ENTSO-E Public Workshop on NC HVDC

General Requirements for HVDC Systems: *Active Power Control and Frequency Support*

Brussels, 4 December 2013

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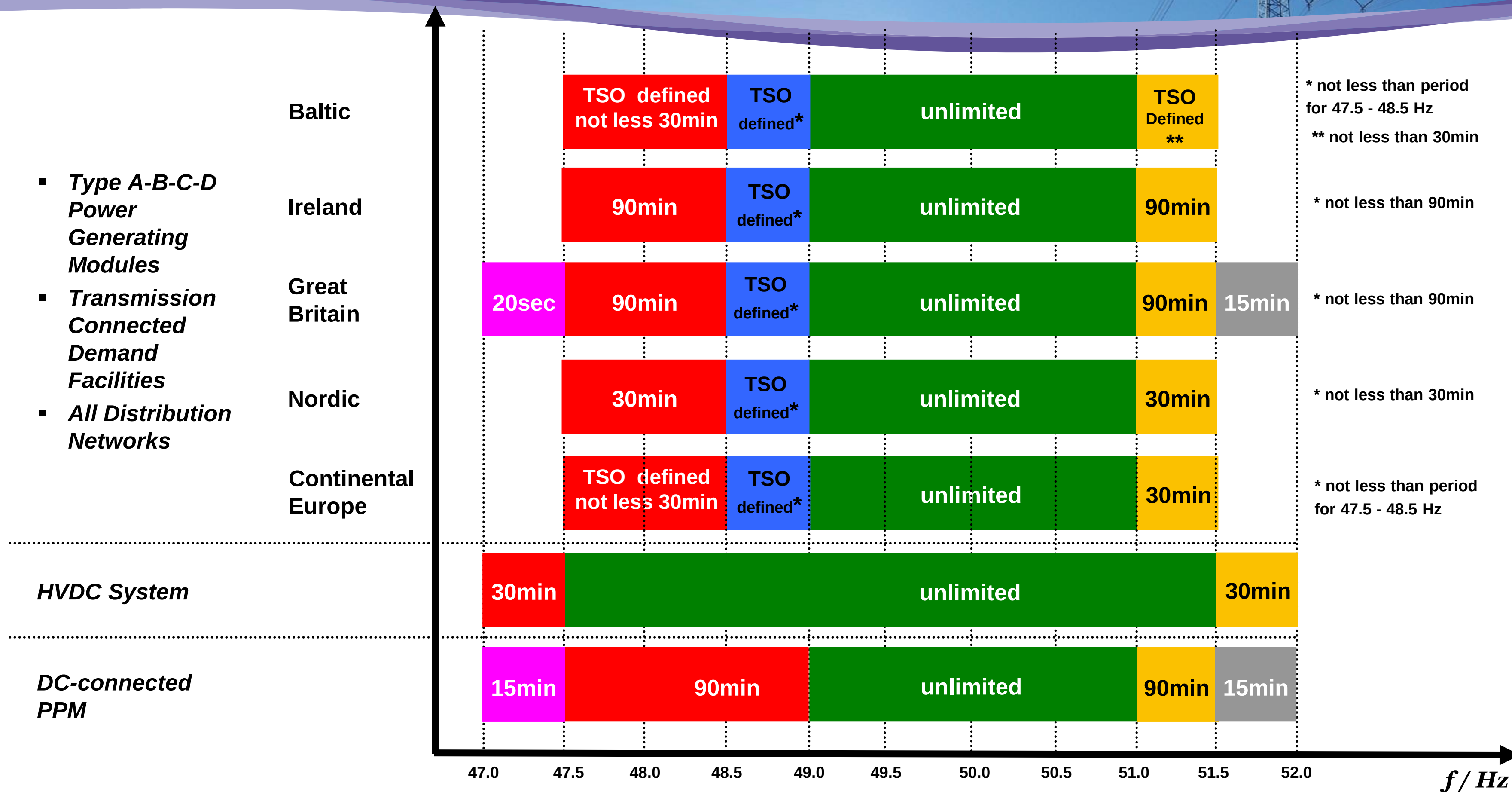
Art 7 - Frequency ranges across three connections codes



➢ **NC HVDC ranges ensures that the network is more resilient to disturbances than generation or demand**

