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DC Technologies for Widespread Renewable Deployment and Efficient Use of Energy

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University of Strathclyde Engineering

Outline

- Background and research experience
- Core research activities
- Opportunities for future collaborations
- Summary
- List of publications

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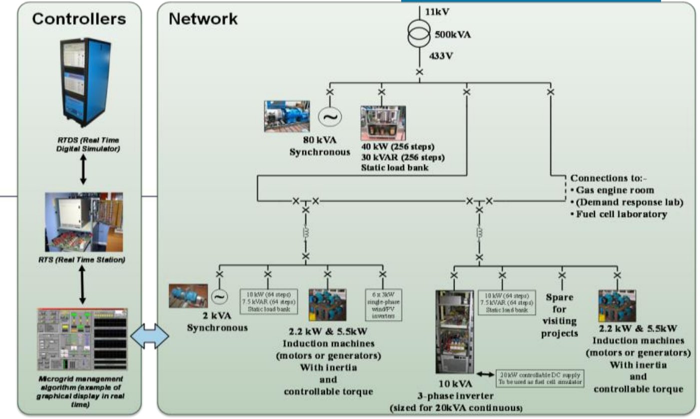
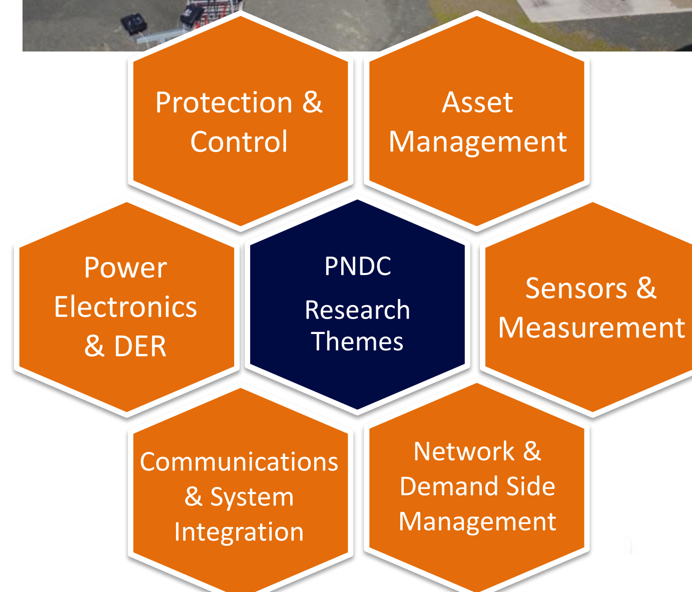
Institute for Energy and Environment

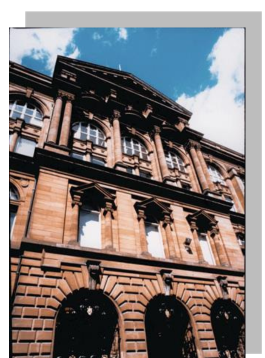
INSTITUTE FOR ENERGY AND ENVIRONMENT

<u>Core disciplines</u>

- Power System Analysis
- Power System Simulation
- Power System Economics
- Energy Markets
- Active Network Management
- Machines & Power Electronics
- Control, Protection & Monitoring
- Wind Energy Systems
- Renewables
- Dielectric Materials/Pulsed Power
- HV Technology/UHF Diagnostics
- Energy System Modelling
- Research portfolio: £40m







Background and research experience

Personal Experience
- The General Electric Company of Libya (GECOL), National Control Centre, (2002-2003 Tripoli, Libya)
- MSc in Electrical Power Systems (2005 from University of Bath UK)
- PhD in Electronic and Electrical Engineering (2010 from University of Strathclyde UK)
- Senior post-doc researcher at the University of Strathclyde (since 2012)

Core research
- Power system protection and stability with more focus on DC systems
- Protection and safety of LVDC last mile distribution networks
- HVDC and wind energy modeling in Real Time Digital Simulation

