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HABILITATION THESIS

Summary

RESEARCHES ON CONTROL OF POWER ELECTRONICS CONVERTERS FOR INTEGRATION OF RENEWABLE ENERGY SOURCES AND ENERGY STORAGE SYSTEMS IN ELECTRICAL MICROGRIDS

Domain: Electrical Engineering

Author: Assoc. Prof. Șerban Ioan

University: *Transilvania* of Brașov

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(A) Summary

The habilitasion thesis presents the main scientific achievements of the author obtained after PhD graduation, focusing on innovative results published in high impact journals and being the subject of several patents applications. According to the author's main area of expertise, the control of power converters for integration of renewable energy sources, energy storage systems and active loads, represents the subject tackled by the thesis. The habilitation thesis is structured into two sections, with the first part describing in four chapters the author's main scientific achievements and the latest section providing a brief description of his career development plan.

Chapter 1. This chapter presents a power decoupling solution for single-phase inverters, exhibiting the main advantage over other existing methods in literature of not requiring additional semiconductors, but only a minimalist passive circuit consisting of two film capacitors connected between the midpoint and one end of each inverter leg. An original control method of the inverter ensures the double-frequency power ripple transfer towards the two decoupling capacitors without affecting the inverter output voltage. The simple design makes the proposed solution easy to adapt for single-phase inverters in H-bridge configuration. The proposed solution has been validate experimentally by using a 1kW single-phase inverter, operating autonomously and grid-connected. Moreover, the advantage of the proposed power decoupling solution when using silicon carbide transistors (SiC-MOSFET) has also been shown.

Chapter 2. The chapter describes a control solution developed by the author for frequency support in microgrids by using power electronics converters designed for interfacing battery energy storage systems. The proposed control strategy focused on two main aspects, namely power quality support in microgrids and ensuring the security of supply for a local consumer. The developed study has also shown how the microgrid short-term frequency control can be improved by means of an original control structure for battery energy storage system enhanced with both inertial response and an adaptive droop characteristic during battery state-of-charge limitations. Aggregated models for the involved control mechanisms in the microgrid have been developed and the validation of the proposed control system has been carried out on a hardware-in-the-loop platform including a real-time digital simulator.

Chapter 3. An integrated control strategy for microgrids, operating autonomously and grid-connected, with a seamless transfer between the two modes is proposed in this chapter.

Being coordinated by a leading inverter with special control architecture, the microgrid operation and the transition between the autonomous and grid-connected modes require only minor control changes in the microgrid. Moreover, an algorithm to facilitate grid code compliance for distributed generators has been developed for operation of microgrids connected to the grid. To validate experimentally the proposed microgrid control solution, a complex laboratory platform has been developed in the *Advanced Electrical Systems* laboratory at the R&D Institute of *Transilvania* University of Brasov.

Chapter 4. This final chapter presents an innovative control solution for active loads designed to improve power quality in microgrids with renewable energy sources. The control scheme has been developed for a particular type of active loads to ensure frequency support in microgrids, and harmonic compensation. The second function is based on an innovative control method, which provides harmonic control by only adding a control loop without any hardware changes of the active load. The proposed solution has been validated experimentally using a laboratory test-bench.

The research activities of the author, presented in this thesis, have been supported in part by research projects in which he has participated as a director or member. The results have been included in papers published in ISI journals with a cumulative impact factor of 49 (according to JCR2017), in international conferences and in patent proposals (one issued and three other pending).

The research impact of the author can be quantified by the number of citations of his papers. According to the author's Scopus profile the total number of citations without self-citations is around 420 and the author's Hirsch index is 11, while the author's GoogleScholar profile counts more than 700 citations and a Hirsch index of 15. Moreover, the research activity of the author includes a high number of reviewed papers (more than 100) in high-quality ISI journals from IEEE and Elsevier mainly.

Among the results achieved in the last years the author would like to emphasize the most important three ones, as follows:

- "Power Decoupling Method for Single-Phase H-Bridge Inverters With No Additional Power Electronics" - Paper published as sole author in the journal IEEE Transactions on Industrial Electronics (FI=7.05), cumulating more than 60 citations;

- "Control Strategy of Three-Phase Battery Energy Storage Systems for Frequency Support in Microgrids and with Uninterrupted Supply of Local Loads" - Paper published in the journal IEEE Transactions on Power Electronics (FI=6.81), cumulating more than 120 citations;
- „Energy Storage Systems Impact on the Short-Term Frequency Stability of Distributed Autonomous Microgrids, an Analysis Using Aggregate Models" - Paper published in the journal IET Renewable and Power Generation (FI=3.48), which received the IET Award for Best Paper in IET Renewable Power Generation, issued by *The Institute of Engineering and Technology (IET)* in 2015.

Taking into account the gained experience in the approached research fields until now, the author's career development plan is focused on research topics such as:

- Control of power electronic converters for efficient integration of renewable energy sources in grids and microgrids;
- Implementation of integrated control solutions for power quality enhancement in microgrids operating islanded and grid-connected by means of power electronic interfaces;
- Development of power converters topologies optimized for specific applications in the field of renewable energy conversion;
- Protection on microgrids with high penetration level of inverter-based micro-generators.