Simulation and Control of Energy Storage in Low Voltage Networks

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Introduction

- Why install energy storage in low voltage networks?
- Customer Led Network Revolution – LV Storage Trial Results
- Energy Storage and Real-Time Thermal Ratings
- Vehicle-to-Grid electric vehicles as energy storage
- Frequency Response from LV networks
- Conclusion

Why Install Energy Storage in LV Networks?

- Power flow congestion management:
  - Accommodate additional demand and Low Carbon Technologies
  - Manage congestion upstream on the HV and EHV networks
- Voltage Control:
  - Accommodate additional demand by preventing voltage sag
  - Prevent voltage rise in systems with high solar PV penetrations
- Balancing Service Markets:
  - Frequency response can be offered through aggregation

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CUSTOMER LED NETWORK REVOLUTION – TRIAL RESULTS

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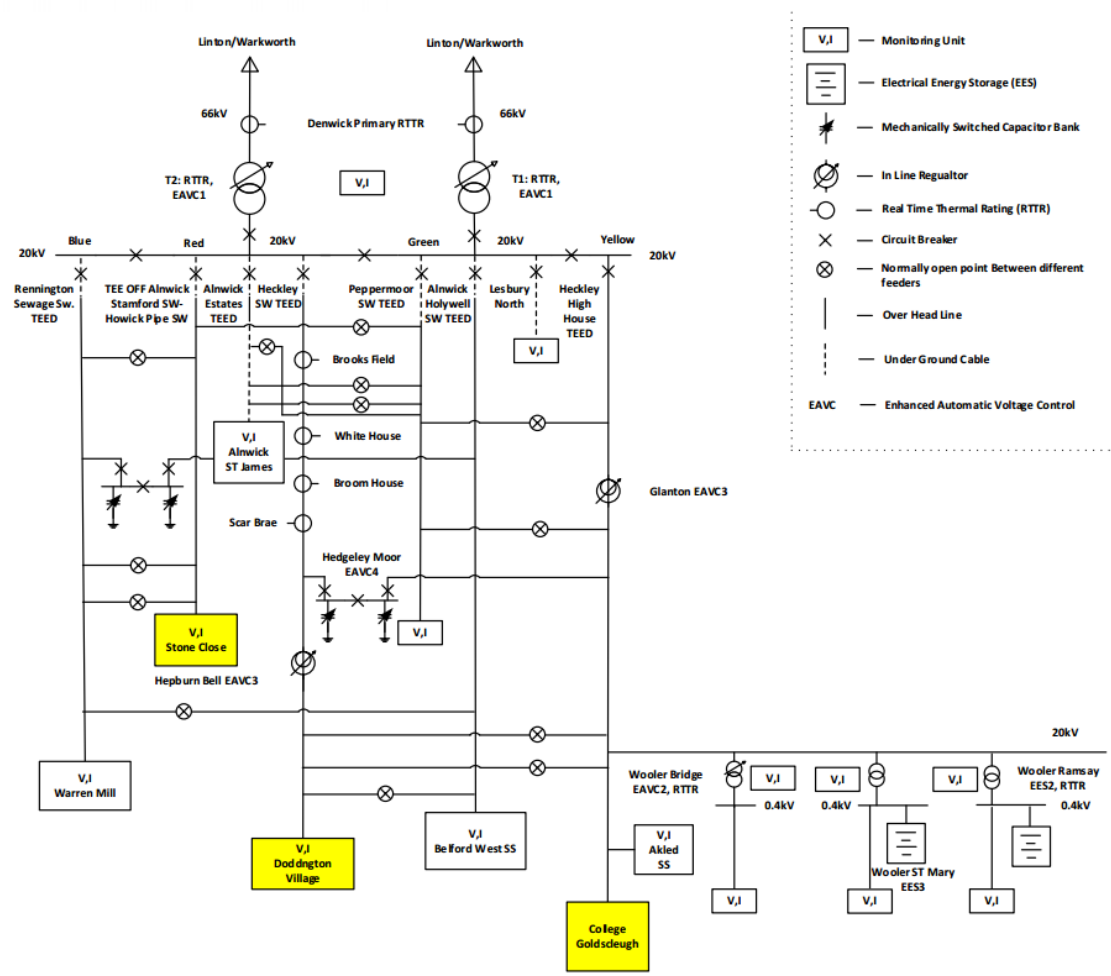
Energy Storage in LV Networks – Results from the Customer Led Network Revolution

- Energy Storage installed on LV network to address problems at HV and LV
- Collaborative operation with Real-Time Thermal Ratings and capacitor banks



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LV Energy Storage Installation

- 2 Systems installed on the LV network
- 50/100 kVA Inverters
- 100/200 kWh of Litium-Ion Nano-Phosphate batteries

