INSTITUTE FOR ENERGY AND ENVIRONMENT

University of Strathclyde Engineering

Co-Simulation Experiences in Real Time Power Systems Laboratory

M. H. Syed, A. Emhemed and G. Burt

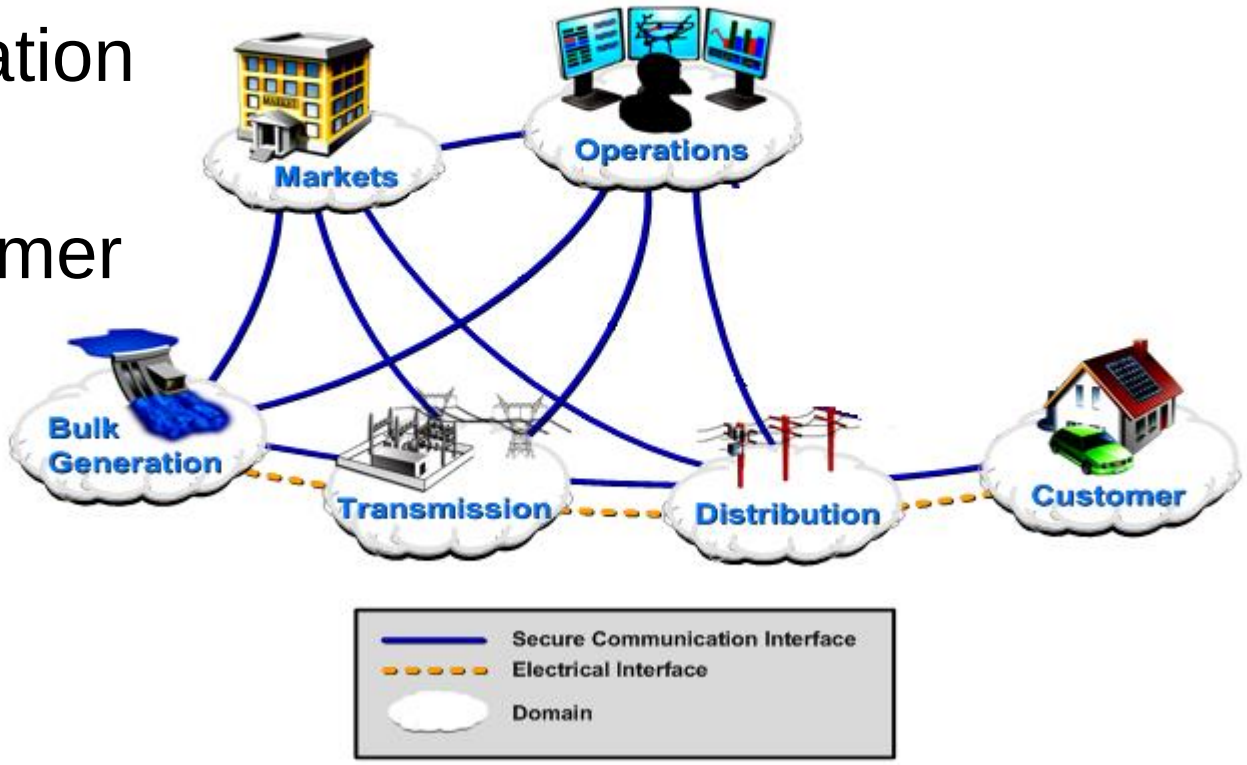
Institute for Energy and Environment

University of Strathclyde

Glasgow, Scotland

Progression of Power System

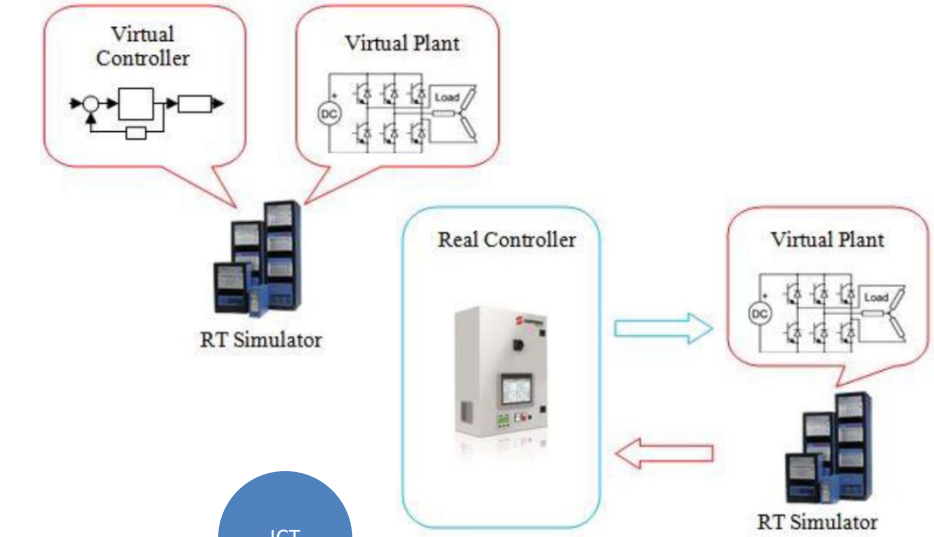
- Passive customer
  - Consumer
- DER Penetration at LV
- Active Customer
  - Prosumer
- Services

