APME — Actualităţi şi Perspective în Domeniul Maşinilor Electrice
Electric Machines, Materials and Drives - Present and Trends
19, *1*, pp. 109-118, 2023

EDUCATIONAL PLATFORMS WITH DIFFERENT TYPES OF MOTORS FOR THE STUDY OF ELECTRIC PROPULSION SYSTEMS

Liviu POPESCU[1]
[1,2]National University of Science and Technology POLITEHNICA Bucharest, RO-060042, Bucharest, Romania
liviu_p@yahoo.com[1]

Abstract. Electric vehicles are already known but simultaneously new. In the last decades, an important evolution has been seen in electric energy storage systems, motor control, and the design of electric motors. The present paper's objective is to illustrate some examples of laboratory works implemented at the university didactical level. It emphasizes the importance of choosing an adequate electric powertrain as an integrated system, but also the role of the powertrain components for the performance of the electric vehicles. The implementation of the program involves simulation tools for the vehicle and the powertrain components, but also physical platforms integrating direct current, asynchronous, and synchronous motors.

1. INTRODUCTION

In recent years, the social context has implied the usage of remote tools and more and more digital learning scenarios [1]-[2]. But for the preparation of future EV (Electric Vehicle) specialists, the integration of physical applications in the learning process is a must. EVs are not a novelty [3], but the preparation for the future requires the development of new technologies and the integration of new techniques to improve their performance.

For the didactical platforms presented in the actual paper, the first step consists in offering via simulation [4]-[5], examples of the vehicle and the powertrain behavior. The next step consists of performing practical experiments on physical platforms [6]-[7]. There is a possibility to compare simulation and physical results for motor control [8], and torque distribution [9]-[10] in the case of powertrains with multiple motors, study the influence of motor efficiency maps [11], improve the energy consumption, and increase the whole vehicle performance. There is a triple looked-up objective in developing practical applications for propulsion systems, comparing the results of simulation and physical experiments, and offering perspectives for dipper research in this area.

Section two gives a general image of the simulation tools and physical platforms used, while section three gives information on their implementation. The next section presents the expected results and some examples of the realizations. Finally, the conclusion summarizes the achievement of the objectives by realizing the educational platforms and perspectives for the extension of the works.

2. STRUCTURE OF THE WORKS

As specified in the introduction the laboratory works are split into two categories: platforms using simulation tools, and physical platforms.

2.1 Simulation tools

The finality expected by the usage of simulation tools is to offer rapid results in controlling the electric powertrain components and the behavior of an electric vehicle.

For the powertrain components, the focus is on:

ISSN / ISSN-L: 1843-5912
DOI: 10.36801/apme.2023.1.14

- battery and charging process,
- electric motor types and techniques for their control.

A dedicated tool, SIMPLORER, has been used to develop such specific works.

Regarding the vehicle simulation, MATLAB/SIMULINK offers large perspectives. Once the models are built, the accuracy of results gives satisfaction. However, comparing different propulsion systems in different EV configurations becomes laborious. An alternative, also under MATLAB, is more appropriate for rapid results, using ADVISOR. The tool offers the possibility to build the SIMULINK model for the chosen EV configuration.

2.2 Physical experiments

A model explained in [6] has served as a base for the physical implementation of the works. Each studied motor is controlled individually and has a dedicated load. The objective is the control the motor for load coverage.

3. IMPLEMENTATION OF THE WORKS

3.1 Advanced vehicle simulator (ADVISOR)

Several parameters are available for simulation configuration. For the described laboratory works it is possible to configure the EV, and choose the motor, the electric energy source, and vehicle load, as presented in Fig. 1.

