IMPROVING HVDC SYSTEM RELIABILITY

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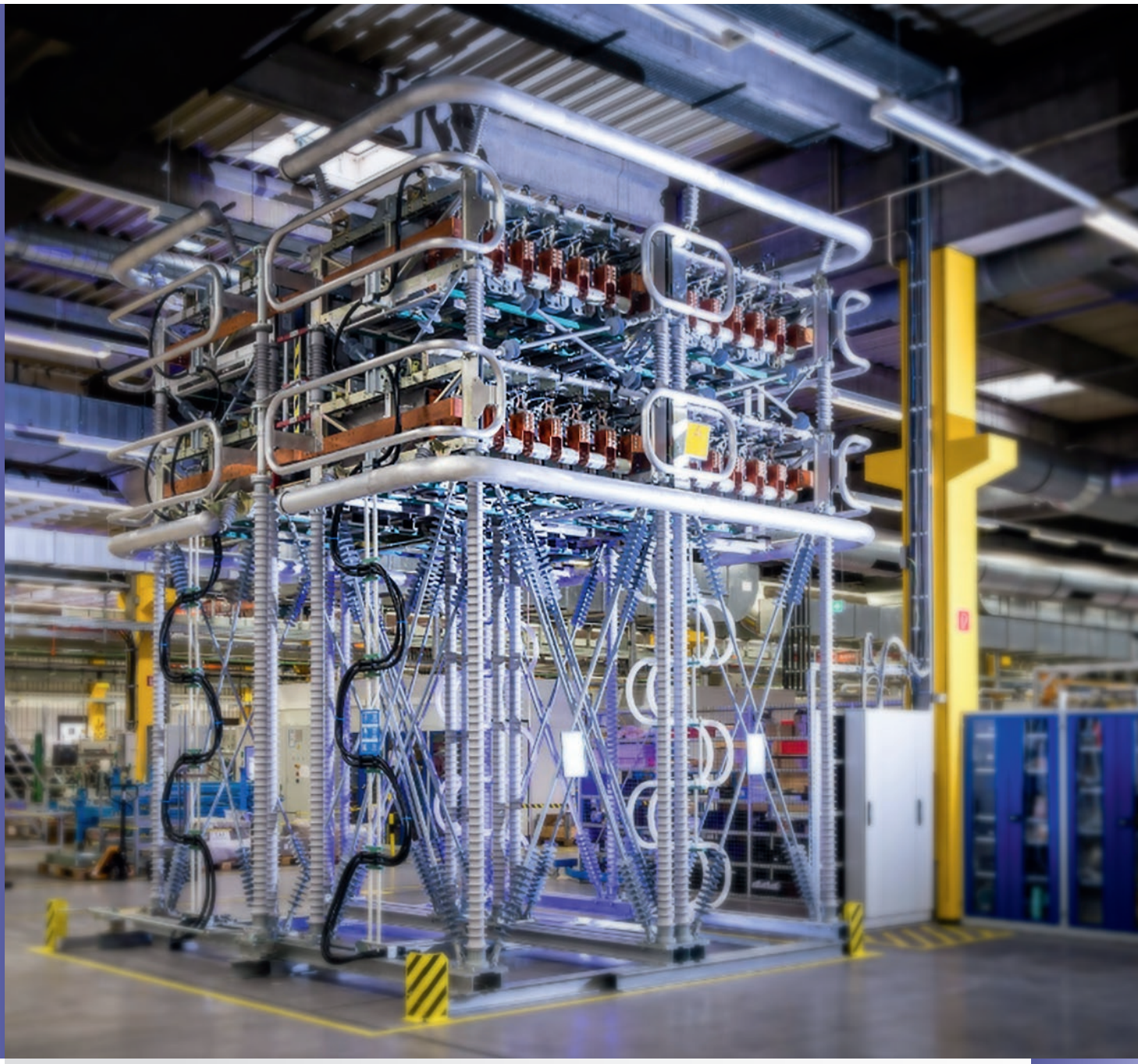

High-voltage direct current (HVDC) is an increasingly important method for transferring large amounts of electrical power for the pan-European transmission grid. New HVDC connections have a key role in the future development plans of the European transmission grid; high reliability, availability, compatibility and robustness will be essential for the electricity market and system security.