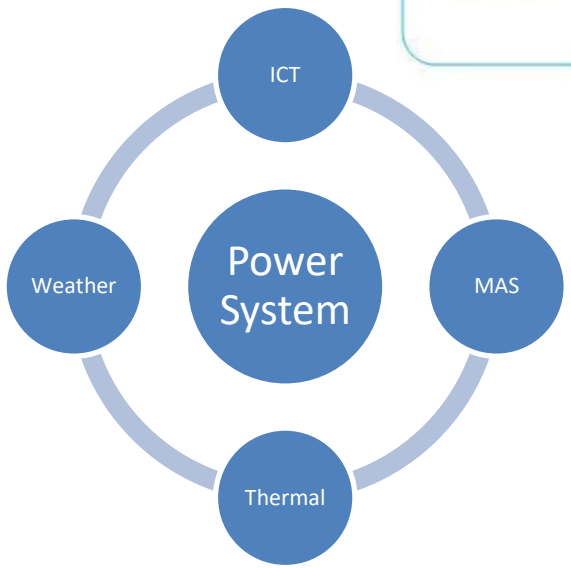


Source of figures: NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1

Challenges of Progression

- New technologies need to be de-risked before deployment at large scale
- New domains need to be included in simulation
- More detailed modelling required to capture and characterize the interactions
- Increased computational complexity

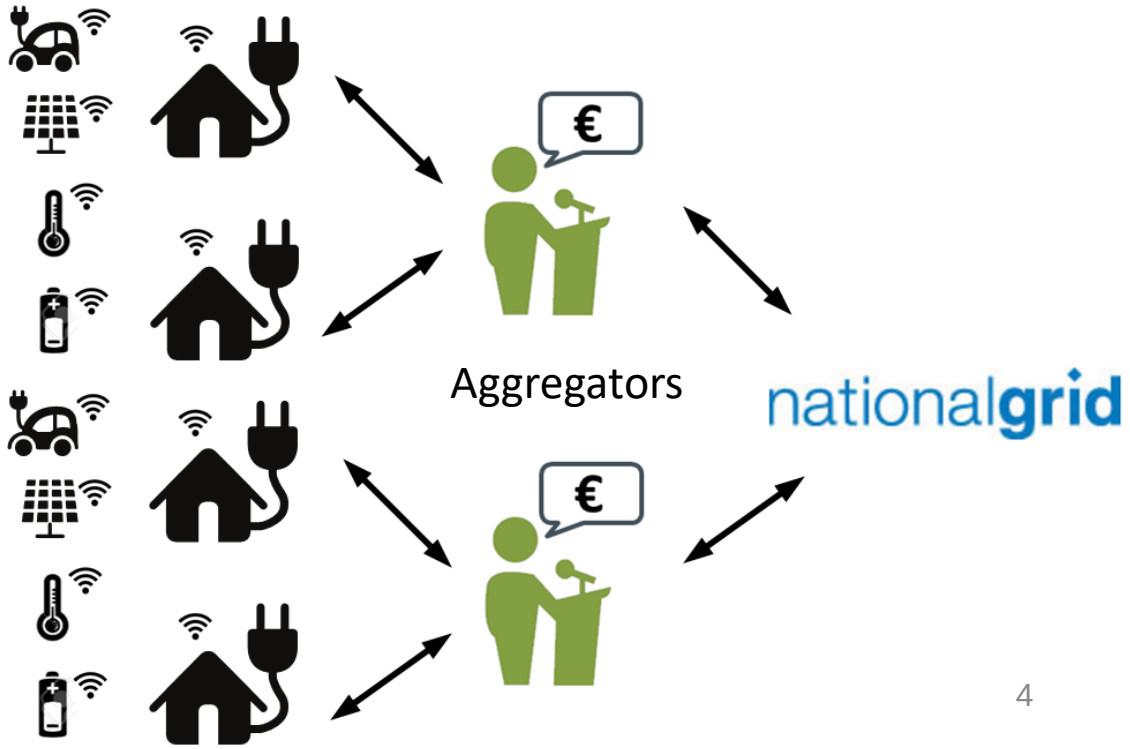




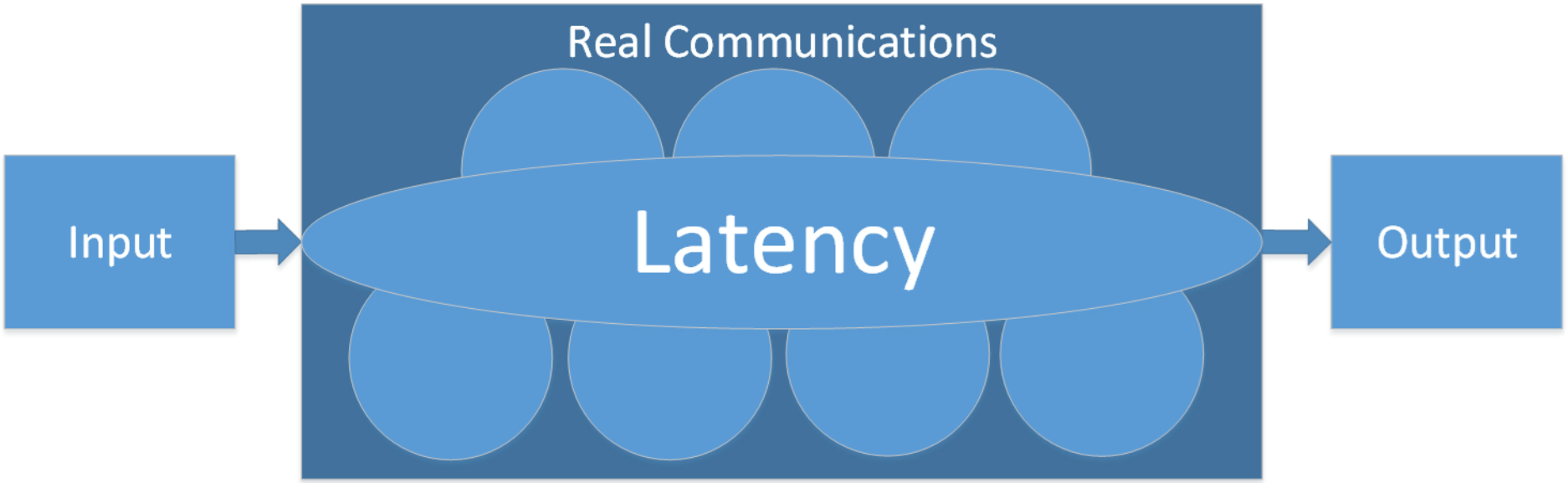
Ancillary Service Provision by Demand Side Management

