Review of doctoral thesis

made on request of the Chairman of the Automation, Electronics and Electrical Engineering Discipline Council of the Wroclaw University of Science and Technology in accordance with the resolution of the Council of 19/04/2021.

Student: **Vishnu Suresh**

Title: **Microgrid energy management systems with hybrid optimizers, embedded deep learning forecasters and e-vehicle charging stations**

Supervisor: **dr hab. inż. Przemysław Janik**

Co – supervisor: **dr inż. Zbigniew Wacławek**

1. General characterization of doctoral thesis

Reviewed doctoral thesis deals with microgrid energy management systems with focus on forecasting models and optimization. Submitted work consists of 117 pages and is divided into five chapters plus summary and appendix. Objectives of doctoral thesis are vaguely defined at the beginning.

Chapter 1 describes the main terms. Introduces the microgrid concept and provides the literature review behind the existing methods for optimization and forecasting relate to electrical power systems.

Chapter 2 propose forecasting alternatives using deep learning models and offers a comparison with the existing Auto Regressive Integrated Moving Average model.

Chapter 3 is focused on optimal power flow calculations, introduces the hybrid optimization algorithms and then makes a comparison with the existing approaches.

Chapter 4 is concentrated on evaluation and improvement of energy management based on economic dispatch of microgrids. It consist of balanced cost calculation of energy for all energy sources included in the microgrid. It is aiming for cost minimization during its operation.

Chapter 5 presents several charging scenarios for Electrical Vehicle Charging Stations and finds the best option based on which the optimal location of the EVCS is determined in the network.

Last part of the thesis summarises and make general conclusions.

2. Original parts of dissertation

I consider the most important own and original scientific achievements of the author of the dissertation are:

a) The modified algorithm for hybrid optimization that combine excellent solution search capabilities of meta-heuristic algorithms and conventional optimization algorithms.

b) The development of deep learning neural network models that perform better than conventional forecasting models for short term forecasting applications.

c) Proposed method of an Energy Management System for optimal microgrid operational management that can be used in real power system of Wroclaw University of Science and Technology.

d) New approach of an optimal operation of the Electrical Vehicle Charging Stations is introduced including the consumer and also the power system needs. Its functionality was proven by finding EVCS optimal location in the microgrid.

From above I declare that procedure of solving all four issues is logical and correctly structured. Furthermore student presented original improved methods and proved their correctness by well presented results.

3. Notes and substantive questions

1. I would prefer if the thesis contain list of symbols and abbreviations. It is more convenient because there is so much abbreviations that reader could be lost.

2. Chapter 1, page 6, 1st paragraph: what is the percentage increase of installed capacity of renewable sources comparing to 2% increase of energy share?
3. Chapter 1, page 8, 2nd paragraph: what does it mean "suitable manner"?
4. Chapter 2, page 30, 4th paragraph: is there any difference in input data among 3 different types of solar PV modules during entering to forecasting models?
5. Chapter 3: What are the demands on computing power for proposed modified algorithm for hybrid optimization? For how large network is it suitable?
6. Page 56, 1st paragraph: There is only PV system from WUST in the model?
7. Chapter 4: What modifications should be done to energy management if we consider possible accumulation of water (chapter 4.1.5) for some time? I do not mean pump-storage it is more complicated. I mean simple cumulation of water when we do not need electricity for example during 1 hour peak production of PV.
8. Chapter 5.3: What is the minimum waiting time?

4. Assessment of the dissertation and final conclusion

Student deals with very actual problems of electric power system - utilizing renewable sources. Thesis is very well elaborated.

In all main chapters, student first described the needed theory and he introduced a number of possible approaches and methods which are commonly used. Then he described in detail some of them the most convenient for appropriate problematic. Finally he proposed new approach based on improved solutions described before. Achieved results are presented at the end of each main chapter.

I declare that proposed objectives from chapter 1 were fulfilled. In terms of formal side thesis is at high level.

Fulfilment of indicated objectives is contribution not only for Electrical Engineering but also for other scientific disciplines. I find very important the effort to apply new knowledge to practice.

The methodologies of its solution is logical and used techniques are complex referring to their advantages. The quality of the thesis is above average. Student introduced the original solutions and results in this thesis.

His models use data from real distribution networks. Student introduces also the direction of further research.

The doctoral thesis is logically structured and particular chapters are logically interconnected. The graphic and language level fulfils fully the doctoral thesis requirements. List of references is extensive and up to date.

On the basis of submitted thesis and author's publication activities, which are indexed in worldwide recognized databases Web of Science and Scopus, is obvious that scientific core of the thesis was published properly.

Doctoral thesis of mgr inż. Vishnu Suresh demonstrates his good theoretical knowledge and his ability to apply pieces of knowledge into professional research work. The presented doctoral thesis is very extensive and brings new original solutions to very important field of Electrical Engineering.

As a consequence of evaluation of this doctoral thesis, I declare that thesis **fulfils** the requirements of a doctoral theses and I **recommend** it for defence.

Furthermore, I would like to recommend Vishnu Suresh to be honoured with **distinction** because his achievements are outstanding. His thesis shows high level of research, the applied methods are original and that the research results has been published in recognised international journals (6 with impact factor).

Ostrava 28/06/2021

prof. Ing. Radomir Goňo, Ph.D.
Reviewer

Appendix: List of specific comments and editorial errors

As for the size of the dissertation, 117 pages in total, and the scope of the issues discussed, I noticed a few of editorial inaccuracies in the work. I am convinced that they do not affect my overall assessment of the thesis. I present below some of the noticed editorial errors and comments to the text that arise when reading the dissertation, hoping that they will contribute to the development of the author's further research. **I do not expect any answers** to the editorial comments presented below.

1. Do not use abbreviations in chapter titles.
2. Numbering of Fig., Tab. and formulas is confusing. Use gradual increase of number from beginning of thesis or add chapter number.
3. Page 7, line 8 from bottom: "...can connect and disconnect..." should be "...can be connected and disconnected..."
4. Page 12, 2nd paragraph, line 1: "...more..." should be "...the most..."
5. Chapters 1 - 3 "Figure", chapters 4 - 5 "Fig.", unify them.
6. Page 31, 2nd paragraph, line 3: "...model..." is doubled
7. Page 31, 2nd paragraph, line 5: "...algorithms is..." should be "...algorithm is..."
8. Page 34, Figure 3 is twice there.
9. Page 47, Figure 12 should be Figure 14.
10. Page 48, Figure 13 again.
11. Page 50, Figure 8?!
12. Page 90, title 4.1 rather "Power Sources"
13. Page 92, Figure 1 should be Figure 2 ...
14. Page 96, last paragraph, line 3: "...pv..." should be "...PV..."
15. Page 96, last paragraph: "in node", "of node" "at node" should be unified