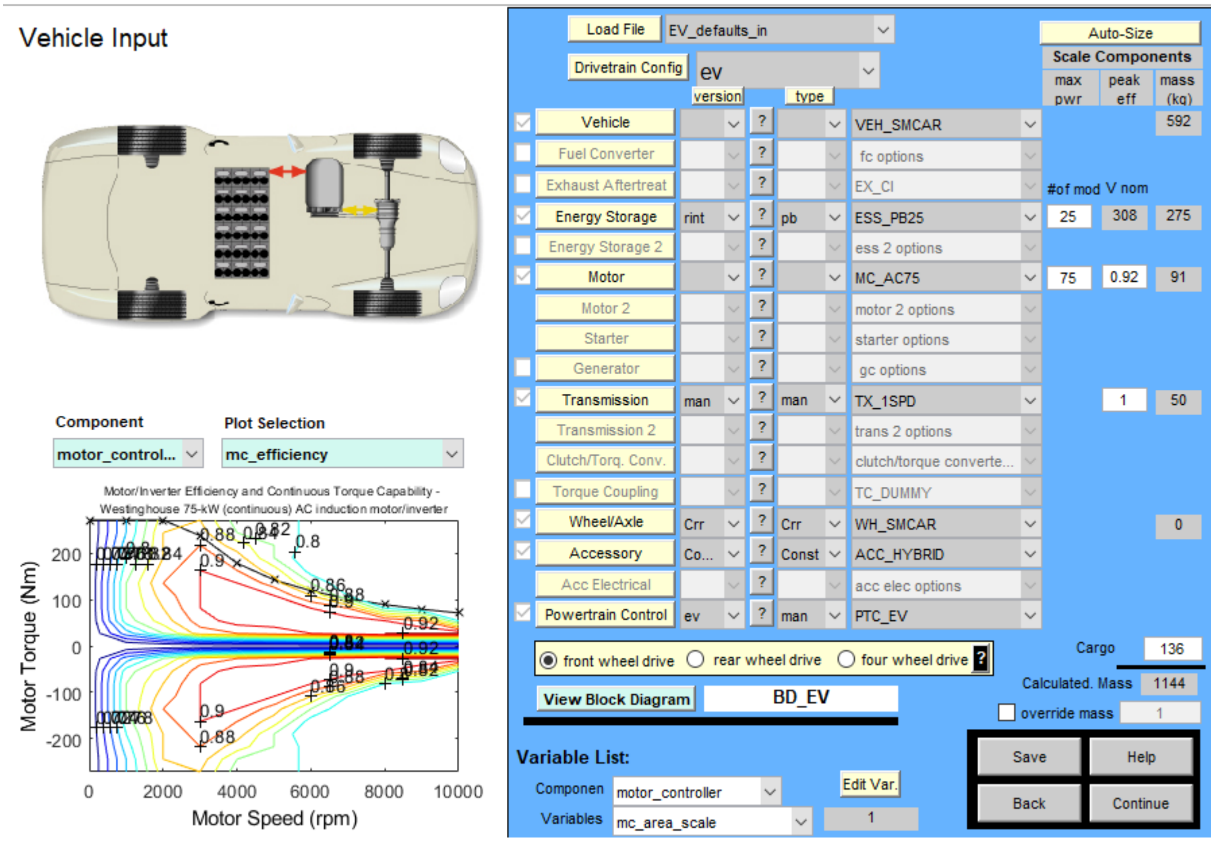

Fig. 1. Configuration of the simulated vehicle using ADVISOR

Additionally, the tool allows us to choose a testing cycle or to define one. It is also possible to modify or use predefined parameters.

3.2 EV powertrain components simulation

Figure 2 shows the main working screen in SIMPLORER which offers the possibilities to integrate predefined components (from the left side), build electric schema (as presented at the top of the figure), and observe the variation of chosen parameters during the simulation period.

