

Modelling of HVDC connections and grids with high penetration of renewables: recent developments and future trends

Elisabetta Lavopa, GE Vernova HVDC



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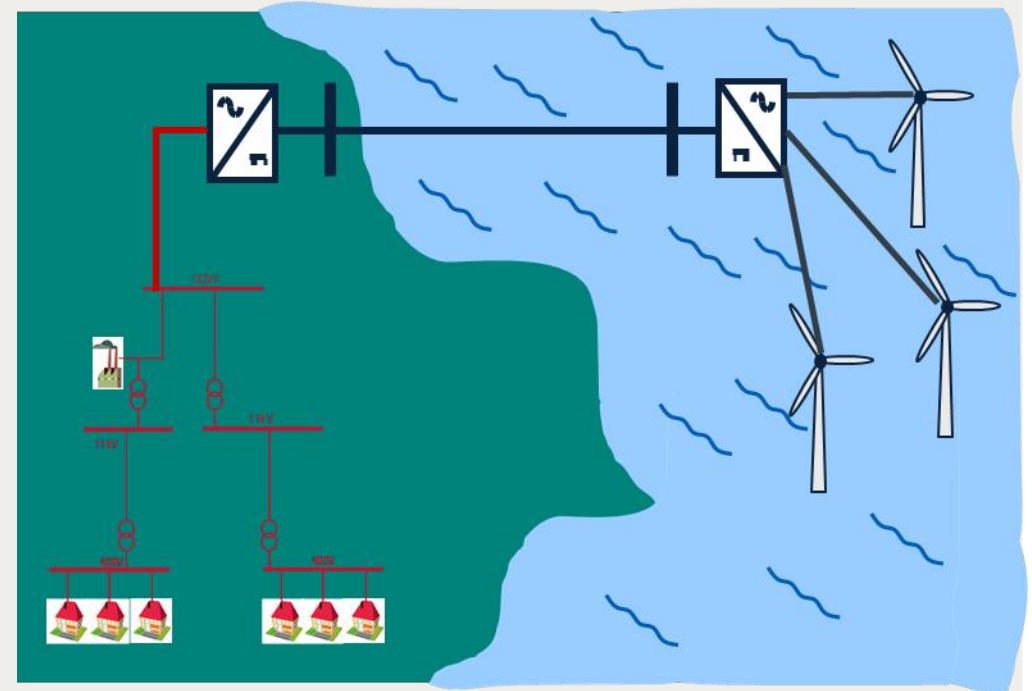
Agenda

1. Introduction on Systems Studies for HVDC interconnections;
2. Examples of studies carried out at GE Vernova HVDC;
3. Challenges related to modelling and data;
4. Future developments;
5. Conclusions.

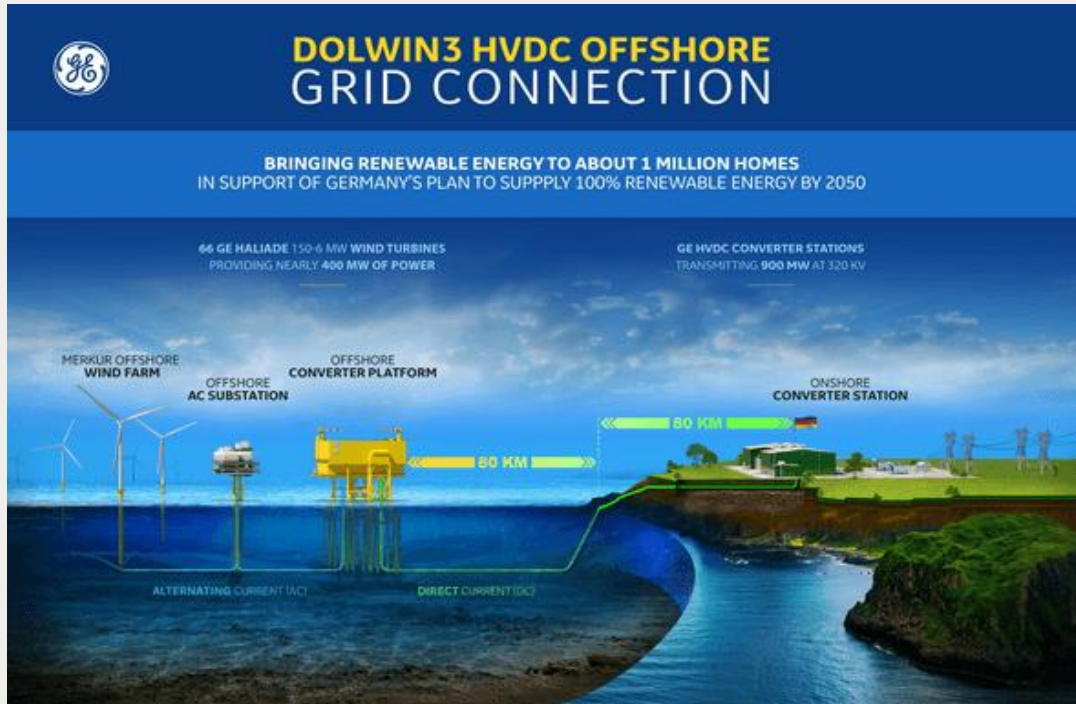


Introduction

- Renewable generation with Inverter-Based Resources (IBR) grown in rated power in recent years. Mainly driven by offshore wind power plants, onshore wind, solar photovoltaic generation.
- VSC-HVDC most common solution for long-distance transmission from renewable generation plants to the AC grid.
- Modelling of HVDC and renewable grids crucial for accurate assessment of interactions.
- Example studies in HVDC project:
 - Load Flow and Short Circuit
 - Harmonics
 - Transient Stability
 - High Frequency Interference
 - Insulation Coordination
 - Dynamic Performance
 - Losses
 - RAM
 - Noise

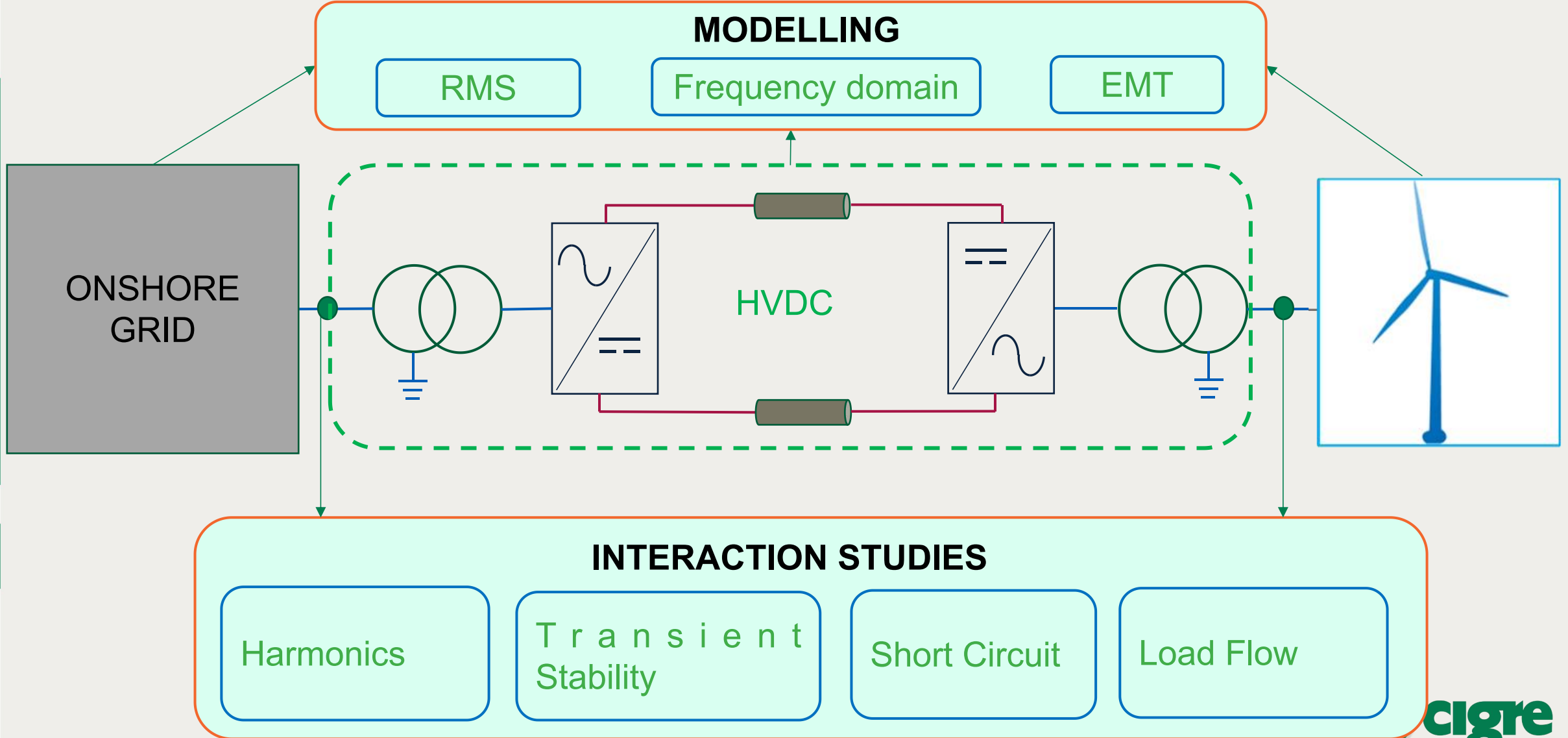


Offshore HVDC transmission expansion

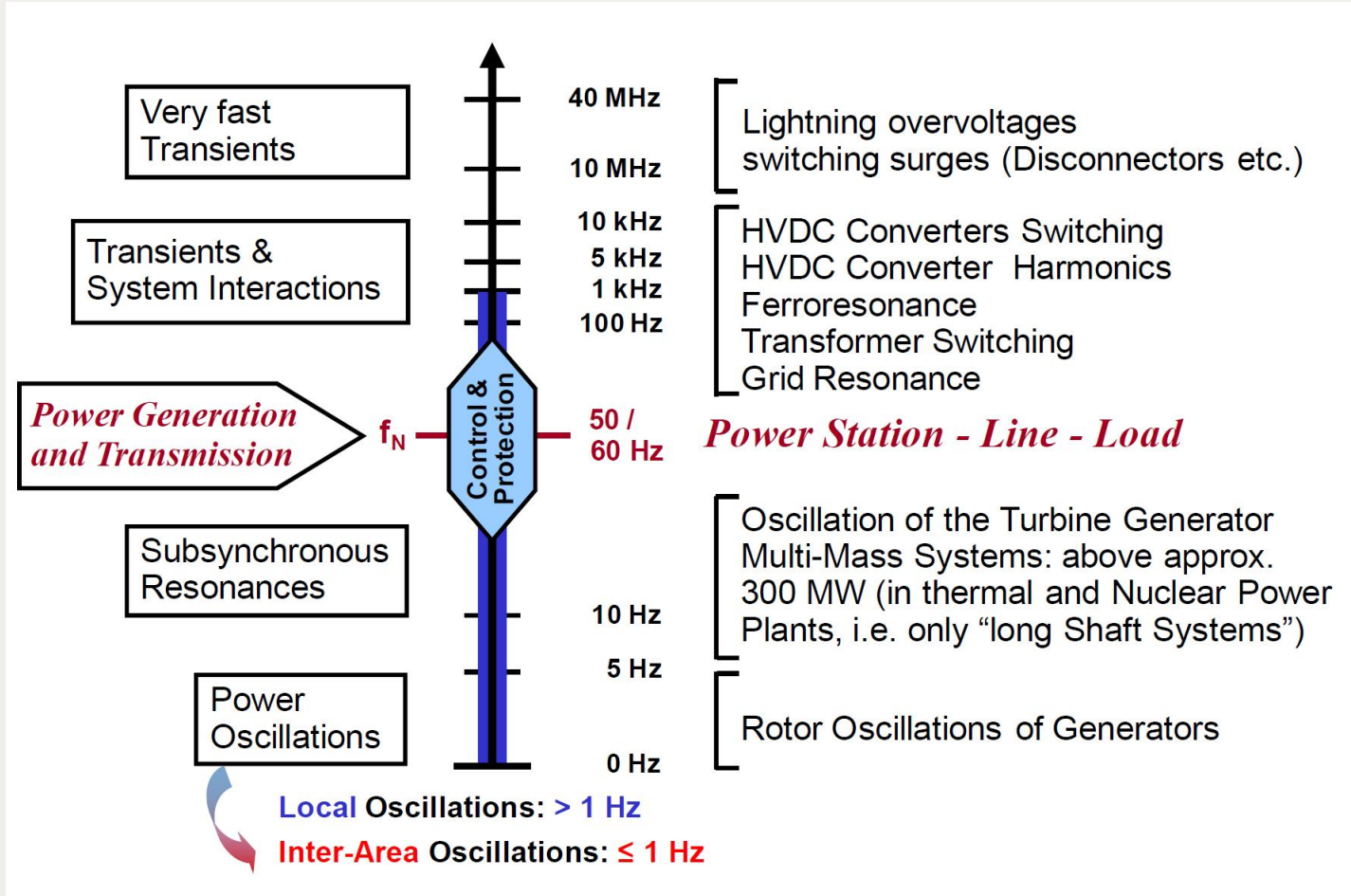


Kick-off in April 2023:
5 x 2 GW \pm 525 kVdc Offshore Windfarm Connections
TenneT Germany and Netherlands

