REVIEW

on the defense of a dissertation on a topic "Evaluation of mixed installations with alternative energy sources" for obtaining a scientific degree "doctor of science" by the specialty „Processes and apparatus in chemical and biochemical technology", professional field 4.2. Chemical Sciences with a candidate Aleksandar Georgiev Georgiev, Prof., PhD., Eng.

Reviewer: Georgi Ivanov Valchev, prof., PhD, eng.

1. Brief biographical data and characteristics of the scientific interests and scientific activity of the candidate for the degree "doctor of science".

Prof. Dr. Eng. Aleksandar Georgiev Georgiev was born on March 22, 1958 in the town of Dobrich. He graduated with a master's degree in "Heat and Nuclear Energy" at the Technical University of Sofia in 1981 obtaining the degree "Mechanical Engineer". In 1988 he defended the "Doctor" degree of the scientific specialty "Energy Conversion Technologies and Systems", cipher 02.06.07. In December 1988 he was appointed after winning a competition for "Seniour assistant professor" to Department "Mechanics", TU-Sofia, Plovdiv branch with subject of teaching and research activity, and since 1990 has been promoted to "Main assistant professor". Since July 2000 was elected as associate professor in the specialty "Energy Conversion Technologies and Systems" of Department "Mechanics" TU-Sofia, Plovdiv branch. From 02.2011 to 02.2013 he was an "Associate Professor" and "Professor" in "Energy Conversion Technologies and Systems" at the European Polytechnic University, Pernik. He was a head of the Department of Green Energy and the bachelor's degree in Green Energy in the time period 11.2011-02.2013.

The scientific interests of the candidate are determined by his participation in various courses and specializations in projects at leading universities in the specialty abroad. In 1992-1993 he had a post-doctoral stay in the field of renewable energy sources at the Institute of Energy Technology, University of Siegen, Germany, in 1994 he specialized in thermodynamics and heat transfer under the Joint European TEMPUS Project in Nottingham, England. From October 2001 to September 2003 he specialized in the field of renewable energy at the Technical University of Federico Santa Maria, Valparaiso, Chile, in June 2005 he exchanged in the field of teaching and research at the Polytechnic University of Valencia in Spain, and in October of the same year specialization in the field of renewable energy sources as a participant in the Erasmus project at the Institute of Metrology and Climatology at the University of Hannover,

Germany was realized. In December 2006 he specialized in the Department of Applied Physics, Polytechnic University of Valencia, Spain, and in October 2007 at the Geothermal Center, University of Göttingen, Germany, specializing in renewable energy as a participant in the Erasmus project. For the period 2005-2018 he was the scientific supervisor of nine research projects, one of which is international, and for the period 2002-2011 participated in ten international research projects.

2. Relevance of the problem developed in the dissertation.

The issue of the use of renewable energy sources (RES) has been a top priority for the European Union (EU) since 2001. Directives for EU member states have been introduced to double the production of energy from renewable sources over the next ten years. Since 2011, quotas have been introduced until 2020 for different countries to produce this energy. The trend is that in 2050 about 60% of the energy produced in the EU will be from renewable sources. The topic of the dissertation is relevant because it meets the requirements of the modern legal framework in our country. In pursuance of the „Europe 2020" Strategy in the Republic of Bulgaria, the Energy Act, the Energy Efficiency Act, the Renewable Energy Sources Act and Regulations to them have been adopted, which are in line with EU Directives. The introduction of renewable energy sources will reduce the harmful emissions from the environment when burning conventional fuels, which will help prevent climate change on our planet. In order to achieve a sustainable energy future, it is necessary to develop and implement specific energy saving measures in accordance with the requirements of the legislative framework.