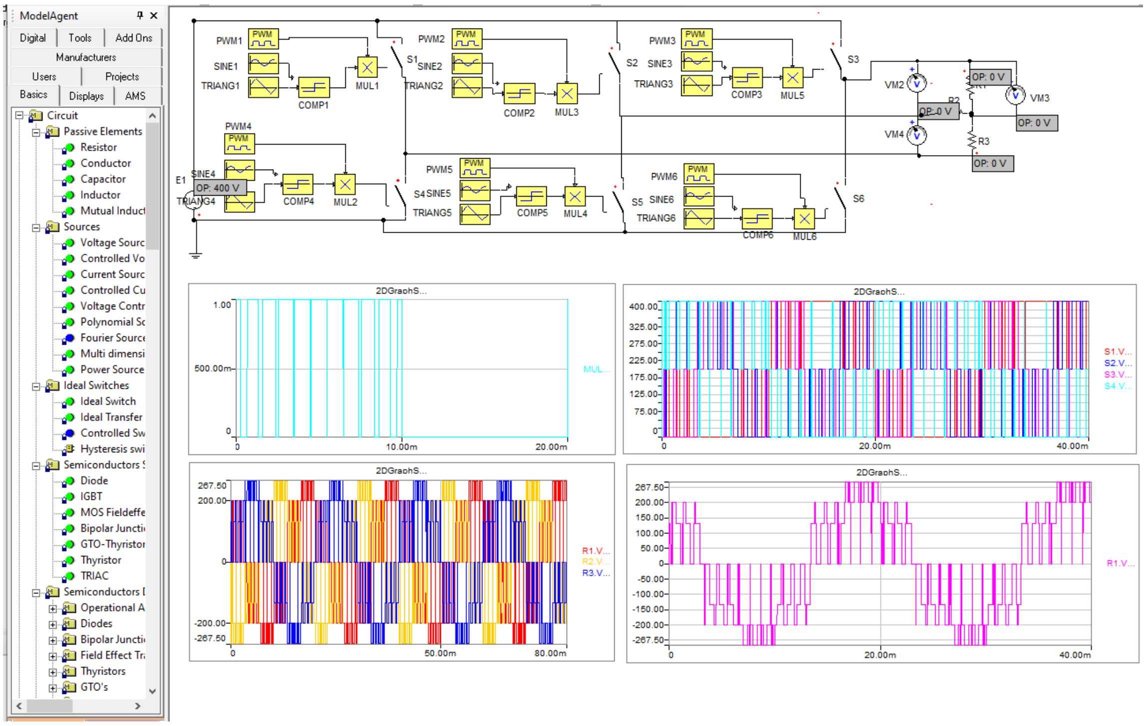

Fig. 2. Working screen for components simulation

3.3 Physical platforms

The platforms include DC (Fig. 3), asynchronous (Fig. 4 and 5) and synchronous (Fig. 6 and 7) motors.

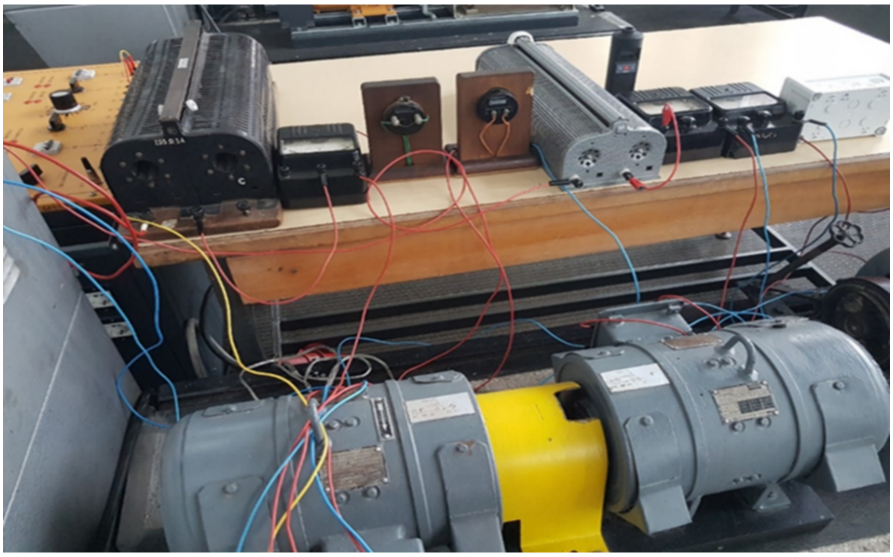

Fig. 3. Physical platform for DC motors


Fig. 4. Physical platform for induction motor – machines side

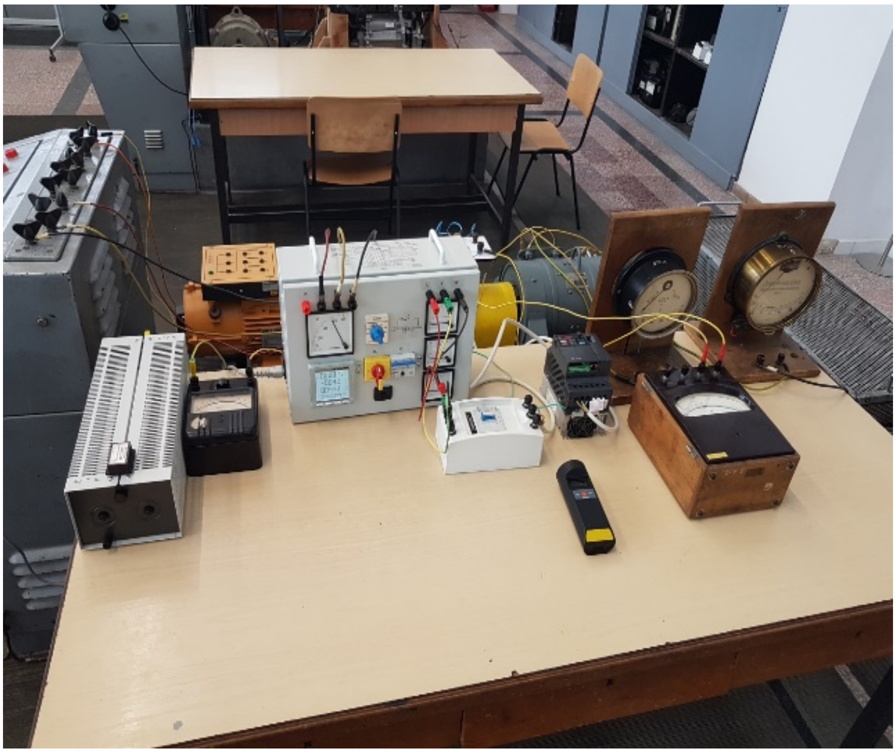
Fig. 5. Physical platform for induction motor – controller and measurement tools

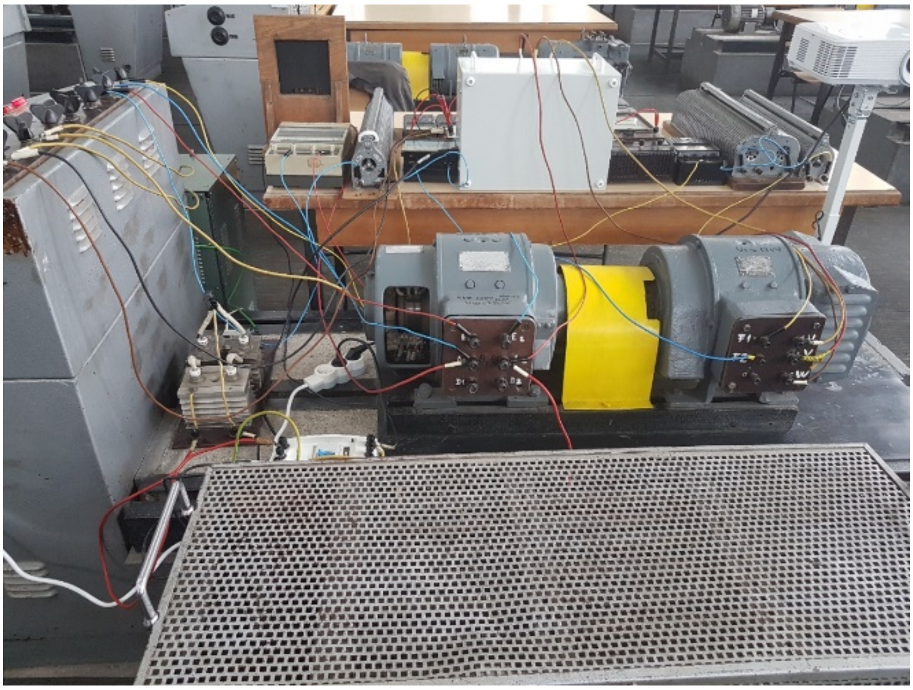

Fig. 6. Physical platform for synchronous motor – machines side

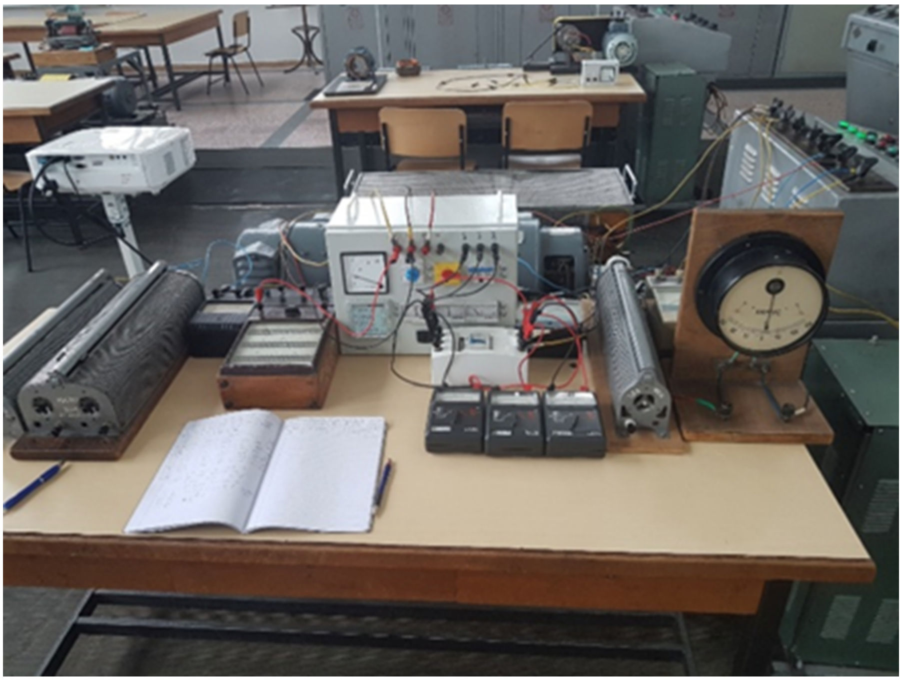

Fig. 7. Physical platform for synchronous motor – measurement tools

4. RESULTS

4.1 Powertrain components simulation studied matters.

1. Acceleration control of a DC PM electric motor:
   - realize under simulation a basic power supply schema of PM DC electric motor,
   - integrate a hysteresis control for the maximum motor current,
   - study the load influence of the motor capabilities in attempting the maximum speed.
2. Control of an Induction Motor (IM):
   - realize a basic power supply schema of an IM (Induction Motor) under simulation,

- control the motor using a constant ratio between voltage and frequency,
- supply the motor from a DC source (battery).

3. Controlling the charging of an electric battery from the power grid
   - realize under simulation a constant current charging schema for an RC equivalent electric battery,
   - integrate a hysteresis control for the maximum charging current,
   - study the parameters influencing the energy stored and the battery capabilities to move an electric vehicle.
4. Powering sinusoidal motors from DC sources:
   - realize under simulation different investors to provide sinusoidal motors with the alternative current,
   - use PWM signals for frequency control and inverters switches (transistors) command,
   - built an SPWM logic to control a sinusoidal motor.

Examples of the implementation of powertrain components using simulation are given in Fig. 8 and Fig. 9.

