MULTI-TERMINAL AND MULTI-VENDOR HVDC SYSTEMS

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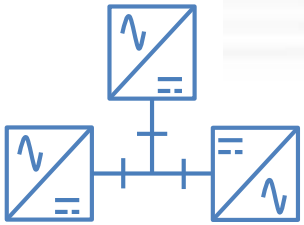
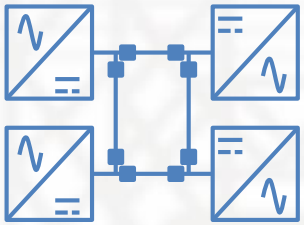
INTRODUCTION

PtP
Point to Point link
2 terminals



MTDC
multi-terminal system
>2 terminals



DC grid
>1 protection zones

PtP links vs MTDC and DC grid

- Loss reduction (less conversion)
- More cost efficient compared to multiple PtP
- With proper protection, increase in system reliability

Why now?

- Remote wind (offshore) combined with interconnection
- Increasing impact of grid constraints
- VSC HVDC mature

The North Seas Countries' Offshore Grid Initiative

DESIGN OF A MULTI-TERMINAL HVDC SYSTEM

Turn-key

Nordbalt

- Lithuania-Sweden
- Power: 700 MW
- Voltage: ± 300 kV
- Total length: 400 km
- VSC technology
- Turn-key MTDC prepared
- Prepared for add. terminals

Turn-key delivery

- Specifications on system level
- Supplier responsible for system design and performance

Package delivery

- Owner responsible for system design and performance
- Specifications on equipment level
- Supplier responsible for equipment design and performance

MTDC READY “PLUG & PLAY”

Complete design for all terminals done in first phase

- All details for future terminals needed as input at phase 1
- Increase in schedule approx. 6 – 12 months, also for tender
- All equipment designed for the final MTDC configuration
- Design for switching station to be done in phase 1
- C&P equipment for the future terminals are tested during Factory System Test for phase 1 (including master control)

Options (examples)

- to supply/install future converter and switching station
- to supply/install cables for future converters/switching station

MTDC PREPARED

Design only for the first phase, but future-proof for further extension

- Data for future converters at phase 1 can be minimum (number of stations, base ratings)
- No change in schedule (compared to 2 terminal system)
- Cable design need to be adopted for final configuration (little impact for a radial MTDC configuration)
- Operation modes and voltage profiles along the DC cable is recommended to be defined at phase 1

Options (examples)

- to modify existing converters at phase 2 for extension to MTDC
- to supply/install future converters and switching station
- to supply/install cables for future converters/switching station

