Online Workshop

Grid Code Compliance Evaluation

Best practices and potential for standardization

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National HVDC Centre, GB
The National HVDC Centre is an Ofgem funded simulation and training facility available to support all HVDC schemes.

Using state of the art simulators, we model and resolve potential issues in real-time before they impact delivery of HVDC projects or the Grid Network.
Content –

• **The changing environment and its relevance upon compliance.**
• Project development processes, key milestones and considerations.
• How does PROMOTioN inform this topic?
• Current practices
• Gap Analysis
• Key recommendations.
Purpose of Compliance evaluation

- Demonstrate performance.
- Provide clear basis for onshore network operation and development
- Define Responsibilities & Duties against technical codes
- Manage Project and System Risk
- Support Commercial, Market and Investment processes.
  - Provide effective data and model exchange defining performance
  - Verify model performance against clear “real world” testing references
GB environment

Beyond GB..

Knowledge from other projects

HVDC Risks

HVAC Risks

Technology risks

Compliance a function of composite control and protection performance

Onshore, Offshore & Interconnector planning & design

Offshore HVAC Design:

Offshore HVDC Design:

Traditional point of compliance test
HVDC Grids can be part of the problem… or part of the solution.

Single point failure risks, as network conditions change and more complex designs emerge.

Tracking and managing changes occurring over lifetime.

Completeness of information and analysis possible ahead of connection.

Hidden project interactions.

New vulnerabilities…

Hidden project behaviours.

Completeness of codes & standards & Data Exchange.
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HVDC Project Life Cycle & Simulation Tools

**Feasibility and options**
- Transmission Owners, Consultants
- Bidders (Manufactures)
- RMS and EMT
- Technical Specification
- Qualification Stages

**Planning & Development**
- Transmission Owners
- Consultants
- Bidders (Manufactures)
- RMS and EMT
- Technical Specification
- Qualification Stages

**Tender / Bid**
- Transmission Owners
- Bidders (Manufactures)
- RMS and EMT
- Technical Specification
- Qualification Stages

**Base Design**
- Manufacturers
- Control Design
- Protection Design
- Dynamic Performance
- Protection Coordination

**Detailed Design**
- Manufacturers
- Control Design
- Protection Design
- Dynamic Performance
- Protection Coordination

**Factory system test / Factory Acceptance test**
- Manufacturers
- Control Design
- Protection Design
- Dynamic Performance
- Protection Coordination

**Commissioning**
- Manufacturers, TO, SO
- Commissioning Tests
- Converter Performance
- System Performance
- Compliance

**Operational support**
- Manufacturers, TO, SO
- New functions
- Software upgrade
- Replica

**Upgrade**
- Manufacturers, TO, SO
- Control and Protection Replacement
- Valve Replacement etc
- Replica and FST, FAT

**Refurbishment**
- Manufacturers, TO, SO
- Control and Protection Replacement
- Valve Replacement etc
- Replica and FST, FAT

**CIGRE Phases**
- **Phase 1**
  - Feasibility and options
- **Phase 2**
  - Planning & Development
- **Phase 3**
  - Tender / Bid
- **Phase 4**
  - Base Design
- **Phase 5**
  - Detailed Design
- **undefined**
  - Factory system test / Factory Acceptance test

**Simulation Tools**
- DIGSILENT
- PSSE
- PSCAD
- RTDS Technologies
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Workshop Harmonization of HVDC systems
relevant inputs into Grid compliance processes

WP1 - Requirements for Meshed Offshore Grids - TenneT

WP2 - Grid Topology & Converters
RWTH Aachen

WP3 - WTG – Converter Interaction
DTU

WP4 - HVDC Grid Protection Systems
KU Leuven

WP5 - Test Environment for HVDC CB
DNV GL

WP6 - HVDC CB Performance Characterisation
UniAberdeen

WP7 - HVDC GIS Demonstrator
ABB

WP8 - Regulation & Financing
TenneT

WP9 - Protection System Demonstration
SHE Transmission

WP10 - HVDC Circuit Breaker Demonstration
DNV GL

WP11 - Harmonisation Towards Standardisation - DTU

WP12 - Deployment Plan for Future European Offshore Grid - TenneT

WP13 - Dissemination SOW

WP14 - Project Management DNV GL

WP15 - Test Environment for HVDC CB

WP16 - MMC Test Bench Demonstrator
RWTH Aachen
Practical testing example

PROMOTiOn WP9: Protection System Demonstration

✓ Hardware-in-the-loop test environment and guidelines for non-selective protection systems demonstration
✓ Demonstration of selective protection systems interoperability and primary and back-up protection

