

Traducere din Engleză:

RAPORTUL COMISIEI DE ABILITARE

din data de 29.08.2014

Nume și Prenume candidat:

FODOREAN Daniel

Titlul tezei de Abilitare:

Optimum Design of the Motorization of Electric Vehicles
based on Multiphysic Approach

Domeniul de studii universitare de doctorat :

Inginerie Electrică

Instituția la care s-a susținut public teza:

Universitatea Tehnică din Cluj-Napoca

Punctele tari ale tezei de abilitare:

ACTUALITATEA TEMELOR STUDIATE, INTERDISCIPLINARITATEA METODELOR
ABORDATE, REALIZAREA STANDURILOR PENTRU VERIFICĂRI EXPERIMENTALE

Punctele slabe ale tezei de abilitare:

NU ESTE CAZUL

Număr de voturi de acceptare:

3

Număr de voturi de respingere :

0

Rezultatul votului. Observații/Concluzii :

COMISIA A ACCEPTAT IN UNANIMITATE TEZA DE ABILITARE

Comisia de abilitare :

Președinte : PROF. DR. ING. DUMITRU TOADER

Membru : PROF. DR. ING. MARCEL ISTRATE

Membru : PROF. DR. ING. HUMBERTO KENAO

Semnătură

HABILITATION REPORT

dated on 29.08.2014

Last name & first name of the candidate: **FODOREAN Daniel**

Title of the habilitation thesis:

**Optimum Design of the Motorization of Electric
Vehicles based on Multiphysic Approach**

Domain of the research

Electrical Engineering

The institution where the public
presentation took place:

Technical University of Cluj-Napoca

Strong points of the habilitation thesis:

**NOVELTY OF THE STUDIED TOPICS, MULTIDISCIPLINARY APPROACH,
PUTTING IN PLACE SEVERAL TEST BENCHES, EXPERIMENTAL
VALIDATION OF THE STUDIED APPLICATIONS.**

Weak points of the habilitation thesis:

NOT THE CASE FOR WEAK POINTS.

Number of acceptance votes:

3

Number of rejection votes :

0

The result of the vote. Comments/Conclusions :

**THE COMMISSION AGREES TO GRANT THE HABILITATION
DEGREE.**

The habilitation jury :

President: **PROF. DR. ENG. DUMITRU TOADER**

Member: **PROF. DR. ENG. MARCEL ISTRATE**

Member: **PROF. DR. ENG. HUMBERTO HENAO**

Signature



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Amiens, July 2014

Report on the dissertation of Dr. Daniel FODOREAN for the accreditation to supervise research

The documents presented by Dr. FODOREAN give a synthesis of his research work and activities starting from 2001 with his PhD Thesis until now. These documents are constituted of a brief description of Dr. FODOREAN curriculum vitae, a list of his research publications and a detailed description of the research topics he has treated.

The research contributions of Dr. FODOREAN are quite broad and judiciously summarized around the optimization of electric motors for light traction and more precisely oriented toward electric vehicles. Some specific research investigations carried out by Dr. FODOREAN are related to the design and optimization of many types of electric motors, as well as to the study of their thermal behavior, their tolerance to internal or external faults and their speed variation capability. The hybrid source to supply electric vehicles is also considered including its control strategy for an optimal energy management.

Dr. FODOREAN is actively involved in the management of national and international projects of his area of expertise, for research and technological development involving some industrial projects. His research work is well described but his activity associated to the supervision of undergraduate and post-graduates students is not commented in this dissertation. The managerial capacity of Dr. FODOREAN connected to his research experience make possible the effective projects realization.

The research perspectives of Dr. FODOREAN are clear, concise and realistic. Considering all my comments made above, I have no doubt that Dr. FODOREAN possesses the ability and aptitude to conduct and supervise research and in this way I agree with the defense of his Habilitation Thesis.

Professor Humberto Henao

Director of the Power Electrical Engineering Research Lab

Review report on the Habilitation thesis:

**Optimum Design of the Motorization of
Electric Vehicles based on Multiphysic Approach**

by **Daniel FODOREAN**

The undersigned Dumitru TOADER at "Politehnica" University of Timisoara, Department of Fundamentals of Physics for Engineers, was appointed to the Commission by habilitation the public to present habilitation thesis "Optimum Design of the Motorization of Electric Vehicles based on Multiphysic Approach" by dr. eng. Fodorean Daniel, we analyzed referred thesis and found the following:

1. General considerations

The habilitation thesis contains the summary of main scientific and teaching achievements of the author, presented clearly, in a detailed report and submitted to receive the habilitation degree and the right to conduct research. In his work, the author proposes several topics in relation with the **Motorization of Electric Vehicles (EV)**. First of all the author presents the state of the art with respect to the EV application. Next, after a short summary of the main results and achievements, he details the multi-physic approach on the studied application. At the end of the report are presented the research and teaching perspectives, in the light of a long term international collaboration. The report is accompanied with an extended reference list and the copy of the main scientific papers.