MTDC PREPARED

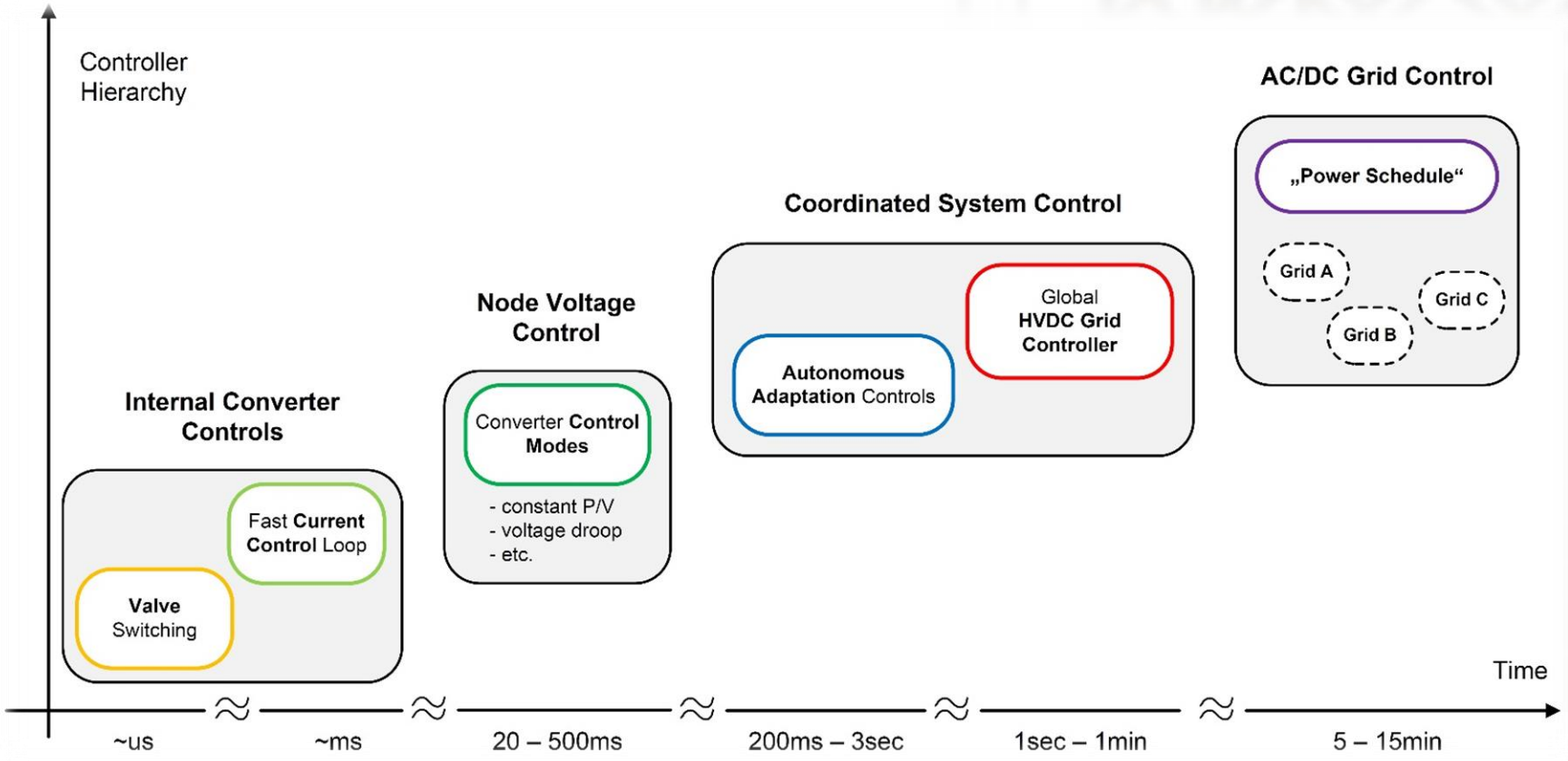
Typical approach for future-proof design

- Necessary preparations in control and protection, optionally with inclusion of required hardware and software for master controller
- Reserve space in service building to accommodate the master controller
- Reserve space in DC switchyard (at least to the extent possible within the assigned area for the converter station) for connection of further pair(s) of cables, required busbars and switching equipment
  (optionally including DC circuit breakers)
- Supply simulation models at phase 1 for studies of a later extension
  (optionally including replicas of the C&P system for real-time simulations)

Scope of works:

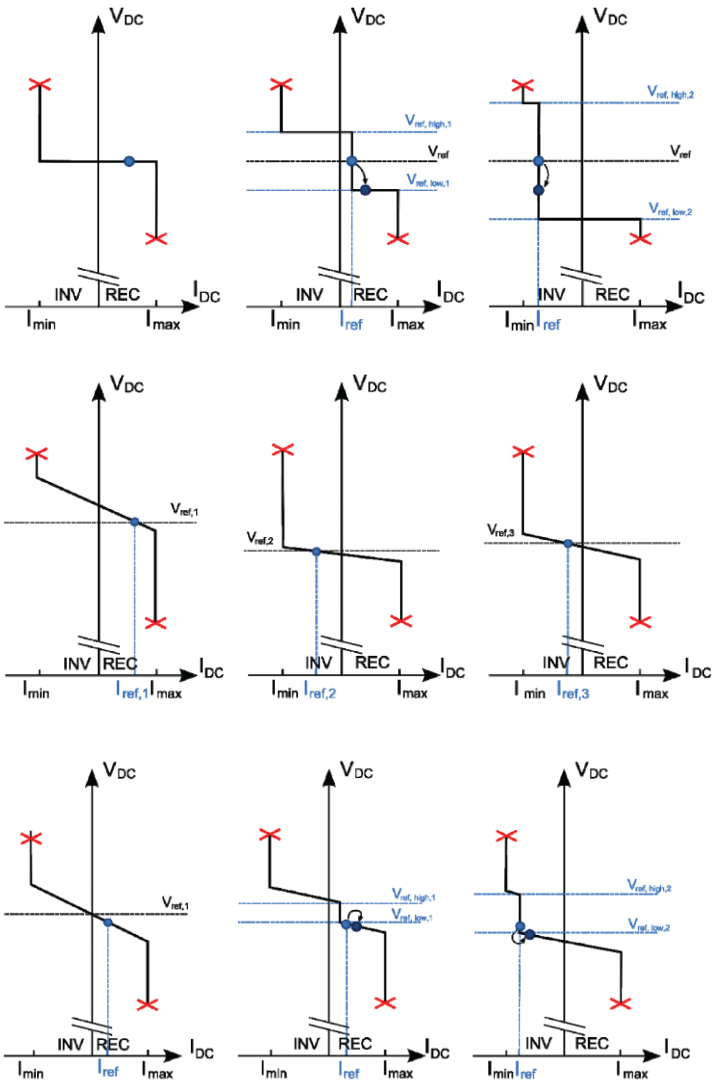
- Detailed studies of additional, future terminals are not required, neither in tender phase not project delivery phase
- System rating and performance based on requirements from phase 1

