

REVIEW

on the thesis "Energy Router for Hybrid Microgrids for efficient and robust energy and power management" of Mohammadreza Azizi, submitted for the degree of Doctor of Philosophy in specialty 141 "Electrical power engineering, electrical engineering and electromechanics"

Relevance of the chosen topic of the dissertation research.

Currently, distributed energy resources (DERs) connected to the distribution grid are experiencing a noticeable increase. These resources, mainly photovoltaic (PV) roof installations, manageable loads as electric vehicles are massively connected to the grid without an energy management strategy that guarantees the viability of the power system operation under any circumstances. In this context, the figure of the energy router is essential to provide the required energy management as well as to guarantee the support of the grid operation.

On the other hand, these DERs often operate in DC, while classical loads are still configured to operate in AC. The coexistence of both DC and AC systems in a building is nowadays an important research topic, as it poses safety and operational challenges, like the safety regarding leakage currents and grounding.

The topic selected in this thesis is, consequently, timely and valuable. A solution for an inverter that acts as an energy router and that allows to connect both AC and DC elements is presented, discussed and validated. The current state of the art justifies the topic selected.

Assessment of the validity and reliability of scientific propositions, conclusions and recommendations.

Along the thesis the proposals are justified, described and validated from a theoretical point of view as well as simulated and experimentally validated.

Simulation is performed by means of the PLECS software. This software is widely used and recommended for power electronics simulation and for control systems implementation. At this stage, a comparison has been made between the proposed control method and a conventional one, showing convincing results.

An experimental prototype has been used for validation. The experimental prototype of the proposed energy router has been developed by the candidate, whereas the distributed energy resources are emulated by means of adequately selected power sources.

The results obtained by both simulation and experimental test are convincing and prove the initial assumptions formulated in the document.

Structure and content of the Thesis.

The thesis document is organized in six chapters:

- The first chapter deals with the state of the art of power electronics applied PV installations and energy resources in buildings. The interest of DC distribution systems at this level is also discussed in this chapter.
- Chapter 2 analyzes the challenges posed by DC distribution systems, specifically related to leakage currents, grounding and isolation.
- As a result of analysis in previous chapters, in chapter 3 a novel structure for a hybrid energy router is proposed. This structure is a single-stage common-ground inverter. Its design, protection and devices are discussed in this chapter.
- Chapter 4 proposes a flatness-based control (FBC) for the inverter, analyzing its advantageous dynamics compared to classical proportional-resonant control (PR).
- Chapter 5 validates the previous proposals by means of simulation and experimental tests.
- Finally, chapter 6 deals with conclusions.

The structure of the document is consistent, as it presents hypothesis and the proposes and validates solutions. Explanations are clear and concise and figures are illustrative. The quality of presentation is also adequate.

A recommendation is provided regarding the contents: it would be interesting to add a reflection regarding future works that may emerge after this thesis.

Scientific novelty of the obtained results.

Novelties present in this thesis are summarized below:

- The topology and control of an inverter for hybrid AC-DC microgrids, acting as an energy router is developed in this thesis.
- A novel non-isolated common-ground structure is developed for AC and DC sides, and safety and leakage currents are analysed with this configuration.
- A single-cell configuration is developed even for supplying three phase AC loads. This configuration enables dynamic phase selection, contributing to grid balancing.
- The dynamics of the low-level control is improved using flatness-based theory (FBT), in comparison to conventional control techniques.

Theoretical and practical significance of the results of the dissertation research.

Research outputs obtained from this thesis could contribute to a faster and safer development of energy routers for AC and DC integration at building level. Future work may be its application to different power solutions, with other DERs and loads, to adjust control and validate its performance in different situations.

On the other hand, once a high-level energy management system is developed for this energy router, the participation of building users in power system support and in energy markets may be improved.

Therefore, the results of this thesis are on track to energy transition.

Completeness of the dissemination (publications).

The results of this PhD thesis have been published in four international conference papers, and three papers in journals indexed in Q2 Scopus. Especially relevant is the paper published in IEEE Power Electronic Magazine, as this journal usually collects reference works in power electronic topics.

The candidate is the firsts author in all of them. As a conclusion, these papers are a result of the candidate work during the development of his PhD thesis.

This reviewer considers that these publications sufficiently guarantee a reviewed quality of the thesis contents and meet formal requirements of the doctorate programs.

Academic integrity.

No violations of academic integrity or plagiarism suspicions are found in this work.

Reference to other works published in literature are clearly cited and correctly formatted.

Remarks, Limitations, and Critical Comments.

Some descriptions are included in the thesis regarding topics that finally have not been developed in this work. For example, a high-level control including cloud-computing and edge-computing is described in chapter 4. However, this description helps in providing a context for a deeper study of the energy router. Therefore, this description is considered adequate.

On the other hand, some data, as the output voltage of the PV model in simulation, are not clearly shown in the thesis. This information is useful to determine if the converter must act in boost or buck mode. The last information is clear in each case, only the numerical data is missing in the simulation section.

Final Evaluation and Assessment of the Thesis.

This thesis constitutes a complete study of a hybrid AC-DC energy router with a common-ground configuration that is considered a novel approach in the field of power electronics applied to building energy systems. This reviewer considers that the thesis contains enough novelty as scientific work.

The initial hypothesis is adequately formulated and justified according to the state of the art. The scientific method is correct, consisting in initial mathematical formulation of the problem and validation of the proposal by simulation and experimental tests. The structure of the document is clear and correct. All the references to other scientific works are properly cited. Finally, the results are convincing and contribute to meet the objectives.

On the other hand, this thesis meets the requirements for a PhD thesis and complies with regulations in doctorate programs from both universities.

As a conclusion, the author deserves to be awarded the degree of Doctor of Philosophy in Electrical Engineering.

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