CIGRE Study Committee B4

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG [1]N° B4. 85	**Name of Convenor:** Staffan Norrga (Sweden)
Technical Issues #[2]: 2-3-6-8-10	**Strategic Directions #[3]:** 1
The WG applies to distribution networks[4]: No	
Potential Benefit of WG work #[5]: 2-3-4	
Title of the Group: Interoperability in HVDC systems based on partially open-source software	

Scope, deliverables and proposed time schedule of the WG:

Background:

Currently, the vast majority of HVDC connections are of the point-to-point type. Typically, both converter stations in such a link are supplied by the same manufacturer, which simplifies the coordination of the control and protection systems. A way of reducing the number of converter stations and increasing reliability is to connect HVDC links together on the DC side into multiterminal DC (MTDC) systems. Eventually, these could be expanded into an HVDC grid which can offer even larger cost savings and reliability improvements, compared to point-to-point connections.
The behaviour of HVDC equipment, such as converter controls and protection IEDs is to a large extent defined by software. The existing control and protection software are all proprietary to the respective OEM (Original Equipment Manufacturer), and their functions (control block diagrams and parameters) are usually disclosed to a sufficient level to operate the HVDC converter(s). However, details are usually not known. This implies challenges in terms of interaction and interoperability of the involved converter stations and protection systems, as being investigated in CIGRE WG B4.81. Operating two or more converters from different manufacturers connected to the same AC busbar or DC network becomes challenging (see papers B4-104 Paris 2018, B4-40 Aalborg 2019). Oscillations and unstable behaviour may occur under steady-state, dynamic or transient operating conditions as it has been reported in some HVDC projects. Another significant challenge is the ability to adapt existing converter controls to suit new requirements occurring in the lifetime of HVDC systems (e.g. control retuning if new active components are installed in the vicinity of a link at a later stage).
At the same time, the competition between manufacturers of HVDC equipment has given rise to rapid innovation, which has brought significant benefits in terms of the performance of the software offered along with the hardware.

HVDC control and protection systems are commonly divided into upper-level and lower-level control functions. Upper-level controls are containing software elements that have the most impact on the external behaviour of the equipment. For an HVDC converter this concerns for instance the DC voltage control and active power control. Likewise, the lower level controls are containing software that handle internal processes of the equipment, such as circulating current controllers, cell capacitor-voltage balancing and pulse-width modulation, in the case of MMC-HVDC technology. They interact directly with the converter hardware, and is therefore mostly a concern of the supplier.

Standardisation of performance requirements as well as standardisation of certain interfaces and parameters governing the behaviour of the converter when interacting with other converters are important measures to enable interoperability. However rapid innovation still ongoing within HVDC VSC might however set limits on the possible scope of standardisation. With this working group, it may be possible to discuss the possible issues and countermeasures in different new applications such as connecting on the DC side to be part of DC grid or connecting on AC side to be part of multi-infeed. The countermeasure may eventually be defined as specific performance requirements.

Furthermore, standardisation of the interfaces between upper-level and lower-level control functions is an interesting option that could pave the way for more flexibility when selecting the software for the upper level control. The lower level controls will mostly be the realm of the concerned supplier, given that these interact directly with the converter hardware, which is specific to the supplier.

In particular, an efficient way of further enabling interoperability and adaptability is to use a combination of open-source and closed-source software elements. The open part will contain software elements that have the most impact on the external behaviour of the equipment i.e. the upper-level controls. The proprietary, and closed, parts may concern internal control and protection elements in the lower-level controls.

This proposal extends earlier work performed in CIGRE B4 (cf. TB604 where a standard control hierarchy was described) to investigate relevant borders between higher-level and lower level parts of these controls, as well as the relevant interface between them.

However, suppliers cannot be expected to share their existing proprietary HVDC control and protection software with the project developers, academia and others as this code represents years of R&D, past project experiences, adaptations to specific hardware design as well as intensive studies together with customers providing pre-conditions during specific projects. Notably, the use of open-source software for HVDC control and protection implies no requirements on the part of the suppliers to make their existing proprietary software open. Instead, alternative code bases for the upper-level controls could to be provided by other means, either commercial, or through open-source collaborative efforts. Furthermore, the mentioned use of partly open-source software does not imply that the existing paradigm with fully closed source software will cease to exist.

Verification could, for instance, be performed in a multi-vendor simulation setup where each vendor is responsible for the respective contribution fulfilling the agreed upon control strategy and information exchange with the other vendor(s) and the customer. A potential practical approach could be that a third party conducts the studies under NDA from the suppliers.