CONTROL OF MTDC AND DC GRIDS



TB 699 „Control methodologies for direct voltage and power flow in a meshed HVDC grid“

NODE VOLTAGE CONTROL

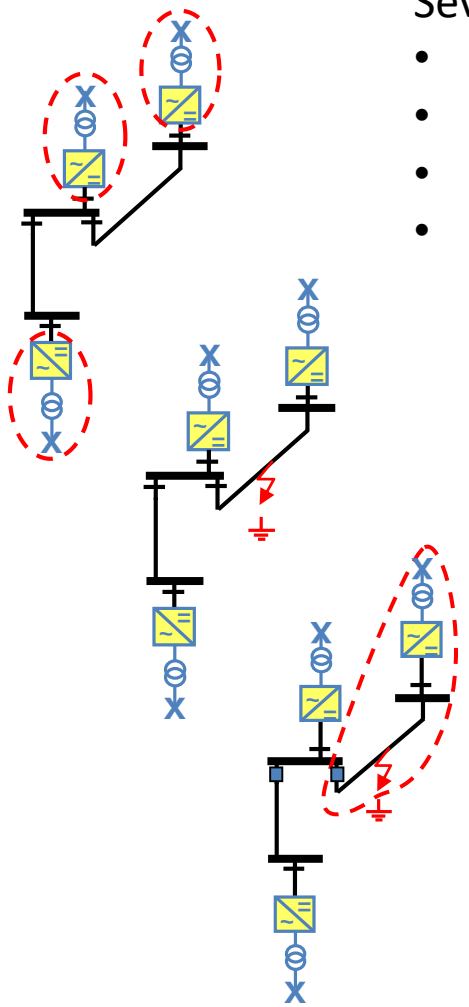


Control with voltage deadband
- Designated slack
- Master-Slave setup

Control with power-voltage droop
- Distributed slack
- No settling point for DC voltage

Control with droop and deadband
- Designated slack
- Slave converters contribute only during larger power imbalance
- No settling point for DC voltage

MTDC PROTECTION



Several zones for converter faults

- Faults in controls, cooling, filters cause trip of converter
- Rest of system continues operation without any interruption
- Local control redistributes power flow initially
- Master control optimizes power redistribution

One zone for DC cable faults

- Limited impact of rare loss of the MTDC system
- DC fault sequence and start-up of healthy part possible
- Converter DC breakers or FB converters if reactive power support is required during DC line faults

Several zones for DC OHL faults

- Large impact or frequent loss of DC lines (OHL)
- DC fault sequence without disconnection tripping converters in healthy part

MULTI-VENDOR INTEROPERABILITY

R&D project founded by the European Union
Goal of demonstration #2: outline conditions to ensure maximum interoperability for HVDC-VSC converters connected to a DC system
Partners involved:

- Manufactures: ABB, GE and Siemens
- TSOs: Elia, REE and RTE
- Universities: Lille and Strathclyde

Findings

- Off-line simulations showed more potential issues than real-time simulations
- Accurate simulation tools needed
  - Generic models provide good indication of HVDC grid feasibility
  - Accurate models (off-line and real-time) are mandatory for interoperability

Recommendations

- “DC grid integrator” to solve interoperability issues and ensure confidentiality
- “DC grid integrator” should specify and implement high-level control and protection algorithms and organize tests
- manufacturers incentivised to share a common pool of patents and techniques

SUMMARY

Multi-terminal HVDC systems can be built and operated today
Single-stage or multi-stage development based on project timeline

- Single-stage design and delivery easiest for supplier, but cash flow may not be optimized for owner
- MTDC ready approach (“plug & play”) reduced total design effort, but is not compatible with multi-vendor delivery
- MTDC prepared approach can be used if the system configuration after final development is not known from the beginning. With the proper set-up it can also ensure multi-vendor supply