PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Online Workshop

Grid Code Compliance Evaluation

Best practices and potential for standardization

Ben Marshall
National HVDC Centre, GB

The National HVDC Centre

Part 2
HVDC systems control and grid codes
Time: Friday | 19 June 2020 | 10:00–13:00
Location: ***Microsoft Teams Meeting***

The National HVDC Centre *part of* Scottish & Southern Electricity Networks *together with* nationalgridESO nationalgrid *and* SP ENERGY NETWORKS

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.

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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.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

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*

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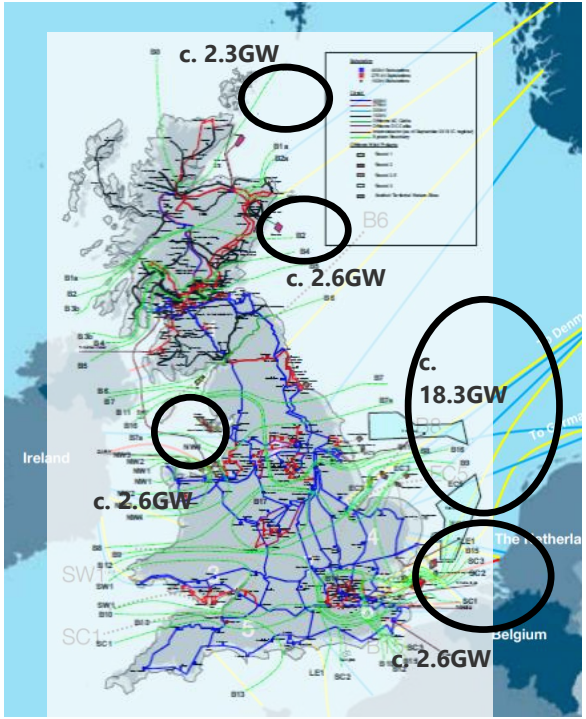
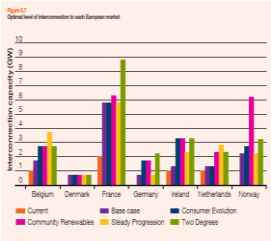
GB environment



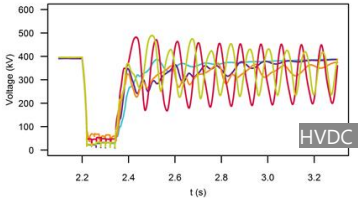
Onshore, Offshore & Interconnector planning & design

Beyond GB..

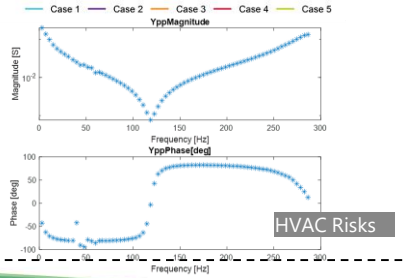


Knowledge from other projects

Technology risks



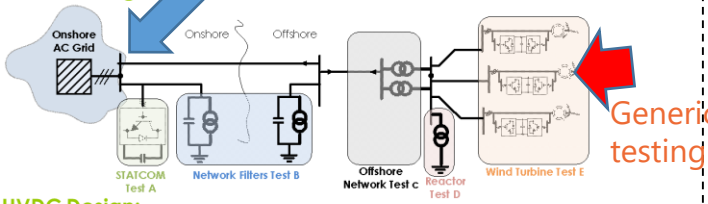
HVDC Risks



HVAC Risks

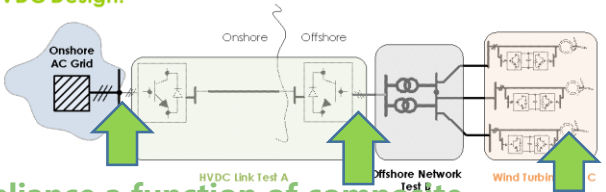
Traditional point of compliance test

Offshore HVAC Design:



Generic testing

Offshore HVDC Design:



Compliance a function of composite control and protection performance

Process

compldxity

Technical Risks Emerging…

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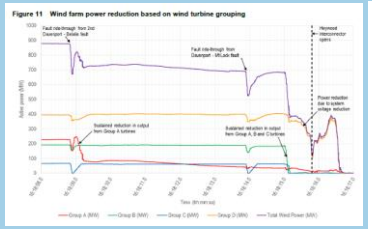
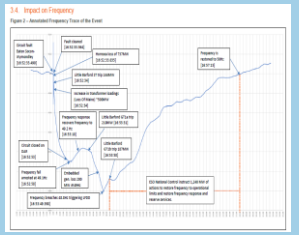
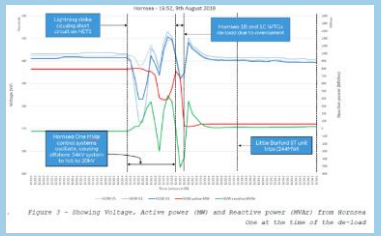
Single point failure risks, as network conditions change- and more complex designs emerge.

Tracking and managing changes occurring over lifetime.



https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf



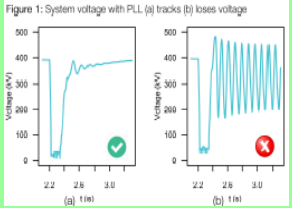


https://www.ofgem.gov.uk/publications-and-updates/investigation-9-august-2019-power-outage

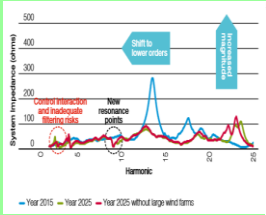
Completeness of information and analysis possible ahead of connection.

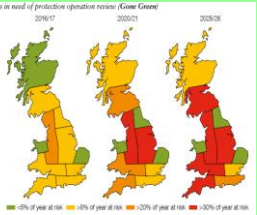
Hidden project interactions.

New vulnerabilities…

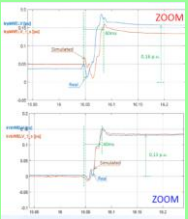


https://www.nationalgrideso.com/publications/system-operability-framework-sof





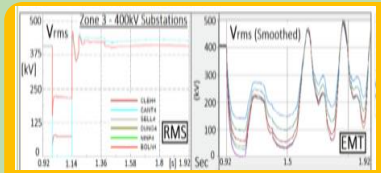
https://www.nationalgrideso.com/publications/system-operability-framework-sof



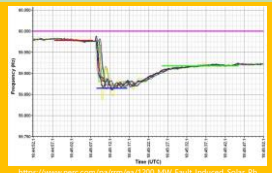
https://www.aanmelder.nl/ac-dc/wiki/470968/presentations

Hidden project behaviours.

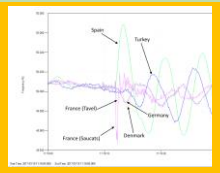
Completeness of codes & standards & Data Exchange.

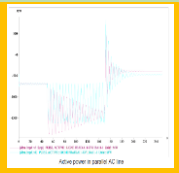


https://www.smarternetworks.org/project/nia_nget0187/documents



https://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf





https://www.wecc.org/Administrative/14_RTE-Interarea%20oscillations.pdf

HVDC Grids can be part of the problem…. or part of the solution.

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HVDC Project Life Cycle & Simulation Tools

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

- Manufactures
- Control Design
- Protection Design
- Dynamic Performance
- Protection Coordination

- Manufactures, TO, SO
- Commissioning Tests
- Converter Performance
- System Performance
- Compliance

- Manufactures, TO, SO
- New functions
- Software upgrade
- Replica

CIGRE Phase 1 | **CIGRE Phase 2** | **CIGRE Phase 3** | **CIGRE Phase 4** | **CIGRE Phase 5** | **CIGRE undefined**

Feasibility and options → Planning & Development → Tender / Bid → Base Design → Detailed Design → Factory system test / Factory Acceptance test → Commissioning → Operational support → Upgrade → Refurbishment

- Transmission Owners (TO), System Operators (SO) or Developers
- RMS domain Studies.
- Widely used tool in UK is DIGSILENT and PSSE.

