

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Oleg Khamisov

PhD Program: Engineering systems

Title of Thesis: Optimization of Frequency Control in Power Systems

Supervisor: Assistant prof. Anatoly Dymarsky

Co-advisor: Prof. Janusz Bialek

Date of Thesis Defense:

Name of the Reviewer: David Pozo

I confirm the absence of any conflict of interest

(Alternatively, Reviewer can formulate a possible conflict)

Signature:



Date: 05-03-2020

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

Brief evaluation of the thesis quality and overall structure of the dissertation.

The doctoral thesis *Optimization of Frequency Control in Power Systems* by the student *Oleg Khamisov* addresses the problem of frequency control and congestion management. In this thesis, a new control scheme is proposed that performs frequency control, congestion management, and inter-area flows control in a distributed way. The new control scheme is proved to be a global asymptotic stable. Several numerical experiments back the theoretical proposal showing better transient dynamics. The thesis is composed of 16 chapters. The thesis has a significant theoretical component. But it is also supported by illustrative examples and numerical experiments (chapter 14).

The overall thesis is well structured, and it has a coherent storyline. The contributions to the field are relevant. The quality of the thesis is sound. The outcomes are extensively discussed, supporting this dissertation with merits for the aim and purpose of the present thesis manuscript. There are minor issues that should be clarified in the final version of the thesis manuscript. They are listed below.

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

Power systems need to be always balancing. Although energy storage is available, they are not usually integrated into power systems. Thus, it is necessary to balance supply with demand in real-time. They can understand as a "flow problem over networks" problem, but unlike other networks, controllability over the flow-through edges (lines) of the networks is limited due to the second Kirchhoff law, i.e., a physic-based constrain. It makes that control of power systems a challenging problem. Despite having running power systems for over a century, the current control practices implemented in the industry have some limitations, e.g., the need for n-k security criteria. But, most importantly is the next generation of power systems need for new forms of control algorithms for dealing with a significant increase of stochastic generation and for harnessing the potential of ancillary service provision from the demand side. This thesis is framed in the new control paradigms needed for the next generation of power systems.

The relevance of the methods used in the dissertation

The methods used in this thesis lies in the interface of power system modeling, control theory, and optimization. The methods are adequate for the problem addressed in this thesis. Some critical issues have been highlighted over the manuscript that supports the novelty and significance of the proposed control algorithms. Shortcomings of the present are also raised and discussed.

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

The proposed frequency control methods by the student are novel with regard to the current state of the art on frequency control. A key element of his work is the derivation of a global asymptotically stable control to a desired power system state at a minimal cost. Although there are previous works on the topic of frequency control and congestion management, this doctoral thesis genuinely overcomes some limitations of the existing works.

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

The results obtained are relevant not only for academia but also for practitioners in power systems. A complete chapter is dedicated to the discussion of results endorsing the contributions collected within the scope of this thesis. The applicability has solid bases on control theory, and mathematical programming and new formulations and models result in high applicability for other researchers.

The quality of publications

The student has six publications directed related to his thesis (three of them as a solo author and the other three as the first author). The student has also presented his work in top-tier conferences related to his Ph.D. topic. The quality of the publications is backup by the reputation of the proceedings and journals on the fields of power systems and mathematical programming. Besides, he has delivered in six occasions seminars at the Russian Academy of Science.

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

The thesis has presented in a comprehensive way, highlighting not only the value of the proposed control methods but also the limitations. There is a dedicated chapter for discussion about the future line of research to overcome the boundaries of the current work. I think this thesis is excellent and does not need significant changes. I believe that it could be the base for other future research works. I have only minor issues that should be addressed before the defense.

- a) Page 14. It is mentioned, " *2016 averaged amount of available but not used wind power in Ireland is equal to 227 GW*". Please review the units. It seems to be more than the wind installed capacity in Ireland.
- b) Eq. 10.1. The summation symbol does not need superscript "n."
- c) Page 32. "the last 4 problems" should be replaced by "The last 4 problems"
- d) Page 65. Could you clarify what is the meaning of "workability of buses"?
- e) Table 7.1. Replace "bu" by "bus"
- f) Equation 7.10h. Should it be multiplied by α_i^k ?
- g) Equation 7.6, right-hand side. Shouldn't be N-x instead of x?
- h) Page 39. Replace " P_Q is reactive power" by " Q_G is reactive power".

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