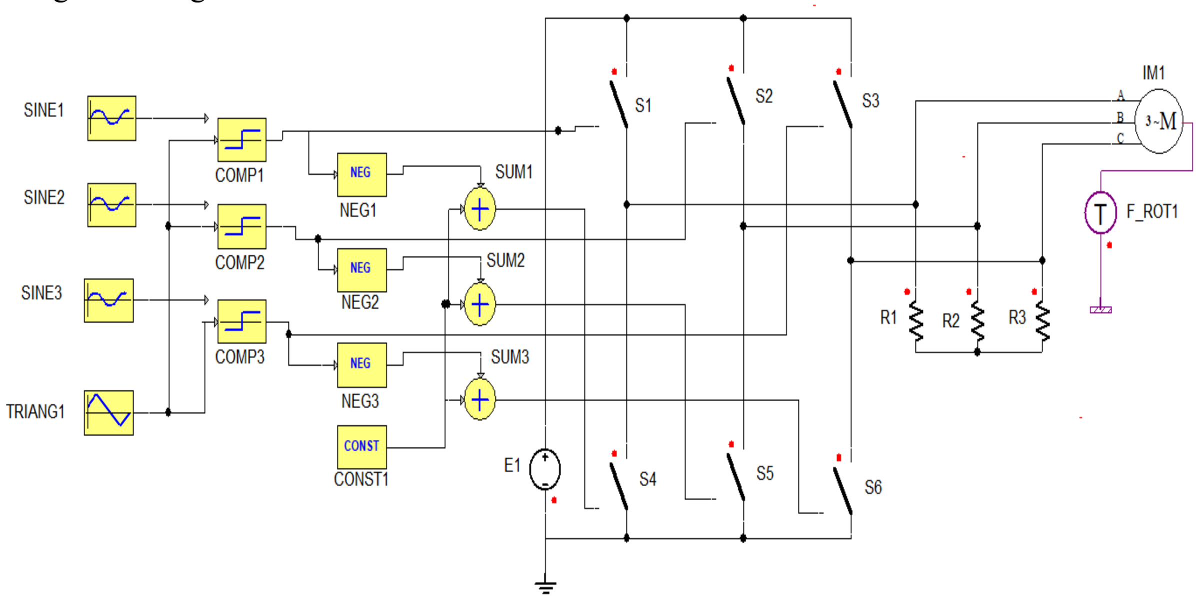

Fig. 8. Implementation of an SPWM logic control

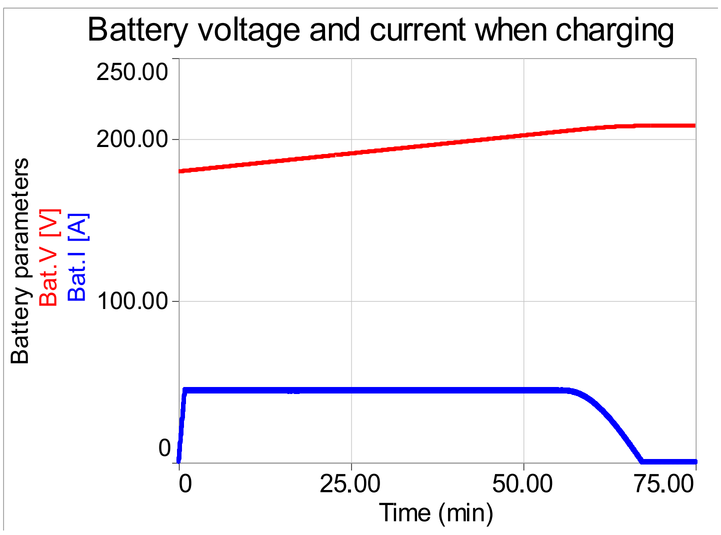

Fig. 9. Results of a constant current charging process implementation

4.2 Vehicle simulation studied matters.

1. Analysis of different onboard energy storages for EV:
   - realize an acceleration testing cycle,
   - configure the energy storage for an EV,
   - simulate the completion of the test cycle with different energy storages.
2. Vehicle mass influence on the propulsion system:
   - realize a comparative study of the capabilities of an electric propulsion system when increasing its power,
   - determine the minimum motor power and torque for a configured vehicle, able to respect a testing cycle,
   - for the chosen testing cycle, determine the dependence of the additional vehicle mass on the additional power needed for the motor.
3. Propulsion system calculation for the EV:
   - from a testing cycle profile, calculate the resistant forces for the EV,
   - represent the operating points in a torque speed plan,
   - choose the appropriate motor controller for the EV.
4. Electric motor efficiency map influence on the vehicle performance
   - understand the efficiency map of an electric motor,
   - analyze the vehicle performance using electric motors with different efficiency maps,
   - choose the appropriate motor controller for the EV.

The next figures present an example of a four-wheel drive vehicle using a PM powertrain. In Fig. 10, the image has been obtained directly from the simulation tool and gives the motor-speed characteristics and the efficiency maps of the motor.

