CIGRE Study Committee B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

<table>
<tr><td rowspan="2">WG* N° B4.76</td><td colspan="2">Name of Convenor : Professor Dragan Jovcic, UK</td></tr>
<tr><td colspan="2">E-mail address: d.jovcic@abdn.ac.uk</td></tr>
<tr><td colspan="2">Technical Issues # : 3</td><td>Strategic Directions # : 1</td></tr>
<tr><td colspan="3">The WG applies to distribution networks : Yes</td></tr>
<tr><td colspan="3">Title of the Group: DC-DC converters in HVDC Grids and for connections to HVDC systems</td></tr>
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Scope, deliverables and proposed time schedule of the Group :

Background :

DC-DC converters have not been used for high and medium voltage transmission applications. However in recent years there has been significant research on DC-DC technologies by manufacturers, based on the latest advances in HVDC converters in particular related to MMC (Modular Multilevel Converter) technologies. It is accepted that high-power DC-DC is feasible but there are numerous possible topologies with wide ranges of technical performance indicators and cost-economic characteristics. It is understood that DC-DC technologies will need to follow DC voltage and power range of existing and future HVDC systems. The manufacturers crucially need more professional interactions with systems developers and operators to understand the market needs and characteristics.

Simultaneously, the applications of DC-DC converters have been discussed and researched in academia, at systems operators and manufacturers. It is accepted that DC-DC will play an important role in DC grids but the exact functions, performance requirements and applications are not clear. DC-DC converters will be essential in transforming DC voltage but they also may have other functions. As an example, many DC-DC converters can work as DC circuit breakers and fault current limiters. In particular DC-DC converters provide alternative solutions for some DC grid topologies and more work is required to understand how to exploit DC-DC converters in developing/simplifying DC grid protection and control. DC-DC converters might facilitate power exchange between different DC topologies, i.e. monopolar and/or bipolar systems. They could meet other requirements like power control, voltage control, regulation of DC harmonics, energization and start up, and integration of wide range of existing DC systems. It is essential to provide a platform for discussion with manufacturers to understand the economics and performance of DC-DC converters.

The DC collection systems for (offshore) wind farms are very actively studied and a range of new topologies have been proposed such as an example solutions based on diode bridges. The ongoing work in CIGRE C6.31 will collect the state-of-art knowledge in developing MV DC systems, which will be used here to evaluate technology needs for interconnecting HV and MV DC systems.

Some studies have demonstrated that DC/DC converters may provide attractive solution for tapping (tap is a load/source generally below *0.1pu* power) on large HVDC systems. This application needs further evaluation by key industry players to understand the needs and most suitable technical options.

The WG is expected to provide broad guidelines on the applications of DC-DC converters and establish a platform for developments in the area. Further scope for subsequent WGs may be identified in the course of this initial WG.

CIGRE has been very active in promoting and studying DC grid development in the last 10 years with at least 5 WGs either completed or in ongoing work. In 2009 SC B4 initiated WG B4-52 “HVDC Grid Feasibility Study”, to investigate the feasibility of this concept. DC-DC converters are mentioned as important components in DC grids in several chapters. Two subsequent WG have also, in brief, discussed DC-DC:

B4-57: Guide for the development of models for HVDC converters in a HVDC grid, considers some initial modeling options for DC-DC, and

B4-58: Load flow control and direct voltage control in a meshed HVDC Grid, provides initial considerations for DC-DC for load flow control in DC lines and DC grid control.

The outputs from the above 3 WG will be the starting point for the new WG.

