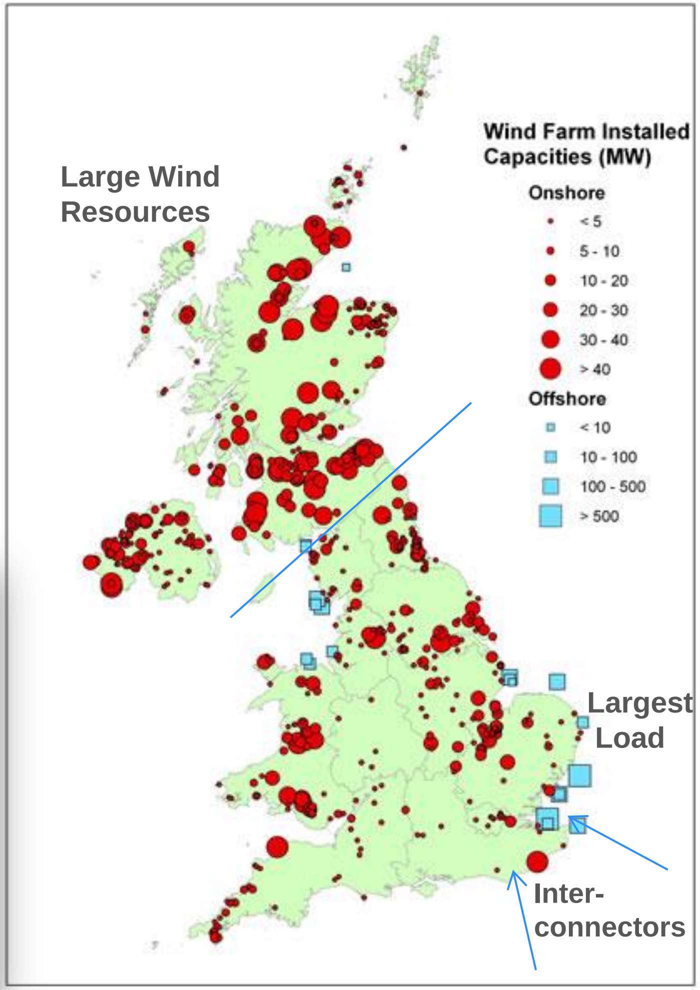
Reducing Inertia with Increasing Share of Wind

Large high wind N→S power flow

Major constraint Scotland-England

Inertia reducing, especially in Scotland

- Wind power - no inertia
- Interconnectors – no inertia
- Synchronous plant closed or constrained off



The Fast-Frequency Response Challenge

Rate of Change of Frequency (RoCoF) Is not equal across system

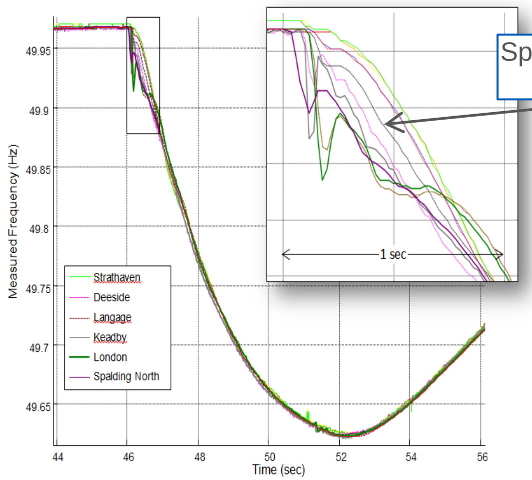
- Dependent upon event proximity & Regional Inertia
- Reflects changes in power flows as the angle behaviour is perturbed

What is the danger of Fast Frequency Response (FFR)?

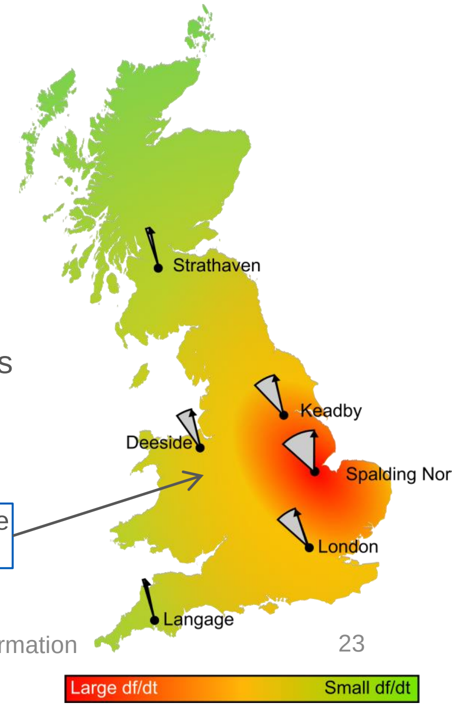
- Similar time frame to first swing angular stability
- Risk of system splitting

Need to consider the angle behaviour through a coordinated response

- Used to prioritise action closer to event
- Using wide-area measurements

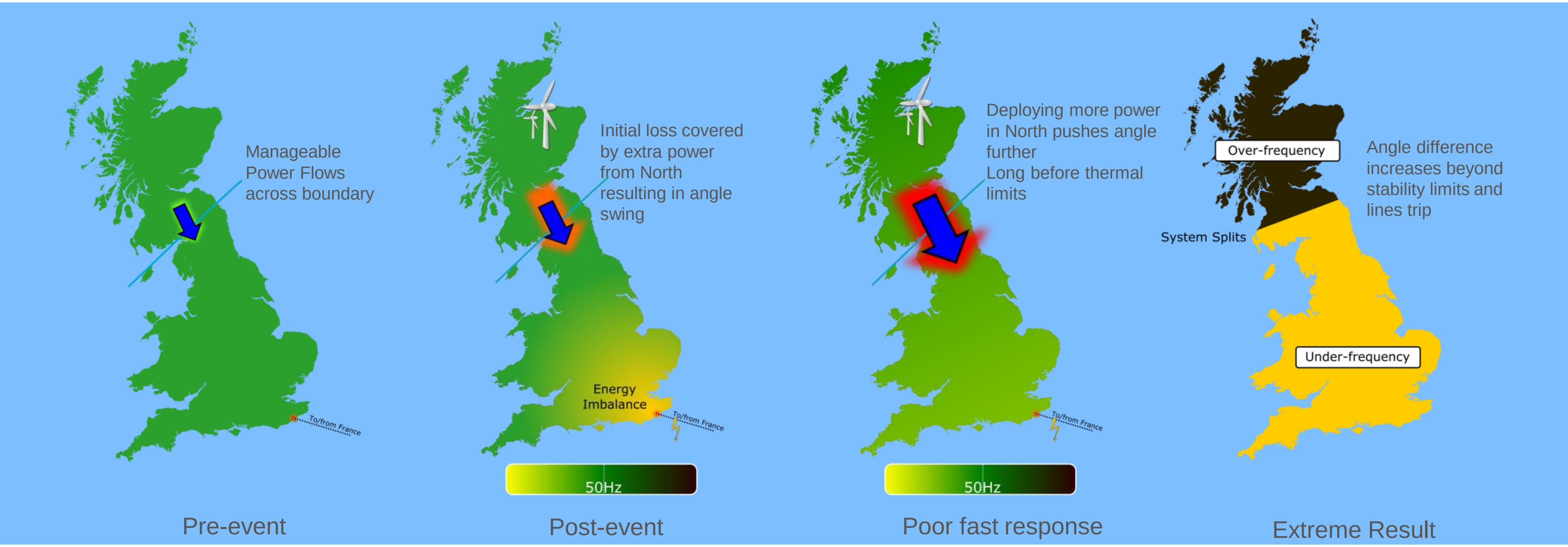


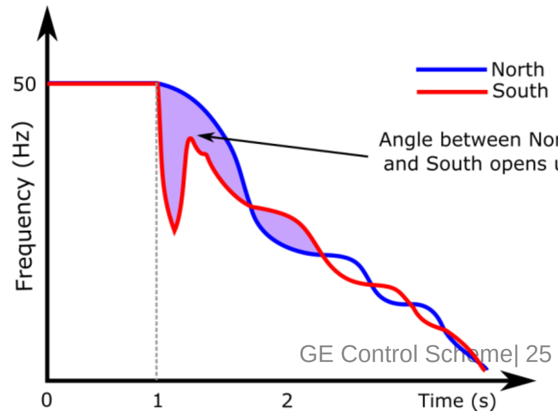
Measured Frequency response to generator loss

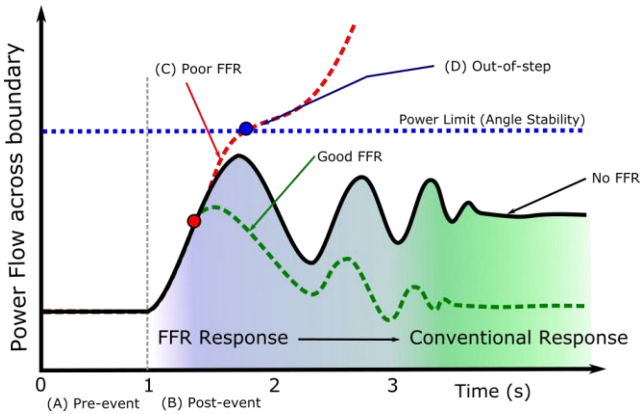


Implications of Poor FFR Location

Example Extreme Behaviour during a frequency event

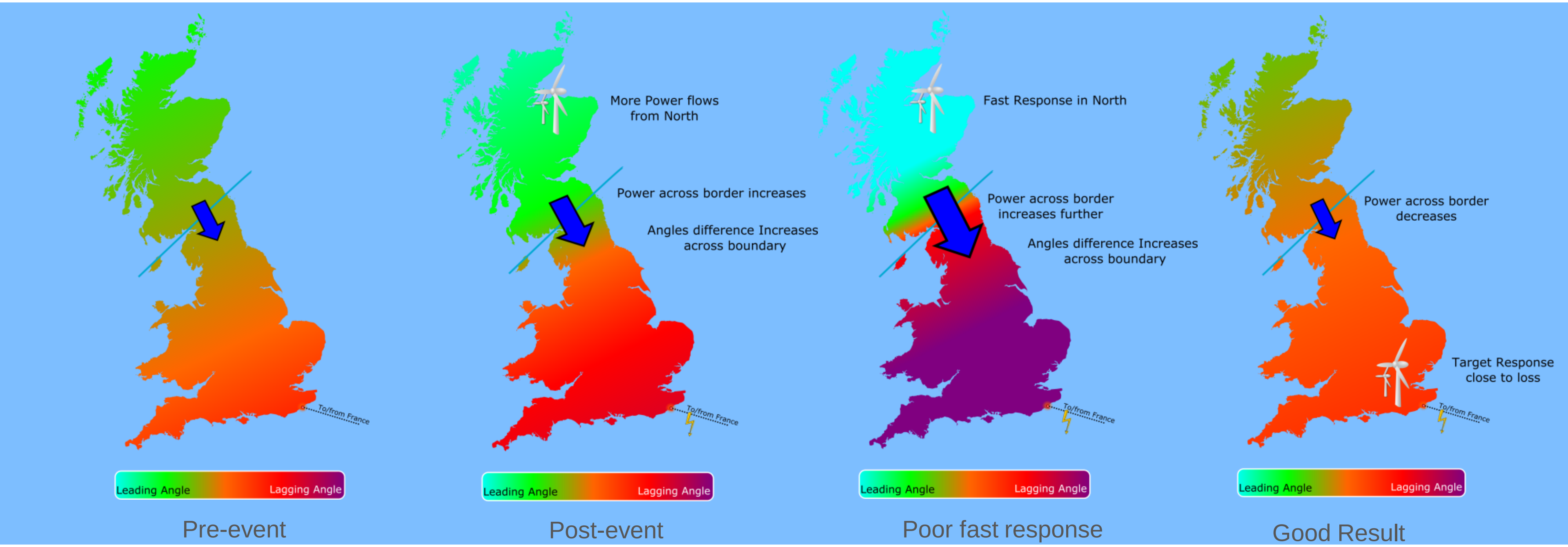




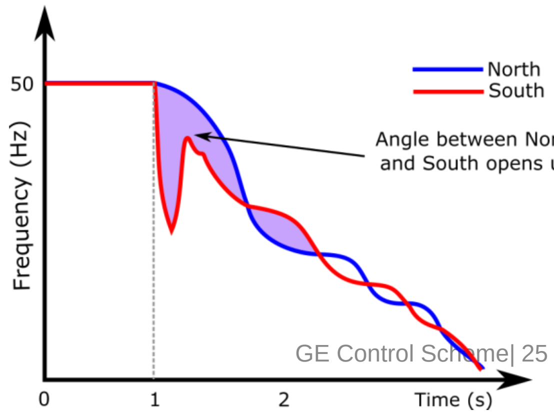


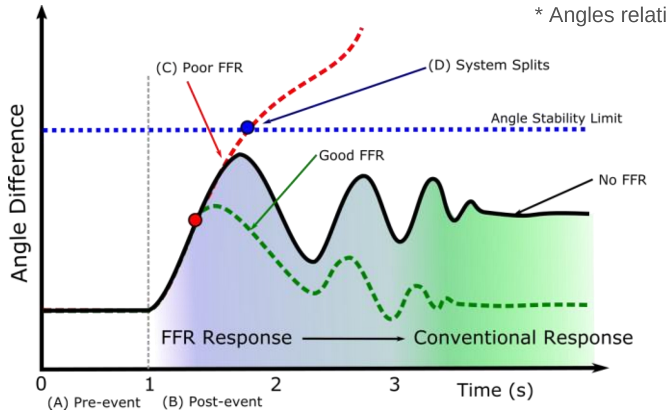
Implications of Poor FFR Location (angles)

