Anticipating Complex Network Issues Through the Use of Advanced Simulation Models

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BACKGROUND

Wind energy penetration in the transmission networks has been continuously increasing during the last decades. This situation propitiates integration problems with the electrical grid.

Regarding the power converter, these problems can be classified as follows:

- Working with very low SCR or quality factor grids: the resonance frequency of the harmonic filter decreases and can destabilize the current control loop.
- Sub-synchronous resonances: when series capacitors used in long transmission lines interact with the converter control loops, resonances at low frequencies appear.
- Parallel resonances: the use of capacitor banks on a wind farm level can have an influence on the system stability.

OBJECTIVE

An accurate modelling of the converter control loops and its interaction with the grid becomes indispensable in order to overcome these challenges. Using SIL and HIL systems meet this requirement, but these systems are time-consuming. The modelling of the control loops, grid, and generator systems as linear time-invariant (LTI) models, instead, allows high agility to run parameter sweeps and test new algorithms.

The LTI model allows to express the whole system (grid + control + generator) as one state-space matrix. The stability and dynamic behaviour of the system can be obtained easily from the LTI model.

The non-linearities of the system (converter switching, non linear control algorithms…) must be linearized or eliminated.

METHODS

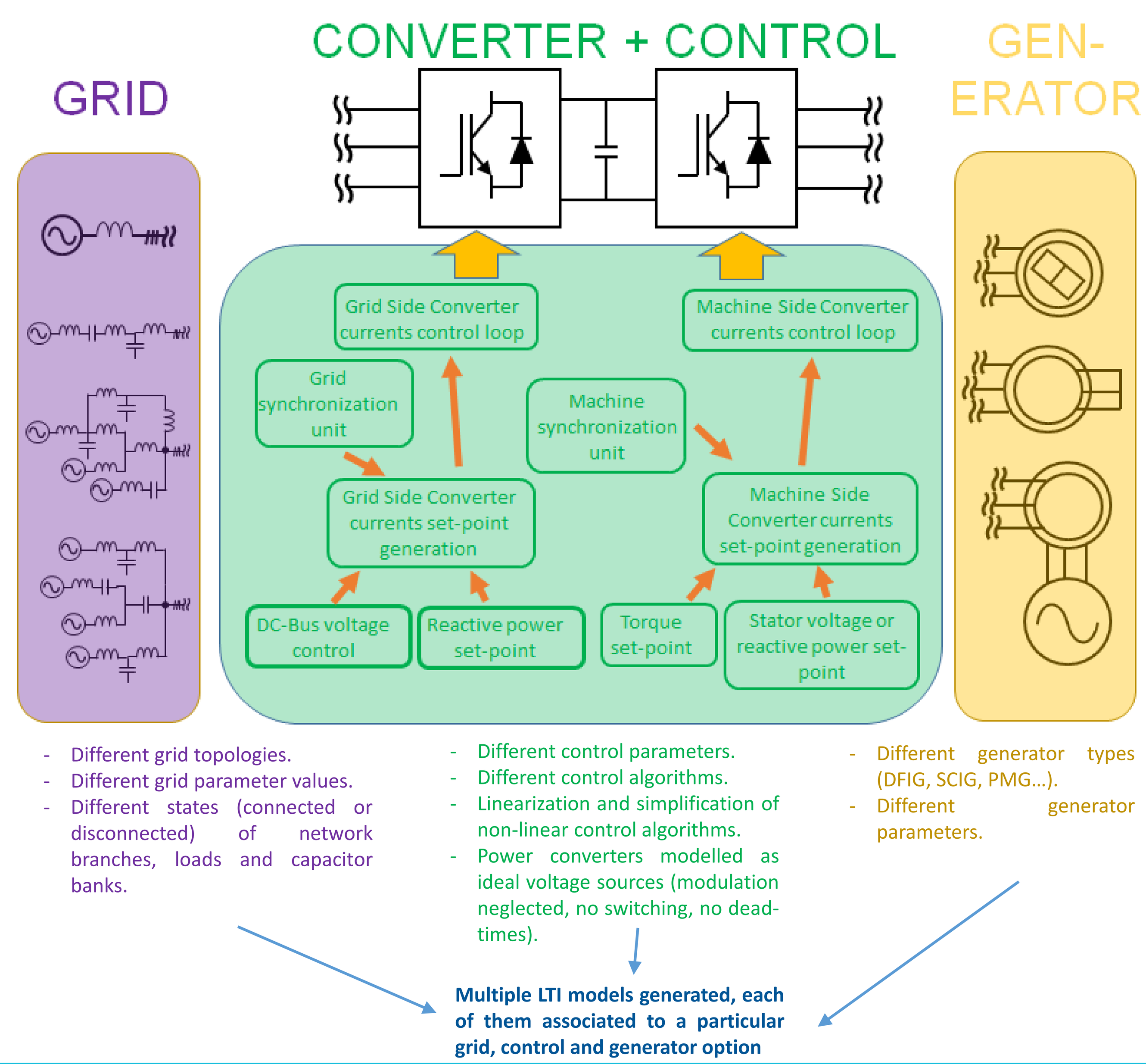
The following workflow is proposed to anticipate grid interaction problems:

- Characterization of all possible casuistics of a grid: parameter variations (e.g. number of turbines connected), network branches connected or disconnected, capacitor banks connected or disconnected.
- Generation of LTI models of all possible grid, generator and control algorithm casuistics to analyze the control loops behavior and obtain the set of parameters or new algorithms to assure the good performance.
- Validation of the solution using SiL and HiL systems.

RESULTS

Generation of LTI models

LTI model of a certain grid, LTI model of a certain converter control option and LTI model of a certain generator are combined to form a LTI model associated to a particular grid, control and generator combination.



Validation of LTI modelling

Despite simplifications (no switching and dead-time, linearization of non-linearities), the LTI model replicates with sufficient precision the current response measured in real test-bench.

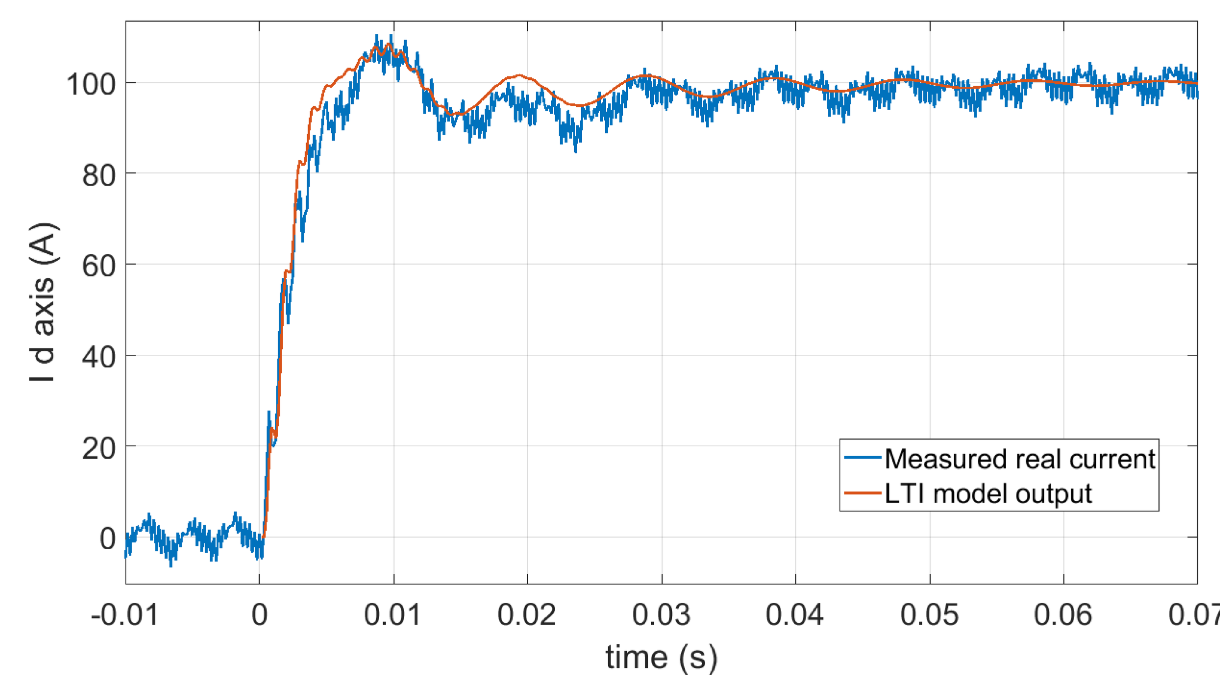


Fig. 1 Real and LTI model current response comparison

Obtaining an optimized control structure

Low time (~100 ms) is needed to generate and analyze one LTI system. That brings the possibility to test high number of different control parameters and algorithms with all possible different grid and generator combinations, obtaining stability maps and dynamical behaviours.