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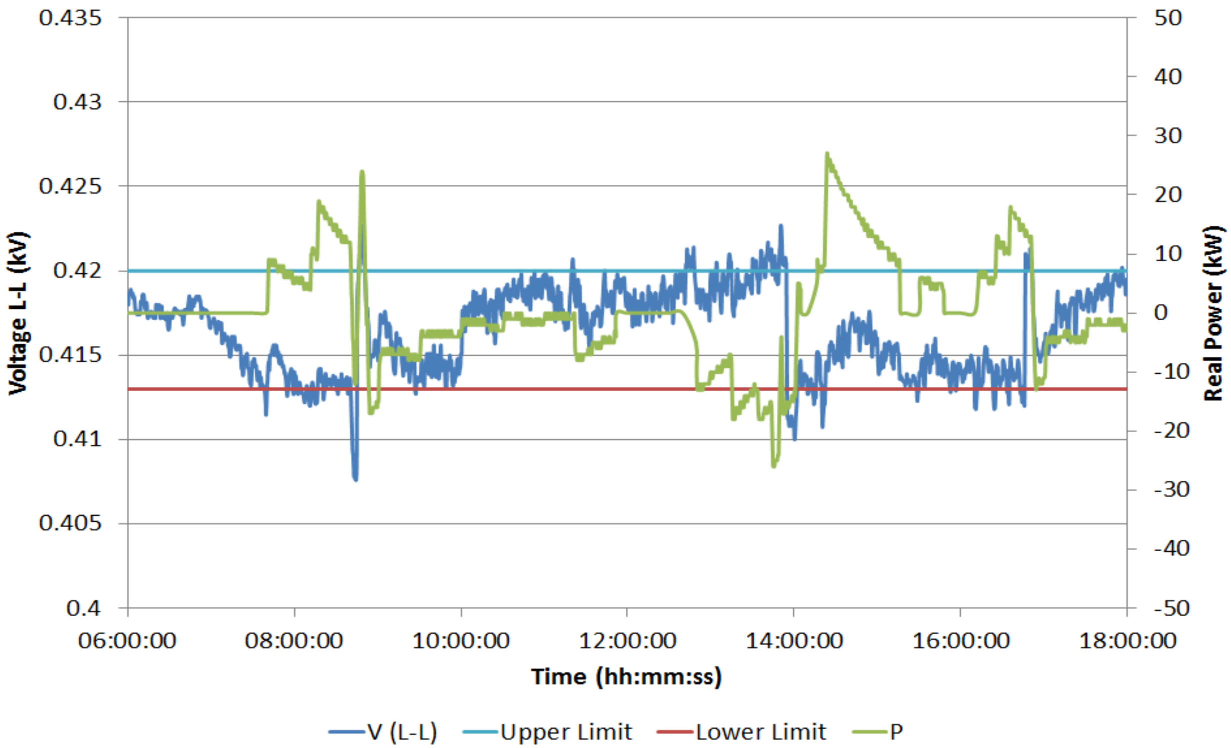
Real power control of voltage



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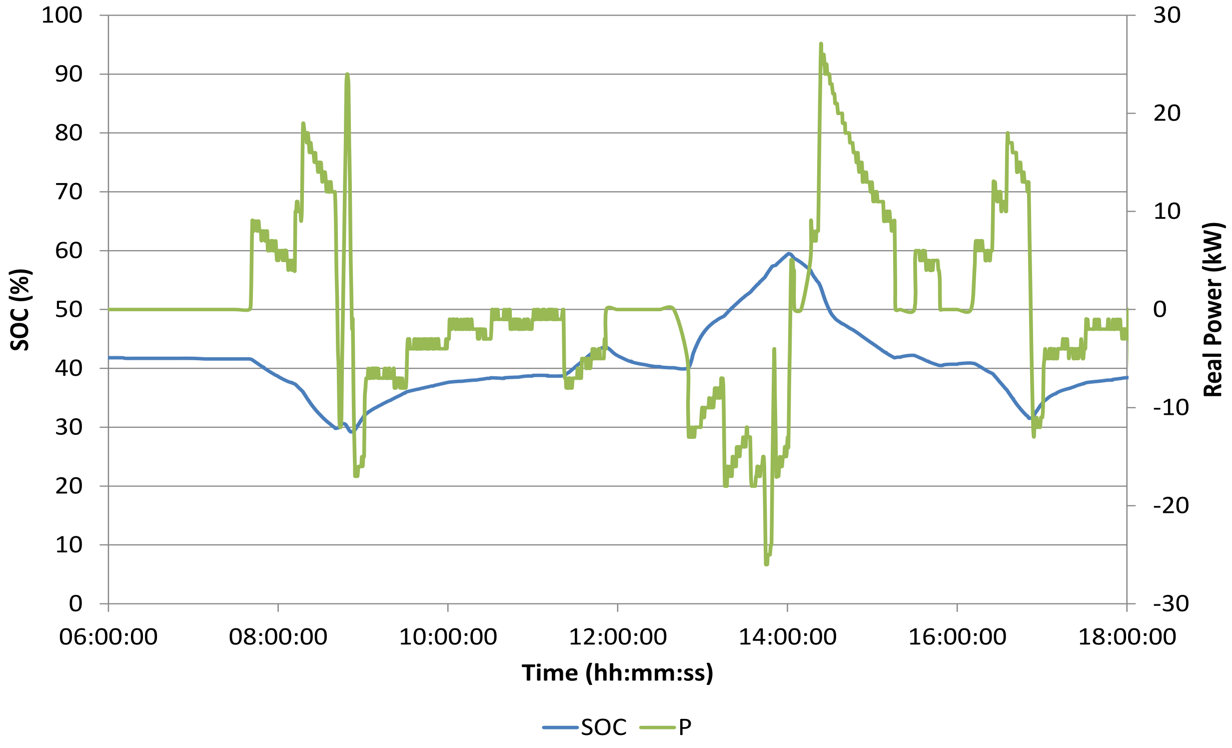
Real power control of voltage