Example of HVDC System Studies at GE



Example of HVDC System Studies at GE



RFI & EMF

TOV

Harmonics

Transient Stability, LF & SCL

UIF&SSO

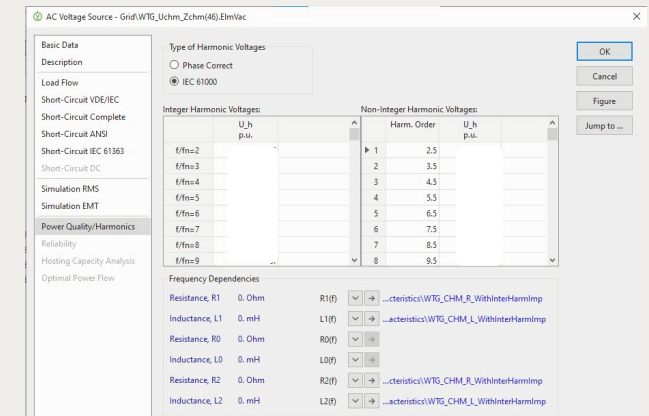
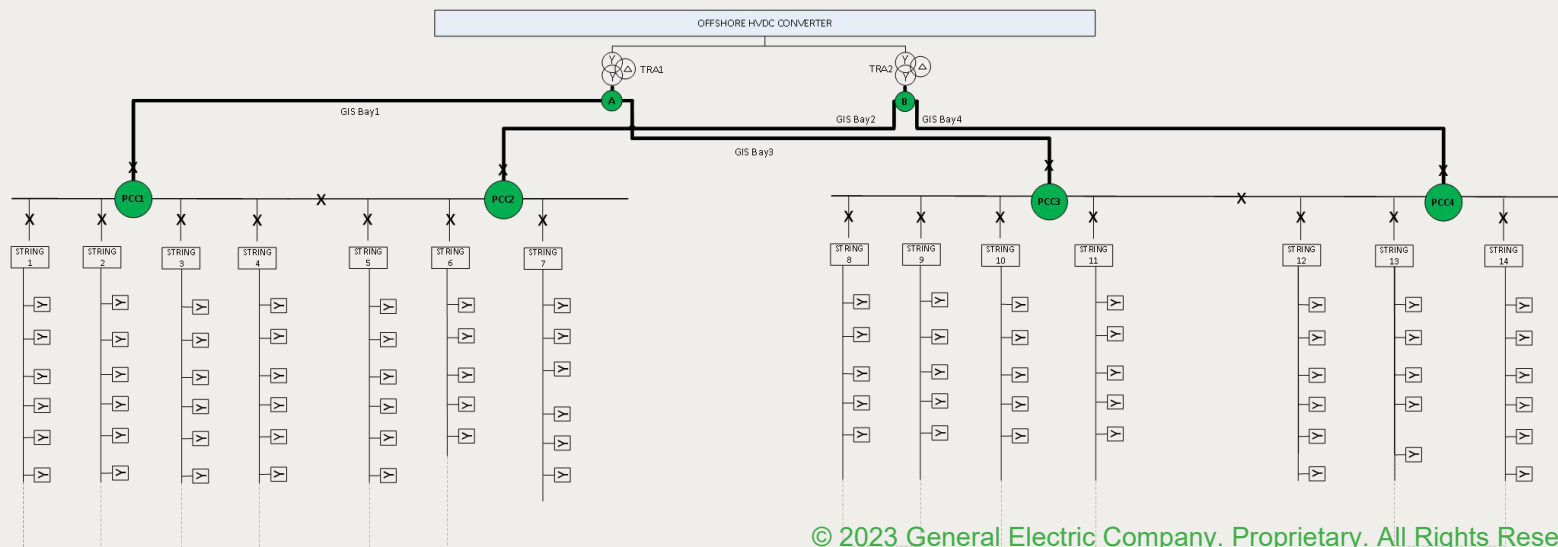
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From CIGRE TB 563 "Modelling and Simulation Studies to be performed during the lifecycle of HVDC Systems"

