Expert Group Interaction Studies and Simulation Models (EG ISSM) for PGMs/HVDC

- Timeline
- Report Structure and content
- Next steps and risks

Presentation to GC ESC on behalf of the EG ISSM

Prepared and presented based on EG ISSM material by Mario Ndreko, TenneT TSO GmbH
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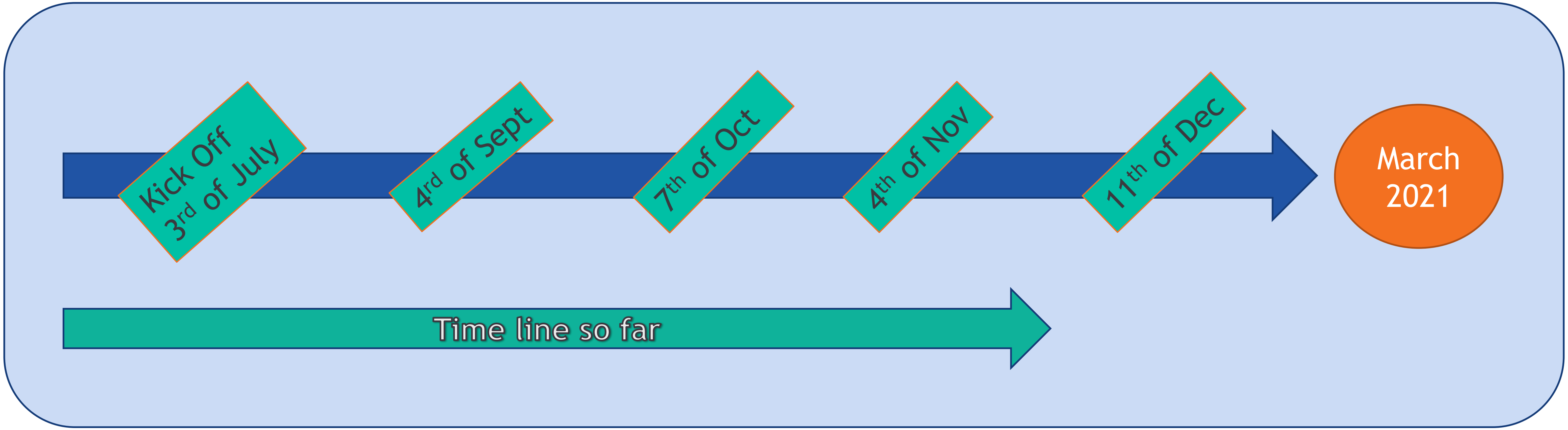
Time line of the EG ISSM



Report Outline

Expert Group Interaction Studies and Simulation Models (EG ISSM)

FINAL REPORT

Drafting has started/ Work in Progress

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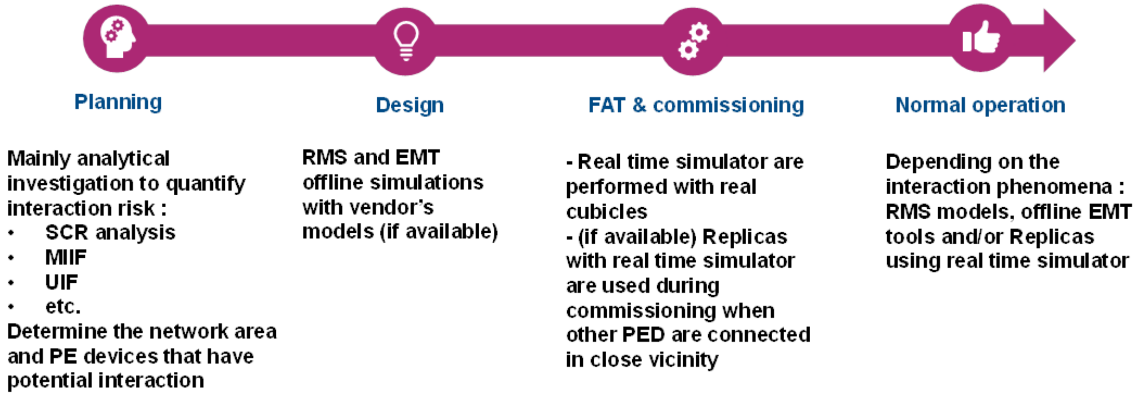
Chapter 3: Interaction Studies

- The increasing penetration of Power Electronic Devices (PED) within the AC network leads to higher risk of interaction of such systems between PED, network elements and/or conventional power plants.

- **Performing interaction studies with high PED is challenging due to:**
  I. The complexity of their control and protection system
  II. The high influence of PED on the power system
  III. Confidentiality and IP issues with the C&P algorithms
  IV. The different software tools, versions, and simulation parameters in which the model is provided
  V. The model maintenance through the lifetime of the project

- For each project phases, several studies are performed. To detect potential interaction issues between PEDs, a different type of tool is used, as shown



Chapter 4: Interaction Phenomena

The following table provide a general overview on the multi-infeed and interaction phenomena that can occurs between at least two main power electronic devices. The table is based on the ongoing Cigré WG B4-81.