➢ Combined with the protection schemes and hardware prototypes has been integrated into a realistic radial multi-terminal HVDC system to test different protection scheme
➢ A mesh grid DC protection will be demonstrated
➢ To allow overall system performance pole re-balancing and post-fault recovery sequences will be considered
Findings relevant to Compliance evaluation

• D1.7 requirements for meshed offshore grids, requirement on offshore windfarms
  • Frequency ranges, RoCoF withstand capacity, FSM
  • Power control, ramping and control range
  • Synthetic inertia
  • Voltage ranges, reactive power, FRT, FFCI.
  • Damping power quality energisation and synchronisation, black start.
  • Control and protection
  • Information exchange and co-ordination

• D3.6 wind power park compliance tests.
• D3.8; DRU concepts
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A variety of practices..

Figure 3. Fractions of requirements which are subject to compliance simulations or compliance tests during the 5 project phases.

Figure 5. Fractions of requirements which are subject to compliance simulations or compliance tests during the 5 project phases.
Stakeholder feedback examples

“EMT models based on compromises respecting IP but limiting insight and completeness”

“We need to go beyond black box models to define terminal equivalent behaviours.”

“it is critical to validate models based on Factory testing and real experience”

“There are limited processes to specify and verify EMT models at present.”

“There is an increasing need to conduct RTDS-HiL analysis beyond factory test. This would benefit from standards and specification.”

“The developer takes care of the compliance tests and demonstration but it is not clear if this will be sustainable into the future”

“Compliance stops at commissioning. Doesn’t it?”

“Compliance needs to be sustained by in service monitoring and periodic verification of models”

“Model exchange and verification relates to RMS models predominantly”

“Compliance processes focus on onshore system interface.”
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The TSO analysis environment.. now

Input data information:
- Spatial and national demand
- Spatial generation by type
- RMS & balanced validation
- Harmonic emissions spectra
- EMT and FAT simulation results
- EMT Model*
- Settlement (averaged), operational (1s)
- NPS 20min avg
- Harmonics 20min avg
- PMU*
- Event logs

Data use:
- Energy Forecast Data Quantities
- Generation data
- Real-time telemetry
- Power Quality monitoring
- Transient monitoring

Use:
- Forecast network RMS simulation models
- Operational network models
- Specialist dynamic modelling
- Local project-specific EMT modelling

Activity:
- Standard Planning and operational analysis suite
  - Steady state Thermal, Voltage RMS analysis
  - Dynamic Voltage and Angle stability analysis
  - Dynamic national frequency containment analysis
- Compliance/ Acceptance analysis suite
  - RMS model dynamic Plant verification against required and expected performance
  - Plant specification related (TOV, earthing, switching/energising)
- Non-Standard analysis suite
  - Operability risk & post event investigation

Outputs:
- Network development, inputs to Operational processes & tools
- Plant control / connection design / operation
- Risk management and/or dynamic Plant/network re-design

Current Analysis Environment

Scottish & Southern Electricity Networks
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The TSO analysis environment...Future

Input data
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- EMT & RTDS Models*
- Settlement, operational & PMU
- NPS 20min Avg & instant
- Harmonics 20min avg & instant.
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Future Analysis Environment
The Gaps

• Information, Models and Data Exchange
  • Improved standards and specification aligned to enabling effective routine EMT, harmonic and small signal analysis.
  • EMT model exchange both supporting offline and real time analysis.
• Standards supporting device interoperability, including tests validating overall control and protection concepts in addition to device performances.
• Practical I/O tests, monitoring and visibility of performance, combined with enhanced simulation base of verification.
• Commonly established methods for identifying and supporting the needed scale and detail of data exchange between parties.
• Commonality and compatibility between models and platforms
• New areas of converter specific testing and performance clarifications needed
• Insight into high level principles surrounding the control and protection of devices being combined.
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Key Recommendations

• Model Exchange
  • Importance of visibility of tuning parameters, completeness of control and protection; user guides describing high level principles of models.
  • Verification against FAT, in service data and recorded phenomenae
  • Critical role of RTDS-HiL in detailed control and protection interaction study, offline model verification and interoperability considerations. Key role in demonstrating acceptability of intended solutions.

• Compliance tests need to re-orient to provide model verification and overall control response verifications allowing overall solutions to be demonstrated from devices in combination.

• New tests need to be described that are specific to the conditions of the offshore AC grid and its role within the meshed DC solution.
The Map of Network Stability analysis is being re-drawn.

- Define & Design
- Areas of Risk
- The less well defined...
- The familiar...

Data; Models and Monitoring

- More Detail & Variables

- We need to work together, to develop the Tools, Systems and Skills for navigating this.
APPENDIX

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