FUNDING APPLICATION

Project title:

Energy Conversion System for an Electric City Bus/Microbus, with Supercapacitor Energy Storage and Superhigh Power Density Drive

Acronym:
ECON-BUS

B.2 Scientific description

B. 2.1 Project Scope and Objectives

B. 2.1.1 Presentation of the project scope and the description of the demonstration model

This project goal is the development of a small scale (reduced power) laboratory demonstration model for an *urban electric transportation energy conversion system*, using supercapacitors (SC) as main energy storage devices and a super-high torque/power density permanent magnet synchronous motor/drive. *The description of the proposed demonstration model is based on the concept* presented in the block diagram from Fig.1.

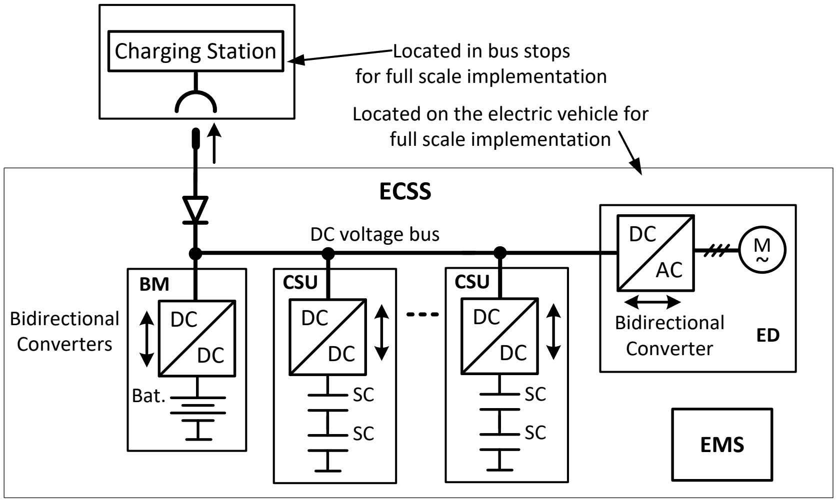

Fig. 1 The block diagram of the proposed demonstration model, representing the energy conversion and storage system located in an urban public transportation vehicle (electric bus or microbus).

The demonstration model implements the elements enclosed in the rectangle, representing the energy conversion and storage system (ECSS), composed of: bidirectional DC-DC converter-supercapacitor units (CSU), backup battery module (BM) and electric drive (ED). Load torque profiles, simulating real vehicle regimes, required for tests, will be provided by a *programmable active load* (not represented in **Fig. 1**) including an electric machine mechanically coupled with ED. In full scale implementation, ECSS is located in the public transportation vehicle (electric bus or microbus). BM is used as an auxiliary energy storage device. The energy and power flow control is implemented by the energy management system (EMS). ECSS main operating modes are: charging, driving and regenerative braking.

In charging mode, ECSS is connected to the charging station. The supercapacitors are charged very fast, at maximum allowed current, controlled by the bidirectional DC-DC converters. For full scale implementation, *the charging is done in less than one minute, while the vehicle is stopped in a station*. The charging stations are placed in some bus stops or stations on the route.

In driving mode, ECSS is disconnected from the charging station and the energy is taken from SCs through DC-DC bidirectional converters and delivered to the electric drive. One or more CSU modules are used as a function of the required ED instantaneous power and energy levels, *having an innovative modular structure*. EMS automatically connects the battery to the DC voltage bus if the energy of the SCs drops below the minimum allowed level. *The battery has low energy storage capacity and is used only as a backup power source*. Normally, the battery should contain only enough energy to ensure that the bus travels on a route that is equivalent to twice the maximum length between two stop stations, no more. Or, the energy stored in the battery must ensure that the bus moves to the service station in the event of a fault in the supercapacitor charging system.

During the regenerative braking periods, the energy is taken from ED through the bidirectional DC-AC converter and transferred to the DC voltage bus. The bidirectional DC-DC converters use this energy to charge the SCs. *In all operating modes, the DC voltage level is controlled by EMS* through the bidirectional DC-DC converters from CSU and BM.

B. 2.1.2 Novelty and relevance of the preliminary results related to the project

Supercapacitors have much higher power density compared with batteries, being suitable for very fast charging with many charging/discharging cycles (up to *1 million compared to up to 5000 for a battery*), a clear advantage in modern urban electric transportation systems. The main disadvantages compared with the batteries are the reduced energy density and relative higher cost [1].

The recent improvements in the supercapacitors technology, regarding especially the energy density [2,3], already allows the usage of these devices in energy storage systems, in association with or without rechargeable batteries. Due to this fact, there are research efforts in some universities and companies in the world to develop a viable technology for electric public transport vehicles with SCs for energy storage, assisted or not by rechargeable batteries [3,4].

