Skoltech
Skolkovo Institute of Science and Technology

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: 02 April 2020

Name of the Reviewer: Elena Gryazina

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: 23-03-2020**

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

The thesis provides a detailed study of frequency control in power systems and contributed novel original algorithms to the problem. Besides, the proposed algorithms can be applied in the distributed manner that makes them highly attractive for modern power systems.

The structure of the thesis seems excessive. Some of the chapters (sections), namely, 2,3,4,5 could be the part of Introduction, the others – 8, 10, 15 – are too small for independent chapters. The chapter 14 is devoted for the numerical experiments while numerical test are reported subsections 12.4 and 13.5 in as well. Unfortunately, the detailed discussion of the numerical experiments is missing. The topic and the title of the thesis is relevant to its actual content.

The existing approaches to the frequency control can be separated into two main groups: controls based on the averaging approach and control based on the primal-dual optimization algorithm. The thesis presents a new approach based on the idea of separation of control and physical system dynamics as much as possible. There are several inventions on the way, in particular, measurements of bus frequencies and electrical powers are used to obtain an approximation of the disturbance. Specific attention is payed to the choice of power system model when linearized power flow equations were used together with rather detailed dynamics of the generator including response of governor valve to the control signal and energy carrier dynamics in turbine.

The described research is performed at high international level and is consistent with current state-of-the-art in the area of power systems control.

Speaking about the relevance to applications, it's hard to judge at the current state. Power systems give an example of rather conservative industry. The control protocols that Independent System Operators (ISO) follow in their daily routine for frequency control are mainly based on the methodology developed decades ago. But these days we witness significant change the whole paradigm and this thesis give an excellent of novel methodology with complete theoretical validation. Many steps towards real-life implementation of the described results are needed and the candidate clearly understands it as some of these steps are mentioned in Chapter 15.

The results are published in several conference proceeding including one journal paper. The most valuable publication is in IEEE Conference on Decision and Control – the most reputable conference in control sciences with very low (highly competitive) acceptance rate.

Comments on typos and some specific questions:

There are many typos in the text. Here is the list of typos noticed but I assume there are much more:
p. 31 line 2. Allows us instead of «as»
p. 31 point is missing at the end of the section.
p. 32 line 2 we discuss instead of «in»
p. 32 line 8. Capital letter is missing
p. 32 line 10. In order instead of «on»
p. 50 line 5. Systems sufferS («s» is missing)
p. 76 parentheses are missing when referring equations (9.8) and (9.6)
p. 95 line 6 in the word «either»
p. 95 line 15 proof instead of «prove»
p. 95 line 18 in the word «inter-area»
p. 114 last three lines - proof instead of «prove»
p. 124 The function (13.7) is Lagrange function for optimization problem (13.5), not Lyapunov.
p. 139 line 6, 8 in the word «inter-area»
p. 159 the first word is probably «there»

Other specific questions:

1. What do you mean by «nonlinear DC power flows» used in numerical simulations (Chapter 9, p. 72)?
2. Theorem 12.3 (p. 102) requires a certain inequality for the parameters that are not defined before. It would be better to state the theorem in such a way that the introduced inequality sound self-explained at system level. Parameters t^g, t^m are introduced in p. 75 that is pretty far from the theorem statement.
3. Problem statement at p. 106 «Main difference is in the presence of the vector ζ». What does it mean when I can't find any ζ by the end of the subsection 12.2?
4. Figure 12.5 repeats the figure 7.5 with the only difference that the power outage is in Russian in Fig. 12.5.

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*