Development of Functional Specifications for HVDC Grid Systems


(1) TU Darmstadt, Germany, {j.dragon, {jutta.hanson}@e5.tu-darmstadt.de
(2) Universidad Politecnica de Madrid, Spain, lbeites@etsii.upm.es
(3) ABB, Sweden, magnus.callavik@se.abb.com
(4) RWTH Aachen University, Germany, eichhoff@ifht.rwth-aachen.de
(5) TU Ilmenau, Germany, {anne-katrin.marten, [dirk.westermann]@tu-ilmenau.de
(6) DiGSIILENT Ibérica, Spain, a.morales@digisilentiberica.es
(7) Red Eléctrica de España, Spain, sisanz@ree.es
(8) Siemens AG, Germany, [frank.schettler], [stephan.wietzel], [marcus.zeller]@siemens.com
(9) Alstom Grid, UK, robert.whitehouse@alstom.com

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Abstract

Several processes have been initiated for the development of technical concepts, guidelines and common requirements of HVDC Grid Systems. For implementing extended HVDC Grid Systems on a multi-vendor basis consolidated and agreed functional requirements for equipment and solutions are needed. Providing such requirements is the role of international standardisation bodies.

With the primary focus on elaborating technical standards for HVDC Grid Systems, the CENELEC Technical Committee TC8X has started a new Working Group (WG06) “System Aspects of HVDC Grids”. Considering that Grid Systems are an entirely new application of HVDC technology, the first goal of this working group is elaborating a document describing clear functional specifications of different aspects for HVDC Grid Systems and associated equipment.

With view on the early stage of technology this paper discusses the need for standardisation and presents the scope and methodology of WG06. The approach chosen to develop functional specifications is explained using two examples. The main contribution of this paper is to present a methodology for and the challenges in developing standards in a new field of technology and to foster discussion.

1 Introduction

1.1 The need for functional specifications for HVDC Grid Systems

High Voltage Direct Current (HVDC) systems are gaining importance in the currently planned grid reinforcements throughout Europe. The state-of-the-art Voltage Sourced Converter (VSC) technology allows for necessary power transmission capabilities as well as the connection of multiple DC converters into an HVDC Grid System. The feasibility of HVDC Grid Systems has been investigated and in principle affirmed by Cigré working group B4-52 [1] as well as the European HVDC Study Group [2]. However, for the realisation of HVDC Grid Systems, system planners and owners would prefer to combine the solutions of different vendors within one HVDC Grid System. The development of standardised functional specifications for HVDC Grid Systems and the related equipment is seen as a key step towards the necessary multi-vendor and multi-user capability and thus the realisation of such HVDC Grid Systems.

1.2 WG 06 in the context of other related international activities

Several processes have been initiated for the development of technical concepts, guidelines and common requirements of HVDC Grid Systems. ENTSO-E, the European Network of Transmission System Operators for Electricity, has submitted the "Network Code on High Voltage Direct Current Connections and DC-connected Power Park Modules" to the European Agency for the Cooperation of Energy Regulators – ACER. The Code defines common rules for HVDC Systems and DC-connected Power Park Modules connected to the European power system [3]. The rules are applicable to the AC Connection Point(s) or the Interface Point of such systems. By nature, many of the requirements have direct or indirect implications on possible corresponding interface points on the DC grids, however, these aspects are not within the scope of this version of the Network Code. Furthermore, various requirements are categorized as being non-mandatory or non-exhaustive, meaning that some freedom is left to the national level for implementing the corresponding requirements.