Art 8 - Rate-of-change-of-frequency withstand capability

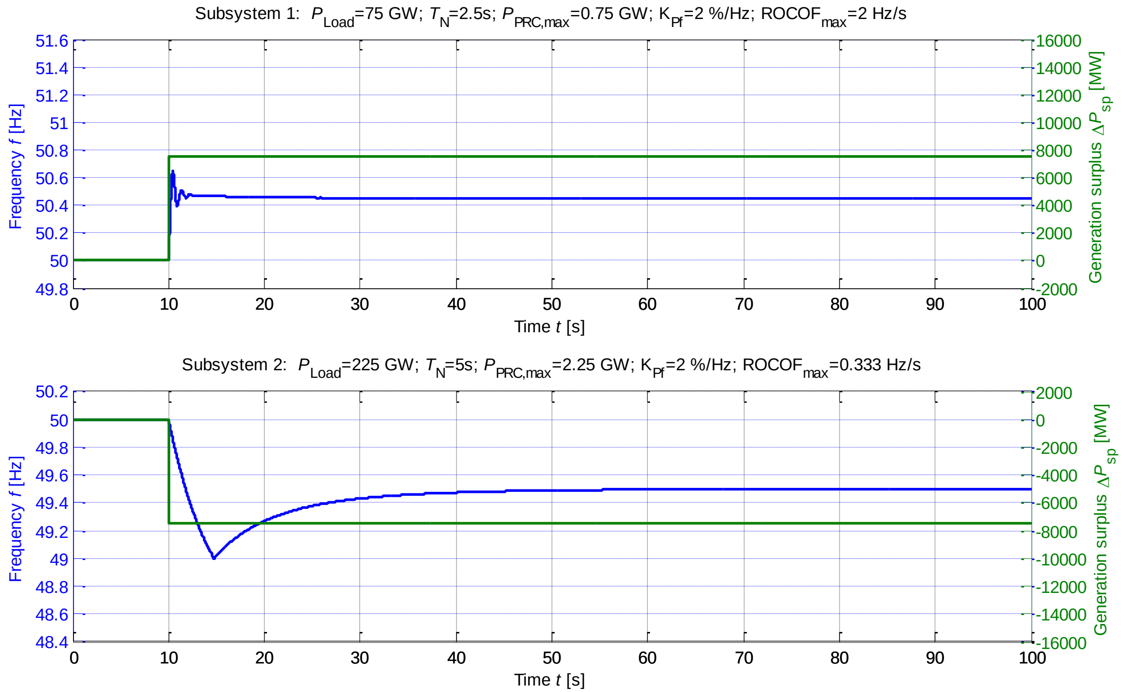
Even within synchronous area with high inertia (i.e. Continental Europe) high ROCOF (Rate-of-change-of-frequency) **can be experienced in case of network split**

Simulation

- Continental Europe split in two subsystems (225 GW / 75 GW) connected with HVDC link
- ROCOF in the smaller subsystem = 2 Hz/s

➢ **Importance of withstanding ROCOF > 2 Hz/s**

➢ **Requirement > 2,5 Hz**

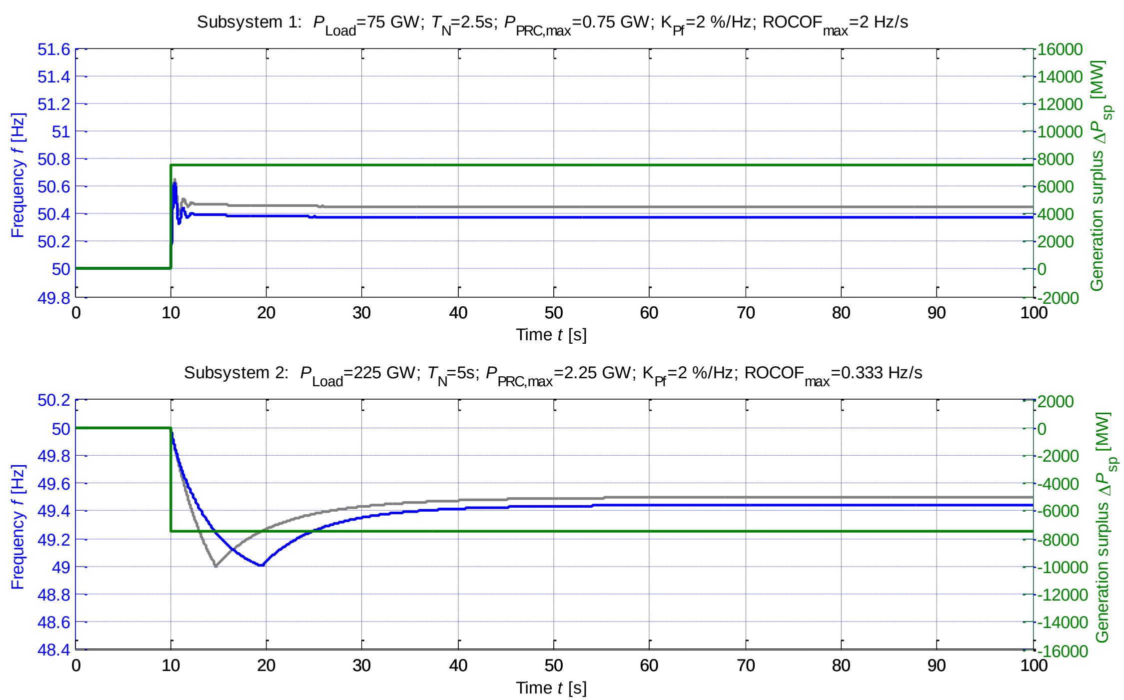


Art 10-13 - Frequency Sensitive Modes and Synthetic Inertia

- **With FSM/LFSM: Better stabilization in subsystem where generation is lacking (within seconds) and reduces need for load shedding when frequency is reaching 49Hz**
- **Synthetic inertia expected to have a stronger impact than FSM in the first seconds (lower ROCOF in both subsystems)**

