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VALIDATING DECENTRALISED FREQUENCY CONTROL REGIMES: A DISTRIBUTED HARDWARE IN THE LOOP APPROACH

Introduction

- An increasing level of complexity is associated with power system operation, with increased levels of distributed generation contributing to this.
- Reduced levels of system inertia are emerging as synchronous plant closes in the GB grid.
- Novel control schemes can increasingly be validated using proven systems testing HIL infrastructure like the University of Strathclyde's Dynamic Power System Lab (DPSL) and Power Network Demonstration Centre (PNDC).
- The scalability of increasingly decentralized schemes places new demands on infrastructures, causing increased interest in distributed experimentation.

GB Frequency Problem

- Increasing number of distributed resources and large synchronous plant closing leads to the following:

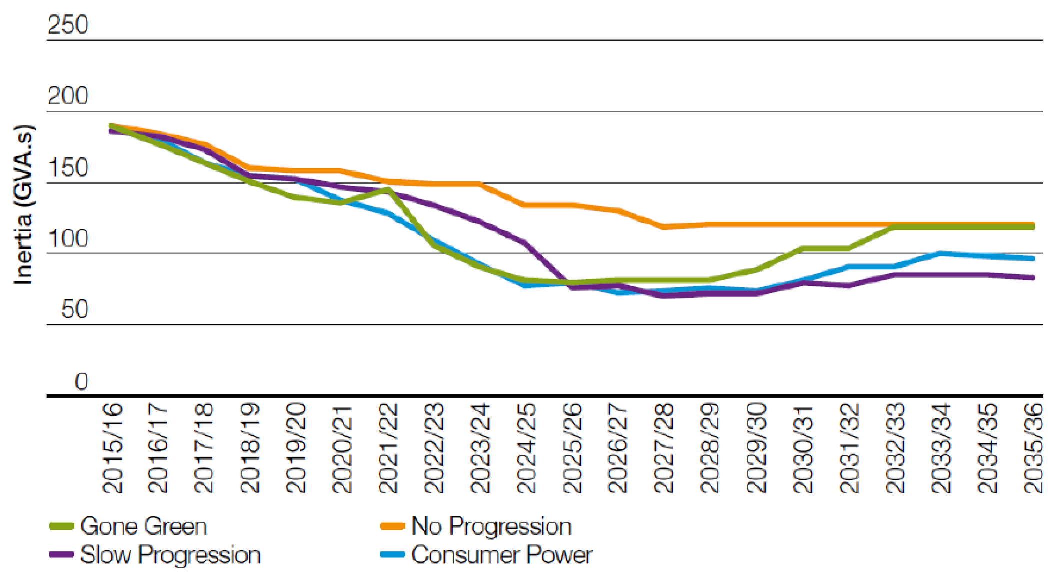

Fig. 1 Minimum System Inertia (Source: SOF 2015)

→increased RoCoF
→Frequency/voltage instability
→Controller interaction
→Sub-synchronous oscillations and interaction with conventional machines
→Increased sensitivity

Novel Frequency Controllers

- Web-of-Cells (WoC) and Enhanced Frequency Control Capability (EFCC) projects – two novel solutions to GB frequency problem
- WoC distributed and decentralised control paradigms within each cell enables more effective and scalable frequency regulation
- A "responsibilizing" frequency control approach enables cells to address frequency events locally, with resources in the cell → has been demonstrated at the DPSL with hardware in the loop (HIL)
- Transient phase offset (TPO) droop based method shown to provide improved regulation when compared to existing droop