- Transmission Owners
- Manufactures
- RMS and EMT
- Transient Stability Studies
- TOV, TRV
- Equipment design

- Manufactures
- Control and Protection implementation verification
- Dynamic Performance with Real Control System
- Protection Coordination with Real Control system

- Manufactures, TO, SO
- Investigation of incidents
- Faults, failures
- Replica, Site, offline studies

- Manufactures, TO, SO
- Control and Protection Replacement
- Valve Replacement etc
- Replica and FST, FAT

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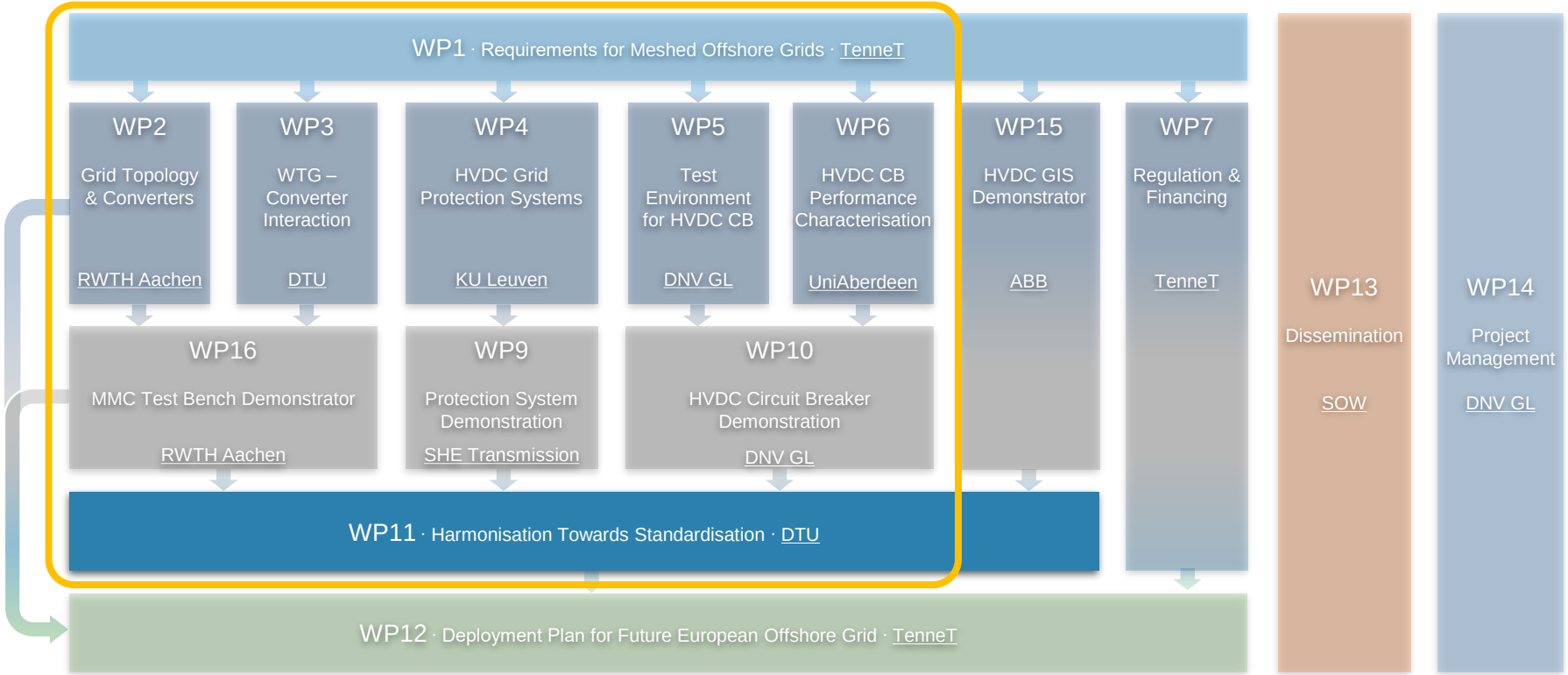
Workshop Harmonization of HVDC systems
relevant inputs into Grid compliance processes