The SCs are used in electric and hybrid transportation systems *as auxiliary energy storage devices*, to harvest the energy at braking periods and provide additional energy (to boost the power) for short period of time with high currents [5].

The use of supercapacitors as a main power source, for an urban electric public transportation vehicle (EPTV) is not a new idea in the scientific literature and automotive industry. However, the concept described in *this project proposal presents relevant novelties in more than one engineering subdomain*. As Fig. 1 shows clearly, there are three major electrical engineering subdomains involved in ECSS: dc/dc power energy conversion; electric drive – topology and control; energy conversion management.

The most important novelty aspects of the proposed project regarding these three subdomains are:

1. **DC-DC power conversion**:
   - *Hybrid bidirectional converter topologies were proposed recently as novel and efficient solution* for energy management and power flow control in ECSS between SCs and the DC voltage bus, due to their *high performances related to large voltage conversion ratio required by SCs energy storage. The research team published several conference papers on hybrid DC-DC converters, connected to SCs, in some applications similar to this project [6-9].*
   - A few of the proposed solutions for charging supercapacitors through power electronics converters from the local electricity grid have been already implemented in industry. However, some of them use old technologies (like thyristors), that *are definitively not appropriate for the evolution of the smart grid, especially due to the lack of the control flexibility. Other commercial solutions use well mature power converter topology, which are characterized by high performance, but the number of power switches is high* (just to mention the 6 transistors three-phase bridge, and not to mention the controlled back-to-back power converter for bidirectional operation, having 12 transistors), making the solution sometimes very costly. **In contrast, as some papers published by the members of the research team show, a hybrid DC-DC converter with 3 transistors can provide the bidirectional power flow** for applications focused on supercapacitor charging and power flow control between two DC buses [6-7].
   - The **high control flexibility of the DC-DC hybrid power converters** have to be emphasized because it is easier to control the power and energy flow in DC, than in AC. The use of the DC voltage buses and DC-DC converter topologies in smart grid and in particular in electrical vehicles charging stations is increasing. In addition, it was proved in the literature and it is a fact already known that high level power can be obtained using DC charging. Taken in consideration these aspects, in our opinion at this moment DC charging is preferred for electric buses/microbuses for urban public transport.
   - In order to achieve high power density and high efficiency, Wide-Bandgap (SiC and GaN) switching devices will be used for the power converters.
2. **Electric drive:** the proposed solution for electric drive, which includes a dual-stator, permanent magnet synchronous motor (PMSM), is distinguished by the following advantages:
   - **Short-term torque density without demagnetization of magnets over is 120Nm/liter** at an outside diameter of 270mm. According to our information, the highest torque density in industry, (at the same current density: 19A/mm^2) was obtained and is commercially available HEV and EV (Toyota, etc.) and

it is about 80 Nm/liter at the same outer diameter (270mm). Similar torque density figures (80Nm/liter) were been obtained for a race car PMSM drive [10]. According to electrical machines experts, the density of torque/liter of active material increases "naturally" with the outer diameter of the motor; that's why the proposed solution can have in real conditions (1:1 scale microbus) even better performance in this aspect. The work on this motor (theoretical calculations, torque estimation, FEM analysis, etc.), was performed at the Electrical Engineering Dept. from University of Texas at Dallas, under supervision of **Prof. Boldea (a member of the project team)**, which proposed the motor topology. The preliminary results, with detailed FEM analysis, were published in [11].

- As a consequence of the advantage mentioned above, **the type of PMSM proposed in the project can also be used for direct drive**. For a complete analysis, two variants will be tested: one with mechanical transmission (probably with fixed ratio), the other with direct drive (having the advantage of eliminating mechanical transmission). Because no prototype has been built for the motor until now, its performances in both situations have to be experimentally verified, in order to confirm the theoretical and preliminary simulation results.
- **The proposed PMSM, due to the use of permanent magnets, has low rotor losses** (only the additional ones) and therefore works best at small speeds (regarding efficiency, heating etc.), so it is suitable for public transport applications, with supercapacitors charging in stations, in short time, and low capacity back-up battery.

3. **Energy management system:** its purpose is to check and control the power and energy flow in ECCS. Two major advantages are:

- **The capability of raising the voltage level at the connection with the charging station**, in Fig. 1. When the bus is stopped in a station, before the connection to the charging station is made, EMS controls the voltage of the vehicle DC bus at a value higher than the voltage at the charging point. After the voltage of the DC bus in Fig. 1 exceeds the voltage at the diode anode, the connection to the charging station is initiated at zero current. The starting of the charging process is as simple as to smoothly decrease the DC voltage bus until the diode goes in a polarized state. Of course, the charging current will be continuously controlled after that moment. The diode is used only to illustrate the principle. In a 1:1 scaled system it is replaced by a three-phase diode bridge.
- **The flexibility of the droop control, which can be used for dc/dc hybrid converters.** Details of this aspect are provided in [12-14]. The droop control has the advantage of being decentralized, autonomous and easily expandable without needing a communication network between system's elements. For this case, each CSU has its own controller which does not communicate to other controllers from the DC bus therefore it has more options with regards to compatibilities between different strategies applied in the project. The latest research papers, focused on energy and power management in EPTV prove that the control of the DC voltage bus provides high flexibility and efficient power flow control [12]

B. 2.1.3 Presentation of the project objectives and their correlation with the outcomes of the project

The project objectives and the related outcomes are presented in **Table I**.