European Network of
Transmission System Operators
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1. EXECUTIVE SUMMARY

To manage the future challenges and fulfil the needs of an efficient European interconnected energy market, as well as to keep high system security, it is essential that HVDC owners, in co-operation with other relevant HVDC stakeholders, focus on developing HVDC so that not only the technology but also processes, HVDC grid integration studies and maintainability performed by TSOs, with appropriate tools like models and control & protection (C&P) replicas, services and life-cycle aspects, are systematically addressed. As the European transmission system operators (TSOs) aim at ever-higher average availability and reliability levels, ENTSO-E strongly promotes a more efficient co-operation of all stakeholders to overcome the main challenges that today still may affect the success of HVDC as the fundamental building block to transport bulk power and support grids in future transmission systems:

1. The only worldwide HVDC performance statistics for 2005–2016 collected by CIGRE (International Council on Large Electric Systems) show that present levels of HVDC system availability and reliability are not fully adequate, as systems suffer from rather many trips (7.7 pcs/yr) and outage durations are quite long (24 d/yr), in average. Although median values are significantly better, ENTSO-E is striving to reach better availability and reliability figures. Co-operation is needed to simplify and enhance the fault data collection, as well as the possibilities to further analyse data, to learn more from the incidents and further improve HVDC performance in future;

2. Co-operation, means, venues and sufficient TSO expert resources should be allocated for the collection of appropriate HVDC fault data and the efficient and transparent sharing of HVDC experiences and knowledge both between users and between users and manufacturers, so that the whole industry gains the benefits of a higher knowledge level;

3. Co-operation to improve the compatibility of HVDC converters and other components of the high-voltage grids. This includes active and transparent information sharing to study and solve any system issues caused by the implementation of rapidly developing technologies in the networks, enabling also proper grid connection studies. Appropriate models and tools are needed for this, e.g. European BestPaths project is one means to meet this incentive;

4. Network code (NC) HVDC ensures HVDC functional performance requirements coherency within Europe but is not detailed enough to steer the HVDC reliability development in an efficient way. As the NC HVDC provides rather broad boundaries, the TSOs can benefit by co-operating in aligning their detailed performance or modelling requirements more uniformly. This could lead to less compromises in new HVDC implementations, as any common TSO requirements strive to steer the development of the future vendors' solutions to fulfil these requirements; and

5. Co-operation between TSOs and manufacturers to facilitate a more efficient implementation of new operational mode and functionality needs, by upgrading existing HVDC systems, which the current flexible technology certainly allows for. With proper documentation, the upgrading work will be efficient even if the vendors' knowledge level to make changes to older systems is fading with time.

With the above improvements in co-operation, the higher availability and reliability needs of the future European transmission network can be achieved. Measures for improvements are stated more in detail below in this paper. Many of them address at the same time the development needs related to robustness, flexibility and compatibility.

2. MEASURES TO IMPROVE HVDC SYSTEM RELIABILITY AND AVAILABILITY

Based on the outcome of the ENTSO-E 1st HVDC Reliability Workshop in 2015 and the work of a Drafting Team and Task Force HVDC Reliability, arranging a 2nd HVDC Reliability Workshop and performing further analysis of the listed HVDC issues and experiences, as well as possible mitigation measures, the following main directions needed for further improvement work of HVDC system reliability and availability have been identified:

1. Influencing the industry to address better the needs of European TSOs/owners;
2. Improvements in fault data collection & analysis and sharing of experiences and knowledge; and
3. Developing TSO work methods, HVDC resources, requirements, specifications, and interaction studies and maintenances support tools.

These main directions are not fully separate measures; they should be considered as a set of improvement means that should be carefully considered by each TSO to be able to gain additional benefits from a higher HVDC system reliability and availability level. This includes selecting from and adopting among the best practices available, focusing on the ones most suitable for its HVDC assets and organizational structure.