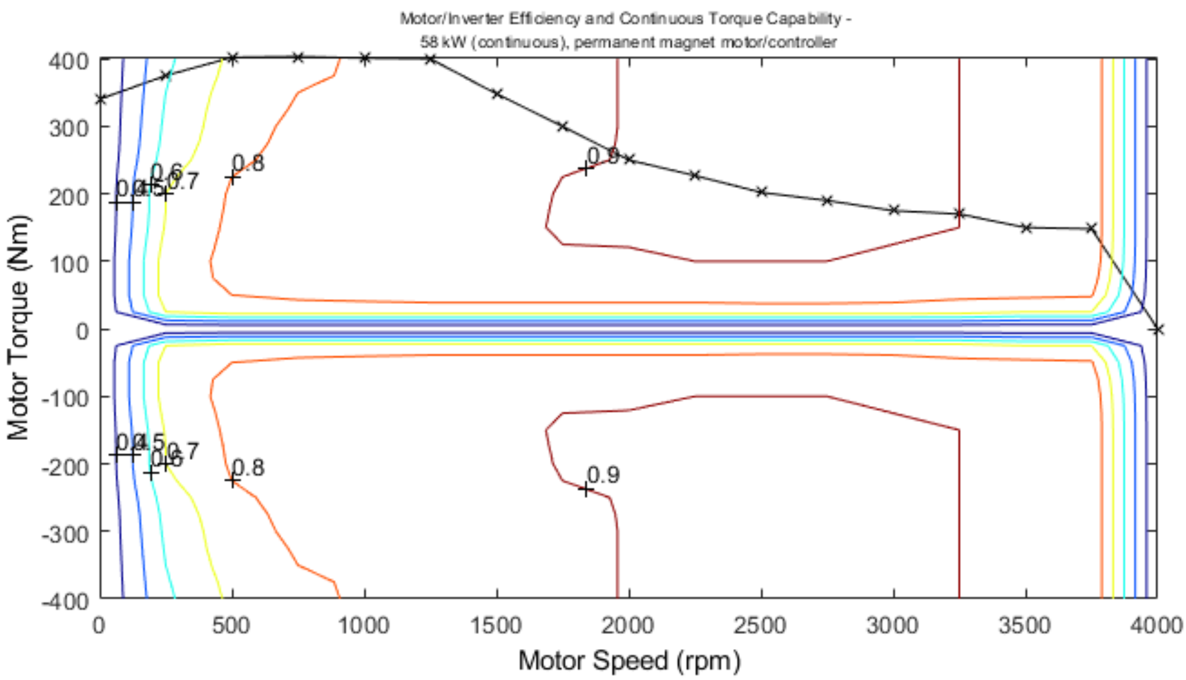

Fig. 10. Motor characteristics

Figure 11 shows an example of a testing cycle, FTP, used to compare the powertrain and vehicle performances for different studied parameters. Additional examples are given in Fig. 12 and Fig. 13 for two battery types used to provide the powertrain energy, one is based on Li-Ion, and the other on a NiMH battery.

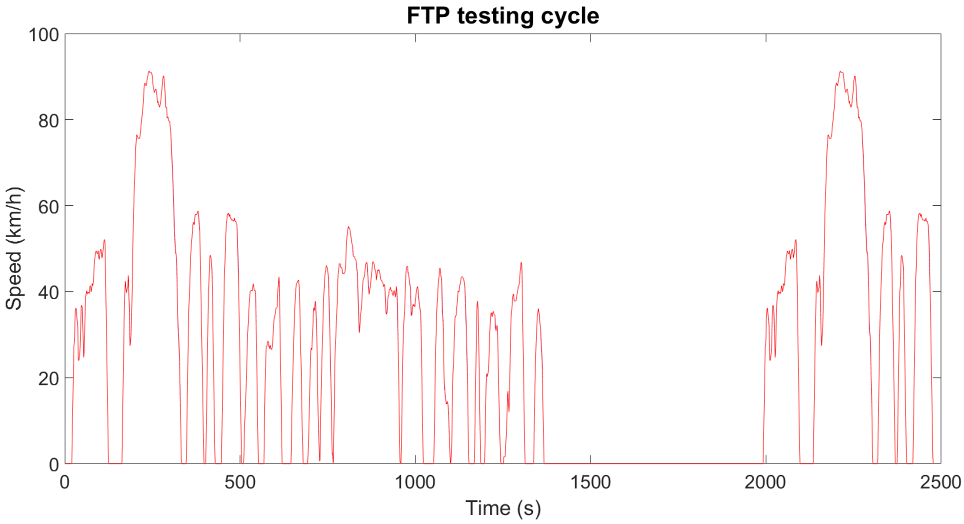

Fig. 11. FTP testing cycle (speed – time evolution)