The first objective (O1) is oriented to the integration of the system components (converters, drive, storage units, energy management concepts) previously investigated during the project team research activities in one single unit, in order to obtain the digital simulation model. The simulation results will define the specifications to be introduced in the entire system design and the implementation of the demonstration model.

The second objective (O2) is to make extensive tests in a dedicated test bench. Various control strategies and energy management of the system will be implemented and compared in order to evaluate and select the proper solution for an optimum energy efficiency, drive and storage performances. The results will be introduced in an extensive report on the system.

The third objective (O3) consists in capitalizing the obtained results through patent application, scientific papers and workshops with the participation of the industry, in order to continue this project at a superior TLR level.

Table I Project objectives and outcomes

No.	Objective	Outcome
O1	*Design and implementation* of the demonstration laboratory model, *based on preliminary research and digital simulation results*	O1.1. *Technical project of the demonstration model including the digital simulation model*, containing the electrical diagram, drive and converter topologies, supercapacitors, batteries; O1.2. Demonstration model implementation: hardware and software.
O2	*Demonstration model validation* in various operation modes, by experimental results	O2.1. Experimental results for the demonstration model, in different operating modes and situations; O2.2. Project reports, including demonstration model validation.
O3	*Dissemination* of the project results	O3.1. Patent application O3.2. Conference and journal papers O3.3. Technical workshops for companies from automotive industry

Technical feasibility of the project is assured by the fact that the research team members were involved in projects which deal with subsystems similar to the modules included in this project. For example, a part of the project research team (in charge with power electronics) proved through simulations and experimental results presented in conference and journal papers that SC can be interfaced with a DC voltage bus (with a level close to that used in this project) in a microgrid system. The part of the team in charge with the electric drive was involved in numerous projects focused on optimal motor design, electric drive control, etc., publishing many high cited conference and journal papers. Moreover, in our team there is also a respected control specialist, which has a long term experience in electrical drive control and power electronics control.

Economic feasibility is warranted by the fact that the demonstration model will be a small scale (reduced power) system; in this way the financial costs related to the equipment acquisition will be well within the project budget. The scaling can be done down to (2kW - 10kW), in which range all the electric and electronic components will be affordable. *The most expensive component is the supercapacitor.* However, the evolution of the supercapacitor technology encourages the use of this device in electrical vehicle for public transportation in near future. The supercapacitor energy density has increased several times, in the last years, according to information available [2,3]. Continuous improvements are expected in the future, due to the high research effort sustained by the manufacturers, most of them willing to get a superior percent from a multi-billion market.

B 2.1.4 Presentation and argumentation of TRL values at the beginning and ending of the project

The project is focused on the implementation of a small scale laboratory demonstration model for an *urban electric transportation energy conversion system* starting from the concept presented above and partially documented in [15-16], representing the *technology readiness level TRL2*.

The concept is defined by:

- Energy conversion and storage system structure shown in Fig.1
- Energy management system which implements the energy and power flow control for operating modes described in B2.1.1

The project outcomes are targeting the technology readiness level TRL3, defined as experimental proof of concept, due to the following:

- A small scale (reduced power) laboratory model for the complete energy conversion and storage system of a public transportation electrical vehicle will be implemented;
- The software packages for energy management and power flow control will be produced;
- The laboratory model will be tested in all operating modes and situations and the experimental results will be included in intermediate and final reports;
- The outcome of comparative performance analysis between various energy management and power flow control strategies will be provided.

The results can be used as a starting point for 1:1 scale validation (TRL4).

B. 2.2. State of the art

SC based electric vehicle prototypes for public transportation have been initially tested in China, in collaboration with USA, in the recent years [17]. SCs can be recharged in very short time, while the bus (or microbus) is stopped in a station [18]. Recently the supercapacitor powered electric bus has been also introduced to Europe [19] therefore it is a trend for *replacing conventional public transportation vehicles with "green buses"*, and SCs are a possible energy storage solution with continuous improving performances. The state of the art of SC technology on the market is based on graphene. Compared with lithium battery, the graphene supercapacitor has much higher specific power density, but at lower specific energy density [20]. The highest SC energy density already obtained, according to [3], is presented in Table II. From the initial expectations of [2] the present results have more than double the expected performances, as presented in Table II, which may lead to extending the travel between two chargings considerably.