In parallel, Cigré has initiated several working groups, amongst them Group B4-56 which develops connection guidelines for multi-terminal HVDC schemes and HVDC grids, and Cigré Working Group B4/C1.65 which intends to suggest common voltage levels for HVDC grids. Other important working groups in the field of HVDC grids are [4]:

- CIGRE WG B4 – 57, "Guide for the development of models for HVDC converters in a HVDC grid."
- CIGRE WG B4 – 58, "Devices for load flow control and methodologies for direct voltage control in a meshed HVDC Grid"
• CIGRE WG B4 – 59, "Control and Protection of HVDC Grids"
• CIGRE WG B4 – 60, "Designing HVDC Grids for Optimal Reliability and Availability performance"

At the point of writing, most of these working groups are expected to finalise their work and publish their Technical Brochures in 2014/15. The findings and conclusions of the working groups will be highly relevant for future HVDC Grid Systems, however, they will not constitute standards.

To overcome the constraints in the topic of the related activities as well as to develop a standard in a multi-lateral cooperation of different stakeholders, the CENELEC Technical Committee TC8x has started a new Working Group (WG06) “System Aspects of HVDC Grids”. At the time of writing, the group consists of 36 members, thereof 10 representing manufacturers of HVDC systems and simulation software, 10 representing TSOs, 12 representing universities and 4 from other organisations.

The first goal of this working group is to elaborate a document describing clear functional requirements for all relevant aspects of HVDC Grid Systems and associated equipment. The requirements will be summarized in a Functional Specification document intended to serve as a reliable guideline for planning, specifying and constructing HVDC applications having the potential for future HVDC circuit expansions including their possible integration into a pan-European HVDC grid. This will contribute to developing the market for such HVDC grid applications and will thus be supporting corresponding HVDC projects. Real projects are expected to provide practical experience which is seen a prerequisite for developing technical standards. Thus, the introduction of Functional Specifications is an important intermediate step on the way to technical standards in a new field of technology.

1.3 Structure of this paper

Section 2 presents the methodology that the working group is currently following to develop functional requirements for HVDC Grid Systems. In the following, two examples are presented to illustrate the methodology and show first results of the working group’s activities. In section 3, the effects of DC faults will be described. These effects are heavily dependent on DC fault-clearing schemes and thus an aspect related to hardware requirements. In section 4, another example will be given related to requirements regarding the operation of HVDC grids. A possible hierarchal structure for secure and coordinated operation of multi-terminal or meshed HVDC grids will be presented.

2 Methodology

2.1 Scope and Structure

The team goal of WG 06 is the elaboration of standards for HVDC Grid Systems on a European level. To this end, the following objectives will be pursued in chronological order:
• Elaborating Technical Guidelines and Functional Specifications for HVDC Grid Systems which are characterized by having exactly one single connection between two converter stations, often referred to as radial systems
• Elaborating technical Guidelines and Functional Specifications including applications in meshed HVDC Grid Systems
• Identification of items for HVDC Grid System standardisation
• Elaboration of the HVDC Grid System standards

In order to deal with the comprehensive topic in an efficient way, five subgroups have been formed inside WG06 dealing with different aspects of HVDC Grid Systems, as there are:
• Coordination of HVDC Grid and AC Systems
• HVDC Grid Control
• HVDC Grid Protection
• AC/DC Converter Stations
• Models, Validation and Testing

The focus is set on radial systems first, as such systems are expected to be realised soon and providing timely results for the first projects is of the essence. When developing the requirements for radial systems, care will be taken not to create technical obstructions for meshed systems.

The core parts of a Functional Specification are systematic and well defined parameters associated with recommended or even standardised parameter values. Reflecting the early stage of technology, a Functional Specification for HVDC Grid Systems will also need comprehensive explanations and background information for the parameters. This dual character of the content will be represented by the Functional Specification being divided into two corresponding parts:
• Part I "Concepts and Guidelines" containing the explanations and the background information
• Part II "Operating Conditions and Performance Requirements" containing the essential parameter lists and values describing properties of the AC respectively DC system (operating conditions) and parameters describing the performance of the newly installed component (performance requirements).

Both parts are planned to have the same outline and headlines to aid the reader.

2.2 Working approach

For defining the scope and structuring the Functional Specification documents, WG06 started collecting and analysing the existing publications including those by Cigré and CENELEC [1], [2], [4]. As a first milestone this information was used to develop a complete outline of the Functional Specification as well as comprehensive parameter lists. Developing the parameter lists at the beginning is intended to provide a clear guideline for identifying where reference can be made to existing publications or further conceptual work would be needed.

The primary objective at the present working stage is identifying and defining technical parameters which precisely describe the required functions of systems as well as the equipment in a systematic way. The determination of values
for the respective parameters will be done later. Subgroups within WG06 have already started elaborating the background
descriptions (Part I) of the Functional Specification and the parameter lists (Part II) are currently being developed.

Liaising with active working groups, e.g. at Cigré, has been very important in order to benefit from the latest findings of a powerful community of worldwide research and development.

Important stakeholders in the process of elaborating the Functional Specifications are the Transmission System Operators (TSO). TSOs such as REE, RTE, Terna and 50Hertz are active contributors to WG06 and new members are always welcome. WG06 has already started building up a close relationship with the European Network of Transmission System Operators for Electricity (ENTSO-E) as the representative of all electric TSOs in Europe. A first workshop of ENTSO-E's Working Group 'Standardisation' of the Research & Development Committee and WG06 took place in June 2014. The workshop was considered a useful exercise and it was decided to continue the collaboration and have meetings on a regular basis.

As a means of keeping all Stakeholders informed and involved with the process, at the point of writing WG06 intends to publish first parts of the Functional Specification by end of 2014 as a Document for Comments inside CENELEC. Updates are planned on a yearly basis.

3 Example: Effect of DC faults

3.1 Systematics of DC fault clearing schemes

DC insulation faults can happen for various reasons and they affect the power flow in the transmission system due to disturbances of the DC circuit voltages and currents as well as the voltages and currents of the connected AC systems. The disturbances depend on a multitude of factors such as:

- the fault type (line-to-line, line-to-ground)
- the DC voltage polarity (symmetric monopole, asymmetric monopole or bipole)
- the DC circuit earthing
- electrical system properties (line length, resistivity, capacity, reactances)
- the existence of concentrated DC capacitors or DC filters
- possible additional equipment such as overcurrent limiters
- the fault clearing scheme applied

As a first example for illustrating how WG06 develops the Functional Specifications for HVDC Grid Systems, the influence of the fault clearing scheme shall be considered here.

The key functions of the fault clearing scheme are to break DC fault currents and to isolate the faulty part. This is to prepare the transmission system for power recovery and commence normal operation.

There is very limited experience with fault clearing in HVDC Grid Systems today, various fault clearing concepts have been proposed and more can be expected in the future. This situation calls for a systematic approach of structuring all the different concepts in a technology independent way. As physics is the common ground of all technologies, WG06 has focused first on identifying technical categories covering important physical aspects relevant to the matter of fault clearing in HVDC systems. Such a structure will visualise the technical features of the various concepts as well as their relationship to one another. If the physical concepts are represented completely, all technical solutions developed in the future should find their place according to the categories defined. Elaborating sustainable systematics in this way is seen a key step to future standardisation work.

A systematics for DC fault clearing is shown in Fig 1. It represents the present findings of WG06 and may be developed further. The following categories have been defined as shown from top to bottom:

- Fault-location. Here, only DC line faults are considered. Faults inside the converter station cannot be presented in detail.
- Fault separation time: this time is defined as time between fault detection and fault isolation. From today's point of view, three typical groups of response times can be distinguished: schemes acting in the range of microseconds, schemes acting in the range of milliseconds and schemes requiring several cycles of the AC system power frequency.
- Location of fault clearing / fault controlling device: The protective devices can be located either in a DC line feeder inside the HVDC Grid System, a DC/DC converter station or an AC/DC converter station.

To date, the following fault clearing schemes have been identified:

- Electronic DC Breakers, Hybrid DC Breakers [5], AC Breaker and Disconnector [6], Mechanical DC Breakers, AC/DC or DC/DC Converters [7]. Depending of the position of the equipment, additional fast or ultra-fast disconnectors will be needed. In the following, just two of these schemes will be explained in further detail.