Simulation (HVDC with FSM/LFSM)

- Continental Europe split in two subsystems (225 GW / 75 GW) connected with HVDC link (4 GW)
- HVDC link still operating and FSM/LFSM providing 2GW to the subsystem where generation is lacking



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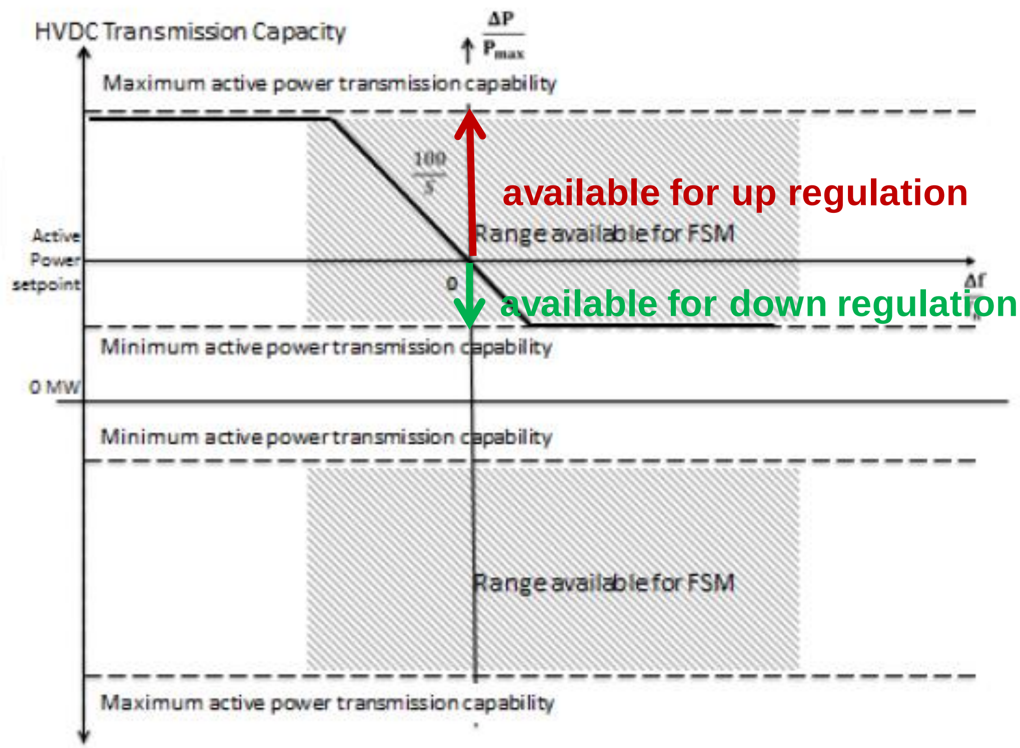
Art 11 - Frequency Sensitive Mode

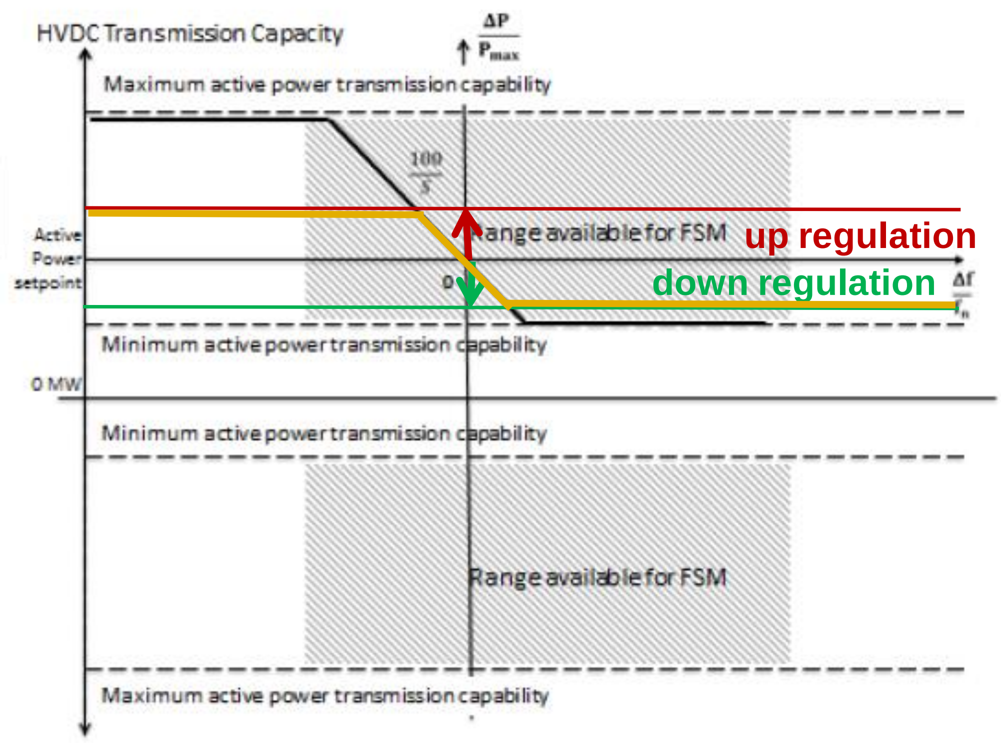
Proportional towards NC RfG requirements: a better response is expected from HVDC systems than from a generating unit (no limitations due to rotating masses)

