



## WORKING GROUP FORM

Study Committee: B4

<b>WG number:</b> B4-58	<b>Name of Convener:</b> Kerstin Linden, SE
<b>Title:</b> Devices for load flow control and methodologies for direct voltage control in a meshed HVDC Grid	
<b>Terms of Reference</b>	
<b>Background:</b>	
<p>HVDC has been used mainly for point-to-point transmission with one sending and one receiving converter station. Although the connection of more than two HVDC into a multi-terminal HVDC configuration is feasible, there are only a few such schemes in service. The need for integration of large scale renewable generation, the electrification of oil- and gas-platforms from on shore grids, the integration of markets, has resulted in a demand for new transmission capacity and interconnectors. To meet this need consideration is being given to applications of more multi-terminal or meshed HVDC grids. The evolving Voltage Sourced HVDC (VSC HVDC) technology has made it easier to build such HVDC schemes.</p> <p>In 2009 SC B4 initiated WG B4-52 "HVDC Grid Feasibility Study", to investigate the feasibility of this concept. The WG has identified a number of issues that need to be studied to a greater level of details. Therefore, SC B4 is now proposing five additional WGs as follows:</p> <p>B4-56: Guidelines for the preparation of "connection agreements" or "Grid Codes" for HVDC Grids</p> <p>B4-57: Guide for the development of models for HVDC converters in a HVDC grid.</p> <p>B4-58: Load flow control and direct voltage control in a meshed HVDC Grid. - <b>This ToR</b></p> <p>B4-59: Protection of HVDC Grids.</p> <p>B4-60: Designing HVDC Grids for Optimal Reliability and Availability performance.</p> <p>These WG will use the information developed by B4-52 as their starting point. Their focus will be on the HVDC grids, and not on the HVAC network to which they are connected. However, ac/dc interaction issues, such as the real power changes injected/extracted from the ac network during dynamic and fault conditions will be identified, where appropriate.</p> <p>These WGs will consider HVDC Grid which are meshed, with some radial part, and possibly including sub-grids. The Grid may include balanced monopolar, monopolar and bipolar converters. A configuration and complexity similar to that of the proposed MEDGRID or Desertec HVDC Grids may be used.</p> <p>The majority of the work will be based on the use of VSC HVDC, but each WG will also discuss the impact of the use of LCC HVDC. Further WGs focusing on the use of LCC HVDC within an HVDC Grid may be started at a later date, if necessary.</p> <p>The output from these five WGs will also be of relevance to multi-terminal HVDC schemes being developed with the aim of allowing multiple converter station vendors.</p> <p>In a HVDC Grid the steady state power flow and voltage distribution is determined solely by the resistance of connections and the voltage difference between nodes. If the Grid consists of cable and overhead line connections, and the line ratings are determined according to the envisaged point to point needs, there is a risk that some lines may become overloaded, in case of outages of some lines. Additionally, efficient operation of the grid and the provision</p>	

of lowest cost converters depend on the direct voltage at the various nodes being controlled to be within a narrow band.

## Scope

The objective of the WG are to:

1. Confirm the feasibility of power flow control in the HVDC grids to meeting changing import and export needs at the HVDC Grid nodes
2. Identify methods and devices for controlling the power flow in HVDC grids.
3. Compare the merits of different methods and devices.

The WG will commence with an analysis of the potential steady state voltage profile and the power flows within a large conceptual HVDC Grid. The HVDC Grid will include both overhead line and cable segments. In some cases OHL and cable segments may be in parallel to each other, with the cable route potentially being of lower resistance than the OHL route. Parts of the grid will be primarily radial, whilst others will be heavily meshed. The import and export at each node will be varied to reflect changing needs.

Different locations of voltage controlling converter(s) will be examined. The impact of contingencies within the HVDC Grid (line, converter and switching station outages) will be considered. The use of passive devices, as well as DC/DC converters and series devices in some lines shall be considered. Methods to ensure that the power flow on lines is balanced to avoid overloading of lines in the event of tripping of other lines will be similarly examined. The voltage profile in the grid will be determined for the various conditions, and the rating for the individual lines will be determined. The investigation will conclude with a discussion of the relative advantages and disadvantages of the different options.

Recommendations for the voltage range to be used will be provided, taking into account overall costs.

The WG will then examine possible control strategies for dynamic load flow and dc voltage control for nodes and lines in the meshed HVDC Grid. Control strategies such as conventional control, the use of a single voltage controlling converter, control with several voltage controlling converters, voltage droop method, voltage margin method or a combination of these have in literature been proposed for multi-terminal HVDC links. Introduction of a dead-band for both the dc voltage controller and the power controllers will be considered. Some control strategies may be inadequate for HVDC Grid applications. The WG should thus describe these methods and identify which changes/developments would be required in a meshed HVDC grid application.

The control strategies should mainly focus on the near steady-state domain by proposing operating points in the form of VI-diagrams, leaving the slower control from dispatch optimisation and area error control to future work. The proposed control strategies must be able to secure a new stable operating point (within voltage limits and line capacities) after various disturbances such as trip of a converter, trip of DC line or sudden change in the power exchange between a converter and the DC grid. Assessment of transient behaviour is not considered within the scope of this WG.

The load flow in a multi-terminal HVDC link or in a HVDC Grid must be calculated by a DC power flow solver. The solution methods of DC power flow controller (such as sequential and combined approach) and constraint parameters (such as DC voltage range and DC line capacity), shall be described. If the control principles requires, the WG shall describe how the calculated power flows can be transmitted to all converter controllers for simultaneous change in the appropriate settings to achieve the desired load flow in the DC grid.

The WG shall consider the relative merits of central and de-centralised control of the HVDC

Grid, for small, medium size and large size Grids.

The control strategies must be designed for possible expansion scenarios of the HVDC Grid, such as addition of a new converter or a new dc line. This applies both to the load flow aspect and also to integrate a new converter in the VI diagram.

#### **Interaction with other B4 WGs and with other SCs**

Since the work in each HVDC Grid WG could impact on work in other parallel WGs it is proposed to take the following steps:

- A B4 Advisory Group will be set up to oversee, co-ordinate and advise the 5 WGs.
- Notes of meetings will be exchanged with the other WGs
- The draft WG documents will be made available to the other WGs
- A joint workshop between the WGs will be arranged during each SC B4 meeting, where members can exchange information and request assistance from other WGs, as appropriate.

Other SC's are invited to nominate experts with knowledge in this area to contribute to this WG, and their contribution will be acknowledged in the TB in the usual way.

#### **Deliverables and time schedule:**

Technical Brochure, Tutorial, Electra Paper

WG start 2011. Completion end 2013.

#### **Other SCs/ Target Groups concerned by the work:**

Transmission companies, Issuing bodies of Grid Codes, Manufacturers, Consultants, Academia

**Approval by Technical Committee Chairman: Klaus Fröhlich**

**Date :** 24/02/2011