ROUND TABLE ON AC-DC[1] – HYBRID GRIDS

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I. MOTIVATION

A simple analysis of today's electrical power system shows that, on the generation side, a wide part of the renewable generation is in DC or needs a double conversion AC/DC/AC (e.g. solar PV and wind turbines respectively) and on the consumption side, a wide part of the loads and equipment is in DC. Furthermore, for DC interconnections, there have been significant developments in power electronics allowing better efficiency in HV transmission systems.

Linking these observations with the transition the European energy system, it ensues that a deeper investigation of these topics to have a broader overview on the available technologies would be beneficial to better direct R&D&I in the next years and target accurately investments. The round table was organised with the intent of opening the discussion on the available grid technologies and topologies options for the next decades, addressing technological as well as non-technological aspects. The relevant stakeholders were called to present and compare the state of the art of the technologies, also with use cases and (social) cost-benefit analysis aspects, with the aim of extracting constructive conclusions and follow-up actions.

II. MAIN FINDINGS

The round table was intentionally organised to deal with DC grids, indistinctively at all voltage levels:

- as a first step to bring and to position the overall DC topic into the energy policy discussion;
- and to have a holistic approach thinking of DC grids altogether, across HV/MV/LV[2] on architectures and standards.

This taken into account, as the specific characteristics, objectives and market actors for HV/MV/LV are different, the relevant findings are classified according to following areas: global system level, HVDC, MVDC and LVDC[3]. At each finding in this section II, corresponding action points have followed and reported in the next section III.
Further discussions will follow-up separately, but always keeping a link active among the areas.

[1] AC-DC: Alternate Current-Direct Current
[2] HV/MV/LV: High, Medium and Low Voltage
[3] HVDC/MVDC/LVDC: High, Medium and Low Voltage Direct Current

A. At global system level

1. It was mentioned during the presentations that overall, up to 10% better efficiency can be achieved in a DC grid system compared to AC, based on avoiding AC/DC/AC transformations in case of RES integration and lower losses on transport and distribution lines. Improvements may even be higher depending on DC grid topology. In case of large reactive power flows, DC grid brings huge benefits. Due to higher efficiency and easier interoperability of DC systems, acceleration of decarbonisation seems plausible with lower social costs.
2. Discussing about grid topology and technologies taking into account the socio-economic aspect, it was recommended to analyse how DC grids can be addressed in the TYNDP (Ten–Year Network Development Plans) of ENTSOe.
3. Consider the potentialities of DC grid when designing new power (or local) systems and the impact in developing countries.
4. As it happens for all new systems since the cyber threat appeared, the cybersecurity part must be included as of the design phase for a DC grid: cybersecurity by design. Retrofitting might not be as effective and/or could be much more costly.
5. Power Electronics (PE) is a key enabling technology. It is present at all voltage levels and, for each with its peculiar characteristics. PE is one of the main elements at the basis of the development of the converters and renewables. For converters, new power electronics allow better conversion efficiencies and loss reduction. On the other hand, systems requesting high reliability (such as offshore wind generators) are penalised for the downtime due to (older) power electronics failure.

B. High voltage system (HVDC)

1. The HV technology pertains mainly to the interconnection of different AC grids or wind farms through HVDC. The technology exists since decades and has significantly developed lately on system device level (e.g. for the latest VSC-HVDC converters the losses dropped from 1,6 – 1,8 % to 0.6 %) and on device component level (power electronics). Nevertheless, more R&D&I is needed, for example for Multi Terminal HVDC (MT HVDC) systems where Europe is lagging behind China. MTT HVDC can be the key technology for the development of an offshore grid. With scenarios for 2030 - 2050 of increasing energy demand and nuclear power plants (NPP) to be dismissed, it makes sense to see wind energy as a major contributor with the integration of new energy sources and for the replacement of NPP. A wide part of this wind energy would come from offshore. Therefore, it is indispensable to deepen the knowledge and to implement demonstration on how to bring in the most efficient way all this power to the consumption centres.
2. It was also mentioned that to connect offshore wind farms with distances over 50km, AC links are not technically feasible. The DC connection is the only option. Offshore DC grid technologies (e.g. DC/DC converters, DC hubs, DC grid and control, multi terminal solutions) should be further investigated and demonstrated.

3. Vendors' locked-in MTT HVDC grid control and protection solutions prevent the offshore grid development and limit its diffusion: it is a barrier for the market development opportunities of converters.
4. New components are being developed and improved for DC grids such as DC protection, DC switchgear (DC Circuit breaker)

C. Medium voltage system (MVDC)

1. The MV systems refer mainly to the part of the grid between the HV and the LV. Not much is available today for the development of DC MV distribution grid solutions. Some examples are DC/DC converters at different voltage levels, on how to protect and create selectivity in DC grids. More R&D&I is needed on MVDC solutions to prove the technology, to demonstrate its reliability and give confidence to the relevant stakeholders.
2. Standards are needed to enable the development and deployment of DC grids.
3. Lack of regulations in areas of DC distribution grid can penalise grid functioning and affect the costs.

D. Low voltage system (LVDC)

1. Low voltage DC systems refer mainly to applications in the home sector, in tertiary sectors (commercial buildings and offices) and in the industrial sectors (smart factories). The target in these sectors with LVDC systems is cost reduction by the means of: 1) energy efficiency, 2) controllability enhancement, 3) architectures convergence (for example, Power over Ethernet allows having one common infrastructure for telecom and electric power).
   Home grid in DC is today feasible; it could facilitate self-consumption and broader integration of RES. For their DC nature, solar PV, storage and vehicle to grid integration systems are suited to contribute to the diffusion of DC grids. The building sector could take benefit of DC grids in both the new and retrofitting business.
2. There are standards in development for DC grids, for example on voltage level, wiring systems, protections, metering, etc. Unavailability of standards for DC grids is a barrier to the development and deployment of DC technologies.
3. There are today AC equipment and appliances, which can operate also in DC. They could be used immediately in a DC or hybrid grid fostering the adoption of DC at home level if the voltage level is not too high (<325 volts).

III. CONCLUSIONS - ACTION POINTS

The key points mentioned above allow extracting the following conclusions and action points to follow-up:

A. At global system level

1. To substantiate and foster the development of DC grids, specific, in depth, accurate and factual socio-economic analysis of the advantages of a DC grid is needed. The Commission will evaluate the need of making (further) cost-benefit analysis after having an overview on existing studies.
2. Investigate the development of planning and operation tools for DC – Hybrid grids, including in the TYNDP.
3. Evaluate the creation of a collaborative program EU-Africa for DC grids (how, what type, at what level).
4. Cybersecurity by design has to be ensured (or systems must work independently).
5. Pushing the application to a growing demand of efficiency and constraints, PE and systems needs further improvements. This leads to two strands of demand in R&D&I and applications:
    i. New systems with new power electronics (namely SiC and GaN). The cost of PE is still excessively high today due to low demand. Set up actions on the PE value chain to increase volumes and trigger diffusion.
    ii. Health monitoring for existing systems of the critical PE, to anticipate failures, program maintenance, i.e. allow better performance and reduce downtime of energy system generation, namely wind. Health monitoring could be designed in new elements (component, equipment or system) as, for example, to monitor DC/DC converters in the future grid.

The actions above need to be implemented in collaboration with ECSEL[4].

B. High voltage system (HVDC)

1. Further studies and modelling of a large HVDC - MVDC systems are needed as well as new modelling tools for dynamics, control, dispatch, etc. Modelling should include the AC grid to which the DC system is connected.
2. To further analyse and define in more detail the new and further R&D topics on offshore DC grid technologies (e.g. DC/DC converters, DC hubs, DC grid and control, multi terminal solutions).
3. Support the discussion among manufacturers and work together for interoperability/controllability of DC grid equipment in light of international competition. A solution could be "one terminal package", i.e. the converter is built and delivered interoperable by default to be connected to an existing system. This allows a modular development without vendor lock-in.

[4] ECSEL: Electronic Components and Systems for European Leadership

4. To collaborate with the standardisation[5] bodies, manufacturers and end users for the emission of standards for the High Voltage DC grids.

C. Medium voltage system (MVDC)

1. More R&D&I in MVDC projects at higher power levels should be demonstrated in real life, to ensure correct and safe functioning and to demonstrate the reliability of the technology.
2. To engage and involve manufacturers and standardisation[5] bodies to define the standards for the distribution grid (e.g. voltage levels, protections, safety, etc.).
3. Engage the discussion and involve Regulators to see if there is a way to adapt the codes to DC grids.

