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Call for Ph.D. thesis applications for

MODELLING AND CONTROL OF MODULAR MULTILEVEL POWER ELECTRONIC CONVERTERS (MMCs)

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Dead-line: May 20th 2019
Please provide CV, relevant transcripts, letter of motivation, record of publications (if any)

Keywords:
Control and estimation of energy conversion systems, renewable energy conversion systems, power electronic converters, switched model, averaged model

In the context of transition of energy systems and grids to carbon-free, renewable-energy-based, modular and flexible operation, the multiple technological shifts must be accompanied by modelling and control paradigm shifts, to fully enable efficiency growth and reduced costs along with smooth and safe operation and eased maintenance.

Modular Multilevel Converters (MMC) represent a shift in the power electronics converters technology, that consists in multiplying number of layers containing switching devices, which are thus required to operate at a switching frequency being lower than in previous converter topologies. Lower losses and higher operating efficiency are thus obtained. Multilevel topology also ensures improved harmonic performance at a given switching frequency [1]. MMCs are a promising solution to high-voltage direct-current (HVDC) transmission systems over long distances, to facilitate grid integration of renewable energy systems, being thus coherent with long-term European strategies of renewable grid-integration.

The objective of this thesis is to propose pertinent solutions to control problems of MMCs operation. Instead of a large DC-side capacitor, MMCs have many lower-capacity capacitors, behaving like a sort of spatially distributed energy storing capacity. The dynamic energy balancing between submodule capacitors over time has been identified as one of crucial problems to solve by control actions; its solution defines in general the lower limit for the switching frequency [1]. Control of circulating current of each leg has been identified as a possible way to ensure the energy balance between submodules. Computation of reference of this current control loop is an issue; a frequency-separation approach has been proposed in [2]. The passivity-based control approach has also been recently proposed, that exploits the "natural" property of converters of storing and dissipating energy. Under some proper modelling assumptions, the state-space incremental model of an MMC becomes passive [3].

The proposed control design must guarantee stability and performance for an as wide as possible operating domain (robustness), as well as easy implementation as widely accepted by practitioners. That is why one must rely upon the most appropriate formal model. MMCs may be modelled as nonlinear (bilinear) systems, possibly containing binary variables, like the ones indicating if a submodule is inserted or bypassed at a given time. Like for the other converter types, there exist *averaged* and *switched* models for MMCs; several types of averaged models are available, depending on which physical level average is made (leg level, arm level, submodule level) [1].

Averaged models are suitable for most applications, control techniques based on feedback linearization may be a good control solution based on such models [4]. However, switched models may be necessary when binary variables are explicitly taken into account. It is pertinent to explore the relevance of considering modulation process modelling within the control design for submodule energy balancing, as they are intimately linked by the issue of when to switch the individual submodules. Such approach would allow stating the control problem as a complex optimization problem, whose solution might not be easy to implement. Different relaxations may then be possible, leading to acceptable levels of sub-optimality in the solution.

A second issue interesting to explore concerns some light topology variation in the MMCs, namely the case when batteries – instead of capacitors – are used in the submodules. In such case, accurate battery state-of-charge (SoC) estimations are necessary to achieve the energy balancing. Use of Kalman filters has recently been investigated for providing reliable SOC estimation [5].

<u>*References*</u>

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[3] G. Bergna, M. Pirro, E. Berne, A. Arzandé, M. Molinas Cabrera, R. Ortega (2015). Modular Multilevel Converter Passivity-Based PI Control suited for Balanced and Unbalanced Grid Conditions. *Procs. of 2015 IEEE International Conference on Industrial Technolog – ICIT 2015*.

[4] S. Yang, P. Wang, Y. Tang (2017). Feedback Linearization Based Current Control Strategy for Modular Multilevel Converters. *IEEE Transactions on Power Electronics*, 2017, DOI 10.1109/TPEL.2017.2662062, vol. 33, no. 1, pp. 161–174..

[5] Z. He, M. Gao, C. Wang, L. Wang and Y. Liu (2013). Adaptive State of Charge Estimation for Li-Ion Batteries Based on an Unscented Kalman Filter with an Enhanced Battery Model. *Energies*, *6*, 4134-4151.

APPLICANT PROFILE

Ideally, a person having a strong background in linear and nonlinear control, with interest and skills in technology and applications of power electronic converters for energy conversion is sought for. Proficiency in MATLAB®/Simulink® is indispensable. Capacity in mathematical modelling for control purpose is necessary.

Proven high academic performance (excellent transcripts) is expected. A record of publications in high-level journals and/or conferences is a plus (but not mandatory).

THESIS SUPERVISING:

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FINANCING

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Thesis will begin on **October 1st 2019**.