Harmonic studies for large offshore networks

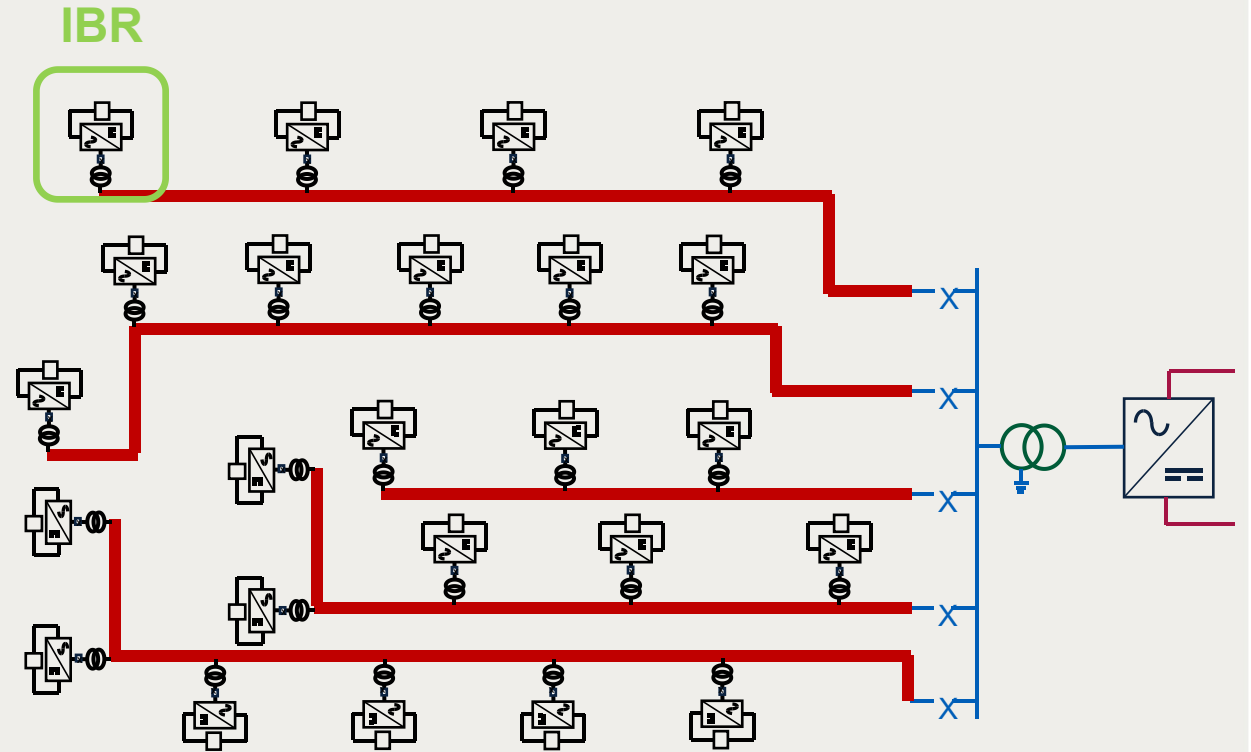
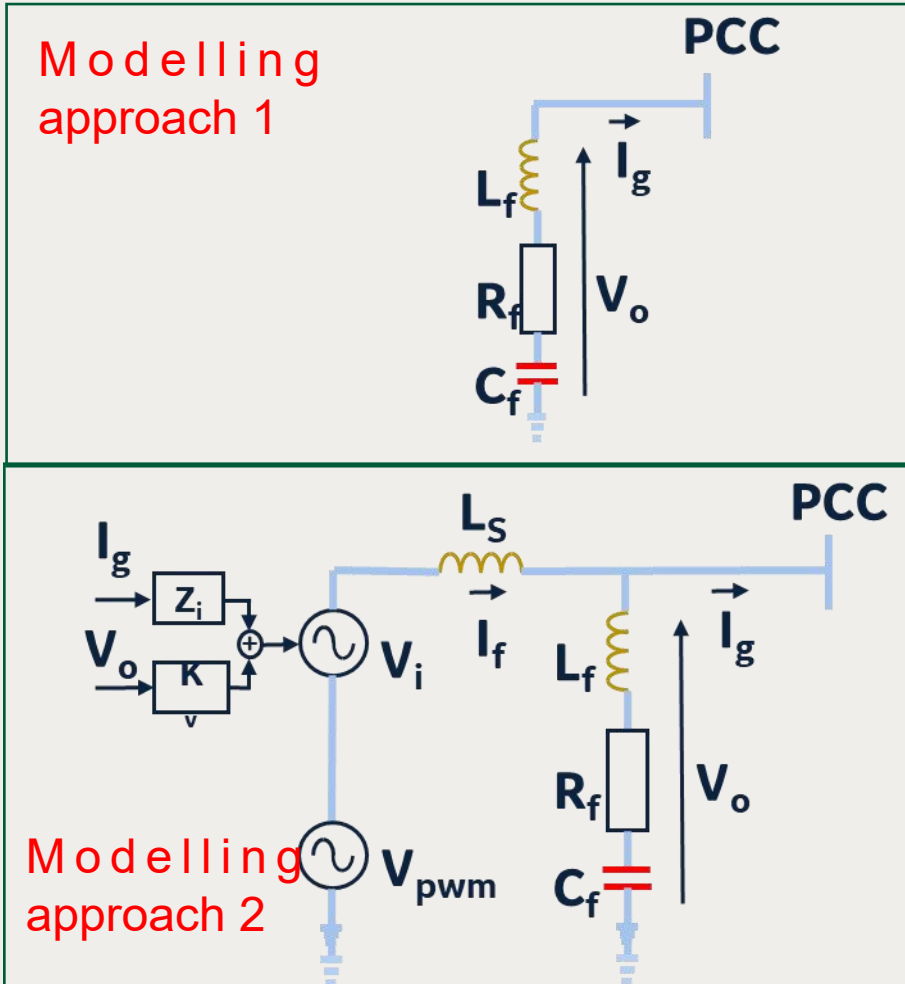
Harmonic load flow:

- IEC 61000 / Phase correct
- Multiple operating scenarios (~ 500)
- Relative phase angles of multiple sources: fixed for characteristic harmonics, random for non-characteristic harmonics
- Correct representation of phase angles leads to more realistic results
- Number of cases can go up to $200(\text{angles}) \times 100 (\text{IBRs}) \times 900(\text{configurations}) = 18\text{M}$. Distortions monitored at all nodes of the network