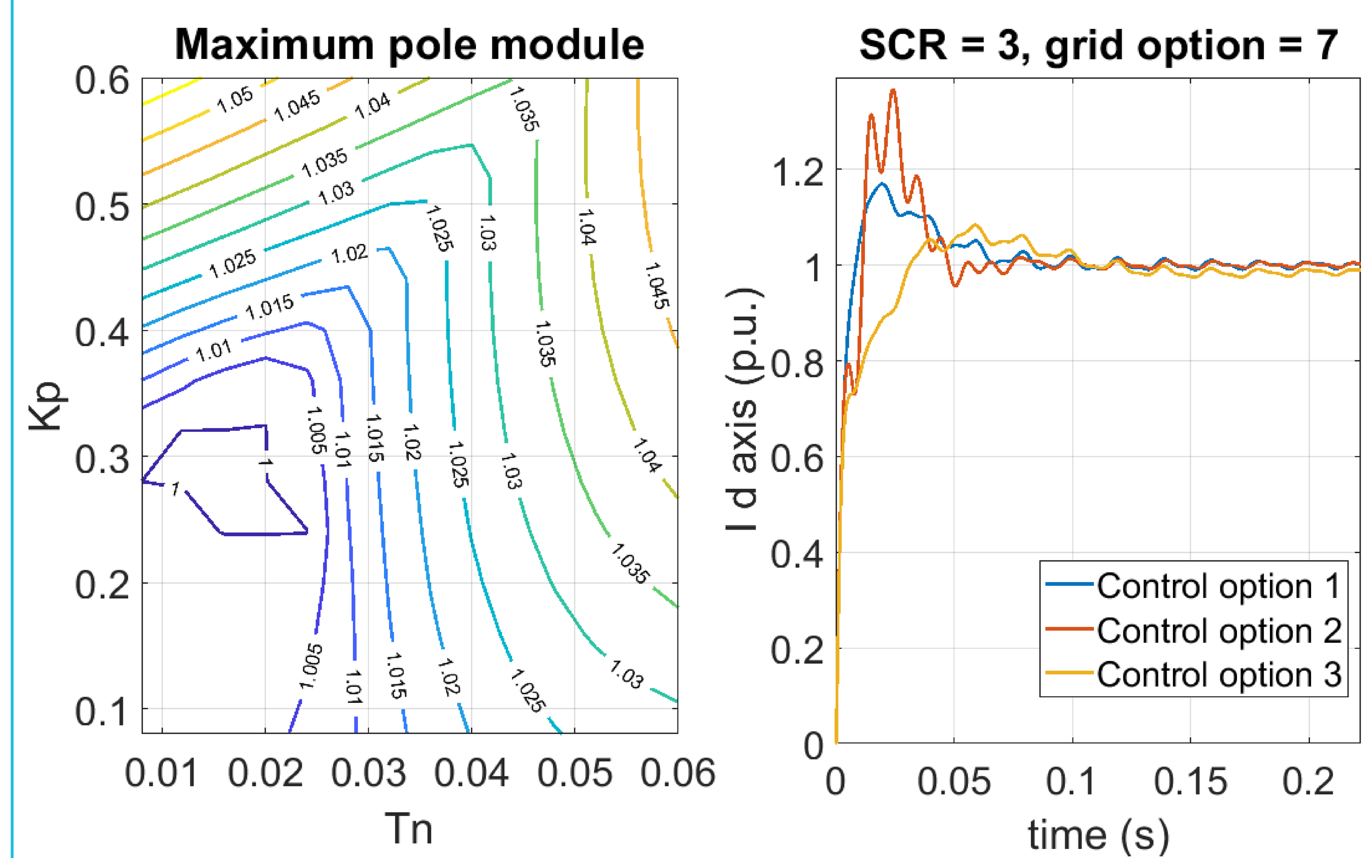


Fig. 2 Stability map (left) and dynamic behavior (right)

The optimal control structure and its parametrization are selected, which are stable with all possible grid and generator casuistics and present best dynamical behaviour.

