

REVIEW

On a doctoral thesis

for obtaining the educational and scientific degree "doctor",
from the field of higher education – 5. Technical sciences,
professional direction – 5.2. Electrical engineering, electronics and automation,
doctoral program – Supply of electricity and electrical equipment

Author: MSc. Eng. Elizabeta Trajko Arsova

Topic: Analysis of the possibilities for the implementation of new photovoltaic power plants in the electricity system of the Republic of North Macedonia.

Reviewer: professor Dipl. Eng. Ivailo Stefanov Stojanov PhD, University „Angel Kamchev” in Ruse

The presented review is according to Protocol №1 of a correspondence meeting of the scientific jury committee, compiled on the basis of an order of the Rector of the Technical University - Gabrovo № 3-01-72/22.02.2024 for the evaluation of a dissertation for the acquisition of an educational and scientific degree " doctor" on the topic "Analysis of the possibilities for the implementation of new photovoltaic power plants in the electricity system of the Republic of North Macedonia", prepared by MSc. Eng. Elizabeta Trajko Arsova.

Elizabeta Arsova graduated from the University of Ss. Cyril and Methodius, in the city of Skopje, Republic of North Macedonia. It was registered according to Order no. № 3-01-489/09.11.2022 at the Technical University in Gabrovo in the independent form of doctoral studies in the doctoral program of Electricity Supply and Electrical Equipment. Her academic supervisor is Associate Professor Dr. Eng. Plamen Tsenkov Tsankov. The training was conducted according to an approved individual study plan. In accordance with it, the doctoral student passed the exams with the following grades:

- after professional exam (Order № 3-01-60/13.02.2023) – Excellent (5.50);
- in English (Order № 3-01-138/27.03.2023) – Very good (5.00).

I highly appreciate her desire to continuously upgrade her qualifications during her work at AD EMO - Design Institute Ohrid and AD ESM Macedonia - Skopje branch by participating in development projects for uninterrupted power supply and designing new power supply facilities based on renewable sources of energy. Since 2011, she has been working in the Energy Regulatory Commission of the Republic of North Macedonia as an advisor in the Technical Energy Sector for electricity, and since 2019 she has been its head. She participated in working groups in the

preparation of a large number of normative documents for the needs of the Republic of North Macedonia and in the work of work forums, seminars, etc. specialized events organized by USAID, World Bank, ERRRA, etc.

I think that MSc. Eng. Elizabeta Arsova's preparation of the doctoral program was realized in accordance with the valid normative documents in the country and at the Technical University - Gabrovo.

The dissertation work is developed in the volume of 172 pages, structured in introduction, 5 chapters, conclusion, appendices, publications and used literature. The dissertation is richly illustrated with 100 pictures, 29 tables and 4 appendices, which present data on the economic justification of the proposed technical solutions for connecting powerful photovoltaic power plants to the electricity system of the Republic of North Macedonia.

1. Topic and topicality of the dissertation

Traditional electricity production with conventional energy sources is one of the biggest sources of industrial air pollution. This has a negative impact on the climate, soils and waters, as well as on the quality of life of people. The data on the continuous global warming made the world community to reconsider the way of exploitation of natural resources and to look for new sources of energy that do not pollute and save the environment. In response to these trends, governments and institutions in their management programs envisage a continuous increase in the share of energy obtained from renewable energy sources. The main goal is to reduce the emission of greenhouse gases into the atmosphere, to protect the Earth's limited supply of fossil fuels, to prevent the problem of pollution and fuel waste disposal, and to improve the environment and people's quality of life. Therefore, tasks related to renewable energy methods, approaches and technologies are particularly relevant and correspond to EU goals and strategies, energy taxation, emissions trading, etc., which largely answers the questions of the current dissertation work.

The peer-reviewed dissertation studies specific scientific and scientifically applied problems in the use of photovoltaic power plants and their impact on the electrical mix of the Republic of North Macedonia. The PhD student performed simulations of the operation of two high-power photovoltaic plants with different types of photovoltaic panels by type and power and under different operating conditions. In this case, a large number of scientific and technological tasks arise, some of which are solved in this dissertation. To solve these tasks MSc. Eng. Elizabeta Arsova demonstrated excellent theoretical and practical knowledge and skills for working with specialized software products.

All this gives me reason to assume that the topic of the current dissertation, the problem of assessing the possibilities for the implementation of new powerful photovoltaic power plants in the electric power system of the Republic of North Macedonia, is particularly relevant from a scientific and scientific-practical point of view.

