CENELEC TC 8X/WG 06
System Aspects of HVDC Grids

Best Paths Dissemination Event
Paris, 5 November 2015

Frank Schettler (Siemens, Convenor)
Overview

► Introduction to CLC TC 8X/WG 06
► Scope and present status of work
► Examples of topics in discussion

► Coordination of HVDC Grid System and AC systems
► HVDC Grid Control
► Models and Validation
► HVDC Grid System Integration Tests
CLC/TC 8X/WG 06
Key Figures

- 1st Meeting: 11th April 2013 (Kick-Off)
- 14 regular Working Group meetings until today (6 Meetings in 2015)
- 5 Sub Groups dealing with different technological aspects:
  - Coordination of HVDC Grid and AC Systems
  - HVDC Grid Control
  - HVDC Grid Protection
  - HVDC Grid System Characteristics and HVDC Grid Equipment
  - Models and Validation, HVDC Grid System Integration Tests
- 43 registered members (October 2015)
  - 10 of Manufacturers (ABB, ALSTOM, DIgSILENT, Siemens)
  - 12 of TSOs (ENEL, REE, RTE, Terna, 50Hertz)
  - 15 of Universities (Imperial Collage London, HS Karlsruhe, TU Clausthal, TU Darmstadt, TU Ilmenau, RWTH Aachen, UPM Madrid)
  - 7 of other Organisations/Institutions (Arup, ECOS, DKE, ObjectFarm)
Team Goals (excerpt)

The CENELEC TC 8X Working Group 06 elaborates standards for HVDC Grid Systems on a European level.

The Working Group focuses first on preparing the ground for a competitive supply chain of HVDC Grid System components and solutions.

The work builds on the findings of the European HVDC Grid Study Group (2010 to 2012) with the following objectives in chronological order:

► Elaborating technical Guidelines and Functional Specifications for:
  ► Radial HVDC Grid Systems (Radial systems are characterized by having exactly one electrical connection between any two converter stations)
  ► Applications in meshed HVDC Grid Systems
► Identification of items for HVDC Grid System standardisation
► Elaboration of the HVDC Grid System standards

Aiming at providing best benefit to the technological development, the Working Group liaises with other organizations working in the same field or actively contributes to their work as appropriate.
The specifications shall cover all HVDC Grid specific topics
# A Set of Two Complementing Documents

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<th>HVDC Grid Systems – Guidelines and Parameter Lists for Functional Specifications</th>
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<td><strong>Sub Title</strong></td>
<td><strong>Part 1 Concepts and Guidelines</strong></td>
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<td><strong>Working Title</strong></td>
<td><strong>(Background)</strong></td>
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<td><strong>Example:</strong></td>
<td><strong>Grid Characteristics (Operating Conditions)</strong></td>
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<td>Harmonic voltage distortion</td>
<td>Explaining backgrounds like:</td>
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<td>- How to obtain „pre-existing harmonic voltage levels“</td>
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<td>- How to calculate harmonic voltage distortions</td>
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<td>- How to demonstrate compliance with requirements</td>
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Approaching a New Technology  
From System Function to Specification

► Establish structure of Part 2 (Parameter Lists)
► Define Parameters and Requirements of Part 2
  ► focus on system functions (assure technology independence)
  ► categorise and develop systematics of functions and technical principles
  ► define parameters, assure completeness in addressing all relevant physical effects
► Elaborate Part 1 (Guidelines)
  ► make reference to publications and work of other Working Groups, e.g. CENELEC and CIGRÉ
  ► elaborate principles as appropriate
► Recommend Parameter Values
  ► investigate applications
  ► define scenarios where appropriate
  ► derive parameter values and describe reasoning
  ► standardise values
HVDC Grid Systems – Guidelines and Parameter Lists for Functional Specifications

► First Draft of Documents circulated as TC8X/Sec0140/DC and TC8X/Sec0141/DC more than 80 comments received, mainly by NCs of France and Germany, currently under investigation

► Scope
  ► Radial topologies, open for extension to meshed ones
  ► Symmetrical Monopoles, Monopoles, Bipoles, combinations thereof
Coordination of HVDC Grid System and AC systems (I)

