REPORT on WEBINAR:

“Low Voltage Direct Current (LVDC) and DC Technologies:

Potential applications for a clean energy transition”

Monday 8, Tuesday 9 and Wednesday 10 November 2021, 09.10 ÷ 12.30

I. CONTEXT

The **European Green Deal** aims at climate neutrality by 2050 transforming the EU into a modern, resource-efficient and competitive economy while concurring to reducing greenhouse gases and preserve our planet. It covers all sectors of the economy; in particular, transport, agriculture, infrastructure and energy. For what pertains the electrical energy sector, all areas are covered, from generation to loads and the electricity grid infrastructure. For the latter, an innovative way of distributing electricity, which can contribute to the goals of the Green Deal, is **Direct Current Technologies**. In this specific context, we are addressing **Low Voltage Direct Current** with applications in the electrical distribution grid, in industry, in data centres, in EV charging stations and in buildings.

We are living in world of equipment - from generation (e.g. PV, Fuel Cells, batteries, etc.) to loads (e.g. DC motors, Electrolysers, LEDs, televisions, computers, etc.) –, which, for a wide part, is based on Direct Current (DC), yet we are still using Alternating Current (AC) to interconnect each other. This implies a double conversion at the generation and load sides. For example, for a PV panel, the DC voltage generated is converted first in AC, conveyed along the cables in the house in AC up to the load and there it is converted back in DC, in a computer for example, functioning in DC. This is valid for many other generation and load cases. A question arises spontaneously: why there is the need to use AC to link two equipment working in DC? The question is pertinent because, as it happens in all energy conversions, this double energy conversion DC/AC/DC implies losses, which could be avoided removing the conversions and using DC from generation to load. Furthermore, DC provides other benefits in terms of efficiency, controllability, savings on energy and raw material.
The reason why we are using AC for the distribution of electricity today is because we inherited this standard from the past. AC is a consolidated technology in use since its early adoption in the late 1880’, which was mainly due to a simple and reliable electrical AC machine: the transformer. Stepping-up to high voltage at generation side and stepping-down to low voltage at load side, the transformer is the key AC technology enabler for the transmission of electricity over long distances. This was not the case for DC at that time and therefore, AC was adopted while DC use was relegated to specific applications such as trams, elevator motors and battery-operated systems. Today, with the significant development of **Power Electronics (PE**) in the last decades, the conversion AC/DC, DC/AC as well as DC/DC (to step-up or step-down the voltage in DC) can be achieved as efficiently as it happens in AC with the corresponding “transforming machine in DC”, the **converter**. In addition, for its intrinsic properties and with ad-hoc control mechanisms, the converters and the LVDC link can provide increased grid management capabilities, flexibility and grid services to the AC network, which

can not be provided by the transformer. In this context, the two systems, AC and DC can work in symbiosis in an AC/DC hybrid network, bringing their own advantages reciprocally and to the entire electricity network. For example, the use of local DC microgrids can optimise the grid efficiency, reduce distribution lines congestion and consequently avoid costly AC grid reinforcements.

Some LVDC applications exist in the distribution grid while others appeared recently with examples in industry, in EV charging infrastructures, in data centres, in buildings, etc. A beneficial side-effect of using DC technologies is the opening of new markets and the creation of new jobs.

As the use of AC technologies is consolidated with more than 100 years of application, **DC Technologies need R&I&D** to bring them to market as a viable option to complement the AC Technologies and optimise the whole electricity network. In addition, there are **regulatory and standardisation barriers** that impede the development and deployment of LVDC Technologies. These challenges need to be addressed and can be taken as an opportunity to enlarge the range of new technologies and systems contributing to the clean energy transition.

The webinar aimed at giving a better understanding of the potentialities that LVDC & DC Technologies can bring to contribute to the achievement of the Green Deal objectives:

- Take stock of the actual technological development on LVDC and the related applications in different areas;
- Highlight the potential benefits of applying LVDC technologies in any suited area of the actual electricity grid (in industries, homes, EV charging, data centres, etc.) as a valid contribution to the clean energy transition;
- Identify the barriers (technical, regulatory, standardisation) for further development;
- Collect input/recommendations for further actions.

The webinar builds on the DC – AC/DC hybrid grid workshop of 17.05.2018, where one of the main conclusion was to address separately and systematically the different voltage levels (High, Medium and Low Voltage DC) to target appropriately the intrinsic specificities of each. DG ENER addressed HVDC in 2019. With this webinar, the LVDC topic has been developed. The remaining voltage level – MVDC – would need to be addressed in the future.

II. MAIN FINDINGS

Different aspects of LVDC were addressed in the presentations and the panel discussions:

- **Technical**:
  - DC Technologies give many advantages such as avoiding multiple DC/AC/DC conversions, the better usage of cables, less losses, etc. Some examples: 8-25% energy efficiency increase can be achieved due to recuperation; less cooling energy demand for buildings; 20-65% less copper; 8-11% increased efficiency of data centres; high power charging hubs for EVs. All these elements concur for LVDC to be a key technology for a high integration of renewables and storage in the grid.