- Increasing interest in ancillary service provision by DSM
- 22 demand aggregators within the UK

- Transactive Energy
- More distributed and smaller devices
- Increased access to new markets
- Response from devices within 1 second being explored

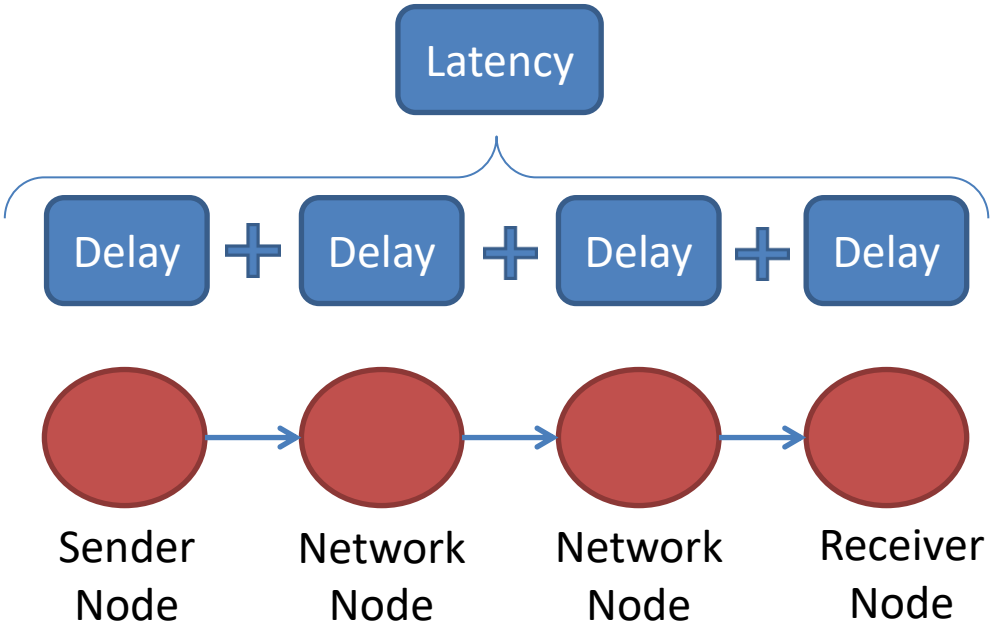


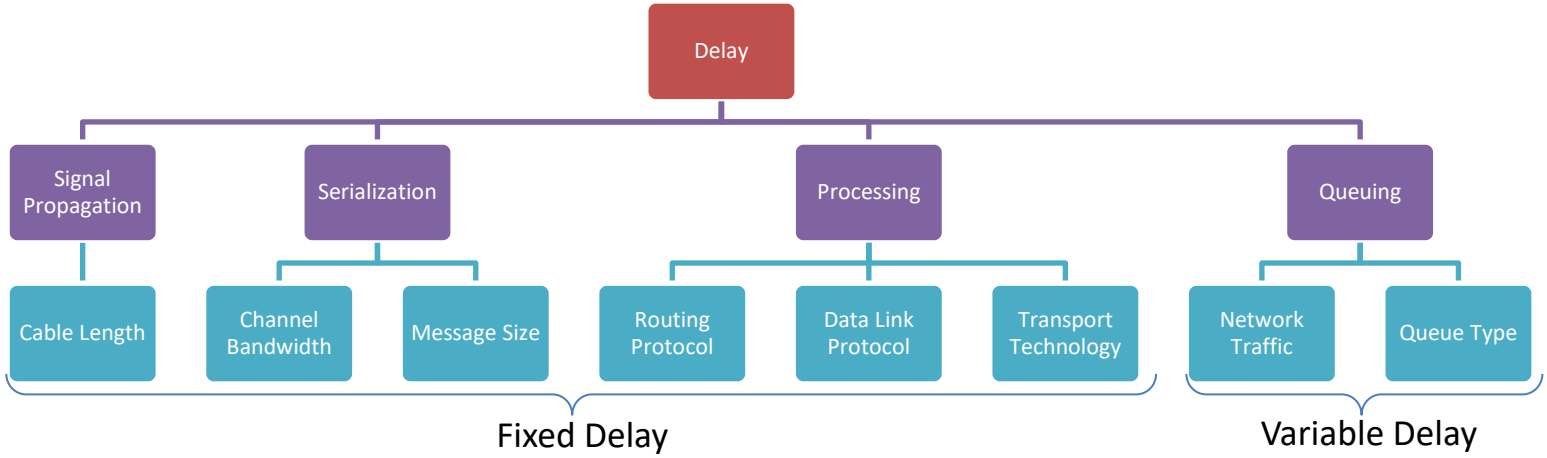
Communications



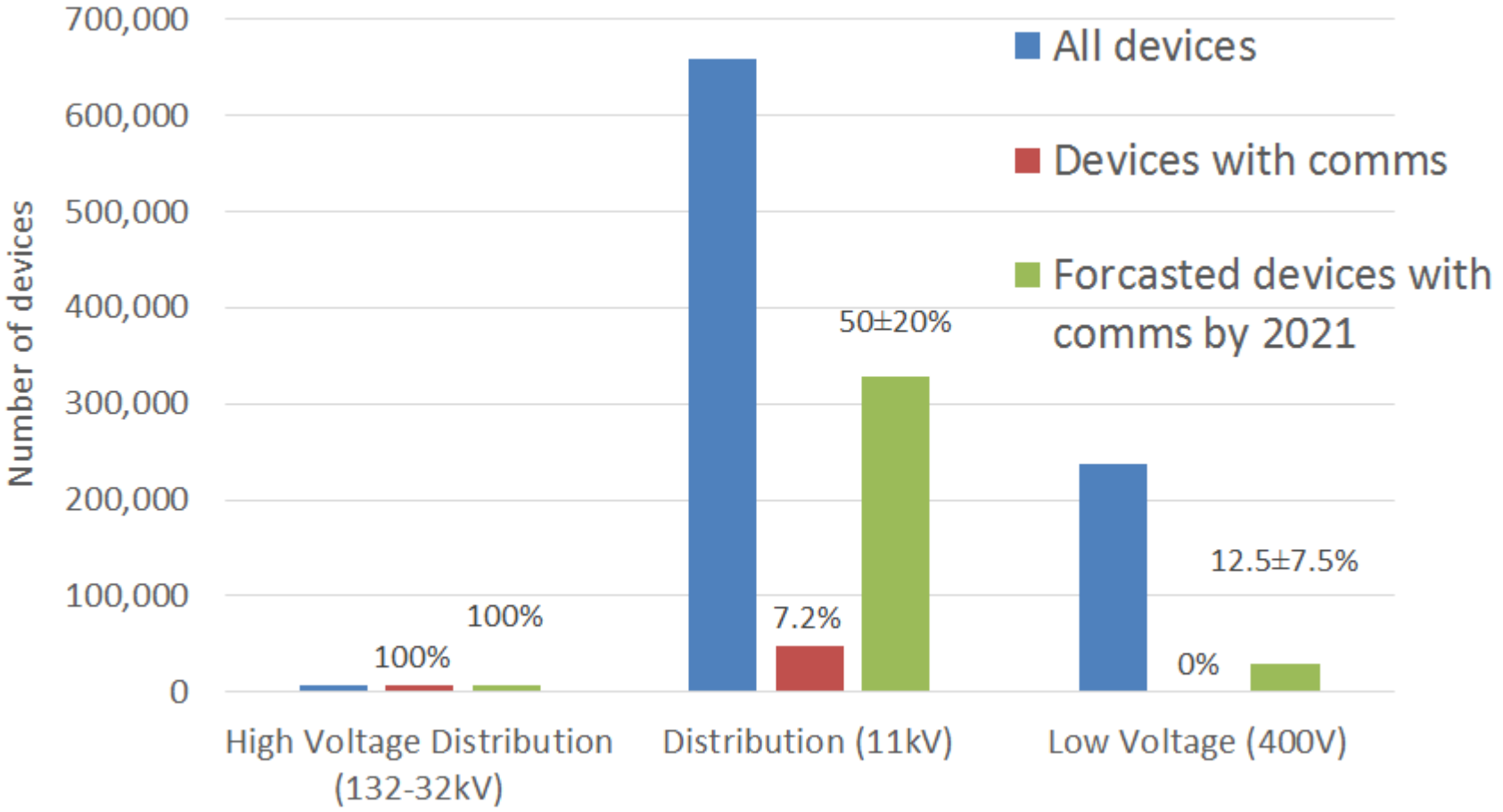
- It was satisfactory to model the COMMS as a set delay within Power System simulations.