For a multiterminal HVDC grid, system protection will be an important issue, just like in an AC grid. A fault in the DC network may rapidly jeopardise the operation of the entire system if it is not cleared. Similarly, as for the control system, it is therefore proposed that the software within intelligent electronic devices (IEDs) for protection is investigated with regard to required information in a multivendor setup. In particular in fully-selective protection schemes using fast DC breakers, knowledge about the behaviour of different IEDs will be useful (e.g. algorithm design and software filter design). . Relevant information about the IED behaviour can preferably be open, while less relevant software elements can be closed-source. Therefore, it is important to define the necessary protection action time depending on the DC circuit setup which may be also be standardised e.g. with a specific current rate of rise.

Scope:

1. Define the necessary performance requirements depending on the relevant application pre-conditions such as multiterminal/DC grid applications or multi-infeed applications. In particular: Standardizing the DC grid fault current rate of rising and define the required protection action time accordingly.

2. Standardisation efforts of control and protection signal exchange / communication needed for interoperability between HVDC converters or other equipment in the grid.
3. Investigation of the suitable sectioning of the protection and control software into upper-level and lower-level controls, with the aim of facilitating interoperability.
4. Definition of suitable and practical interfaces between the upper-level and lower level control functions with regards to enabling interoperability.
5. HVDC converter control including open source software elements: in compliance with TB604. Which relevant border(s) can be drawn between open and proprietary controls? What are the requirements on each of them (accuracy, bandwidth, etc.)? How do the different controls translate and interface in a real system, or in HIL simulation, or in off-line simulation (for different types of models)?
6. HVDC protection using open source software elements: Which information is required in a multivendor setup (algorithm design, filter design, which parts of the hardware e.g. inductor)?
7. Define suitable verification approaches and tools for HVDC systems involving open-source software elements. In particular simulations, off–line as well as real-time and hardware-in-the-loop simulations.
8. Identification of suitable open-source software licenses for use in HVDC control and protection applications.
9. Investigate commercial aspects regarding the accountability of the system performance created by the use of open-source code for part of the control & protection code for the HVDC system.

Deliverables:

☒ Technical Brochure and Executive Summary in Electra

☒ Electra Report

☒ Tutorial[6]

☒ Webinar[6]

Time Schedule: start: Jan 1-2020 **Final Report**: July 1-2023

Approval by Technical Council Chair:

Date: December 14, 2019

Notes: [1] Working Group (WG) or Joint WG (JWG), [2] See attached Table 1, [3]See attached Table 2, [4] Delete as appropriate, [5] See attached Table 3,
[6] Presentation of the work done by the WG

Table 1: Technical Issues for creation of a new WG

1	Active Distribution Networks resulting in bidirectional power and data flows within distribution levels up to higher voltage networks
2	Digitalization of the Electric Power Units (EPU): Real-time data acquisition includes advanced metering, processing large data sets (Big Data), emerging technologies such as Internet of Things (IoT), 3D, virtual and augmented reality, secure and efficient telecommunication network
3	The growth of direct current (DC) and power electronics (PE) at all voltage levels and its impact on power quality, system control, system operation, system security, and standardisation
4	The need for the development and significant installation of energy storage systems, and electric transportation, considering the impact they can have on the power system development, operation and performance
5	New concepts for system operation, control and planning to take account of active customer interactions, and different generation types, and new technology solutions for active and reactive power flow control
6	New concepts for protection to respond to the developing grid and different generation characteristics
7	New concepts in all aspects of power systems to take into account increasing environmental constraints and to address relevant sustainable development goals.
8	New tools for system technical performance assessment, because of new Customer, Generator and Network characteristics
9	Increase of right of way capacity through the use of overhead, underground and submarine infrastructure, and its consequence on the technical performance and reliability of the network
10	An increasing need for keeping Stakeholders and Regulators aware of the technical and commercial consequences and keeping them engaged during the development of their future network

Table 2: Strategic directions of the Technical Council

1	The electrical power system of the future: respond to speed of changes in the industry
2	Making the best use of the existing systems
3	Focus on the environment and sustainability
4	Preparation of material readable for non-technical audience

Table 3: Potential benefit of work

1	Commercial, business, social and economic benefits for industry or the community can be identified as a direct result of this work
2	Existing or future high interest in the work from a wide range of stakeholders
3	Work is likely to contribute to new or revised industry standards or with other long term interest for the Electric Power Industry
4	State-of-the-art or innovative solutions or new technical directions
5	Guide or survey related to existing techniques; or an update on past work or previous Technical Brochures
6	Work likely to contribute to improved safety.
7	Work addressing environmental requirements and sustainable development goals.