«ОСОБЕННОСТИ ИСПОЛЬЗОВАНИЯ СИМУЛЯТОРОВ ЭНЕРГОСИСТЕМ RTDS И PSCAD ПРИ ВЫПОЛНЕНИИ НАУЧНЫХ ИССЛЕДОВАНИЙ В УЧЕБНОМ ПРОЦЕССЕ»

RTDS for Smart Monitoring and Control of Modern Electrical Power Systems

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Date: 15/12/2020

Presentation Outline

- The *Manchester RTDS* HiL facilities
- RTDS Testing of an Advanced Situational Awareness Tool
- RTDS for Wide Area Control - EFCC scheme
- Conclusions

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The Manchester RTDS HiL facilities

MANCHESTER 1824 The University of Manchester

Real Time Digital Simulator RTDS Simulation, Controls and Automation *SMARTLabs*

RTDS facilities enable rigorous real-time innovative development and interoperability testing of multifunctional power systems and controls automation infrastructures with intelligent electronic devices IEDs

General/Overview

- 6 x RTDS simulator racks
- integrated capacity of 30 x PB5 core processors
- 5 x Modular Multi-level Converters MMC support units
- GTWIF, GTNET, GTSYNC
- analogue and digital I/O GT-interface capability
- Global Bus Hub GBH for multiple simulation rack interface capability

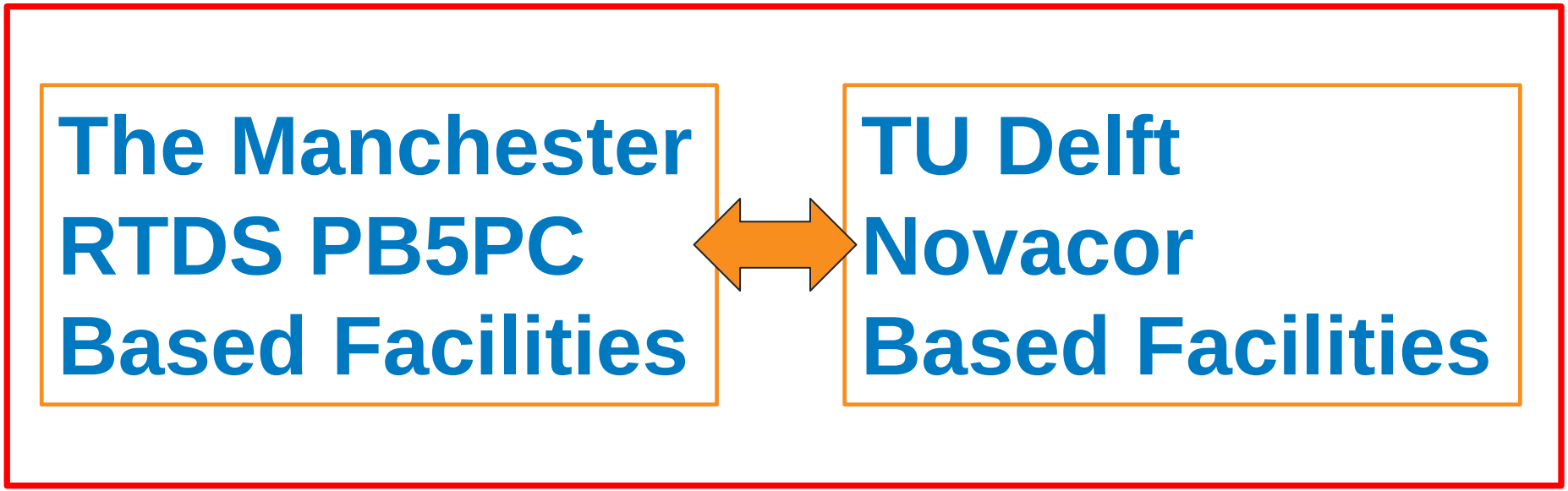
The Manchester RTDS HiL Facilities - Details

The Manchester RTDS HiL facilities offer a parallel processing ‘modular’ design with features like; Giga Transceiver Workstation Interface **GTWIF** for interconnecting parallel processing hardware to external computer workstation interface via **Ethernet LAN**, Giga Transceiver Network Communication Interface **GTNET** for protocol emulations of process and control bus automation using standards like IEC61850, DNP3, IEEEC37.118.1, External Time Synchronization Interface **GTSYNC** for external GPS timestep synchronization, a high precision flexible and expandable analogue and digital I/O GT-interface capability; **GTAI/GTAO/GTDI/GTDO** capability with 12 channel isolated 16-bit analogue and 64 channel isolated digital input/output interface; interconnectivity with PB5 processors, Global Bus Hub **GBH** for multiple simulation rack interface capability under common synchronization timestep for simulations, Inter-Rack Communication Switch **IRC** for direct digital data communication between multiple simulation racks, a fibre enhanced backplane for timestep simulations upto ~ 1.4 – 2.5 µs and a total of ≤ 90 nodes per PB5 processor computing power each operational at ~ 1.7 GHz for enhanced power network simulation capacity. Facilities offer **6 x RTDS simulator racks** with integrated capacity of **30 x PB5 core processors** and **5 x Modular Multi-level Converters MMC** support units.

A fully flexible and integrated closed-loop HIL facility for dynamic performance testing and prototyping for power and energy transmission and distribution systems of the future.