Latency and Sources of Delay



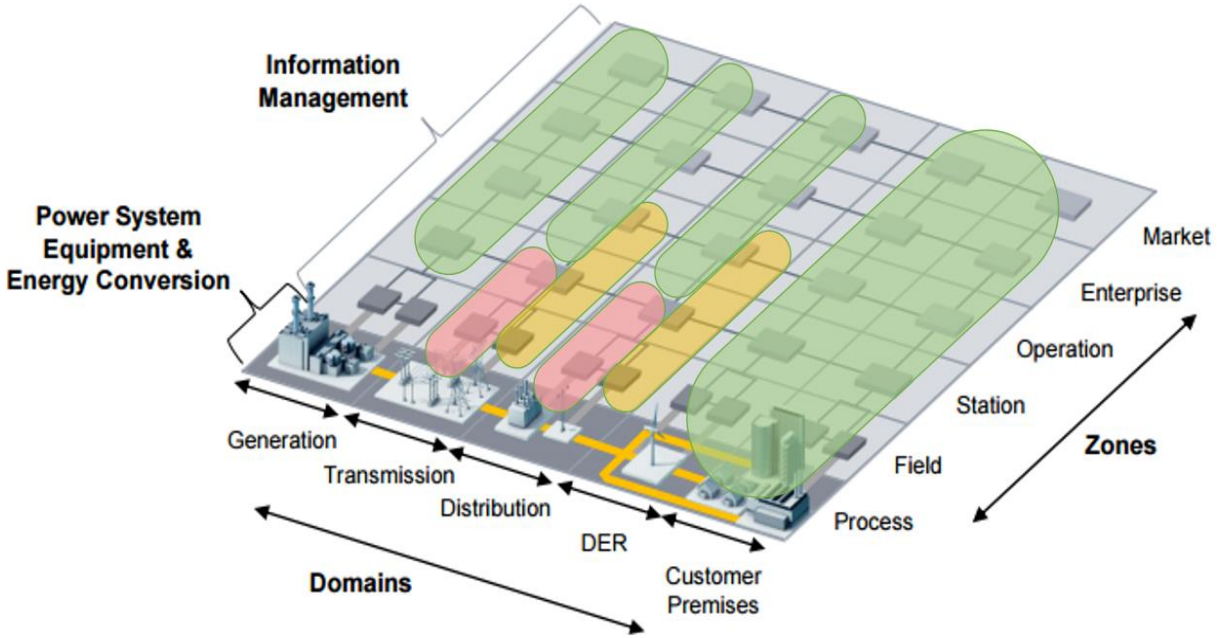


Communications capable assets in the UK Power Grid



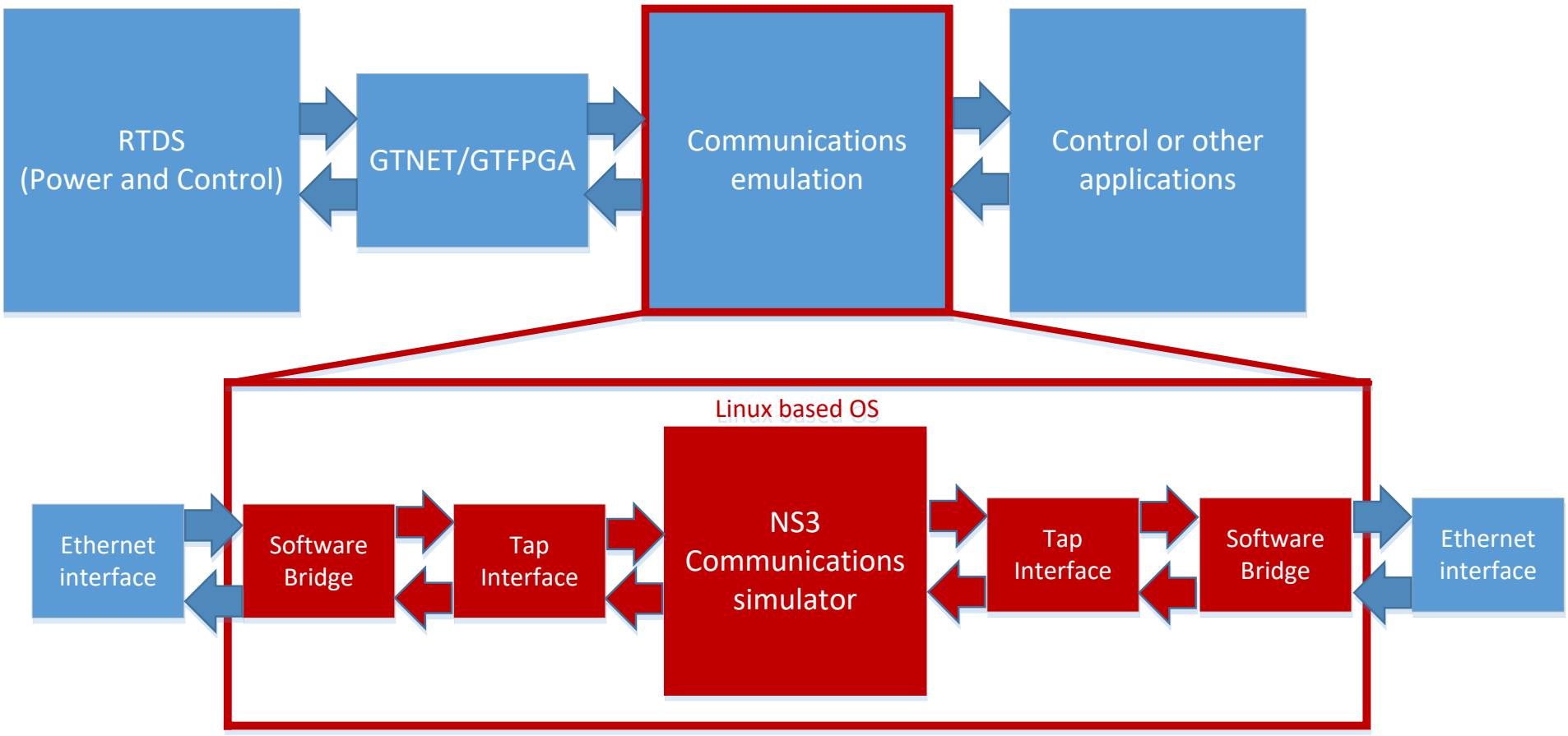
A. Hulme, V. Sennes, "DNO - SMART GRID COMMUNICATIONS REQUIREMENTS", Energy Networks Association, 20th Dec 2011. [Online] Available: http://www.energynetworks.org/assets/files/electricity/engineering/telecoms/eitc/restricted/Reference%20Doc/Telent.pdf