Example Extreme Behaviour during a frequency event

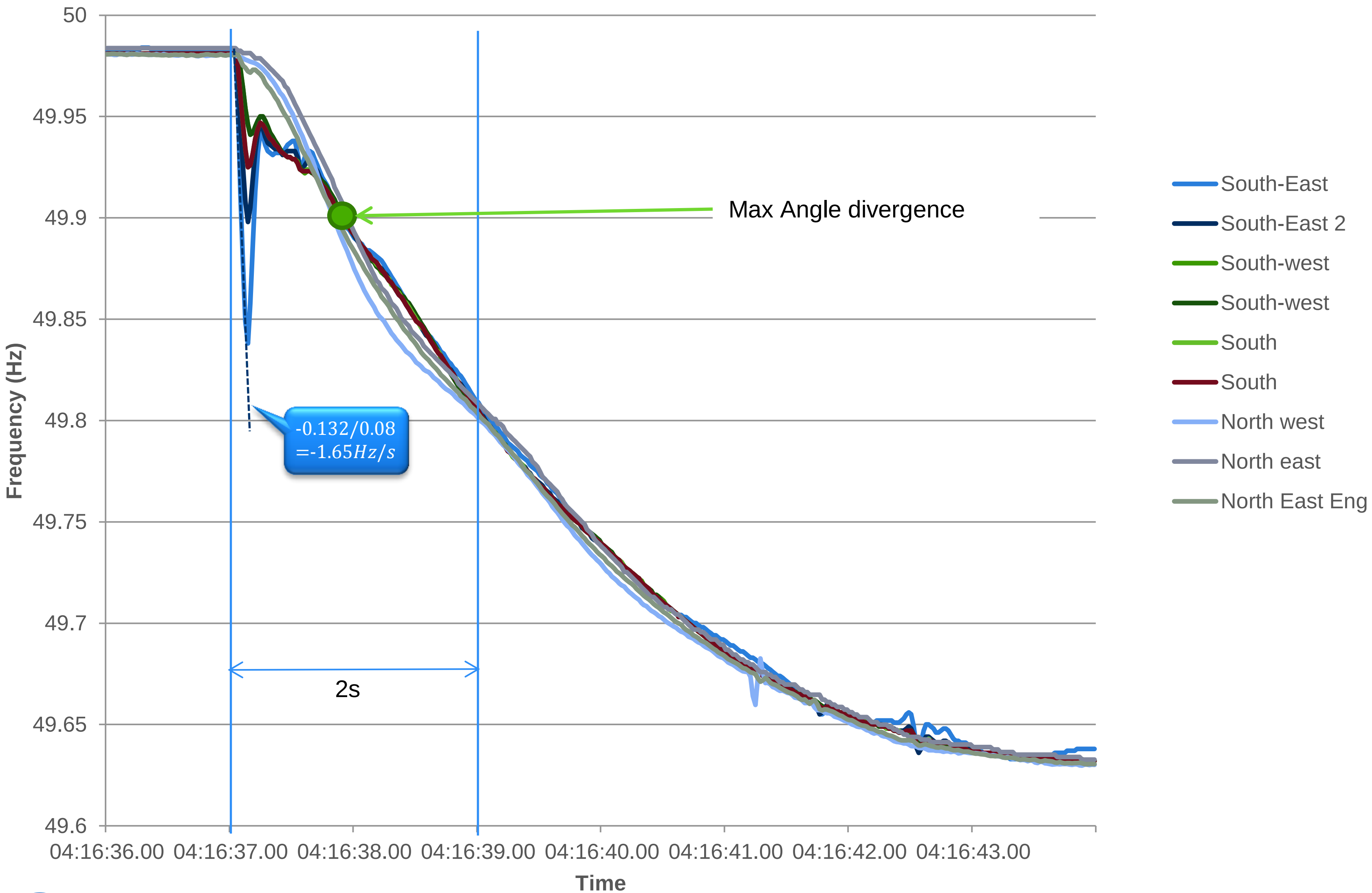


* Angles relative to a single centre of inertia

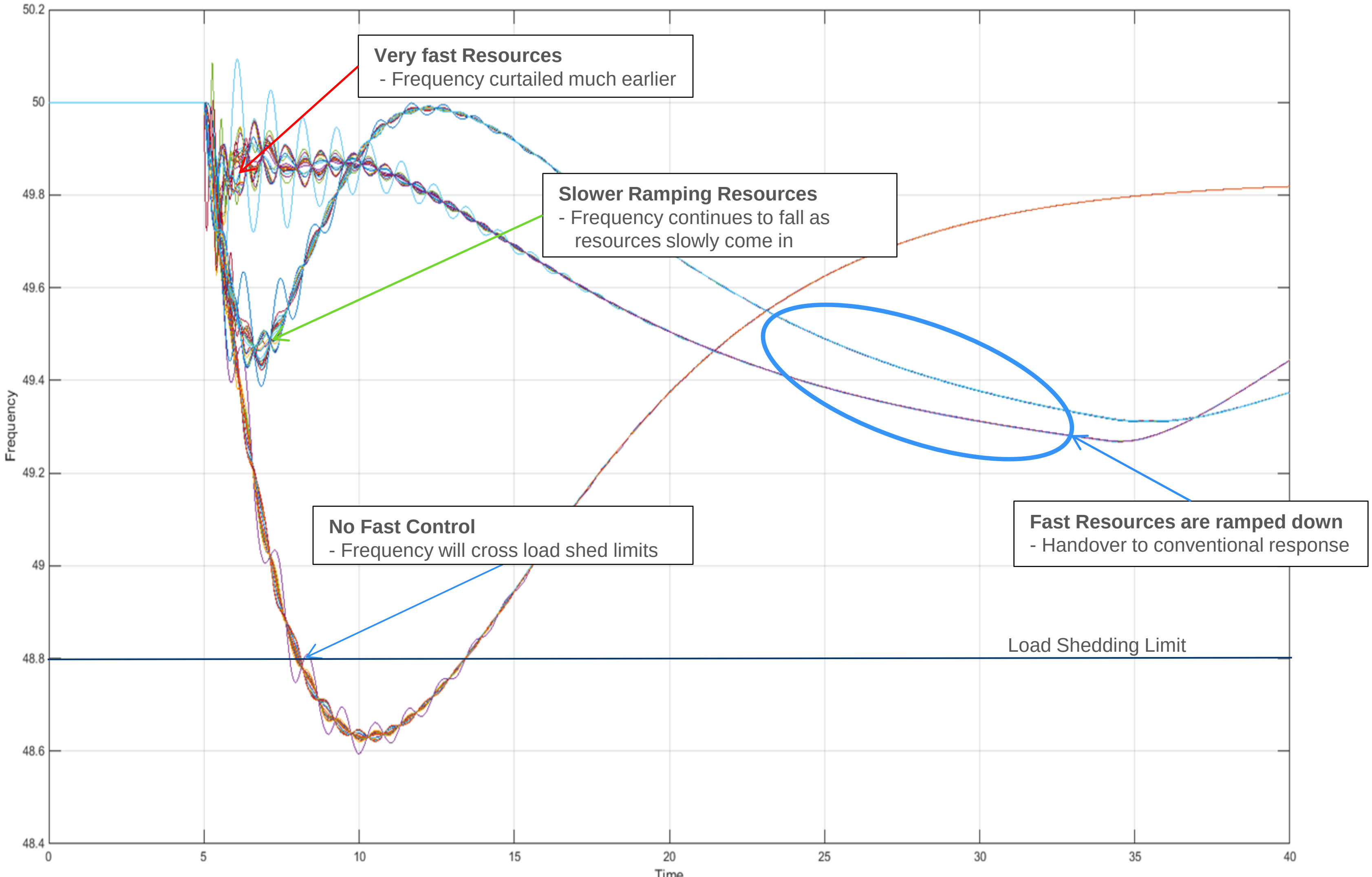




NG Interconnector Event



Effect of Response

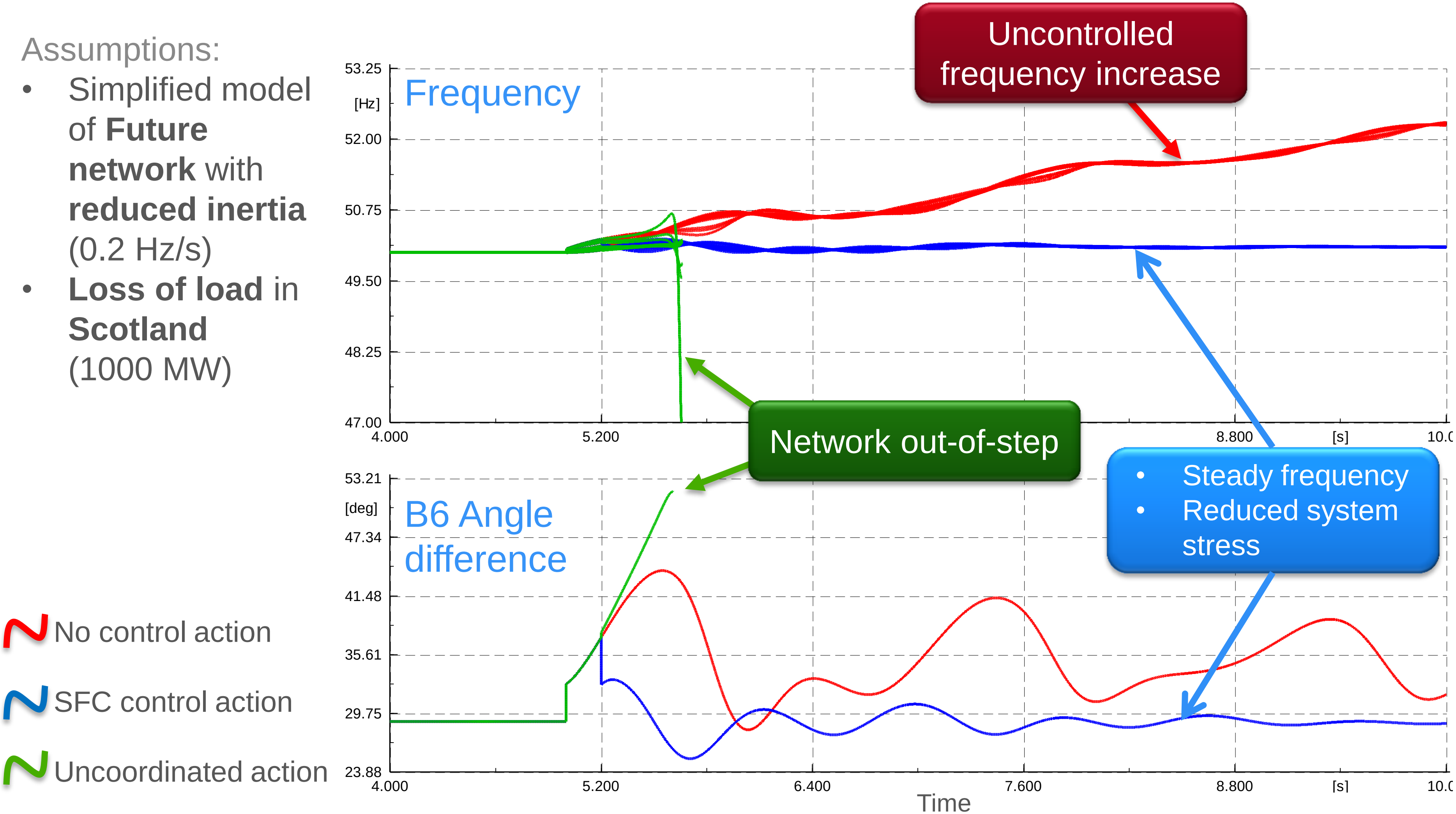


* Results from a simulation

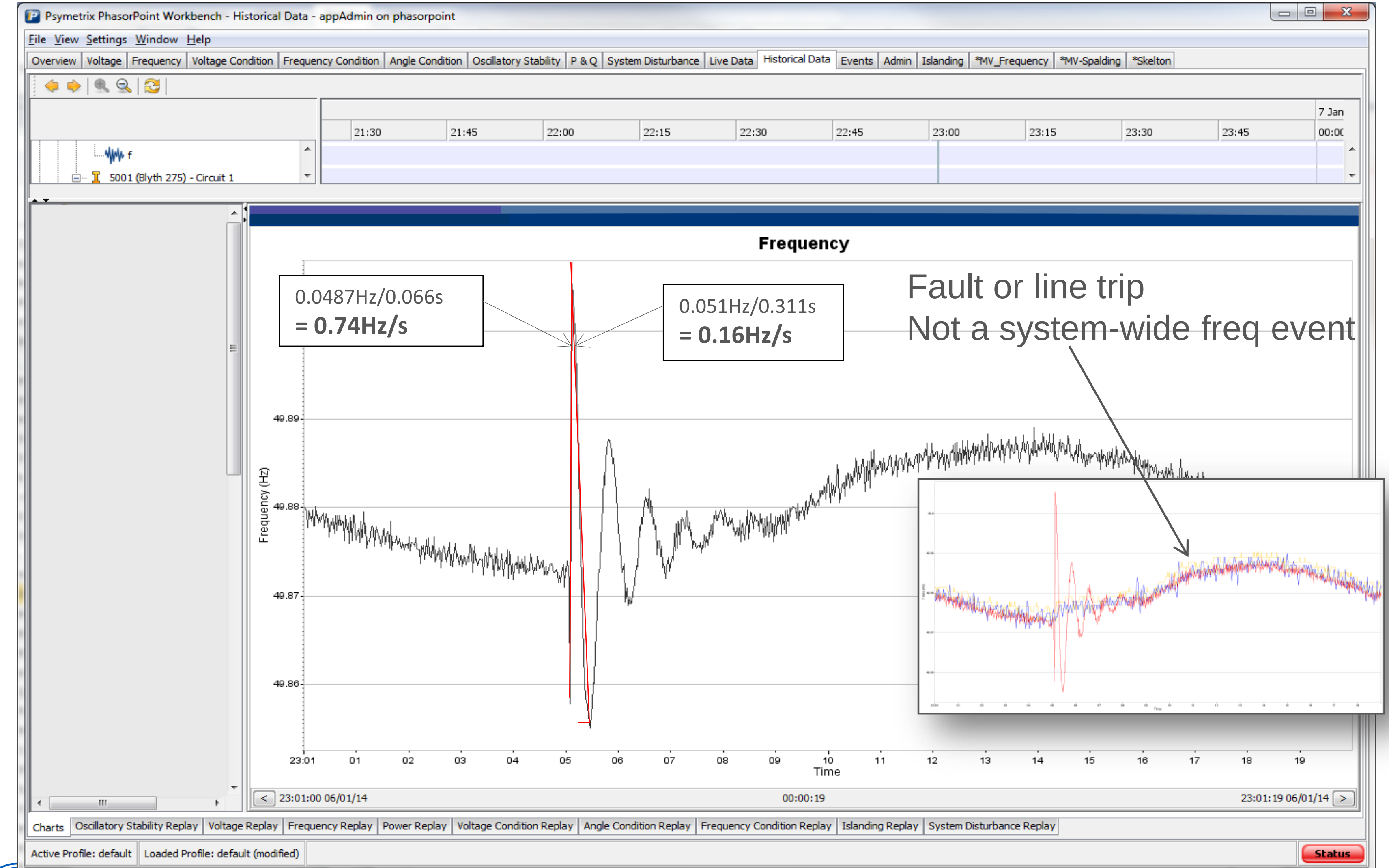
Simplified GB Network Simulations

Assumptions:

- Simplified model of **Future network** with **reduced inertia** (0.2 Hz/s)
- **Loss of load** in **Scotland** (1000 MW)



Local frequency disturbances



Uncoordinated local Control

Local frequency/RoCoF varies across system – noisy signal

Deploying on Frequency or RoCoF can lead to **spurious triggering**

- Line fault or trip event will perturb local frequency
- Responding to non-frequency event negatively impacts stability

Following frequency or RoCoF can lead to poor **oscillation damping**

- Delays in measurements/response can excite oscillations

Higher occurrence of events on lower voltage networks

- What would the effect be on resources connected at these levels?
- Excessive trips/response, reduced resource lifetime, reduction in confidence

- How would resources be rewarded for responding to non-frequency events?

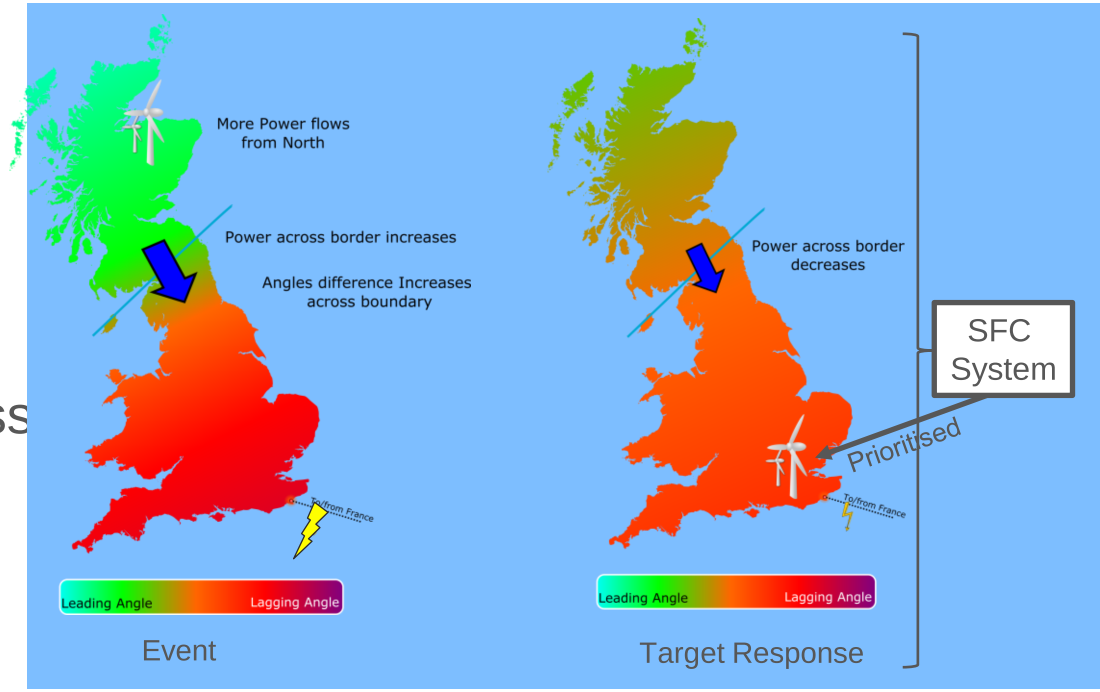
How to **distinguish frequency events** from other events such as line trips?

Uncoordinated local control should act **slower than wide-area** to prevent these negative impacts

Wide Area Frequency Control

Monitoring & control system targets:

- Detecting true system frequency events quickly
- Prioritising response in area, reducing network stress
- Proportionately, predictably deploying fast response



Control Scheme

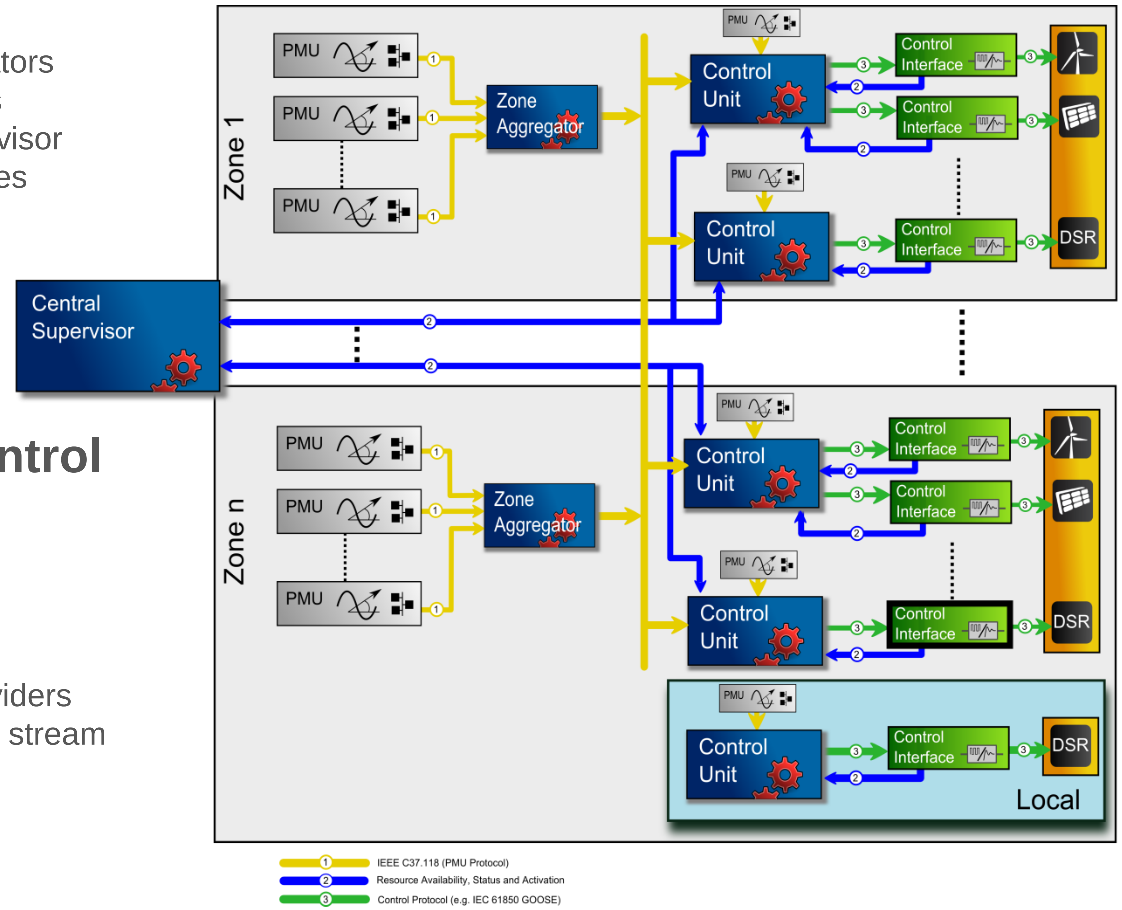
Design of the Control Scheme

Distributed Control Scheme

System split into a number of regions

- Multiple distributed controllers
- In each region, PMUs send data to Aggregators
- Aggregated signals broadcast to Controllers
- Resource information sent to Central Supervisor
    - CS coordinates scheme and resources

- **Not** model based
    - Would be too slow for fast control action
    - Uses real-time measurements



Distributed Vs. Centralised Control

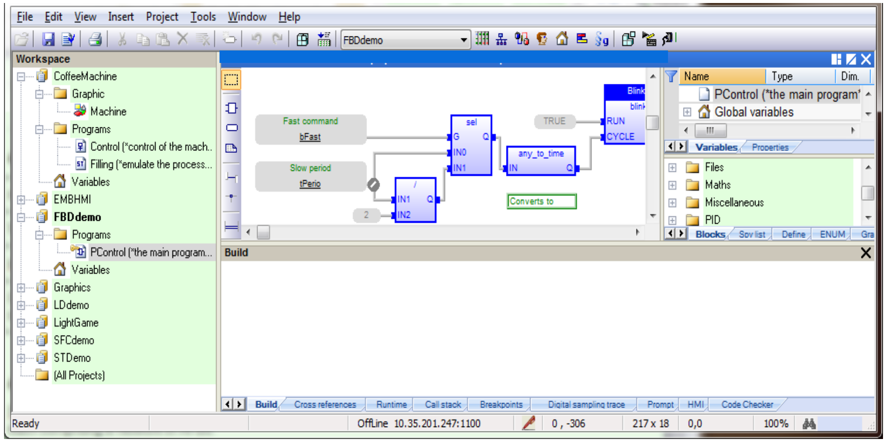
- Better Self Regulation (autonomous decisions)
- Communication:
    - Efficient use of bandwidth
    - Well defined latency
- Plug & play Infrastructure
    - No scheme reconfiguration for new providers
    - New service just receives common data stream
- Robust - No single point of failure
- Graceful Degradation
    - Signal loss
    - Communications loss

Flexible Control Platform

Flexible control platform at centre of scheme

- Library Elements and Custom Elements
  - Greater flexibility for scheme design and algorithms
  - Developed by Power Systems Engineers in a familiar environment
  - Implemented in a PLC environment
- Variety of implementation protocols
  - IEC 60870-5-104
  - IEC 61850
  - IEEE C37.118
  - Modbus
  - Digital I/O's
  - Other protocols possible

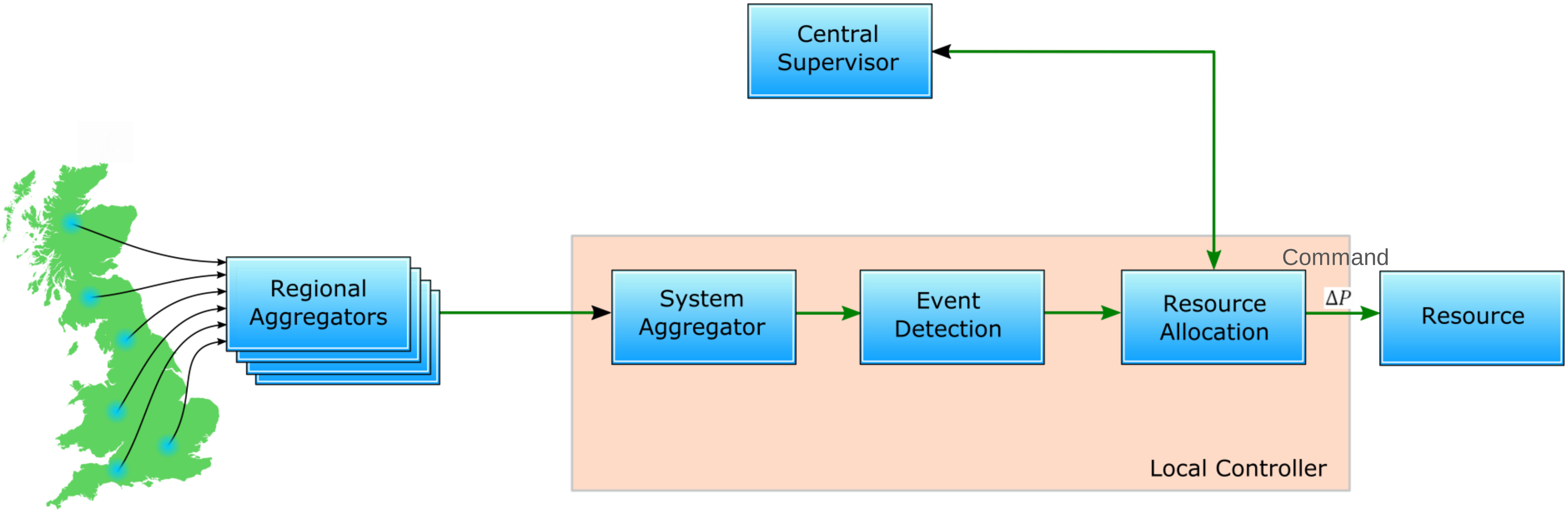
e-terra*phasorcontroller*



PLC Environment

Applications

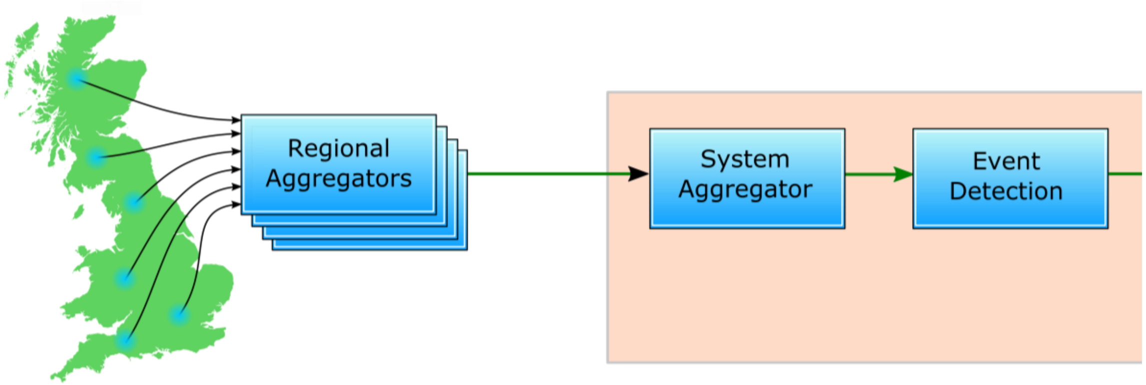
SFC Application Overview



Event Detection Requirements for SFC

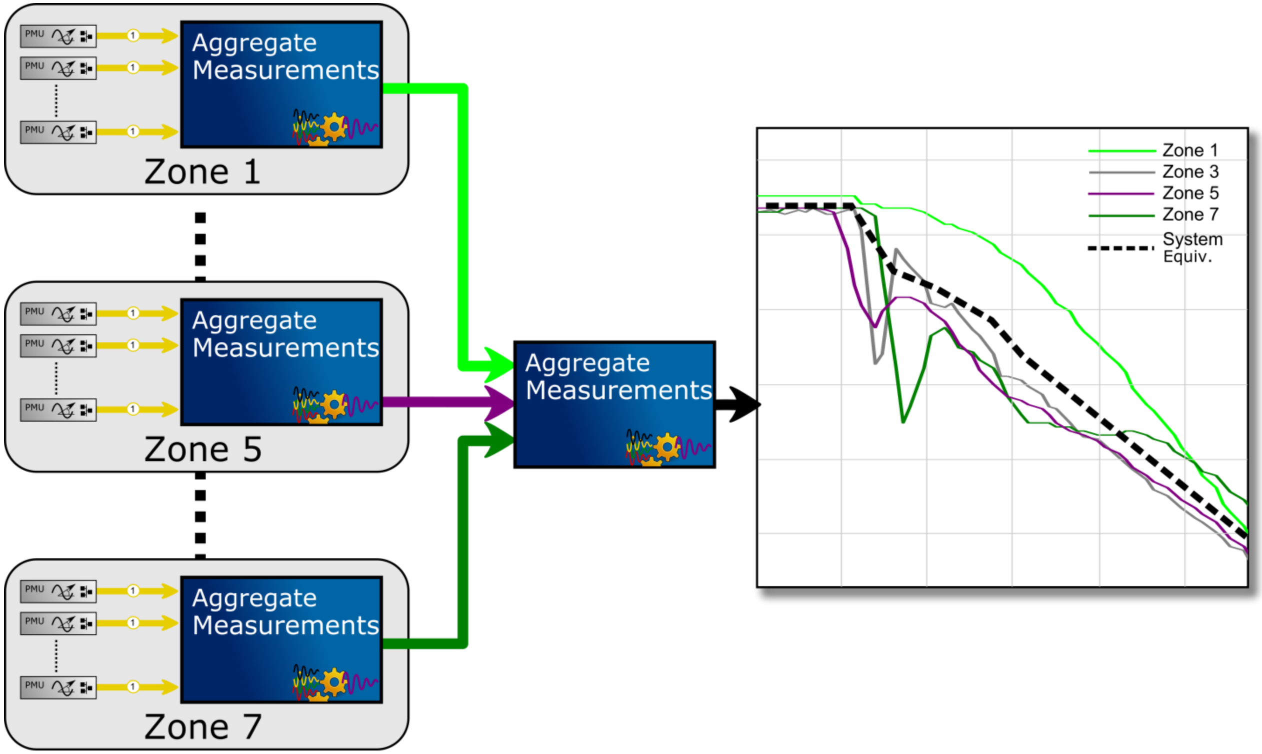
- *To detect, as quickly as possible, events which warrant system response*
  - *Target of 500ms from event to trigger for large events*
  - *Significant Generator/load loss (including after faults, trips etc.)*
  - *Interconnector loss*

- *Not trigger on non-frequency events such as*
  - *Faults*
  - *Line trips*
  - *Oscillations*
  - *Small Generator/load loss*



Event Detection Concept

- Each PMU signal assigned to a region
- Aggregate signals represent the region
- Aggregate regions into System equivalent
- Detect 'System Events'



Event Detection Concept

Roles

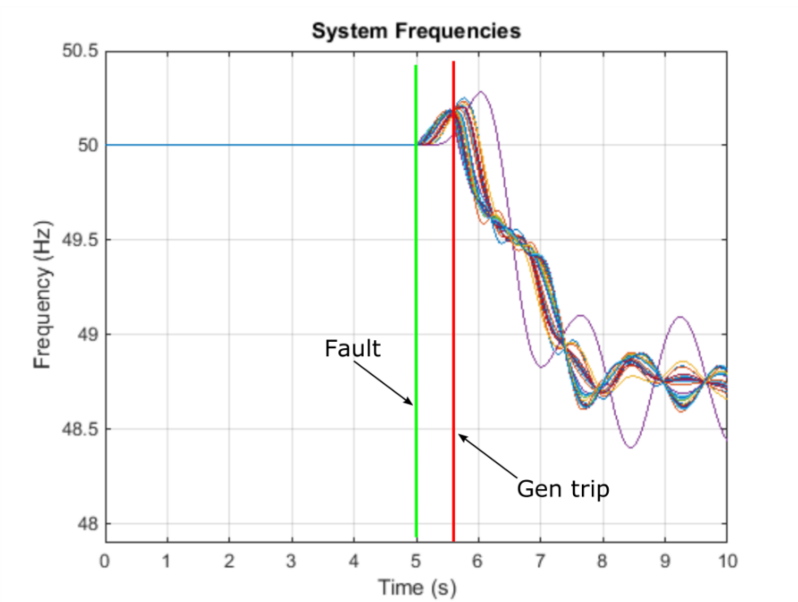
Field PMU Measurements → **Regional Aggregation** → **System Aggregation** → **Event Detection**

Field PMU Measurements
- Collect phasor and frequency measurements

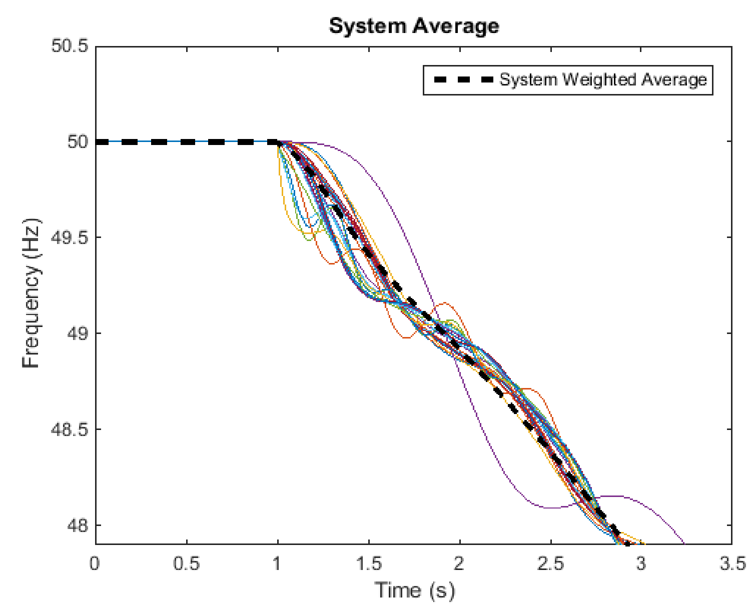
Regional Aggregation
- Aggregate PMUs
- Remove local modes
- Fault Detection
- Weight PMUs
- Minimise required bandwidth

System Aggregation
- Aggregate regions
- Remove inter-area modes
- Weight Regions
- System Frequency

Event Detection
- Detect 'real' events
- Calculate df/dt for event
- Provide continuous df/dt following event

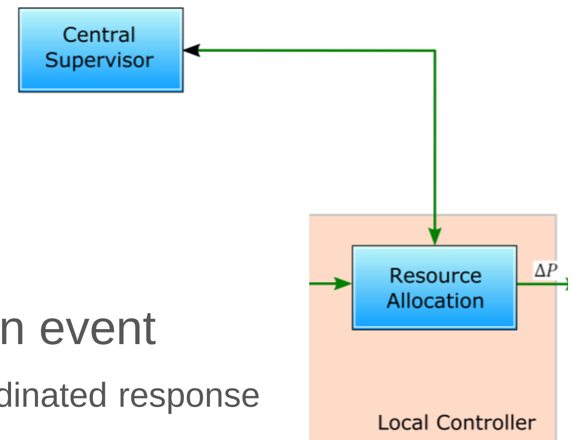


Fault Case



System Frequency

Resource Allocation - Supervision



Variety of resources in system

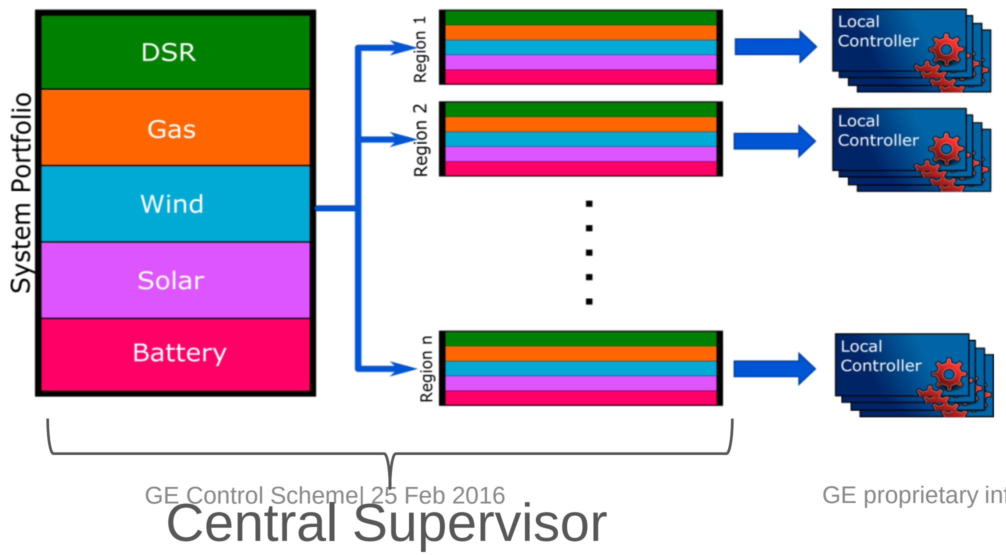
- Different resource characteristics – ramp rates, duration etc.
- Need to manage active portfolio of available resources
- Ranked according to Optimization algorithm
  - Aim to deploy fastest response first

CS communicates active portfolio information prior to an event

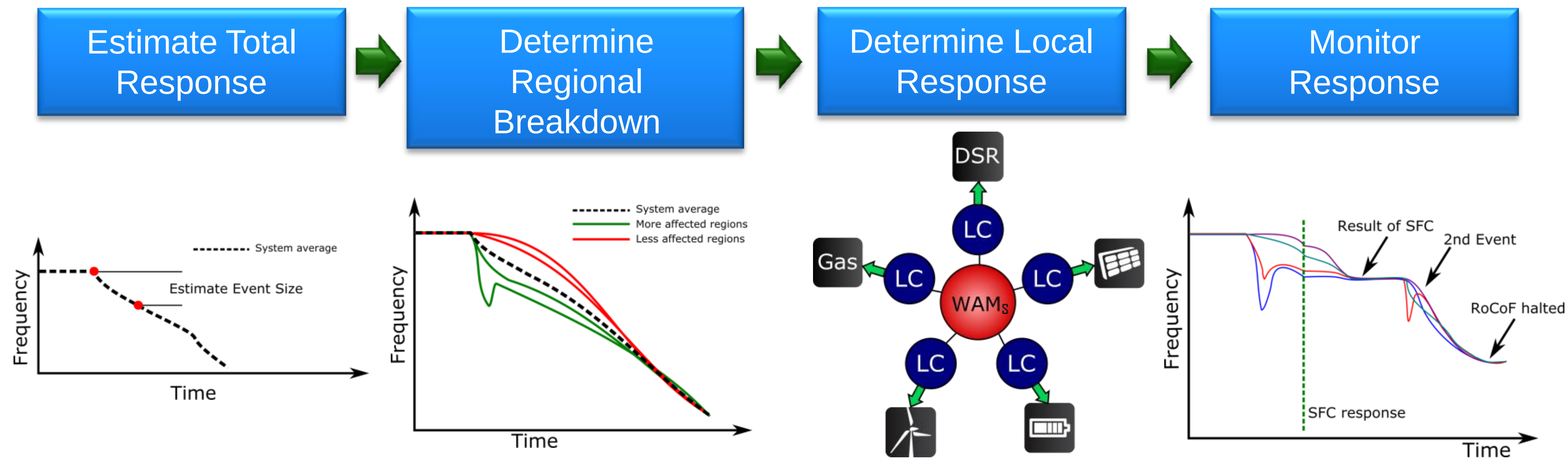
- Local controllers need information on the active portfolio to deploy a coordinated response

Resources are deployed according to an optimisation algorithm

- Selects which resources to deploy and how much to request from them



Resource Allocation - Deployment



Local Controllers determine:

- Appropriate size of response
- Locations at which to target response
- Which resources should be utilised in delivering response
- If any subsequent response is required, due to insufficient response, or subsequent events

Information about resource portfolio is received from Central Supervisor prior to an event

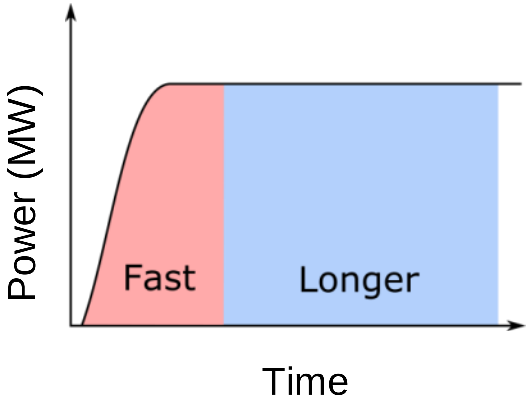
Optimisation - Ideal response

The ideal response is one that reduces the event's effect before the system degrades

For example:

- Region A loses 500 MW of generation at time 0s
- If 500 MW of load is tripped in Region A at time 0s, the event becomes negligible

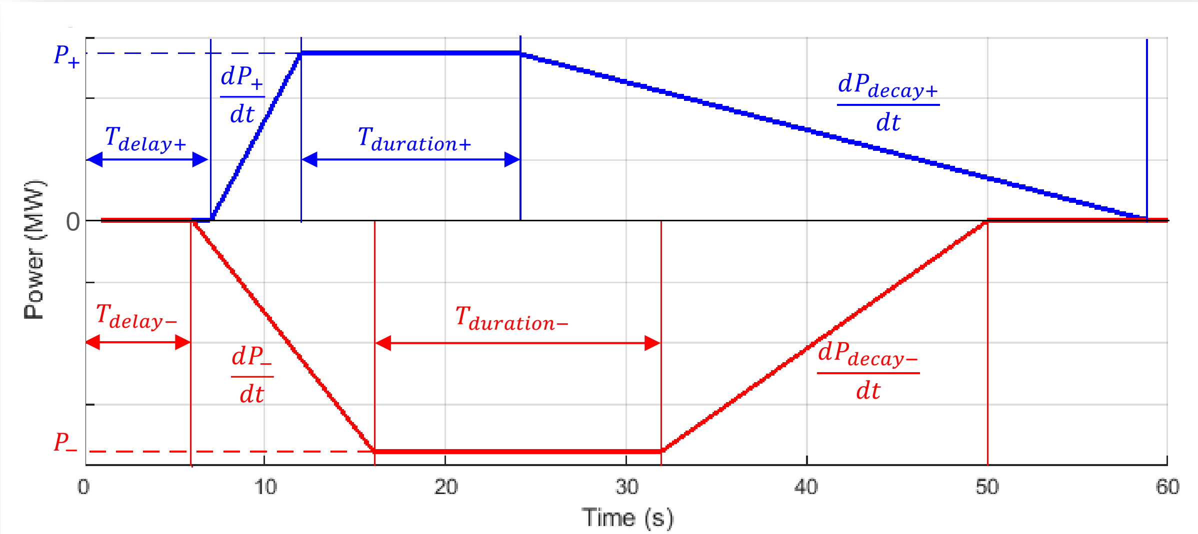
Whilst this is obviously not possible, it provides a target with which to rank responses:

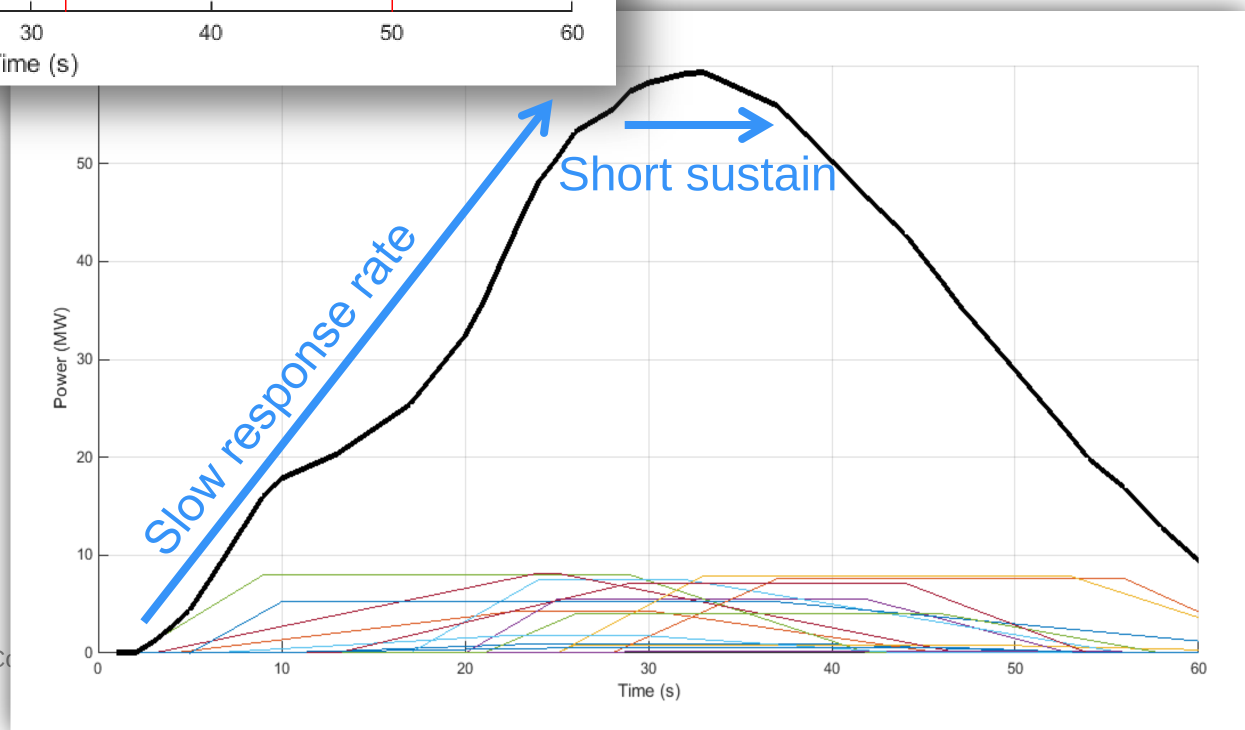


Square wave is best

- 0 s time delay
- Infinite ramp rate
- Sustained response

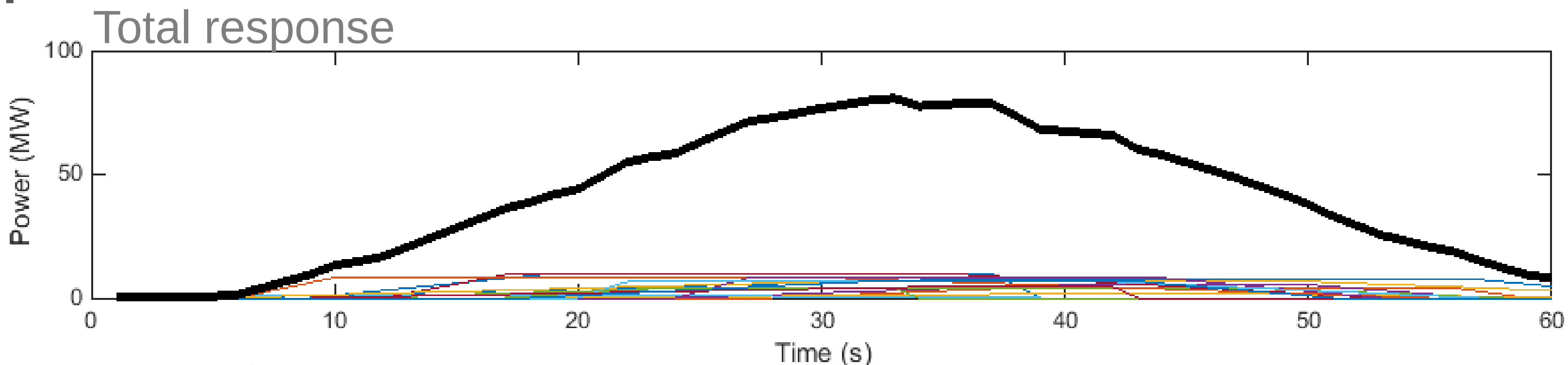
Optimisation – Total regional response

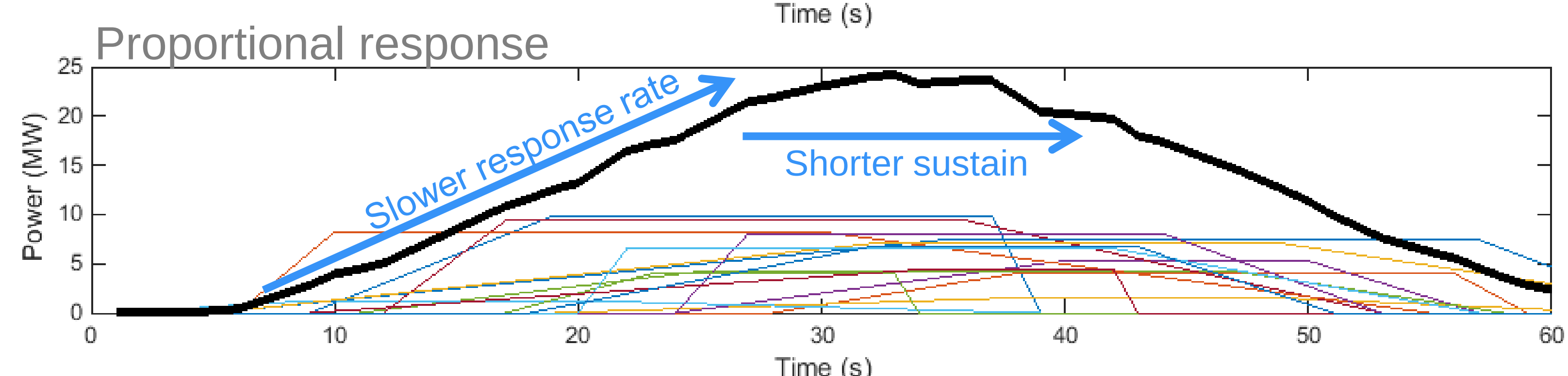


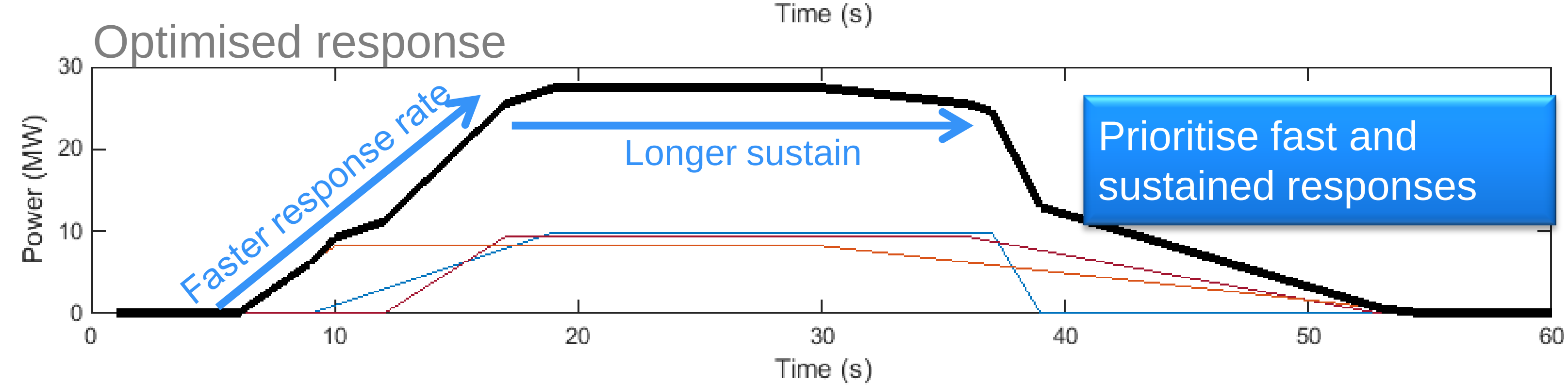


Total response tends away from ‘ideal’ response

Optimisation outcome







Perspective of a Service Provider

Perspective of a Service Provider

- What is expected of a **Service Provider** and **Service Operator**?

National Grid as Service Operator	Service Providers
Need to know the response profile	Provide NG with **response profile**
Need to **maintain active portfolio**	Update NG on status of resource
Needs to alert service provider if they are live or not	Will be aware if they are live in scheme
Determine how service providers will be rewarded: • Speed of response • Duration of sustained fast response • Availability etc.	• **Greatest value will lie in speed of response** (in coordinated way) – connection to WAMS • Local control is possible but care must be taken not to **reduce system stability** – reducing value • Cost – benefit analysis of installing comms
Facilitate the **integration of new service providers** to the scheme	May not be called upon for all frequency events – **locational element**
Prioritisation of resources by 'willingness to be deployed'	An option to bid according to a 'willingness to be deployed', e.g. so many times per month/year etc.
Determine suitable data resolution for response payment – particularly with greatest value on	Capture the deployed response for reward – **higher resolution data capture**

Wide-Area Frequency Control Scheme
25th february 2016

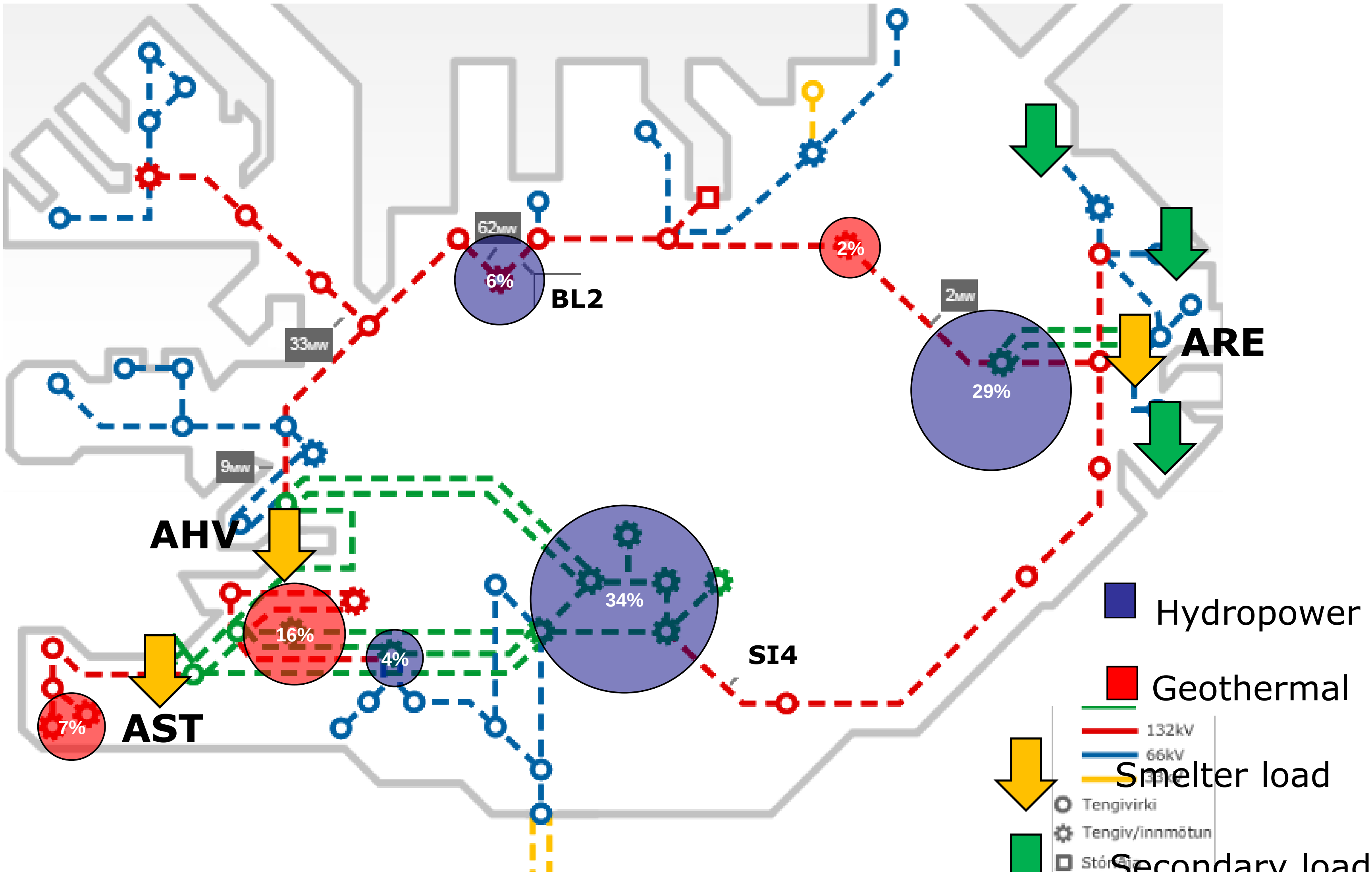
Ragnar Guðmannsson

Overview

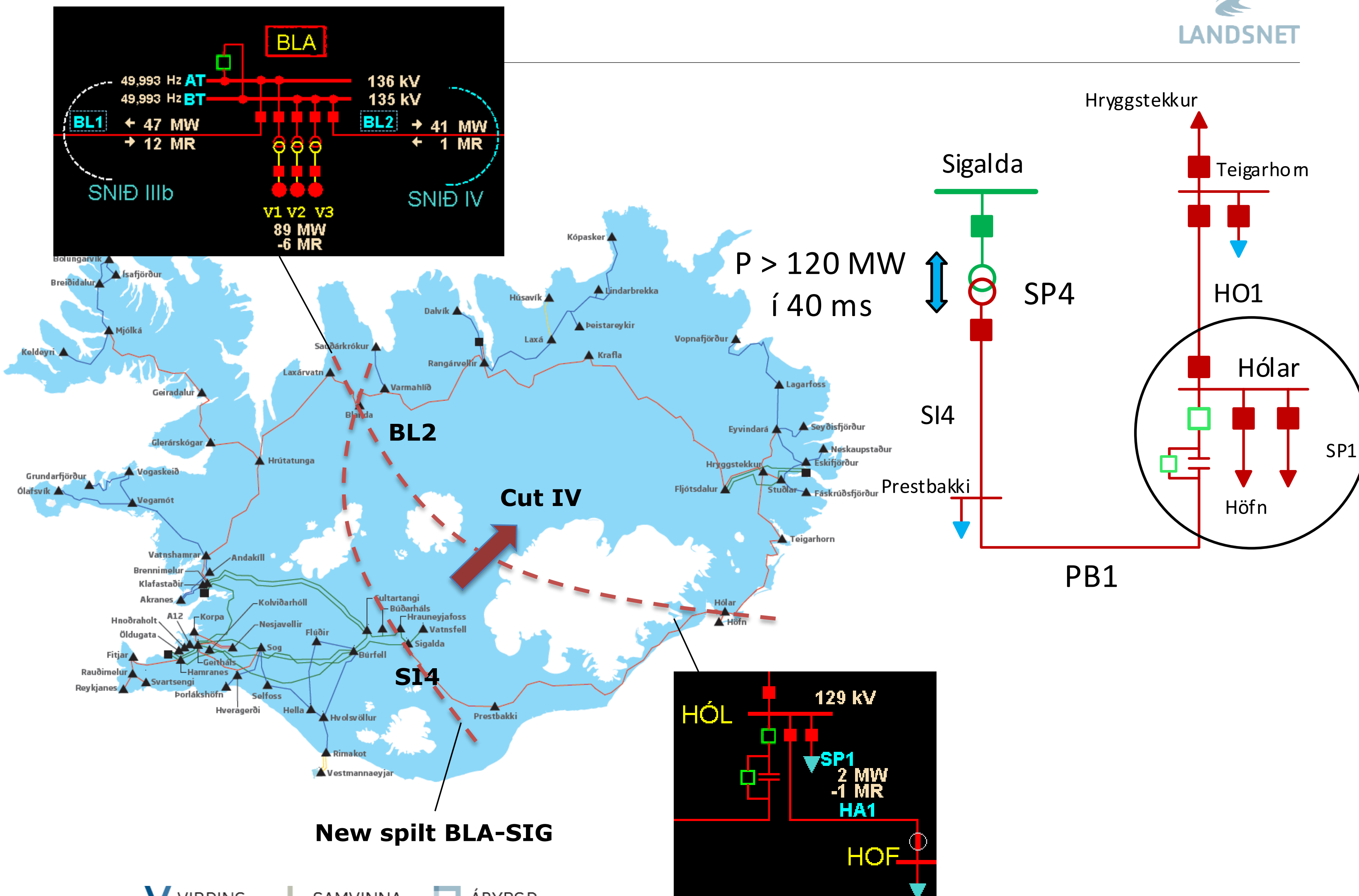
1. The Icelandic Transmission System
2. WAMS in Landsnet´s control room
3. Operational challenges in cut IV
4. WACS in operation
5. Summary and future plans