The Manchester RTDS HiL facilities - Mission

The UoM and TU Delft



Proved joint efforts: MIGRATE project
https://www.h2020-migrate.eu/

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RTDS Testing of an Advanced Situational Awareness Tool

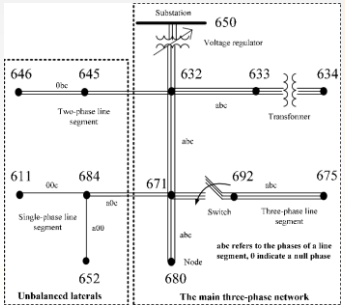
Overview

1

DSSE
-Three phase
-Unbalced
-PMUs

2

IEEE 13 bus test system

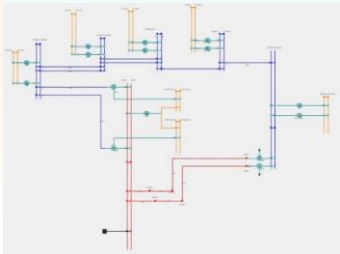


3

Algorithms for disturbance detection, algorithms for defence from cyber attacks

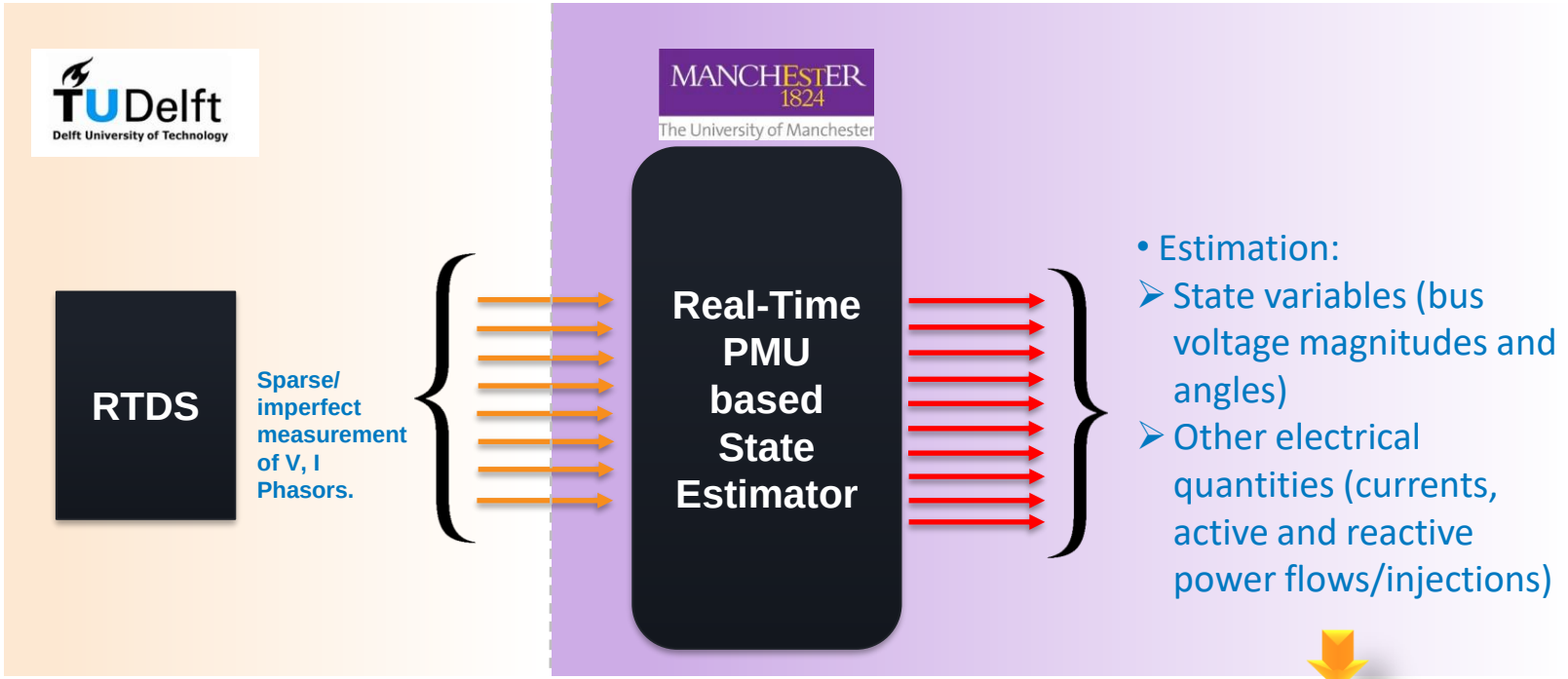
4

Implementation to real DN: 50 kV Enduris network, Netherland

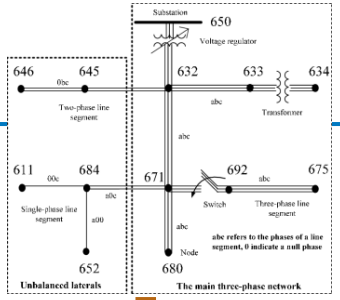


RTDS Testing of an Advanced Situational Awareness Tool

Functional Block-Diagram



RSCAD
App



PMU Firmware

x 8

openPDC
GRID PROTECTION ALLIANCE

PDC

Streams 8 PMU data packets into a single bundle

MATLAB

RTDS Patch
&
Distribution Estimation Tool

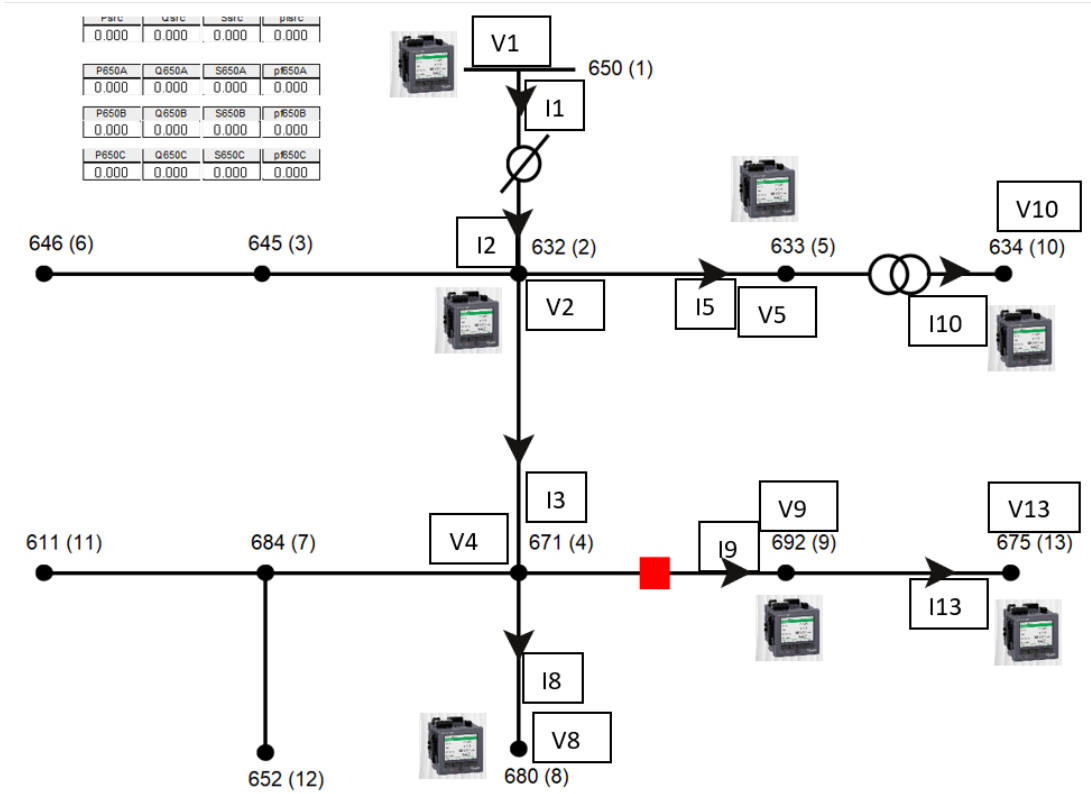
RTDS Testing of an Advanced Situational Awareness Tool

Test Network and Scenarios

IEEE 13 bus grid with installed PMU's

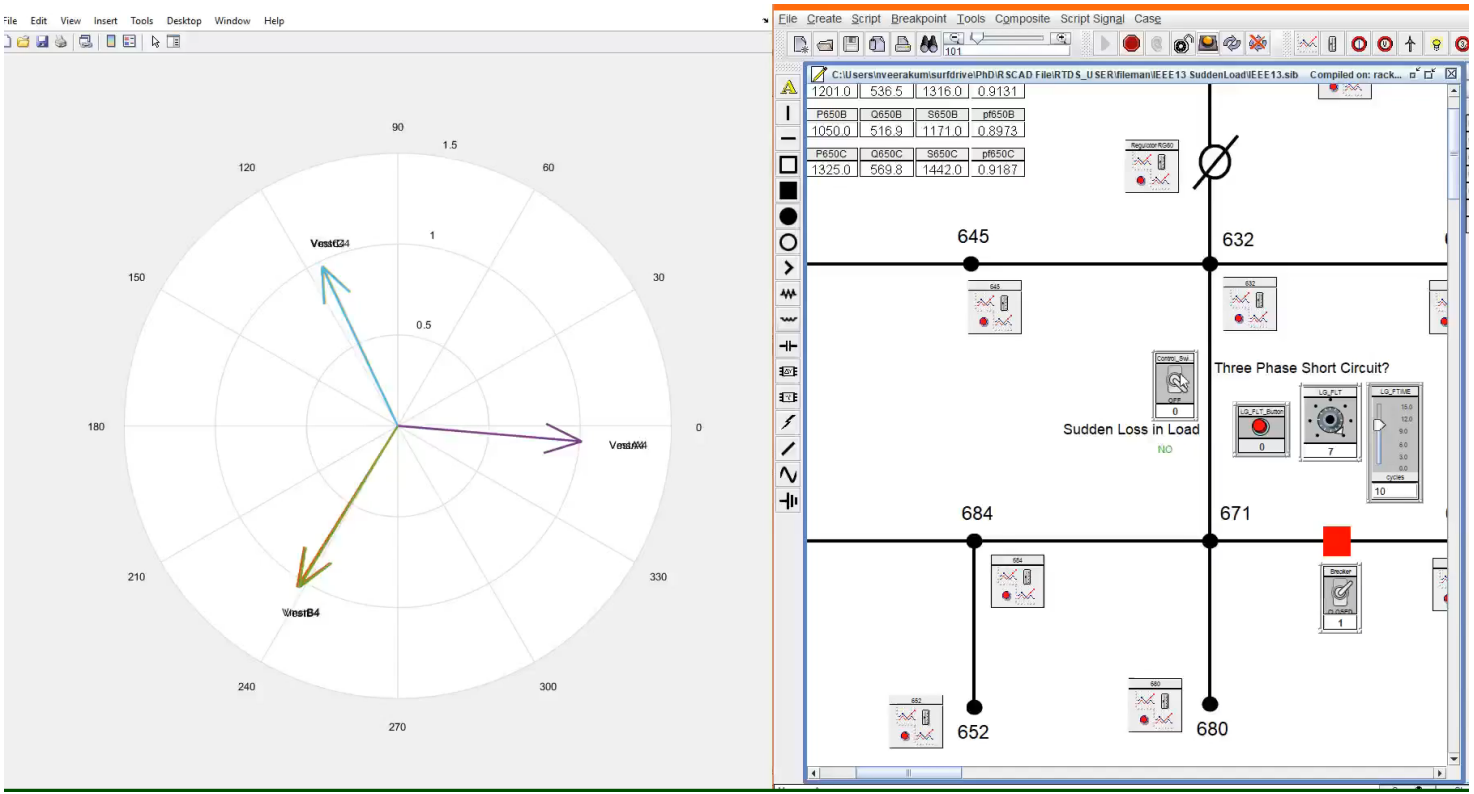
Test scenarios:

- **Steady-state**
- **Sudden load change at node 671**
- **Short-circuit on line 632-671**



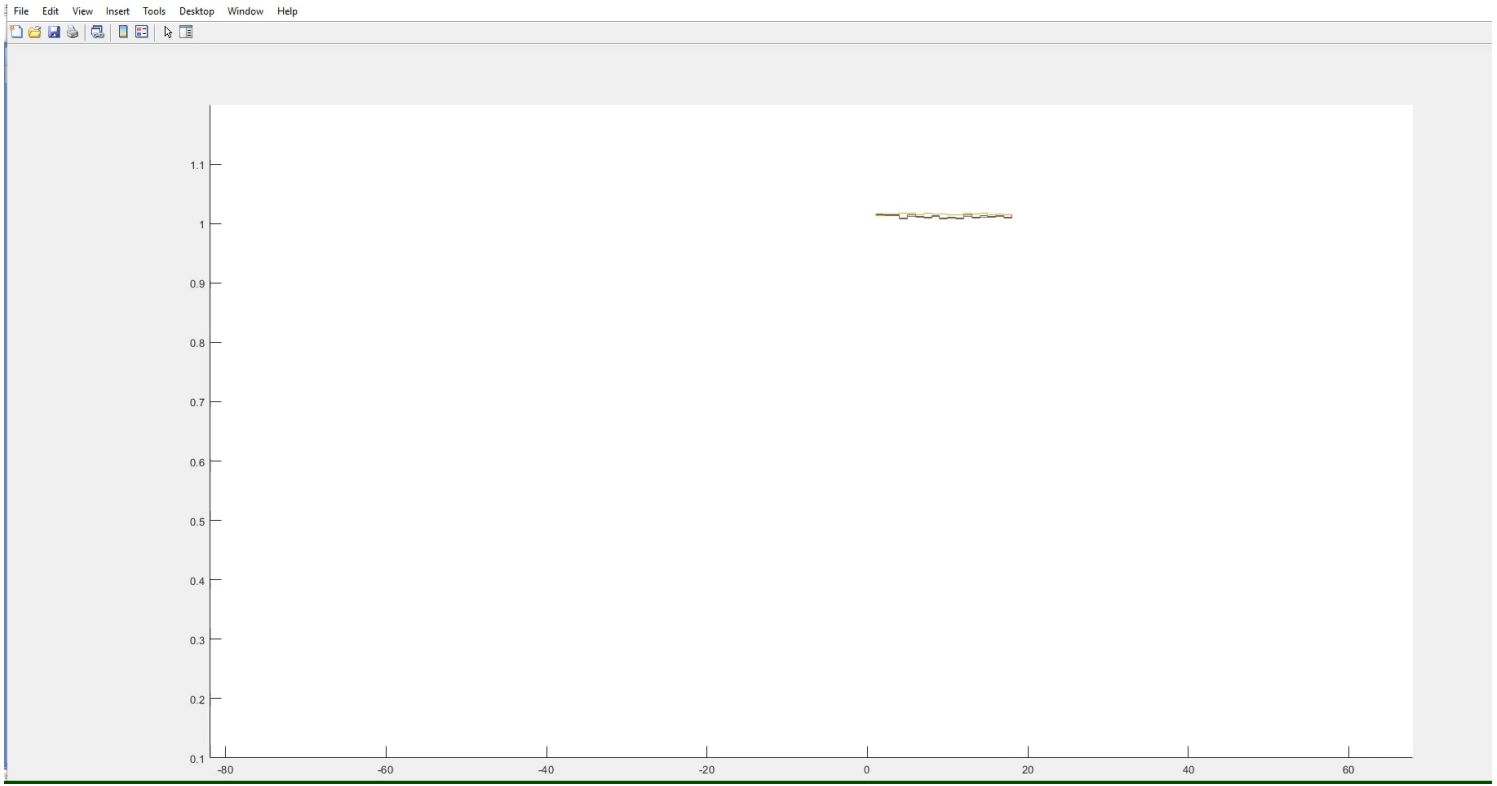
Visualization – voltage phasors

Node 671 phase A phase B phase C
estimated
measured



Visualization – voltage magnitudes in time domain

Node 671 - phase A - PMU
Node 671 - phase A - estimated
Node 646 - phase B - estimated



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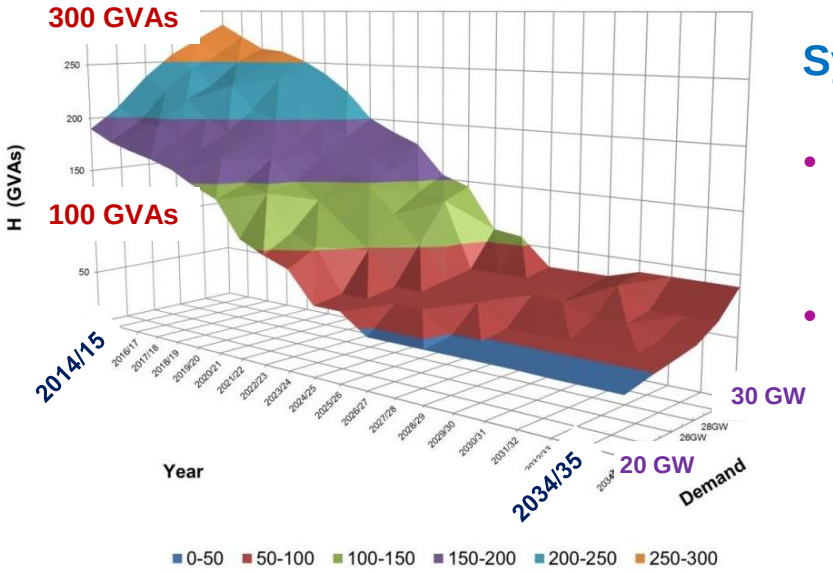
Challenges with increasing penetration of renewables - UK



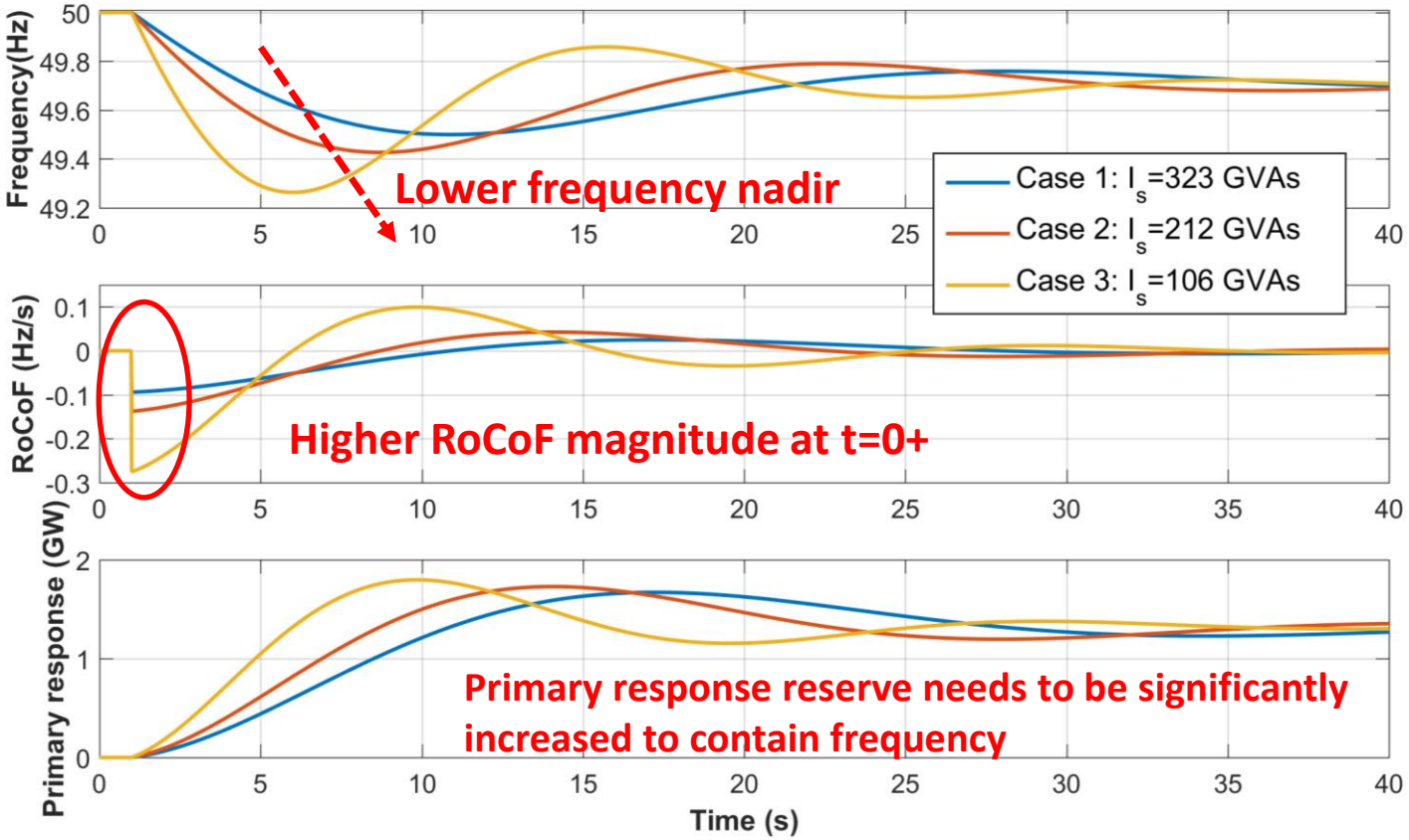
System inertia is decreasing

- Higher RoCoF after power imbalance events -> more sensitive to disturbances
- Larger volume of response reserve (under Gone Green, potential additional cost of ~£200m)