- FSM available across the range of active power output
- Minimum droop 0.1%
- Maximum admissible initial delay 0.5 second



Art 11 - Frequency Sensitive Mode

- Active power range available for FSM can be adjusted by the TSO
- Example: In orange, new response in active power output expected from the HVDC system according to FSM range defined by the TSO



Art 14 - Maximum loss of Active Power

- Equivalent requirement is not included in RfG and DCC: present design of generation or demand facilities gives an active power variation in case of outage lower than +/- 1,5 or 2 GW.
- But, technology does not limit capacity of HVDC facilities to such level. Possible new HVDC connections of high capacity (e.g. > 4 GW) needs to be covered by the NC HVDC.
- **To avoid unreasonable increase in costs of operational reserves, the NC HVDC requires new connections to design their system as to limit the loss of power in case of outage (e.g. redundancy in design). Limit defined per LFC Block.**

Example : in France current transitory rules for HVDC connection require a maximum loss of active power of 1800 MW to avoid an excessive increase of Frequency Restoration Reserve (FRR).

Questions?

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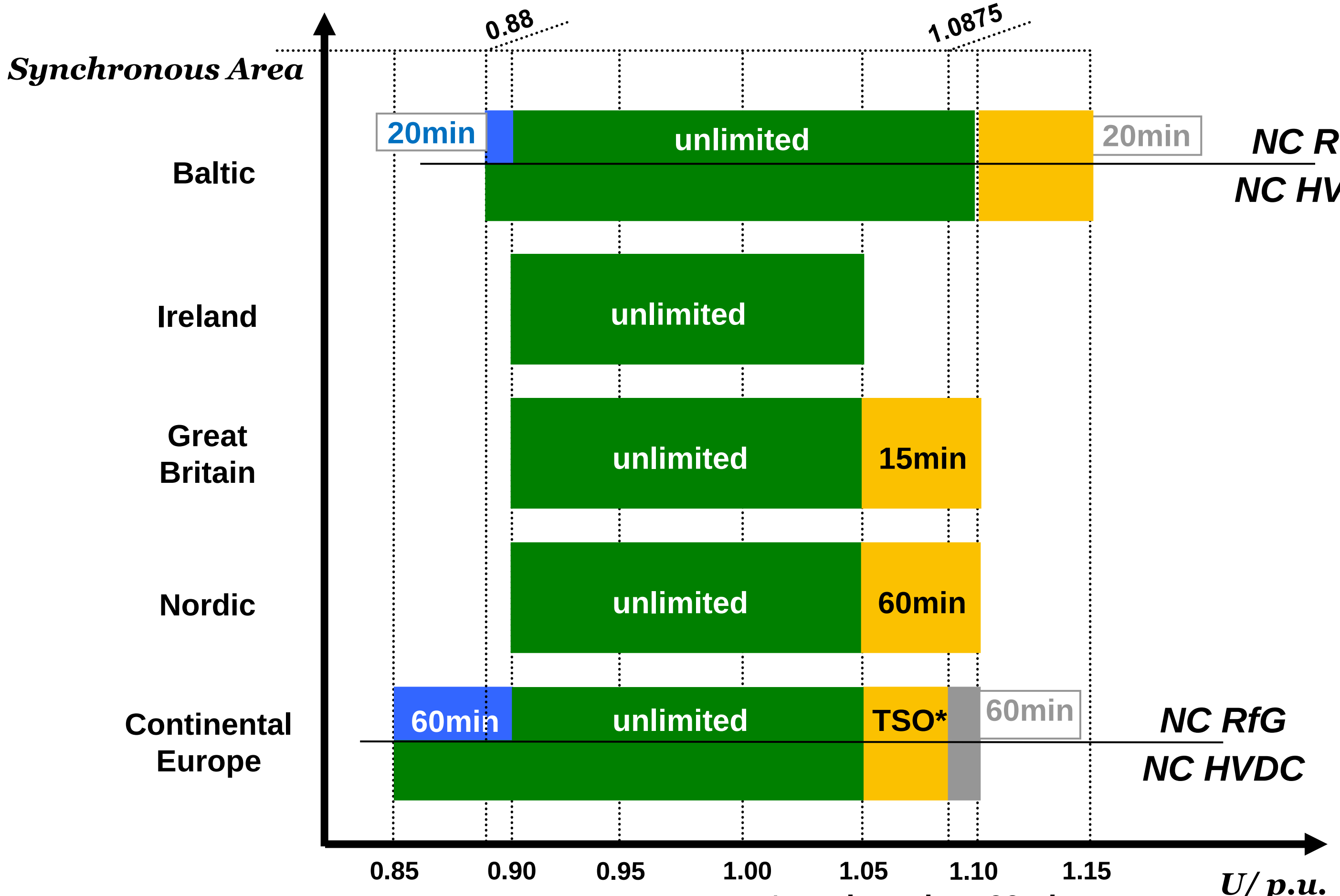
Art 16 - Voltage Ranges