Applications and Requirements Map



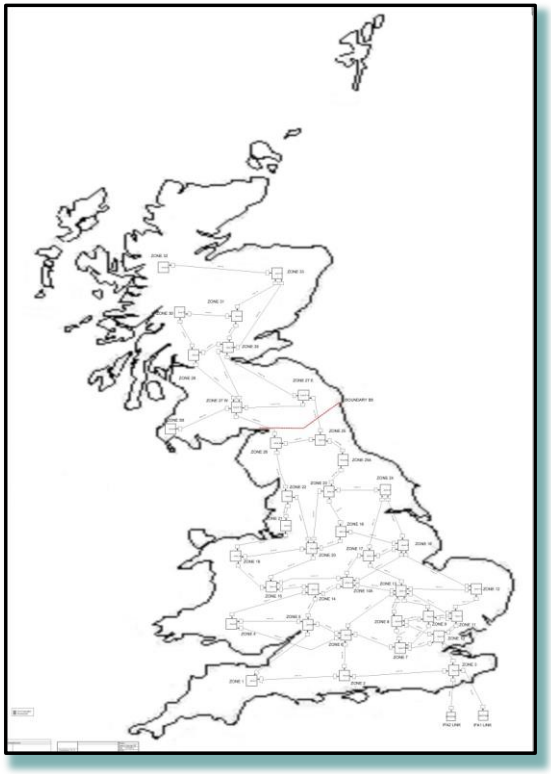
	Latency \ Domain	Generation	Transmission	Distribution	Distributed energy resources	Customer Premises
LAN	6ms		**Protection**			
LAN	30ms			**Protection**		
LAN/ WAN	100ms		**Real-time sensing and actuating**			
LAN/ WAN	100ms		**Substation automation**			
LAN/ WAN	100ms		**Transmission automation**			
WAN	100ms	**Active Generation management**		**Distribution automation**	**Demand side management**	
WAN	1s	**Active Generation management**	**Active network management**	**Distribution automation**	**Demand side management**	
WAN	10s	**Active Generation management**	**Active network management**		**Demand side management**	
WAN	1min+	**Non-real-time measurements for diagnostics, telemetry, asset management**				

Real-Time Co-Simulation



Impact of High Converter Penetration

- Potential tipping points (penetration of converters beyond which the system could become unstable) have been found and investigated.
  - DIgSILENT PowerFactory (RMS simulation) show a high frequency instability with high converter penetration, with tipping point at 60-70% [1].
  - Similar results with an aggregated power system model in Matlab SimPowerSystem (EMT simulation) [2].



[1] H. Urdal, R. Ierna, Z. Jiebei, C. Ivanov, A. Dahresobh, and D. Rostom, "System strength considerations in a converter dominated power system," *IET Journal on Renewable Power Generation,* vol. 9, pp. 10-17, 2015.
[2] M. Yu, A. J. Roscoe, A. Dysko, C. D. Booth, R. Ierna, J. Zhu*, et al.*, "Instantaneous Penetration Level Limits of Non-Synchronous Generation in the British Power System," *IET Journal on Renewable Power Generation,* 2016.

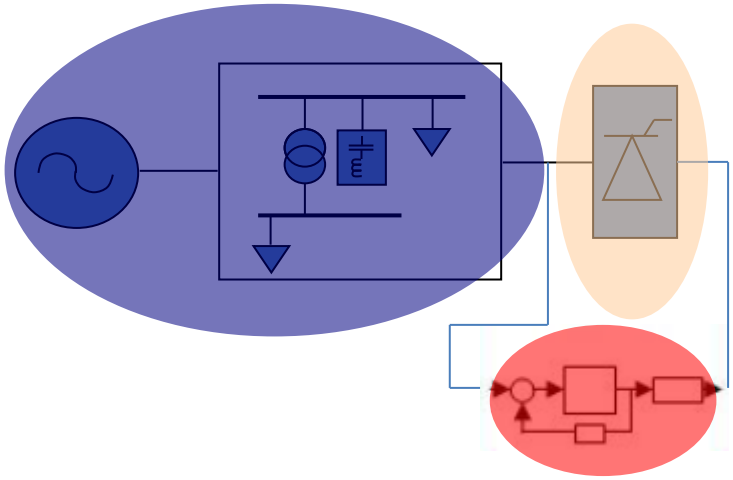
Computational Complexity

Problem:

- In a multi-domain model evaluated at a single rate, the slower time step sub-models are forced to run at the rate of the fastest time step system – over computation.

