

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Fernando Davalos Hernandez

PhD Program: Engineering Systems

Title of Thesis: Supercapacitor Energy Storage System based on Modular Multilevel Converter with embedded self-balance control

Supervisor: Associate Professor Federico Martin Ibanez

Name of the Reviewer: Dr. Henni Ouerdane, Associate Professor

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	Date: 15-08-2023
--	-------------------------

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- **Brief evaluation of the thesis quality and overall structure of the dissertation**

The doctoral thesis manuscript is composed of 5 chapters, including the Introduction and Conclusion over 100 pages. The thesis contains more than 50 figures illustrating some statements and showing block diagrams and numerical results. The list of references is fine and covers a sufficient number of relevant works that help substantiate the points made in the thesis. The literature review chapter in particular provides an interesting and useful overview of the thesis' research field. The proposed approach to the problem stated in the Introduction is presented in Chapter 3, and Chapter 4 provides experimental results and the validation of the results of the preceding chapter. The main criticism concerns the writing style that shows that the writing was somehow rushed, which lowers the overall quality of the thesis that otherwise contains good scientific and engineering works.

- **The relevance of the topic of dissertation work to its actual content**

The topic of the dissertation is of obvious relevance to the timely problem of integration of energy storage systems (ESS) to further enhance the stability and flexibility of modern power grids that include an increasing share of intermittent renewable sources. This is well illustrated by the literature view (Chapter 2) but also shown by the experimental validation (Chapter 4) of the proposed approach (Chapter 3). The ESS technology considered in the doctoral work involves supercapacitors combined with modular multilevel converters, which are traditionally used for high-voltage applications.

- **The relevance of the methods used in the dissertation**

The goal of the doctoral work reported in the thesis is to design, assemble, and study a supercapacitor energy storage system based on a modular multilevel converter with embedded self-balance control. For that purpose, a series of submodules (here DC-DC converters) is used to perform DC-DC and DC-AC conversion. In that way, the whole system can be simplified compared to that shown in the block diagram, Fig. 7, showing a typical ESS with all the stages. Concretely, an objective is to integrate one or several supercapacitors in each submodule. Chapter 3 discusses the design of the modular multilevel converter and the selection of components. A series of numerical simulation is performed to gain insight into the proposed system and facilitate the manufacturing of a prototype so that the approach underpinning the doctoral can be validated with an appropriate experimental study. Interestingly, it is found that increasing the number of submodules does not increase the complexity of the main controller which here only manages the power flow between the supercapacitors and the grid, but not the balancing (done in each submodule). The methods used thus are quite relevant for the studied problem and this concretely shows in the results.

- **The scientific significance of the results obtained and their compliance with the international level and current state of the art**

The significance of the obtained results is demonstrated as they contribute solutions to timely problems in the field of power systems; further their publication in reputable peer-reviewed international journals and presentation at international conferences.

- **The relevance of the obtained results to applications (if applicable)**

There is good potential for application of the results presented in the thesis considering the need of innovative solutions for energy storage systems for low-voltage applications such as AC microgrids. The thesis has shown that challenges like controller complexity and efficiency if modular multilevel controllers are used can be managed. If done successfully with more work, the potential is interesting given the increasing penetration of the so-called renewables to power residential and industrial loads.

- **The quality of publications**

The work reported in the thesis is the basis of 4 scientific publications where the candidate is first author: two articles published in Q1 and Q2 journals in the energy engineering and power technology fields, plus two conference proceedings of works presented at two Scopus-indexed international conferences. These publications start being cited, which means that the community has an interest in the work and the results produced in the frame of the doctoral studies.

The summary of issues to be addressed before/during the thesis defense

From the scientific viewpoint, I do not have particular issues to point out to be addressed before the defense. However, I ask that the manuscript is improved. At present it looks like the writing has been rushed with not enough care and attention to details.

Work is needed to polish the thesis manuscript. The following is a non-exhaustive short list of revisions to do to improve the manuscript:

- IRINA in the caption of Fig.1, page 14, should be corrected: IRENA.
- The page number of publication 4 listed page 5 should be given for proper reference.
- Given the number of abbreviations used throughout the thesis manuscript, a nomenclature would be useful as a reference.
- Chapters should be separated and not follow each other like sections of a paper.
- “Low-voltage” is mentioned throughout the text, but to what range this applies, is never explicitly stated.
- I also strongly advise that the whole thesis manuscript is proofread after the revisions.

Provisional Recommendation

I recommend that the candidate should defend the thesis by means of a formal thesis defense

I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report

The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense