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Annex: HVDC Code comments

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Introduction

This letter provides comments on the public consultation on the Elia grid code for HVDC. Given the experience of our research group in the field, we found it important to highlight the possible issues with the current version as proposed by Elia.
We are aware that the current version builds on the ENTSO-E grid code, and no fundamental changes to that grid code are made. Some of the comments made below relate indirectly to the ENTSO-E grid code, or to Elia's interpretation of this code.

We have also included some limited comments to the DCC code.

We would be happy to provide further details on the statements made below when deemed necessary.

General comments

As a general note, the grid code is specifically favouring the installation of one technology, the voltage source converter (VSC). However, an LCC-based HVDC installation can also be considered for some of the HVDC-link schemes defined in the code. This is specifically seen in those articles defining any reactive and active power controllability with specified times because the LCC is slower than the VSC. Also, this is applicable to the FRT or voltage control requirements. If the requirements are defined as now, this will increase the cost of an LCC-based HVDC link because of the required use of more advanced technologies to compensate the reactive power, which might not otherwise be necessary. Particularly, most of the LCC-based HVDC links installed up to date do not make use of such reactive power installations - this is based on experience from this kind of installation developed for more than 20 years. More generally, technology is evolving, and new types of technology are continuously developed, potentially leading to completely "new" converter types that behave fundamentally different from "traditional" converters. For example, the dynamic behaviour of the 2-level converter differs from the MMC, and future converter types might differ also. This might lead to cost reductions (e.g. Diode rectifier units, DRU, for offshore connections and MMC converters with DC fault blocking capability). These evolutions might lead to a significant decrease of cost (DRU) or increase of possibilities (FB MMC).

As a second note, some requirements are interacting with ancillary services markets (voltage control, black start, frequency control and, probably, a future synthetic inertia market). Despite the technical capabilities of the technology to fulfil the technical requirements, the future HVDC station will usually be a TSO-owned asset and the use of those capabilities will interact in the mentioned markets, thereby potentially adversely affecting other installations participating in these markets. As ancillary services markets are expected to undergo several changes in the upcoming years, it would be prudent to avoid creating a grid code that might hinder the development of such markets.

Furthermore, it is important to note that the grid code should be equally open to TSO projects as to merchant projects. We feel the latter might be overregulated or could be potentially blocked due to the possibility to create too stringent limits.

Page 7: 'Current HVDC knowledge and translation of this knowledge in general or site-specific requirements'. We believe the maturity of HVDC is grossly underestimated.

- Elia's HVDC experience might be limited still, but it cannot be said that current HVDC experience/knowledge is limited. HVDC systems have been in operation for over 60 years.
- HVDC VSC is not “experimental” - perhaps this was true when the ENTSO-E grid code was drafted, but it is not the case today.
- Elia Group including 50Hertz has HVDC experience.
- Academic research is not in the early stages, quite the contrary: although specific research is still needed, there is much work already done. One example of this: it should be considered how existing knowledge regarding AC/DC interactions might be extended and acted upon.

Specific comments on the grid code and comments on particular articles

Reference to RSO can be removed throughout. Are these regional operation centres, and are they the same as an RST?
Reference to “relevant TSO” throughout unnecessary.

2.1.2.4:

- 10 ms seems arbitrary (no technical requirement to be so fast), although we are aware of the fact that the number comes from the ENTSO-E code.

2.1.2.5 Active power reversal

- The requirement of active power reversal in less than 2 s may limit the HVDC technologies which can be used.

2.1.2.6:

- Is it necessary to always have automatic remedial actions in the grid code? Seems that this could be too strict. Aren't these ancillary services? There is some technical requirement for this within the grid code - doesn't this interfere with the ancillary services / markets? If it is a market product, activation should be done according to the market rules.

2.1.3.2:

- Synthetic inertia - Is this really 'site specific'? Not a local problem, but a system problem - perhaps project specific?

2.1.4:

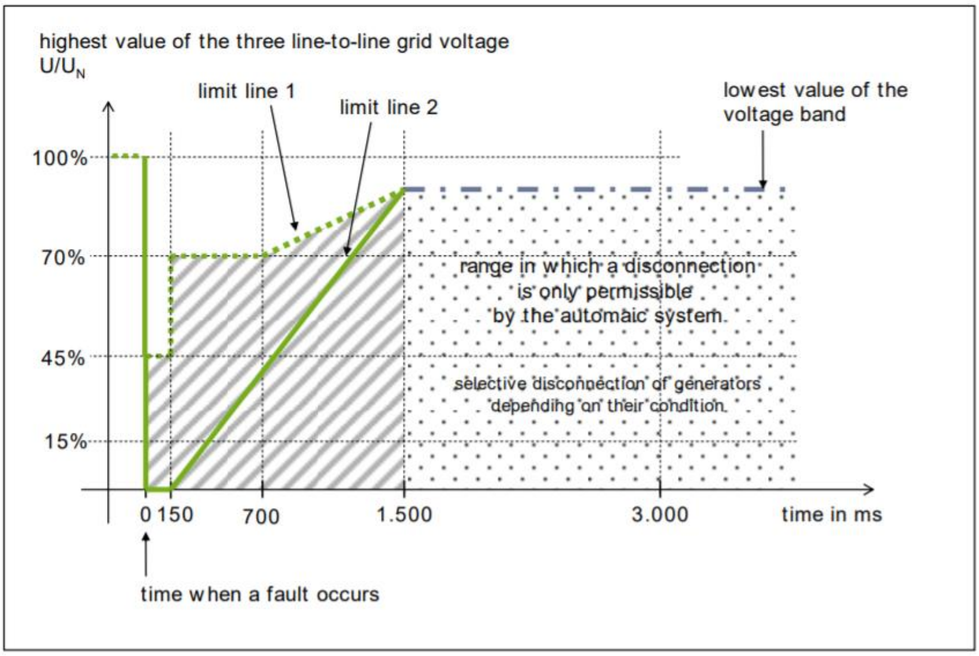
- Comment on ancillary services as above (comment on 2.1.2.6).

2.1.6:

- To allow for different options towards multi-terminal extension, the parameter “specify limit for maximum loss of active power” could be extended with an interval during which this active power is lost. The interval specification during which the active power is lost, is considered in standardization working groups (CENELEC) and is an ongoing topic within research (Promotion, Abedrabbo et al.).
  (CENELEC) CENELEC TC 8X/WG 06, "System Aspects of HVDC Grids," 2016.
  (Promotion) Promotion WP 4, “D4.2 – Broad comparison of fault clearing strategies for DC grids”, Final Report, 2017
  (Abedrabbo et al) M. Abedrabbo et al., "Impact of DC grid contingencies on AC system stability," in Proc. 13th IET International Conference on AC and DC Power Transmission (ACDC 2017), Manchester, UK, Feb. 2017, 7 pages.

2.2.1.4:

- This is a significant fault ride though period - 3 seconds is a very long time and perhaps this could block technology. Why is the period taken to be 3 seconds? Technology-wise, this is possible, but it comes at a cost. Compared to other grid codes, this seems a stringent limit, and quite slow (below a comparison to Tennet is included – a European TSO with extensive experience with HVDC). It would be preferable to reduce the mandatory recovery time and have longer conditions in site specific cases.



[Tennet grid code - High and extra high voltage – 2015]

2.2.5.2 Reactive power control mode

- (b) STATCOM mode: Under given events, such as a DC link fault, this requirement is not possible unless the use of a very specific converter configuration (not available with all HVDC

manufacturers) or the installation of additional equipment to both disconnect the line and supply voltage to the converter DC side.
- 'All previously specified' is not clear. Is this 'in this article'?