It is expected that the energy density will increase more in near future, because the potential of this technology is not fully achieved.

Other environmentally friendly technologies developed from orange peel nitrogen [21], or PET waste [22], for developing SCs are researched, offering competitive performances.

Table II. Comparison between lithium battery and various types of supercapacitors,

Storage Device	**Specific Energy Density (Wh/kg)**	**Specific Power Density (kW/kg)**
Lithium battery [2]	70-250	0.2-1
Conventional Double layer SC [3]	5	9
Asymetric Double layer + pseudocapacitance [3]	30	5
Hybrid Double layer + faradic [3]	100	4
2016 Forecasts of Graphene-Based SC performances [2]	41	26
SC with highly porous graphene electrodes [23]	148	41

Three applied research directions are important for this project: *energy conversion and storage system structures* with the associated energy and power flow management strategies; *bidirectional DC-DC converters topologies and control*; *high performance electric drives*. State of the art components, presented below, are required for this project concept implementation for optimal energy consumption, in order to efficiently use the SC stored energy.

The energy conversion and storage system structures presently used in public electric transportation vehicles, shown in Fig. 2, connect the energy storage and conversion devices through a DC voltage bus, allowing easy implementation and providing a high level of flexibility and efficiency.

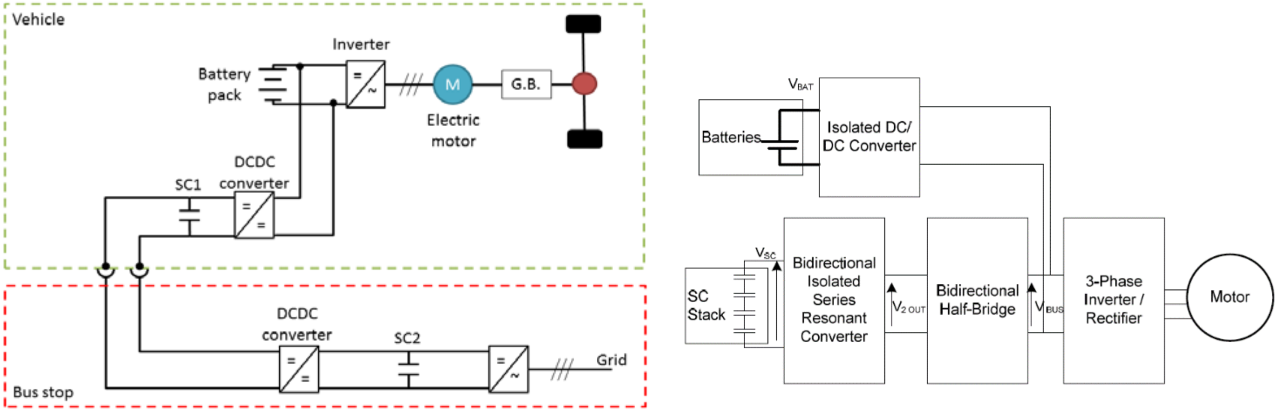

Fig. 2.Conversion and storage system structures: Structure 1 (left); Structure 2 (right).

In structure 1, the battery can be used only in worst operation conditions such as traffic jams or long runs, or can work as most as possible in a steady state condition [15]. Power peaks are taken from SC to extend the battery life.

In structure 2, using a separate DC-DC converter to connect the assisting battery has the advantage of selecting the batteries at a voltage level different than the DC voltage bus. In addition, the battery power flow control is much better because it is done independently.

Various algorithms can be used for the energy management, including state machine control based on an equivalent consumption method [24], or optimal energy management and control method [25].

Even if the classical methods are centralized methods, in microgrid applications decentralized methods are also employed, such as [12-14], which can be very useful for electric vehicles when the benefit of modularization is desired for the SC storage units. Using a decentralized energy management strategy has the advantage of adding any number of SC storage element in the vehicle, without the need of major changes in the system.

Even though the classical bidirectional converter (buck/boost) can be used, *the requirement of high energy conversion efficiency for these applications imposes the use of novel structures.* Soft switching techniques can be used in these novel topologies to further improve the efficiency [18]. Coupled inductors included in bi-directional DC-DC topologies help to achieve higher conversion ratios at high efficiency [19]. With a carefully designed control, some bidirectional DC-DC converters allow efficient utilization of the SC energy, in all operating modes (buck, boost and buck-boost), for a large voltage variation, providing full SC stored energy usage [20].

