Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Mikhail Pugach

PhD Program: Engineering Systems

Title of Thesis: Vanadium Redox Flow Batteries modeling and performance analysis

Supervisor: Assistant Professor Aldo Bischi

Name of the Reviewer:

	Signature:
I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	13-10-2020 **Date: DD-MM-YYYY**

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 relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

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

In general, the thesis is very interesting and it can be accepted. It has many applications and it will improve the current knowledge of the redox flow batteries. In my opinion the topic is very relevant and the method is interesting, the publications confirm that.

However, I miss some detail information in a more comprehensive manner particularly for the model in Section III. Figures and simple diagrams help a lot to understand models, and in this thesis I think that some new figures can be added for showing the crossover effects, the three mechanisms, showing the models, and explaining the variables. I noticed that through the thesis figures are rarely explained and detailed in the text. Finally, I can mention that captions in the figures have the same format and font than the main text and this induces misunderstandings.

I would like to add that even if there is a glossary about the nomenclature in the beginning. It would help the readers to add closer to the main expressions what is each variable. There are many variables and it becomes tedious to follow the expressions by checking the glossary each time. In the beginning of the chapter III it will be good to somehow explain the variables of the model.

Furthermore, in the figures, there are too many acronyms which make difficult to follow the text and ideas.

Finally, some comments that can improve the manuscript:

1. Section 2.2 is poor in references, as there are many types ESS. It will be good to have at least one reference of each technology.
2. In pag. 34, FC means fuel cell right? Try to avoid acronims if there are not really necessary.
3. In Section 2.3 could you please clarify what is smoothing instability?
4. In pag. 38, CAES and PHS have a short response time or a slow response?
5. In pag. 38, what is the relation with the toxicity of the batteries and the first and second boundaries?
6. Pag. 47, try to be accurate "several V" sounds too vague.
7. Pag. 50, eq. number please put it in the correct place.
8. Fig. 15, PCS is what? Avoid acronyms when is possible
9. In pag. 57, empirical models , could you add some references?
10. Pag. 60, technics or techniques? Tool or tools?
11. Pag. 60 When the first numerical dynamic zero model was developd? Add please some dates.
12. Also in pag. 61, it will be good to know the progress chronologically
13. Eq. (4) please explain +/- signs, in general equations are not well explained and detailed try to be explain the concepts clear.
14. Pag. 65, in general I would avoid the term "a bit" for example you can say slightly smaller…
15. Pag. 65, the model is difficult to follow as the variables are not mentioned in the text only in the glossary, an analysis of each term can be useful. Also eq (15) – (17)
16. Pag. 68, you can explain what is lambda.
17. Pag. 68 please mention what is Ved
18. Pag. 70, probably if you give some range for alpha and beta it will help and some values for Ilim
19. Pag. 71 you define SOC, but it was mentioned before
20. Pag. 72 typo error They can also….
21. In Section 3.7, experimental results, I miss some pictures of the test bench
22. Fig. 29, Q3, Q2, Q1 are not clear
23. Pag. 80 typo witch
24. In (33) it is beta or gamma, the text talks about beta and in (33) is gamma

25. I would appreaciate a better explanation about Fig. 26.
26. Last paragraph of 99 is confusing, where re the cycles?
27. In (34) j is what? Current? Or the number of cell? It is confusing

28. Pag. 100 is important for understanding the crossover effect. It will be good if you can clarify the concepts using figures.
29. The coulobic efficiency is around 88% and 70%) for VRFB what is in other technologies?
30. It seems like Pag. 115 was written before
31. First paragraph pag. 117 is not clear.
32. Acronyms NS PR and ST can be avoided
33. Fig. 40 Can you normalize the curves somehow?
34. Section 4.7, can you explain why the crossover presents an asymmetric behavior?
35. Section 5.1, the current is determined by an inverter if the battery is connected to a AC grid using just an inverter. In general it will be the power electronic converter which can be a combination of DC/AC and DC/DC convetters.
36. Section 5.1 probably a is needed to clarifiy the ideas.
37. Section 5.1 About damping and oscillations in 2nd paragraph, please add some references
38. Again you mention many control methods, some diargrams will help to understand the differences
39. In pag. 128, why a PI controller requires such a significant computational power?
40. In pag 140, you define VE and EE but I saw the same efficiency before in the text.
41. Can you highlight the important numbers in table 9, can you explain it in the text?
42. Pag. 151, "our paper" or this thesis?

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*