ENTSO-E Public Workshop on NC HVDC

NC HVDC – General Principles

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NC HVDC General Approach

Capability of HVDC systems supporting cross-border system security

- Use HVDC technology's inherent capabilities (e.g. fast active and reactive power control, supplementary control) in meeting Europe's energy objectives
- Network assets should retain their integrity during system events at minimum as long as generation/demand has to remain connected
- Increase grid flexibility, capability and controllability
- Maintain system security

Synergies between DC-connected PPMs and HVDC links

- Need to have consistent, coordinated and economically balanced requirements so as not to impair requirements at AC onshore transmission connection point
- Consider the long-term development of the network

Coping with different technologies

- Not favouring nor discriminating technologies

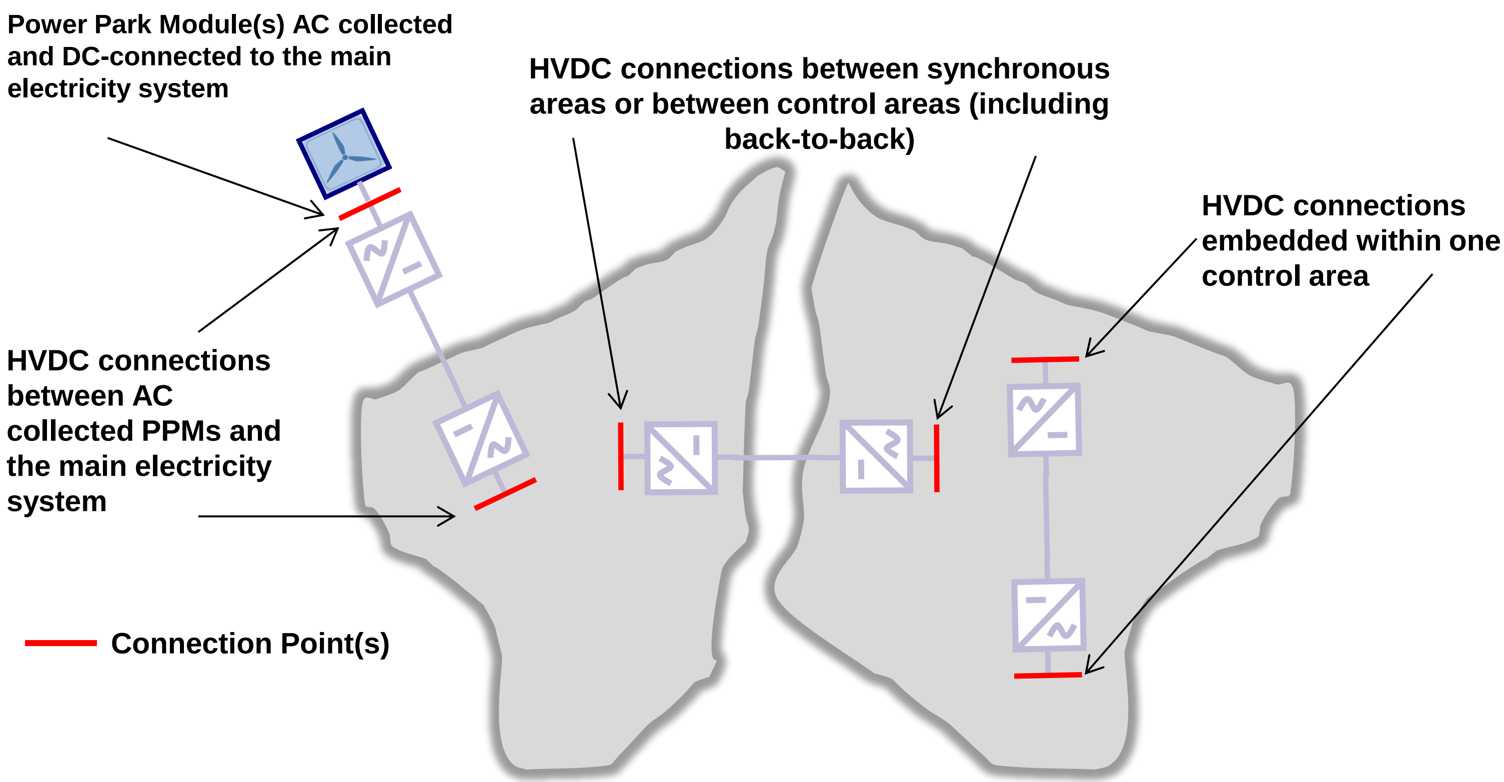
Considering potential future DC grids

- No barrier to future expansion into multi-terminal or meshed DC grids

Aligned approach between grid connection codes

- All connection codes are a coherent package

HVDC Systems and DC-connected Power Park Modules covered by NC HVDC



*NC HVDC applies to **new** connections*

Different HVDC technologies under different conditions

- ***Objective***
  - Allow for grid user to choose preferred approach that satisfies the requirements and to support the specific system needs
  - Define the minimum performance requirements needed to ensure reliable operation of connections
  - Avoid restraining R&D programs, and promote innovative solutions

- ***Approach for NC HVDC requirements***
  - **Technology-neutral** requirements (no LCC or VSC classes)
  - System needs result in **functional capabilities**, instead of design specifications
  - Local conditions and the need for a balanced treatment of all users necessitate a level of **flexibility** to be maintained in the NC HVDC:
    - mandatory and non-mandatory requirements
    - exhaustive and non-exhaustive requirements

General requirements for HVDC Systems

- **ACTIVE POWER CONTROL AND FREQUENCY SUPPORT**
  - Frequency ranges
  - Rate of change of frequency withstand capability
  - Active power controllability and control range
  - Synthetic inertial capability
  - Frequency sensitive mode
  - Limited frequency sensitive mode (overfrequency)
  - Limited frequency sensitive mode (underfrequency)
  - Frequency control
  - Loss of active power
- **REACTIVE POWER CONTROL AND VOLTAGE SUPPORT**
  - Voltage ranges
  - Short circuit contribution during faults
  - Reactive power capability
  - Reactive power exchange
  - Reactive power control mode
  - Priority to active or reactive power contribution
  - Power quality
- **FAULT RIDE THROUGH**
  - Fault ride through capability
  - Post fault active power recovery
  - Auto reclosure
- **CONTROL**
  - Converter energisation and synchronization
  - Interactions
  - POD capability
  - SSTI damping capability
  - Network characteristics
  - System robustness
- **PROTECTION DEVICES AND SETTINGS**
  - Re-connection
  - Electrical protection schemes and settings
  - Priority ranking of protection and control
  - Changes to the protection schemes and settings
- **POWER SYSTEM RESTORATION**
  - Power system restoration
  - Black start
  - Isolated network operation

Active Power Control and Frequency Support

Coordinated approach for maintaining system security

- Frequency withstand capabilities: Ensure that network assets remain in operation during severe system events, especially under those conditions which generation and demand have to withstand as well.

Frequency control functions

- Essential for a future RES based secured transmission system (more flexibility and controllability)
  - *fast active and reactive power control*
  - *emergency control actions*
  - *supplementary control*

Synthetic inertial capability

- Synchronous generators have an inherent capability to resist / slow down frequency changes which converter based technologies do not have.
- Allow further expansion of RES which does not naturally contribute to inertia,
- Provide a synthetic component by converter based technology to make its contribution to overall system inertia.

Reactive Power Control and Voltage Support

Voltage ranges

- network assets should maintain their integrity during system events at minimum as long as generation/demand has to remain connected

Short circuit contribution during faults

- sufficient magnitude and quickly enough for reliable functioning of system protections

Voltage control functions

- Fast reactive power control is essential for a future RES based secured transmission system (more flexibility and controllability)

Power Quality

- Scale of distortion is an aggregated effect of all connections
- Simultaneously the aggregated distortion levels inversely impacts on all connected parties
- More and more important in case of converter dominated grids

Fault Ride Through

Fault-ride-through capability

- HVDC systems remain connected to the AC transmission system when system voltages are low during and after recovery from temporary fault in the AC transmission system
- Blocking allowed in coordination with the relevant TSO
- Post fault active power recovery depends on system needs

Auto-reclosures

- HVDC systems shall not disconnect in case of auto-reclosures in the AC system
- Capability for transient faults on HVDC system Fault clearing and active power recovery in case of DC faults would enable fast restoration of the integrity of the network and reduce risk of system stability

