TRI1 “DC technologies for power networks”

- RES integration into the energy system requires a fundamental change in infrastructure. Direct current (DC) technologies can have a leading role thanks to their flexibility, efficiency and sustainability.
- HVDC is essential for offshore generation, for the integration of energy islands and its role is becoming increasingly important for long-distance transmission as well.

Green Deal implications:

- large-scale integration of **RES**
- **decarbonisation** of the building stock, transport, industry, and energy systems, **largely through electrification**
- active engagement of **consumers and citizen communities** in the energy systems
- **digitalisation of the energy sector** as an enabler of environmental transition and of **participative energy markets**
- reductions in **transport** related emissions
- increased reliability, adaptability, and resilience of the **integrated energy systems**.

European Technology and Innovation Platform Smart Networks for Energy Transition

HLUC 1: Optimal Cross sector Integration and Grid Scale Storage

HLUC 2: Market-driven TSO–DSO–System User interactions

HLUC 3: Pan European Wholesale Markets, Regional and Local Markets

HLUC 4: Massive Penetration of RES into the transmission and distribution grid

HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the center

HLUC 6: Secure operation of widespread use of power electronics at all systems levels

HLUC 7: Enhance System Supervision and Control including Cyber Security

HLUC 8: Transportation Integration & Storage

HLUC 9: Flexibility provision by Building, Districts and Industrial Processes

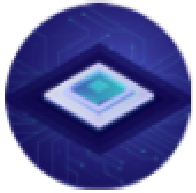
ETIP SNET, R&I Roadmap 2022-2031, Implementation Plan 2022-25

HLUC 4: Massive RES Penetration into the transmission and distribution grid identifies technical barriers and develops measures for handling massive RES with their control and operation and related infrastructure and their functioning with RES-based markets, policies and governance. HLUC4 also develops planning tools with the goal of high system resiliency.

- The integration of higher levels of RES must be considered in the context of **more DC connections** from UHV level (embedded interconnections) downwards to **Power Electronics** connected devices, raising the need of **extensive grid-forming capabilities** and evoluted control of such devices.

- Ensure the integration of massive RES at multiple voltage levels through advanced grid solutions (e.g., HVDC, FACTS) and increasing flexibility capabilities from RES.

ETIP SNET, R&I Roadmap 2022-2031, Implementation Plan 2022-25



HLUC 6: Secure operation of widespread use of power electronics at all systems levels

identifies, simulates with digital twins and then realises control solutions for PV integrated with batteries and their inverters thereby considering transition path to hybrid AC/DC electricity grids, adapted distribution substations, HVDC multi-terminal configurations and their standardisation.

- **Power electronics driven components** are becoming a key asset for modern power grids, but there is not yet a clear understanding of how these devices will **shape system operation**.
- The more the share of power electronics devices grows, the more there is a need to involve these devices with an **active role**. This is true at different levels for the grid.
- Transmission system shall consider the evolution of HVDC towards **multi-terminal multi-vendors meshed DC grids**. These are appearing first of all for **off-shore RES applications**, but are expected to spread also in **on-shore solutions** and to move from HV also to MV applications.
- In particular, the definition of the roles of **grid-forming converters** is still mostly at research level and a flexible transition between different modes of operation shall be further investigated, including how substations with traditional transformers can be enhanced by power-electronics and how the penetration of smart power routing devices such as FACTS and Solid-State Transformers can be applied.
- Explore the role of the power electronic devices at every level from the transmission to the LV distribution and prepare the condition for a **system level operation that is fully capable of using the control capability of power electronics**. The overarching goal is to facilitate a power electronics dominated grid.

SOME TECHNICAL CHALLENGES

- With significant **integration of converter interfaced generation technologies** (CIGs), loads, and transmission devices, the **dynamic response** of power systems has progressively become more dependent on (complex) **fast-response power electronic devices**, thus, altering the power system dynamic behavior.

- The increasing share of CIGs in power generation mix affects all types of **system stability, frequency, voltage and rotor-angle stability** and leads to new types of power system instability problems, like converter driven or harmonic instability.

- These problems arise due to the different dynamic behavior of CIGs compared to that of the conventional generators. The stability issues arise due to interactions between CIG controls, reduction in total power system inertia, and limited contribution to short circuit currents from CIG during faults.

- **New tools** are needed to model and simulate all these types of fast and slower stability phenomena.

- Further challenges include the need of analysis tools to map all uncertainties – both power electronics and power systems, the need of new **testing methods** to analyze thousands of power converters operating at the same time and how to aggregate 1000's of them in complex systems and to **develop reliability assessment methods** of complex systems.

- In the future we can expect meshed DC grids at all voltage levels, **hybrid transmission and hybrid distribution AC/DC grids**. These topologies will require **new control concepts** for system integration so to guarantee a safe operation of the grid.

- From the grid operation perspective, a **new generation of substation with high adoption of power electronics** is emerging. This means the possibility to substitute old transformers with the so called smart-transformers, but also to integrate DC buses in the substation or other advanced power electronic solutions such as FACTS.

- Goal is to transform the substation in an intelligent node able to guarantee a high level of reliability in the region of operation.

SOME FOCUS AREAS:

- Clear understanding of the **dynamics** of a power grid with high penetration of power electronics
- Advanced **simulation tools** implementing the aforementioned concepts; go beyond the classical separation between phasor simulation and electromagnetic transient analysis
- New generation of grid-connected inverter able to provide **grid services** in a flexible way and able to commute
- Grid operation principles for **multi-terminal HVDC and MVDC networks**; keep the main advantages of point-to-point DC transmission networks and to maximise the utilisation of the assets
- Grid operation principles for **hybrid AC/DC networks**; necessary control solution that support the development of hybrid AC/DC grids in HV and MV; **SCADA and Control Center tools** to handle hybrid AC/DC networks
- Development of the proper concepts that support **interoperability** and cooperation between converters operating in the DC and in the AC section of the system; improve the investment on assets and the environmental impact of the power system infrastructure; development of the necessary methodologies, tools and models for the analysis of the operation of such configurations
- Definition of a fully electronic substation able to provide **active control of the power flow**
- Process of **standardization** to support all the aforementioned principles
- **Supply chain** issues
- **Legal**, **regulatory**, multi-country issues
- **Market** related aspects