3. Review of the dissertation and analysis of the results.

The dissertation contains 345 pages, including 201 figures and 29 tables. The list of author's publications in full text on the topic presents 36 articles. Of these, 15 are in journals with an impact factor for the year, 11 have been published in specialized international journals or in full in collections of international scientific forums with editor and publisher, and 15 have been published in the years 2016 - 2020. The author of the dissertation is in first place in 17 of the publications, and in second place in 10 pcs. As the author has not presented a separation protocol for co-authorship in scientific publications, the reviewer assumes that they are equal for all authors. An overview of the state of science on the topic of the dissertation of a large volume of 229 literary sources was made, of which 6 pcs. in Cyrillic and the rest in Latin. I share with conviction that there is a good knowledge of the state of the problem worldwide. The main conclusions of the main components of mixed systems with alternative energy sources are made. As a result of the literature review and the main conclusions from it, the main goal of this paper is defined: Research and evaluation of different types of

mixed installations based on alternative energy sources, as well as their main components. To achieve the goal, 9 basic tasks are determined:

* Vacuum solar collector with flat-plate absorber and heat pipe: mathematical modeling of a vacuum collector with a flat-plate absorber and a heat pipe; programming of the mathematical model; performing simulations; experimental tests of a vacuum collector with a heat pipe.

* Thermal storages: mathematical modeling and testing of a mixed water storage with stratification; mathematical modeling of a water storage with four turn pipe windings and performing experiments; Thermal response test (TRT) of seasonal Underground thermal energy storages (UTES) including construction of installations, conducting experiments, data processing with different methods, performing simulations; study of a latent storage with paraffin as a phase change material (PCM) including design, construction, modeling and simulations.

* Vacuum solar collectors with water thermal storage: experimental study of the installation with vacuum solar collectors and water thermal accumulator; mathematical modeling; programming of the mathematical model; comparison of the calculated with the experimental data.

* Refrigeration installation with built-in solar collectors and thermal storage: creation of methods for calculating the main thermal parameters of the system; performing sample calculations.

* Borehole thermal energy storage (BTES) with solar collectors: design and construction of the BTES installation; experimental study during charging and discharging; performing simulations.

* Photovoltaic-thermal (PV/T) installations: construction of PV/T installations; conducting experiments with PV/T installations; processing of the experimental results.

* Ground source heat pump system with solar collectors: construction of GSHP system with solar collectors; creation of investigation methods; conducting experiments; TRNSYS simulations of a house powered by GSHP with solar collectors.

* Ground source heat pump installation using phase change materials (PCM): creation of methodology; modeling; conducting simulations.

* Mixed micro-cogeneration system with photovoltaic panels and Stirling engine for local heating: construction of an experimental system; conducting experiments.

4. Main scientific and scientific-applied contributions.

The main contributions of the author in the dissertation are presented. They are divided into three sections - SCIENTIFIC, SCIENTIFIC-APPLIED and APPLIED. The reviewer agrees with the contributions formulated in this way.

SCIENTIFIC CONTRIBUTIONS

1. A vacuum solar collector with a heat pipe was studied in detail (by experiment and mathematical modeling). A computer program was created, with which simulations were performed in different modes [4, 7].

2. Experimental tests of a mixed water storage with stratification of the working fluid have been performed. With the selected mathematical model, a computer program was created, which facilitates its verification on the basis of the conducted experiments [1].

3. An industrial water storage with two separate coils has been studied experimentally and a mathematical model describing its operation has been selected. The verification of the model is done with the help of the created computer program [5, 6].

4. Three different installations have been built (one stationary in Chile, one mobile with an electric heater in Bulgaria and one with a heat pump in Spain) to conduct the new effective Thermal response test (TRT). Borehole heat exchangers (BHE) have been built in Valparaiso, Chile and Plovdiv, Bulgaria, where TRTs have been carried out to determine the thermal properties of the soil. The obtained results are processed by various mathematical methods. Simulations were made with the commercial software TRNSYS, comparing the calculated values with the experimental data. It is planned to create a cadaster in Bulgaria to be used in future geothermal projects [3, 10, 11, 12, 16, 17, 23, 24, 26, 27, 30].

5. Latent storage using phase change materials (PCM) is designed and built in TU Sofia, Plovdiv branch, which is equipped with a specialized autonomous measuring system developed by the research team in Plovdiv. Several types of paraffin were studied, whose thermal properties were studied in detail. Mathematical modeling and simulation of storage processes was performed in two different ways - by the finite element method based on Comsol multiphysics and by the enthalpy porosity technique used in ANSYS Fluent [29, 31, 32].