HVDC Control Functions

Interaction between HVDC systems - A proper and robust control design and control coordination is required

- Achieve a secure operation of the connecting network(s) and the (multi-terminal) HVDC systems by a robust design of HVDC system(s)
- Avoid adverse interaction between converter controls during transient or steady state conditions of HVDC systems or other grid users in close proximity
- Prevent sub-synchronous torsional interactions by SSTI control
- Support power oscillation damping

Consider the long term developments

- Converter synchronization to and disconnection from the AC or DC-network
- Requirements at each converter AC connection point include meshed HVDC systems as well, whereas requirements for each converter DC connection point should not pose a barrier to future expansion into multi-terminal or meshed DC grids
- Each HVDC converter station (of a multi-terminal system) shall handle in a predefined way in case of expected and unexpected changes in the HVDC system without tripping

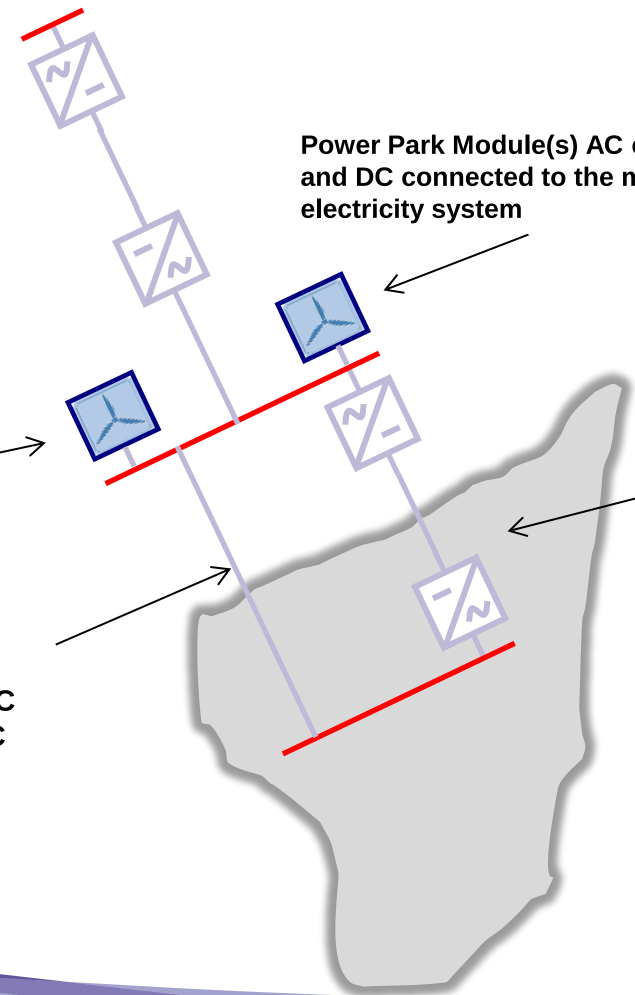
DC Connected PPMs and associated HVDC converter configurations

HVDC connections may become DC connected to another synchronous electricity system

Power Park Module(s) AC collected and DC connected to the main electricity system

Other 3rd party Power Park Module(s) AC collected

HVDC connections between AC collected PPMs and the main electricity system



AC connection in parallel with HVDC connection to AC collected PPMs

Connection Point(s)

DC Connected PPMs and associated HVDC converter

NC HVDC uses NC RfG and DCC as starting point. Specific consideration needs to be given to

Frequency ranges	Offshore system behaviour, control and dynamics differ from synchronous areas
Active Power Control	Frequency support service from PPM via HVDC connections to the different synchronous area(s) connected to
Reactive power	Economic optimization options, e.g. link and generation are owned by the same entity, system needs, etc.
Voltage support	Voltage support, harmonic distortions and robustness against disturbances

- PPM and HVDC System(s) need to have **economically consistent, coordinated requirements** so as not to impair requirements at AC onshore transmission connection point

- **Long-term network development** needs to be considered, allowing for installing reactive power capabilities at a later stage, and provide a process to optimise the design of the DC link and the PPM

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Thank you for your attention!

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