Regarding the relevance of the discussed topic, it should be mentioned that the Electric Vehicle application is a common research preoccupation today, mainly because of the gas emissions which produce pollution, and the risk of earth resources depletion. In order to compete with thermal vehicles, researches need to be done especially with respect to the storage unit and the traction chain. Of course, on board of an EV there are many other auxiliary systems, which affect the energy consumption (i.e., all micro-motors used for the electric chairs/windows/mirrors, steering/braking/air-conditioning systems etc.), which consume an important quantity of the installed energy. But the battery, the main supplying source from an EV (even for hybrid electric configurations) is mainly affected by the traction chain (motor and included gear). For high accelerations the electric motor consumes the most important part of the stored energy. In order to spare as much as possible the battery, an improved energy management of the traction chain should be assured. Thus, optimizing motorization, controlling with improved energetic performances and optimal energy management are the key elements to respond to the EV's need: the improved autonomy.

2. Habilitation thesis structure

The habilitation thesis is structured in eight chapters, has 141 pages, ending with references which contains 117 titles. Out of the 117 titles of the reference 17 references is author or co-author Mr. D. Fodorean.

The 1st chapter presents a short state-of-the-art of the EV, the most important moments in its history, starting from his birth and up to its present, and taking a prospective look towards the next 50 years. Also, the author's main results are summarized here and they are concerning only his activities after the PhD thesis public defense, July 2005 until June 2013 when the habilitation report was written. From this chapter we have retained that the author's achievements are related to a continue collaboration with universities from France and other companies from Romania and Switzerland, in the frame of several research project and grants.

The 2nd chapter is dedicated to the motorization variants, especially for light EVs. Several electrical machines and excitation and winding configurations were studied. These variants were designed analytically through specific approaches which were briefly presented in the 3rd chapter of the report. Also, the numerical validation by means of finite element method was presented here.

In order to exploit the maximum performances of the motorization it is needed to optimize the core of the traction chain: the electric motor. Thus, in the 4th chapter several optimization techniques were presented. An important aspect of the motorization is related to a sensitive problem: the thermal behavior of the machine, knowing that the EM should assure the safe operation for an imposed driving cycle. Thus, the heat transfer for several electrical machines and its implication was evaluated in the 5th chapter.

In the 6th chapter were discussed the control techniques used for the motorization of the EV, the motor-drive capability to operate in faulty conditions and the operation beyond the rated speed. The energy (necessary to assure the motor's operation) comes from a battery (most commonly), or ultra-capacitors and fuel cells. This topic, of the hybrid source and the energy management was presented in the 7th chapter.

Interesting new research topics were discussed in the 8th chapter of the habilitation report: the use of high speed motorization and its control, the use of magnetic gear instead of the classic mechanical one, and the implementation of the Hardware-in-the-Loop (HiL) and Rapid Control Prototyping (RCP) concepts. Such topics are opening a wide research perspective in which national or international partners could be involved.

3. Conclusions

I mention, just from the beginning, that I greatly appreciate the research activity and the results obtained by Mr. Daniel Fodorean. This assessment takes into account both the scientific results and the visibility of the published scientific papers. Mr. D. Fodorean has published 10 papers in ISI journals, 13 in international conferences volumes with ISI quotation, a patent ISI, 23 papers in international conferences

volumes listed IDB. The published scientific papers have a significant impact because they have over 90 citations.

I make the remark that D. Fodorean had an important preoccupation for the implementation of scientific research results in the industry. In this context the following research contracts are relevant, for some of them he was manager of the project:

- "Design of two types of special electrical machine". Industry project between Technical University of Cluj-Napoca and XANTOS (Switzerland). Manager: Daniel FODOREAN.
- Assistance for the manufacturing and the testing phases of special electrical machines". Industry project between Technical University of Cluj-Napoca and HYTEN (Switzerland). Manager: Daniel FODOREAN.
- Hardware-in-the-Loop Modular Platform for Testing the Energy Management of Competitive & Highly-Efficient Hybrid-Electric Vehicles - PCCA
- Intelligent Hybrid Vehicle for Individual Transportation of Low Mobility Persons – TE
- Design and control of a dual excited synchronous machine - TD

These research contracts allowed equipping a research center (CAREESD -of the UTCN) with good quality and high performances equipment. This infrastructure provides a greater value and higher credibility in scientific research leading to better opportunities in the cooperation with the electrical engineering industry.

From the content of the habilitation thesis and due to all research activities results that Mr. Daniel Fodorean has good research competences, undeniable, in the following research directions:

- Electromagnetics (methods of calculation of the electromagnetic field, including numerical methods);
- The design and the control of electrical machines and the associated static converters;
- The design of electrical machines used for the propulsion of vehicles or in wind systems;
- The tolerance to faults of the electrical machines and drives.

All these competences are part of the electrical engineering domain, so that the solicitation of the candidate for habilitation in this area is fully justified.

The topics studied by Mr. Fodorean Daniel have great theoretical but also practical importance. It should be noted that by making experimental models he was able to verify experimentally the theoretical research results.

