EPSRC
Engineering and Physical Sciences Research Council

Research Councils UK Energy For a Low Carbon Future

Energy Networks

Optimisation of HVDC for Offshore Platforms

- Analysis of trade-offs between volume, efficiency, control performance and fault tolerance of modular power converters
- Control algorithms created to optimise current waveform quality in new converter circuit topologies and minimise stored energy requirement
- Experimental validation of ride-through of short-circuit faults

The UK has some of the best resource for wind energy generation in the world. The North Sea has many hours of high wind speeds leading to good utilisation of the turbines and load factors approaching 40%. Features such as Dogger Bank mean the sea is shallow even a long way from shore so turbine foundations remain feasible. But being a long way from shore requires that the sub-sea connection cables are operated with DC and that requires an AC to DC converter of perhaps 1,000 MW on a platform offshore. It is crucial for cost-effectiveness that the converter is optimised for its size, power efficiency and control performance.

The Supergen HubNet consortium identified that there were a number of converter design requirements that are in tension. Control performance is aided by having large capacitors in each module but they add volume and cost to the platform design. Ability to ride-through faults requires extra modules and adds power losses. We have conducted analysis of the fundamental choices in circuit design that determine these trade-offs. We have found new operating principles for some circuits that reduce the volume of components and reduce the power losses. We have also characterised the redundancy needed to operate through internal faults. We have gone on to show how short-term emergency ratings can be provided to outages in the main UK system.

Case Study: The Alternate Arm Converter

GE Grid Solutions (formerly Alstom Grid) has been a HubNet partner from the outset and helped researchers understand the factors that determine the success of a High Voltage DC installation. This has driven our researchers to ask how design trade-offs that appear to set limits might be broken. We have then taken our understanding of these trade-offs and worked as consultants to GE on a new circuit topology known as the "Alternate Arm Converter". At first sight it gave advantages being able to ride-through short-circuit faults that might occur on the DC cable and do so without paying a large penalty in standing power loss. However, it required large filters to reduce distortion. We have now overcome that problem with an innovation in operating principle of the circuit and been able to demonstrate fault-ride through with the new controller in our laboratory-scale test-rig. This was a key step in GE adopting the innovation for their product development.

The quest for an optimised design does not stop here and we continue to work with GE to explore hybrid circuits taking various combination of semiconductor types and modules types to achieve the best balance of properties. We also work with EDF Energy R&D on how these new converter designs would change the approach to building DC networks and their protection systems.

Achievements:

- Established analytical means to express trade-offs between power efficiency and circuit volume for various configuration of high-power modular AC/DC converters
- Created new operating principle for the "Alternate Arm Converter" to remove need for large filter circuits
- Created a method to dynamically rate an AC/DC converter based on temperature rise to allow additional power flow in emergencies
- Provided analytical assessment of the degree of redundancy needed to tolerate internal module faults by working in collaboration with Xi'an Jiaotong University (via ESPRC-NSFC funding)

EPSRC Outcomes Focus:

This case study delivers impact with industry in the form of a new product design that contributes to the following outcomes: R1 and R2

Resilient

Connected

Productive

Healthy

Academic partners:
Imperial College London and Xi'an Jiaotong University (via EPSRC-NSFC ERIFT Project)

Industrial partners:
GE Grid Solutions and EDF Energy

The Supergen Programme, part of the Research Councils UK Energy Programme, led by the Engineering and Physical Sciences Research Council (EPSRC), aims to contribute to the UK's environmental emissions targets through a radical improvement in the sustainability of the UK's power generation and supply.

EPSRC
Engineering and Physical Sciences Research Council