ENERGY STORAGE AND REAL-TIME THERMAL RATINGS

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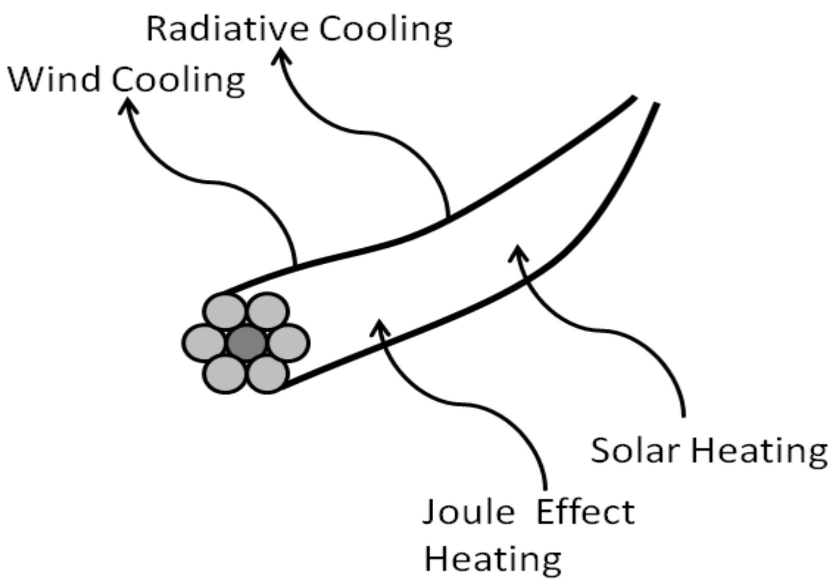
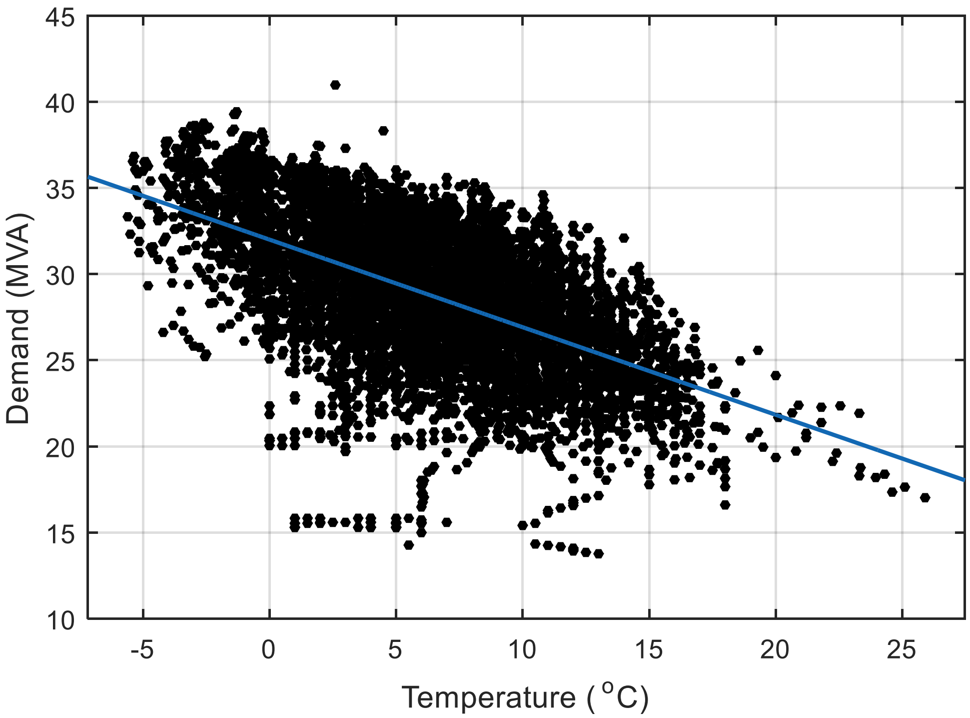
Energy Storage and Real-Time Thermal Ratings - Motivation





By combining these technologies can we decrease the utilisation of storage for local applications and increase security of supply?

