

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"

1. Relevance of the chosen topic of the dissertation research

The rapid growth of renewable energy sources (RES), the increasing penetration of distributed generation (DG), and the transition toward zero-emission buildings (ZEBs) requires efficient, flexible, and reliable hybrid AC/DC power systems. The development of an energy router (ER) capable of integrated energy and power management directly addresses current challenges related to grid congestion, system efficiency, safety, and dynamic performance in modern microgrids. Therefore, the topic of the thesis under review is relevant and important.

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

The scientific statements formulated in the thesis are properly substantiated. They are based on a comprehensive review of the latest industrial solutions for integration of RES to residential buildings and thorough analysis of the related challenges, as well as well substantiated propositions of the hybrid ER based solution and its detailed verification by simulation and experimental tools.

The obtained results are reliable enough since they have been verified by the modern research methods, including electrical circuits' theory and control systems theory, analysis in time and frequency domain, simulation using MATLAB, PSIM and PLECS along with the experimental verification. All this ensured validity and reliability of scientific propositions, conclusions and recommendations.

3. Structure and content of the thesis

The thesis under review has clear structure and consists of an introduction, five technical chapters, conclusions, a reference list of 169 sources and 2 appendices. The total volume of the work is 149 pages, including 57 figures and 13 tables.

Chapter 1 reviews power electronics solutions for ZEBs and compares ER configurations and grid-connected scenarios in terms of efficiency for AC, DC, and hybrid systems.

Chapter 2 analyzes the challenges of integrating DC systems with AC grids, focusing on safety, grounding, protection, and leakage current issues, and proposes solutions based on common-ground structures.

Chapter 3 presents a single-cell three-phase ER topology based on a common-ground inverter, including its operating principles, component design, and protection mechanisms.

Chapter 4 describes the multi-level control architecture of the ER, applying flatness-based control to enhance dynamic performance and discussing alternative current control and energy management strategies.

Chapter 5 validates the proposed topology and control methods through simulation and experimental results under various operating and dynamic conditions.

The thesis is a well-structured, coherent, and complete work.

4. Scientific novelty of the obtained results

The results obtained in the thesis provide original contribution and have scientific novelty. The main points of the scientific novelty of the results are as follows:

1) A new topology of the energy router based on the single-cell three-phase concept has been proposed which allows reducing phase imbalance and improving size and costs parameters.

2) A novel non-isolated hybrid structure of the energy router with common ground for AC and DC sides has been proposed and analyzed eliminating leakage current and ensuring safety.

3) A novel energy router control approach has been developed based on the multi-level control architecture using flatness-based control which allows enhancing the dynamic performance of the system.

5. Theoretical and practical significance of the research results

The thesis under review has theoretical significance since this work advances the theory of hybrid AC/DC microgrids by developing and analytically substantiating a non-isolated single-cell three-phase energy router topology and a flatness-based control approach that enhance system safety, dynamic performance, and controllability.

The obtained results have the practical value providing engineering solutions for the design and implementation of efficient, cost-effective, and robust energy routers for zero-emission buildings and hybrid microgrids, validated through simulation and experimental studies under dynamic operating conditions.

The developed calculation methodologies for selecting and sizing passive elements offer practical value as reusable design tools that can be directly applied in the development and optimization of other power electronic converters and hybrid AC/DC energy systems.

6. Completeness of the dissemination

The research results of the thesis have been sufficiently and systematically published in reputable international journals and conference proceedings. Thus, PhD applicant is the author/co-author of 7 scientific publications, including 4 IEEE international conference papers and 3 journal articles indexed in Scopus (Q1/Q2).

The publications cover all key aspects of the thesis. The content of these publications is fully consistent with the thesis, reflects its scientific novelty, and confirms the adequate dissemination of the obtained results within the international scientific community.

7. Academic integrity

The dissertation complies with the norms and principles of academic integrity and copyright.

Neither violations of these norms, nor academic plagiarism have been identified.

The thesis contains the references to other relevant works published which are clearly cited and correctly formatted.

8. Remarks, limitations, and critical comments

1) The proposed single-cell three-phase energy router enables dynamic phase selection and reduced hardware complexity, however, as simultaneous power exchange with all three phases is not possible, further discussion is desirable regarding potential instantaneous phase imbalance and neutral conductor stress under highly asymmetric loading conditions.

2) The flatness-based control (FBC) demonstrates good dynamic performance for DC-link voltage regulation, yet its reliance on an accurate system model raises questions about robustness under parameter uncertainties such as DC-link capacitance aging, component tolerances, and time-varying load characteristics.

3) While the thesis thoroughly analyzes grounding and leakage current mechanisms, the experimental validation is performed on a laboratory-scale prototype; additional discussion on scalability and compliance with emerging LVDC standards would strengthen the practical applicability of the proposed solutions.

4) The comparison between FBC and PR control for grid current regulation shows higher THD when FBC is applied to the current loop. This limitation suggests that hybrid or adaptive control structures could be explored to combine fast dynamics with improved harmonic performance.

5) The high-level energy management system (EMS) concept based on cloud and edge computing is presented at a conceptual level. Future work could include quantitative evaluation of communication delays, cybersecurity considerations, and their impact on system stability.

These remarks do not diminish the scientific value of the dissertation and may be considered as directions for further research, while the overall assessment of the thesis remains highly positive.

9. Final evaluation and assessment of the thesis

The PhD thesis of Mohammadreza Azizi entitled “*Energy Router for Hybrid Microgrids for Efficient and Robust Energy and Power Management*” is a well-structured and complete work that contains original contributions and reliable results. These results have been sufficiently disseminated and demonstrate scientific novelty as well as practical value. The research conducted within the framework of the thesis fully corresponds to the subject area of specialty 141 “*Electrical Power Engineering, Electrical Engineering and Electromechanics*”.

Considering the abovementioned, I conclude that the PhD thesis under review meets the established requirements, and therefore I recommend that Mohammadreza Azizi be awarded the degree of Doctor of Philosophy in specialty 141 “*Electrical Power Engineering, Electrical Engineering and Electromechanics*”.

Dr. Serhii Stepenko

Senior Researcher, Associate Professor

Department of Electrical Engineering, Information and Measurement Technologies
Chernihiv Polytechnic National University, Chernihiv, Ukraine



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