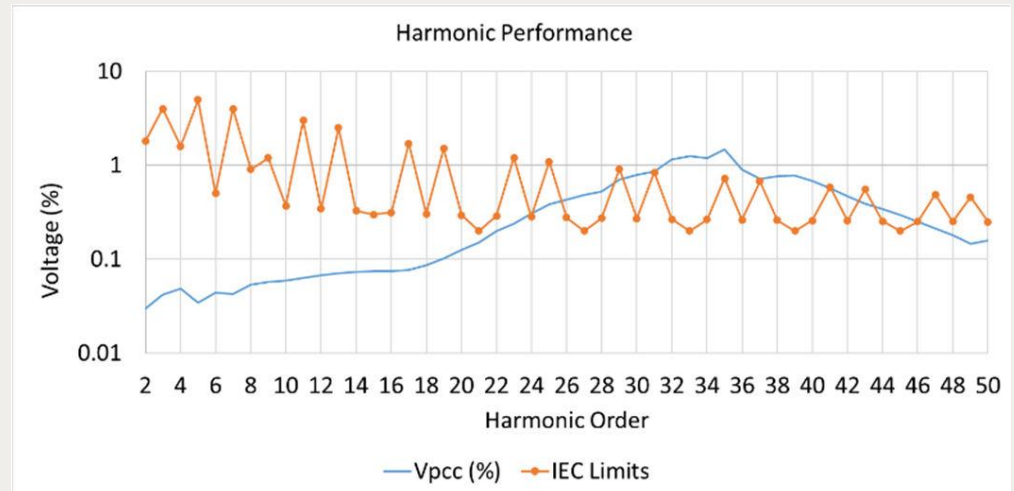
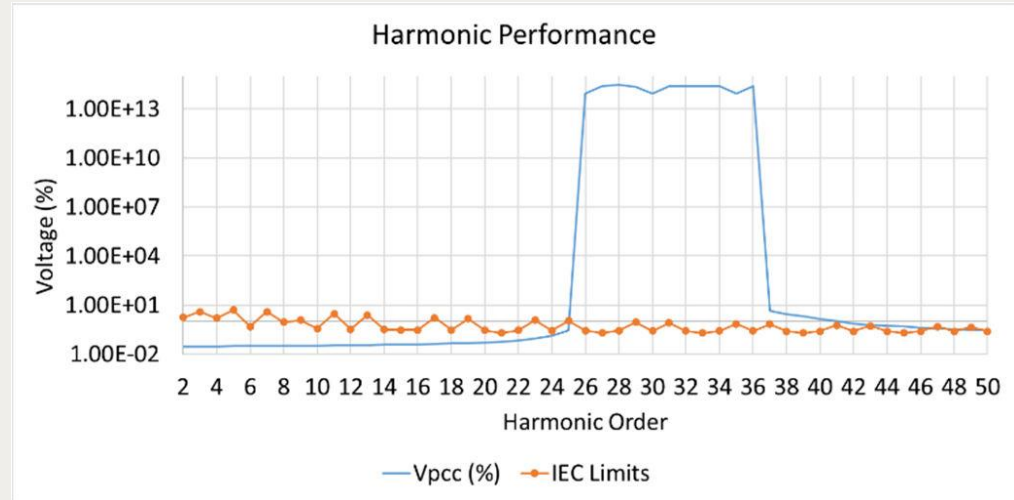
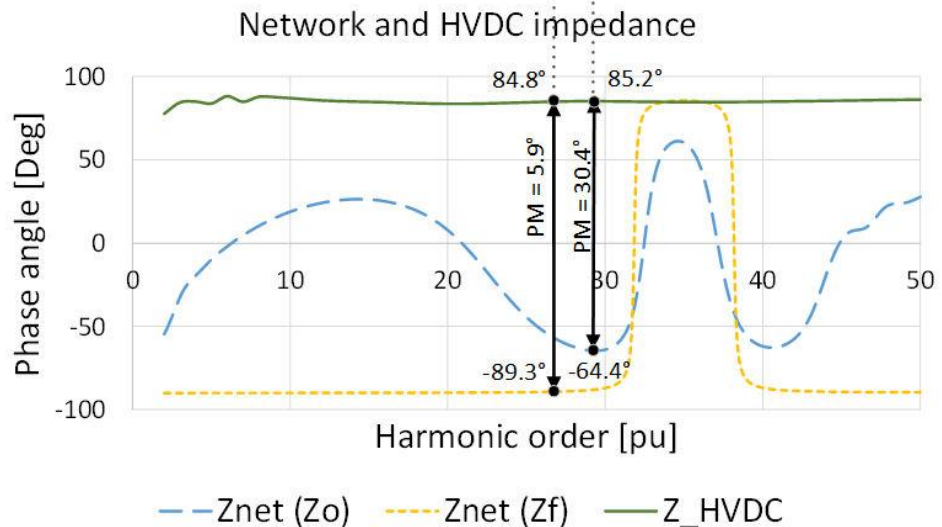
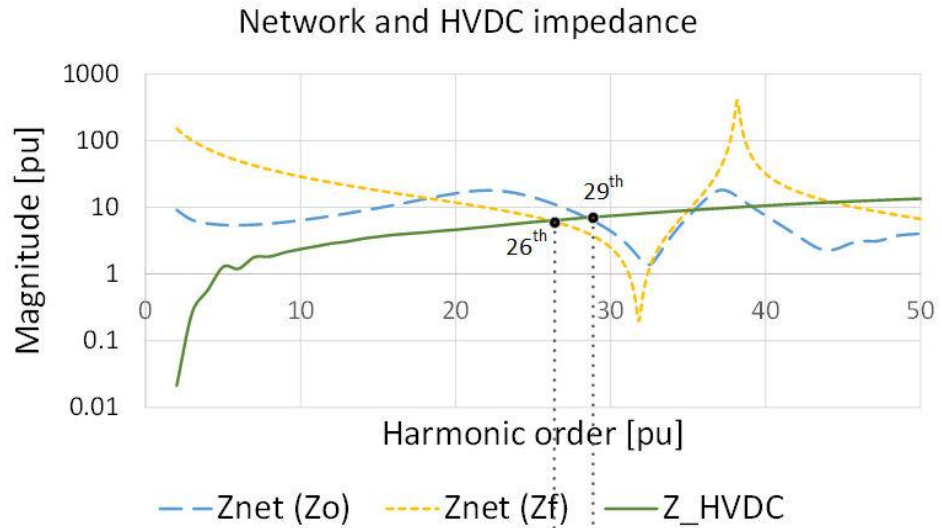
IBR harmonic modelling approaches

The accuracy of the modelling of the VSC converters in the AC network and their control system can have a significant impact on the harmonic performance estimation, and, consequently, on the harmonic design and planning of the HVDC station.