All of the proposed schemes have their merits and drawbacks, and WG06 does not intend to promote any technology. Instead, its intention is to clearly describe the effects of any such equipment on the system behaviour in a standardised way. This will facilitate the TSO’s task of describing the required performance. In addition, the clear description of operating conditions will enable manufacturers to calculate their equipment’s performance.

3.2 Effects of DC fault clearing schemes on voltages and currents

The various fault clearing schemes can be further described by their influence on the DC and AC side voltages and currents.
In order to do this in a comparable way, WG06 identifies common reference frames for describing the physical behaviour of the fault clearing schemes. Describing the influence of a scheme on the fault current in the DC system, a qualitative fault current wave shape can be defined. In order to be appropriate for all technical concepts, this wave shape should exhibit all physical phenomena determining DC fault currents in a qualitative way. Not all of these physical phenomena need to be present in a given system, but using a generic wave shape allows the deduction of parameters for all possible systems. As identified by [2] two contributions can be distinguished for any DC fault current:

- Discharge current of the passive components of the HVDC Grid Systems (DC lines, cables, capacitors, DC filters)
- Currents fed by the converters

These contributions are reflected in Fig. 2 in a qualitative manner, assuming there is no influence of any fault clearing scheme. The generic “undisturbed” fault current wave shape can be described by a number of specific parameters, as there are:

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Unit</th>
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<tbody>
<tr>
<td>$I_{\text{peak}}$</td>
<td>peak short circuit current</td>
<td>kA</td>
</tr>
<tr>
<td>$I_{\text{steady}}$</td>
<td>steady state DC fault current</td>
<td>kA</td>
</tr>
<tr>
<td>$\frac{\text{d}I}{\text{d}t}$</td>
<td>average rate of change of DC fault current</td>
<td>kA/s</td>
</tr>
<tr>
<td>$\frac{\text{d}I}{\text{d}t}_{\text{init}}$</td>
<td>initial rate of change of DC fault current</td>
<td>kA/s</td>
</tr>
</tbody>
</table>

The real fault current will depend on the fault clearing scheme as well as the measurement location. However, the systematics described above will allow specifying the fault behaviour at any point of interest in the HVDC Grid System in a defined way. The specification may describe the duties of equipment, e.g. the fault current stresses of a reactor, or it may describe the performance requirements, e.g. the fault current contributions requested from a converter.

Fig. 2: Qualitative DC fault current for parameter definition

As an example, in the following the effects of a fault-clearing scheme with AC breaker and DC disconnector will be compared to the scheme with fault current-controlling converters.

For the AC breaker scheme, the AC breaker on the AC side of the converter station will open after the fault detection. The fault separation time is in the range of several AC frequency cycles.
cycles (typically three cycles). After the opening of the AC breaker, DC fault current will continue to flow through the DC inductance and the converter module diodes until dissipated by the circuit resistance. In practice the current decay time constant (L/R) is typically several hundred milliseconds and therefore the DC current will take up to several seconds to reach zero. The isolation of the faulty line can be carried out by disconnectors after the decay of the fault-current, or by breakers with a certain DC current breaking capability, with the latter resulting in a significantly shortened fault separation time. Recovery actions for the remaining system can only begin after the faulty part is separated.

An alternative to the described technology is the use of fault-current controlling converters [7]. They have the ability to change control mode when a DC side fault is detected. Thus, the DC disturbance will affect the AC side voltage only for a short time before the converter station detects the fault and acts to reduce the DC fault current to zero. This has the advantage that the converter will remove the energy “trapped” in the DC system.

The removal of the “trapped” energy, and the rapid reduction of DC current to zero, allow for a quick isolation of the faulty line using fast disconnectors and a quicker recovery of the remaining system. While the DC current is controlled to zero, the converter could be able to provide reactive power to support the AC voltage.