Hybrid topologies, obtained inserting C-switching cells or/and L-switching cells into the structure of conventional converters, also have a high voltage conversion ratio and are suitable for supercapacitor-based energy conversion and storage systems [6-9]. Two hybrid bidirectional DC-DC converter successfully tested by members of this project research team, for interfacing a SC to a DC voltage bus incorporated in a microgrid system [6-7] and are presented in Fig. 3. Both topologies were used with good results as a supercapacitor charger, proving also the stability. A novel nonlinear droop control method [12] for the supercapacitor energy management was also employed with one topology.

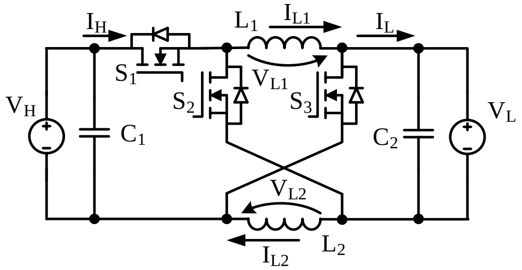

Fig. 3. Bidirectional hybrid DC-DC converters successfully tested for SC storage [6,7]

Our team is currently developing other topologies developed specifically for supercapacitor storage applications, already presented at conferences, and can be seen in the following figure.

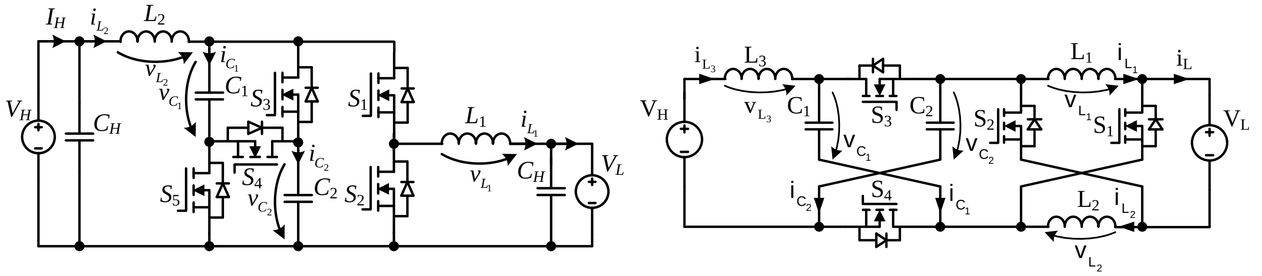

Fig. 4. Bidirectional hybrid DC-DC converters under development [8-9]

A high efficiency, high torque/power density double stator PMSM is considered in this project. The double stator machine and tangentially magnetized PM rotor (the proposed solution) in between has been evaluated by finite element analysis to produce a high torque density up to 120Nm/l and 19.6Nm/kg for short time, at 264mm outer stator diameter/ 166mm length and 19A/mm2 current density.[11]. According to available information, the highest torque density 80Nm/l at the same current density (19A/mm2) is commercially available on HEV and EV Toyota at similar diameter (270mm) on a PMSM spoke type motor and 15Nm/kg on YASA 400 axial PM motor [26].

The project team has the following structure:

The coordinator (ROMANIAN ACADEMY, TIMIȘOARA branch) has 4 senior researchers in the team, one of them being full academician. The project leader is Prof. Nicolae Muntean.

The research team of the partner (POLITEHNICA UNIVERSITY TIMIȘOARA) has 8 members, one is senior researcher, one is CS3, one is research assistant, four are PhD students and the last is a master student. The person in charge for partner is Lecturer Octavian Cornea.

The background of the project members relevant to the project proposal is shortly presented below:

ROMANIAN ACADEMY, TIMIȘOARA branch:

1. Prof. Nicolae Muntean, project leader:
   - -more than 35 years' experience in power electronics and electric drives
   - -more than 80 conference and journal papers on power electronics and electric drives
   - -more than 20 research projects (as member or coordinator) including industry cooperation in the field of power electronics, renewable energies and energy efficiency
   - -17 Romanian patents
2. Acad. Ion Boldea:
   - -30 book titles on www.amazon.com, on the topics of electric machines and drives
   - -received the Nikola Tesla Prize (equivalent to Nobel Prize for Electrical Engineering)
   - -more than 200 conference and journal papers on topics of motor design and control
3. Prof. Nicolae Tutelea:
   - -more than 20 years' experience in motor design and control
   - -more than 100 conference and journal papers on topics of motor design and control
4. CS2 Ileana Torac:
   - -more than 30 years' experience in motor design
   - -more than 60 conference papers on topics of motor design and optimization

POLITEHNICA UNIVERSITY TIMIȘOARA:

1. Lecturer Octavian Cornea, person in charge for partner:
   - -more than 20 years' experience in power electronics
   - -more than 40 conference and journal papers on topics of power electronics
2. Prof. Gheorghe-Daniel Andreescu:
   - -more than 20 years' experience in power electronics
   - -more than 40 conference and journal papers on topics of power electronics
3. Asist. Prof. Ana Popa:
   - -more than 10 years' experience in electric drive control
   - -more than 10 conference and journal papers on topics of electric drive control
4. PhD student Dan-Cornel Hulea;
   - -more than 10 conference and journal papers on topics of power electronics
5. PhD students: Liviu-Danut Vitan, Adrian Martin; involved in several research and industry projects in the field of electric drives and automation
6. PhD student Denisa Diaconu and Masters student Mihaita-Constantin Gireada: held various engineering positions in automotive industry in companies with potential interest in technology transfer

B. 2.3 Method of project implementation

B 2.3.1 Description of the activities required to meet the project goals, with the explicit contribution of the research team members. Deliverables associated with each activity.

