UNIVERSITY OF ABERDEEN

SCOTTISH ENTERPRISE PROOF OF CONCEPT PROJECT:
HIGH GAIN DC-DC TRANSFORMER/ CIRCUIT BREAKER

Project background:

A novel DC/DC power converter topology has been developed by the University of Aberdeen Power Laboratory team led by Dr Dragan Jovcic. After the modelling stage and feasibility demonstration on on digital simulators, a prototype 30KW 200V/900V DC-DC transformer and circuit breaker has been designed, assembled and tested, as shown in Figure 1. This converter uses L-C resonant principles to provide bi-directional DC power transfer between DC terminals at different voltages. Some of the key advantages over existing AC-based technologies will be:

- Providing a wide range of controllable DC-DC voltage stepping ratios,
- Good efficiency because of zero-current resonant switchings
- Considerable weight savings compared to common DC-DC converters. While conventional DC/DC converters use internal an iron-core AC transformer, the new concept employs a capacitor and air-core inductor,
- Unique DC fault isolation capability,

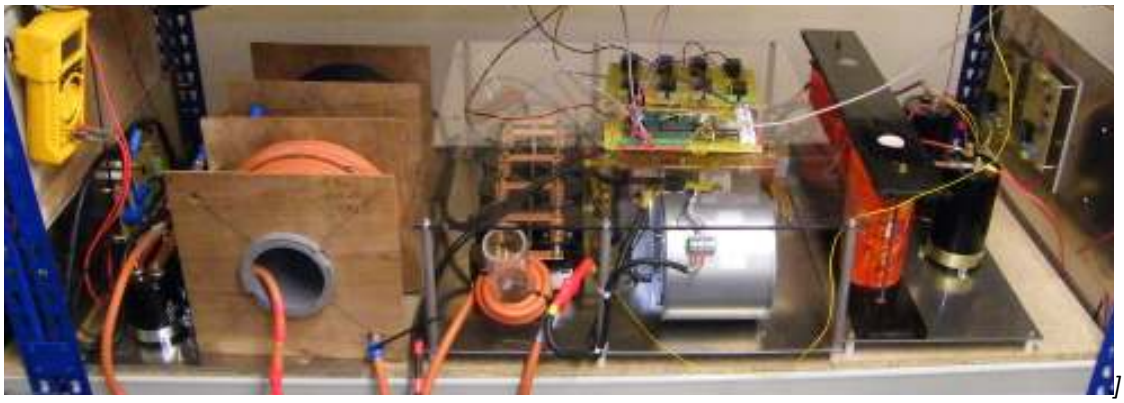

Figure 1: 30KW 200V/900V DC-DC transformer and circuit breaker prototype (2011)

DC fault protection and multiple functions:

A key innovation and distinctive element of the prototype developed is the ability to operate at high (MW) power levels and the capability to provide multiple functions in future DC grids. The converter is an electronic DC/DC substation which achieves the following:

- Connecting two DC grids/sources at high stepping ratios ($V_2/V_1<10$ is economically suitable),
- Fast power flow regulation including power direction reversal,
- DC fault protection and isolation for faults at either of the two connecting DC grids,

With the prototype showing full functionality with feedback control, its fault isolation capability has also been confirmed and is shown in Figure 2 (see over) for open-loop operation. It can be seen that a low impedance DC fault that causes the MV side voltage (V_2) to drop to 1-2% of rated value leads to very little change in the LV side voltage (V_1). During the fault, the converter continues to operate as normal, but the input current (I_1) inherently reduces without need for control action.

This project has received financial assistance from the Proof of Concept Programme managed by Scottish Enterprise and from the European Regional Development Fund. The Proof of Concept Programme supports the pre-commercialisation of leading-edge technologies emerging from Scotland's Universities, Research Institutes and NHS Trusts.

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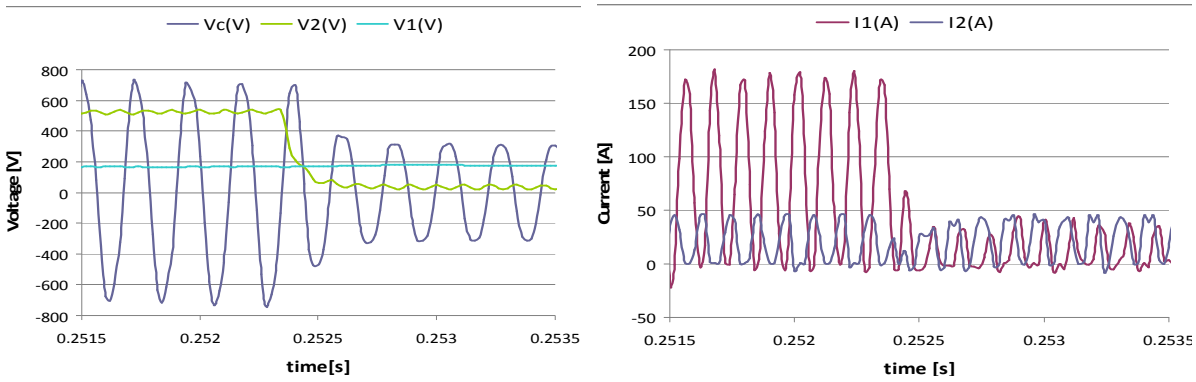

Figure 2: Prototype testing for DC faults on V_2=520V DC bus, in step up mode (V_1/V_2=180V/520V). It is seen that the DC transformer naturally reduces power transfer and does not propagate DC faults.

We are now entering the last six months of the Scottish Enterprise Proof of Concept project and some of the remaining research and development activities include:

- Use of high frequency switches/ thyristors,
- Testing bi-directional operation and power reversal at full power,
- Demonstrating interconnection between DC sources of different types (DC current reversal on one side and DC voltage reversal on the other side),

The market opportunity:

The team believe that its DC-DC transformer/ circuit breaker could represent a facilitating technology for the development of an EU North Sea Supergrid, integrating offshore power parks with HVDC lines. An offshore DC grid with reliable and fault-tolerant medium voltage DC connection points would be key facilitator for the Crown Estate's Round 3 offshore windfarm programme.

While DC transmission is more efficient and has no reactive power issues compared with AC transmission, historically it has been hampered by the difficulties with DC fault protection and DC/DC stepping. Virtually all electricity storage systems operate on DC current and their integration with transmission/distribution grid has been challenging. All variable speed machines (including wind generators) require simpler technology for connection with a DC grid than with 50Hz AC grids.

The Aberdeen University team is currently exploring commercialisation options for its novel technology and is actively seeking industry partners to further develop and for field demonstrations of the DC-DC transformer and circuit breaker.

Key Project Contacts:

Dr Dragan Jovcic
School of Engineering
University of Aberdeen
AB24 3UE
Tel: +44 1224 272 336
Email: d.jovcic@abdn.ac.uk

Darran Gardner
School of Engineering
University of Aberdeen
AB24 3UE
Mob: 07971 667 424
Email: d.gardner@abdn.ac.uk

Dr James Duncan
Research & Innovation
University of Aberdeen
AB24 3FX
Tel: +44 1224 272918
Email: j.s.duncan@abdn.ac.uk

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