BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Opponent Review of Doctoral Dissertation

Applicant: Ing. Laila Znbill

Title of Dissertation:
LOW ENERGY SOLID STATE CONVERTERS FOR ENRGY HARVESTING

Opponent: doc. Ing. Ota Salyk, CSc.

Opponent's Department: Brno University of Technology, Faculty of Chemistry

In accordance with the Study and Examination Rules of BUT, in his/her review the opponent will mainly comment on:
a) the topicality of the dissertation,
b) whether the dissertation achieved its given objective,
c) the problem-solving procedure and the results of the dissertation along with the concrete contribution of the doctoral student,
d) the significance for practical application or the progress in the field,
e) formal and language qualities of the dissertation,
f) whether the dissertation fulfils the conditions of Section 47 (4) of the Act,
g) whether the student proved his/her creative abilities in the given research field and whether the work does or does not comply with the standard requirements placed on the dissertations in the given field. The review is not valid without this conclusion.
It is necessary to add a concise commentary to each of the points below.

Ad a) Topicality of the dissertation

The topic of the dissertation is very topical.
Comment: The PhD student dealt with the very topical issue of advanced methods of electrical energy harvesting based on principle of photovoltaic and thermoelectric – Seebeck – effect.

Ad b) Objective of the dissertation

The objective of the dissertation was achieved as described below.
Comment: The following objectives were presented:
1. Compile overview concerning preparation of EH photovoltaic structures and suggest solutions for their operation on low energy level.
2. Compile overview concerning preparation of EH thermoelectric cells and suggest solutions for their operation on low energy level.

3. Research and design of a low voltage low energy DC/DC converter to process the output from EH transducers.
4. Research and design of a thermoelectric converter using simple technologies and available materials

Ad1. and 2. The compile is the comprehensive review with large bibliography containing 172 title, paper and other references, concerning both photovoltaics and thermoelectricity.
Ad3. The two type of transformer were designed as well as DC/DC converters and tested mostly on modelling condition, not in intended appropriate application of thermoelectric generators.
Ad4. The thermoelectric generators (TEG) were suggested and calculated on the basis of Ni-PEDOT:PSS and compared by Ni-NiCr and Bi_2Te_3 doped, not tested on real samples enough.

Ad c) Problem-solving procedure and the results of the dissertation and the concrete contribution of the doctoral student

The problem-solving procedure and the results of the dissertation are average.
Comment:
Recently relatively high expectations of promising materials and technologies appeared in the professional literature related to Energy Harvesting (EH). Due to the very wide scope of the thesis, the doctoral student was not able to actively intervene in all related technologies, but she was able to follow the development trends. Therefore, thanks to the acquisition of a good knowledge and orientation in the relevant topics, the experiments performed in the presented work were based on the detailed analysis of the effects reducing the efficiency of energy conversion. To process the output voltage of EH transducers at the level of tens of millivolts, all photovoltaic and thermoelectric generators were used together with low-voltage DC to DC converters.

Ad d) Significance for practical application or progress in the field

The significance for practical application or progress in the field is average.
Comment: The thesis was focussed on suggestions and design of DC to DC converters and thermoelectric generator:
1. Concerning photovoltaics the main attention was paid to photovoltaic cells in a single cell arrangement, which is simple and reliable and is very suitable for processing small energy flows. The method of dynamic measuring the series and leakage resistances of the cell and their possible dependence on the operating conditions is original contribution of the work and allows measurements of serial and leakage resistances to be made with standard instruments available. Crystalline silicon cells was confirmed in the experiments that it is still the most advantageous for most applications. The measured leakage resistance of thin-film photovoltaic cells was significantly lower than that of crystalline silicon.
2. Converters with low input voltage for applications in photovoltaics and energy harvesting (EH) from thermoelectric generators (TEG).

The special design of the transformers made it possible to achieve virtually any conversion ratio. Two types of transformers have been developed: the planar transformer has a modular construction with primary and secondary windings on one printed circuit board and the flat transformer, based on the adding the

ferrite toroidal cores to a common magnetic core. The conversion ratio can be significantly greater than 100 in both cases.