The activities, corresponding deliverables, team members responsibilities and the person-month (pm) work effort are presented in Table III.

Table III Activities, deliverables and the roles of the research team members

No.	Activities	Deliverables	Team member's roles	pm
A1.1	Development and test of the simulation models for the system components	D1.1-1 Simulation model for bidirectional DC-DC converter – supercapacitor module - software package and simulation report	Responsible: L. Tutelea Control strategy: G.D. Andreescu Software implementation: D. Hulea	2,5
		D1.1-2 Simulation model for bidirectional DC-DC converter – rechargeable battery module – software package and simulation report	Responsible: O. Cornea Control strategy: G.D. Andreescu Software implementation: D. Hulea, D. Vitan, M. Gireadă	
		D1.1-3 Simulation model for the electric drive (DC-AC converter and PMSM motor) – software package and simulation report	Responsible: I. Boldea Control strategy: G.D. Andreescu Software implementation: L. Tutelea, A. Martin, I. Torac, A. Popa	
A1.2	Integration and extensive testing of the component models of energy conversion and storage system in simulation	D1.2-1 Complete simulation model of the energy conversion and storage system –software package and simulation report, including testing	Responsible: N. Muntean Control strategy: G.D. Andreescu Software implementation: O. Cornea, L. Tutelea, D. Hulea, M. Gireadă, D. Diaconu	3
A1.3	Design of the energy conversion and storage system	D1.3-1 Technical project	Responsible: N. Muntean Conversion and storage: O. Cornea, D. Vitan Drive: I. Boldea, L. Tutelea, A. Popa, I. Torac Automation: G. D. Andreescu	3
		D1.3-2 Documentation related to the procurement of the necessary equipment and components	Responsible: N. Muntean Technical specifications: O. Cornea, D. Vitan, A. Martin	
A1.4	Implementation of the demonstration model	D1.4-1 Complete hardware of the energy conversion and storage system	Responsible: O. Cornea Hardware: D. Hulea, N. Muntean, L. Tutelea, D. Vitan, A. Martin	6,5
		D1.4-2 Software packages for the energy management and power flow control	Responsible: G. D. Andreescu Software implementation: D. Hulea, L. Tutelea, M. Gireadă	
A2.1	Design and implementation of the test bench for the demonstration model	D2.1-1 Test bench technical project	Responsible: L. Tutelea Technical team: A. Martin, D. Vitan	3,3
		D2.1-2 Test bench		
A2.2	Extensive testing of the demonstration model	D2.2-1 Intermediate report with the experimental test results	Responsible: O. Cornea Testing: D. Hulea, M. Gireadă Technical documentation: A. Popa, I. Torac, D. Diaconu	2,5

		D2.2-2 Comparative performance analysis between various energy management and power flow control strategies	Responsible: L. Tutelea Testing: D. Hulea, M. Gireadă, Technical documentation: A. Popa, I. Torac	
A3.1	Patenting	D3.1 Patent application	Responsible:N. Muntean Patent documentation: O.Cornea, N.Tutelea, G.D. Andreescu	0,8
A3.2	Dissemination of the project results in scientific and academic environment	D3.2-1 International conference paper (1)	Responsible: I. Boldea Project web site: A. Martin Conference paper: D. Hulea, D. Vitan, I. Torac, A. Popa	0,8
		D3.2-2 Project progress information on project website		
A3.3	Industrial, scientific and in mass-media results dissemination	D3.3-1 Technical presentations materials regarding the project results and perspectives to transfer in the industry - Workshop	Responsible: N. Muntean Conference paper: I. Boldea, O. Cornea, G.D. Andreescu Workshop: O. Cornea, D. Diaconu	0,8
		D3.3-2 International conference paper (3)		
		D3.3 Project progress information on project website		
A4.1	Project management	D4.1-1 Project website	Responsible: N. Muntean, O. Cornea Scientific adviser: I. Boldea	1,8
		D4.1-2 Time schedule of technical, administrative and financial tasks connected with the activities		
		D4.1-3 Analysis reports of the project stage and progress		
		D4.1-4 Financial reports		
		D4.1-5 Analysis reports of the project deliverables		

The activities are divided in four categories: *A1 – simulation, design and implementation of the demonstration model; A2 – testing the model; A3 – project dissemination, including patenting; A4 – project management*.