Solution:

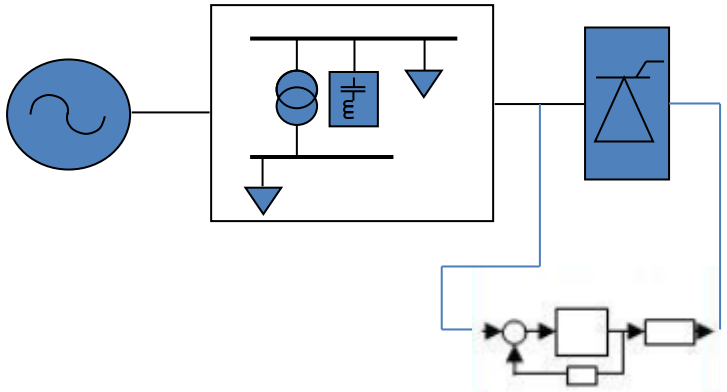
- Model abstraction
- Multi-rate simulation



Power Electronic Switching	5µs
Electrical distribution	50µs
Controller	500µs

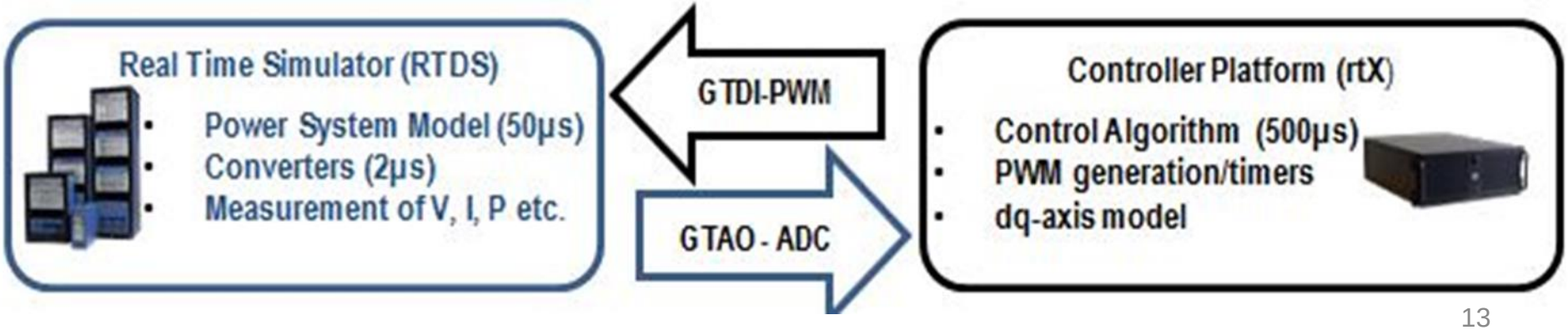
Real Time Multi-rate Co-Simulation

- Impact of high penetration of Convertors within the UK Power Grid (DQCI, SEBIR, VSM and VSM0H)



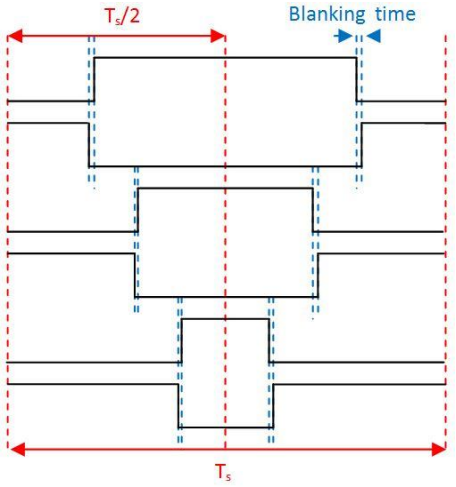
The small time-step, high fidelity representation of the converter devices and the large time-step model of the grid

Controller prototyping, including the converter switching strategy

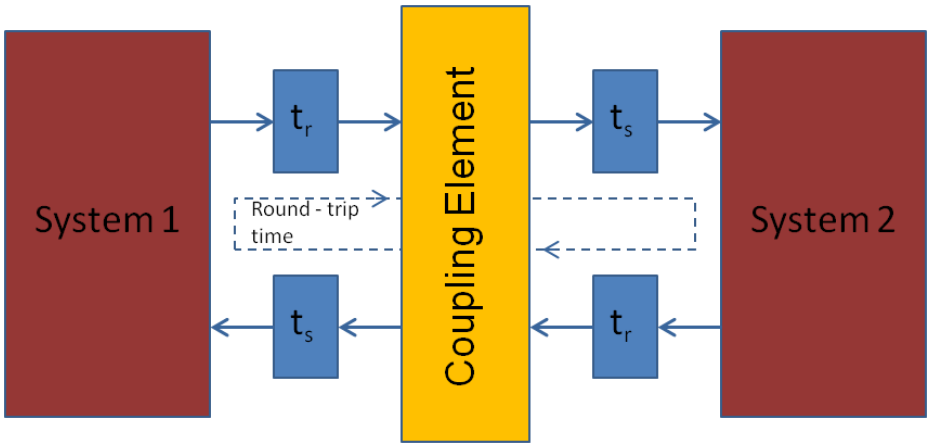


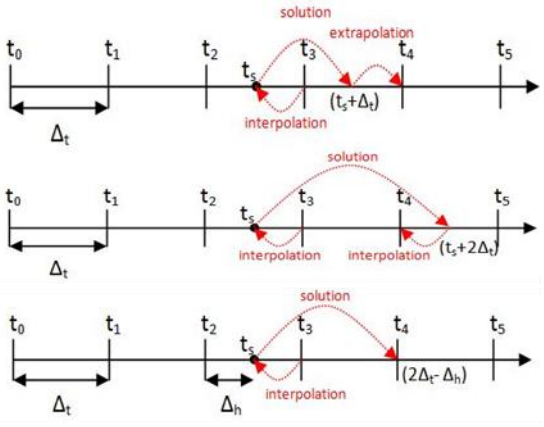
Challenges: Real Time Multi-rate Co-Simulation