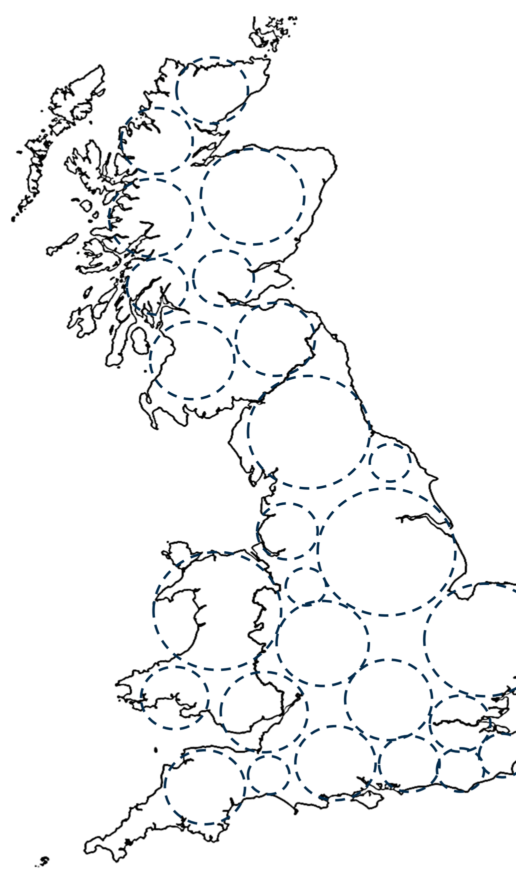

Fig.2 WoC representation of the GB grid

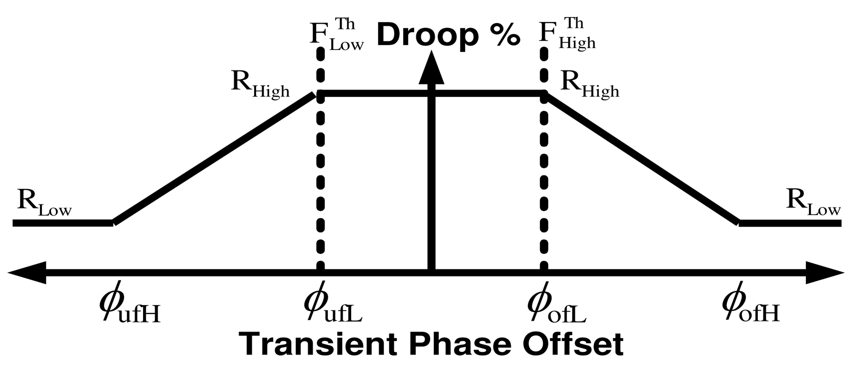

Fig. 3 TPO based droop

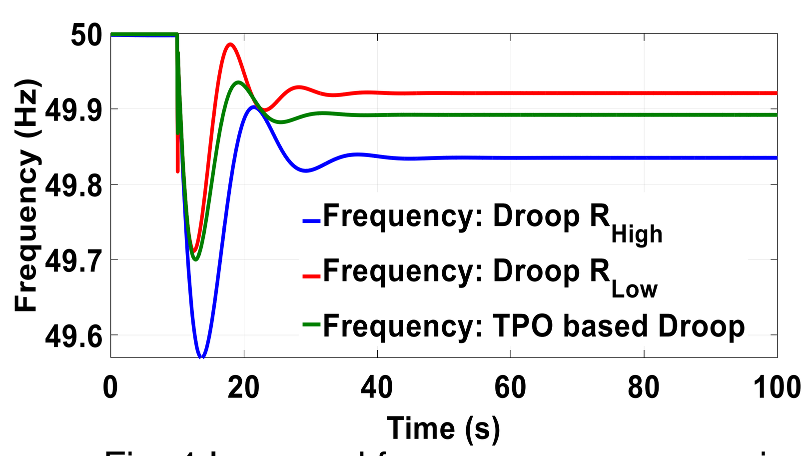

Fig. 4 Improved frequency response using decentralised TPO method

- EFCC: RoCoF triggered, regional, 100% active power < 1 second (target 500 ms).
- Real time digital simulation (RTDS) GB network model coupled with 11 kV network at PNDC

