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

- Report the EG ISSM content
- Next steps and discussion

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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Interaction Studies (1/2)

1. **Performing interaction studies with high PED is challenging due to:**
   - The high complexity of their control and protection system and the importance of their accurate representation of the phenomena.
   - The confidentiality and the intellectual property issues related to the control and protection algorithms.
   - The use of different software tools, different software versions and compilers.
   - The importance of simulation parameters/data in which the model is provided.
   - The model maintenance through the lifetime of the project.

2. **Interaction assessment / common tools during the project phases**
   - Planning: Mainly analytical investigation (for network planning generic open source models are usually used)
   - Design Stage: RMS and EMT simulations are used (offline simulations)
   - FAT/Commissioning: Real time simulations with control and protection cubicles may be used depending on technology and the use case.
   - Operation: A new simulation is required only in case of substantial modification or after major incidents, which demonstrate that requirements were not fulfilled. Usually RMS or EMT simulation models are used.

Interaction Studies (2/2)

AC network model

- Specific and realistic network behaviour shall be reproduced to analyze the impact of PGMs, HVDC converter stations and demand side behaviour on the network and vice-versa.
- Along the same lines, the accurate representation of the transmission and distribution system is also important for interaction studies (at least range 5Hz to 2.5kHz).

- **AC network modeling shall include the following aspects**
  - Transformers with impedances and saturation characteristics
  - Lines and cables with geometrical and electrical characteristics to generate frequency-dependent line/cable models
  - Min/max short-circuit current/power for each Thevenin source connected to the reduced grid
  - Min/max active and reactive load at each substation.
    - Here accurate load modelling is important when control interaction studies are performed in a wide frequency range.
  - Busbar configuration, especially in the substation where the converter station is connected
  - Generators and associated controls affecting the relevant phenomena studied
  - Power electronic devises connected in proximity (also at demand side)

Interaction Phenomena

1. **List of phenomena covering all type of interactions**
    - Control loop interactions
        - Near steady state (slow control loops such as active and reactive power control)
        - Dynamic (fast control)
    - Interaction due to non-linear functions
        - AC fault performance
        - Transients and other non-linear interactions
    - Harmonic and resonance
        - Synchronous resonance
        - Harmonic emissions
2. **Methodologies for interaction of wide frequency (up to 2.5kHz) studies (emphasis placed on the practicality of using such methods in real project studies)**
    - Impedance-based analysis:
        - this method can be applied without any prior knowledge of the system, since the equivalent impedances of both systems can be also obtained from measurements.
    - EMT Simulations:
        - The biggest advantage of this method is its ability to use very detailed and nonlinear models, as well as to interface black-box models of controls to other components provided by manufacturers.

Simulation model requirements for interaction studies (EMT, RMS)

The EG details on requirements for simulation models for performing interaction studies that are used in the various study phases

1. HVDC systems / PPMs models are detailed

- Define RMS model requirements with purpose to be harmonized across EU
- Define EMT model requirements with purpose to be harmonized across EU
- Introduce model requirements in frequency domain (at least in range: 5Hz – 2500Hz)

2. SPGMs

- **Discussion on the accuracy of standard IEEE AVR and PSS models in SSTI studies is still ongoing**
- **The model requirements cover the following:**
  - Dynamic RMS model of AVR (Automatic Voltage Regulation)
  - Dynamic SSTI (Sub-Synchronous Torsional Interactions) model of AVR
  - Dynamic RMS model of PSS (Power System Stabilizer)
  - Dynamic SSTI model of PSS according to NC HVDC Art. 29.3 and 31.3:
  - Dynamic model of turbine-governor
  - Model of synchronous alternator
  - Mass-spring model of turbine and alternator shaft
- The EG has identified a gap in the accurate representation of SPGMs for SSTI studies up to 200Hz.

Model Validity / Set up definitions

Clarification and common understanding for:

- **Validation** is the process of determining the degree to which a simulation model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.

- **Verification** is the process of determining that a model implementation and its associated data accurately represent the developer's conceptual description and specifications.

- **Accepted Models**: Models provided with developer's description of what the model or simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the user's requirements. They could be also certified models, but this is not a prerequisite.