Target: Provide guidelines for specifying functional requirements for HVDC Grid Systems from an AC system's perspective

**HVDC grid functions for AC systems**

**Basic operating functions:**
► Main purpose of the HVDC Grid System, design and optimization criteria
► Static power flow
► Main active power controls

**Ancillary services:**
► Energy balancing
► Power modulations
► Voltage services
► System restoration
► Stabilizing functions

**Boundary conditions: Network Code requirements**
Example: Static power flow optimization – What to specify?

a) Conditions and capabilities
   ▶ DC line ampacities (normal, overload)
   ▶ voltage and power ratings of converters
   ▶ DC line resistances

b) Optimization criteria
   ▶ reserve capacity, e.g. to cover n-1 contingencies
   ▶ overall minimization of power losses
Coordination of HVDC Grid System and AC systems (III)
Ancillary services for AC systems

Example: Energy balancing
▷ Frequency containment control (primary frequency control)
▷ Frequency restoration (secondary and tertiary frequency control)
▷ participation in unplanned AC power flow changes (e.g. in response to tripping)
▷ Synthetic inertia (faster response time than automatic frequency control)

Example: Power modulations
▷ Inter-area oscillations
▷ Power oscillation damping
▷ Subsynchronous torsional interactions
HVDC Grid Control (I)

Target: Describe principles of HVDC Grid controls and provide guidelines for specification of grid control functions and interfaces.

Controller Hierarchy

- **Internal Converter Controls**
  - Valve Switching
  - Fast Current Control Loop

- **DC Node Voltage Control**
  - Constant P/V
  - Voltage droop
  - Etc.

- **Coordinated System Control**
  - Autonomous HVDC Grid Controller
  - Global HVDC Grid Controller

- **AC/DC Grid Control**
  - Power Schedule
  - Grid A
  - Grid B
  - Grid C

- **Analogy to AC system operation**

Controller Hierarchy:

- Primary Control
- Secondary Control
- Tertiary Control

Transience:

- Transient
- Dynamic
- Stationary

Time:

- ~us
- ~ms
- ~50ms
- ~sec
- ~5sec
- ~10min

Marcus Zeller (Siemens, Lead Subgroup 2)
HVDC Grid Control (II)

Characteristics for DC Node Voltage Control

Marcus Zeller (Siemens, Lead Subgroup 2)
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HVDC Grid Control (III)

Coordinated System Control

- Intermediate-term modification of set values
  - Response to fluctuating injection / contingencies etc.
  - Faster than “Power Schedule”

- Station-autonomous mechanisms (no communication)
  - Set of rules (staggered in location & time)
  - Robust, but prior definition required

- Elaborate schemes via “HVDC Grid Controller”
  - Communication required, but…
  - …optimisation due to “global” grid knowledge!

Marcus Zeller (Siemens, Lead Subgroup 2)
Models and Validation (I)

Target: Provide guidelines to the design and validation of simulation models needed for studies in various phases of a project

Scope: models, control replicas, real time simulation, offline simulation.

Examples:

► Contingency analysis
  → concern on the reconfiguration and automatic adaptation of the DC system and converter controllers following a disturbance.

► Harmonic analysis
  → concern on AC and DC system models and methods, testing is needed.

► Small-signal Stability studies
  → concern on modal analysis.
Models and Validation (II)

Guidelines for modelling and model validation:
- Multi-vendor systems: many involved actors (manufacturers, TSOs, HVDC Grid System owners and operators…)

How can models be specified and qualified for multivendor systems?

Ana Morales (DIgSILENT, Lead Subgroup 5)
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HVDC Grid System Integration Tests

Target: Provide guidelines to the specification of system integration tests

System integration tests
► Laboratory Acceptance Tests: multi-vendor.
► Commissioning Tests: on site.
► Compliance tests and simulations: steady state calculations, dynamic simulations.

How can tests be specified and qualified for multivendor systems?
► Independent laboratory?
► Every TSO or HVDC Grid System operator?

Ana Morales (DlgsILENT, Lead Subgroup 5)
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Looking forward to a fruitful collaboration!

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