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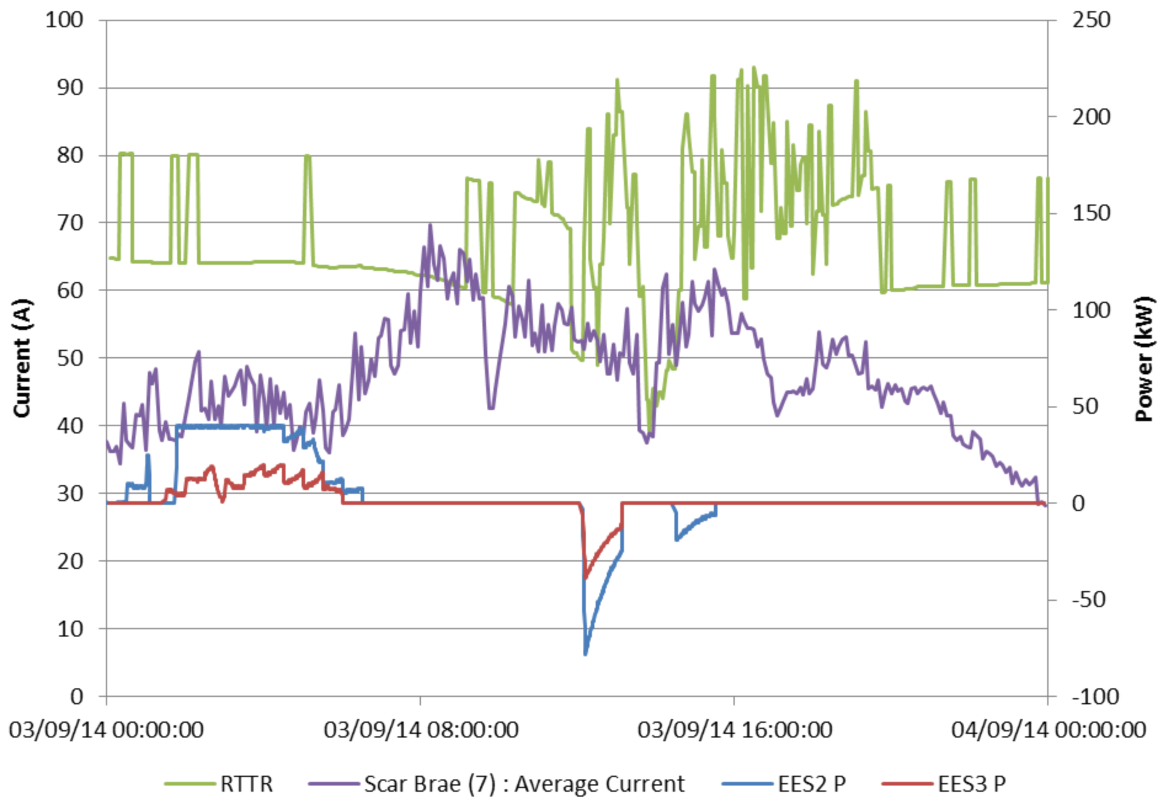
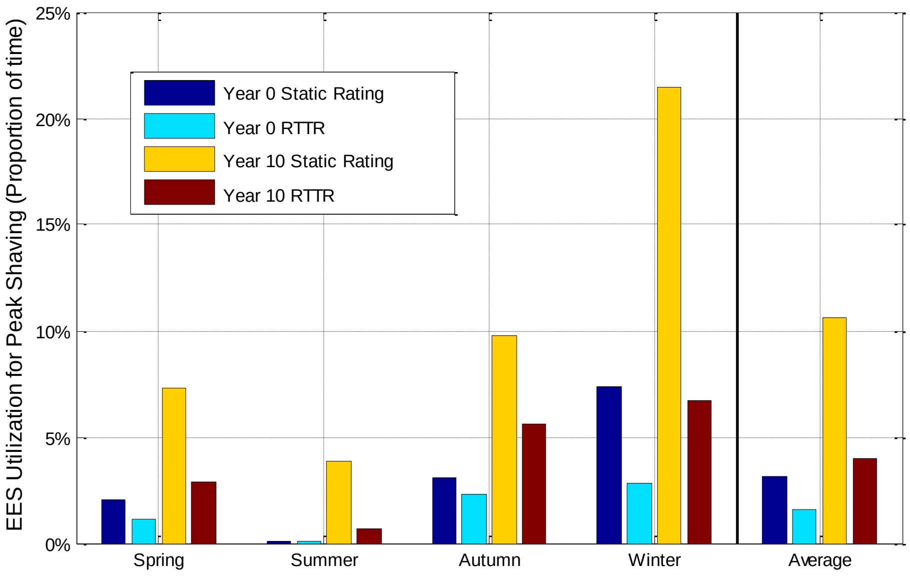
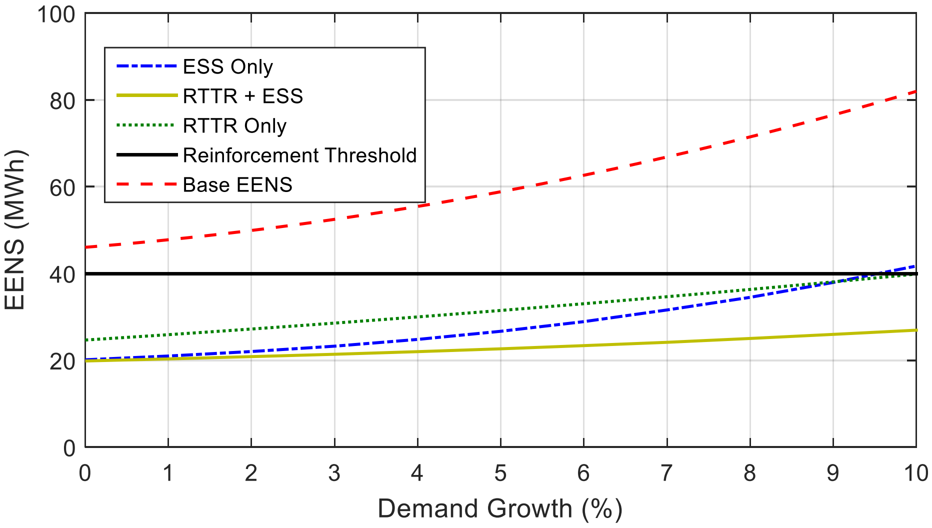
Powerflow Management with Real-Time Thermal Ratings



Energy Storage and Real-Time Thermal Ratings - Results





ELECTRIC VEHICLES AS ENERGY STORAGE IN LOW VOLTAGE NETWORKS

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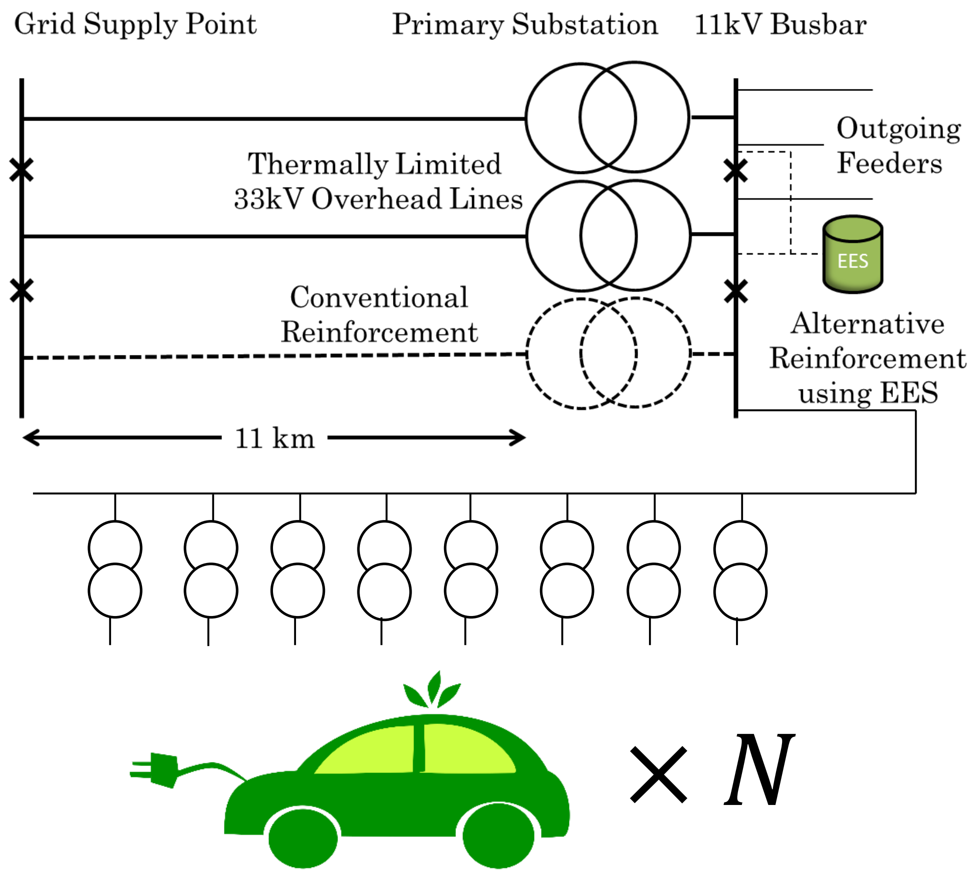
Deferring Network Reinforcement via V2G