![AC Breaker and DC Disconnector Scheme](image)

### Example: Operation of HVDC Grid Systems

The operation of HVDC grid systems represents an aspect that is less specific to hardware. As with the previous example, this topic needs to be structured at first. On the one hand, it may refer to different “Operating Conditions” that can be classified analogously to what is known from AC grids, namely:

- **Normal:** all operating points can be obtained continuously without violating equipment limits
- **Alert:** all operating points can be obtained (during contingency situations) by invoking elevated temporary limits
- **Emergency:** only reduced operation according to short-term limits possible due to severe contingencies,
- **Critical / Collapse:** load flow interruption imminent, protective action required

On the other hand, the operational point of view is strongly related with “HVDC Grid Control”. However, this term refers to not one, but several control functionalities. Again, these

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Unit</th>
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<tbody>
<tr>
<td>( I_{\text{max}} )</td>
<td>maximum short-circuit current</td>
<td>kA</td>
</tr>
<tr>
<td>( t_{\text{separation}} )</td>
<td>Time between fault detection and fault separation</td>
<td>s</td>
</tr>
<tr>
<td>( t_{\text{break}} )</td>
<td>Time between fault detection and starting the breaking action</td>
<td>s</td>
</tr>
</tbody>
</table>

The shown systematics and parameter lists are not complete. WG06 is in the process of completing the shown description. Additional aspects need to be covered and specified, which include:

- Additional fault-clearing schemes
- Recovery of the remaining HVDC Grid System
- System behaviour in case of overhead line faults
- Effects on DC voltage, AC voltages and AC currents
- Evaluation of fault behaviour with respect to the affected area for different time ranges

The goal has to be a guideline specifying DC fault clearing schemes which cover multivendor aspects.
may be classified with respect to various categories and may even depend on the actual operating conditions in the interconnection of AC and DC systems. Therefore, WG06 sorts the variety of possible controllers by the following criteria:

- Hierarchy / precedence
- Control approach (open- vs. closed-loop)
- Implementation (local vs. central)
- Time range (fast to slow)
- Available data (local vs. global)
- Range of effect (near to broad/remote)

One of the apparent consequences from this structured approach is the fact that a holistic definition of performance requirements is of little use; however, these need to be defined for distinct functionalities of HVDC grid control. Fig. 4 provides an overview over the controller hierarchy as proposed by WG06, where the general level of hierarchy of each control is illustrated against its typical time range of operation. The used terminology and structure is thereby in line with the concepts elaborated by Cigré WG B4.58 [8] and is further outlined in the following:

**AC/DC Grid Control:** This level of control represents the broadest range of effect as it is concerned with the combination of both AC and DC load flow. To this end, the parameters and requirements defining the joint “power schedule” that needs to be dispatched on a regular time basis have to be specified here. It should be noted that this layer is therefore influenced not only by technical but also by economic considerations.

**Internal controls:** Contrary to the above AC/DC grid control, the internal controls of all AC/DC converter stations are purely local and represent the lower-most end of controls in each HVDC grid system. Due to their nature, these controls are considered fast, but also highly vendor-dependent as they describe the actual switching of the converter valves and their effective scheme for controlling all currents. Nevertheless, the interaction with higher-level controls can be specified sufficiently well by the voltage/current conditions at the converter arms and its maximum time range of operation in order to ensure a decoupling with the other higher-level controls.

**Node Voltage Control:** Directly on top of the internal converter controls, the so-called (DC) node voltage control defines the actual target of the internal controls and the algorithmic means by which the corresponding set values for these should be achieved. Comparing with AC grids, this level may therefore be thought of as being the primary control in DC systems and could be referred to as the actual “control mode” of each converter in the HVDC grid system, e.g. whether the converter is controlling directly DC node voltage or its active power. Note that the functional specification of these controllers will be exemplified in more detail below.