1. The Icelandic Transmission System

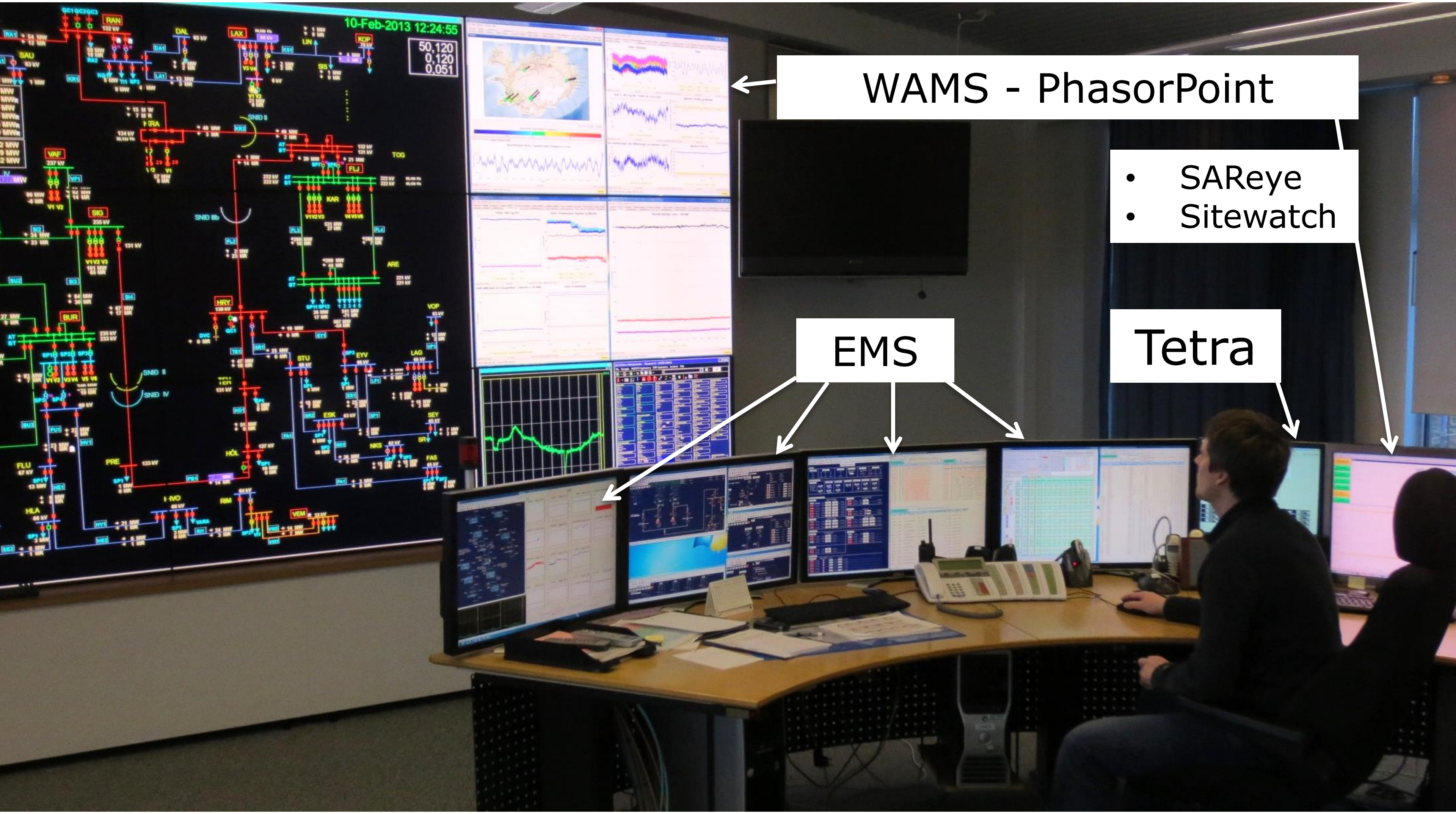
LANDSNET



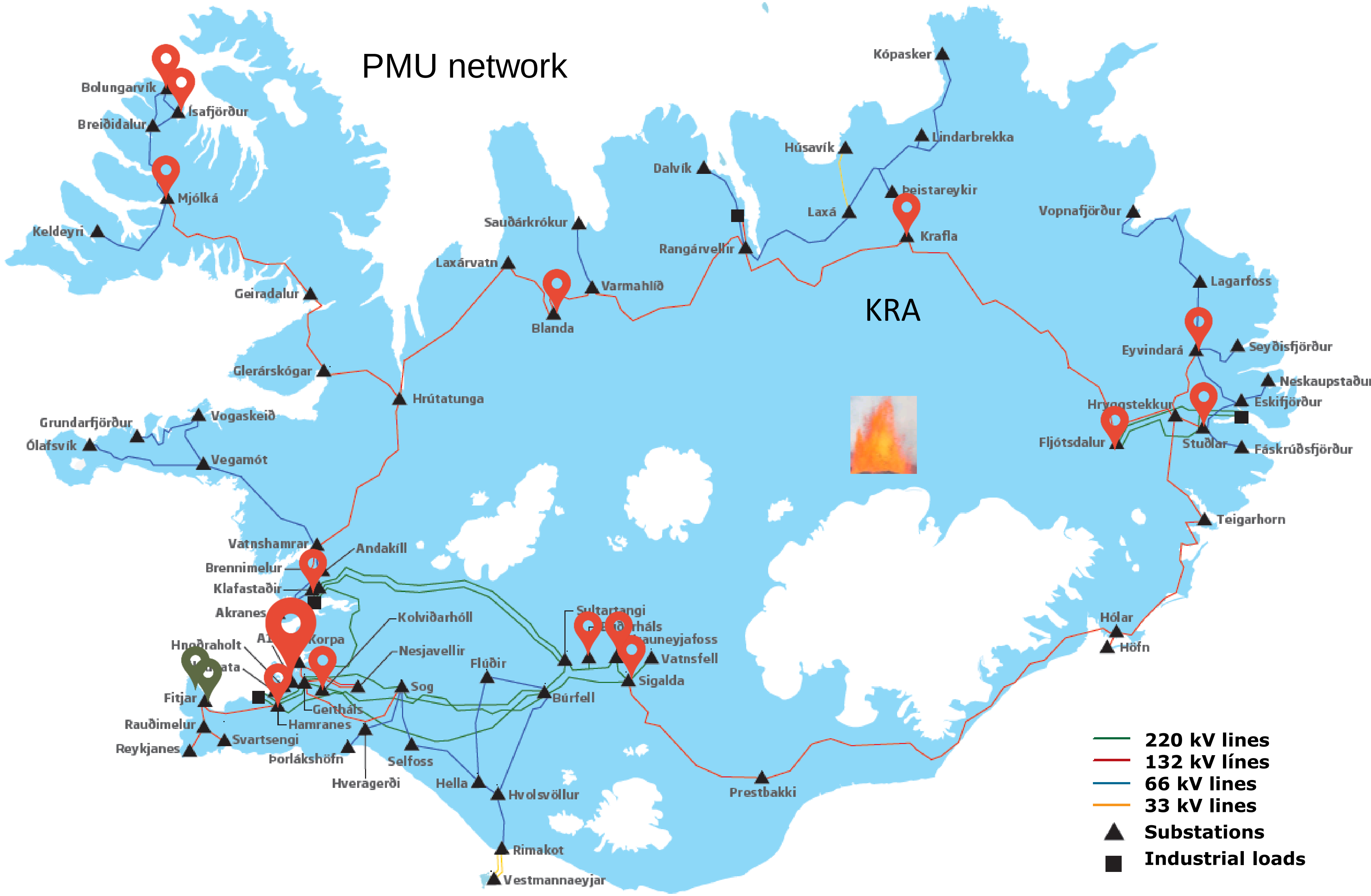
1. The Icelandic Transmission System



2. WAMS in Landsnet´s control room

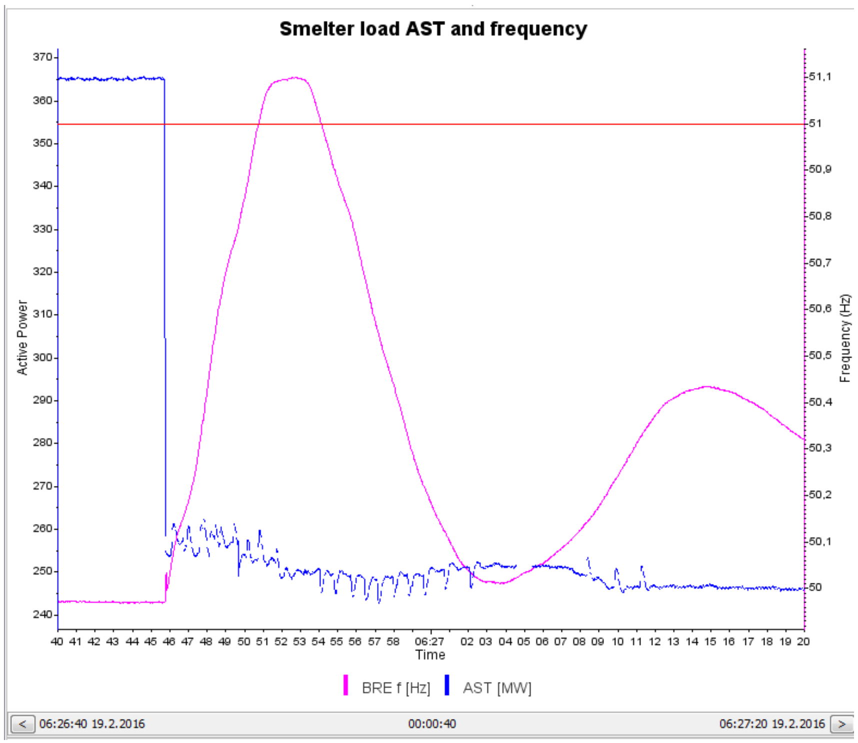


PMU network

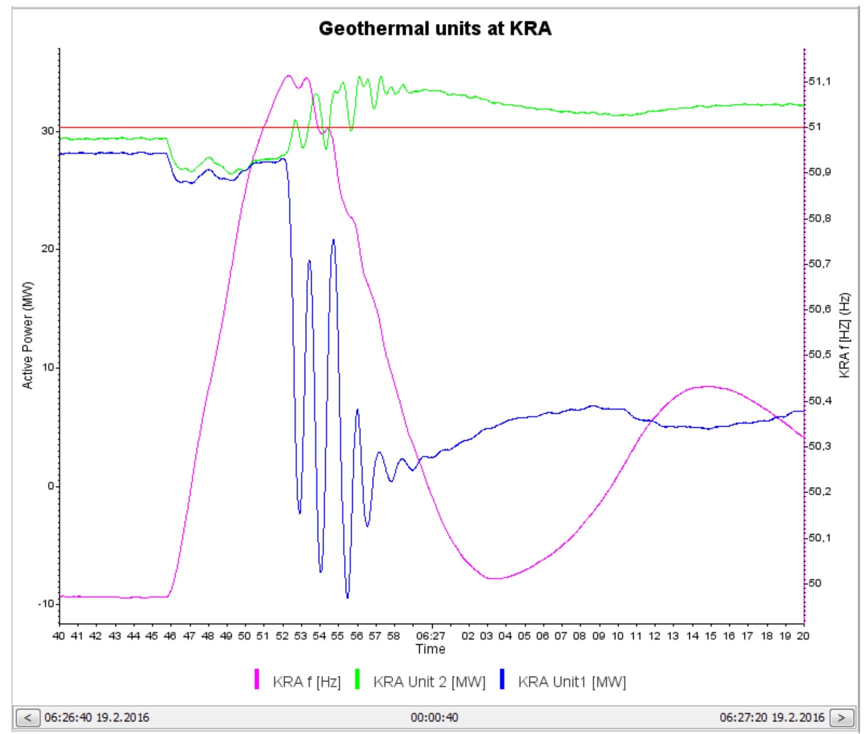

KRA
Bolungarvík
Ísafjörður
Breiðidalur
Mjólká
Keldeyri
Geiradalur
Glerárskógar
Grundarfjörður
Ólafsvík
Vogaskeið
Vegamót
Hrútatunga
Laxárvatn
Blanda
Sauðárkrókur
Varmahlíð
Dalvík
Rangárvellir
Húsavík
Laxá
Kópasker
Lindarbrekka
Þeistareykir
Krafla
Vopnafjörður
Lagarfoss
Eyvindará
Seyðisfjörður
Neskaupstaður
Eskifjörður
Fljótsdalur
Stuðlar
Fáskrúðsfjörður
Teigarhorn
Hólar
Höfn
Prestbakki
Vatnshamrar
Andakíll
Brennimelur
Klafastaðir
Akranes
Kolviðarhóll
Korpa
Nesjavellir
Sultartangi
Vatnsfell
Sigalda
Flúðir
Sog
Búrfell
Geitháls
Hamranes
Fitjar
Rauðimelur
Svartsengi
Reykjanes
Þorlákshöfn
Selfoss
Hveragerði
Hella
Hvolsvöllur
Rimakot
Vestmannaeyjar
220 kV lines
132 kV lines
66 kV lines
33 kV lines
Substations
Industrial loads

WAMS in control room – 19.2.2016

- Trip of Smelter load

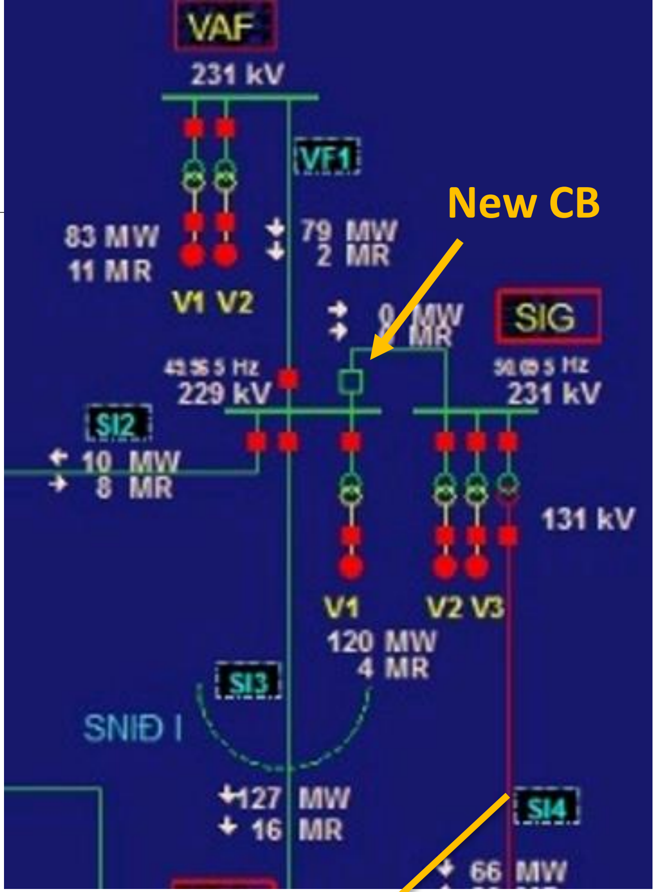


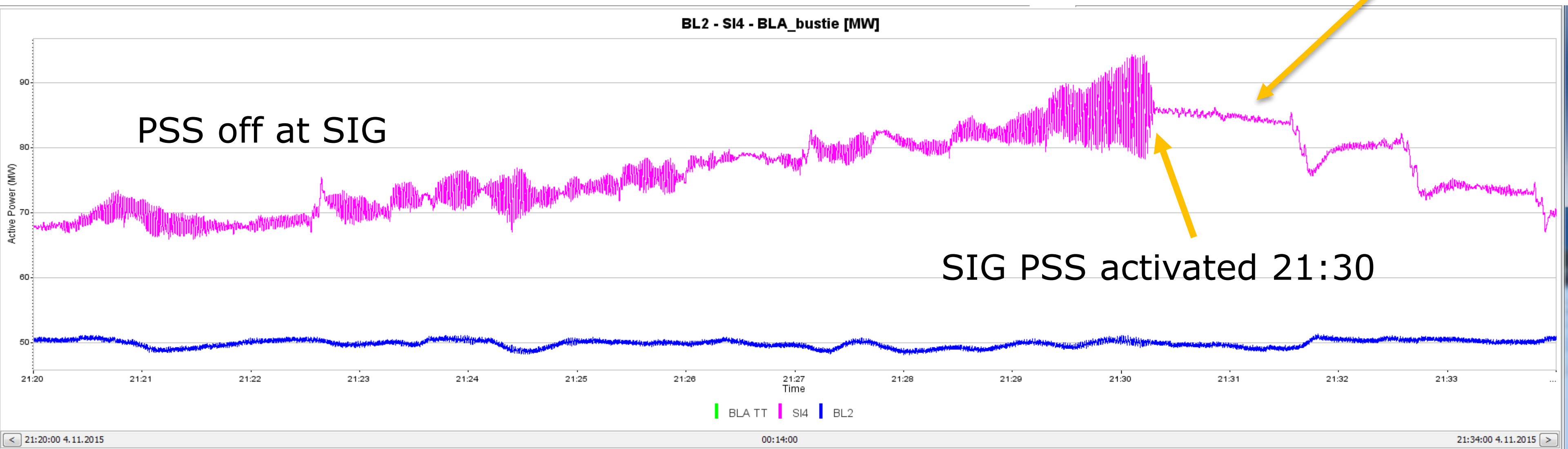
- Geothermal unit response
  +/- 51 Hz - 1 s → speed control



WAMS in control room – 4.11.2015

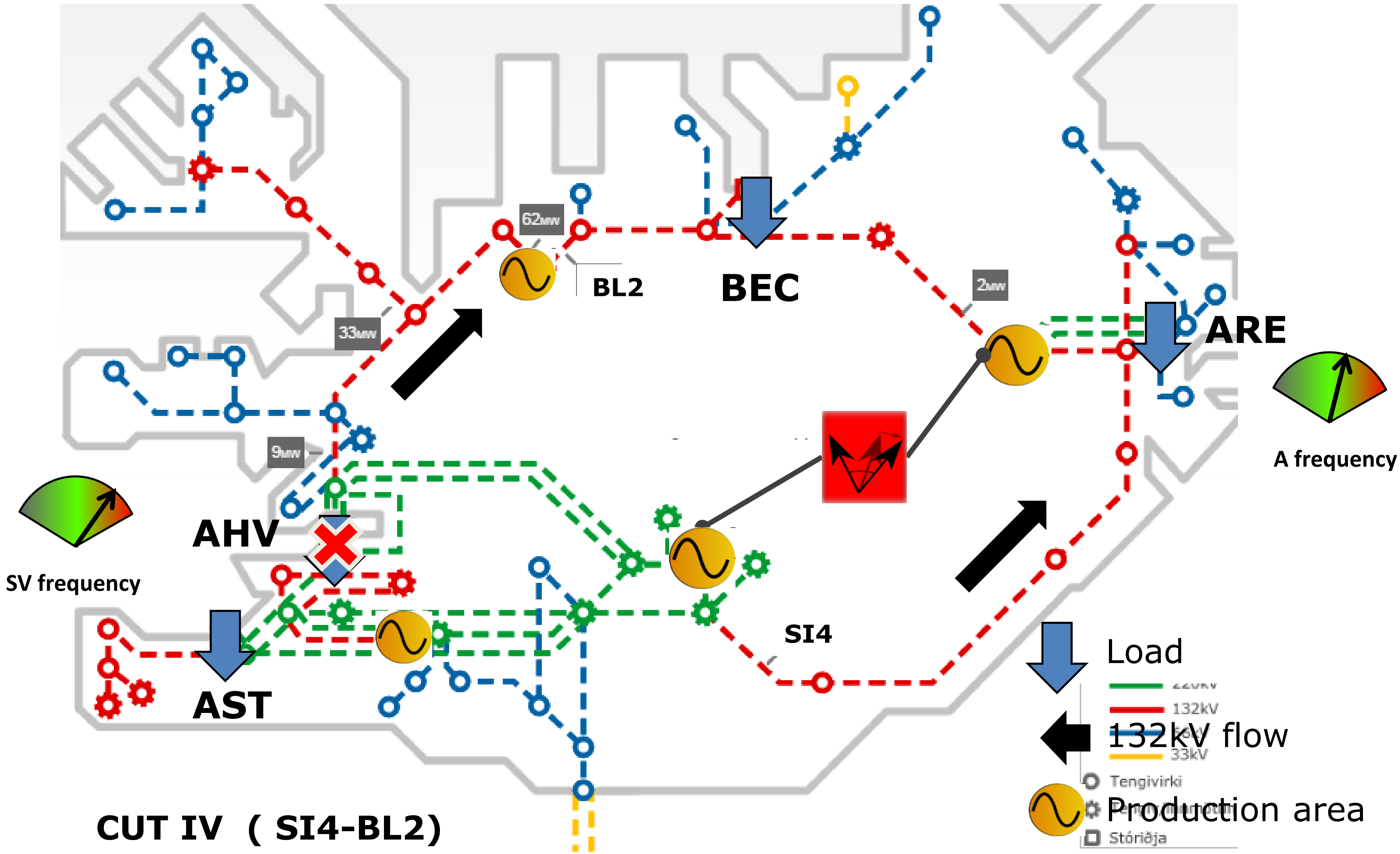
- PSS testing at Sigalda
- New CB installed to enable a better balanced split and to increase transfer in cut IV