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UK Power Networks
Delivering your electricity

The first real world trial of V2G chargers in the UK

Working with Nuvve, Nissan and Enel

10kW bi-directional chargers

1 at Newcastle University
9 at Nissan Research Centre- Cranfield

NUVVE

Newcastle University
UK | Malaysia | Singapore

enel

NISSAN

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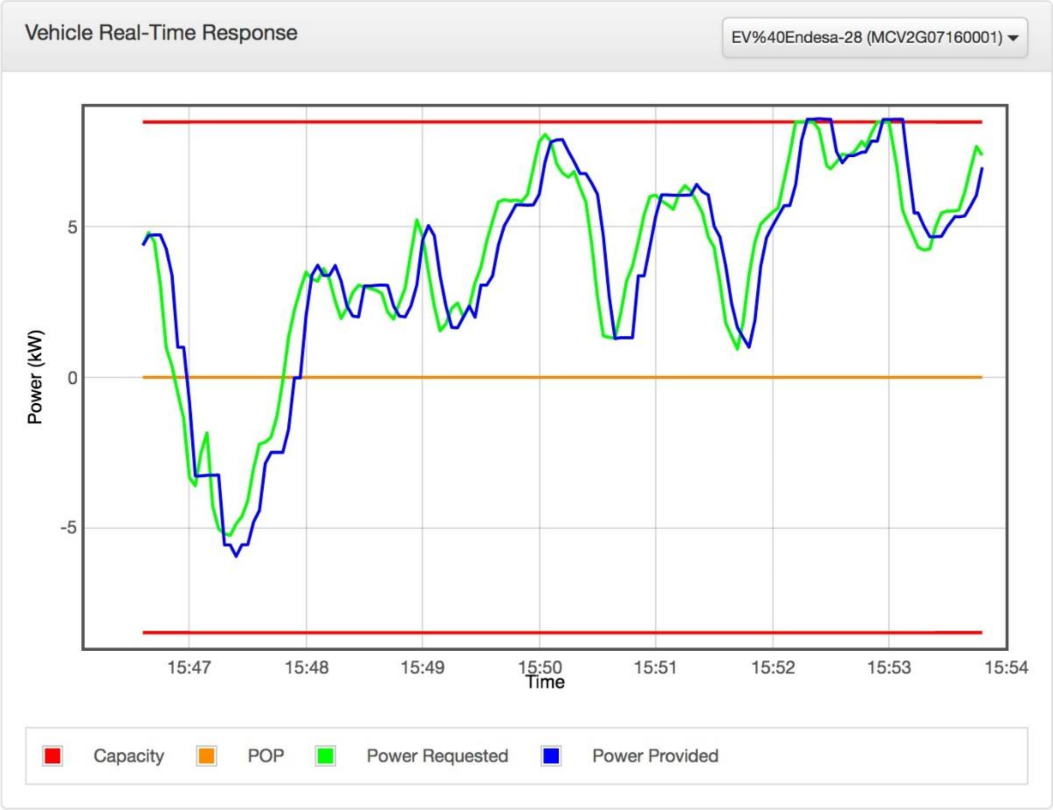
Response Time



FREQUENCY RESPONSE IN LOW VOLTAGE NETWORKS

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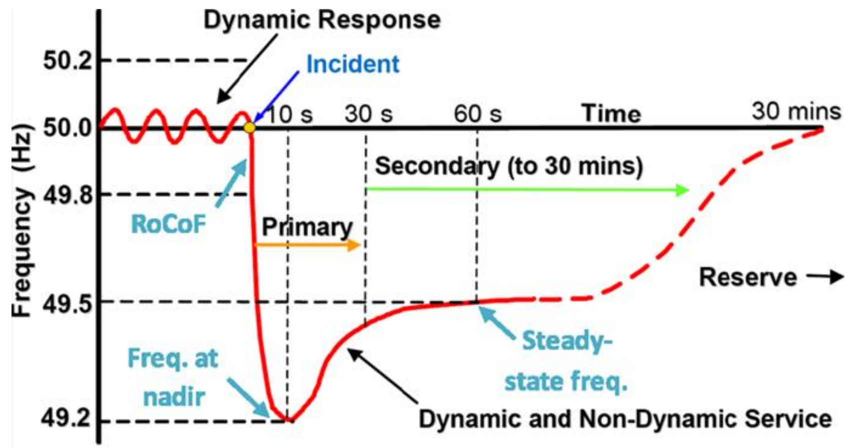
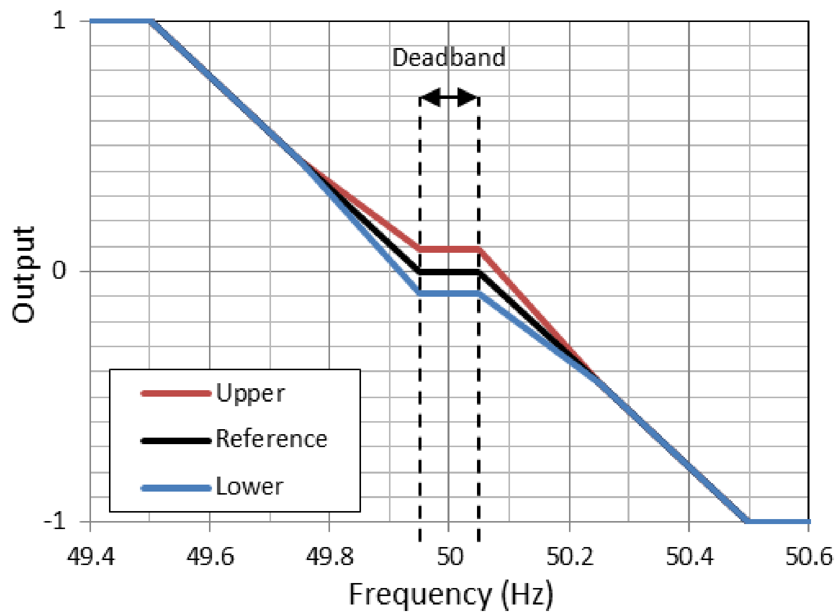
What is Frequency Response?