Scope :

The objective of the WG are to:

1. Confirm the feasibility of high power DC-DC converters and provide basic technical characteristics in terms of DC configurations (monopole, bipole, symmetric/asymmetric, isolated/non-isolated) and power/voltage ranges.
2. Identify the role and need for DC-DC converters in DC Grids.
3. Evaluate the applications for DC-DC converters in interconnecting HV and MV DC systems.
4. Identify benefits of DC-DC converters in applications of tapping on HVDC

High Power DC-DC converters have not been implemented but there has been lot of research at manufacturers and academia. The working group will review principal technology concepts like: non-isolated converters, isolated dual-active-bridge, DC-DC auto-transformers, high/low stepping ratios, multiport converters and others. The performance indicators will be studied, including range/variation of DC-DC stepping ratios, efficiency, DC fault isolation capability and power flow control. The power reversal capability will have important implications on the DC-DC technology costs and losses. In particular this WG will provide guidelines on the power reversal options (DC voltage or DC current reversal) and link these options with DC-DC technologies. It is not the intention to delve in depth in DC-DC technologies (particularly not MV DC-DC concepts), but rather to collate knowledge on accepted technologies and to establish a platform for further developments. Some attention will also be given to DC-DC modelling methods.

The published studies indicate that a DC-DC converter can achieve a range of functions in DC grids including: DC voltage stepping, galvanic isolation (connecting bipolar and monopolar systems), DC fault isolation and DC fault current limiting, power/voltage/current control and system stabilisation. These functions will be discussed with systems operators and implications for DC grid development will be evaluated. In particular it is important to identify DC-DC applications that can potentially simplify DC grid protection by segmenting DC grids or limiting fault current magnitude. Similarly, the opportunities for DC grid cost reduction by reducing voltage in some segments will be analysed. The manufacturers are particularly interested to receive requirements in this new market. Both LCC and VSC DC technologies will be considered and the role of DC-DC converters in interconnecting LCC with VSC as well as interconnecting DC systems of different manufacturers will be investigated.

In terms of standardisation and interoperability in DC grids, the WG will evaluate the “firewall” function and DC voltage stepping of DC-DC converters. TSOs and grid code developers will elaborate on the DC-DC converters role in DC Grid control, response to contingencies and preventing blackouts.

The DC-DC technologies for MV DC systems might be somewhat different from those for HVDC systems and technical implications and opportunities will be evaluated. The requirements for integrating wind farm DC collection systems with HVDC will be evaluated, including the diode-bridge based wind farms. It is not the intention to study DC collection

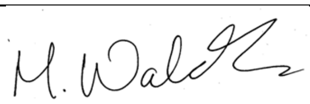
grids, but rather to understand the applications and requirements of DC-DC converters when connecting between HV DC and MV DC systems.
This WG will further evaluate benefits of tapping on large HVDC systems using DC-DC converters, considering both LCC HVDC and VSC HVDC. It is important to understand the performance and economics of DC-DC taps and in particular impact on reliability of HVDC.

Deliverables : Technical brochure with summary in Electra

Time Schedule : Start : January 2017 **Final report** : 2020

Comments from Chairmen of SCs concerned :

Approval by Technical Committee Chairman :
Date : 28/11/2016



(1) Joint Working Group (JWG) - (2) See attached table 1 – (3) See attached table 2
(4) Delete as appropriate

Table 1: Technical Issues of the TC project "Network of the Future" (cf. Electra 256 June 2011)

1	Active Distribution Networks resulting in bidirectional flows within distribution level and to the upstream network.
2	The application of advanced metering and resulting massive need for exchange of information.
3	The growth in the application of HVDC and power electronics at all voltage levels and its impact on power quality, system control, and system security, and standardisation.
4	The need for the development and massive installation of energy storage systems, and the impact this can have on the power system development and operation.
5	New concepts for system operation and control to take account of active customer interactions and different generation types.
6	New concepts for protection to respond to the developing grid and different characteristics of generation.
7	New concepts in planning to take into account increasing environmental constraints, and new technology solutions for active and reactive power flow control.
8	New tools for system technical performance assessment, because of new Customer, Generator and Network characteristics.
9	Increase of right of way capacity and use of overhead, underground and subsea infrastructure, and its consequence on the technical performance and reliability of the network.
10	An increasing need for keeping Stakeholders aware of the technical and commercial consequences and keeping them engaged during the development of the network of the future.

Table 2: Strategic directions of the TC (cf. Electra 249 April 2010)

1	The electrical power system of the future
2	Making the best use of the existing system
3	Focus on the environment and sustainability
4	Preparation of material readable for non technical audience