The activities start with components and *whole system simulation in order to obtain all necessary information for the expected performances evaluation and for design the demonstration model*.

The model implementation needs the *hardware and the control software* as main tasks. The software elements will be implemented and tested first in the *existing infrastructure*, using the digital systems and the converters of the “Intelligent Control of Energy Conversion and Storage” research center, in order to use efficiently the period when the demonstration model is built, after the design procedure is finished.

To validate the simulation results and the concept functionality, design and implementation on a *dedicated test bench* are needed. Some measuring and test devices, from the *existing infrastructure*, will also be used for this scope.

Extensive testing procedures of the demonstration model will be performed in order to decide the *best energy management methods and power flow control strategies*.

Patenting, conference papers, technical presentations materials for the industry (to prepare new possibilities to access a superior TRL in upcoming research programs) and a workshop, will be the elements of the *dissemination activities*.

Project management will ensure, by proper means, the project development and evolution: time schedule of technical, administrative and financial tasks connected with the activities, technical and financial reports, deliverables analysis etc.

The project leader will be assisted, by Acad. Ion Boldea, the most experienced senior researcher of the team (as a scientific adviser), correspondent member of the Romanian Academy, IEEE Life Fellow. This association is an additional guarantee for the project realist objectives and success.

B2.3.2.The Gantt chart

The Gantt chart, with planned activities during the project, is presented in Table IV. The chart illustrates the overall flow of research, implementation and evaluation, identifying the interdependencies among the various project activities via deliverables and working documents.

Table IV Gantt chart

	Activities/month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A1.1	Development and test of the simulation models for the system components	▨	▨	▨																	
A1.2	Integration and extensive testing of the component models of energy conversion and storage system in simulation				▨	▨	▨														
A1.3	Design of the energy conversion and storage system: power converters; electric drives; control strategies; energy flow management.					▨	▨	▨	▨	▨											
A1.4	Implementation of the demonstration model										▨	▨	▨	▨	▨	▨	▨	▨			
A2.1	Design and implementation of the test bench for the demonstration model													▨	▨	▨	▨	▨			
A2.2	Extensive testing of the demonstration model																		▨	▨	
A3.1	Patenting										▨	▨							▨	▨	

A3.2	Dissemination of the project results in scientific and academic environment								▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
A3.3	Industrial, scientific and in mass-media results dissemination																		▨	▨	▨
A4.1	Project management	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨

B 2.3.3 Dissemination of results and intellectual property rights

The dissemination activities take in considerations the following aspects:

- *Patenting.* To protect the intellectual property rights, the project team will analyze the claims potential for: the proposed concept, the energy management and power flow control strategy.
- The knowledge (intellectual property) acquired within the project will be managed to offer specialized consultancy and know-how for potential clients from industry or academic community.
- *Dissemination of the results will run after the patent application completion and will be focused on the national and international visibility and on making connections to potential industrial partners.*

The project management team will identify the indexed national and international conferences most suitable for papers presentation and publishing. The main targeted events will be: transportation and environmental oriented conferences (especially about urban transport); power electronics, drives and energy storage conferences; joint conferences that make a connection between urban transportation, environmental issues and power electronics topics (topologies and control).

A guidance plan for scientific papers and workshop is presented below.

Conference papers:

- A conference paper with state-of-the-art in the project research fields and some preliminary results will be published after the patent application;
- A conference paper will be published at the end of the project implementation and will contain the final project results;
- The project management team will analyze the results obtained at the end of each phase of the project and will decide if the outcomes have potential for dissemination through additional conference papers.

Workshop:

- One workshop will be organized toward the end of the project implementation, with the goal to inform the companies about the final results and to discuss the possibility to go forward for reaching in common a superior technology readiness level (TRL4).

Mass-media, social media, website:

- Press releases will be prepared to disseminate key project achievements. Further press releases may be issued, accompanying major public achievements of the project, like public workshops and demonstration events;
- Social media channels (Twitter, Facebook, LinkedIn etc) will help to extend dissemination of project activities and results and, in particular, engage the general public and media;
- Team members will also use the project website to highlight project progress, upcoming events and publications.

B 2.3.4 Presentation of the research infrastructure available for the project and its development during the project

The project will use the infrastructure of the "Intelligent Control of Energy Conversion and Storage" research center (https://erris.gov.ro/Intelligent-Control-of-Energ) at Politehnica University Timişoara:

- The existing hybrid power converter, from the "*Microgrid laboratory*", will be used to develop the new conversion structure presented in the project;
- The control boards with DSP and the computer network, from "*Drive and industry automation*" platform will be the means to develop the software packages and the technical documentations, reports etc.;
- The existing mechanical coupled electrical machines and the bidirectional power inverters, from the "*Advance electrical machines test benches*", will offer the possibility to emulate various load regimes of the drive;
- The existing measuring devices (multimeters, digital scopes, power analyzers) and data acquisition modules, from "*Drive and industry automation*" platform and "*Microgrid laboratory*", will be integrated in the test bench dedicated to evaluate the demonstration model performances.

