

OPINION
on the acquisition of educational and scientific degree "Doctor"

Field of higher education 5. "Technical sciences", Professional direction 5.2. Electrical engineering, electronics and automation with a scientific specialty "Application of the principles and methods of cybernetics in various fields of science"

Author of the dissertation work: Master. Eng. Ekaterina Popovska, Institute of Robotics at BAS (IR-BAS)

Member of a Scientific Jury : Prof. Dr. Anna Kostadinova Lekova, Institute of Robotics at BAS

Theme of the Dissertation work: Mathematical methods for research, modeling, analysis and forecasting in energy and energy markets

1. General characteristics of the dissertation work

The set of materials presented by Ekaterina Popovska is in accordance with the Internal Regulations of IR-BAS and the Law on the Development of the Academic Staff in the Republic of Bulgaria. The structure and volume of the dissertation meet the requirements. It includes text material with a volume of 183 pages, contains an introductory section, four chapters, a conclusion and 4 Appendices. Dissertation is illustrated with 54 figures and 6 tables. The bibliographic reference consists of 139 sources. A good indicator of knowledge of the author is the logical and competent way of presentation when presenting the problems. The author explores forecasting, modeling and analysis methods in energy and energy markets, develops methods for quantifying sustainability for short-term and long-term processes, and presents results of reporting and analysis of empirical research data. The main conclusions and contributions of the dissertation are formulated, summarizing the decisions and conclusions in the four chapters. There are 6 publications related to the topic, and in 4 of them the doctoral student is the first author, which states of her personal participation in scientific research on the topic of the doctoral studies. There are 7 citations, which states for the significance of the achieved scientific and scientific-applied results.

2. Relevance and significance of the problem developed in the dissertation work

Changes in the energy sector, where the transition to competitive markets and the creation of electricity trading exchanges, imposes the need for innovation and adaptation in business strategies. These changes not only affect the production and supply of electricity, but also highlight the importance of competition, transparency and up-to-date market information in the sector. Accurate market value prediction is key to maximizing trading profits while keeping risk low. An appropriate forecasting model is needed to help traders, investors, regulators and other stakeholders analyze trends, make the most optimal

investment decisions and minimize risks in electricity trading, making them more competitive.

3. Expediency of the set goals and tasks. Knowing the problem. Results analysis.

As a result of the analysis in the first chapter, the aim of the dissertation is set - Creation of methodology and algorithms for research, analysis, modeling and forecasting of electricity market prices "Day Ahead" part of the organized stock market by using the methods of analysis of time series of data. The main tasks that have been solved to achieve the set goal are related to the development of a methodology for research and analysis of electricity prices, including appropriate methods for the analysis of both long-term and short-term data from the energy market in Bulgaria and the region. The first part of the research focuses on the analysis of real long-term data and the creation of a methodology for researching electricity exchange prices and techniques for improving energy forecasting. In the second part, a methodology was created for the study of data on electricity prices in the analysis of real short-term data on stock exchange prices of electricity. Demonstration software programs are then developed that include analysis, simulation and forecasting of electricity prices using the selected scientific methods and analysis models. Chapter 4 makes a particularly good impression with its seven takeaways, which are illustrated with 37 comparison graphs to determine the most effective simulation models for forecasting and analyzing the behavior of the studied data depending on the market fundamentals. Through a graphical analysis of the market trend, the advantage of forecasting using the SARIMA method (compared to ARIMA and LSTM models) has been proven, as the variable nature of electricity prices show seasonality. Through comparison graphs, it is illustrated that the choice of an appropriate model depends on the characteristics of the data, and the Hurst and DFA methods can be applied to the analysis of trends and noise in time series, and thus successfully used in the analysis of electricity prices.

4. Evaluation of the contributions received and their significance

I accept the formulated contributions in the dissertation, which have a scientific-applied and applied nature and are based on a correctly chosen research methodology, which allows achieving the set goal and tasks solved in the dissertation work. The research and results contribute to the expansion of existing knowledge in the field of energy market dynamics, supporting a new methodology for research, analysis and forecasting of electricity prices, based on ARIMA, SARIMA and LSTM methods, which provide optimal price forecasts in the market of electricity depending on the various input factors. Furthermore, for the first time, a methodology for research and analysis of the long-term sustainability of time series data on electricity exchange prices based on the DFA method was created. I accept the experimental studies that confirm that the DFA method is more suitable in forecasting long-term electricity price data compared to the R/S method.

5. Abstract

The abstract is made according to the requirements and correctly reflects the main results obtained in the dissertation.

6. Critical notes and recommendations

I have no significant critical remarks to the author. It would be good in the future the author to describe this research and the achieved results in a book, as they are significant in forecasting, modeling and analysis of energy markets and are a prerequisite for the optimal management of energy resources, the effective forecasting of demand and supply, as well as for the successful adaptation of business strategies in the environment of rapidly changing conditions of competitive and unregulated energy markets.

CONCLUSION

After acquainting with the dissertation work in details, I believe that it contains scientific and scientific-applied results, which are a new contribution to science and meet the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for the Implementation of this law and the relevant internal Regulations of IR-BAN. The dissertation shows that the author has a sufficiently high theoretical and scientific-technical training in the Professional direction 5.2 and demonstrates qualities and skills for conducting research with obtaining original scientific contributions.

Due to the above, I give my positive assessment of the conducted research in this dissertation work, abstract, achieved results and contributions, and **I propose to the members of the Scientific Jury to award the educational and scientific degree "Doctor" to Ekaterina Popovska in the Field of higher education 5, Professional direction 5.2. Electrical engineering, electronics and automation with a scientific specialty "Application of the principles and methods of cybernetics in various fields of science".**

Member of the Scientific Jury:

11.01.2024

(Prof. Dr. Anna Kostadinova Lekova)