- Blanking Time and Pulse Synchronization
- Interpolation and Extrapolation
- Synchronization



"System Black Start"

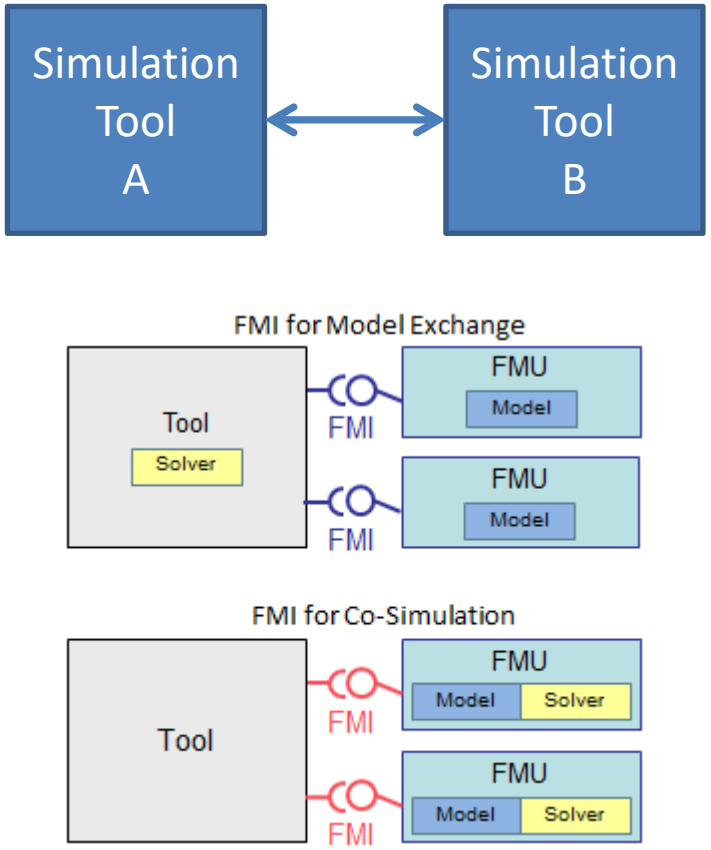




Interpolation & Extrapolation Algorithms

Facilitating Co-Simulation

- Co-simulation interface
- Functional Mock-up Interface (FMI)
- FMI for CS and ME
- Use being explored in Power Systems
- A positive step forward



Source of figure:
https://www.modelica.org/publications/newsletters/2014-3

Summary

University of Strathclyde Engineering

- Power System is faced with the challenge of rapid progression
  - New domains
  - Validation/De-risking difficult than before
  - Increased computational complexity
- Co-Simulation becoming an integral part of validation
  - New domain interactions captured in more detail (realistic)
  - Facilitates sharing of computational complexity
- Introduces further challenges
  - Can be dealt with
- FMI a positive step forward

University of
Strathclyde
Glasgow

International Researcher Exchange: ELECTRA REX

University of Strathclyde Engineering

Global exchange	•Global organisation •to/from •ELECTRA partner
European exchange	•European organisation •to/from •ELECTRA partner
Intra-ELECTRA exchange	•ELECTRA partner •to/from •ELECTRA partner

EERA electra

European Liaison on Electricity Committed Towards long-term Research Activity Integrated Research Programme

ELECTRA REX

A Researcher Exchange Programme for Smart Grids

Fifth Call for Applications for industry and research organisations including Global & European partners

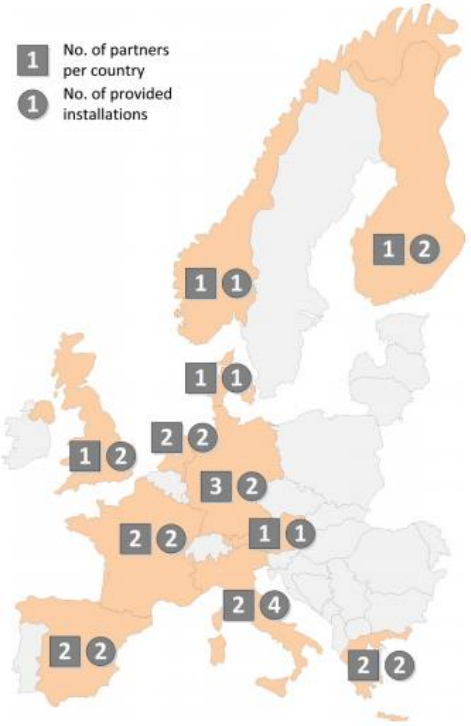
- 20 potential hosts within the consortium
- Exchange durations 2 – 12 weeks
- Fifth call open to EU and Global organizations

For more details go to www.electrairp.eu mobility tab

Transnational Access: ERIGrid

University of Strathclyde Engineering

- Access to 21 first-class Smart Grid labs
- Next call will be opened in March 2017
- Call every 6 months, until December 2019



- Chance to conduct your own experiments free of charge
- Reimbursements of your expenses
- Access to concentrated know-how and best practices in the field of smart grids.

European Commission
Joint Research Centre