G. Tremouille, K. Carvalho, J.C. Urrego, A. Kumar, "Equivalent Impedance of Wind and Solar Power Plants for AC Harmonic Performance Assessment of VSC-HVDC Systems", CIGRE Session Paris 2022

Impact of IBR model on harmonic performance



E Lavopa, A Kumar, K Carvalho, "Impact of Harmonic Modelling of Renewable Power Plants on the Design and Performance of VSC-HVDC Systems", The 11th International Conference on Renewable Power Generation, September 2022, London.



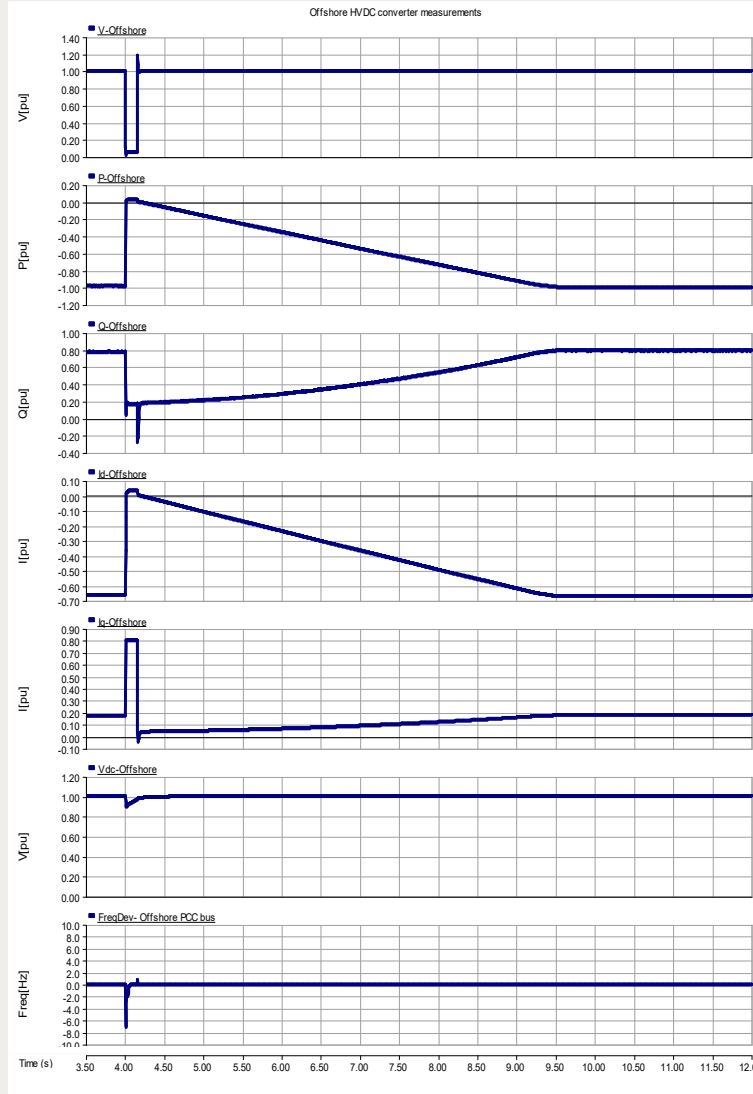
Transient Studies in the RMS domain

**HVDC
RMS
MODEL**

**GRID
RMS
MODEL**

Control interactions

- These studies capture potential control interactions between the HVDC and the AC grid.
- Simplified RMS model of the HVDC with detailed model of the grid, for validation of dynamic response.
- Need for generic models, accurate enough for planning stage studies ahead of design finalization.
- Transient Stability, FFTOV, Interaction studies, Power Oscillation Damping.

