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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: Göran Andersson

I confirm the absence of any conflict of interest	**Date:** 28-05-2021

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

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

Summary of the thesis

How to take uncertainty and variability of different quantities into account in power system planning and operation has been a concern since the first systems were designed and put into operation. Different methods to address the issue have been developed and implemented over the years, some based on heuristics and some on rather simple simulations approaches. Due to the significant advances in optimization techniques and computing capacity during the last decades, more realistic models and advanced approaches have been proposed and full scale systems can be studied using realistic computational efforts and within acceptable time frames. The thesis of Vladimir Frolov is a contribution to this increasingly important field of research and some new interesting and potentially useful methods and results are presented.

The dissertation consists of two thematic parts. In the first part, the candidate develops a framework for operational and uncertainty aware planning for mid- and long-term using a stochastic approach, where the operational diversity is modelled by a set of deterministic samples. The overall goal is to optimally place and size FACTS devices considering capital and operational costs together with future uncertainties and conditions. The candidate extends the system models from DC to AC power flow so that both Series Compensation and Static Var Compensators can be considered. A key contribution in this part is the scenario sampling method for incorporation of future uncertainties. In order to get a tractable problem a number of approximations are done. The approach is demonstrated on realisc power systems, i.e. IEEE 30-bus and Polish 2736-bus systems.

In the second part the uncertainties are represented by probabilistic representation of the operational conditions. Here the candidate proposes and develops a method that is a modification and extension of Chance Constraint Optimal Power Flow, that has been used for similar applications in recent years. By model reduction a so called Cloud-AC-OPF is obtained, which represents a collection of samples by their mean and standard deviation. Finally, a Multi-Stage Multi-Scenario AC-OPF is formulated and the method is demonstrated in case studies.

In a final chapter, the dissertation is summarized and conclusions are given together with recommendations for further research. In an appendix, details of the mathematics and other technical information used in the derivation of the models and methods of the thesis are summarized.

Evaluation of the thesis

The thesis is well written and structured, and generally easy to follow. Assumptions are well described and motivated, and the introduced simplifications well argued. The candidate shows that he masters the mathematical methods and tools used.

The topic is of high international interest and the results of the thesis will be a valuable contribution to state-of-the-art. The findings of the thesis will be of interest to the research community.

Since the developed methods have been applied to realistic power systems, the candidate has demonstrated that they can be applied in practice and can thus, in principle, be used by grid companies in actual planning. (It should be mentioned that the software developed by the candidate should be regarded as research tool, and before the methods can be applied in real life they must modified and extended. This is usually the case for software developed in research projects.)

The work has resulted in six publications with the candidate as the first author. Of these, three are published in established journals with rigorous peer review and two presented at conferences with peer review. One publication is about to be submitted for publication. This can be regarded as an adequate publication record for a PhD thesis.

In summary: The scientific level of the thesis compares to what is required for PhD theses at good universities internationally. It has been shown that the candidate masters the mathematical tools and methods needed to tackle complex power system problems and that he is capable of formulating optimization problems that correspond to current real problems in power systems. Also, the thesis is well written and in general easy to follow. A reasonable number of publications have been written and published in good journals or presented at quality conferences.

Recommendation

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

Suggestions for improvement

To enhance the readability of the thesis and to further improve the value of the dissertation I suggest the following:

1. Some acronyms and abbreviations are used without any explanations, therefore a list with definitions of the abbreviations and acronyms in the thesis should be included, e.g. as a new section in the Appendix.

2. A summary of the conclusions is given in the thesis, but it would be helpful for the reader to also have a short summary of the main results and conclusions at the end of each individual chapter.

3. Mid-term and long-term planning is mentioned at several places in the thesis. There is no formal definition of these terms, e.g. with regard to time horizon, so it would be of value if it were defined what is meant in this thesis.

4. The word “market” occurs only twice in the thesis. Since energy and power markets, and also other markets, are integrated parts of modern power systems, a discussion of how these are considered in the developed framework is recommended to be included.

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*