- DC can be integrated at different levels in LV, MV and HV to offer substantial benefits for grid operators and customers.
- The cost of components is high as the production volumes are still low. The cost of engineering is also high and depends on the lack of standardisation.
- The lifetime of converters, risking to be shorter than its equivalent in AC - the transformers - can be addressed through condition and health monitoring of PE components.
- For a valid and reliable assessment, the evaluation of the pros and cons do not have to be made at component level, but at system level.
- New applications such as EV charging, industry, datacentres will require more DC in the future, therefore more implementations and demonstrations in real environments are needed.
- Some protection concepts have been developed, but more needs to be done.
- In order to find cost effective solutions, simulation tools have been developed to compare AC grid reinforcement with the conversion to full DC or hybrid AC/DC grids and assess the scenarios from a techno-economic perspective.
- Hybrid AC/DC grids with optimal control strategies, protection, and stability of the networks increase the grid efficiency by reducing reverse and optimising power flows in meshed networks.
- Deployment of local DC microgrids can extend the lifetime of existing AC grids. Their deployment does not replace the AC system, but complements and optimises the existing AC system.
- Control strategies are available for small scale systems, but for more complex systems interactions are expected and therefore control strategies need to be developed.
- The DC voltage level (via "droop control") can be used to ensure **LVDC grid stability without the need to recur to ICT solutions, thus reducing the exposure to cyberattacks.**
- **ICT solutions would not be used to perform critical control of the grid stability,** but only for monitoring purposes and to optimise and plan the electricity system.
- Some use cases of applied LVDC presented:
    - Using a +/-750VDC for multiple EV charging (up to 450 kW) can reduce the cabling section by 3 and cabling losses by a factor of 9, compared to 3-phase 400VAC.
    - In the Netherlands, a LED lighting (DC) systems has been installed along the highways;
    - In Finland DC pilots have been developed over more than a decade, such as AC lines replaced in rural sparsely populated areas with DC installations or integration of PV and battery systems.
    - In a DC home, DC nanogrids with a 350V backbone are connected to the AC grid and the appliances are connected to the DC grid. A "smart power router" can redirect the power flow to the needed loads or to the grid and thus maintain the electrical stability. It can be used also in islanding mode.

    - EV charging infrastructure in DC has higher upfront costs compared to AC solutions, but it is preferable when considering the services provided by the converters to the grid and the increased reliability.
    - Applications of DC Technologies exist also in ships, aircraft and space.

  - Main areas for R&I:
    - EV charging, industry, datacentres, buildings.
    - Earthing/grounding schemes.
    - Grid integration protocols.
    - Unipolar and bipolar voltage levels for applications in the industry environment to ensure long term compliance assurance.
    - Protection devices and protection concepts at system level.
    - Advanced current and voltage control strategies for the stability of DC microgrids.
    - Seamless DC disconnection.
    - Implementing grid automation with DC systems, open source initiatives need to be encouraged to support interoperability.

- **Non-technical**:
  - Unclear regulations and standardisation are blocking the fast arising of new markets and investments in LVDC. The lack of standardisation implies a high cost of engineering. The lack of a regulatory framework is a barrier, especially in the building and grid sectors.
  - The lack of standards impacts on DC products development and deployment. A set of ten items for standardisation have been identified (and regrouped under 7 categories after the meeting) :
    - Voltage (level, mono- or bipolar, nominal and non-nominal ranges);
    - System architectures;
    - Stability versus RLC resonances (especially between devices located in buildings);
    - Control strategies (i.e. hierarchical control) to implement truly smart grids while ensuring stability and cybersecurity;
    - Protection strategy and fault current characteristics of components;
    - Earthing / grounding strategies (for corrosion prevention);
    - Design (incl. safety, measurement accuracy), commissioning, maintenance guidelines and procedures;
    - Pre-charging strategies for new devices (including restart).
  - Standardisation processes for DC measurements are supported by projects such as EURAMET.
  - Grid operators are not very active in the standardisation bodies as they do not perceive the DC topic as a priority.
  - A private industry-led initiative for standardisation is the Current OS foundation, which is a non-profit, open, independent foundation for the promotion and adoption of active microgrids based on Current OS protocol. The Current OS

protocol defines an automatic response to power availability in active DC microgrids without the need of central control, which is an intrinsic behaviour of DC microgrids.

- A paradigm change for DC components is to have very strict requirements, which is different compared to AC where there are considerable tolerances.
- Codes need to address electrical safety, product & energy efficiency.
- Regulatory sandboxes are needed to try out new and innovative solutions.
- Education and training on DC Technologies and Power Electronics needs enhancement and integration where not covered.

III. CONCLUSIONS - RECOMMENDATIONS FROM STAKEHOLDERS

A. Standardisation and certification

The lack of standardisation is one of the main barriers slowing down the adoption of LVDC systems. Today, LVDC products are already available on the market, but their specifications are vendor specific and hence they do not match those of other vendors. The result is a complicated design process and additional costs for interfacing - where it is technically possible - LVDC components on the same bus. The outcome is that the LVDC solutions are not facilitated, remain unapplied even if advantageous and do not penetrate the market.