Multi-Infeed and Interaction Study Interaction between : at least two main power electronic devices (HVDC, FACTS, Renewables, etc.)					
Control loop interaction		**Interaction due to non-linear functions**		**Harmonic and Resonance interaction**	
Near steady-state (slow control)	**Dynamic (fast controls)**	**AC fault performance**	**Transient stress and other non-linear interaction**	**Sub-synchronous resonance**	**Harmonic emission and resonance**
• AC filter hunting • Voltage control conflicts • P/V stability	• Power oscillation • Control loop interaction • Sub-synchronous control interaction • Voltage stability	• Commutation failure • Voltage distortion • Phase imbalance • Fault recovery • Protection performance	• Load rejection • Voltage phase shift • Network switching • Transformer saturation • Insulation coordination	• Sub-synchronous torsional interaction	• Resonance effects • Harmonic emission • Harmonic instability • Core saturation instability
• Static analysis • RMS time domain	• RMS time domain • EMT time domain • Small-signal analysis	• RMS time domain • EMT time domain	• EMT time domain	• EMT time domain	• Harmonic analysis • EMT time domain • Small-signal analysis

Chapter 5: Definition of simulation models for interaction studies

Current requirements and practices in Europe are limited to:

- Simulation of Fault Ride Through for a specified voltage dip,
- Simulation of several operating points in the U-Q/Pmax diagram
- Simulation of increase / decrease of active power at frequencies below / above 50 Hz
- Simulations to demonstrate the correct behavior of AVR and PSS at small grid disturbances

Example

EMT model requirements for PPM and SPGMs at AEMO, Energinet and ERCOT

	AEMO	Energinet	ERCOT
Submit model	All	PPM Type D	Modelling generators in weak grids and subsynchronous resonance
Software	PSCAD 4.6 and above	PSCAD version used by TSO	PSCAD 4.5.3. or higher
Open / encripted	Precompiled and encrypted parts	Precompiled and encrypted parts	Precompiled and encrypted parts
Compiler Intel	Fortran 12 and higher	Intel Fortran 12 and higher	Intel Fortran 9 and 12
Time Step	1 µs	Not mentioned	10 µs – 20 µs
List of parameters	Yes	Yes	Yes
Block diagrams	Yes	Yes	Yes
Manual	Yes	Yes	Yes
Validation	PSCAD model with PSSE results	PSCAD model shall be validated	PSCAD model with measurements
Snapshot function	Yes	Yes	Yes
Initialisation	In less than 3 seconds	In less than 3 seconds	In less than 5 seconds

Chapter 5: Definition of simulation models for interaction studies (EMT, RMS)

- **For SPGMs (description of RMS models)**
  - Dynamic model of turbine-governor
  - 2-axis model of synchronous alternator
  - Mass-spring model of turbine and alternator shaft (multi-mass)
  - Dynamic RMS model of AVR
  - Dynamic SSTI model of AVR (NC HVDC Art. 29.3 and 31.3)
  - Dynamic RMS model of PSS
  - more in the report…

- **For HVDC systems (description of RMS and EMT models)**
  - be valid for all specific operating points and all control modes of the HVDC system;
  - include representation of HVDC converter unit and its control systems that influence the dynamic behaviour of the HVDC transmission system in the specified time frame;
  - include the protection function models as agreed between the relevant TSO and the HVDC system owner;
  - more in the report…
- **For PPMs**
  - reproduce the detailed response of the PPM and its control blocks during balanced and unbalanced AC network faults in the valid frequency range;
  - work in progress..

Chapter 5: Discussion of frequency dependent models

ENTSO-E member has proposed new impedance based model requirement besides EMT and RMS as follows:

Frequency-Dependent Impedance model requirements (related to NC HVDC Art 54)

For the purpose of the risk assessment of the resonance stability of the HVDC convert station, the relevant TSO shall have the right to request from the HVDC system owner the frequency dependent impedance model of the HVDC converter station at the AC side. In that case, the following requirements shall apply:

(a) The impedance model of the HVDC converter station shall be requested at least in the range 10-2500Hz;
(b) The relevant TSO shall have the right to request the calculation of the impedance model of the HVDC converter station either numerically (using the EMT model) or analytically (using transfer function);
(c) The relevant TSO shall have the right to request the impedance model of the HVDC station through the whole operating range and control modes of operation;
(d) The impedance model of the HVDC converter station shall be provided for both the positive and for the negative phase sequence;
(e) The HVDC system owner shall take into account the influence of the whole HVDC unit control and measurement system as well as other parts of the HVDC unit which influences the output impedance in the specified frequency range;
(f) The HVDC system owner shall specify and justify simplifications made in the calculation of the impedance model;