Two types of inverters have been designed and prototyping, the Armstrong oscillator which allows multiple transducers to be connected in parallel to one load and a single FET DC to DC converter which is more efficient than an Armstrong oscillator. Complementary circuits have been tested for the designed and manufactured single FET DC to DC converter, which enable a significant increase in efficiency reaching up to 50 percent.

3. The proposal of the thermoelectric generator (TEG) was focused on organic semiconductors with low thermal conductivity and a large value of the Seebeck coefficient. Polymer PEDOT: PSS has been verified to have suitable properties for use in a thermoelectric pair with Ni already widely used in organic electronics. The TEG design and geometry due to minimal serial resistance were carefully calculated and the manufacturing process proposed but not realized. The calculated energy conversion efficiency was 0.1 W/m^2 K. At a temperature difference of 100 K, this corresponds to 10 W/m^2, the value corresponds to the results reported in the literature for organic thermoelectric generators based on PEDOT: PSS.

Following the design of the structure of a TEG with a vertical arrangement, the appropriate materials were selected and suitable technological procedures were chosen to prepare a model thermoelectric cell, which verified the feasibility of the design and operability of the proposed structure. But the feasibility of the design on a model thermocouple Ni-NiCr has been verified. Unfortunately, the whole thermoelectric generator as the assembly of partial thermocouples was not fully realized and measured.

Ad e) Formal and language qualities of the dissertation

Formal and language qualities of the dissertation are weak.
Comment: English is very good, only a small number of irrelevant shortcomings.
On the other hand, there are substantial typographical deficiencies:
1. There are no active links to content, references, images, tables, equations.
2. The references aren't arranged in ascending order, as usual.
3. The bibliography is not organized in accordance with the presence of references in the text.
4. Quantities symbols are not consistently written in italics, indexes are not perpendicular.
5. No larger font is used for chapter names.

Ad f) The dissertation fulfils the conditions of Section 47 (4) of the Act

The dissertation fulfils the conditions of Section 47 (4)*) Act No. 111/1998 Sb. Higher Education Act: YES

((4) Studies are duly finished with a doctoral state exam and dissertation defence, which prove the ability and readiness to work independently in the field of research or development, or in theoretical and creative arts. The dissertation must comprise original and published results or results accepted for publication.*

Ad g) Creative abilities of the student in the given research field. Compliance with the standard requirements placed on the dissertations in the given field.

The doctoral student did prove her creative abilities in the given research field and the work does comply with the standard requirements placed on the dissertations in the given field.
Comment:
The PhD student has demonstrated creative skills in researching the field. She focused on a comprehensive overview of the issues from which she drew the most appropriate solutions, selecting materials, principles and procedures, which she then applied for her proposals to tackle the collection of low flows of heat and radiant energy and their conversion into electrical energy. Implementation has been partially delayed due to the unavailability of laboratories. This was due to unfounded circumstances (Covid 19).

Overall evaluation:
The work is based on detailed and careful theoretical preparation, in this it is very extensive (136 pages) including the bibliography (172 ref.), plus some of the theoretical analyses are relegated to appendixes (187 pages in total). Also, the development of DC/DC transducers is detailed and pushed into implementation. However, I lack the final realisation of own TEG samples (altogether with her DC/DC convertor) and the results of measurements on them. Some results are presented only in tables (practically no graphs are presented). I am aware that the closing work has been negatively affected by the pandemic, with access to laboratories at BUT very limited for more than a year.
The results of the dissertation were published (12 publications) in domestic conferences and their proceedings. Impact and inclusion in the world publishing databases is not listed. The publication with the results was submitted to the Journal of Electrical Engineering.
The dissertation over the aforementioned deficiencies meets standard requirements and I recommend it to the defence.

Opponent's questions:

1. Transparent photovoltaic cells using the energy of IR portion photons were developed. Is it beneficial for them to use low-voltage DC/DC transducers?
2. What limits the use of TEGs as voltage sources?

I ☒ recommend ☐ do not recommend the dissertation for the defence.

Date: 27.07.2021

Signature: ……..