300 - 400kV systems



* not less than 60min

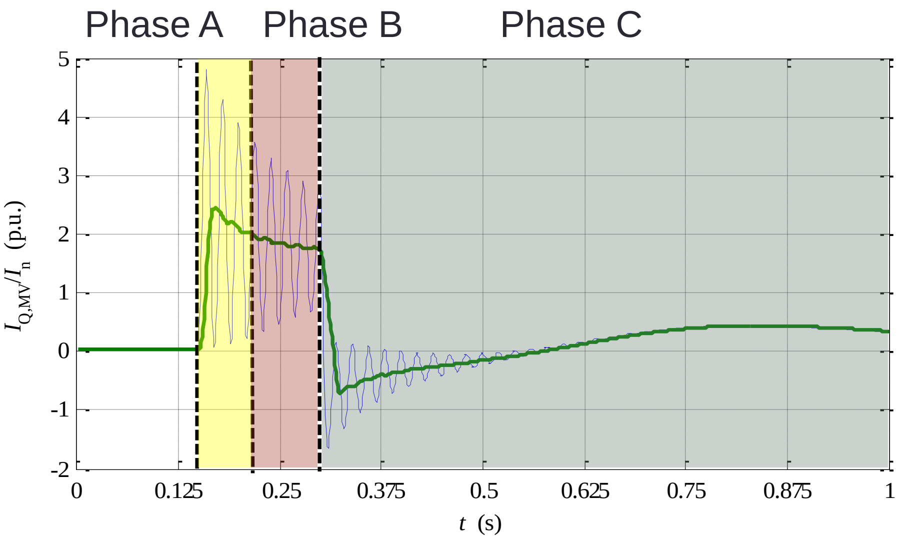
Art 16 - Voltage Ranges

- HVDC Converter Station capability to stay connected to the Network and operating at the maximum output during Voltage excursions at the connection point
- Aligned with RfG / DCC: tables for 110-300kV and 300kV-400kV
- Longer time ranges for low voltages
- **Ensures that the network is more resilient to disturbances than generation or demand**

Art 17 – Short circuit contribution

- Proposal for consistent approach with NC RfG requirement for PPMs
- Inherent capabilities and performance of synchronous generators, which are essential for system security during and after an electrical fault on transmission system level, need to be covered by other grid connections through inherent and/or controlled action:

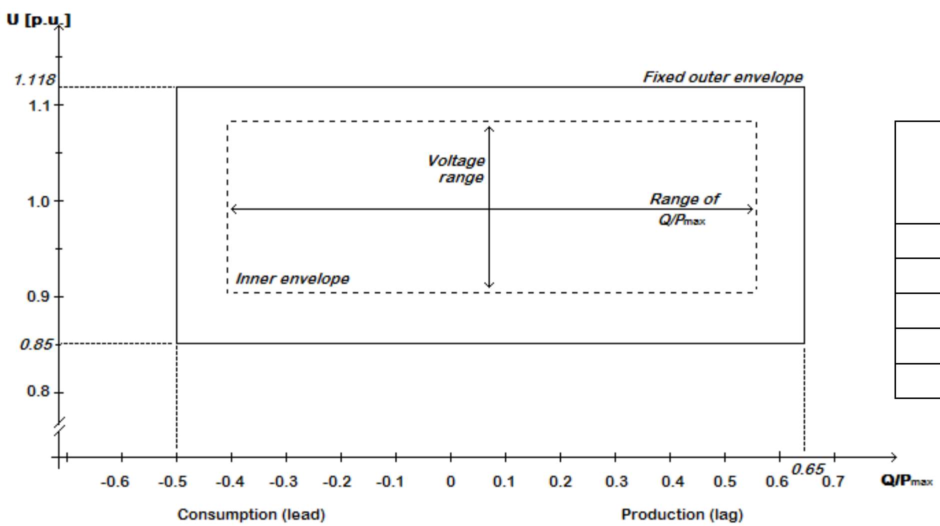
- Initial period of a fault (Phase A): Delivery of a fast fault current to **recognize, locate and initiate clearance of the fault** by electrical protection systems.
- Later period of the fault (Phase B): Delivery of (additional) reactive current **supporting voltage retention**. Magnitude of current prevails over control accuracy.
- After fault clearance (Phase C): Delivery of a reactive current to **restore voltage** and restoration of active power to **remove power imbalances** and corresponding frequency deviations. Control accuracy is crucial to avoid overvoltages.



Typical response of a synchronous generator to a 3-phase fault

Art 18 – Reactive Power Capability

- Mandatory requirement, but open to suit **local system needs** and as not to ex ante discriminate **HVDC technologies**
- Covers reactive power capability across **full range of Active Power**
- Relevant TSO(s) defines **U-Q/Pmax-profile** within the boundary of which the HVDC is capable of providing Reactive Power
  - Does not exceed the inner envelope, and does not need to be rectangular;
  - Within the limits of a fixed outer envelope;



Synchronous Area	Maximum range of Q/Pmax	Maximum range of steady-state Voltage level in PU
Continental Europe	0.95	0.225
Nordic	0.95	0.150
Great Britain	0.95	0.100
Ireland	1.08	0.218
Baltic States	1.0	0.220

Art 19 – Reactive power exchanged with the Network & Art 20 – Reactive power control mode

Objective

- Increasing penetration of RES will displace synchronous generators and their contribution to reactive power management and voltage control.
- Therefore reactive power control capability of all grid users, including HVDC systems, needs to be utilized for a cost-efficient operation of the system.