- **Certification:** The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose

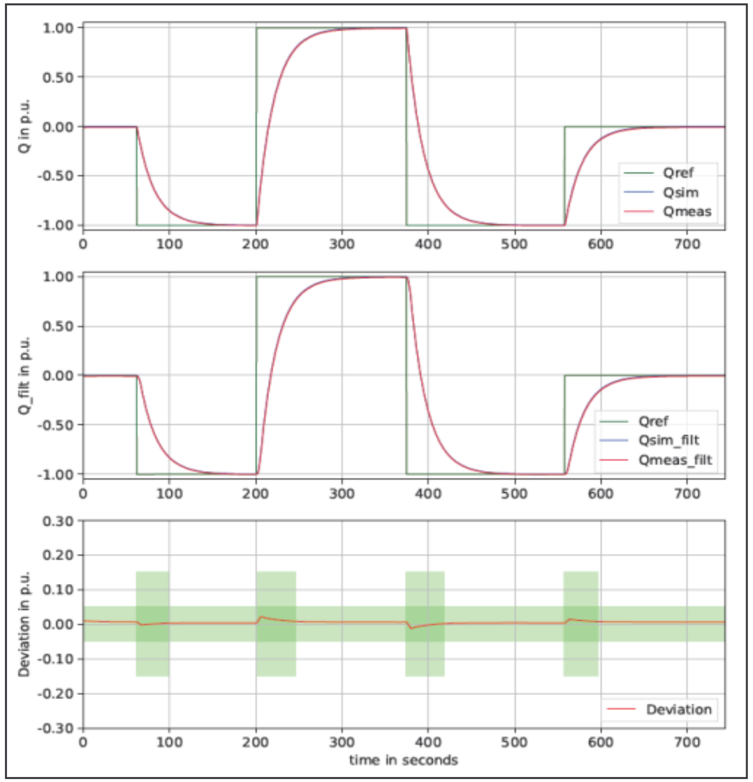
Model Validity / Wind Generators (1/2)

Near steady state control functions:

- procedures from IEC 61400-27 can be used (this process is already state of the art)
- **The base for the validation can be**
  - Online tests
  - Simulations with benchmark models
  - Tests from benchmark models
- **The model is valid**
  - If the maximum deviation during the settling time (acc. IEC 61400-27) is not exceeding a maximum limit of 15% of the rated value of the control variable.
  - The tolerance band for steady state conditions is 5% of the rated value of the control variable.
  - Higher deviations have to be explained in the validation report (ex. bad wind conditions during active power control tests).

example validation graph for reactive power control

failure type	unit	value	limit
Active Power max steady state Error	%	0.4	5.0
Active Power max transient state Error	%	0.4	15.0
Reactive Power max steady state Error	%	0.89	5.0
Reactive Power max transient state Error	%	2.21	15.0



Model Validity / Wind Generators (2/2)

<u>Dynamic (fast control):</u>

- To fulfil the requirements for "Dynamic (fast control)" the model has to represent the correct controller dynamic for interactions in a required frequency range.
- To show the correct controller dynamic the model reaction for different oscillations in grid voltage and frequency shall be validated.
- **The base for the validation can be**:
  - Onsite tests
  - Simulations with validated bench mark models
  - Tests from validated test benches incl.
  - Hardware in the loop systems and real time simulations

<u>AC fault performance</u>

- Existing procedures from IEC 61400-27 can be used, the process is already state of the art for RMS models
- New procedure for EMT models in addition to the existing one is used

<u>Transient stress</u>

- New procedure for switching events (Opening of MV circuit breaker is already part of common test procedure acc. IEC 61400-21)

<u>Harmonic emission and resonance</u>

- New procedure acc. To IEC 61400-21/3 is used

Model Validity / HVDC

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

- **The real-time and non-real time (offline) simulation models can be validated by:**
  - Design calculations and theoretical data obtained during the equipment rating and design study phases
  - Measured data of electrical components or the complete system. This data is obtained during equipment manufacturing, on-site testing phase or operation of the system.

- **As a minimum, the following aspects should be considered:**
  - The most valuable validation is a comparison of models with measured data.
  - If measured data is not available (for example during the engineering phase of a new project), the models can be initially validated with design calculations and theoretical data.
  - A validated and verified model can be used as a benchmark for other models. This applies for all kind of combinations, for example non real-time EMT with RMS models or non real-time with real-time models.
  - Measured data can be also used to verify design calculations.

Model Validity / SPGMs

- **Model validation for SPGMs, involves some form of testing (factory and/or on-site).**

- **If testing is not viable, for example due to system security impact, RMS simulations are required to verify model performance.**

- **In terms of testing work, the following objectives are to be met:**
    - Testing to meet grid connection code requirements.
    - Testing to identify characteristics of the plant that are needed to set up modelling parameters.
    - Testing to verify that SPGMs models are correct and appropriately accurate.

- **Model validation consists of the verification steady-state operational performance, dynamic response as well as small signal response.**

- **For SPGMs the following model equipment, control systems and associated parameters are to be considered:**
    - Generator.
    - Generator step-up transformer.
    - Positive, negative and zero impedance sequence data.
    - Generator capability curve.
    - Excitation system (including automatic voltage regulator (AVR),over excitation limiter (OEL), under excitation limiter (UEL) and power system stabilizer (PSS).
    - Governor control (including turbine, boiler and associated plant control system affecting the operation of the governor).