Research Leadership
- Coordinating Strathclyde Power System Dynamic Research Team
- A technical member of the IET Technical Committee 2.4 DC Power Systems for developing a Code of Practice for LVDC in buildings http://www.theiet.org/resources/standards/lvdc-cop.cfm?orign=event
- A member of the IEC System Evaluation Group (SEG 4) on LVDC
- Acted as a coordinator for forming a European Consortium (6 EU Universities and 13 companies) on LVDC and coordinated the development of an EU H2020 bid on DC in smart distribution systems (submitted Jan 2016)
- Strathclyde PI for EU COST Actions proposal "EUDCMI" (under preparation)

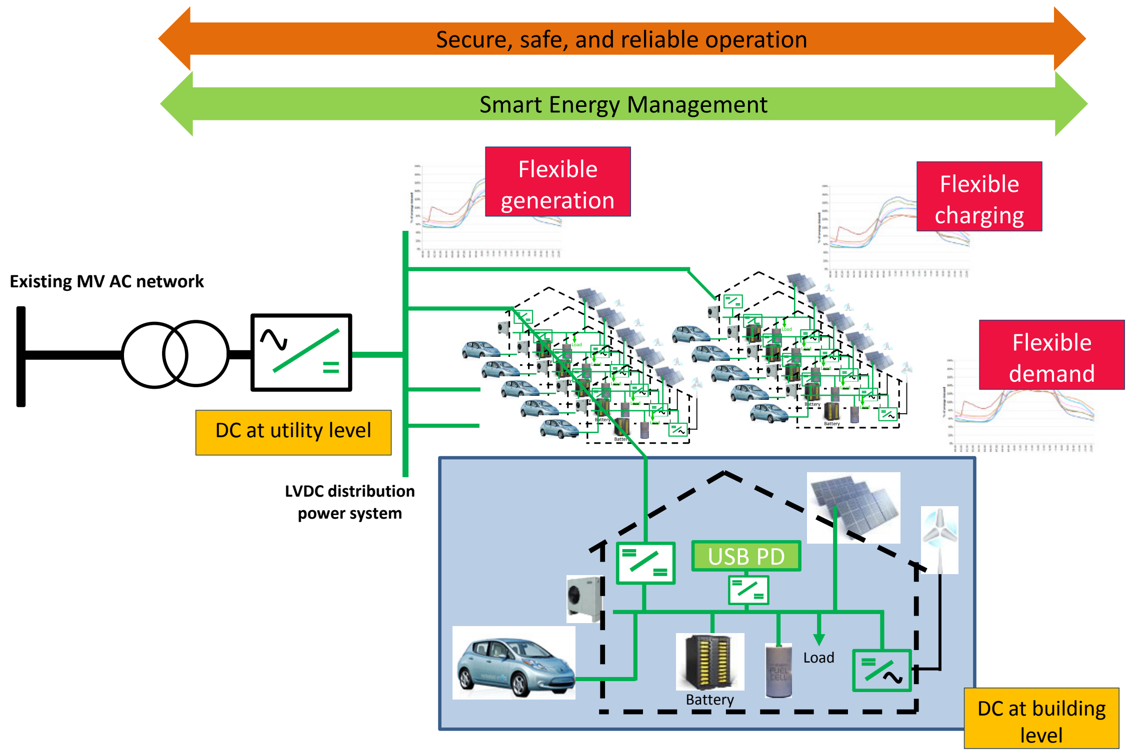
First international LVDC conference in New Delhi India

IEC SEG4 meeting at Strathclyde and visit to the PNDC

DC in Last Mile Distribution Systems

Addressing the technical constraints

- Reduced losses
- Better control of peak demands
- Reduced fault level
- Enhanced voltage profile
- More efficient for renewables
- Easier to connect multiple sources, and No phase balance and synchronisation issues
- powerful ICT platform for integrating various smart grid functionalities