- When the frequency starts to change, the system operator acts quickly to restore it to its nominal value
- Primary frequency response providers will *supply* or *absorb* real power within 10s
- Secondary frequency response providers will *supply* or *absorb* real power witin 30s
- But will this be quick enough in a *low inertia* system with *unpredictable* demand and generation?





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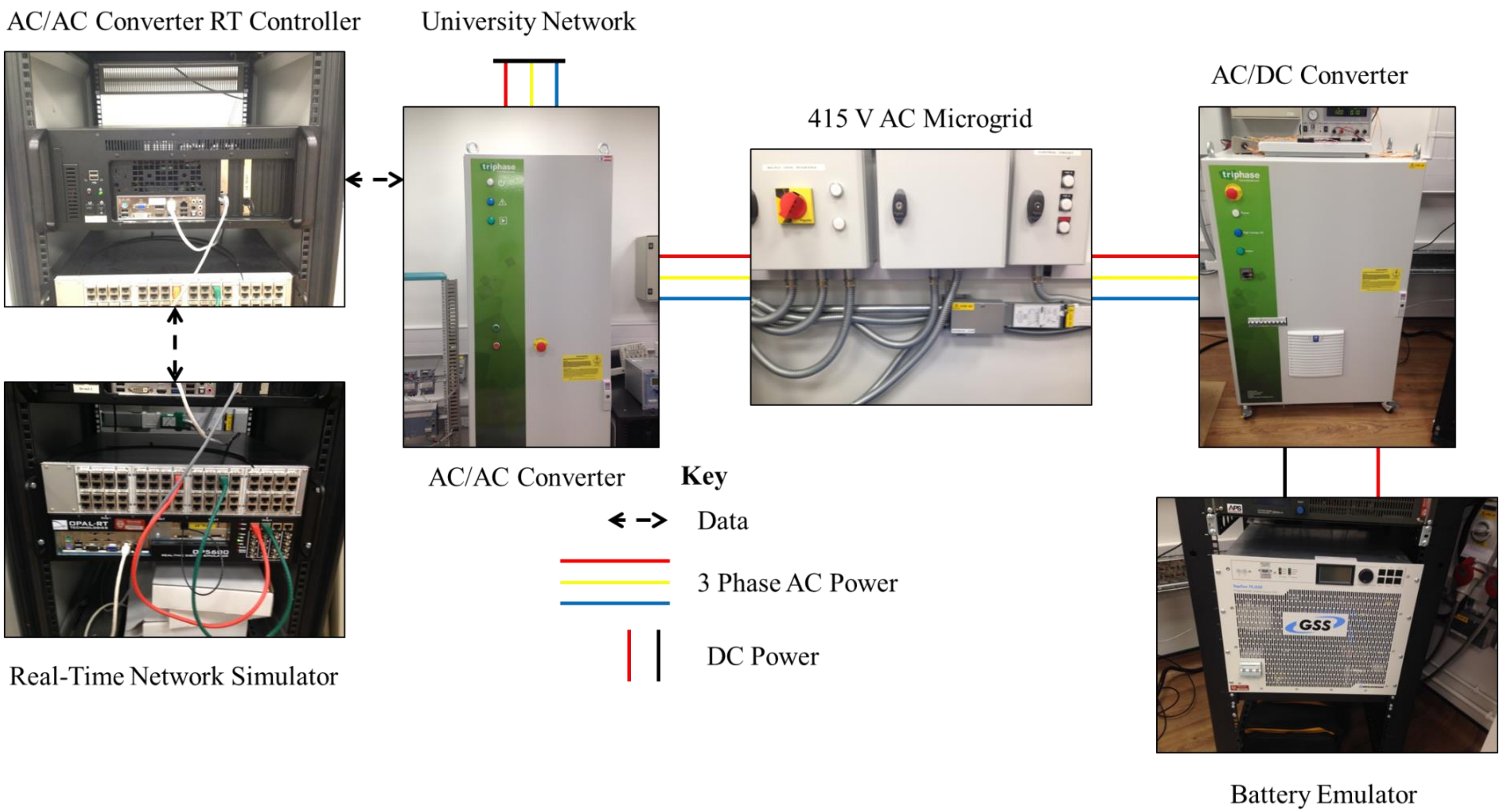
Laboratory Overview