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Practical testing example

PROMOTioN WP9: Protection System Demonstration

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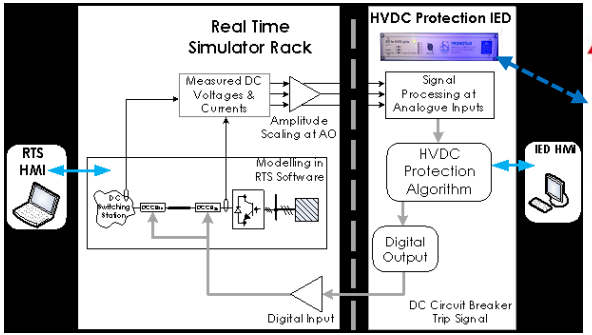
- ✓ Hardware-in-the-loop test environment and guidelines for non-selective protection systems demonstration
- ✓ Demonstration of selective protection systems interoperability and primary and back-up protection



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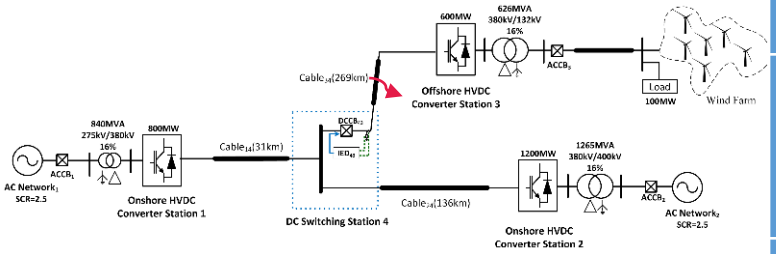
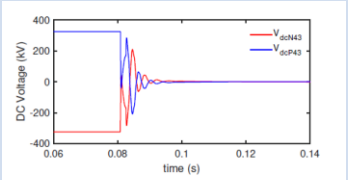


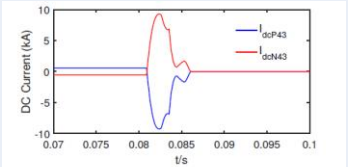
Real time Simulation Test Setup

Example Time Domain Result

Voltage



Current



Notes

Measurements at IED location
Hybrid DCCB
Mid-cable pole-to-pole fault

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- ➢ 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 protecton
  - *Information exchange and co-ordination*
- D3.6 wind power park compliance tests.
- D3.8; DRU concepts

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A variety of practices..

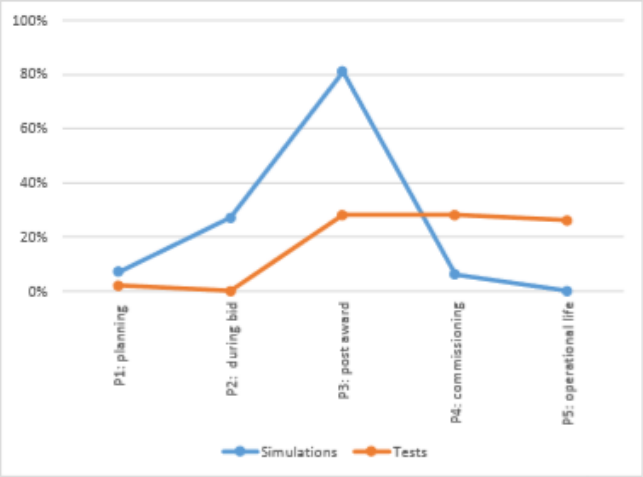

Figure 3. Fractions of requirements which are subject to compliance simulations or compliance tests during the 5 project phases

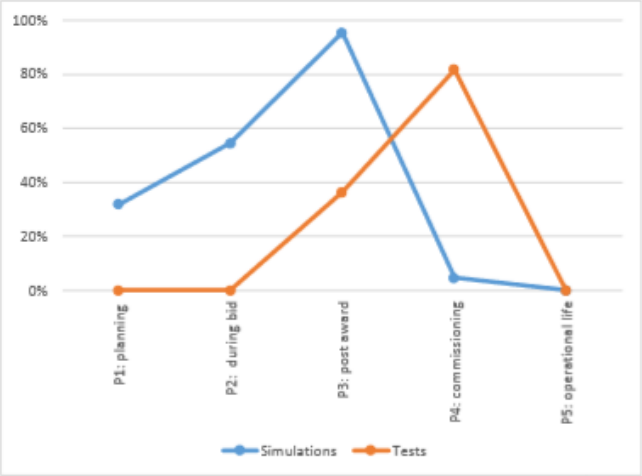

Figure 5. Fractions of requirements which are subject to compliance simulations or compliance tests during the 5 project phases.