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Chapter 6: Model Validation / General Comments

- **Validation is mainly driven by grid compliance** with FRT requirements

- **Higher penetration power electronic interfaced devices** in transmission and distribution systems means:
  - Increased focus on grid compliance which is also driving model validation, e.g. FRT
  - To comply with grid connection code requirements:
    - Measurements are done on a test sites
    - Models are validated against site measurements

- **Interaction studies is a wide topic and validating models on all corners can be challenging and cost demanding**
  - examples: unstable system modes, weak interconnection instability, interaction with active system components, operation condition dependency

- **Clear definition of specific tests** and validation for interaction studies purpose is necessary
  - purpose specific
    - e.g. transients, sub/super synchronous, frequency, etc...
  - plant control and wind turbine level control

- **Flexibility of model use:** driven by project specific phenomenon to be investigated
  - EMT vs RMS, time domain v frequency domain, model features
  - like time steps etc...

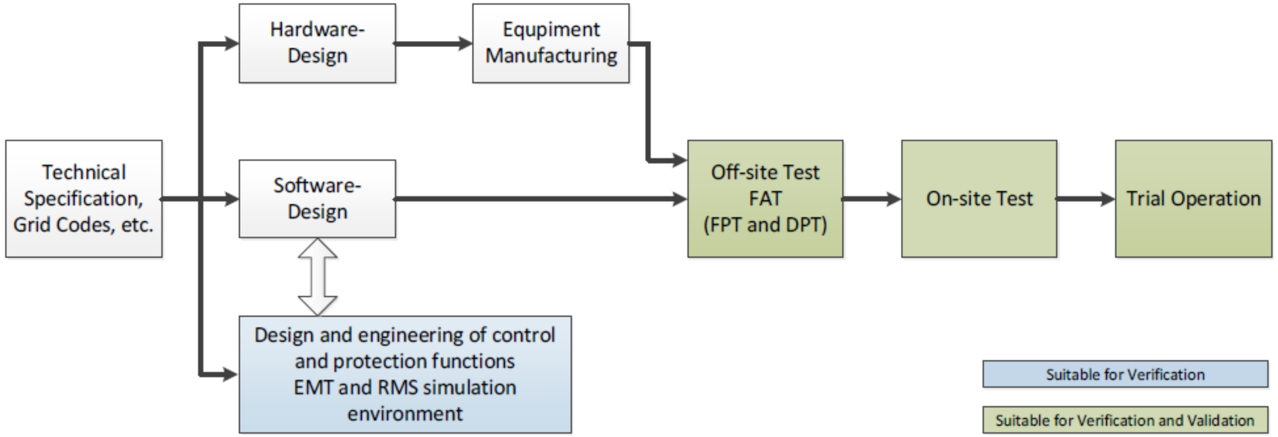
Model Validity / PPMs

Phenomena	Phenomena (Grid Code)	Model validity
FRT	FRT	Model is valid for voltage dip simulations incl. all relevant operation modes and thermal / mechanical limitations
Control functions Active power Reactive power P(f) control Inertia emulation	LFSM-O LFSM-U FSM Reactive power capability	Model is valid for all relevant control modes incl. active / reactive power steps, voltage and frequency control
Low frequency oscillations	Active power oscillation damping Torsional oscillations	Model is valid regarding the reaction to voltage and frequency oscillations
Behavior under weak grid conditions (considering inner control loops)	Island operation Restoration?	Model is valid regarding the behavior in weak grid conditions, relevant inner control loops are considered. Allowed simplifications are proved by tests
Harmonic model (Example IEC 61400-21/3)	-	Model is valid for a specified frequency range and different operation points
Protection	Part of all	All relevant protection systems shall be represented in the model with correct time delays
Transient stress	-	Model is valid for transient switching situations

Model Validity / HVDC

Network Code HVDC Article 54 (3)

Model Verification and Validation – HVDC Design and Engineering Phase



Grid code and technical specification compliance is verified in:

- Studies (such as RMS Stability Study, EMT Dynamic Performance Study, EMT Interaction Study
- Factory Acceptance Test (Real-Time and Non-Real Time)
- On-Site Tests during the commissioning phase

Based on these internal study and testing models, the customer models with verified electrical component, and control & protection system representation are developed.

The On-site tests and the trial operation, as well as commercial operation, provide also information for model validation. This is also related to NC HVDC Articles 54(4) and 54(5).

Next steps & Risks

1. The time line of the work is too short for the amount of work
    - Many tasks to be completed in very short time
    - Big time constant to draft the needed report
2. Engagement of the Stakeholders by providing contribution is important
    - Stakeholders and contributors are engaged

- Request for extension till June 2021