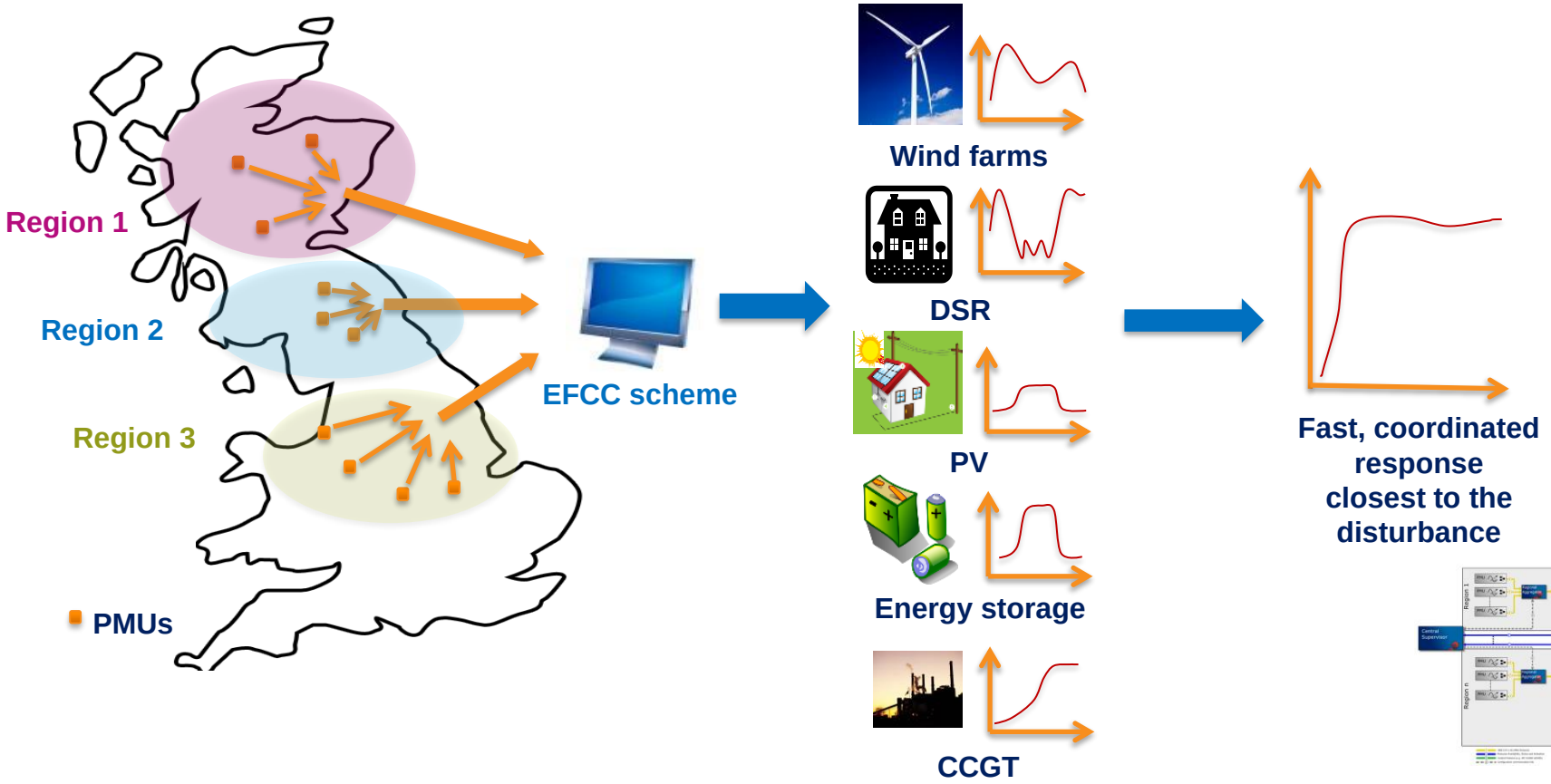
System Inertia Changes for Gone Green Scenario

http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/System-Operability-Framework/

Impact of reduced inertia on frequency control - loss of 1.32 GW generation



Overview of the EFCC scheme



Active power imbalance estimation

V.V. Terzija, "Adaptive Underfrequency Load Shedding Based on the Magnitude of the Disturbance Estimation", IEEE Transactions on Power Systems, Vol. 21, No. 3, August 2006, Page(s): 1260- 1266

$$\frac{2H_i}{f_n}\frac{df_i}{dt} = p_{mi} - p_{ei} = \Delta p_i$$

Swing equation for a single generator

$$\Delta p = \sum_{i=1}^{N} \Delta p_i = \frac{2\sum_{i=1}^{N} H_i}{f_n}\frac{df_c}{dt} = \xi \frac{df_c}{dt}$$