Model Validation / General Comments

- **Validation is mainly driven by grid connection code compliance (i.e FRT requirements)**

- **Higher penetration power electronic interfaced devices** in transmission and distribution systems means:
  - Higher need for model accuracy to perform accurate studies
  - Local interaction issues may have global effect if leading to trip of large PGMs and HVDC
  - Increased focus on grid compliance which is also driving model validation, e.g. FRT

- **Interaction studies is a wide topic and model validity 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...

CNC amendment (under discussion)

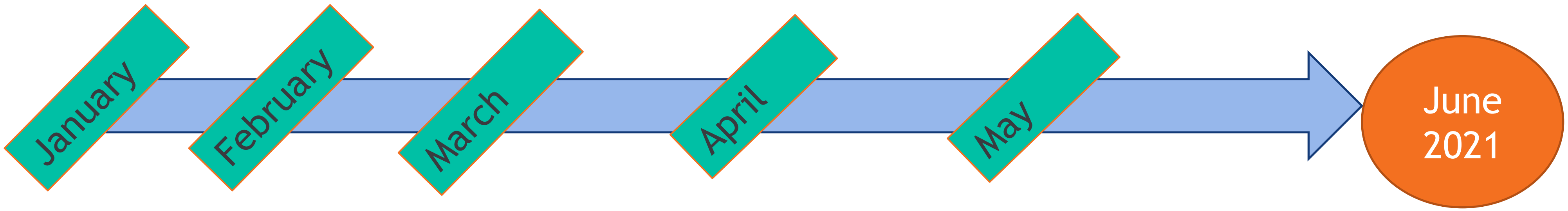
Based on the EG discussions and the model requirements developed in the group (chapter 5 of the report, justified in chapter 3-4), the following articles of the CNCs are under discussion for amendment

1. **NC RfG / Art.15.6.c / General requirements for type C power-generating modules**
   - NEW: A paragraph on RMS model requirements for PPM will be provided
   - NEW: A paragraph on EMT model requirements for PPM will be provided
   - NEW: A paragraph on impedance model requirements (in frequency domain) for PPM will be provided

2. **NC HVDC / Art.54 / Simulation models**
   - NEW: A paragraph on RMS model requirements for PPM will be provided by the EG
   - NEW: A paragraph on EMT model requirements for PPM will be provided by the EG
   - NEW: A paragraph on impedance model requirements (in frequency domain) for PPM will be provided

3. **NC DC/ Art.21 (3) / Simulation models**
   - NEW requirement for frequency dependent impedance profiles at the transmission and distribution interface.

Next steps



The EG is drafting the final report
Up to date it is about 80 pages

Consultation will kick off in April

Revision and final report submission to GC ESC (expected end of May)

Discussion points / Feedback from the GC ESC

- For Information (question raised by the chair):
  - The size of the report is up to date 81pages.
    - Is this acceptable for the GC ESC?
  - Chair position: The report details valid information collected through the discussions.

- For discussion (question raised by VGB):
  - NC HVDC Article 29 is by definition on new installations:
    - how should the studies be performed when new SPGMs are installed next/close to existing HVDC systems?
    - Who is performing the studies?
    - Who has access to the models?

EG ISSM Members

	Name	Organisation	Representation at GC ESC
1	Mario Ndreko (chairman)	TenneT DE	ENTSO-E
2	Ton Geraerds (Vise-chairman)	RWE	VGB
3	Macarena Martín Almenta	REE	ENTSO-E
4	Hani SAAD	RTE	ENTSO-E
5	Tobias Hennig	Amprion	ENTSO-E
6	Ioannis Theologitis / Adrian Gonzalez	ENTSO-E	ENTSO-E
7	Jesus Bernal Lopez	Iberdrola	SolarPower Europe
8	Juan-Carlos Perez Campion	Iberdrola	SolarPower Europe
9	Daniel Premm	SMA	SolarPower Europe
10	Musa Shah	Lightsource BP	SolarPower Europe
11	Naomi Chevillard	SolarPower Europe	SolarPower Europe
12	Vasiliki Klonari	WindEurope	WindEurope
13	Patrick Alizon	Vestas	WindEurope
14	Ranjan Sharma	Siemes Gamesa Renewable Energy	WindEurope
15	Pascal Gartmann	Enercon	WindEurope
16	Eric Dekinderen	VGB	VGB
17	Cedric Lehaire	Veolia	COGEN Europe
18	Luvigi Di Raimondo	Solar Turbines	COGEN Europe
19	Alexandra Tudoroiu	COGEN Europe	COGEN Europe
20	Mike Kay	ENA	GEODE
21	Luca Guenzi	Solar Turbines	EUTurbines
22	Kevin Chan	GE	EUTurbines
23	Magdalena Kurz	EUTurbines	EUTurbines
24	Vincenzo Trovato	ACER	ACER
25	Adolfo Anta	AIT	EASE
26	Christian Krieger	Siemens	Orgalime
27	Stanko Jankovic / Robert Dimitrovski	TenneT DE	Support to the chairman