E.ON Energy Research Center ACS | Institute for Automation of Complex Power Systems	Advisement can be offered in English language Series of MS Thesis topics on **System-level Small-Signal Stability studies in Future Power-Electronics-based AC Power Systems** HiWi + MS Thesis is also possible

Plot
The series of MS thesis topics are within the framework of a European project called RE-SERVE (http://re-serve.eu/). More specifically, the offered topics aim at studying the system-level small-signal stability of future AC Power Systems that are envisioned to undergo profound operational changes due the deeper and deeper integration of Renewable Energy Resources (RESs) and loads through grid-connected power electronics converters. For this reason, the traditional AC Power System is transforming into a Power-Electronics-based AC Power System.

Background
As power electronics penetrate the AC grid, a challenge related to small-signal voltage stability and control is presented for power electronic engineers and power systems engineers. It is known that this proliferation of grid-connected power electronics can have a destabilizing effect on the AC voltage due to interactions among feedback-controlled grid-connected power electronic converters and equivalent power grid impedances seen at the various Point of Common Couplings (PCCs) [1]. A major challenge with these converters is to ensure system-level small-signal voltage stability under all dynamic conditions of load vs. generation.

Impedance-ratio-based stability criteria, such as the Middlebrook criterion and its extensions, were initially proposed for DC power systems. They are reviewed in [2]. Then, the impedance-ratio-based stability criteria were extended to AC power systems [3]. All these small-signal voltage stability criteria, however, were limited only to systems that can be lumped in a cascade connection, i.e. a source subsystem feeding a load subsystem. All these stability criteria are based on the minor loop gain concept, i.e. an impedance ratio at the source/load interface of the cascade system. Considering that the minor loop gain is a type of loop gain of an equivalent negative feedback loop system, the stability study can be performed by applying the Nyquist stability criterion to such a minor loop gain. As a major challenge, the simple cascade model does not easily apply to the more complex topology of AC power systems.

Related to impedance-ratio-based stability criteria, noninvasive online Wideband System Identification (WSI) methods to identify AC power impedances for stability studies are of fundamental importance. Recently, ACS presented at an international conference the implementation, in a real-time PC equipped with a NI RIO device, of a recently proposed online WSI technique, and its validation via Hardware In the Loop (HIL) which exploits OPAL-RT as real-time simulator [4]. The identification technique is schematically shown in Fig. 1 and exploits an existing grid-tied inverter for the estimation of wide bandwidth AC grid impedances, on top of the original power conversion function. This is accomplished by super-imposing a short-duration small-signal Pseudo Random Binary Sequence (PRBS), a digital approximation of white noise which is wide bandwidth in nature, on the inverter control loop so that all frequencies of interest can be excited at once at the Point of Common Coupling (PCC). Then, after post-processing on the measured voltage and current at the PCC, the parametric (and therefore wideband) AC grid impedance can be extracted.

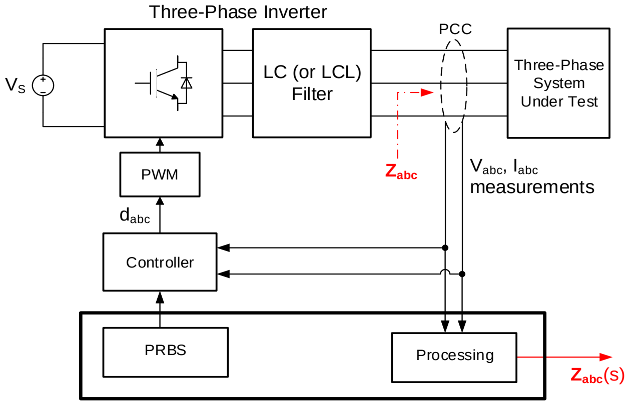

Figure 1: block diagram of the WSI technique for for online parametric identification of AC Power Grid Impedances.

High-level storyline of the Series of MS Thesis topics

The series of MS Thesis topics will be structured and offered to single students in such a way that they singularly address aspects of the following high-level storyline.

The identified impedance parameters of the WSI tool are then provided to a central unit to perform online stability analysis. At this stage, the central unit online calculates the stability margins of an impedance-ratio-based system-level loop gain (similarly to the Middlebrook Criterion and its extensions formulated for AC systems). The central unit has also the duty to coordinate the system-level PRBS injection mechanism in order to minimize the risk for undesired interactions. The result of the small-signal stability analysis will be translated into a system-level impedance profile all grid-connected converters should have to guarantee the overall stability of the system. This information can then be fed back to the grid-connected inverters via the concept of Virtual Output Impedance (VOI) [5], i.e. an active method to shape the output impedance of power converters by acting on their control algorithms so that overall system stability can be achieved.

Requirements

For this kind of job the student may have good knowledge of power electronics with focus on the implementation of switch-mode power electronic converters and their control in MATLAB/Simulink. Knowledge of LabVIEW is a plus.

Your tasks

The student shall work on the implementation of a HIL setup comprising the online WSI technique running in a real-time PC equipped with a NI RIO device acting on an inverter connected to a reference distribution network simulated in OPAL-RT (Simulink-based modeling environment), which is a powerful real-time digital simulator in ACS.

At the beginning of the work the student will get familiar with the operation of grid-tied power converters simulated in OPAL-RT and the existing implementation in LabVIEW of the WSI technique within the existing HIL setup. Then, the student's task will be framed within the specific topic accordingly to the system-level studies described in the high-level storyline.

During the work the student will be supervised and advised by the research associates of the institute.

References

[1] B. Wen, D. Boroyevich, R. Burgos, P. Mattavelli and Z. Shen, "D-Q impedance specification for balanced three-phase AC distributed power system," 2015 IEEE Applied Power Electronics Conference and Exposition (APEC), Charlotte, NC, 2015, pp. 2757-2771

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[3] J. Sun, "Impedance-Based Stability Criterion for Grid-Connected Inverters," in IEEE Transactions on Power Electronics, vol. 26, no. 11, pp. 3075-3078, Nov. 2011

[4] Riccobono, E. Liegmann, A. Monti, F. Castelli Dezza, J. Siegers and E. Santi, "Online wideband identification of three-phase AC power grid impedances using an existing grid-tied power electronic inverter," 2016 IEEE 17th Workshop on Control and Modeling for Power Electronics (COMPEL), Trondheim, 2016, pp. 1-8

[5] K. M. Alawasa, Y. A. R. I. Mohamed and W. Xu, "Impact of control implementations on the output impedance of voltage-sourced converters," 2013 IEEE Power & Energy Society General Meeting, Vancouver, BC, 2013, pp. 1-5

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