SCIENTIFIC-APPLIED CONTRIBUTIONS

1. A mixed installation containing vacuum solar collectors with a heat pipe and a water thermal storage with a four turn pipe windings has been tested experimentally. The created general mathematical model, describing the joint work of the two elements, has been programmed and verified on the basis of conducted experiments [8, 9, 14].

2. The Chilean installation constructed for implementation of TRT has been redesigned to conduct natural experiments on solar energy charging and discharging of underground storages. Long-term experiments were performed under the two

mentioned regimes. A comparison was made between the calculated values with the commercial product TRNSYS and the measured values during the charging and discharging process, and the results showed a good match [13, 15].

3. A solar thermal system combined with photovoltaic panels has been designed and manufactured. A new set of virtual tools has been developed and proven, providing on-line or off-line calculation of the error when performing experiments. The experiments performed characterized the energy efficiency of the cheap construction of PV/T panel and helped to verify the proper operation of the developed virtual tools [34].

4. The ground source heat pump (GSHP) system was experimentally tested in the following five operating modes of the system: charging of water tanks (CWT), Charging of borehole thermal energy storage (CBTES), direct solar heating (DSH), heating with GSHP (GSHPH) and heating by solar assisted heat pump (SAHPH). A detailed energy analysis was performed for the mentioned regimes, taking into account all energy sources and calculating the respective losses and system coefficients of energy efficiency for each regime [33].

5. During the construction of the BHE of the GSHP system, temperature sensors were installed every 10 m in depth to monitor the change of the temperature field. Diagrams were obtained confirming the heating (when charging - CBTES mode) and cooling (when heating – GSHPH mode) of the soil layer over time. The temperature field was also measured after the end of the two modes in the so-called natural relaxation [33].

6. A model was created, built in the simulation environment of "TRNSYS studio", which allows to study different modes of operation of the GSHP system and to analyze the impact of system parameters on the performance characteristics. Attention was paid to the following elements of the system: solar collector, water storage, heat pump, ventilation and house. With the model thus created, a simulation of a house heated by this installation was made [28].

7. Numerical modeling is presented, evaluating a new type of construction for the application of PCM in underground horizontal heat exchangers (GHE), integrated with ground source heat pumps (GSHP). PCM is mixed directly with the soil around the GHE - this is a new approach, not yet studied for horizontal ground heat exchangers. The results show that the merging of PCM with GHE effectively meets the heat loads of GSHP and reduces the sharp fluctuations in heating or cooling of the ground heat exchanger. The conducted simulations are for cases with and without PCM, solved for a simulation period of two years [20].

APPLIED CONTRIBUTIONS

1. It is proposed to increase the efficiency of a solar installation, which will work in the winter, by implementing a heat pump unit. A methodology for calculating the parameters of the system has been created, with which sample calculations have subsequently been performed [2].

2. An existing photovoltaic (PV) panel has been converted into a photovoltaic-thermal (PV/T) panel. Comparative experiments of the mixed installation (consisting of two different panels) were performed, proving the advantage of the combined PV/T element, producing both more electricity and additional heat energy during cooling [18].

3. A concentrating photovoltaic-thermal (CPV/T) system has been created, which is connected to the heat pump (HP) evaporator - the PV modules are cooled by the refrigerant passing through the HP evaporator. The installation is designed for heating of buildings. A theoretical and experimental study was conducted, showing the efficient production of electricity and heat with the described system [35].

4. A new construction of a mixed ground source heat pump (PSP) system has been created, consisting of two borehole heat exchangers, three flat-plate solar collectors (SC), a reversible heat pump (HP) and a fan coil. A methodology for determining the thermal characteristics in the following five modes of operation has been developed: charging of water tanks, charging of borehole thermal energy storage, direct solar heating, heating with GSHP and heating by solar assisted heat pump [19, 21, 22, 25].