2. Review of Cited Literature

In the first chapter MSc. Eng. Elizabeta Arsova performs a thorough analytical review. It researches and analyzes the capacities for electricity production and the role of renewable energy sources in improving the energy balance and energy security in the Republic of North Macedonia with the existing sources of electricity of low, medium and high power, the structure of the electricity transmission system, etc. Modern technical systems and trends for electricity production and management of electrical networks and systems have also been analyzed. A good impression is made by the very high degree of knowledge of the national regulatory framework and the justification of the investigated problems, based on the used literary sources, as well as the knowledge of the results of similar studies by foreign scientists.

MSc. Eng. Elizabeta Arsova correctly analyzed and made a successful interpretation of the literature material. The review includes 139 literary sources - 96 from books, articles in scientific journals, conference reports, dissertations, normative documents and 43 from the Internet. All cited materials refer to the problem discussed in the dissertation. Of the analyzed total of 139 literary sources, most of them were published in recent years, from which it can be concluded that the doctoral student knows well the current state of science for the issues she is developing.

The critical examination of the stated problems in the first chapter, illustrated with the help of figures and tables, thus enabling MSc. Eng. Elizabeta Arsova to justify the conclusions reached about the necessity of the proposed research. Based on them, at the end of the first chapter, the main goal is formulated and 5 (five) main tasks to be solved are proposed.

The dissertation of MSc. Eng. Elizabeta Arsova is in an area that requires competence and the possession of specific knowledge in the field of electricity supply and electrical equipment, electricity, mathematical statistics and mathematical modeling, etc. They were skilfully applied in the organization, implementation and analysis of the research conducted.

MSc. Eng. Elisabeta Arsova demonstrates a high degree of problem awareness, competencies and knowledge, including synthesis and evaluation, necessary to solve key problems in the field of scientific research. In this way, she increased her qualifications and established herself as a scientist who demonstrates original thinking and critical thinking on scientific and scientific-applied issues.

3. Research methodology

Standard methods for conducting scientific research are applied in the dissertation, namely: theoretical analysis, computer design, modeling and simulation studies, using statistical methods for data processing. All of them are summarized in the third chapter, in which a methodology is developed for evaluating the solar energy potential of a given geographical area for the production of electricity from photovoltaic plants and a methodology for modeling and simulating their operation.

Based on an office study of good practices from the neighboring Balkan countries in the preparation of energy balances and the construction of renewable energy sources of electricity,

MSc. Eng. Elizabeta Arsova analyzes the main factors and strategies in the construction of solar energy conversion systems depending on technology, power, climate factors, etc.

The methodological approach with which MSc. Eng. Elizabeta Arsova, with which the scientific research was carried out, it can be summarized in the following basic steps:

- Modeling the elements of photovoltaic power stations with the help of specialized software;
- Simulation studies of synthesized models, development and comparison of 4 (four) alternative solutions;
- Simulation studies and analyzes during the design and implementation of photovoltaic power plants in the electricity system of the Republic of North Macedonia;
- Energy efficiency and technical-economic evaluation to confirm the simulation results of the implementation of photovoltaic power plants in the electricity system of the Republic of North Macedonia.

In the dissertation, electrical engineering projects of two powerful photovoltaic power plants and their connection to the electricity system of the Republic of North Macedonia were developed. A simulation of their main modes of operation was performed, and with the help of the technical-economic analysis, the profitability of their construction was proven, which improves the efficiency and infrastructure in the supply of electricity to the population.

An essential point in modeling the operation of photovoltaic plants is the consideration of the influence of the technology used and various operating factors - solar radiation level, temperature, shading, etc. Model specification and simulation studies were performed in the PVSyst specialized software product environment.

During their implementation, modern methods, equipment and computer software suitable for the respective task were correctly used. I believe that the chosen research approach determines the successful implementation of the tasks and the achievement of the goal set in the dissertation work at a high scientific level.

The applicability of the dissertation work is related to the developed detailed variant projects of 2 photovoltaic plants in the territory of the Republic of North Macedonia with a total capacity of 60 MWp, using 4 different variants of technologies and orientation of the photovoltaic modules available on the market. A technical-economic analysis and evaluation of the profitability of the construction of the new 2 photovoltaic power plants was made, taking into account the dependence on the expected prices on the electricity market in the coming years. Studies on the potential of solar radiation for the production of electricity from photovoltaic power plants in the territory of the Republic of North Macedonia, as well as the synthesis of a model of the electricity system of the Republic of North Macedonia, enabling the analysis of changes in energy flows when new power plants are included, are good basis for the development of future projects for photovoltaic power plants and their connection in the power system.

The service notes for the implementation of the obtained results in practice or use in the educational process are not presented.