From the documents in the map results that Mr. Daniel Fodorean fully satisfies the criteria for public presentation of the habilitation thesis, in order to obtain the certificate of habilitation in Electrical Engineering. The score achieved is 958.84 points, much greater than the minimum of 440 points required by CNATDCU. Criterion 1 - Academic / Professional - Minimum 80 points, achieved 136.88 points, Criterion 2 - Research - more than 300 points, realized 701.54, Criterion 3 - Recognition of the impact of activity - at least 60 points, achieved 120.42 points .

The many methods and mathematical models used prove that Mr. Fodorean Daniel has exceptional scientific background, which allows him to coordinate the work of future PhD students.

Considering all the mentioned above, I believe that thesis for habilitation of Mr. Daniel Fodorean satisfies all the scientific requirements, so that's why I claim that habilitation thesis is acceptable and the author, dr.eng. Daniel Fodorean, is suitable for obtaining a certificate of habilitation in electrical engineering.

Timisoara, 15 August 2014

Prof.dr.eng. Dumitru TOADER
Politehnica University of Timisoara





REPORT

On the Habilitation thesis

Optimum Design of the Motorization of Electric Vehicles based on Multiphysic Approach,

Author Daniel FODOREAN

The present habilitation thesis summarizes the achievements and the perspectives of the teaching and research activities of Daniel FODOREAN, to prove his capability to manage research. The habilitation criteria being fulfilled, we can say that the preliminary conditions for reviewing his scientific report are established.

The multidisciplinary approach of the author is the result of a work in two research institutes, from two countries, carried out during the PhD period. This period opened the opportunity to other collaborations: the author worked several years in France, after that he had the statute of "invited professor", and where he was or he is involved in several research topics and projects proposals. This cooperation has produced significant scientific results which were published in several IEEE journals. The capacity of the author to implement research cooperation, with universities or companies from Romania, France or Switzerland, proves his ability to manage research and researchers, especially in the field of Electric Vehicles. Some results have been obtained also in the field of renewable energies, but the main research focus is oriented to the EV application. In order to keep a high level of his research, the author has been also involved in editorial activity, as scientific secretary for an international journal and reviewer for two IEEE societies: IEEE Industrial Electronics and IEEE Vehicular Technology.

Each chapter starts with the framework of the research and the main scientific results. By applying a metaphysics approach, the author is investigating the electrical motorization having in mind several perspectives: the mechanical perspective, the optimized-design perspective, the thermal behavior aspects, control/fault tolerance/wide speed range perspective. The influence of the hybrid source and energy management is investigated too. The future work chapter brings other topic in the reader's attention: the possibility to increase the power density of the motorization based on high-speed machines and the use of magnetic gears, and the use of RCP HiL concept to improve the analysis quality on the EV's motorization. All these elements are presented in detail in 8 chapters.

The first chapter of the habilitation manuscript contains the state of the art of the EV and the summary of main scientific results: 5 books, 10 ISI journal articles and many international conference proceedings. He was the project manager for 4 research projects: two international/industrial projects and two national grants, financed by the Romanian government. For these results, the author was involved in the elaboration of many test benches; some obtained results are presented for each topic.

The second chapter contains different topologies of electrical machines which can be used to propel electric vehicles in general, and electric scooters in particular. Inner rotor or in-wheel topologies were presented. Also, different hybrid excited configurations were proposed.

The third chapter presents the overall design approach for the main studied machines, on which the optimization algorithms are relying on. The improvement of the studied machines performances is obtained based on optimization algorithms like: gradient type, response surface method or evolutionary algorithms, used to increase the power density of the motorization. These topics are discussed in the fourth chapter and represent an important achievement on the research.

The thermal behavior, the fault tolerance capability, the control and the wide speed range operation are topics discussed in the 5th to 6th chapters and which have been extended to the main rotating electrical machines. Even if more experimental results and validation are expected on these topics, the main performances were presented in 5 ISI journal articles, with important impact factor.

The seventh chapter presents the research results with respect to the energy management topic. The hybrid source on board of the EV is a very sensitive subject and more work needs to be done, knowing that the experimentation involves important budget and risk - especially when working with lithium batteries, which are very unstable, due to their reduced internal resistance.

The perspective of the research is presented in the 8th chapter. The author is trying to explore the limits of the high speed motors, when coupled with magnetic gear. These solutions are intended to contribute to the increase of the autonomy of the EV. Moreover, the use of RCP and HiL approaches play an important role in sparing money and in assuring the appropriate control of electrical machines and drives; this topic can be extended to the other subsystems installed on the EV: the cooling system, the steering system and so on.

In conclusion, we can notice the multidisciplinary character of the author's approach, the quality of the scientific papers and his capability to manage the research and researcher. This is why, I am favourable for the public presentation of this report and I am proposing to grant to Mr. Daniel FODOREAN the Habilitation title.

Iassy, July 2014

Professor Marcel ISTRATE, Dr.eng