Active power imbalance

$$f_c = \sum_{i=1}^{N} H_i f_i \Big/ \sum_{i=1}^{N} H_i$$

$$\xi = \frac{2}{f_n}\sum_{i=1}^{N} H_i$$

Hardware in the Loop tests of EFCC

The Manchester RTDS (30 PB5 Processor Cards)

EFCC controllers

Admin PC to control simulation runs and visualise the results

RTDS to perform flexible HiL tests

Communication Infrastructure

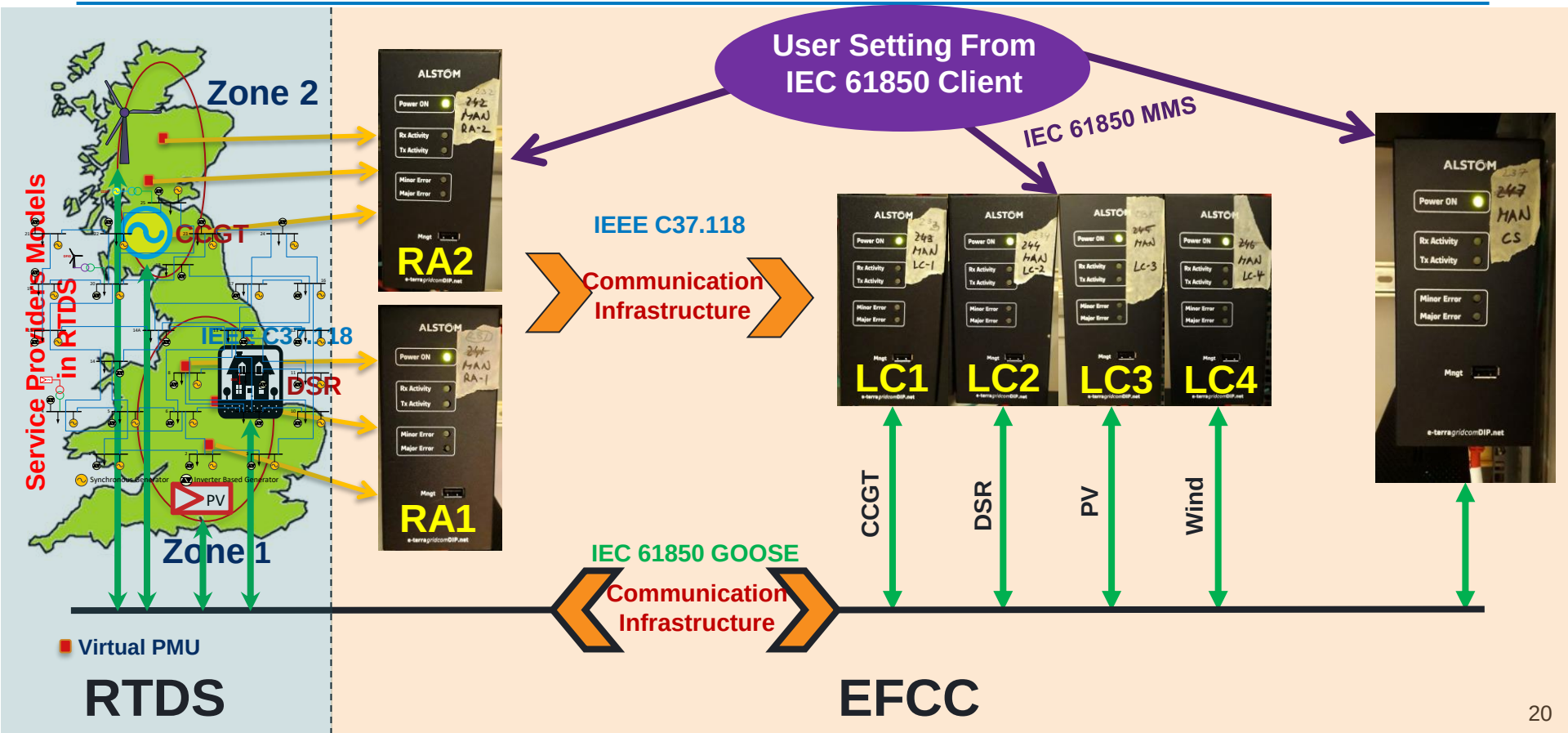
Evaluating **EFCC** hardware components:

a) Regional Aggregators (x2)

b) Local Controllers (x4)