Release additional generation and demand headroom

Offers more flexible market mechanism with better stimulation of customers

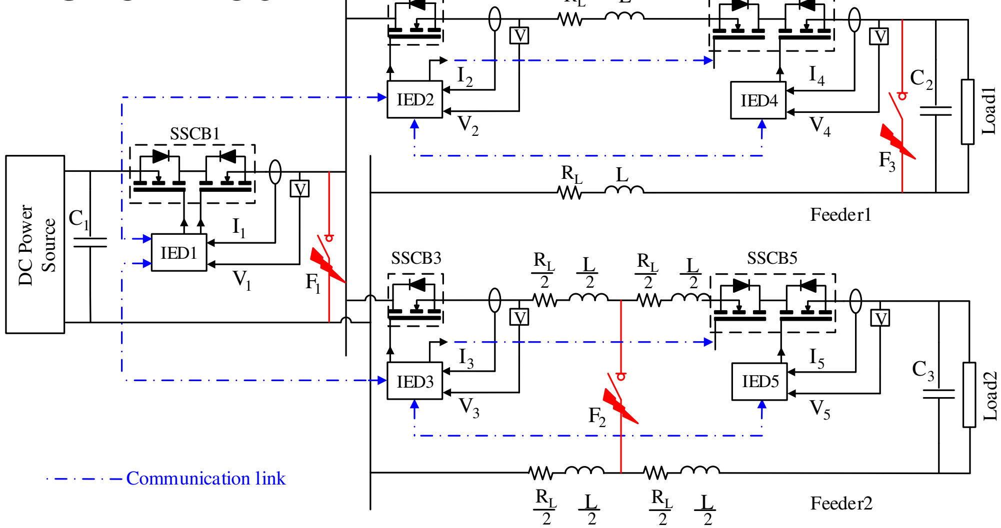
RESEARCHER LINKS

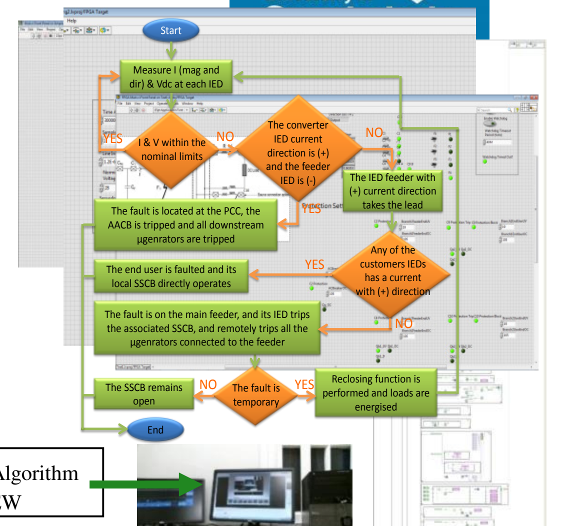
Core research activities

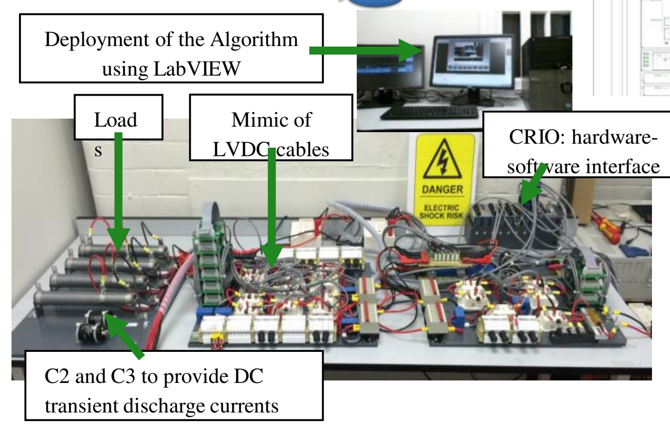
University of

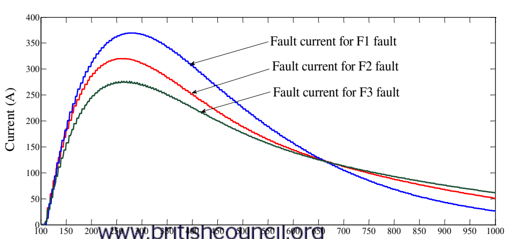
DC Protection Challenges and Solutions

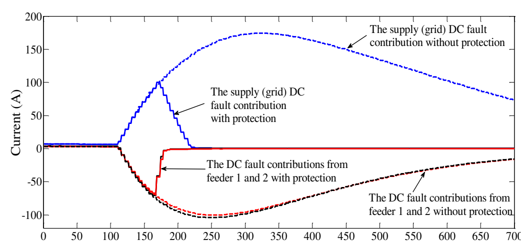
- Modelling the behaviour of an LVDC under different fault conditions
- Development and prototype testing of DC protection scheme with the speed and selectivity required to enable an LVDC last mile