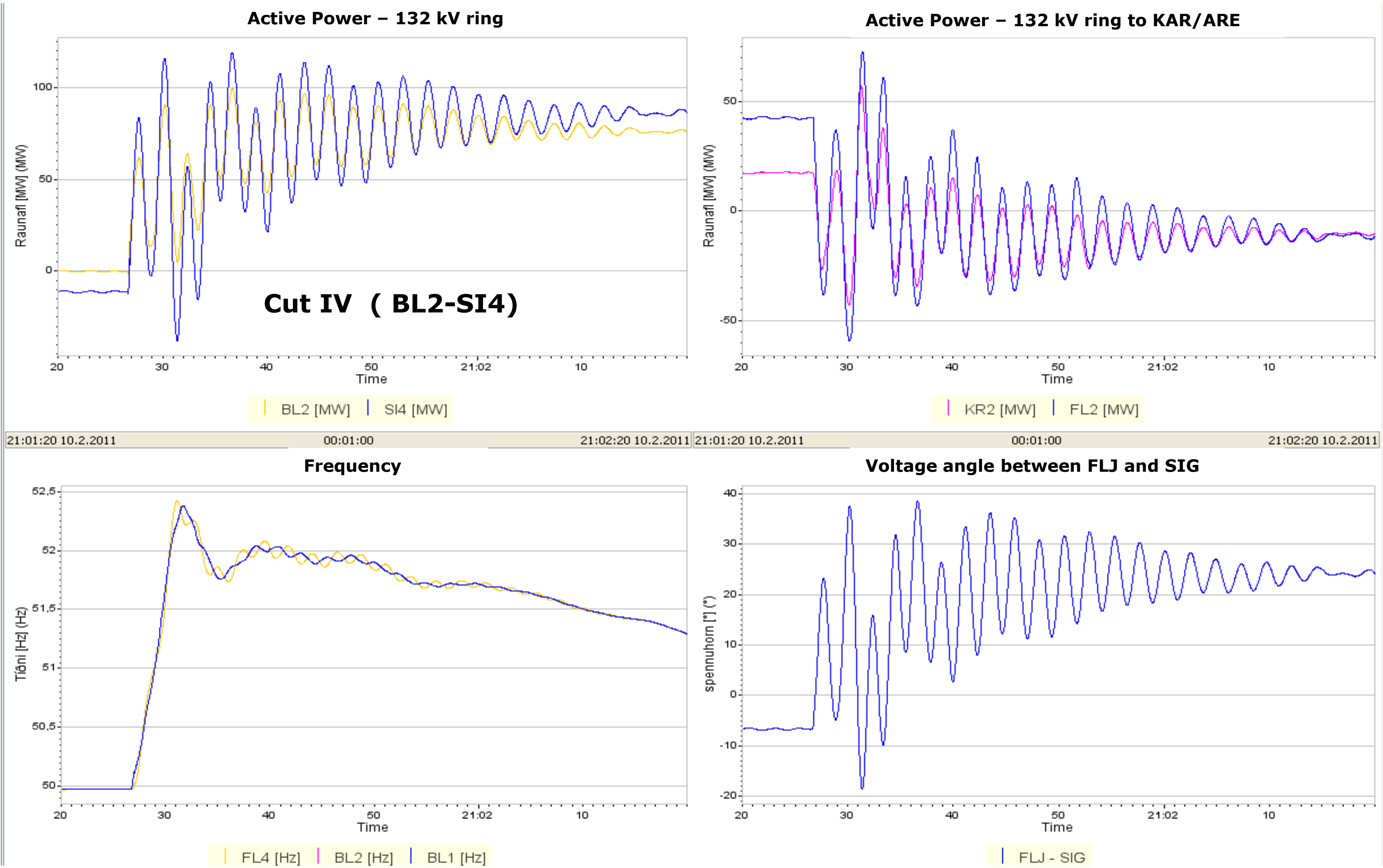
3. Operational challenges in cut IV

trip off smelter load in SouthWest



3. Operational challenges in cut IV
trip off smelter load in SouthWest 500 MW

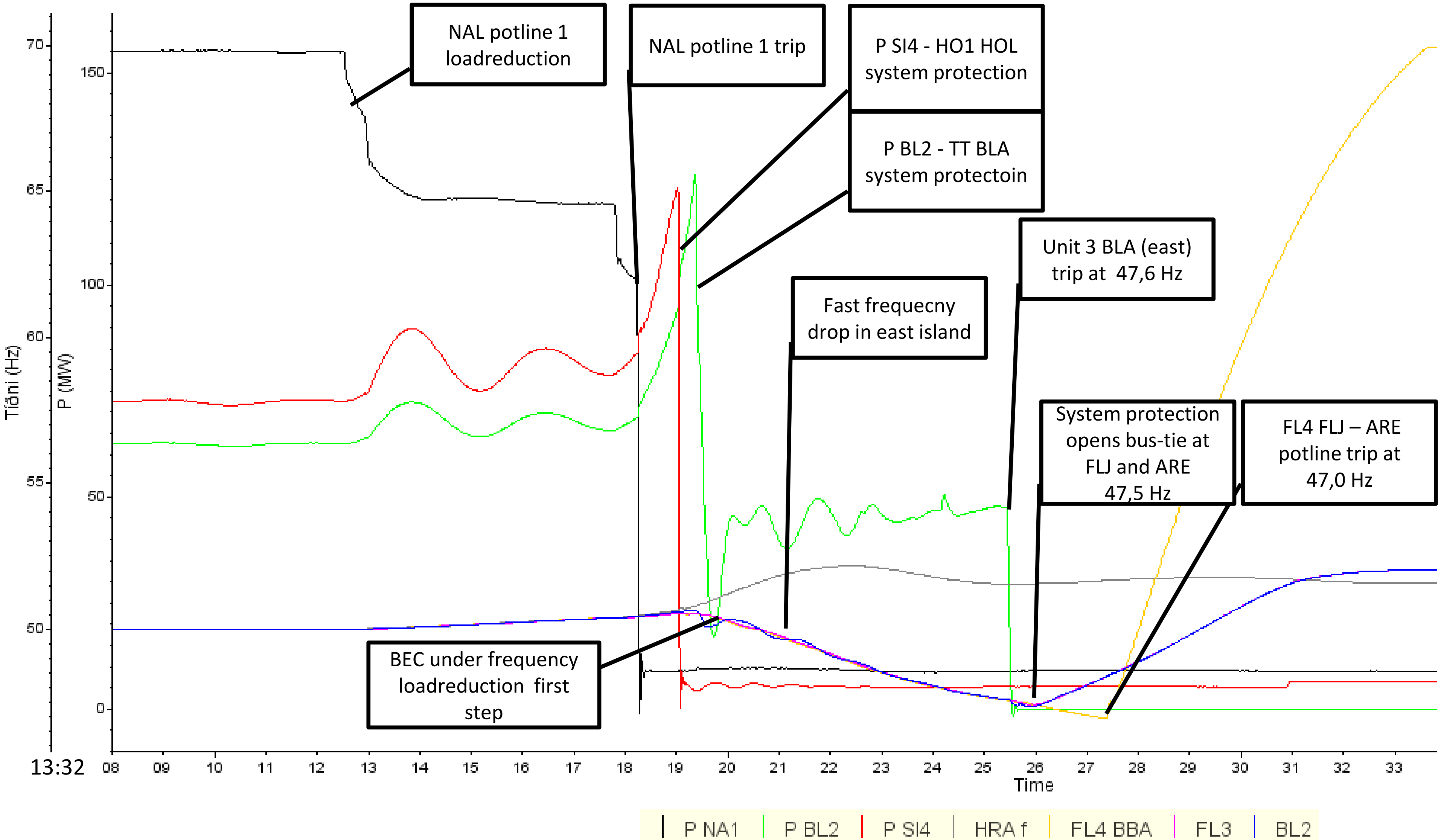
LANDSNET



3. Operational challenges in cut IV

SP split BLA - HOL 08.05.13

LANDSNET



4. WACS in operation

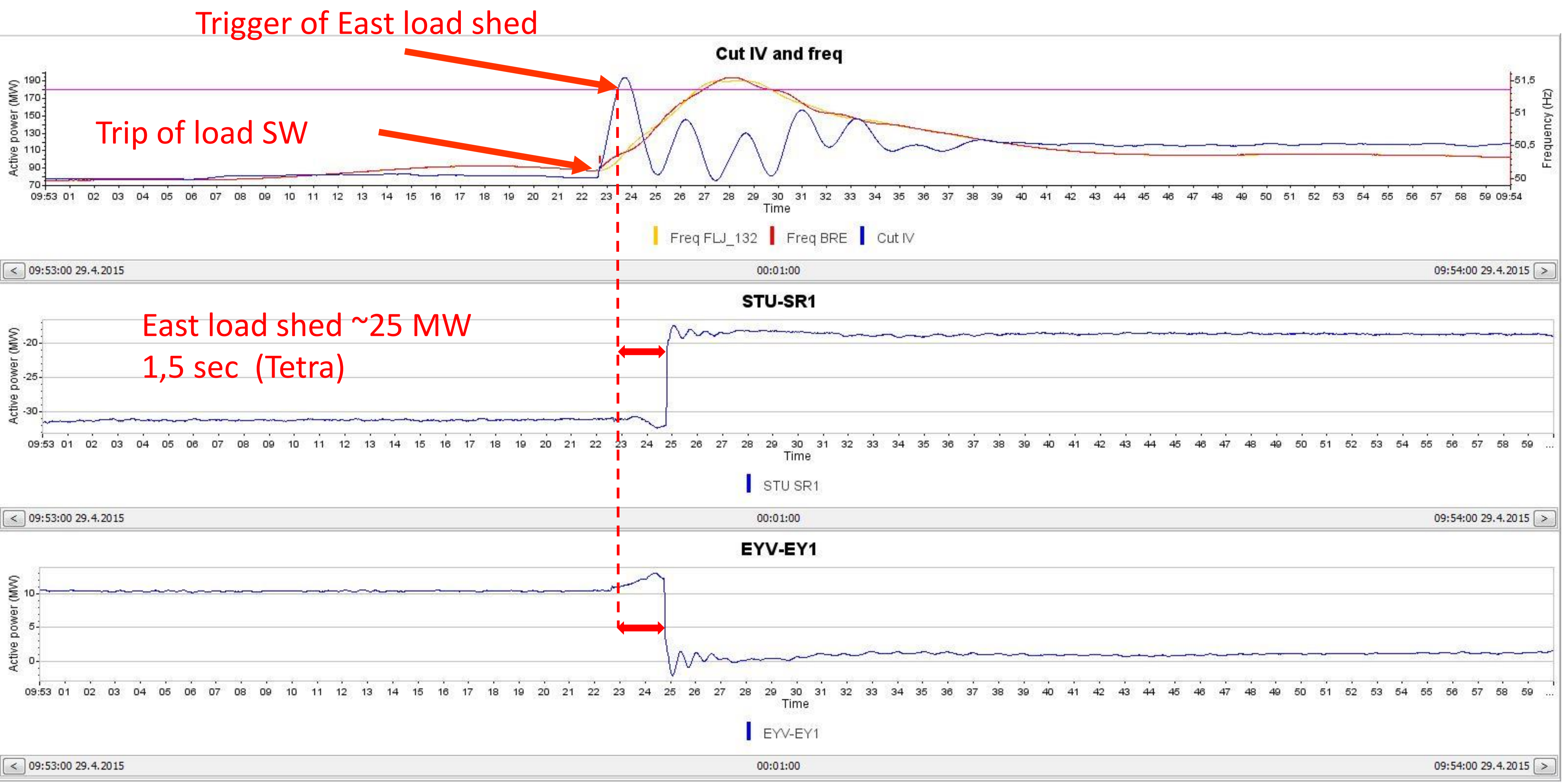
LANDSNET

East Load Shed
Triggered load shed

ARE Ramp
Down action

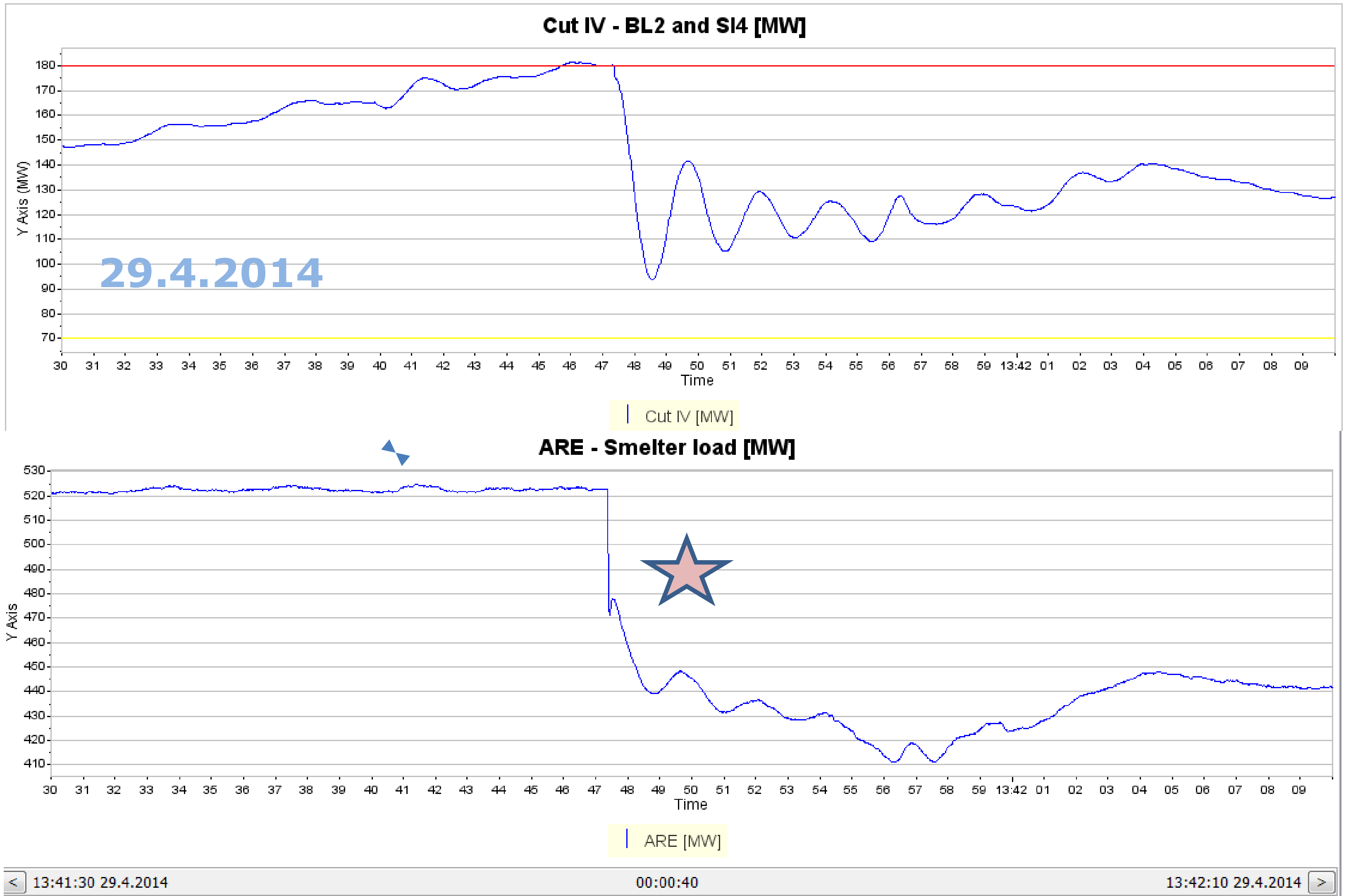
AHV Load Control
Down&Up fast action

East Load Shed
Triggered load shed

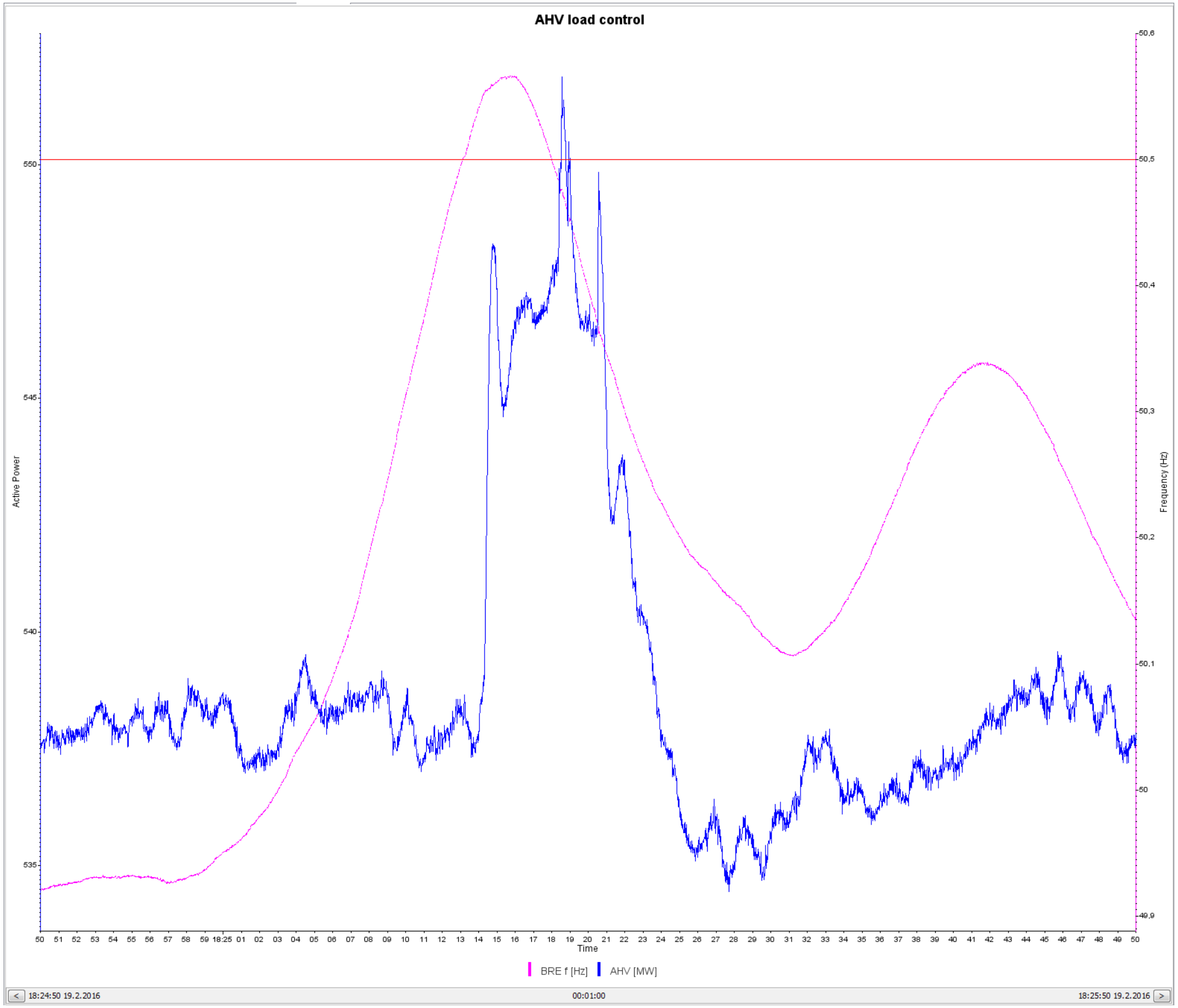


ARE Ramp
Down action

LANDSNET

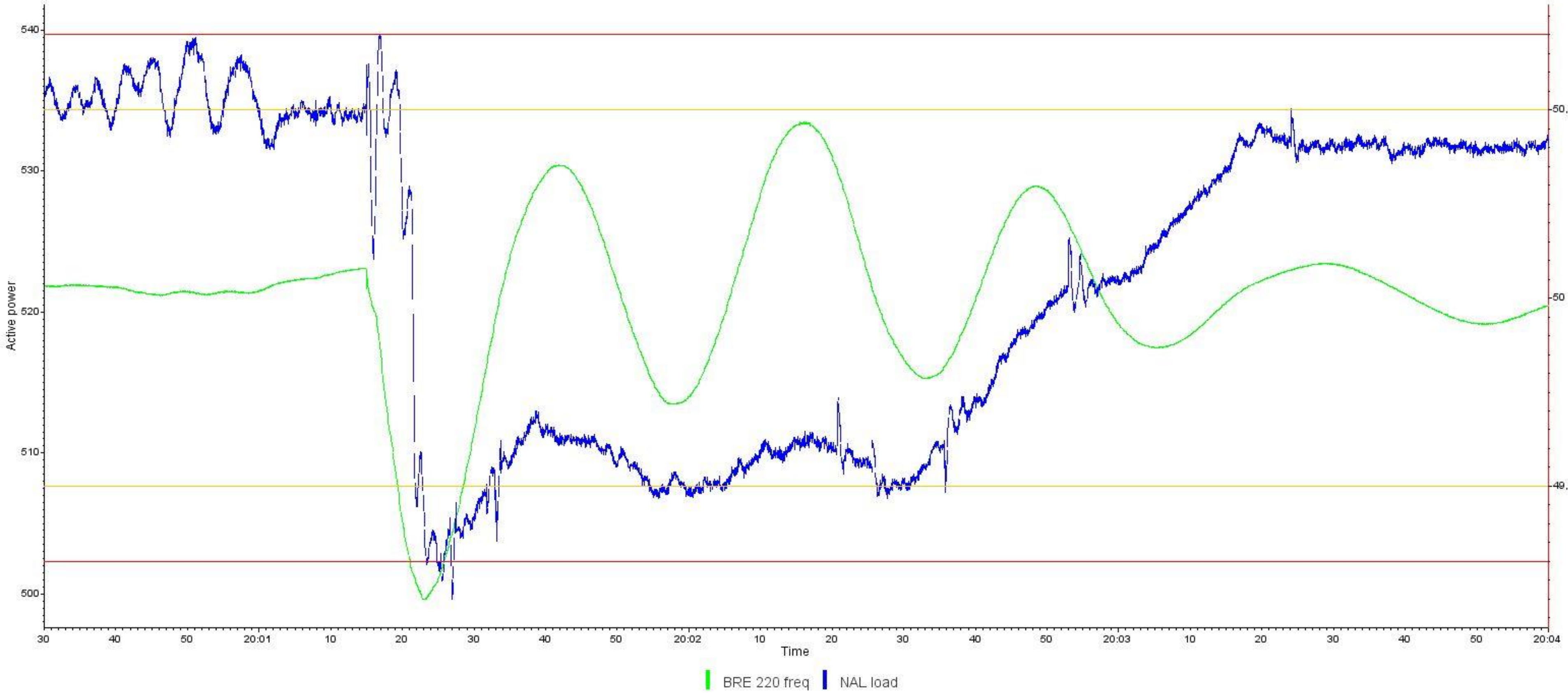


AHV Load Control
Up fast action



NAL Load Control
Down fast action

LANDSNET



Event 25.05.2015

5. Summary and future plans

LANDSNET

Control of all smelter load → (0-120 sec)

- Fast down & up regulation
- Balance action within disturbance area
- Goal to prevent system split

Fast ramping of generating units

- Faster response within disturbance area
- PMU based blocking of change over to frequency mode
- Emergency control in AGC

Adaptive Islanding

- Split-line armed depending on power flow and balance
- Intelligent system design - CB at SIG
- Increased power flow on 132 kV ring

Thank You

EFCC Stakeholder Engagement

Laboratory Testing and Optimisation of SFC at The University of Manchester

Prof. Vladimir Terzija

Dr Peter Wall

Mingyu Sun

Alexandru Nechifor

Negar Shams

Outline

1. Objectives and Role of UoM in EFCC

2. Context for UoM Research

3. Laboratory Testing

4. Economic Optimisation

5. Progress and Next Steps

MANCHESTER
1824
The University of Manchester

Role and Objectives of UoM in EFCC

Laboratory Testing and Optimisation of SFC at The University of Manchester

MANCHESTER
1824
The University of Manchester

Role of UoM in the EFCC Project

1. Laboratory Testing of SFC
   - Using PowerFactory and the Manchester RTDS to test the proposed Monitoring and Control Scheme (MCS)
2. Optimisation of SFC
   - Optimise the response of the proposed MCS
   - Create a supervisory wide-area controller and compare its performance to the proposed MCS
3. Develop SFC as a Balancing Service
   - Valuation of SFC, impact on policy and grid codes and other commercial considerations of SFC
4. Knowledge Dissemination

MANCHESTER 1824
The University of Manchester

Further Objectives of UoM

1. Estimation of System Inertia
   – Create online methods for estimating system inertia with a view to real-time inertia monitoring
2. Understanding and Estimating Regional Inertia
   – Create rigorous methods for defining a region, estimating its inertia and understanding the impact of regional inertia
3. The possible role of locally triggered resources as part of fast frequency control
4. The nature of Frequency/Active Power Control in systems with high penetrations of power electronics

The University of Manchester

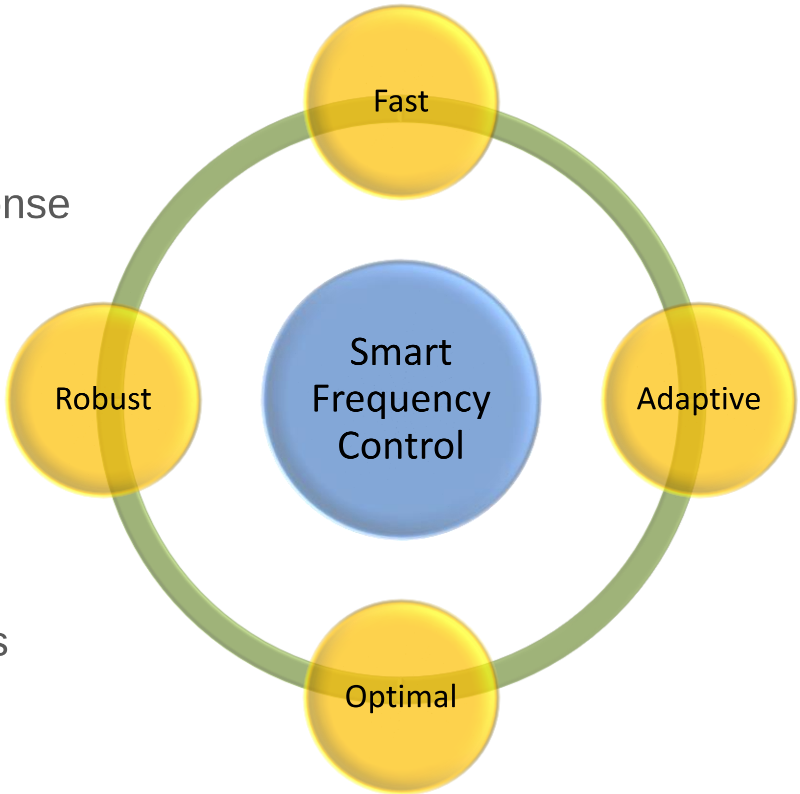
Context for UoM Research

Laboratory Testing and Optimisation of SFC at The University of Manchester

The University of Manchester

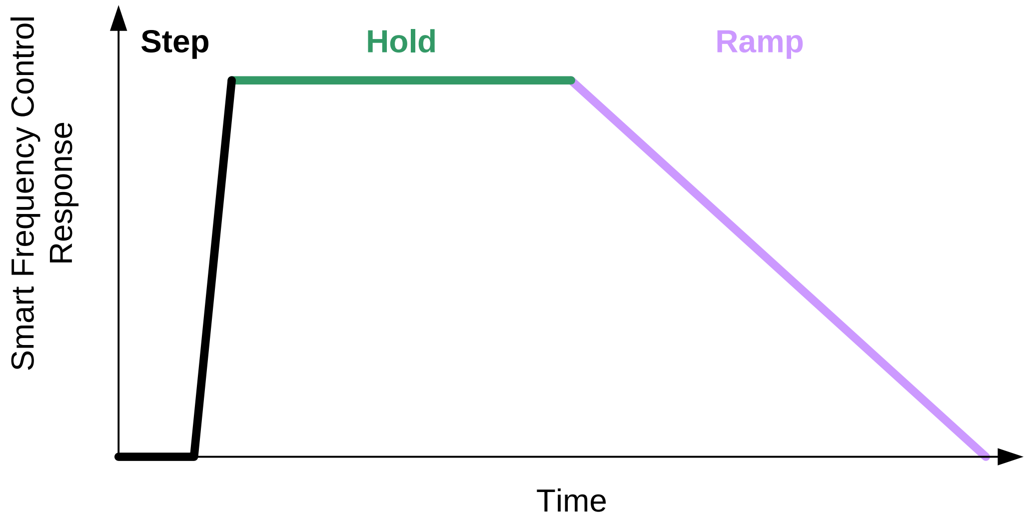
Smart Frequency Control (SFC)

- A new form of frequency control for low inertia systems
- It must be:
  - **Fast**
    - SFC must support inertial response
  - **Adaptive**
    - Variable inertia will require a variable response or it could jeopardise frequency security
  - **Optimal**
    - The cost and impact of service provision must be reasonable
  - **Robust**
    - Many elements of the system controlled in a short time (<1s), so the consequences of failures or errors may be high



Smart Frequency Control

- The response can be broken down into three stages



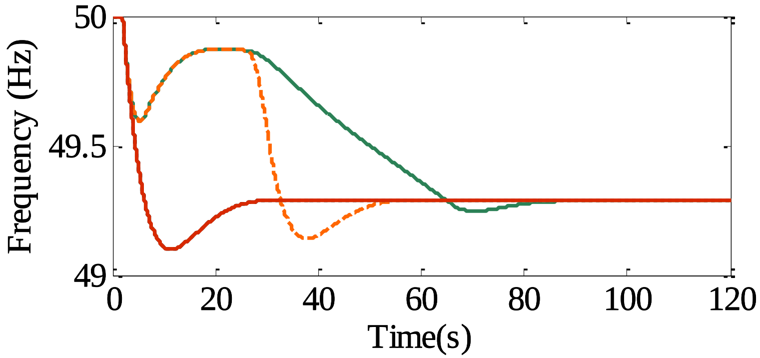
- Is tempting to focus on the step, as the speed of this response is the novel feature of SFC
- However the hold and ramp are equally important