D. Low voltage system (LVDC)

1. R&D&I on DC powered districts/homes/buildings (public/private), eventually within Smart Cities. Projects should demonstrate in real life: LVDC distribution grids with EV, storage, PV aiming at maximizing self-consumption and reducing the cost of the access to the grid.
2. To collaborate with the standardisation[5] bodies involving also electric utilities, manufacturers and end users for the emission of standards for low voltage grids.
3. Evaluate the possibility of a "DC ready" label, which would allow the diffusion of the DC culture and more users could start implementing and using DC based home supply. In this process, the physics constraints linked to safety (e.g. the arc generation differences between AC and DC upon breaker opening) must be carefully taken into account.

[5] With reference to the work ongoing (please, see the presentation on DC standardisation overview)

IV. LOGBOOKS EXTRACTS

- power electronics is a key enabling technology
- cost-benefit AC vs DC including rebound effect value chain (people use more energy when energy becomes more costly)
- Patents limit the introduction of MTT HVDC: interoperability needed
- Design modelling should include existing AC systems
- Reliability of converters compared to transformers
- Develop procedures to make equipment DC ready
- Bring grid designers and PE together
- To convince reluctant stakeholders through education, demonstration examples
- EU should bring legislation together to enable new technologies to cross borders
- New simulation tools and demonstrations are needed. Decentralised control (dispatching) of DC systems.
- EU support for modelling: create RT linked platform
- Very little demand of HV devices > 6,5 KV
- EU should mandate to standardise voltage levels and to “DC ready” certification
- The cost of power electronics dropped from 500€/KVA to less than 20€/KVA
- License models and release of technology deployment patents is good to make industry move forward.
- Health monitoring of PE to reduce WT downtime
- IEC TS 63053 General requirements for residual current operated protective devices for DC system
- Understand how to create selectivity in DC grids; understand how to protect a DC grid; understand the dynamics of a DC grid : SIM (Simulated Integrated Management) platforms needed
- MVDC not developed
- Need to think DC grids together across HV/MV/LV thinking on architectures and standards
- ENTSOe could help support CBA calculations for H2020/PCI smart grid projects
- Need to bring the Power systems and PE communities together to develop a joint architecture together rather than against each other
- Need to bring reliability and DC hub integration into AC as a high priority
- Need to bring lessons learned into new network code SOG2
- Push to develop further vision around wind DC collector and HVDC systems
- Need to standardise in buildings: DC levels, wiring system, safety issues with DC
- Design and support regulation for new buildings; how retrofitting can benefit from DC grid.
- Need to take lessons learned into ENTSOe network codes
- Need to take lessons learned on design and sourcing of HVDC systems
- Strategic for Europe to support its Si industry to keep leadership towards Japan/US: the risk is to lose the converter business
- Keep MV and HV together to investigate synergies and bridge views by deployment strategies
- Improve transient software analysis to allow proper DC integration
- Accelerate down on rated voltages at European level to win the IEC battle later
- Need to define an end to end deployment strategy across the system

- Bring major competitors (manufacturers) around the table to decrease competition and work together against China competition
- Feasibility study of wind farm cluster to backbone interconnector instead of multiple point to point connections
- Assess cost-benefit analysis and identify locks and steps towards deployment
- Identify key areas; market penetration strategies; work on realistic approach feasible in the mid-term
- Select key sectors such as EV charging and disseminate the positive results, which can be a hook for other vehicles.
- Impact of DC grids in developing countries: collaborative program EU-Africa
- Smart meters in DC grid; evaluate benefits compared with AC grids
- Small action group; DC pilots
- Standardisation of converter’s communication protocols, DC system’s interfaces connections and control
- Socio economic studies of high and low voltage separately
- More demonstration projects to increase power level
- Standardisation: DC protection; DC switchgear (DC Circuit Breaker)
- DC/DC converter
- DC hubs
- Modelling of large DC
- Grid DC
- DC grid control
- Disseminate and commence TSO’s need of proper interoperability and reliability of DC
- Cybersecurity