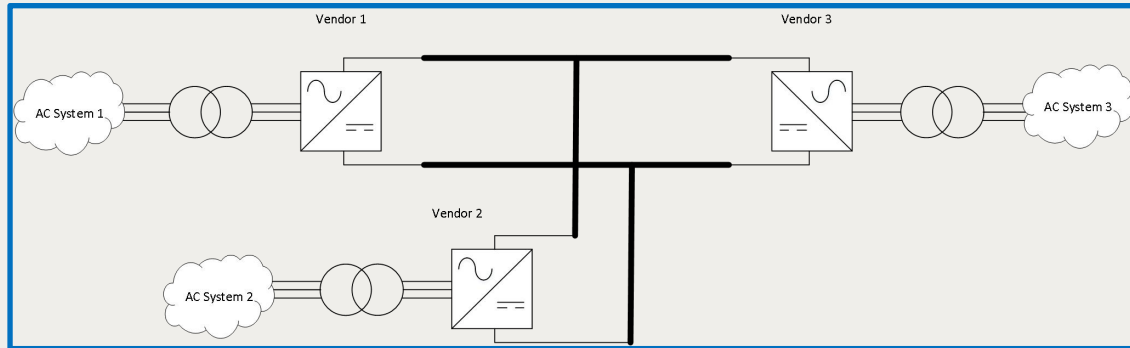


Impact of grid modelling on HVDC design

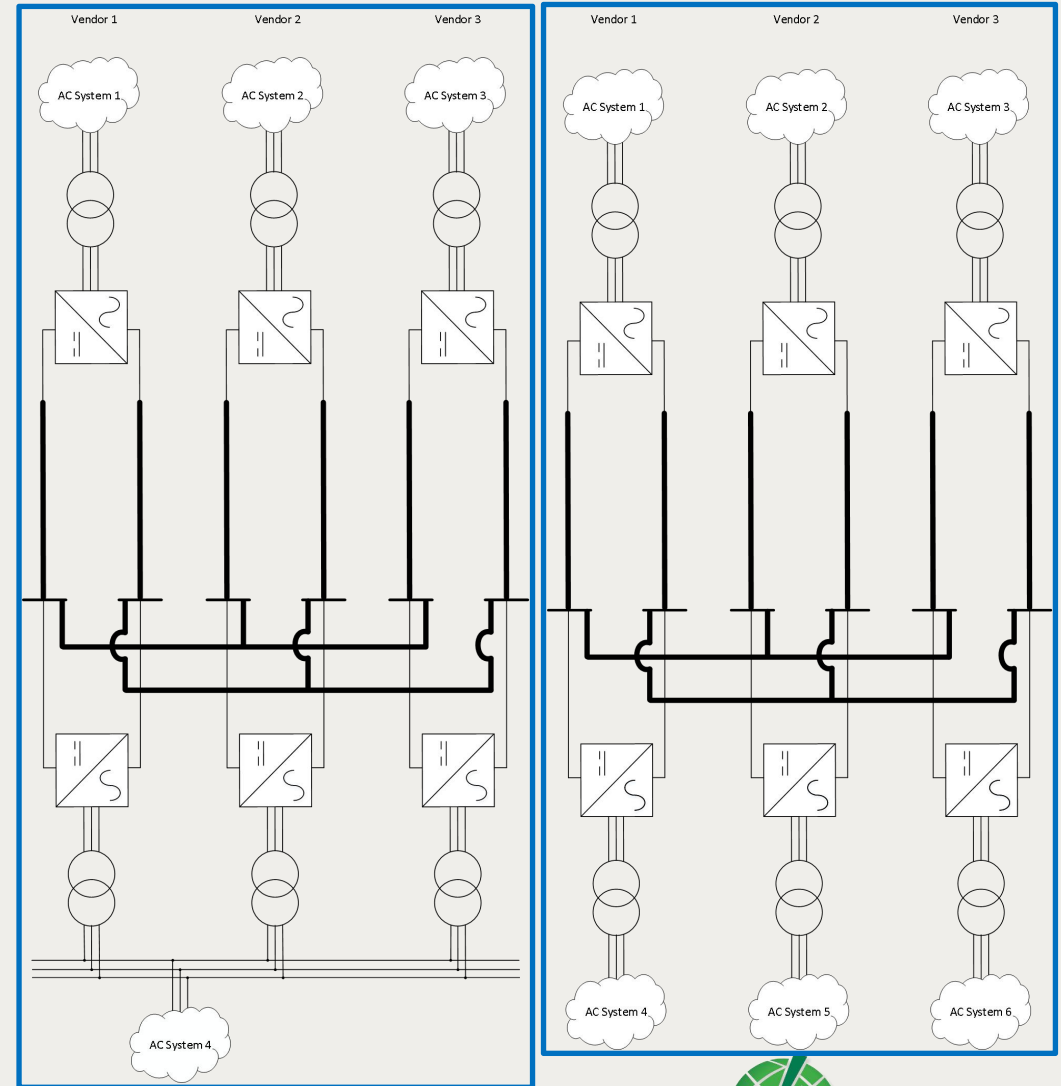
- Inaccurate modelling of the renewable network can lead to incorrect prediction of the interactions with the HVDC.
- Risk of :
 - Incorrect tuning of HVDC controls;
 - Over-sizing of HVDC valve;
 - Provision/Installation of passive filters, even where they are not required;
 - Re-work in design and studies, which requires additional engineering time and effort.
- Vital synergy between vendors of renewable grid components and HVDC vendors to exchange provide models/data, or to be fully clear on assumptions and risks.
- Generic models can be the way forward, as long as representative.

- Crucial for optimized design.
- These data are not always available at the start of a project.

Multi-terminal / Multi-vendor HVDC systems



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- / -
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Future developments

➤ High-frequency characterization of circuit components and control interactions



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Conclusions

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Thank You!

elisabetta.Lavopa@ge.com



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