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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

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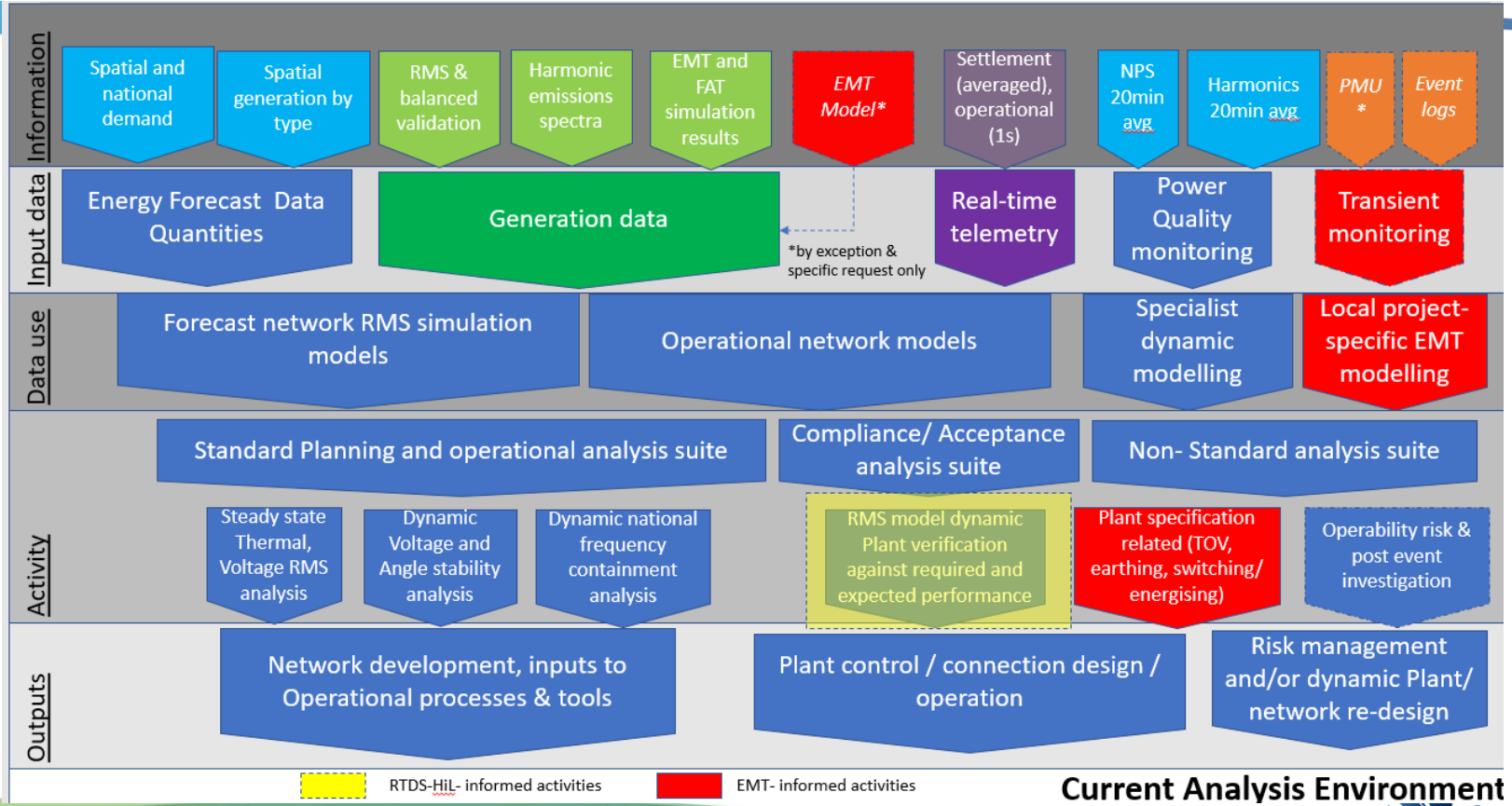