- Contributed to two chapters of the IET CoP on LVDC & IEC SEG4 WG5

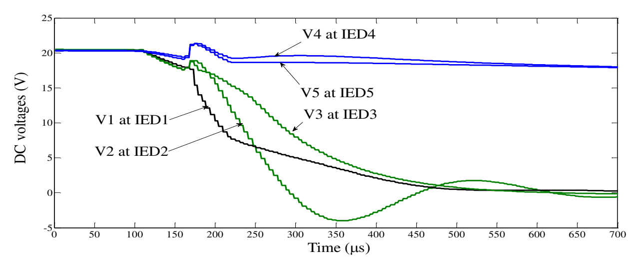












A Emhemed, and G. Burt, "An Advanced Protection Scheme for Enabling an LVDC Last Mile Distribution Network", IEEE Transactions on Smart Grid, Vol. 5, No. 5, pp. 2602-2609, Sep 2014.

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Core research activities

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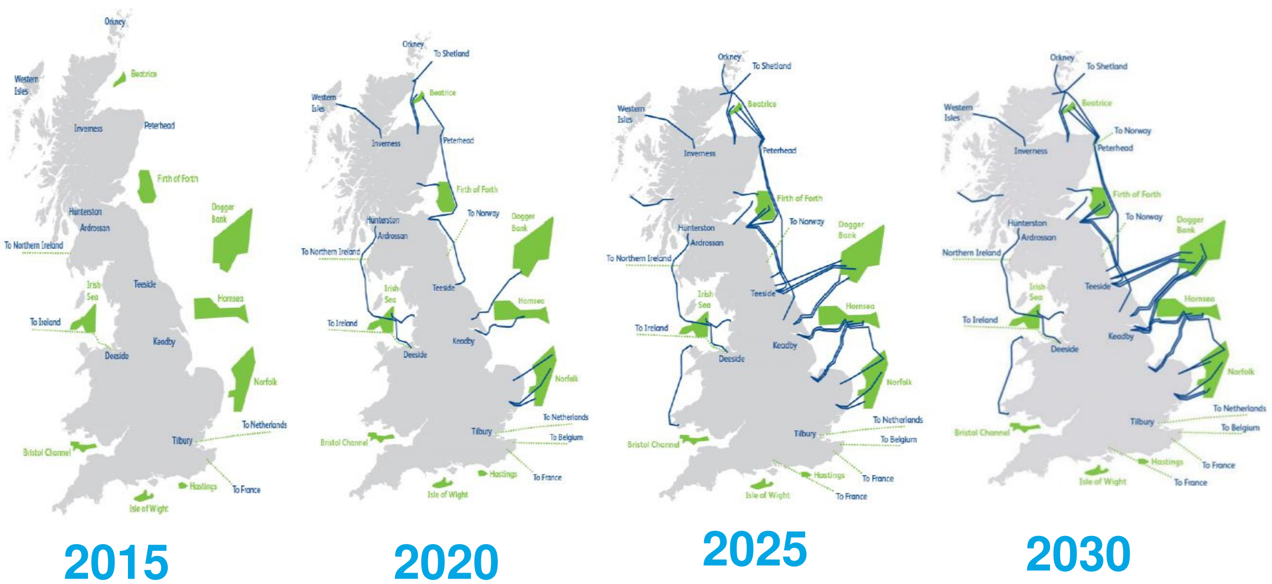
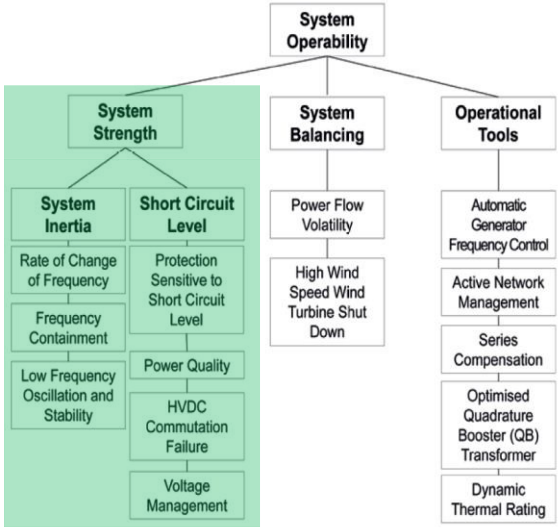
Challenges: Moving to Hybrid AC-DC Systems

UK Future Grid 2015-2030





Aspects of System Operability affected with regard to Future Energy Scenarios [NG ETYS2013]

	Slow Progression Scenario	Gone Green Scenario	Accelerated Growth
Point-to-point HVDC Links	20	37	45
Multi-infeed or Multi-Terminal Locations*	7	14	18
New International HVDC Interconnectors	2	4	6
Total (Point-to-Point + Interconnectors)	22	41	51

- Reduced system inertia
- Reduced fault level
- Intermittency in wind and solar increases the volatility of energy flows, and it will be more difficult to estimate the reserve power for stability
- The maximum secured loss of generator will increase to **1800MW** instead of **1320MW** (as expected to be the size of a single nuclear power plant)

Electricity Network Innovation Competition submission from SHE Transmission Ltd – Multi-Terminal Test Environment (MTTE) for HVDC Systems available at https://www.ofgem.gov.uk

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Core research activities

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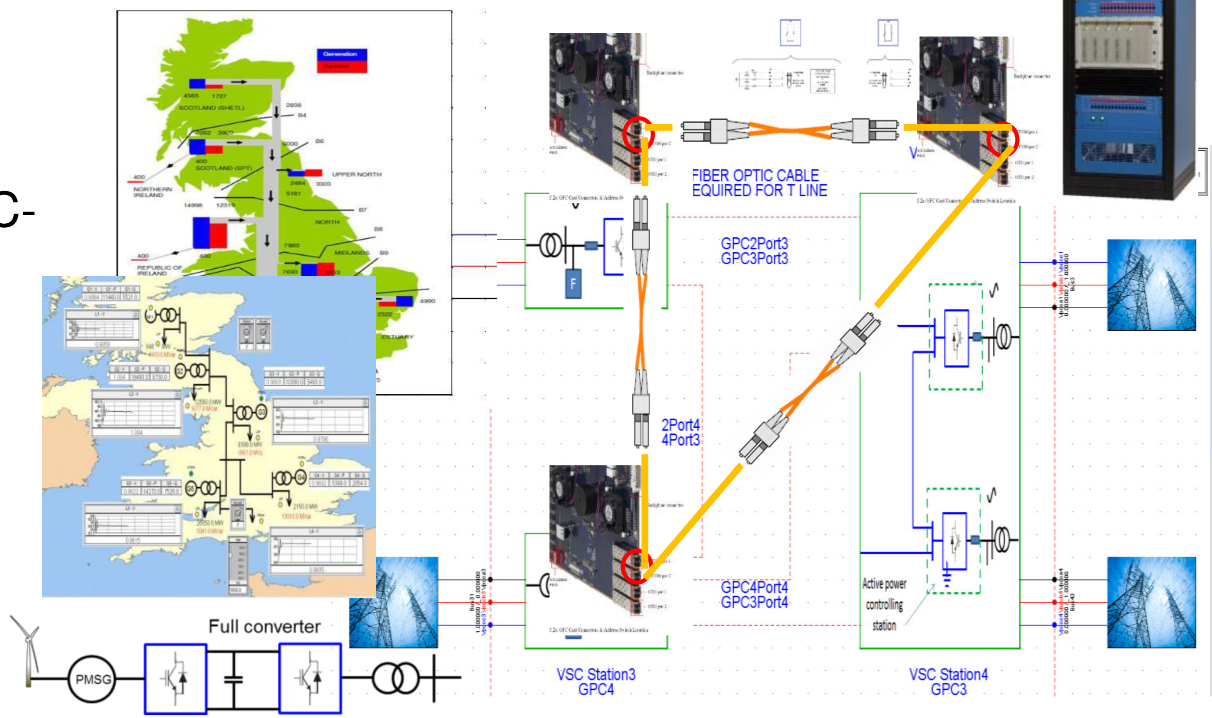
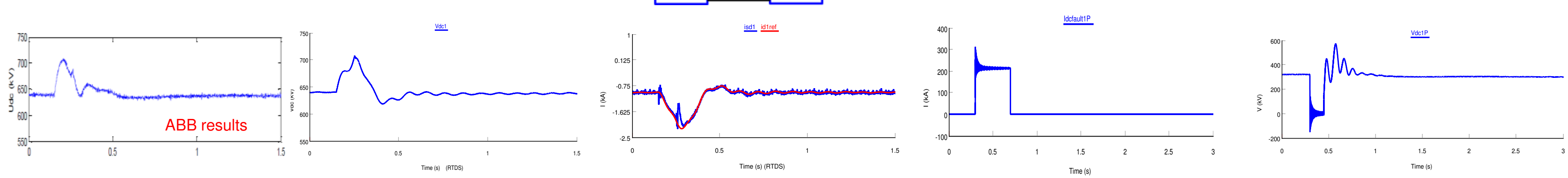
Research on Hybrid HV DC-AC Networks