TSOs and other end-users of HVDC should take into account that improved reliability (e.g. decreasing 1–2 trips per year on average) and improved availability (e.g. decreasing 1–2 outage days per year on average) can bring significant cost savings to TSOs and/or society. Due to the variations in market situations and system conditions at the time of occurred trips, annual savings will vary a lot but can amount even up to a million € level per year for a single HVDC connection (e.g. countertrade costs). As the society dependence on electricity and the importance of the bulk transfer function of HVDC systems is only increasing in the future, these annual monetary savings due to increased reliability and availability are likely to increase, too.

The abovementioned main directions of improvement work needed are presented below more in detail.

2.1 INFLUENCING THE INDUSTRY TO ADDRESS BETTER THE NEEDS OF EUROPEAN TSOs/OWNERS

ENTSO-E aims at influencing the whole industry to direct more efforts on improving the availability and reliability of future HVDC systems. Although the reliability figures have improved a lot since the millennium change, the present average performance values are still not at an acceptable level. Therefore, the TSOs need to define their role and forums how to influence the HVDC field to reach new improved levels in the future. Forums that can be used are via ENTSO-E System Development Committee (SDC), System Operations Committee (SOC), Research, Development and Innovation Committee (RDIC), CIGRE Study Committee SC B4 and IEC for standardization issues.

Each TSO can choose to try to influence industry by itself, acting actively in any forums, but may get limited response for its voice, if being the only end user or one of the few end-users in the relevant working groups that define future standards and guidelines.

However, working together with an ENTSO-E mandate would be much more powerful and efficient. Presently, the HVDC work in ENTSO-E is scattered between working groups and task forces in three different committees (SDC, SOC, RDIC), trying to solve some technical or performance issues from their point of view. As HVDC reliability concerns all stages, from pre-planning and system studies via implementation projects and operation & maintenance all the way to refurbishment, upgrades and decommissioning, it is difficult to bring together all relevant experts and decision-makers for putting up a common ENTSO-E strategy to improve HVDC availability & reliability. This has been clearly seen in the work of ENTSO-E Task Force HVDC Reliability belonging to SDC / Working Group Asset Implementation and Management (WG AIM).

Ultimately, ENTSO-E has to make a decision regarding who will do what to influence the HVDC industry. The Task Force is proposing to continue working with HVDC reliability within WG AIM and building liaisons at least (but not limited) to CIGRE SC B4 and IEC Technical Committee TC 115 working groups. Doing so will improve co-operation between the European HVDC users and these organizations to give a stronger input into their work, too, especially regarding issues that are important for the end users.

2.2 IMPROVEMENTS IN FAULT DATA COLLECTION & ANALYSIS AND SHARING OF EXPERIENCES & KNOWLEDGE

As the HVDC assets of each type are limited in numbers, it is essential that all TSOs collect appropriate data from each outage and each equipment fault event. This information should include sufficient details of durations, object, reasons, consequences and repairs (why, what & how, including prevention & consequence mitigation learnings) in order to use it for further analysis and fault root-cause studies. This data is needed to be able to improve availability and reliability, learn from faults and mistakes, avoid reoccurring faults, optimize maintenance and find better technical solutions. This information should also be sent to CIGRE SC B4 advisory group AG04 for its continuing collection of HVDC performance.

ENTSO-E Task Force HVDC Reliability has set up an example Excel sheet template for minimum outage data collection. Same level of technical details is needed for reporting equipment faults, even if they have not led to forced outages. This information is important for being able to perform proper deeper analysis of the status and condition of the HVDC assets.

As the HVDC assets of each TSO are limited in numbers, it is essential to learn not only from own experiences and mistakes but also from other HVDC users. By sharing lessons learned between TSOs and also between TSOs and other end-users, the risk of some disturbances can be decreased and some future faults may be prevented. Experience/knowledge sharing becomes of even higher interest between TSOs that have similar types of assets, like HVDC systems delivered by same vendor and using same technology version or platform, like HVDC 'siblings" that are built and commissioned near to each other in time. Thus, increased co-operation between TSOs is highly promoted, e.g. bilaterally or in (regional) user groups.

A first set of experiences, lessons learned and hints from several TSOs has already been collected by the HVDC Reliability Task Force in its "European HVDC Reliability Experiences" report. It is foreseen that further experience sharing will be needed also in the future.