2.2.5.4:
- 'of the change of reactive power' - we assume that this relates to the time constant of the controllers, but it must be clarified.

2.2.5.5:
- 'range of 99%' - this should be ±1%. This is very unclear and should be rephrased.

2.2.6.1:
- What is 'low and high voltage' - is this defined?

2.2.7.1:
- As a general practice in industry, it is the responsibility of the TSO to ensure that the harmonic voltage distortion level is below the planning level at all nodes where customers are connected. This is a practice used in all the international IEC standards or IEEE recommended practices, see IEC 61000 or IEEE 519-2014. In both documents, distribution equipment is only required to ensure a given harmonic current distortion level below to the defined limits. The code states that 'the level of allowed distortion or fluctuation of the supply voltage on the network at the connection point of a transmission-connected demand facility will not alter from what is stated in article 46 of the current Federal Grid Code'. However, the level of allowed distortion of the supply voltage is set by the TSO harmonic planning levels and, consequently, it is a responsibility of the TSO. This can be controlled, as it is typically the case, by allowing a lower maximum admissible harmonic current injection limits from the load installation. However, this article is directly giving the responsibility of the harmonic voltage distortion to the load, against international standards and practices.

2.3.1.1:
- How does this differ from 2.2.1.4?

2.3.1.5 FRT capability
- Point (a) is defining a very specific control philosophy to the converter. The way how the converter is controlled (or whether it has a current controller) should be a decision of the manufacturer based on its experience and practice. The requirement should only request for the controllability of positive and negative sequence components during a fault instead of 'there shall be separate positive and negative sequence current controllers'. As an additional note, during an asymmetrical fault, it may be also desired to control the negative sequence of the voltage (not stated here). For this reason, we suggest to define it more generically to avoid giving an unfair competitive advantage to certain manufacturers.
- Point (c) is not clear because the HVDC converter needs to make use of a second harmonic current in order to control the negative sequence during the asymmetrical fault. We imagine that the objective of this point is to require that this event does not result in any transfer of a distortion through the DC link, but this is not clear from the text. However, as the grid code is only related to the interaction with the AC side, the operation at the DC side should not be defined here.

2.4. Requirements for control - Network characteristics
- We find that the code should give some indications about network characteristics in order to already face, obtain and prepare the models to be used in future connections. Particularly, different interactions and dynamics from different equipment will have an influence in the network characteristics at the relevant point of connection. The code should define the type of studies which need to be conducted in order to allow and request the necessary models to all

the stakeholders as specified in Article 27. These network characteristics must contain, but not be limited to, short circuit analysis, phasor-domain, voltage stability and harmonic studies. As a particular experience in our research group, the harmonic network models must be well represented in a sufficiently wide frequency spectrum, extended to frequencies higher than the limits defined at present in IEC 61000 standards. We consider that by setting some guidelines here, efforts and the necessary improvements in developing the necessary tools and methodologies will be triggered. However, by setting now vague indications, the relevant external parties (tool developers, manufacturers, or operators...) will not have the incentive to provide and conduct necessary modifications and improvements.

2.4.1.1:

- Clarify voltage constraints in the last sentence - what level is this? This is unclear. Deviation should be maximum 5%! Please note that it is also wrongly phrased in the ENTSO-E grid code.

2.4.6.2 Network characteristics:

- What are the items that should be specified? Contain but are not limited to: harmonic impedance of the transmission grid up to sufficiently high frequencies.
- This is an unusual specification to include in a grid code.

2.5.1.1:

- 'Proof that the system owner will demonstrate that protection system… has not been used in other similar installations'. This is overly restrictive and should be deleted.

2.5.2.1:

- 3 months seems very slow for Elia to review a protection and control scheme. This should be project specific.

Section 3:

- There are many proposals for the technology for future wind farm connections with HVDC (e.g. Diode Rectifier Unit…). This requirement could be blocking novel technologies and should be restricted. Different technologies fundamentally change this whole section.