**Coordinated System Control:** In between the fast control characteristics of the individual converters on the one hand and the overall AC/DC grid operation providing schedules on the other hand, many aspects related to phenomena in an intermediate time range still have to be covered by appropriate mechanisms, generally termed as “coordinated system control”. It should be noted that these controls are in the particular focus of WG06’s specification work due to the challenges emerging from HVDC grid systems in terms of a timely coordination of all converters in case of unscheduled events in the transmission system. Due to the unclear evolution in this field, both Autonomous Adaptation Controls [9](with little need for communication) as well as HVDC Grid Controller concepts (with presumably global knowledge) are considered here. Nonetheless, the developed specification has to be designed so as to account for any combination of functions from both sub-hierarchies, since this is expected to be the most likely form of controller structures.
4.1 Approach for Functional Specification using Node Voltage Control as an example

Within operation of HVDC grid systems, the so-called (DC) node voltage control level is a very good example to explain the need for functional specifications. This is due to the fact that the DC voltage at each node in the grid can be interpreted as the indicator of energy balance, analogously to the system frequency in AC grids. The capacitances throughout the DC grid system can be therefore be seen as the equivalent to rotating masses in AC grids, defining their frequency behaviour by the associated amount of inertia. Depending on the line configuration and the utilized converter technology, there can be a considerable variation in the capacitance in the HVDC grid. However, since both line resistances as well as the total capacitance in HVDC grids are typically quite small (as compared to the transmitted power), the system behaviour during and after energy imbalances is significantly faster than in AC grids. Therefore, the primary controls in HVDC grid systems are also required to respond much faster to energy imbalances than in AC systems.

In order to provide a safe operation of the whole HVDC grid, the DC system voltage needs to be maintained within certain limits defining steady-state operating conditions. To this end, at least one converter station in the system has to regulate the DC voltage to its reference value. For conceptual simplicity, this task could be realized by equipping a single converter of the entire HVDC grid system with a local DC voltage control using only local (or one central) voltage measurement information. However, this implies that this converter and its connected AC point of common coupling are capable of balancing any possible power imbalances, sometimes referred to as a “slack bus” – a requirement that surely cannot be provided for an increasing number of converter stations. Therefore, it may be better to distribute the grid’s DC voltage balancing controls among multiple converters due to both economic and reliability concerns.

Another conclusion that is always drawn from comparing AC to DC grids is the equivalence of angular difference in AC voltages at two different nodes and local deviations in DC voltage as in both cases these are responsible for driving the corresponding power flows. Due to this, the presence of small differences in DC voltage among all nodes of the HDC grid system is inherent, such that it is not reasonable to include an integral control for DC voltage control concepts based on local voltage measurements. However, such secondary control could be implemented in addition, e.g., by declaring the voltage at a specific node as reference or by generating an average value of all DC voltage information available in the grid system. Furthermore, a tertiary control instance defining optimal DC node voltage reference values may be reasonable as part of the AC/DC grid control or an HVDC grid controller.

Considering only primary DC node voltage control, different approaches using local characteristics have been studied intensively in the literature. Moreover, several of these concepts have also been compared and discussed in [8] and in the European HVDC Study Group [2]. Just for clarification, the typical node voltage control concepts could be differentiated as listed below:

- constant voltage control
- constant power control
- droop control
- droop control including “deadbands”
- droop control with section-wise droop definitions

It is not the task of WG06 to promote one method over the other, but to define performance requirements that have to be met by the respective control method(s) in order to ensure a stable and reliable system behaviour even in multi-vendor HVDC grid systems.

4.1.1 Operating Conditions

Regarding the above descriptions, two main operating conditions can be found in order to describe the behaviour of HVDC grid systems. On the one hand, the DC line resistances, inductances and the total capacitance in the transmission system are observed as a significant influencing factor on the dynamic behaviour. On the other hand, the chosen control mode of all DC nodes (converter stations) determines the fundamental response in both stationary and dynamic cases. Hence, most influencing factors for the stationary and dynamic behaviour regarding DC node voltage control are

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{DC} )</td>
<td>Line resistance(s) of DC system</td>
<td>( \Omega )</td>
</tr>
<tr>
<td>( C_{DC} )</td>
<td>Capacitance of DC system</td>
<td>( \mu F )</td>
</tr>
<tr>
<td>( L_{DC} )</td>
<td>Line inductance(s) of DC system</td>
<td>( mH )</td>
</tr>
<tr>
<td>CM</td>
<td>(set of all) Control modes</td>
<td>Integer</td>
</tr>
</tbody>
</table>

4.1.2 Performance Requirements

For the operation of HVDC grid systems, there will always be the interaction of the above node voltage concepts with some higher-level set point controls. For instance, the relevant set points may be received directly from the AC/DC Grid Control level or modified versions may be obtained through the Coordinated System Control layer (once again see Fig. 4). However, a (sudden) change from one set point to another will results in some step response of the whole transmission system.

Depending on the parameter settings of the converter control this might lead to oscillations between converters on the lines of the DC transmission system. The cause for these oscillations is the interaction of the converter control with all capacitances and inductances in the HVDC grid system. In particular, this problem is likely to occur whenever grid parameters change due to topology changes or after introducing new technologies without proper adjustments of all existing control equipment (e.g. multi-vendor situation). Since oscillations have to be avoided or at least well-damped, this results in certain requirements for all active nodes (i.e. DC voltage regulating AC/DC converters) involved in the operation of HVDC grid systems. On the other hand, the average value of all DC voltage deviations may be seen as another important indicator of the grid.
performance, since any disturbance in DC energy balance will inevitably lead to a deviation in DC voltage at the nodes. Hence, a smaller mean DC voltage deviation during steady-state relates to an improved controller performance. Summarizing this section, the following parameters appear essential for characterizing a reliable and stable behaviour of all grid equipment:

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta U_{\text{DC,mean}}$</td>
<td>Mean voltage deviation between DC node voltage and DC node reference voltage among the entire DC grid after primary DC node voltage control (stationary)</td>
<td>kV</td>
</tr>
<tr>
<td>$\dot{U}_{\text{DC,osc}}$</td>
<td>Maximum voltage oscillation amplitude (“overshoot”) in consequence of DC node voltage control</td>
<td>kV</td>
</tr>
<tr>
<td>$T_{\text{DC,osc, damp}}$</td>
<td>Damping time (“settling time”) for oscillations in DC node voltage control</td>
<td>s</td>
</tr>
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</table>

5 Conclusion and Outlook

In this publication, the need for standardization for HVDC Grid Systems has been presented. From an overview of the ongoing activities in the field, it can be deducted that CENELEC Working Group TC8x WG06 is crucial for creating clear Functional Specifications for many aspects of HVDC Grid Systems. The methodology for the Functional Specification has been explained in general. Two examples have been presented to give a more practical understanding of the goal and challenges of WG06’s work. It was shown that both fault-clearing schemes and DC voltage control strategies are very complex topics and all need to be structured. The presented structures don’t claim to be exhaustive. Further on, the paper shows how parameters can be deducted for both Operating Conditions and Functional Requirements. Some parameters apply to all categories for example of the fault-clearing schemes, but in addition some specific parameters need to be identified for certain types of equipment.

With the intended publishing of first parts of the Functional Specification by end of 2014 as a Document for Comments inside CENELEC, WG06 follows an ambitious timeline. However, due to the complexity of the topics and the number of stakeholders involved, not all aspects will be covered in this first Functional Specification. Updates are planned on a yearly basis. Due to the complexity and number of aspects that need to be considered, the authors would like to encourage interested stakeholders to contribute to this working group. Commonly agreed definitions of Operating Conditions and Performance Requirements will not only enable the development of HVDC Grid Systems, but also facilitate communication between all stakeholders both in scientific discussions and project execution.

References