The infrastructure elements presented before will be also used in the design and preliminary experimental stages of the project, for a better time usage in the periods when the equipment and components, necessary for the demonstrator model implementation, will be acquired.

On the other hand, the project implementation implies new equipment acquisitions, including the demonstrator model and the test bench components. This equipment will be a good complement in the university labs, for research and, also, educational purposes.

B 2.3.5 The structure of research team

The research team is presented in Table V.

Table V The structure of research team

No.	Institution/Name	Position in project research team	Obs.
Romanian Academy, Timisoara Branch			
1	Nicolae Muntean	project leader	
2	Ion Boldea	senior researcher	Scientific adviser of the research team
3	Lucian Nicolae Tutelea	senior researcher	
4	Ileana Torac	senior researcher	
Politehnica University Timisoara			
1	Octavian Cornea	in charge	
2	Gh. Daniel Andreescu	senior researcher	
3	Ana Popa	research assistant	
4	Dan-Cornel Hulea	research assistant	
5	Dănuț-Liviu Vitan	research assistant	
6	Adrian-Daniel Martin	research assistant	
7	Denisa Diaconu	research assistant	
8	Mihăiță-Constantin Gireadă	research assistant	Master student

The medium age of the team members is 40 years that shows a good mixt between people with strong professional experience, enthusiasm and the desire for affirmation in the professional career.

B 2.3.6 Presentation of the risks associated with project implementation activities and ways of treating them

It is the responsibility of the project leader to promote and direct risk management for the project. He will schedule discussions about the risk management issues at management team meetings. In this way, the risks will be identified and assessed correctly and good actions will be planned to deal with them. The effectiveness of risk response actions will be track and monitor by the management team. All technical team members will be informed about the importance to identify in time the risks which could appear during project implementation, to ensure proactive response that will impact the successfully delivery of the project. The following risks can have negative influence on the project schedule and are addressed carefully:

- *Simulation software development delay*, due to the complexity of the component's simulation models. Estimated risk probability: 30%. The risk proactive action consists in development of simple models at the beginning, and growing the complexity only up to the point required for results accurate enough to evaluate the operation by simulation.
- *Theoretical analysis and simulation results do not match experimental results.* Estimated risk probability: 20%. To deal with this risk, the individual simulation models for components will be checked in intermediate steps. In addition, small tests will be designed and conducted for validation of each system component, prior to integrate it in the demonstration model.
- *Team member(s) leaving before project completion.* This will cause time delays. Estimated risk probability: 30%. This risk is managed by introducing common responsibility (more than one team member is familiar with critical aspects). Responsibility reallocation is also possible replacing the person which leaves (temporarily or permanently) with another one with similar qualification.

B2.3.7 Project Budget

The project budget structure, as total and divided per years and categories, is presented in Table VI.

The salary expenses are in relation with the work effort (pm) presented in Table III, *25 pm in total* and represents 40% of the project budget. The average salary is 60 lei/h, including taxes.

The logistics cost represents the equipment, materials and subcontracting, as Table VII shows.

Table VI. Budget structure

Allocated budget / costs (Lei)						
TOTAL		**Personal costs**	**Logistics**	**Travel**	**Indirect costs**	**Total**
Coordinator	**Public budget**	**140.000**	**213.000**	**27.000**	**34.100**	**414.100**
2020		65.000	51.500	12.000	15.700	144.200
2021		75.000	161.500	15.000	18.400	269.900
Partner 1	**Public budget**	**100.000**	**40.000**	**21.500**	**24.300**	**185.800**
2020		40.000	10.000	7.500	9.500	67.000
2021		60.000	30.000	14.000	14.800	118.800

Table VII Logistics cost

Equipments	Materials	Subcontracting	TOTAL Logistics costs (Lei)
240.000	3.500	9.500	**253.000**

The equipment costs (40% of the budget) cover the necessary elements to build the demonstration model (converters, storage elements, drives, control boards) – 70%, and the test bench (measuring and data acquisition devices) – 30%.

The materials costs include small components and consumables, representing 0,58% of the budget.

The subcontracting is 1,58% of the project budget and includes patent associated services, financial audits costs, workshop organization, equipment maintenance services etc.

The travel costs (8% of the total project budget) will be oriented especially on the participation at international conferences.

The indirect costs represent 20% of direct costs, minus subcontracting and equipment costs.

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