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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Vladimir Frolov

PhD Program: Engineering Systems

Title of Thesis: Operational and uncertainty aware planning of power systems

Supervisor: Professor Michael Chertkov

Name of the Reviewer:

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 27-05-2021**

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

This dissertation consists of the introduction, six research sections organized in two parts, conclusion, and appendix. The introduction provides a meaningful description of the underlying motivation, clearly outlines intended contributions, and lists published work.

The first part, which includes four sections, focuses on methods for siting/sizing various FACTS units in transmission grids with different power flow formulations, ultimately representing ac power flow physics in a sufficiently accurate manner, and with different uncertainty modeling assumptions (including deterministic ones; more on that is also reported in part two). Additionally, this part considers operational decisions (dispatch of all assets, including FACTS) under different uncertainty modeling assumptions and internalizes these operational constraints into the proposed siting/sizing optimization. Finally, the resulting siting/sizing optimization is modified to account for multi-stage investments. As model's complexity progresses, so does the dimensionality of the case study and it is commendable that the results are eventually called to the 2736-bus Polish model. The second part, which includes two sections, extends the models developed in the first part to accommodate operational uncertainty using so-called "cloud" approach, which is a non-parametric form of representing empirical/historical observations available to decision makers. The conclusion section

adequately summarizes the scope of this dissertation and provides an adequate overview relative to the claimed contributions.

The topic of this dissertation is at the heart of the core challenges faced by the industry in Russia, as well as in some other places in Europe, which is well outlined in the motivation of this dissertation. The claimed contributions are also motivated as relevant for everyday practice, and are discussed below:

- This dissertation makes it possible to account for operational uncertainty while optimizing long-term capital investments, while considering delicate and non-trivial CAPEX and OPEX trade-offs
- An important modeling accomplishment of this dissertation is a demonstration that ac power flow physics can be internalized in siting/sizing routines, and that the resulting optimization is scalable
- The developed solution technique/algorithm is of great relevance as it allows to scale computations from artificial to realistically scaled network instances (e.g., Polish model). It is also noteworthy that the developed models and algorithms are benchmarked against off-the-shelf solvers to show their relative accuracy
- The proposed "cloud" representation is novel, intuitive (which is important for technology adoption) and is shown to work well via detailed and accurate computer aided simulations. I also acknowledge the importance and significance of the model reduction section, which is enabled by this "cloud" representation
- The dissertation also describes novel web-based visualization tools that are of great interest to both academia and industry as it reduces complexity of multi-faceted uncertainty and decision layers and facilitates their intuitive understanding

Overall, the results obtained in this dissertation are significant to both academia and industry, and may lead to successful commercialization in russia, if the system operator is willing to adopt changes to the current practice in a gradual manner.

The results reported in this dissertation are published four conference and one journal publication, and one more publication is still under review. The journal publication is in an IEEE Transaction, which is the top destination for any inspiring Ph.D. student, and conference publications also appear in competitive venues. Taken together, these publications are comparable to the output expected in other research groups and international universities (as to the best of my knowledge).

The overall review of this dissertation does not reveal any major issue that must be addressed before the defense, except for a few relative minor suggestions:

- Please proofread the document to remove typos and be consistent with punctuation (e.g., Oxford comma)
- It is noteworthy to clarify that the term "cloud", which is used extensively, refers to a set of points/scenarios rather than to cloud computing.

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*