École Polytechnique Fédérale de Lausanne
Distributed Electrical Systems Laboratory
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Student project proposal

Project title
Modelling of Rectifiers in the Harmonic Domain for Power System Analysis

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. The steady-state behaviour of power electronic converters can be analysed in the harmonic domain using Linear Time-Periodic (LTP) systems theory [3]. To this end, one requires accurate models of the devices of interest. In the particular case of diode or thyristor rectifier, the model development is challenging due to state-dependencies between the AC side and DC side of the device (e.g., AC-side inductances or DC-side filters). For thyristor rectifiers, the firing-angle control adds another degree of complexity to the harmonic analysis, which calls for the use of iterative methods [4][5].

The goal of this project/thesis is to develop sophisticated models for the analysis of diode/thyristor rectifiers. In particular, it would be valuable to find approximate models which allow to use non-iterative methods, which are computationally less intensive than iterative ones. To this end, the effects which cause the state-dependency in the device model need to be identified and modelled appropriately. The extent of the project can be adapted based on its type (i.e., semester project or thesis).

Tasks of the student

- Development of mathematical models of rectifiers for harmonic analysis.
- Implementation of the aforementioned models in MATLAB.
- Validation of the harmonic models using time-domain simulation with Simulink.

Requirements

- Basic knowledge of signal processing (i.e., Fourier/Laplace transform).
- Basic knowledge of power electronics and power systems.
- Good knowledge of system and control theory (i.e., Linear Time-Invariant (LTI) systems, open/closed-loop analysis, etc.).
- 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, 2004.

[2] J. Enslin and P. Heskes, "Harmonic Interaction between a Large Number of Distributed Power Inverters and the Distribution Network," IEEE Trans. Power Electron., vol. 19, no. 6, 2004.

[3] 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, 2019.

[4] B. C. Smith, N. R. Watson, A. R. Wood, and J. Arrillaga, "Steady-State Model of the AC/DC Convertor in the Harmonic Domain", IEE Gener. Transm. Distrib., vol. 142, no. 2, 1995.

[5] A. R. Wood, "An Analysis of Non-Ideal HVDC Convertor Behaviour in the Frequency Domain, and a New Control Approach", Ph.D. Thesis, Univ. Canterbury, Christchurch, NZ, 1993.