5. The simultaneous and experimental operation of a Stirling engine and photovoltaic (PV) panels for the production of electricity from a central heating system on solid fuel, aimed at both heating buildings and satisfying the boiler's electricity consumption or supplying the home with electricity, has been studied theoretically and experimentally. The heating capacity of a multi-family house in Mugla, Turkey was provided with a micro-cogeneration system, and the experiment was carried out within three months [36].

5. Description and evaluation of the submitted materials:

The author of the dissertation has attached all the necessary documents (number 6) for the defense of the scientific degree "Doctor of Science". The documents are in the required form (on paper and electronic media), as well as a summary report on the implementation of the minimum national requirements of the ZRASRB Law and the additional criteria of the Institute of Chemical Engineering (ICE-BAS). An Abstract of the dissertation (in Bulgarian and translated into English) in a volume of 72 pages with

text and figures is presented. The content of the abstract fully corresponds to the dissertation work on chapters and figures to them.

Prof. Dr. Eng. Aleksandar Georgiev Georgiev meets the national minimum requirements for awarding the scientific degree "Doctor of Science" in Professional field 4.2. Chemical Sciences in the specialty "Processes and Apparatus in Chemical and Biochemical Technology" specified in the Law on RAS in the Republic of Bulgaria and the Regulations of ICE at BAS-Sofia. With a minimum requirement of 350 points on a group of indicators for awarding the degree, the personal total number of points of the candidate is 674 points. The points on a group of indicators: А-dissertation "Doctor" are 50, if necessary 50; Б - dissertation work "Doctor of science" are 100 with the required 100 points; Г-publications (WoS and Scopus) for the required 100 are a total of 266; Д- Citation (Web of Science) for the required 100 are a total of 258.

The candidate also meets the additional criteria to the scientific activity of the candidates for obtaining the scientific degree "Doctor of Science" of the "Institute of Chemical Engineering". With minimum requirements for Doctor of Science of 25 scientific articles, the candidate has proposed 36 pcs. With minimum requirements of 15 pcs. of the attached articles which must be in specialized international journals, in journals with impact factor or impact rank, or in full text in collections of international scientific forums with editor and publisher, the candidate has submitted 15 articles with Impact factor plus 11 articles in specialized international journals or in full text in proceedings of international conferences or congresses with editor and publisher. If needed 50 citations on the papers included in the dissertation, the candidate has submitted a total of 244 citations of the presented 36 articles.

6. Reflection of the candidate's scientific publications in Bulgarian and foreign literature.

The scientific publications of Prof. Dr. Eng. Aleksandar Georgiev Georgiev have become available to the scientific field working in Professional field 4.2. Chemical sciences in the country and abroad. They have been reported at conferences with international participation at home and abroad, as well as publications in referenced and indexed in world-famous databases of scientific information. A total of 244 citations were noted for the presented publications.

7. Critical remarks and recommendations to the scientific works of the candidate.

I do not have critical remarks on the dissertation. I recommend the author to patent some of the contributions made as a result of scientific and experimental research.

8. Personal impressions of the reviewer about the candidate.

Prof. Dr. Eng. Aleksandar Georgiev Georgiev is an academic lecturer and researcher with very good theoretical, professional and wide range of training in the subject of the presented dissertation. He is known in Bulgaria and abroad for the results of scientific research and will be useful for the scientific community of ICE-BAS in the scientific field.

CONCLUSION

My overall assessment of the dissertation presented, the contributions to it, the research and publication activities, as well as the full implementation of the national minimum criteria of ZRASRB and the Regulations of ICE at BAS-Sofia for obtaining the degree of "Doctor of Science" of the candidate is **Positive**.

I propose to the Distinguished members of the Scientific Jury to give the scientific degree "Doctor of Science" Professional field 4.2. Chemical Sciences in the specialty "Processes and Apparatus in Chemical and Biochemical Technology" to Prof. Dr. Aleksandar Georgiev Georgiev.

Date 07.02.2022
Plovdiv

Reviewer:
/Prof. G. Valchev, PhD, eng./