Current Analysis Environment

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The TSO analysis environment..Future

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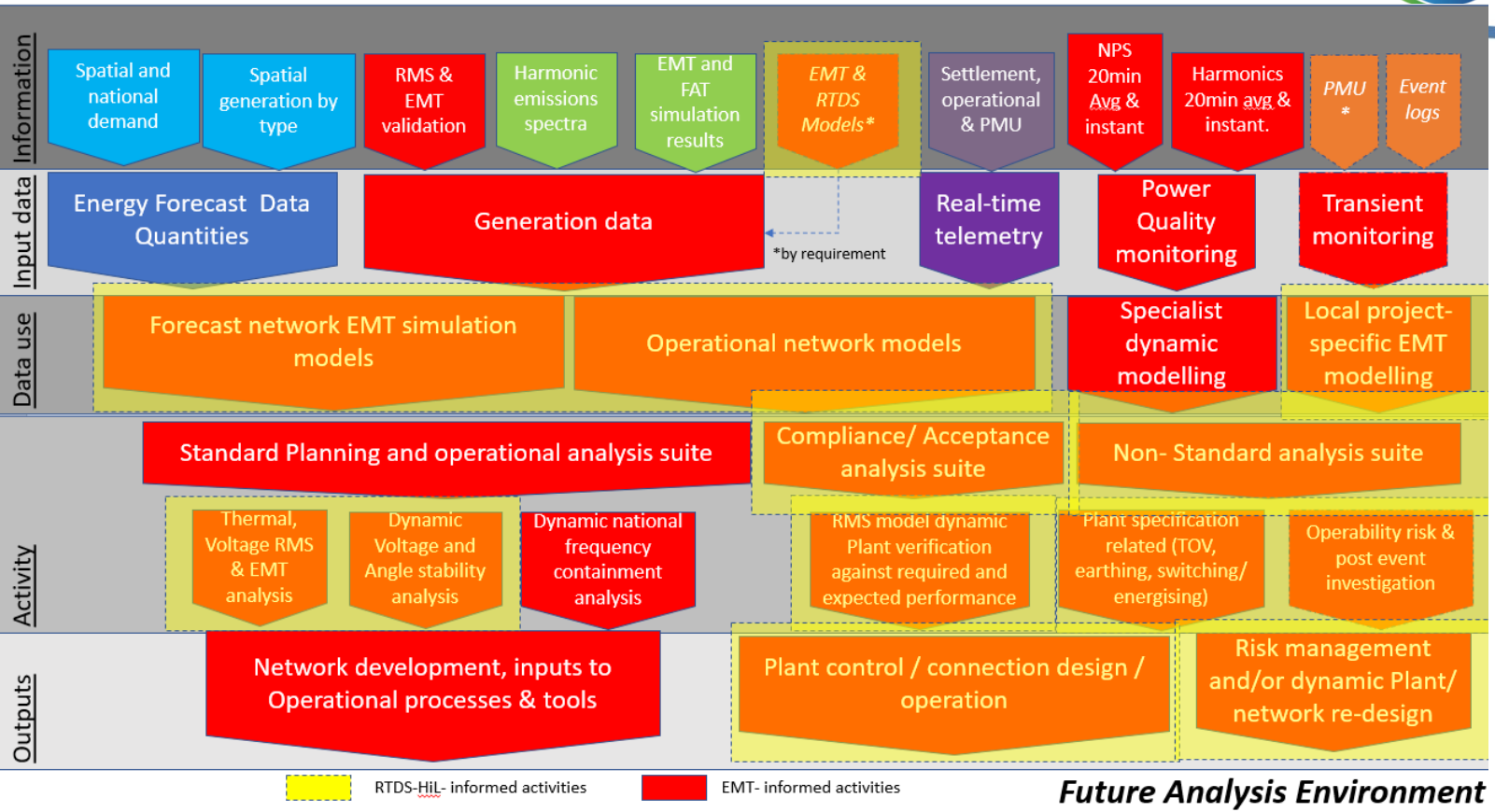

Future Analysis Environment

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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 phenonema
  - 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.

