OPINION

on a dissertation for the acquisition

of the educational and scientific degree "Doctor"

Author of the dissertation: **M.Sc. Ing. Rumyana Angelova Stoyanova**

Topic of the dissertation: **"Development of innovative methods and mechanisms for energy piezoharvesters"**

in the professional field 5.2 "Electrical Engineering, Electronics and Automation", PhD program "Microelectronics"

Member of the Scientific Jury: **Assoc. Prof. Ph.D. Eng. Svetoslav Tsvetanov Ivanov,** Department of Electronics, Technical University of Sofia, Plovdiv Branch

1. Relevance of the problem developed in the dissertation in scientific and applied scientific terms

The global energy crisis and environmental pollution, mainly caused by the increased consumption of non-renewable energy sources, have stimulated researchers to explore alternative energy technologies that can harvest energy available in the environment. Mechanical energy is the most ubiquitous environmental energy that can be captured and converted into useful electrical energy. Piezoelectric conversion is the appropriate mechanism for collecting mechanical energy due to its high electromechanical bonding coefficient and piezoelectric coefficient compared to electrostatic, electromagnetic and triboelectric converters. In addition, miniature devices with lower energy consumption are realized on the market in accordance with the with technological developments in the electronics industry. Thus, it is expected that in the near future, many electronic devices will be powered by piezoelectric generators.

The proposed dissertation investigates new materials and nanostructures of piezoelectric type for converting mechanical load into an electrical signal suitable for powering low-power consumers

In fulfilment of the main objective of the dissertation, five main tasks are set related to: (1) Presentation of a methodology for describing a vibration harvester; (2) Development of monomorphic and biomorphic piezoelectric harvester models; (3) Creation of a methodology for describing a compression piezoelectric harvester; (4) Development of a model of a compression piezoelectric harvester; (5) Experimental studies of the proposed models of piezoelectric harvesters of vibration and compression type.

2. Degree of knowledge of the state of the problem and creative interpretation of the literary material

143 literature sources were used in the dissertation – 140 of them in Latin, 3 in Cyrillic and 57 Internet addresses, which shows that the PhD student is familiar with the publications in the field of piezoelectric harvesters of vibration and compression type, their main characteristics and areas of application for obtaining electrical energy. The literature review shows the correct citation of literary sources, the scientific entry into the studied issues and the creative

interpretation of the literature used, as well as the very good visual presentation of the technologies under consideration and the results achieved.

3. Compliance of the chosen research methodology and the set goals and objectives of the dissertation with the contributions made

After the analysis of the known models of vibration and compression harvesters, optimization was made and 4 new mathematical models were developed, after which they were experimentally studied to verify the proposed models. To carry out the necessary calculations and visualize the results obtained, the program environment MATLAB was used. Mathematical modeling of a unimorphic piezoharvester was made using the finite element method. piezoelectric harvester. The compiled mathematical models are suitable for estimating the amount of energy that can be extracted from the studied energy-generating devices of vibration and compression type. The PhD student has methodically correctly structured the research. The components of the research in the dissertation are interrelated. The goals and objectives set have been achieved. The application and improvement of the proposed methodologies develops the knowledge and experience of the PhD student and contributes to her educational and scientific development.

4. Scientific, applied and applied contributions of the dissertation

I support the contributions formulated by the PhD student. I define them as scientific-applied and applied and associate them with the creation of new methodologies, methods and models. The contributions contain elements of novelty, have the character of enriching scientific knowledge and practice and have their own meaning. I think that the contributions are a personal work of the PhD student. The results of the theoretical and experimental research carried out, in accordance with the purpose and objectives of the dissertation, are reduced to the following most significant contributions:

- Improved equivalent schemes of a vibrating piezoelectric harvester of beam type have been proposed to reflect the real conditions to which this type of structures can be subjected. The elements of the proposed equivalent schemes reflect some of the variable parameters in the operation of this type of harvester (such as parasitic capacities) as well as the parameters of the elements external to the scheme that have an impact on the operation of the harvester;
- A model of planar construction of a piezoelectric harvester of compression type has been created, which reflects the peculiarities of the elements that make up this device, and is based on the basic principles of resistance of materials for vertical and horizontal force. A parallel electrical connection between the individual elements of the compression harvester is proposed on a reasonable assumption, due to the fact that the series electrical connection of elements in this case is not suitable, since in order to generate a signal for the entire matrix, all its elements must be subjected to mechanical pressure simultaneously;
- Two variants of planar construction of a compression piezoelectric harvester and a methodology for their study are proposed. Out of 48 studies, it is proved that the vertical force of interrupted (impact) nature achieves better efficiency compared to

the continuous (horizontal-rotational) impact, which correlates with the model proposed in Chapter Three.

A significant applied contribution is the created design for more efficient energy collection by reducing the distance between the active elements of compression piezoelectric harvesters. This has been proven by the experimental studies carried out.

5. **Evaluation of the publications on the dissertation**

I got acquainted with the scientific works on the dissertation. They fully reflect the theoretical and experimental research carried out. I do not have common publications with the PhD student, and I am not a related person with her within the meaning of paragraph 1, item 5 of the Additional Provisions of the Law on Scientific and Developmental Studies. Part of the results obtained in the development of the dissertation were reported at scientific conferences with international participation, three of which are indexed in SCOPUS. Rumyana Stoyanova is the first co-author of three (out of five) publications, and has one independent publication, presented as a report at a scientific conference. All this emphasizes her role in the creation and presentation of the results of the dissertation.

6. Opinions, recommendations and observations:

I would recommend the PhD student to publish the results in journals that are indexed in Scopus or Web of Science in the future.

The results obtained and the usefulness of the development allow me to give a positive assessment and opinion on the dissertation of Mag. Eng. Rumyana Stoyanova.

7. Conclusion

The presented materials allow for an objective assessment of the dissertation of Eng. Rumyana Stoyanova. The developed methods and mathematical models for harvester research can be used in future practical engineering and research projects. I believe that the PhD student meets the current regulatory requirements for obtaining the degree of Doctor. This gives me grounds to propose to Master. Eng. Rumyana Stoyanova to be awarded the educational and scientific degree "Doctor" in the professional field: 5.2 "Electrical Engineering, Electronics and Automation", PhD program "Microelectronics".

04 January 2025

Signature: ……/signature/……..

(Assoc. Prof. Ph.D. Eng. Svetoslav Ivanov)