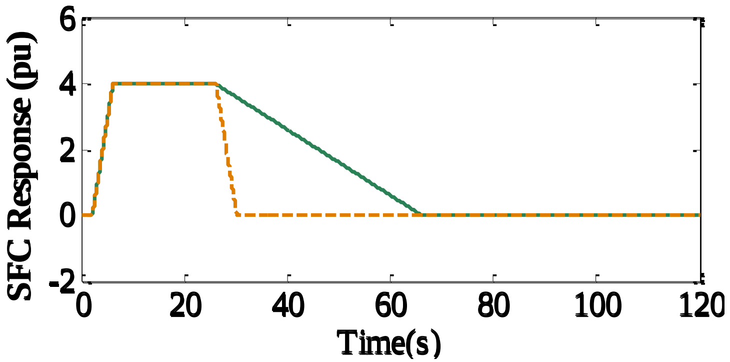
The University of Manchester

Smart Frequency Control

- The role of SFC can be viewed as:

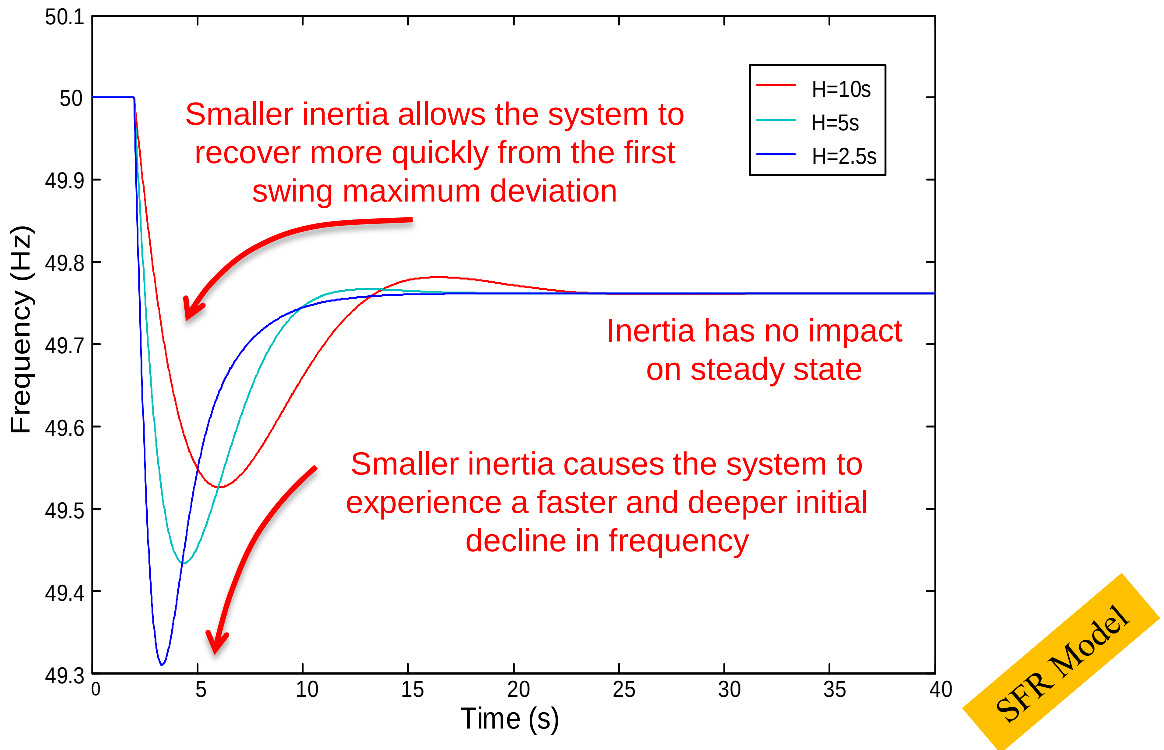
Converting an active power disturbance that the existing primary control **cannot** contain into one that it **can** contain





Impact of Reduced Inertia – Frequency

- Inertia acts to oppose any change in frequency
- Less inertia means larger, faster changes in frequency



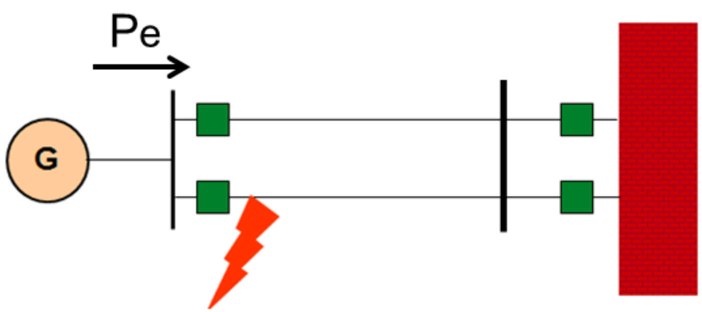
MANCHESTER 1824
The University of Manchester

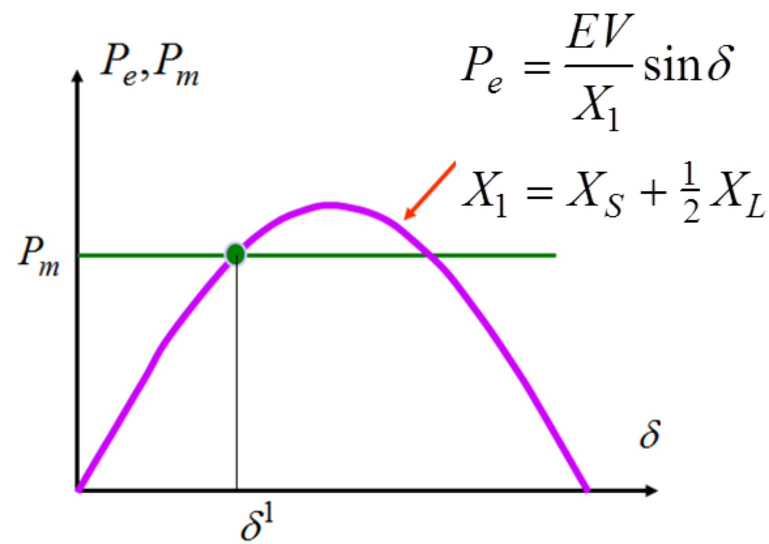
Impact of Reduced Inertia – Angle

- Frequency is the derivative of angle
- Reduced inertia allows angles to change faster
- Regional inertia means regions can separate more easily and the period of vulnerability is longer
- Faster frequency control actions will intrude on period of interest for angular stability

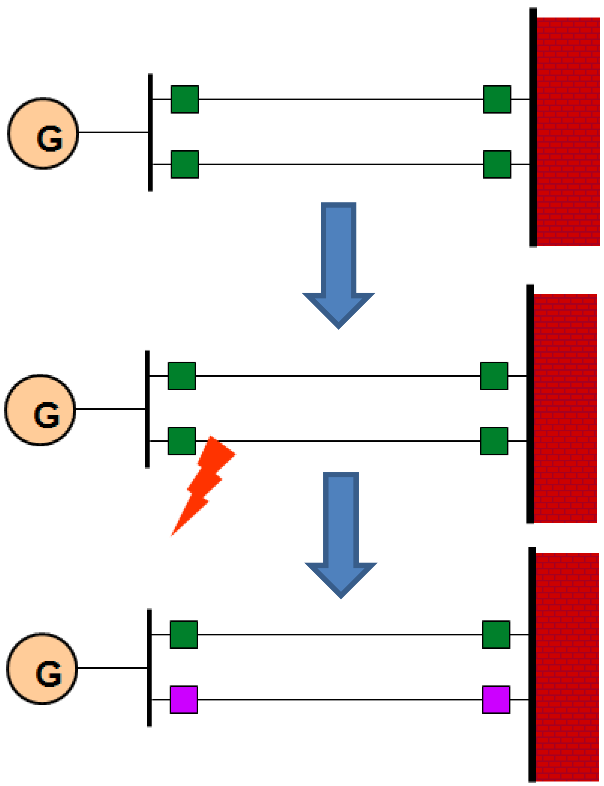
Matlab Example of Equal Area Criteria

Example of a single generator connected to a large network (an infinite bus):

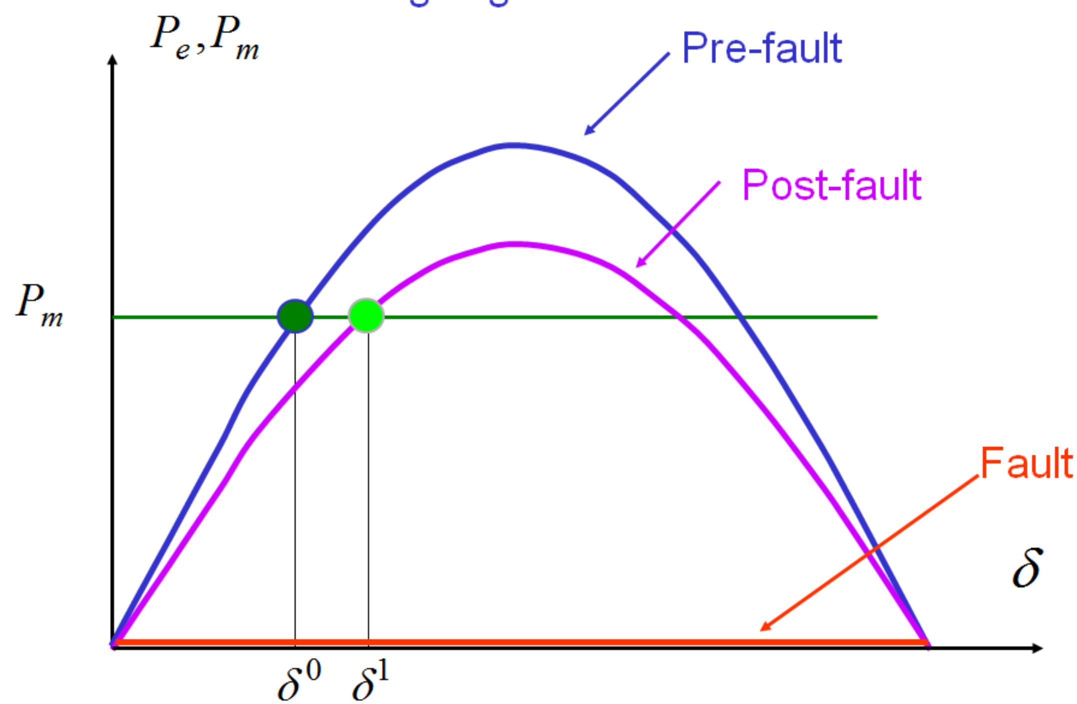




Matlab Example of Equal Area Criteria



Can we get from one steady state operating point to another without going unstable?



MANCHESTER
1824
The University of Manchester

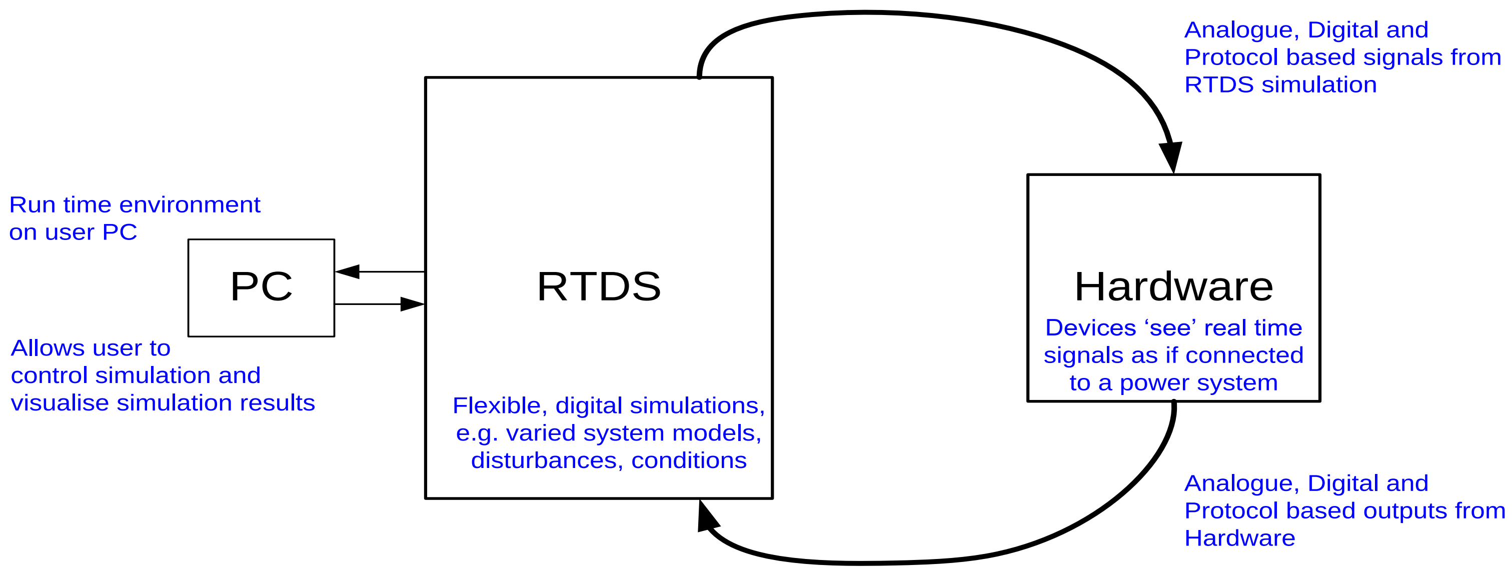
RTDS – Real Time Digital Simulator

- RTDS – Real Time Digital Simulator
- Electromagnetic Transient simulation
  - Simulation uses a 50 μs time step
  - The simulation of 1 second takes ***exactly*** 1 second
- RTDS includes analogue and digital output boards as well as protocol based communication
- Hardware can use these signals as inputs,
  as if they were connected to an actual power system
- This allows Hardware in the Loop Testing

The University of Manchester

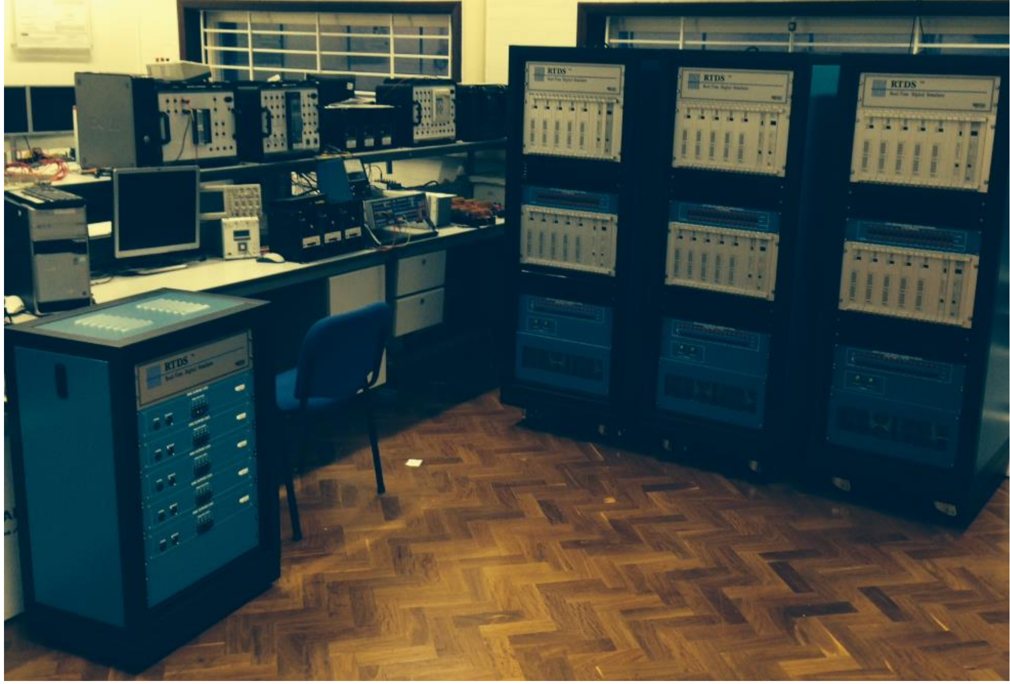
Hardware in the Loop (HiL) Testing

- Closed loop testing of hardware



- Can study the interaction between the hardware and the simulated power system
  - This is critical for studying controllers

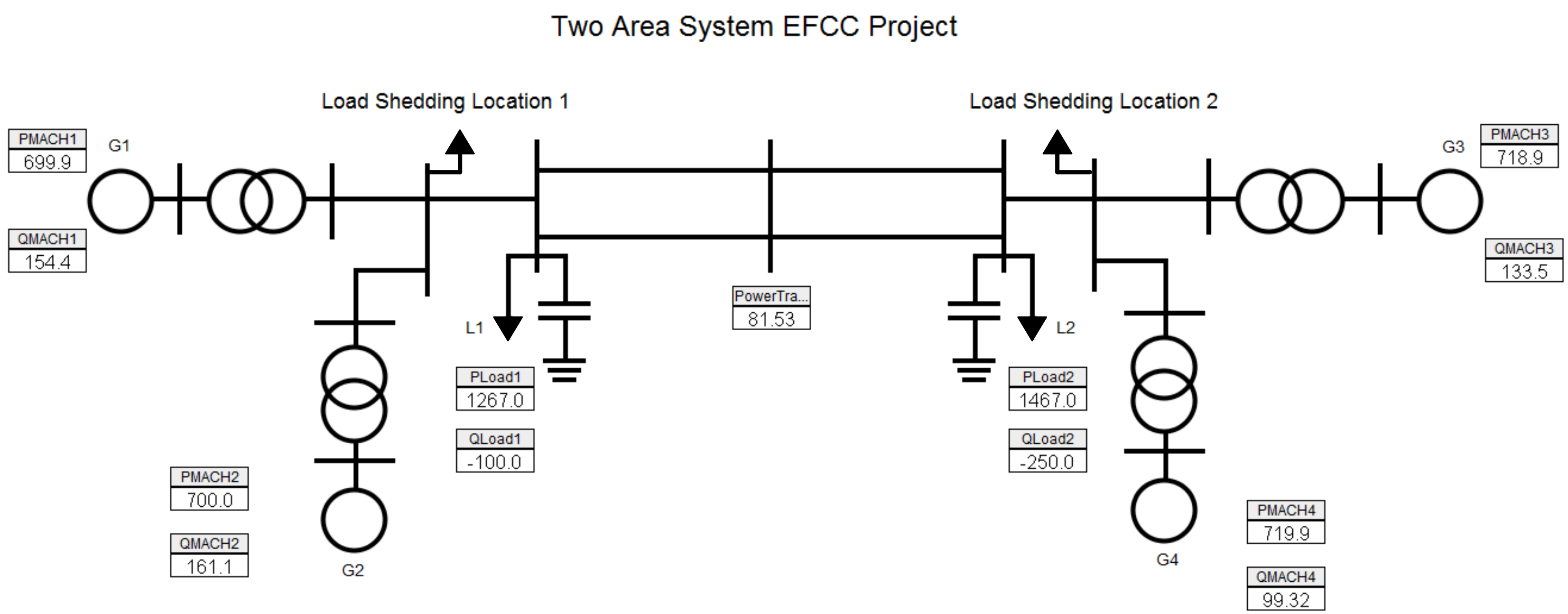
Manchester RTDS



- M-RTDS has:
  - 6 racks 30 PB5 processor cards
  - 5 MMC support units
  - GTSync card for Synchronisation of the RTDS
  - GTNet cards for high level communication (e.g. IEC 61850, C37.118 and IEC 60870 protocols)
  - GTWIF cards to connect to workstations