Modelling of a hybrid AC-DC power network with offshore wind farms in Real Time Digital Simulations for contingency and dynamic stability studies

Simulating very stressed events and understanding the resilience (the dynamic interaction) of the hybrid AC-DC grid base on future UK NG low carbon scenarios

HubNet
The Supergen Energy Networks Hub





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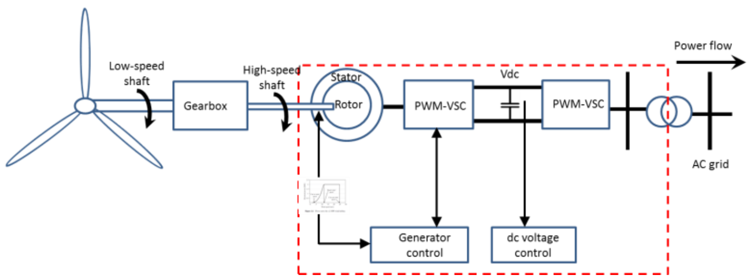
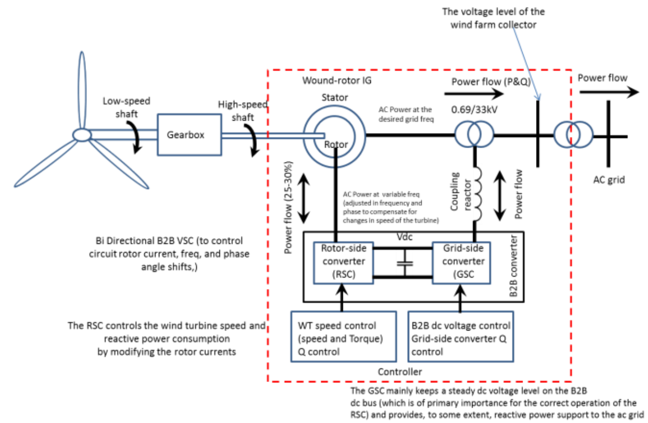
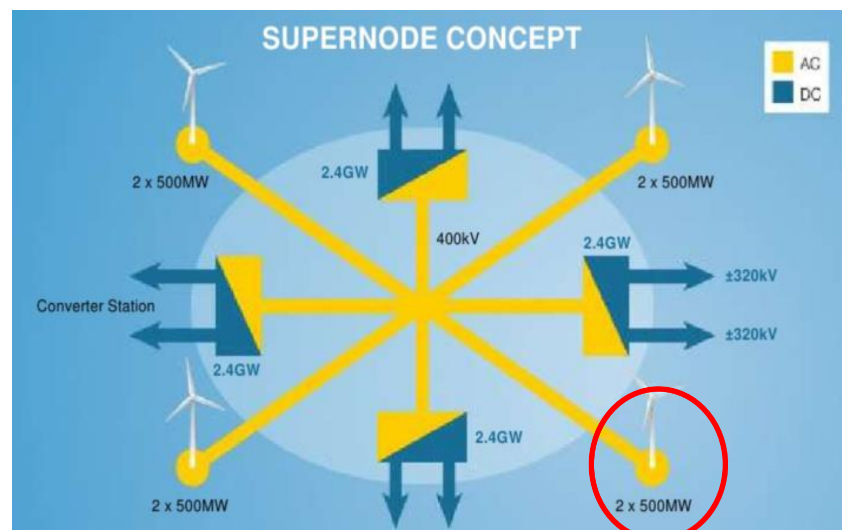
Aggregation model of wind farm