Approach

- Requirement on reactive power control modes is similar to NC RfG but faster due to the possibility/ability of HVDC technology.

Art 21 – Power Quality

Objective

- Increased use of power electronics increases power quality disturbances in the network, all resulting in increased harmonic currents, temperature rises, etc… and related losses/costs

Aim

- Each HVDC converter filter at least own ‘distortions’.
- Each HVDC converters does not introduce harmonics in breach of national/local power quality specifications.

Questions?

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General Requirements for HVDC Systems:
Fault Ride Through
Control
Protection Devices and Settings
Power System Restoration

Brussels, 4 December 2013

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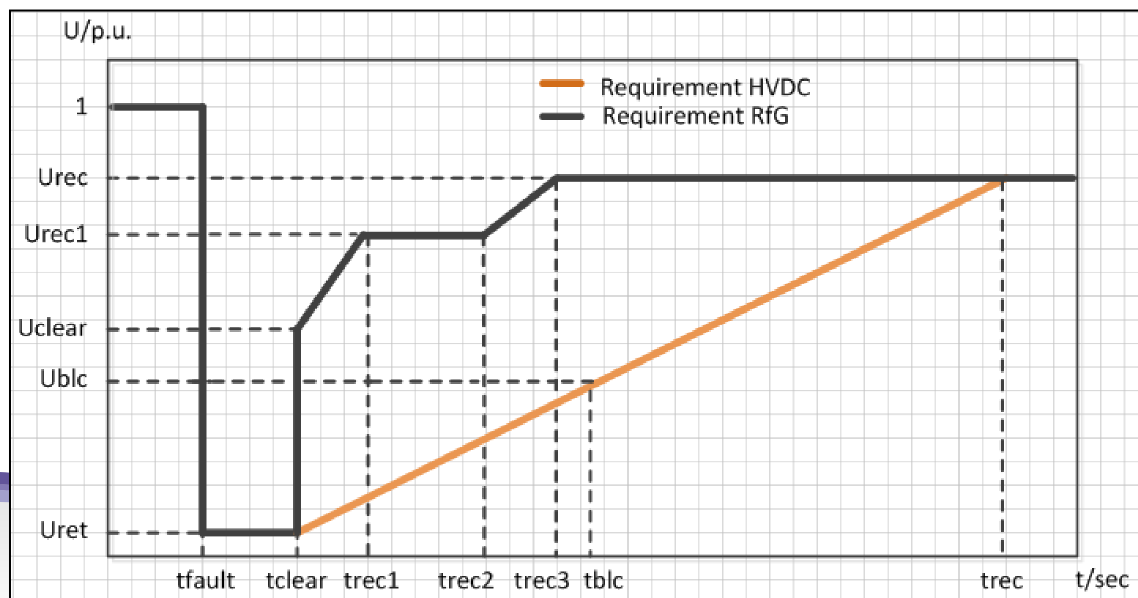
Art 23 – Fault ride through capability

Objective

- Temporary AC or DC faults: HVDC systems (like generation) needs to be resilient to voltage dips in the AC network or within the HVDC system due to.
- If not: Risk of large infeed/outfeed power loss, and resulting large frequency disturbances in both connected ends.

Approach

- After fault clearance HVDC Systems shall stay connected and be ready for fast recovery to its pre-fault transmission level of the power transmission.
- The HVDC System must be able to ride through a voltage profile which cover all types of possible voltage dips caused by transmission faults in a given network. Fault clearance time up to 250ms and recovery time up to 10 s (which makes it more robust then generation).
- The robust profile of the HVDC FRT capability takes into consideration the high penetration of smaller asynchronous generators with a different reactive power profile in close vicinity of the HVDC connection point.



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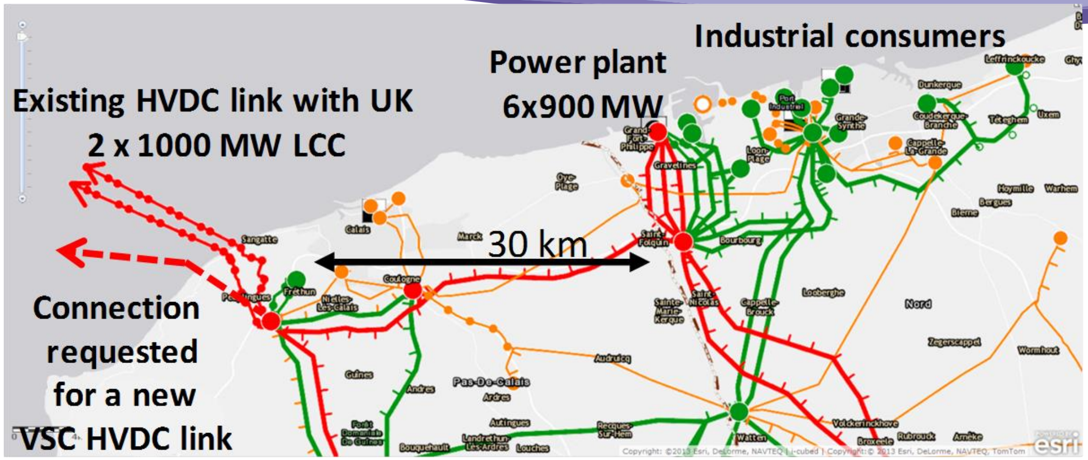
Art 23 – Fault ride through capability