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The Map of Network Stability analysis is being re-drawn..

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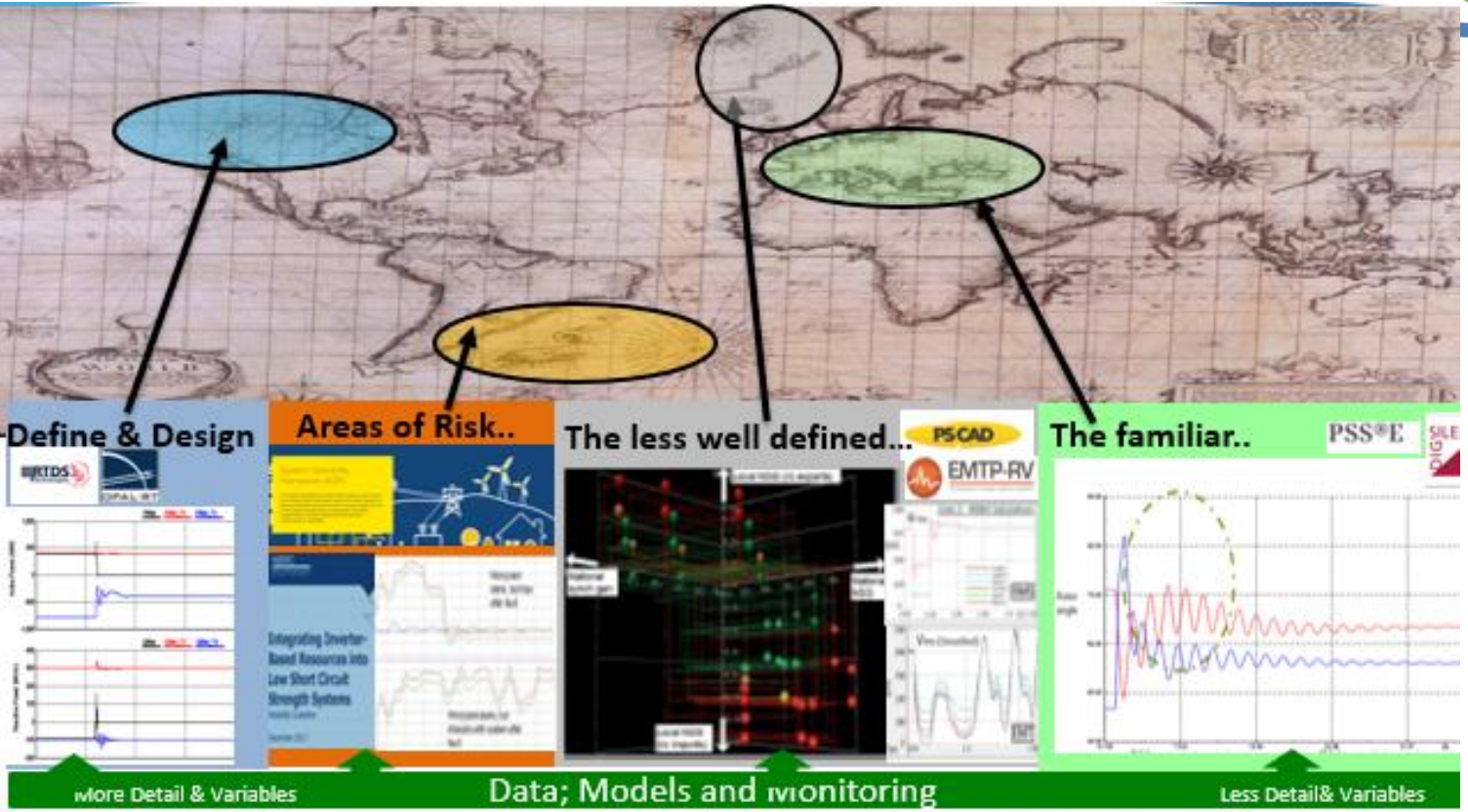

- We need to work together, to develop the **Tools**, **Systems** and **Skills** for navigating this.

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APPENDIX

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