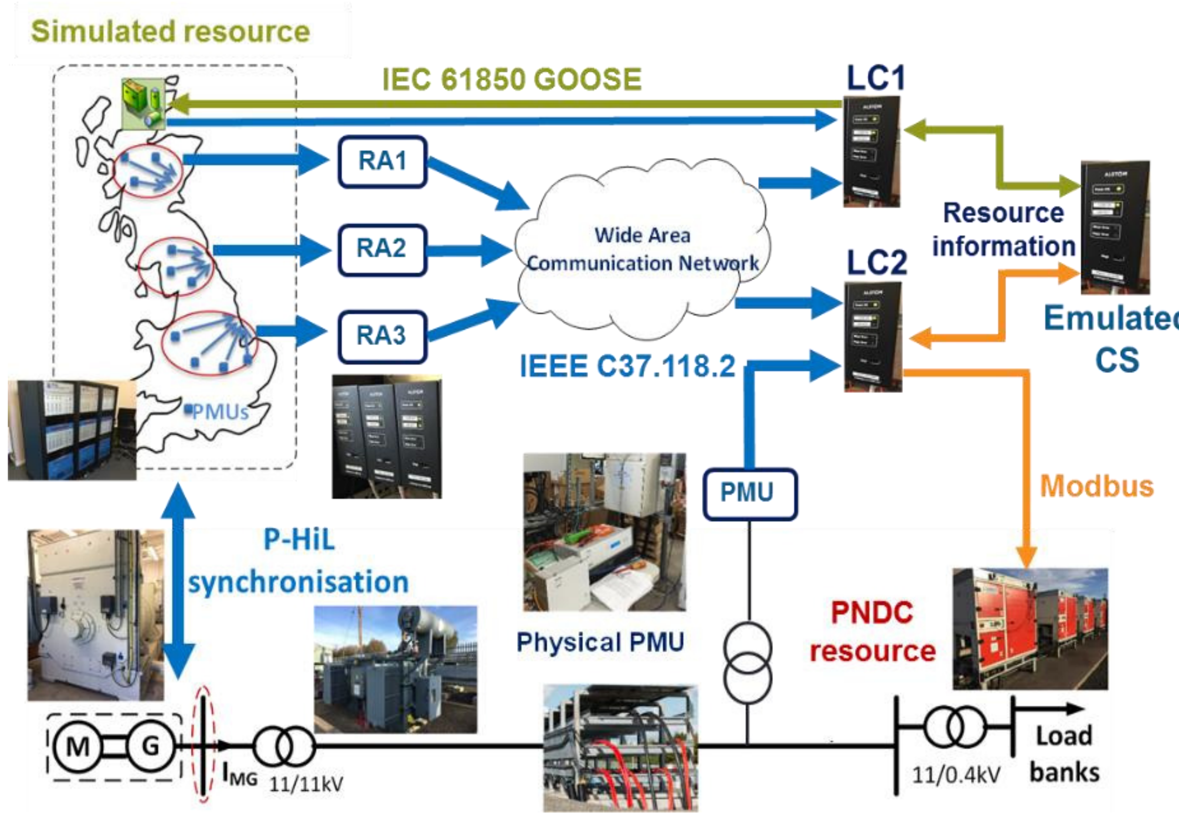

Fig. 5 EFCC set up

Overview of Distributed HIL Approach

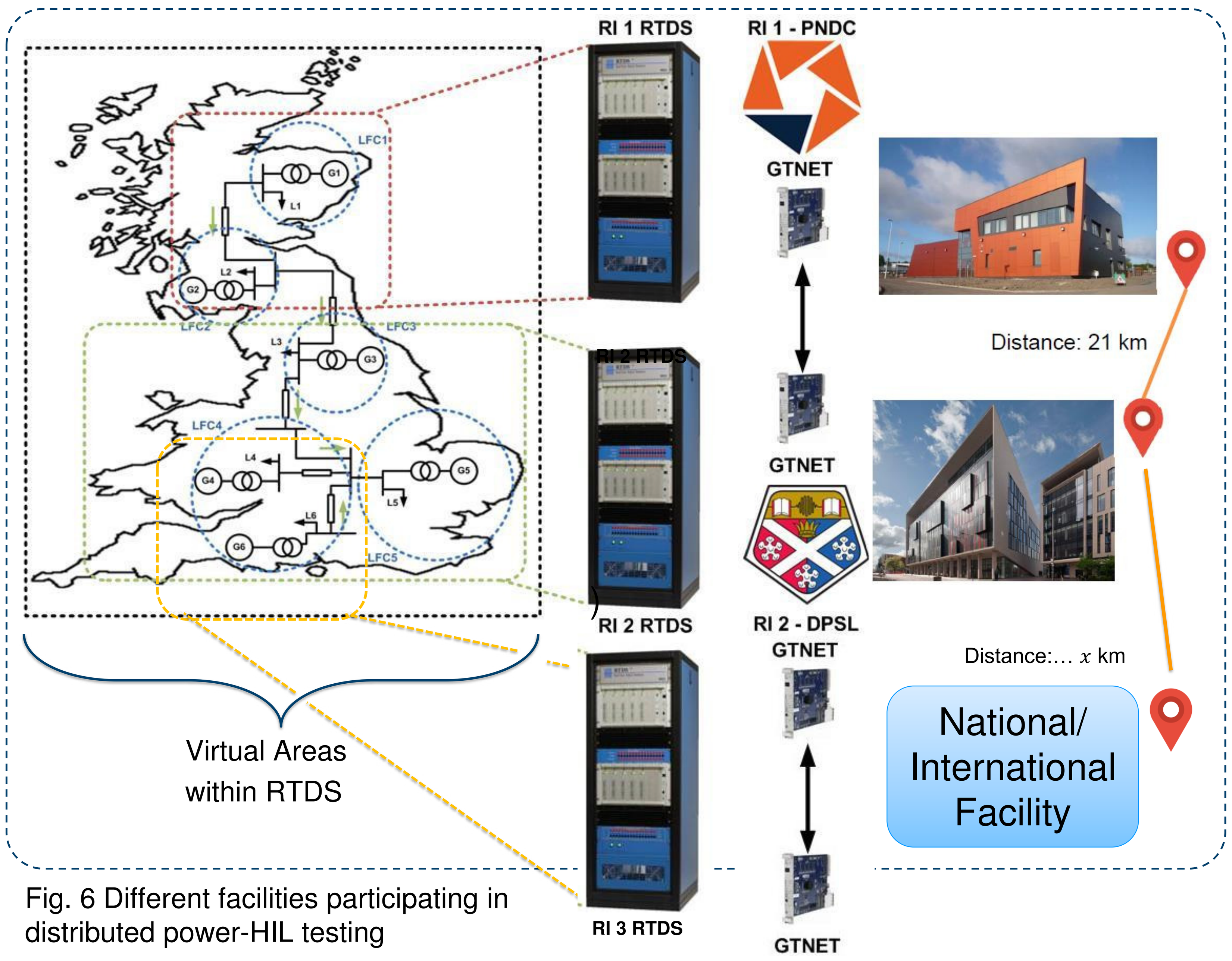

Fig. 6 Different facilities participating in distributed power-HIL testing

- Using multiple platforms enables more computing power per virtual system area, as seen in **Fig. 6**
- Monolithic testing involves one platform (e.g. Using RTDS/model)
- Distributed testing involves more than one platform → can be within one facility or between multiple facilities.
- HIL delays within each platform: inherent in measurement, computing, and communications.
- Communication delays between each platform/facility
- Challenges with variable inherent delays + inter-facility delays.

Power-HIL (P-HIL) Time Delay Challenges, Solutions, and Distributed Real-Time HIL Results

- Contrary to widely deployed fixed determnistic delay, P-HIL delay is variable.
- This delay needs to be accurately characterised to enable accurate compensation – otherwise instability occurs.
- Proposed technique developed offers improved accuracy and achieves stability
- Consequently, the advanced time delay compensation facilitates more accurate system-level studies e.g. Increased fidelity GB network studies.
- Benefits of utilising distributed HIL within the context of frequency response shown in Fig. 10. with effects of inter-platform delays shown