- The TSO must specify **further system conditions** (short circuit power, pre-fault power factor, …) at the connection point.
- Important that schemes for protection for **internal faults** do not jeopardize the fault ride through requirements.
- **Blocking**
  - Voltage dips of typical 15 % at the connection point of a LCC converter operating in inverter mode may cause commutation failures. For severe faults, repeated commutation failures may occur as long as the voltage remains low.
  - Therefore, blocking of the valves is acceptable as an alternative to a high FRT retained voltage.
  - However, no active or reactive power is injected to the Network during a blocking phase.
  - **Agreement** between TSO and HVDC System Owner is needed.
- After fault clearance and de-blocking the HVDC system must **recover to pre-fault level** as required by the TSO.

Art 27 – Example of interaction between a new HVDC system and existing HVDC/grid users in France



- Two HVDC Systems (LCC and VSC) with different operators
- Need for interaction study, in addition to more standard studies, e.g.
  - ➢ adverse interactions with large power plants e.g. sub-synchronous torsional interaction
  - ➢ specific consumers with sensitivity to power quality disturbance
- Wide range of tools is required:
  - ➢ static indicators (during planning stage)
  - ➢ mathematical analysis (small-signal stability),
  - ➢ detailed simulation models
  - ➢ control replicas

Art 27 – Interaction between HVDC system(s) and other Connections

Objective

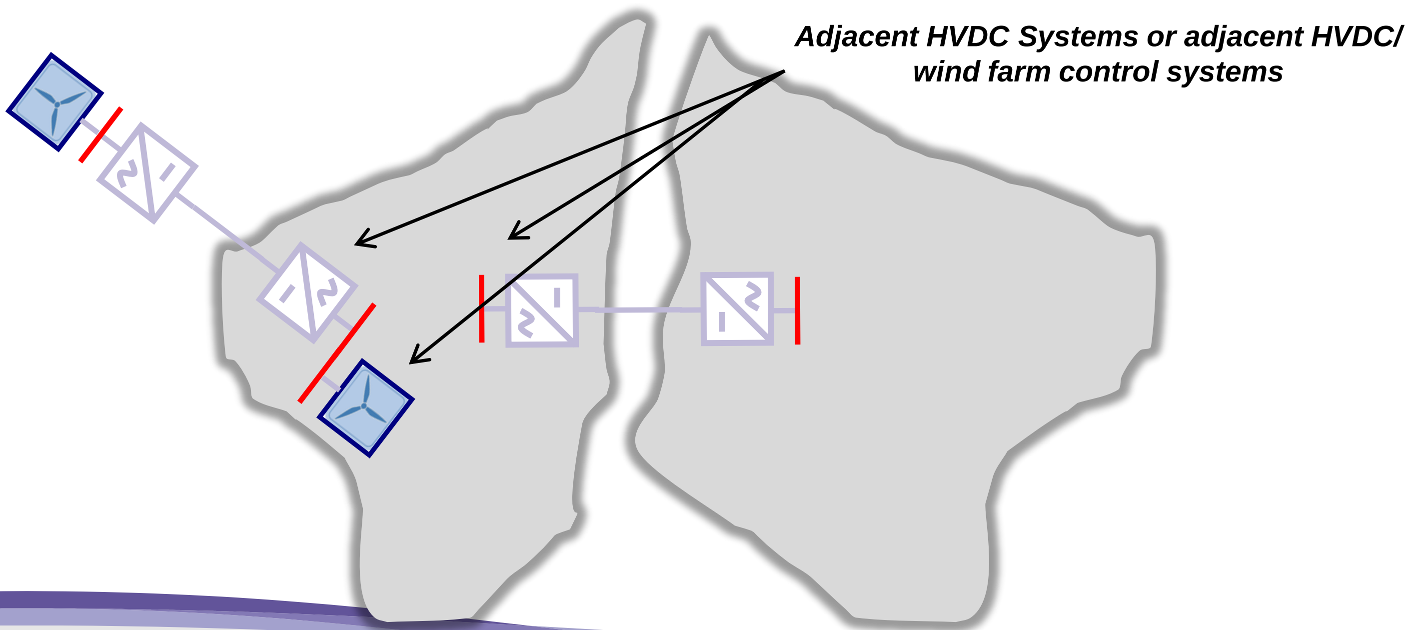
- Connecting a new HVDC Converter Station in an existing network with other controllers should not result in an negative control interaction between the new and existing controllers.
- Risk: Control instability can limit transfer capability of interconnection and compromise the overall system security.