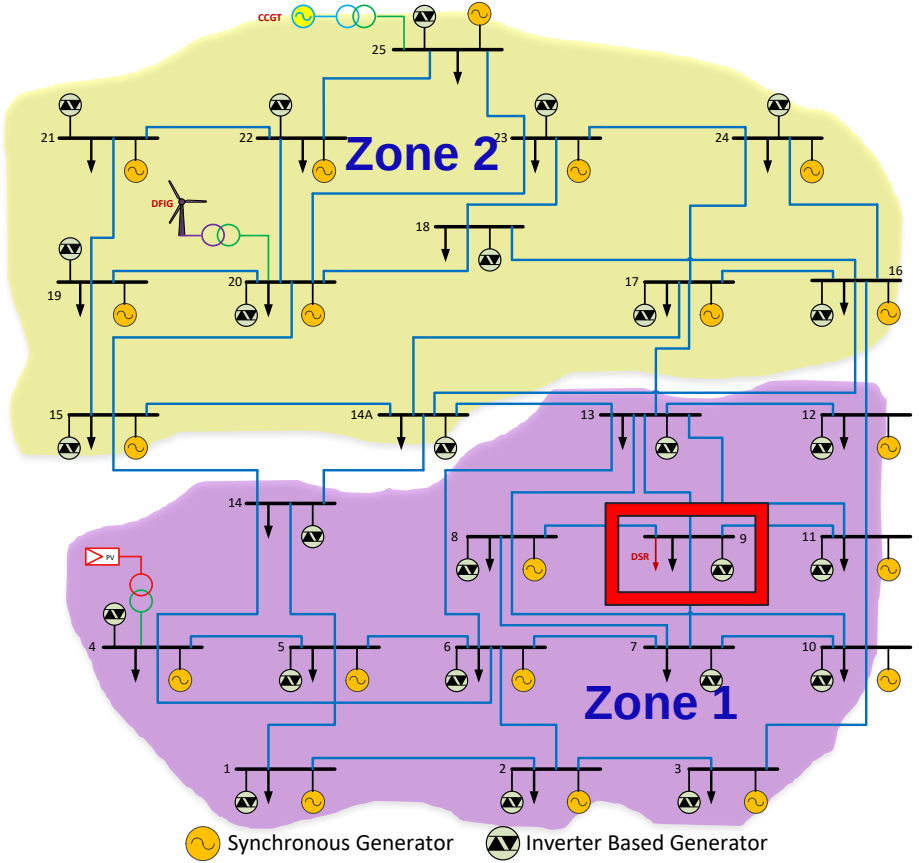
c) Central Supervisor (x1)

EFCC Hardware Connected to the RTDS GB Model



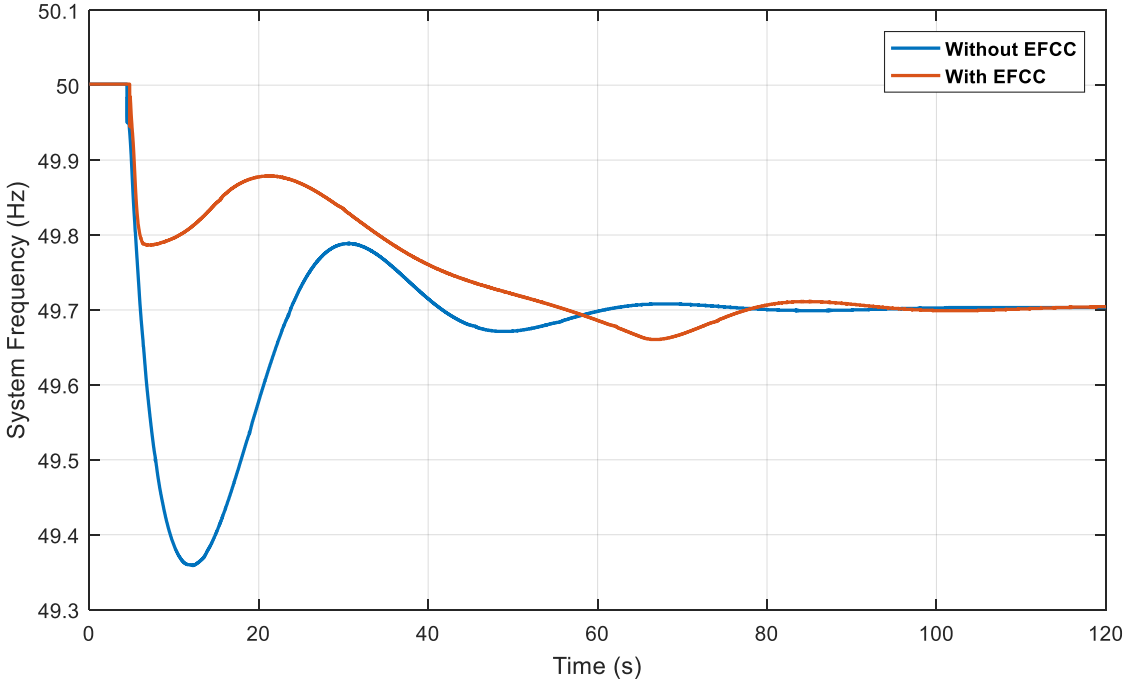
RTDS HiL validation of EFCC

- **Demand: 42 GW**
- **Inertia: 82 GVA.s**
- **Event: Sudden load connection**
- **Size: 1000 MW**
- **Location: Bus 9**
- **Available Power in zone 1: 1500 MW**



Service Provider	Available Power (MW)
DSR	200
PV	1300
CCGT	200
Wind	300

RTDS HiL validation of EFCC



EFCC delivers a faster and more effective frequency response (Lowest frequency is improved from 49.37Hz to 49.66Hz).

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- Significant challenges in changes of system dynamics require new solutions based on wide area measurements
- Validation of new solutions is possible using HiL testing, only
- RTDS – based testing of situational awareness platforms opens avenues for improving proposed solutions
- RTDS – based HiL testing of wide area control schemes makes us confident to move to practical applications (EFCC example)
- Understanding of physical processes, as well as new technology (e.g. sensors, or ICT) is a prerequisite for successful testing and application of novel Smart Grid solutions

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ОАО «НТЦ ФСК ЕЭС»
tecon
КГЭУ
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