ENTSO-E also offers its SharePoint platform to be used for collecting and storing outage and fault data end reports from each TSO using HVDC. This shared information will allow TSOs continuous improvement of HVDC technical requirements and maintenance learning from other TSOs.

To gain maximum improvements in future HVDC system availability and reliability, all stakeholders within the HVDC industry are needed to co-operate more efficiently than today. The broader and deeper the co-operation, then the better the final results will be.

International meetings for HVDC users are very good forums to share experiences and improvement hints, such as those arranged by HVDC manufacturers or collaboration parties and annual CIGRE meetings and colloquia, HVDC cable conferences or similar. It is of significant importance to regularly bring experts of end-users together with manufacturer experts, designers, commissioning engineers and developers to share their knowledge and lessons learned from fault cases and best practises.

To be able to present the case studies thoroughly so that the lessons learned can be shown clearly, it is essential that the non-disclosure agreements (NDAs) of HVDC delivery projects do not prevent it. Otherwise, the whole industry will not be able to learn from all relevant faults and knowledge sharing is not efficient/sufficient, leading to only limited improvement in the future development of concerned issues/solutions. Obviously, all vendor sensitive information shall be kept only within the concerned parties. However, other users of the same type of equipment that has failed need to be informed appropriately regarding the risks they may have. Thus, the case presentations need to have all relevant information for understanding what happened and why it happened, including prevention and mitigation information.

2.3 DEVELOPMENT OF TSOs' WORK METHODS, HVDC RESOURCES, REQUIREMENTS AND SPECIFICATIONS, AND INTERACTION STUDIES AND MAINTENANCES SUPPORT TOOLS

TSOs need to analyse their ways to work concerning the HVDC systems, as these HVDC assets are significantly more complicated than normal AC-grid substations and they differ quite a lot from these. TSOs normally have up to hundreds of AC substations but only a few HVDC systems. Thus, the special expertise needed for HVDC integration in the grid, operation & maintenance has to be taken into account. This includes a sufficiently numbered group of in-house experts, including back-up personnel for each relevant technology area, even if HVDC maintenance is outsourced. The importance of these assets and the growing number of HVDC assets in future have to be considered in good time in TSO resource planning, taking into account that the owner should ensure a sufficient set of HVDC experts for all duties like:

- coming implementations & plans of any new HVDC systems;
- ensuring technical requirements cover reliability aspects in a proper way;
- studying HVDC interactions in the grid (models and replicas); and
- running efficiently existing HVDC systems, including those needed to efficiently collect data, to participate in co-operation work with other users & stakeholders, to influence industry, and to properly analyse and review needed actions and development to improve their HVDC system reliability and availability to a higher level than today.

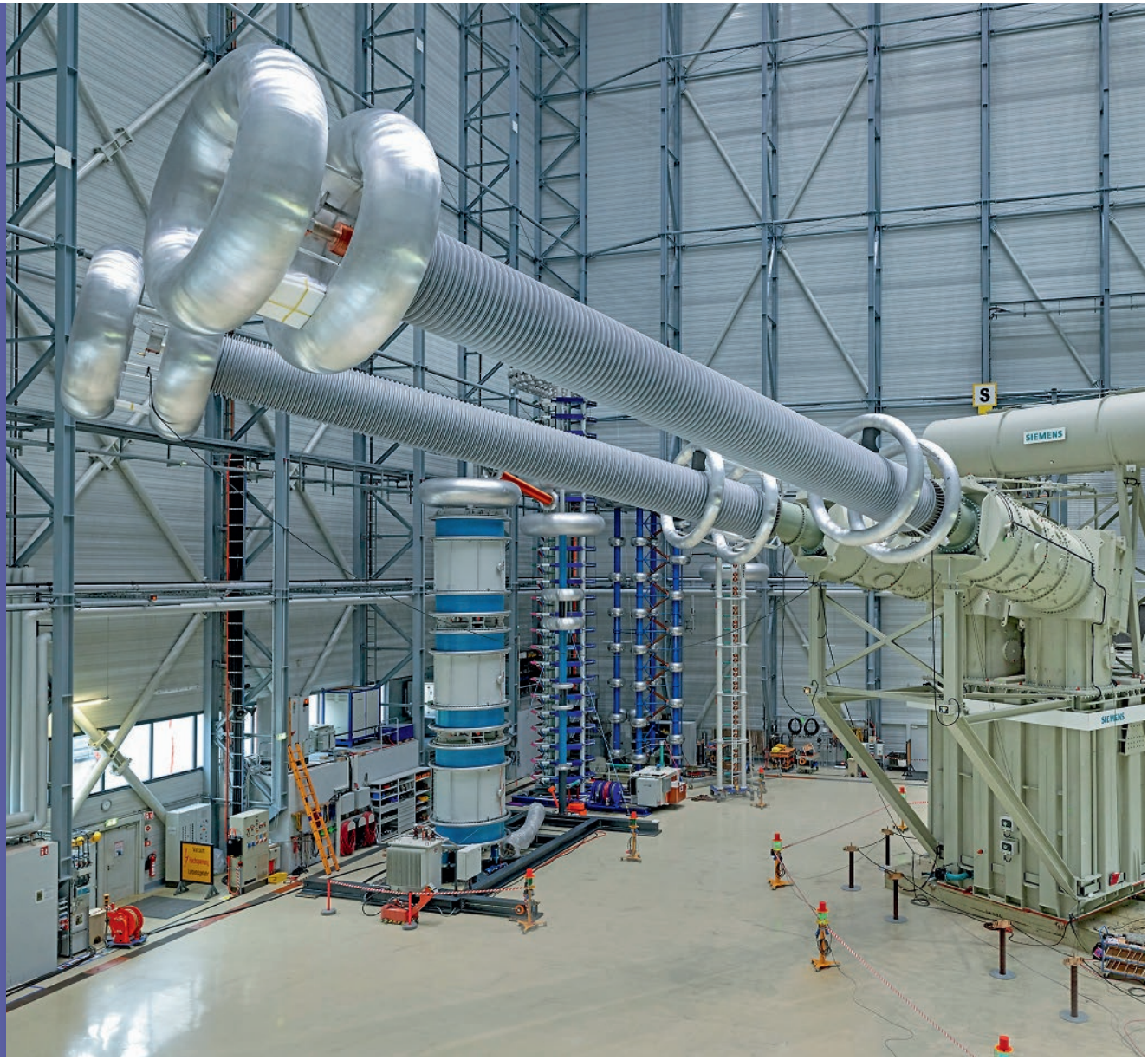
In-house maintenance may ensure a high degree of quality and reliability thanks to quick curative reaction times in case of failure and regular preventive maintenance and it feeds HVDC skills development within the TSO. Proper training of TSO staff in charge of HVDC maintenance by manufacturer during project and systematically and regularly by TSO HVDC experts during life-time is highly recommended and can be well supported with tools such as valves mock-up and C & P replicas. HVDC maintenance is preferably performed by dedicated specialized teams.

When planning and building new HVDC systems, TSOs need to analyse carefully, as applicable, the need of expertise to:

- perform the pre-studies needed for proper interaction with the AC grid and other PE components, with own grid data, and HVDC models and C & P replica;
- review and develop their contract terms and technical specifications for HVDC systems by pointing out and specifying (unambiguously and clearly) their selection of factors and solutions, which fit their particular aims to improve or at least reach their respective HVDC reliability and availability target levels for each case; and
- take into account European common requirements for HVDC inter-compatibility, modelling and performance issues, if available in the future.

HVDC skills management needs to be taken into account comprehensively. The proper skills of experts, engineers and technicians have to be assured for each task during the whole lifetime of the HVDC systems. TSOs should ensure that they have the appropriate knowledge and skills involved in specifications, operation and maintenance work. This can be somewhat challenging, especially if its HVDC asset types differ a lot from each other and/or if most of the work at site is outsourced. Reaction to disturbances and faults need to involve 24/7 expert support services and repair preparedness at least on some level, e.g. preparedness plans, spares & lifetime management, (submarine) cable fault location & repair.

The "European HVDC Reliability Experiences" report by ENTSO-E TF HVDC Reliability gives some examples of experiences, lessons learned, and hints for TSO organizational and skills development.



ANY QUESTION?

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