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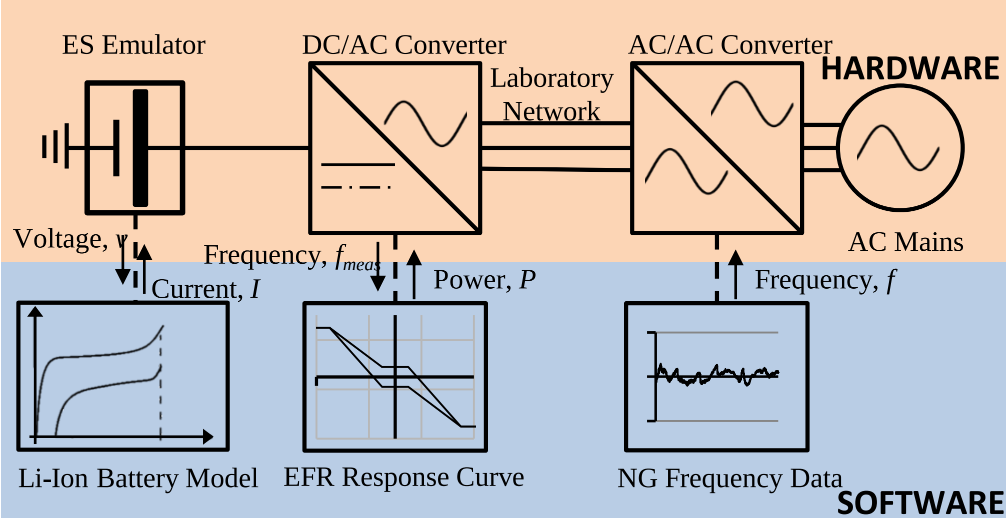
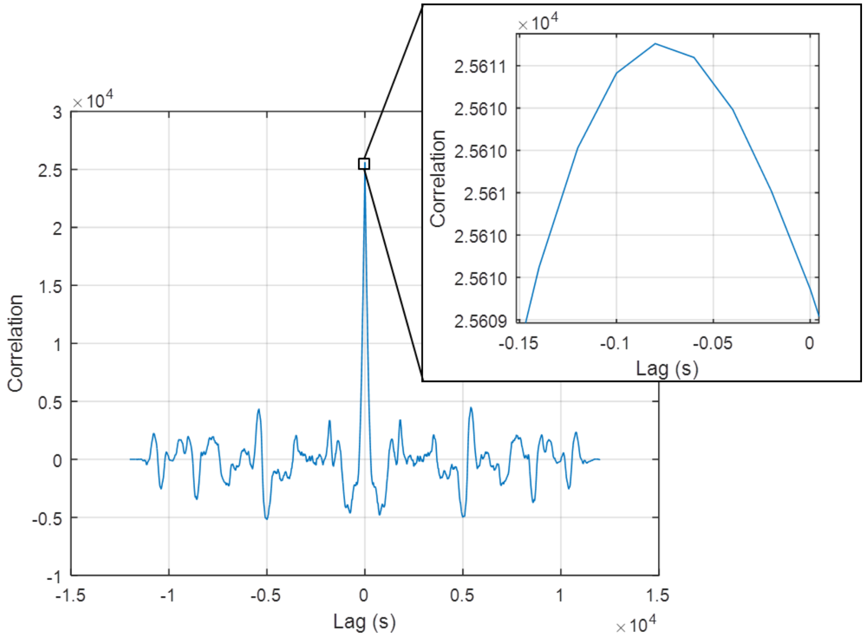
Experiment 1: Aims and setup

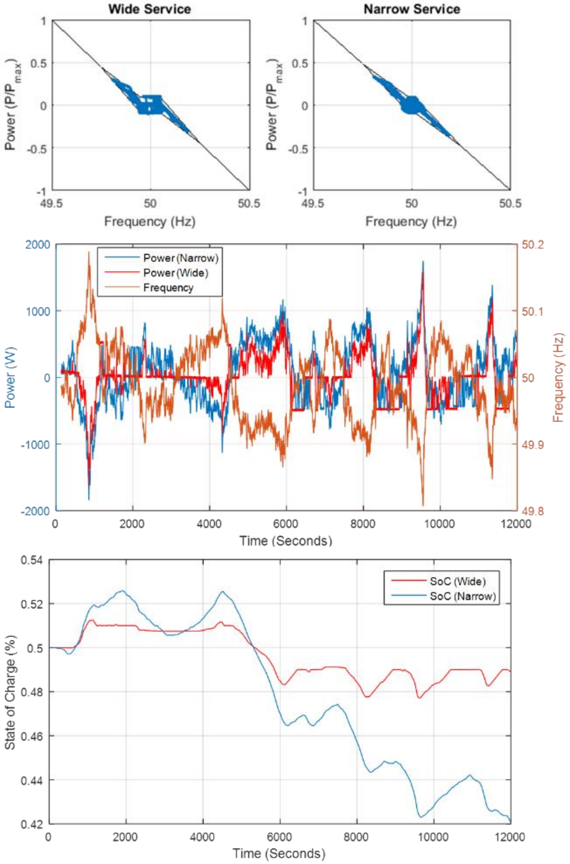
- Historical frequency data was reproduced on the laboratory LV network
- The ESS responded according to the EFR response curve, and managed its state of charge between responses.



Experiment 1: Results

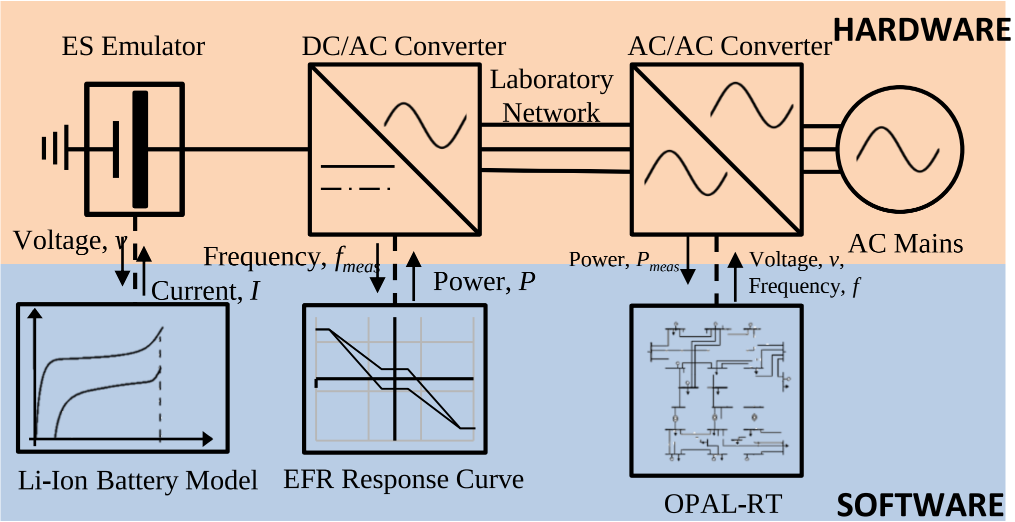
Experimental Investigation





Experiment 2: Aims and setup

- The IEEE 24-bus test network was simulated in the OPAL-RT
- Frequency events were created in the simulation, resulting in frequency changes on the laboratory network
- The ESS responded to the frequency change; the resulting power signal was measured and fed back into the simulated network
- The ESS response was scaled up, representing different ESS penetration levels



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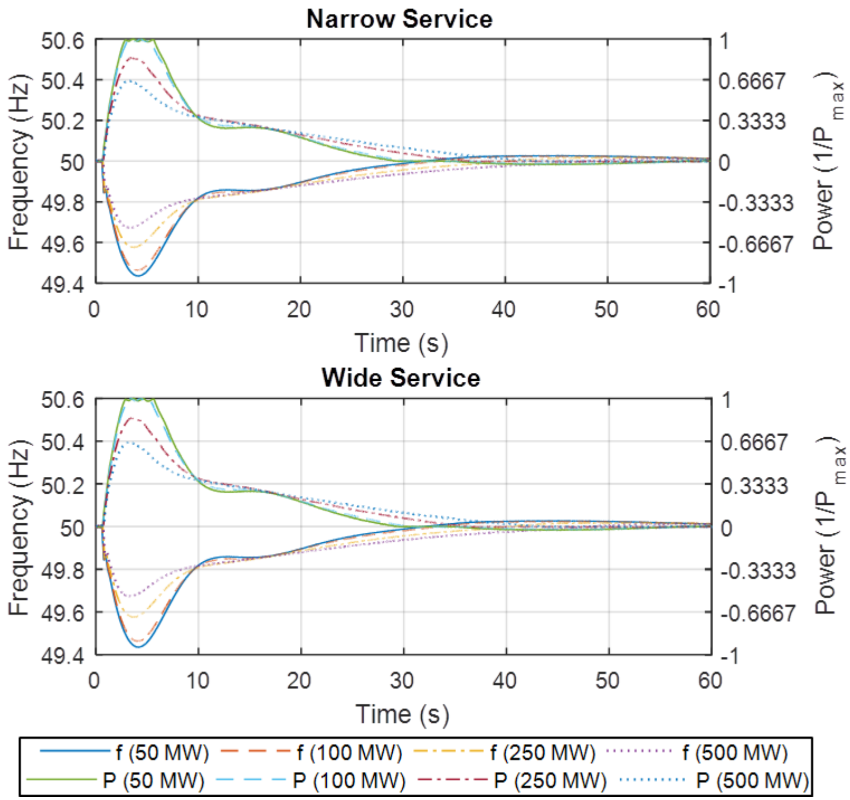
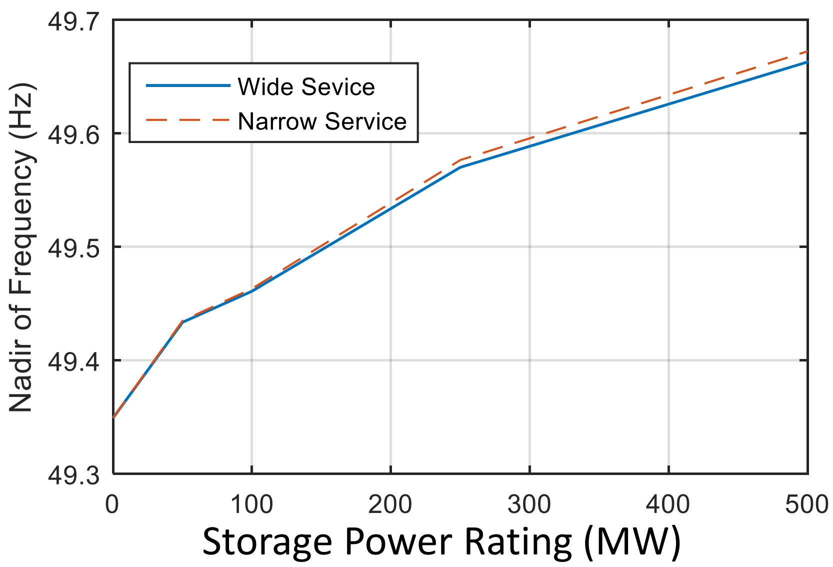
Experiment 2: Results

Experimental Investigation





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Conclusions

- Energy Storage can offer substantial benefits when installed in LV networks
- Services can benefit higher voltage levels, but will require coordinated control and aggregated response
- Energy Storage can operate in collaboration with other smart grid interventions, including RTTR and Demand Response
- Energy Storage can be purpose built, behind the meter, or Electric Vehicles with V2G functionality
- We have developed simulation, experimentation, and demonstration approaches to help realise these benefits

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Publications

http://www.networkrevolution.co.uk/

D. M. Greenwood, N. S. Wade, P. C. Taylor, P. Papadopoulos and N. Heyward, "A Probabilistic Method Combining Electrical Energy Storage and Real-Time Thermal Ratings to Defer Network Reinforcement“, in *IEEE Transactions on Sustainable Energy*, vol. 8, no. 1, pp. 374-384, Jan. 2017.

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Myriam Neaimeh, Robin Wardle, Andrew M. Jenkins, Jialiang Yi, Graeme Hill, Padraig F. Lyons, Yvonne Hübner, Phil T. Blythe, Phil C. Taylor, “A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts”, *Applied Energy*, Volume 157, 1 November 2015, Pages 688-698

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Thanks for your attention! Any questions!?