Demonstration of M-RTDS

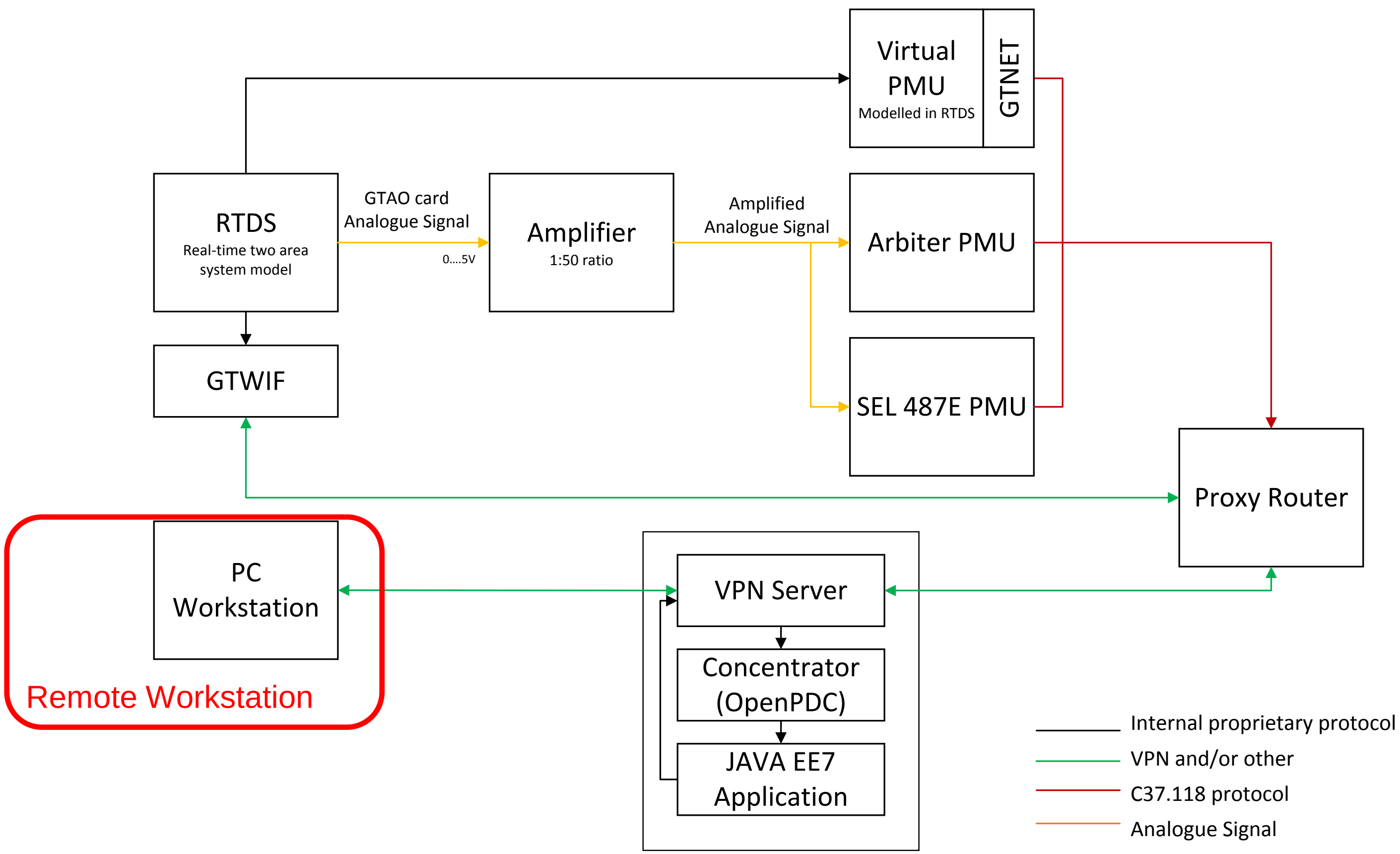
- Use the RTDS to present simulated examples of a Two Area power system



MANCHESTER 1824
The University of Manchester

Demonstration of M-RTDS

- Connect to RTDS Laboratory using a VPN



MANCHESTER 1824
The University of Manchester

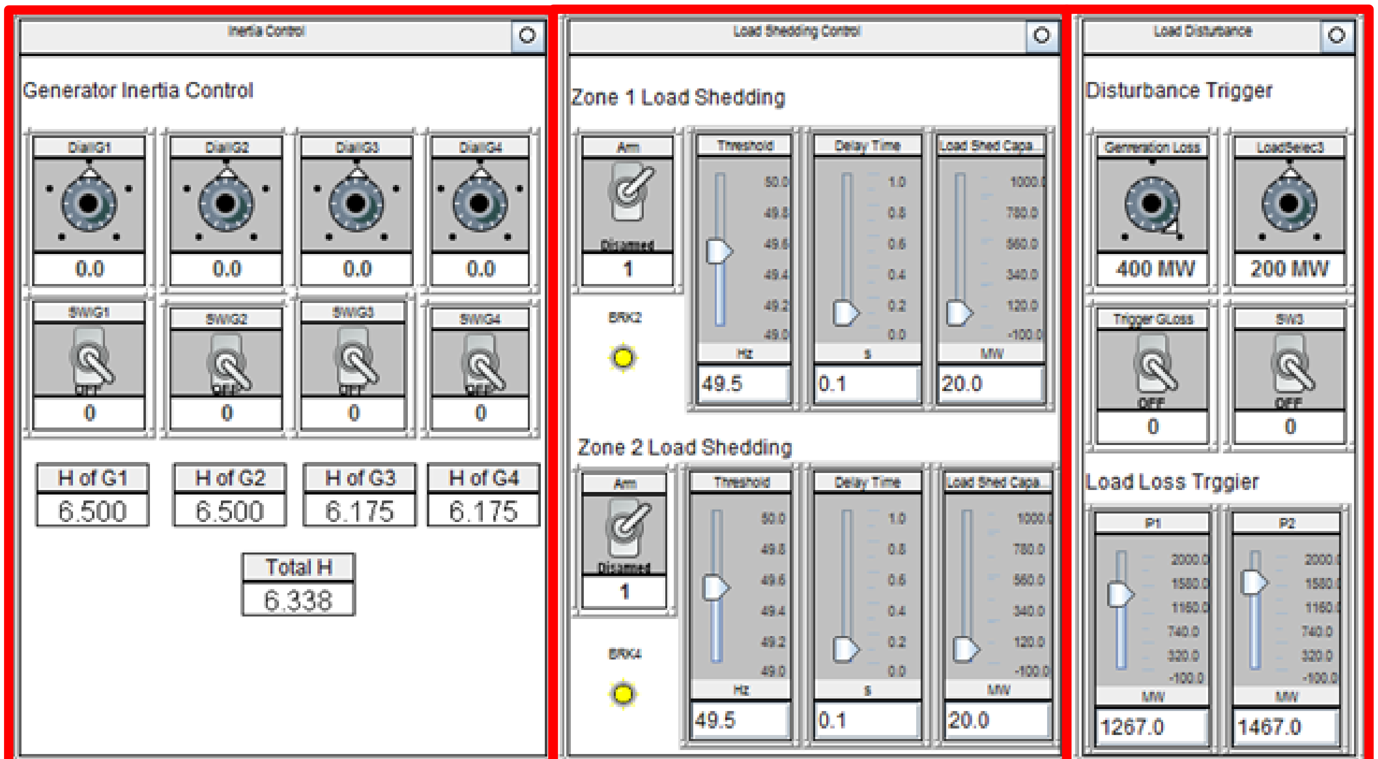
Demonstration of M-RTDS - Runtime

- Runtime allows user to control simulation in real time

1) Vary inertia in each Area

2) Select Fast Control Action

3) Trigger a Disturbance



The University of Manchester

Laboratory Testing

Laboratory Testing and Optimisation of SFC at The University of Manchester

The University of Manchester

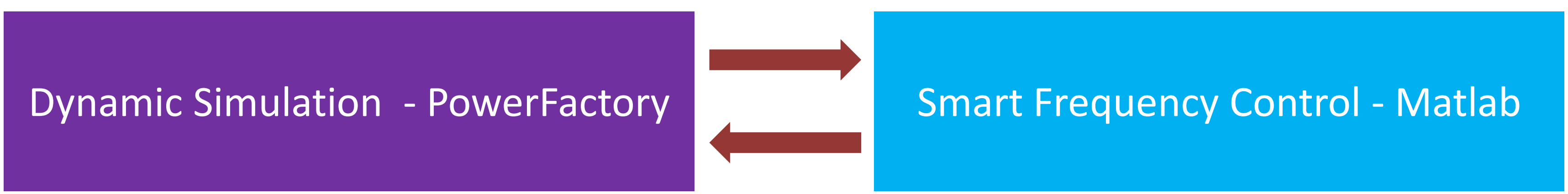
Laboratory Testing at UoM

- Non-Real Time Testing
  - Dynamic simulations using DIgSILENT Powerfactory
  - SFC elements (e.g. local controller) simulated in Matlab

- Real Time Testing
  - Dynamic simulations using the Manchester RTDS
  - Prototype Hardware used for all SFC elements

Non-Real Time Testing

- Closed loop tests to study response of software implementation of SFC elements
- Must Integrate PowerFactory and Matlab to allow the simulation to pass data to the controller and vice versa



- This is possible within PowerFactory
  – But, it requires the SFC modules to be modified (being delivered through collaboration with GE)

MANCHESTER
1824
The University of Manchester

Non-Real Time Testing – Open Loop

- No feedback into the simulation from the SFC
- Focus of testing is:
  - RoCoF estimation in presence of noise and errors
  - Dependability and accuracy of disturbance detection and size estimation
  - Security against short circuits and line disconnections
  - Performance during multiple events (e.g. a short circuit followed by the disconnection of a generator)
  - Impact of improper region selection

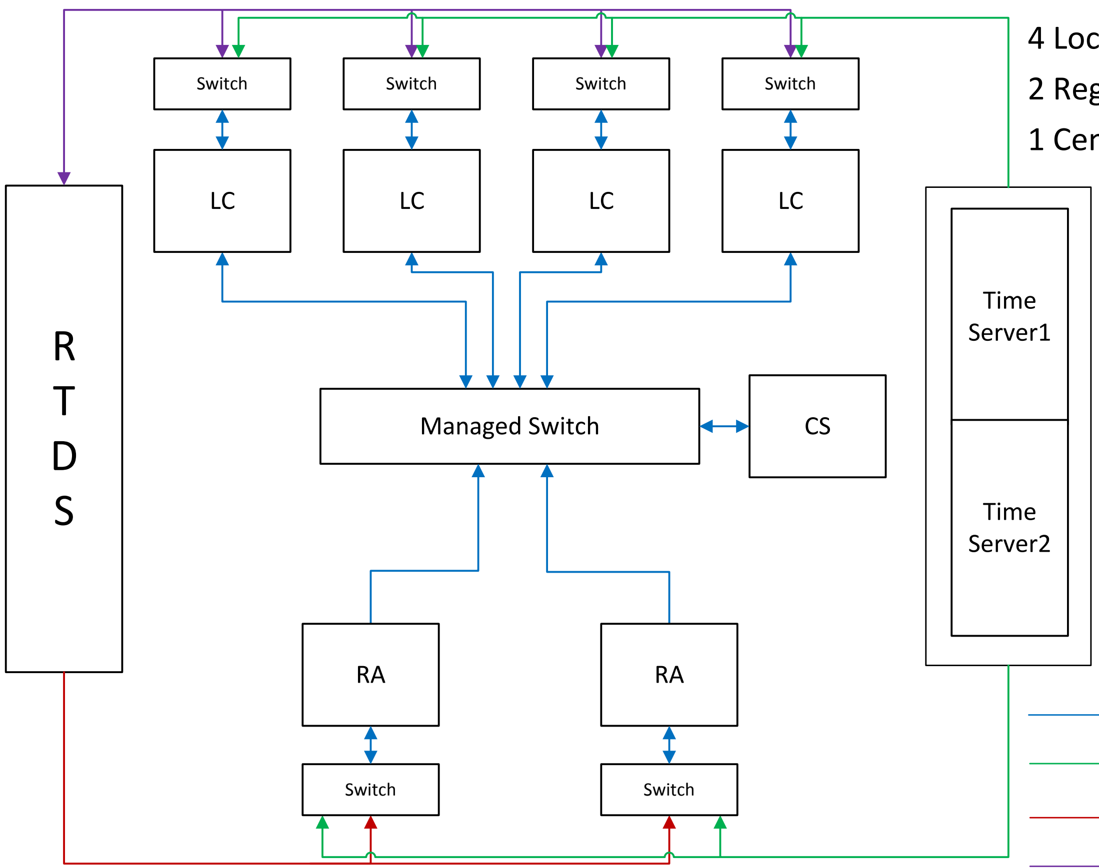
Non-Real Time Testing – Closed Loop

- Feedback into the simulation from the SFC
- Focus of testing is:
  - Resource Allocation by local controllers
  - Impact of noise and errors on resource allocation
  - Impact of finite resource and improper resource response
  - Resource allocation during multiple events
  - Impact of massive communication loss

The University of Manchester

Real Time Testing

- Use M-RTDS to test SFC hardware



SFC Hardware

4 Local Controllers

2 Regional Aggregators

1 Central Supervisor

Fibre Optic

Time signal

C37.118 protocol

IEC 61850

MANCHESTER
1824
The University of Manchester

Real Time Testing

- Use M-RTDS to test SFC hardware
- Testing is separated into two elements:

1. Verify hardware response mimics software response
   – Repeat selected non-real time tests
2. Impact of monitoring and communication performance
   – PMU measurement performance
   – Poorly defined data streams
   – Latency, jitter and lost packets
   – Configuration errors in hardware or communications

The University of Manchester

Question and Answer 1 – Laboratory Testing

Laboratory Testing and Optimisation of SFC at The University of Manchester

Economic Optimisation

Laboratory Testing and Optimisation of SFC at The University of Manchester

MANCHESTER 1824
The University of Manchester

Optimisation of SFC

- Ensuring SFC offers value for money to customers
- Some Key Questions:
  - How much response is required?
    - For a given inertia
    - Balance between slower and faster resources
    - The limitations on the energy of certain resources
  - What is the worst case?
    - Size and location of disturbance
    - Angular stress across the system
    - Availability of intermittent resources
  - How will the market work?
    - Balance between availability payments and utilisation payments
    - Ensuring technical deployment of SFC offers value for money to the customer

MANCHESTER 1824
The University of Manchester

Offline and Online Optimisation

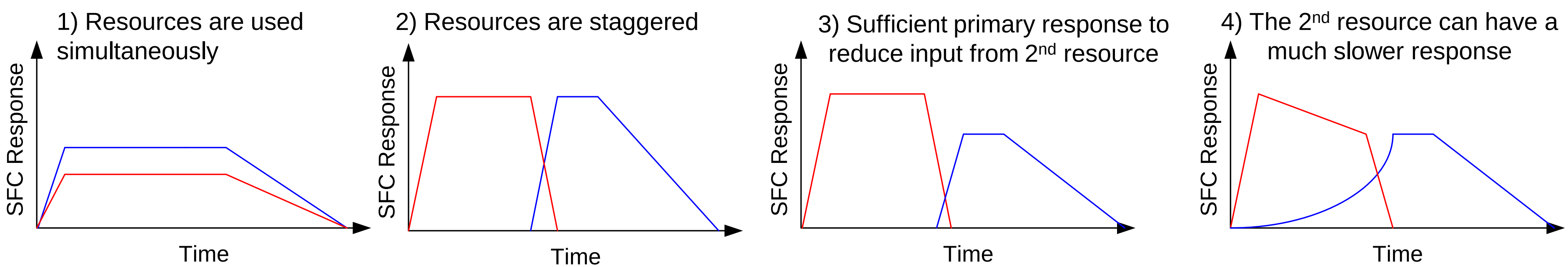
- **Offline** – Which resources are available to use?
  - Incurs Availability Payments
- **Online** - How do we use these resources?
  - Incurs Utilisation Payments
- Offline optimisation is intrinsically linked to the online
  - It ensures that the resources are available to allow the online optimisation to deliver a suitable response
  - How the online optimisation uses the resources will directly determine the resource required
  - Can't ignore utilisation payments for offline optimisation

The University of Manchester

Offline and Online Optimisation

- The approach of the online optimisation will drive the constraints and objectives of the offline optimisation

Consider a simple scenario with two resources (red and blue)



The market structure and pricing is of vital importance:

– What are the cost curves per MW for the resources?
– How much more expensive are faster services?
– Relative value of energy and power?
– Cost of primary response compared to slower SFC resources

The University of Manchester

Offline and Online Optimisation

- What is the worst case for the optimisation?
  - Conflict with angular stability may cause wider variation in this, particularly when optimising the fast resources
  - Disturbances at the edge of the system may require more dedicated resource
  - Regional Inertia may mean that resources in some areas become exclusively for one case
  - Size of disturbance may need to be balanced against location and angular stress (dispatch)

The University of Manchester

Offline and Online Optimisation

- Most cases aren't the worst case
  - How fast must the *fast* response be for these cases?
  - Will the online optimisation for these cases be harder?
  - How best to measure the severity of a frequency disturbance when optimising the response?
  - Will the online optimisation for these cases be harder?

MANCHESTER 1824
The University of Manchester

Wide Area Supervisory Control

- SFC uses local controllers that make independent decisions based on wide area data and merit order
- Coordinated supervisory control, would allow each resource to be directly controlled by a central controller
  – This should offer a more efficient response, as limitations will exist on local, online optimisation
  – But, communication requirements are more significant,

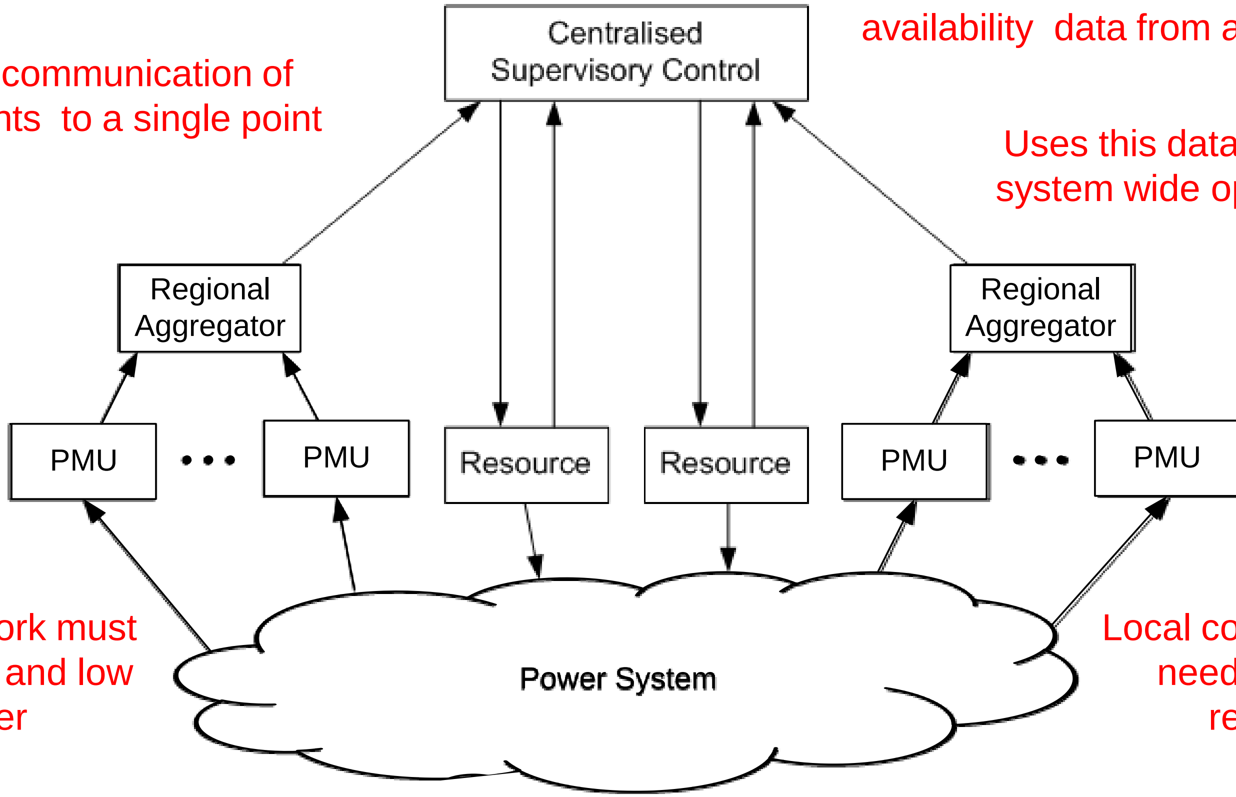
Wide Area Supervisory Control

- Simple example for a Two Region System

Centralised control receives availability data from all resources

Real Time communication of measurements to a single point

Uses this data to determine a system wide optimal response



Communication network must have high availability and low latency and jitter

Local control may still be needed to provide redundancy

Wide Area Supervisory Control

- Coordinated supervisory control, would allow each resource to be directly controlled by a central controller
  - This should offer a more efficient response, as limitations will exist on local, online optimisation
  - Resources could be used more optimally and the performance of the scheme would improve
  - But, communication requirements are more significant, so the scheme may become less reliable or more costly
- Does the benefit of this more complex control justify the increased cost and complexity?

The University of Manchester

Question and Answer 2 - Optimisation

Laboratory Testing and Optimisation of SFC at The University of Manchester

The University of Manchester

Progress

Laboratory Testing and Optimisation of SFC at The University of Manchester

The University of Manchester

Progress

- Defined scope of Laboratory Testing
- Defined requirements for integrating PowerFactory (Dynamic Simulations) and Matlab (SFC models)
- Built Two Area model in RSCAD
- Prototype of Runtime environment for Real-Time tests
- Connection of Hardware (PMUs) to the RTDS

MANCHESTER
1824
The University of Manchester

What's Next?

- Define specific testing plan and expected outcomes
- Implement Non-Real Time Testing
- Begin Non-Real Time Testing
- Connect control hardware to the RTDS
- Finalise laboratory setup for Real-Time Testing

The University of Manchester

EFCC Stakeholder Engagement

Laboratory Testing and Optimisation of SFC at The University of Manchester

Prof. Vladimir Terzija