Main parts of a wind-farm aggregated model: Wind speed model, Specification of wind-farm layout, and wind turbine model







Source: http://www.friendsofthesupergrid.eu/

RTDS Technologies

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Areas of Interest for Future Collaboration

DC in distribution systems

- Hot area of research with very limited experience
- Lack of standards (topology, voltages, cable connections, interference, and etc.)
- International systematic approach on LVDC not yet provided
- Existing LV protection is too simple and not capable of enabling the potential benefits afforded by DC last mile networks
  - DC protection for safety challenge
  - The requirement for high speed DC protection
  - Detecting and locating DC faults challenge
  - Protection against DC voltage disturbances
  - DC faults interruption challenge

Hybrid AC-DC grids with offshore wind farm in RTDS

- Modelling and testing the interaction of the hybrid AC-DC grid with the control and protection systems **(simulated or implemented in hardware via HIL)**

  e.g. evaluating relay performance under different network operating conditions, validation of protection and control algorithms, etc.
- The design of high speed and selective DC protection schemes
- Detecting and locating DC faults on MTDC grids
- **Aggregated modelling of wind farms in RTDS for stability studies**

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Summary

DC technologies and systems are required for wider uptake of renewables

- The requirement for more **flexible and efficient power systems** to deliver **low carbon energy** and the evolutionary leap in power electronics and controls have stimulated the market of DC technologies
- DC distribution systems are one of the new emerging technologies to recently attract attention for **providing more efficient** and **flexible platform** to increase LV power capacity, and connect more distributed renewables
- Multi-terminal HVDC (MTDC) systems have been introduced as the next step for **better control** and **sharing of renewables** within different regions such as in the “Supergrid” concept

DC technologies and systems implementation are challenging

- Replacing or energising an existing part of an AC network using DC is **very challenging**, and present significant **operating and protection** challenges in addition to lack of mature **experience and standards**
- There is still lack of research and application experience on the **quantification of technical, economic, environmental and social benefits** available from the introduction of DC technologies specially at distribution level.
- Further research is also required on innovative key enablers of DC systems including **smart and efficient** power electronics interfaces, **optimal** energy management, and **discriminative** safe and **fast** acting DC protection.

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4. Emhemed, A., Burt, G. & Booth, "Experience from Research into Low Voltage DC Distribution System Protection: Recommendations for Protecting Hybrid HV DC-AC Grids", PAC World, Glasgow UK, June 2015
5. Abdullah Emhemed, and Burt, Graeme, "The effectiveness of using IEC61660 for characterising short-circuit currents of future low voltage DC distribution networks", Electricity Distribution Systems for a Sustainable Future CIRED2013, 10-13 June 2013, Stockholm Sweden.
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Thanks you and Q