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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Timur Saifutdinov

PhD Program: Engineering systems

Title of Thesis: Optimal Siting, Sizing and Technology Selection of Energy Storage Systems for Power System Applications

Supervisor: Prof. Janusz Bialek

Co-advisor:

Chair of PhD defense Jury: Prof. Alexei Buchachenko ***Email:*** *a.buchachenko@skoltech.ru*

Date of Thesis Defense: March 10, 2020

Name of the Reviewer: Prof. Alexei Buchachenko

X I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: Feb 12, 2020**

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

The Thesis submitted by Timur Saifutdinov addresses the problem of optimal usage of electric energy storage facilities within the power systems. One can hardly regard this problem as novel in general, but it remains to be hot, as flexible and reliable energy storage technologies are currently developed much faster and cost-effective than existing power system infrastructure. Proper incorporation of energy storages in existing networks certainly offers huge economic and environmental benefits, but the way to forecast and maximize them is not known in general.

To provide an optimal choice of the Li-ion energy storage facilities, their parameters and location within a network, the Thesis advances one of the most general approach of convex model optimization. The principle novelty is the development of the model that accurately accounts for the degradation of storage facilities. Instead of introducing phenomenological dependence for capacity fade, proposed model describes the performance of a storage facility as a function of its operational history, i.e., rate, number and depth of charge/discharge cycles, heat balance, ambient conditions, etc. To my viewpoint, this feature not only makes the proposed model more accurate and reliable than those available in literature, but may also lead to more detailed formulation of the demands for storage devices from the customer's side. Degradation remains one of the major challenge in the development of Li-ion storage technologies and precise knowledge on customer's needs and underpinning economy may well compromise the choice of storage device materials and architecture.

This important novel component came without simplifications of other aspects of network function. Not being an expert in optimization techniques, I can only say that the steps made to formulate the final model are either well established or well justified. Whenever the variables bear the dependence on operational prehistory, which cannot meet the convex requirement, they are discretized on the grid of integers. The price to pay is to deal with poorly scalable mixed problem. Advanced approaches implemented to cope with scalability issue have solid justification and support in literature. Overall, the results of the case study are impressive. They provide a unique choice of the number, location, type and parameters of the storage devices to be installed to meet the growing energy demands with high cost efficiency. The reliability of the solution found is well assessed by comparison with alternative approaches and qualitative analysis. This leaves no doubts in the accuracy of the proposed model and techniques used for numerical solution. In addition, the main results of the work are published in the most relevant professional journals and their peer reviews are respectful.

The Thesis is very well written and provides clear and deep insight in the problem to a non-specialist. Though the literature review occupying almost half of the essential text may appear excessive, the reading confirms it as fully appropriate and worthwhile. First, it brings together and classifies potential benefits from using storage devices from the viewpoint of power network planning and operation. The range of applications is superimposed by the variety of available storage technologies, with advantages and drawbacks pertinent to each of them. To a certain extent, the review covers common-sense principles of optimum usage of energy storage and identifies important details that can be considered only within mathematically advanced optimization. Second, the review introduces the models and equations, which are then used in

the main part for problem formulation without additional explanation. Third, the review clearly emphasizes the novelty of the research and the author's contribution to the field. Good language makes the reading as pleasant as instructive.

I am very pleased to see, at the end, the section "Fulfillment of Research Objectives". The mismatch between proclaimed slogans and practical outcome, though understandable, happens frequently. Transparent explanation how and to what extent the proposed goals are achieved deserves the best respects. Partial concluding sections or paragraph at each part is also a good style helping the assessment.

To my opinion, the Thesis presented by Timur Saifutdinov is a comprehensive and self-contained work that clearly states the problem, identifies new concepts required for its solution, develops solution methodology and proves its validity, as well as points out potential applications. It certainly complies with all requirements to PhD Thesis set at Skoltech. PhD qualification of the author is out of question.

Saying that, I would like to make some comments.

1. The flexibility of the power system is an important requirement and storage systems can greatly enhance it. It would be instructive to comment to what extent this aspect is (or can be) considered within the proposed model.

2. Experience with convex optimization models in the field is likely enormous. Are there bright examples or common understanding that simplifications in functions and constrains maintain the global minimum of the full non-convex model?

3. Discussing the convergence of ADMM algorithms, the author refers to previous experience. Are the direct tests for few-bus systems possible? To the same point. It is mentioned that decomposition to subproblems allows one to consider each separately. Does the author expect great benefits from parallel computing?

4. Formulating the problem on p.98, the author comments that reward is usually predetermined by the policies. It somehow contradicts the previous material, which exposes various benefits from energy storage. Indeed, considering the case study in Section 4 (p.116), the author introduces quite sophisticated reward term that depends on system variables.

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*