There is compliance of the chosen research methodology with the set goal of the dissertation work.

4. Dissertation Contributions

I believe that the results obtained from the studies of MSc. Eng. Elisabetta Arsova can be summarized in the following two categories of contributions:

- Scientific and applied contribution:

1. As a result of the detailed analytical study of the balance of electricity production from photovoltaic power plants in 4 countries, the expediency of building new photovoltaic power plants in the Republic of North Macedonia has been proven.
2. Models of the electric power system of the Republic of North Macedonia have been synthesized, which enable the analysis of changes in energy flows, energy losses and overvoltages in the power transmission network when connecting the newly designed photovoltaic power plants.

- Applied contributions:

1. The potential of solar radiation for the production of electricity from photovoltaic power plants on the territory of the Republic of North Macedonia has been investigated.
2. Detailed variant projects of 2 photovoltaic plants with high power (20 and 40 MWp) have been developed using 4 (four) different variants of technologies and orientation of photovoltaic modules.
3. A technical-economic analysis and evaluation of the profitability of the construction of 2 photovoltaic power plants with a large capacity in the territory of the Republic of North Macedonia was made in order to confirm the results of the stimulation and the technical proposal of the project. The obtained results are accompanied by extensive evidentiary material and have its contribution to the development of science in the field of stimulation research and modeling of photovoltaic systems. This is a guarantee that the achieved returns have practical significance and applicability.

5. Publications and citations of publications for the dissertation work

A list of 5 (five) dissertation publications is presented. Two are independent, and the rest are co-authored with the scientific supervisor and colleagues working on the question under consideration, fully covering the minimum requirements regarding the considered criterion. She declared 73 points, which meets the necessary minimum conditions for obtaining a "doctor" of the ONS. Two of the publications were reported at the Unitech International Scientific Conference. Two at the TechCo National Conference and 1 of the publications reporting at the International Scientific Conference EEPES 2023, Kavala, Greece, has SJR rank and is indexed in Scopus.

The publications present a large part of the conducted research and present the main conclusions of the dissertation work. All materials prepared for review are related to the research and applied activities of the MSc. Eng. Elizabeta Arsova. This gives me reason to assume that she

has built and established herself as a researcher in the field of photovoltaic conversion at home and abroad. I have no information about her cites.

6. Authorship of the obtained results

The publishing activity of MSc. Eng. Elizabeta Arsova, meets the minimum requirements for candidates for ONS "Doctor". The completed dissertation is her personal work under the supervision of her supervisor Plamen Tsankov. The PhD student successfully coped with the inevitable difficulties in organizing and conducting the research associated with the current dissertation. The successful integration of engineering and theoretical research based on modern specialized software products is impressive.

It is appropriate to present contracts or other documents that confirm the participation of the doctoral student in solving engineering and design tasks related to the dissertation.

7. Abstract and author reference

The abstract is 43 pages long and complies with generally accepted requirements for the volume and content of such a document. It corresponds to the structure of the dissertation work. The topicality of the problem, the goal, the main tasks, the research methods used, the applicability of the obtained results, the structure and the brief content of the paper are described. The summary in English reflects the scientific and scientific-applied contributions achieved through the dissertation developed by the doctoral student.

8. Opinions, recommendations and remarks about the dissertation work

I have the following remarks and recommendations for the thesis presented in this way:

1. Spelling mistakes are made in several places in the dissertation and abstract.
2. The conclusions of the second chapter should better correspond to the subject of the dissertation.
3. The figures in chapter 5 are of low quality and unclear.
4. It is necessary to comply with the requirements for graphic marking of various elements of electrical diagrams and to standardize all letter symbols.
5. It is appropriate to summarize the statistical data from the performed simulation studies in point 4.9 and in graphic form.
6. To specify the values for the expected amounts of electricity produced by the photovoltaic plants - minimum, average, maximum.
7. It is entirely appropriate that conclusions and appendices be distinguished with greater specificity.
8. The bibliography is not formatted as required.

These remarks do not detract the work of MSc. Eng. Elizabeta Arsova and in general the dissertation work has been completed. I believe that the dissertation achieves the stated goal, and the defined tasks are fulfilled at a high scientific level.

9. Conclusion

I believe that the submitted dissertation **meets the requirements** of the Law on the Development of Academic Staff in the Republic of Bulgaria. The achieved results give me a reason to **propose** that the educational and scientific degree "Doctor" be acquired from the MSc. Eng. Elizabeta Trajko Arsova,

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14.03.2024

Signature:/signature/.....

/ professor Dipl. Eng. Ivailo Stefanov Stojanov PhD /