⇒ **Recommendations: to define LVDC standards and certifications. They are a reference for the use of the stakeholders (manufacturers, consumers, engineers, etc.), which would facilitate the penetration of LVDC technologies:**

1. **Identify and list the standardisation needs for a seamless application of LVDC technologies.**
2. **Evaluate standardisation status for LVDC applications and products:**
   - **2.1. Identify the standards existing and the standardisation processes ongoing.**
   - **2.2. Identify the reasons for lengthily standardisation processes.**
   - **2.3. Identify eventual redundant standards and certifications.**
3. **Optimise the standardisation processes:**
   - **3.1. Integrating the standardisation needs missing.**
   - **3.2. Organising solutions to speed-up the lengthily processes to reasonable duration.**
   - **3.3. Eliminating eventual standardisation and certification redundancies.**
4. **Contribute for an efficient architecture of the LVDC standardisation work program that the standardisation bodies undertake.**
5. **Facilitate the standardisation process by means of use cases developed in demonstration projects.**

B. Regulation

The lack of regulation hinders the fast arising of new markets and investments in LVDC, for example, for energy communities, which represents a great opportunity. In the same way they have been a key instrument for the AC grid development, grid codes are needed for

LVDC. The entity who will take action first can have the advantage of taking new technology leadership internationally.

⇒ **Recommendations: to define codes and regulation for LVDC. They are a reference for the use of the stakeholders, which would facilitate the penetration of LVDC technologies:**

1. **Identify and list the codes and regulation needs for a seamless application of LVDC technologies.**
2. **Collaborate with the regulators to put forward the DC systems needs to enable application.**
3. **Identify and support projects providing use cases needed for definition and creation of grid codes for LVDC.**

C. Technical

Currently, the application of LVDC technologies is limited to a small number of cases (compared to AC applications). Even if the technology is in a considerable state of advancement, the development and deployment remains still limited due to remaining technical barriers (apart from the standardisation and regulatory aspects mentioned above). More R&I is needed in specific areas to test and de-risk the technology to enable its application in a real life context.

⇒ **Recommendations: to develop seamless applications of LVDC Technologies in a wide range of areas (distribution systems, industry, EV charging infrastructures, data centres, buildings, etc.), which could enable a high TRL and bring technologies to market:**

1. **Identify how the application cases can be addressed through Horizon Europe in the areas of R&I identified above, namely:**
   - 1.1. EV charging, industry, datacentres, buildings.
   - 1.2. Earthing/grounding schemes.
   - 1.3. Grid integration protocols.
   - 1.4. Unipolar and bipolar voltage levels for applications in the industry environment to ensure long term compliance assurance.
   - 1.5. Protection devices and protection concepts at system level.
   - 1.6. Advanced current and voltage control strategies for the stability of DC microgrids.
   - 1.7. Seamless DC disconnection.
   - 1.8. Implementing grid automation with DC systems, open source initiatives need to be encouraged to support interoperability.
   - 1.9. Further implementation of use cases in the different areas of application, such as industry, buildings, EV charging infrastructures, Data Centres, etc.
2. **Studies to analyse the interactions and behaviour of future more complex hybrid AC and DC distribution systems with micro and nano grids, how it can be operated and what are the operational challenges.**
3. **Development of open source simulation, planning and management IT tools for DC and AC/DC hybrid systems**

D. Education and training

Power system engineers having a system-level perspective perceive the benefits of LVDC. Training and education should increase awareness with engineers making design decisions. Besides, electrical installers and integrators need to be trained and certified to ensure a safe working environment and prevent DC systems becoming perceived as unsafe.

⇒ **Recommendations: to instil the culture on DC Technologies as modern, effective and viable technology for the grid to complement and optimise the current AC network.**

1. **Contribute to the organisation of dissemination campaigns in high schools, universities, research centres, etc. on LVDC technologies (and Power Electronics) and the potential for applications and R&I in this area of research.**
2. **Contribute to the organisation of trainings for installers and integrators on LVDC Technologies.**

IV. ORGANISATION AND IMPLEMENTATION OF THE RECOMMENDATIONS

As experts of the sector, the **collaboration and contribution from stakeholders** is essential to enable launching initiatives for the implementation of the recommendations described above. There are actions where stakeholders can contribute directly with their input and others which need preliminary survey/study/enquiry. For the key implementation actions below, an implementation group among stakeholders needs to be identified. Therefore, the implementation of the action points can be organised in the following manner:

1. **Identification of the implementation group: all those wishing to participate/collaborate can inform sending an email to mario.dionisio@ec.europa.eu.**
2. **The group identifies the action points where stakeholders:**
    a. **Can provide inputs/details (e.g., technical details, scope for DC networks, parameters, safety rules, etc.) for a clear and complete problem definition to be addressed. In this case, the inputs are simply provided for the related action points.**
    b. **Can not provide inputs/details and/or these inputs will be the result of a preliminary survey/study/enquiry. In this case, the terms of reference need to be defined.**
3. **Any other input to further push forward DC Technologies from the group and stakeholders is welcome.**

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