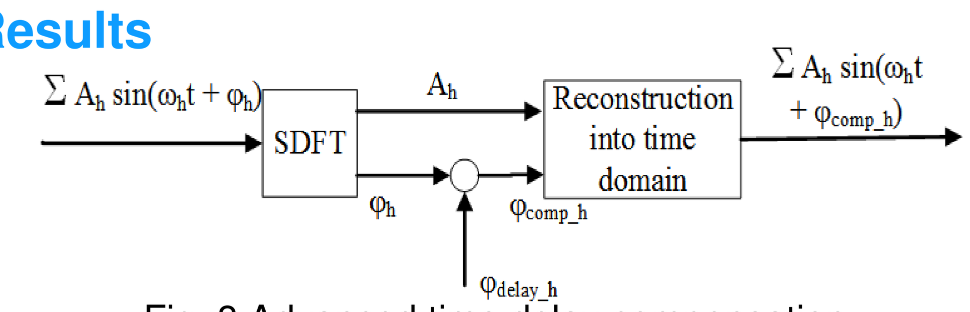

Fig. 8 Advanced time delay compensation

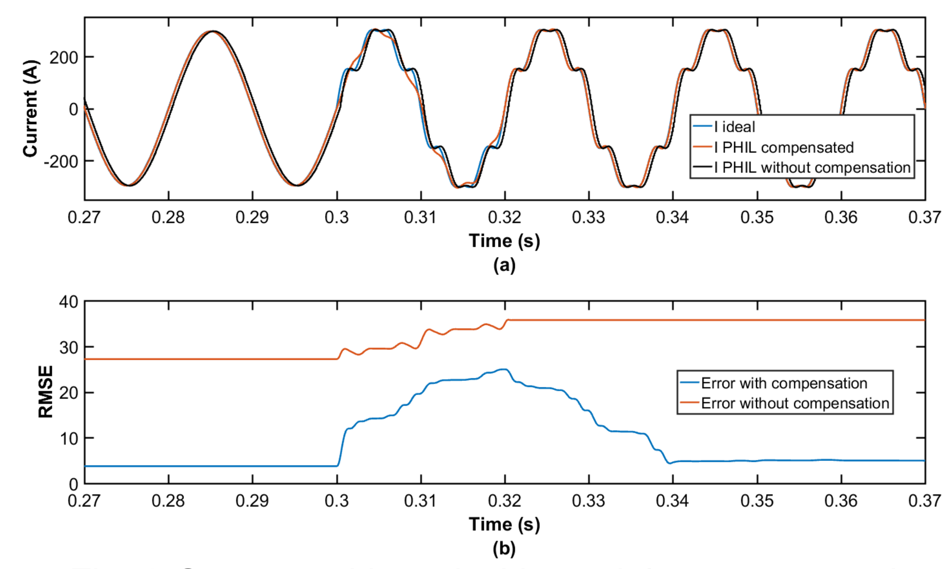

Fig. 9 Current: with and without delay compensation

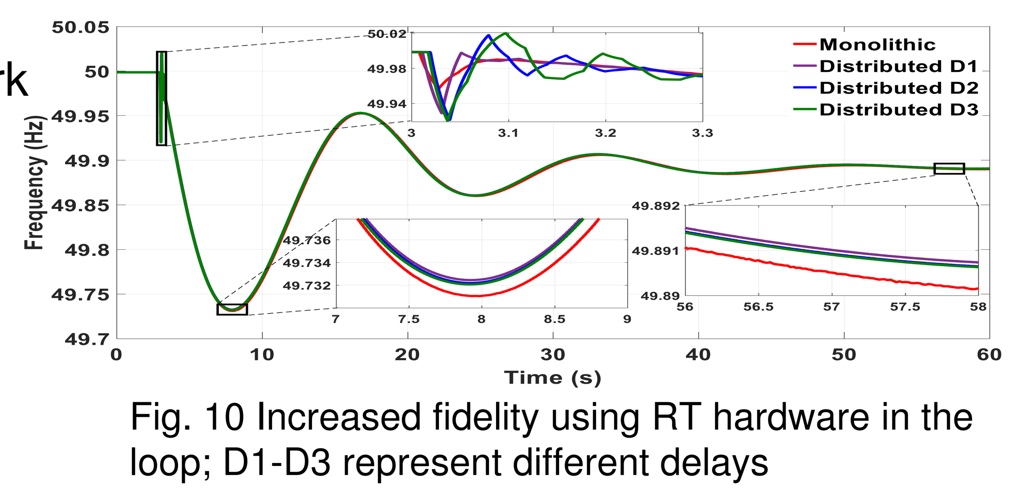

Fig. 10 Increased fidelity using RT hardware in the loop; D1-D3 represent different delays

Conclusions

- Novel frequency control regimes have been tested and evaluated to good effect on RT HIL infrastructures.
- Distributed HIL schemes enable utilization of multiple facilities simultaneously for increased computing power: the developed platform successfully deals with P-HIL delay issues
- The platform offers improved fidelity by combining computing power at multiple facilities.
- Complexity and increasingly decentralized nature of power system problems being tackled within HIL environment is also increasing: combined computing resource extremely useful in addressing these problems
- Future work will investigate and further understand outstanding issues whilst using the multi-platform distributed RT simulation environment, to validate novel controllers as part of the ERIGRID project

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