Approach

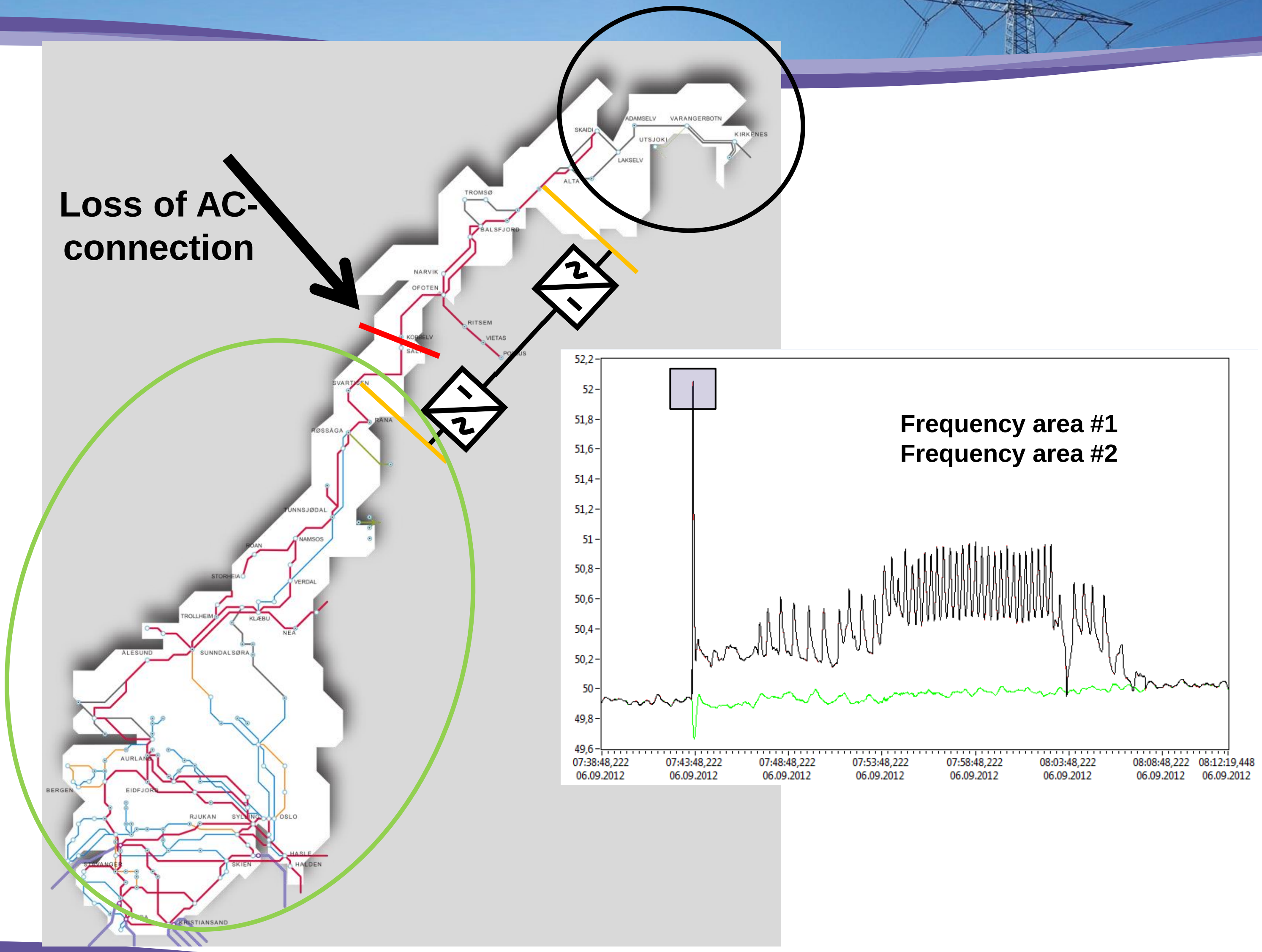
- Ensure that undesirable interaction of HVDC control system with offshore wind farm control or between nearby HVDC controls are avoided by **proper and robust control design** and **control coordination**, and where necessary, other **mitigating actions**.
- Defining the **responsibility for performing interaction studies**.

Art 27 – Interaction between HVDC system(s) and other Connections

- The TSO has the **right to require** an interaction study, and also to **define the scope and extent** of the studies.
- The studies shall be **carried out** by the connecting HVDC Converter Station owner.
- **Contributions** to such study from existing HVDC System Owners shall not be unreasonably withheld.



Art 37 - Isolated network operation



Art 37 – Isolated network operation

Objective

- If the connecting network loses connections to other parts of the synchronous area, there will be a resulting island mode operation of the connecting network.
- For the security of operation of the connecting network, the HVDC system needs to be able to handle this isolated network operation.
- This situation can result in voltage and frequency values, as well as short circuit levels, beyond "normal" values.

Approach

- Capability of a HVDC system to remain connected to the network when there is a transition into an isolated network at one of the connection points.
- No trip and continue providing active and reactive power.
- Need will be defined based on specific circumstances for each link.