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Student project proposal

Project title
Development of a Simulation Model for Power-System Harmonic Analysis in EMTP-RV

Project type ☐ MSc thesis ☒ BA semester project ☒ MSc semester project

Project responsible and e-mail
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Project description
Presently, power distribution systems are undergoing a fundamental transformation due to the massive integration of Distributed Energy Resources (DERs), such as solar/wind generators, battery/supercapacitor storage systems, and charging stations for electric vehicles. Typically, such DERs are interfaced with the grid through power electronic converters, which allow to control these resources [1]. The mutual interaction of converters via the grid can lead to unstable oscillations [2]. As these oscillations occur at harmonic frequencies, this phenomenon is called harmonic instability. Harmonic instability arises due to inadequate control schemes (e.g., harmonic resonance of parallel DERs) and/or poor tuning of one or multiple equipment controllers [3]. In order to analyze and compensate such phenomena, harmonic analysis methods are required. The steady-state behaviour of power electronic converters can be analysed in the harmonic domain using Linear Time-Periodic (LTP) systems theory [4].

In [5], [6] a Harmonic Power Flow (HPF) method, based on a generic, modular and accurate modelling framework is proposed. The distinguishing feature of the method is that it relies on a generic modelling framework for Converter-Interfaced DERs (CIDERs), which notably takes into account the coupling between harmonics. In order to validate this frequency-domain method, time-domain simulations of a benchmark system are needed.

The goal of this project is to implement simulation models of benchmark electrical microgrids (e.g., the CIGRE low-voltage benchmark microgrid) in the EMTP-RV simulation environment. For this purpose, a library of component models has to be developed. In particular, the CIDERs have to be represented in detail, and more sophisticated line models (i.e., including frequency-dependent parameters) need to be incorporated. A simulation model implemented in MATLAB/Simulink is available as a reference.

Tasks of the student
- Development of a library of component models (i.e., different types of CIDERs and other power system components) in EMTP-RV.
- Development of an EMTP-RV model capable to simulate an electrical microgrid.

Requirements
- Basic knowledge of power electronics and power systems.
- Basic knowledge of EMTP-RV.
- Familiarity with MATLAB/Simulink is recommended.

Literature

[1] F. Blaabjerg, Z. Chen, and S. B. Kjaer, "Power electronics as efficient interface in dispersed power generation systems," *IEEE Trans. Power Electron.*, vol. 19, no. 5, pp. 1184–1194, Sep. 2004, doi: 10.1109/TPEL.2004.833453.

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[3] Claudio A. Cañizares *et al.*, "Microgrid Stability Definitions, Analysis, and Modeling," IEEE PES, Tech. Rep. PES-TR66, 2018.

[4] X. Wang and F. Blaabjerg, "Harmonic Stability in Power Electronic-Based Power Systems: Concept, Modeling, and Analysis," *IEEE Trans. Smart Grid*, vol. 10, no. 3, pp. 2858–2870, May 2019, doi: 10.1109/TSG.2018.2812712.

[5] A. M. Kettner, L. Reyes-Chamorro, J. K. M. Becker, Z. Zou, M. Liserre, and M. Paolone, "Harmonic Power-Flow Study of Polyphase Grids with Converter-Interfaced Distributed Energy Resources, Part I: Modelling Framework and Algorithm," *ArXiv210612253 Cs Eess*, Jun. 2021, Accessed: Aug. 17, 2021. [Online]. Available: http://arxiv.org/abs/2106.12253

[6] J. K. M. Becker, A. M. Kettner, L. Reyes-Chamorro, Z. Zou, M. Liserre, and M. Paolone, "Harmonic Power-Flow Study of Polyphase Grids with Converter-Interfaced Distributed Energy Resources, Part II: Model Library and Validation," *ArXiv210612255 Cs Eess*, Jun. 2021, Accessed: Aug. 17, 2021. [Online]. Available: http://arxiv.org/abs/2106.12255