4.1.1.1:

- Why would the TSO set the control hierarchy? Again, this raises questions on implicitly favouring manufacturer-specific implementations. What level of controller is meant here-dispatch? This should be clarified or removed.

4.1.1.2:

- Operation should follow the other grid codes. More specifically, it is expected that the HVDC link is either a regulated link, and will follow the ENTSO-E network codes on system operations, emergency and restoration, Forward Capacity allocation, electricity balancing and Capacity allocation & Congestion Management.

4.1.4.1:

- RST - what is this? Should this be RSO?
- Under what conditions are these models provided? Should this be under NDA?
- Mutual agreement on how detailed this should be – ‘of sufficient detail’?

HVDC non-exhaustive requirements

POWER QUALITY - 'specify voltage and distortion limits'

- In this document, as well in other grid codes, such as the DCC code, harmonic limits are defined to the connectee by the maximum allowable voltage distortion limits. As a general practice in the industry, it is the responsibility of the TSO to ensure that the harmonic voltage distortion level is below the planning level at all nodes where customers, or other types of connectees, are connected. This is a practice used in the international IEC standards or IEEE recommended practices, see IEC 61000 or IEEE 519-2014. In both documents, connected installations are only required to ensure a given harmonic current distortion level below to the defined limits. The DCC code states that 'the level of allowed distortion or fluctuation of the supply voltage on the network at the connection point of a transmission-connected demand facility will not alter from what is stated in article 46 of the current Federal Grid Code', The HVDC code is giving the same message by 'specify voltage and distortion limits'. However, the level of allowed distortion of the supply voltage is set by the TSO harmonic planning levels and, consequently, it is a responsibility of the TSO. This can be controlled, as it is typically the case, by allowing a lower maximum admissible harmonic current injection limits from the installation. However, this requirement is directly giving the responsibility of the harmonic voltage distortion to the connected installation, against all international standards and practices.

‘HVDC system owner’

- Throughout the text, the description 'HVDC system owner' is used to describe the technology vendor and manufacturer. This is very confusing because the vendor does not own and utilise the installation, nor does it control the requested features to provide ancillary services in the AC system.

DCC Code

1.2. HV requirements

- The code details that HV equipment has proven the capability to withstand the required voltage levels in the article. However, it is not clear whether all the different load technologies could withstand and operate correctly under the required voltage levels. Or, this requirement would result in overrating the installation. As a general practice, operators hold the responsibility to ensure sufficient quality in the voltage in order to supply loads in the most effective way. Therefore, this requirement is forcing installations to withstand the maximum levels defined for HV equipment. Whereas, from the connectees point of view, it should be the TSO who must operate within the voltage limits that connectees can withstand.

1.4.2 Reactive requirements

- This requirement decreases the maximum reactive import at demand points because of the reactive consumption of the power transformer, which is an asset of the TSO. Consequently, the code is initially locating the need of investing the necessary equipment to compensate the reactive consumption of a TSO-owned power transformer to the distribution/demand units.

1.9 Power quality

- A similar comment applies as for the HVDC installations: As a general practice in the industry, it is the responsibility of the TSO to ensure that the harmonic voltage distortion level is below the planning level at all nodes where customers are connected. This is a practice used in the international IEC standards or IEEE recommended practices, see IEC 61000 or IEEE 519-2014. In both documents, distribution equipment is only required to ensure a given harmonic current distortion level below to the defined limits. The code states that 'the level of allowed distortion or fluctuation of the supply voltage on the network at the connection point of a transmission-connected demand facility will not alter from what is stated in article 46 of the current Federal Grid Code'. However, the level of allowed distortion of the supply voltage is set by the TSO harmonic planning levels and, consequently, it is a responsibility of the TSO. This can be controlled, as it is typically the case, by allowing a lower maximum admissible harmonic current injection limits from the load installation. However, this article is directly giving the responsibility of the harmonic voltage distortion to the load, against international standards and practices.