Validation of the control structure

The selected control structure and its parametrization are validated with SiL & HiL simulation platforms together with an automated testing procedure, to eliminate uncertainties due to simplifications and linearizations of the control algorithms when generating the LTI model.

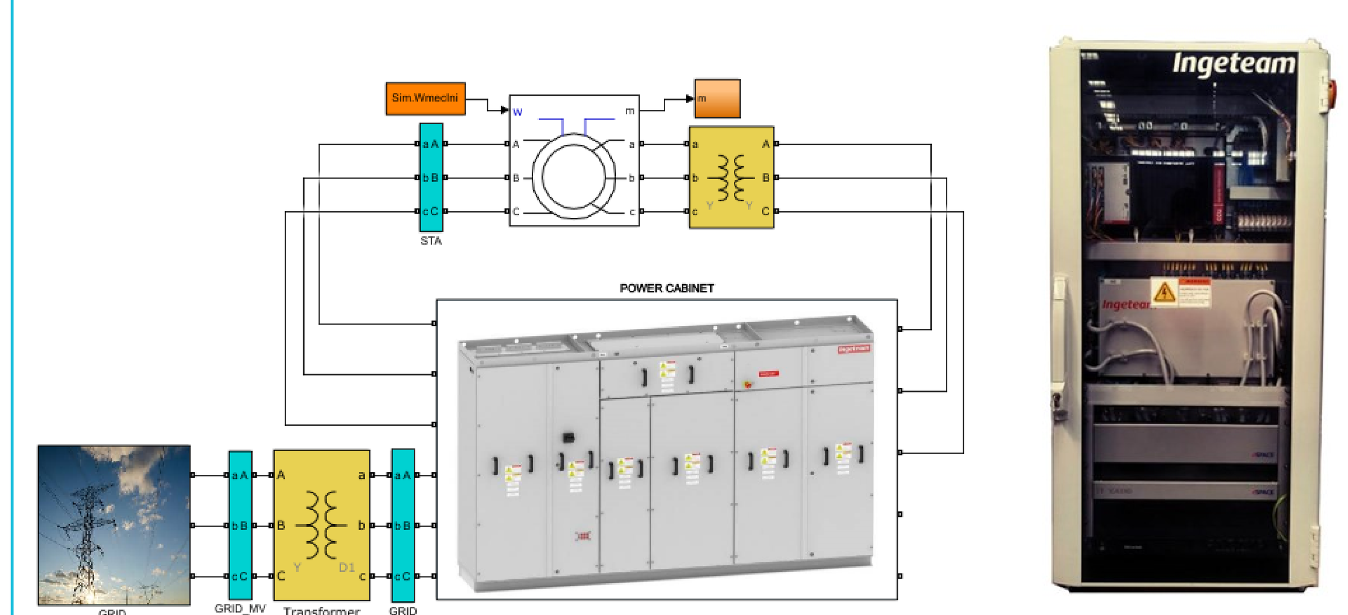


Fig. 3 SiL model (left) and HiL simulation bench (right)

CONCLUSIONS

- The use of LTI models is proposed to anticipate complex network issues. These LTI models are generated to each particular grid, generator and control algorithm and parameter casuistics, allowing to check in a fast way the stability and the dynamic behaviour of the whole system.
- Simplifications must be done in order to generate the LTI models. Switching and dead time are neglected, and non-linear control algorithms must be linearized. In spite of these simplifications, the LTI model and real system responses have a good equivalence.
- Through simulation sweeps using LTI models, an optimal control structure can be selected, that assures stability with all possible grid and generator casuistics and has acceptable dynamical behaviour.
- The selected control structure and its parametrization is finally validated using SiL / HiL simulation platforms. In this way, the good performance of the selected control structure is totally guaranteed.

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