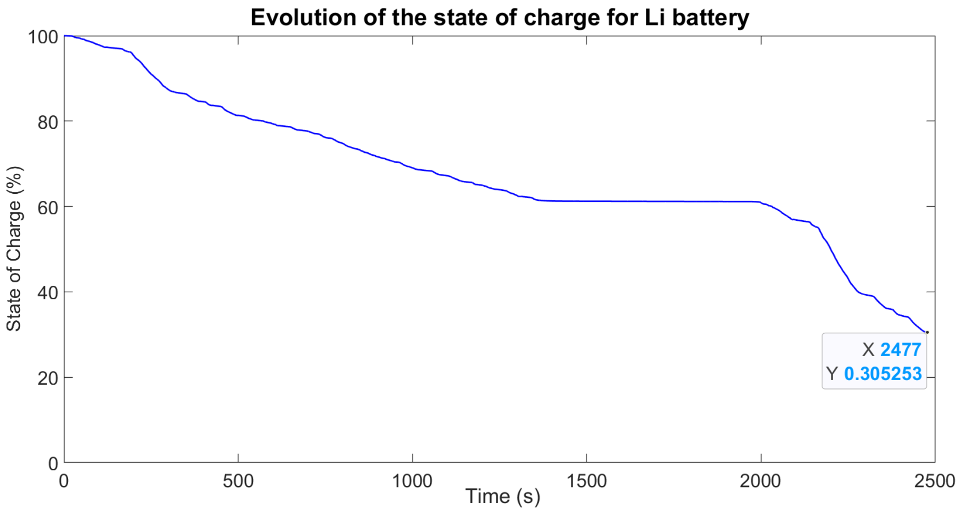

Fig. 12. State of charge of the Li-Ion battery at the end of the testing cycle

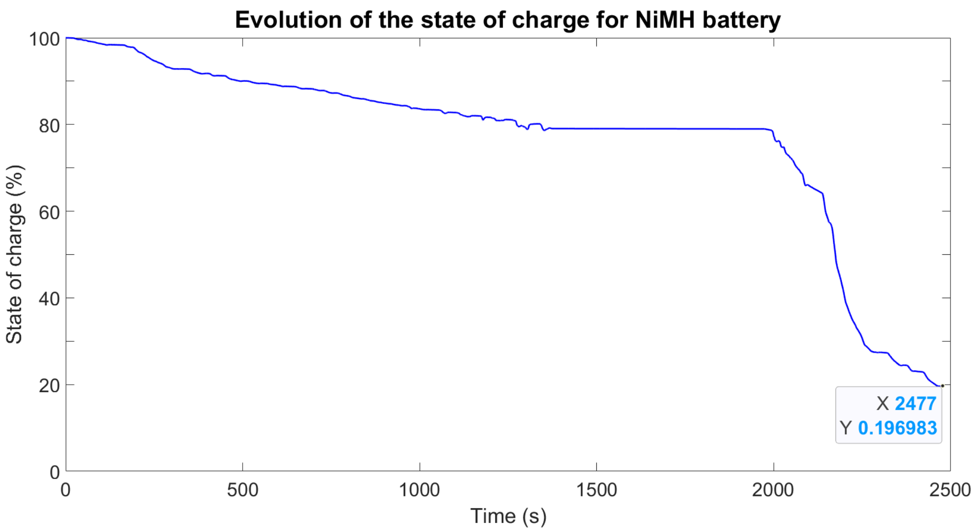

Fig. 13. State of charge of the NiMH battery at the end of the testing cycle

There is the same electric motor, same motor controller, and same vehicle. At the end of the testing cycle (an FTP one), the states of charge of both batteries are analyzed.

4.3 Physical experiments studied matters.

1. Physical platform using a direct current motor:
   - realize the speed control of a propulsion system using a DC motor,
   - respect a driving cycle in parallel with a load cycle,
   - calculate the consumed energy, the produced energy, and the efficiency with respect to a testing cycle.
2. Physical platform using an induction motor:
   -realize the speed control of a propulsion system using an IM motor,
   - use an increasing load when the speed increases,
   - calculate the consumed energy, the produced energy, and the efficiency with respect to a testing cycle.
3. Physical platform using a synchronous motor:
   - realize energy recuperation with a propulsion system using a Synchronous Motor,
   - use an increasing load at a constant speed,
   - calculate the consumed energy, the produced energy, and the efficiency respecting a load cycle.

5. CONCLUSIONS

The results obtained by implementing the presented testing platforms gave satisfaction in offering multiple simulation tools and physical experiments as a set of laboratory works for electric propulsion systems.

An immediate extension is expected to integrate additional kinds of motors. An example of a platform using permanent magnet motors is shown in Fig. 14.

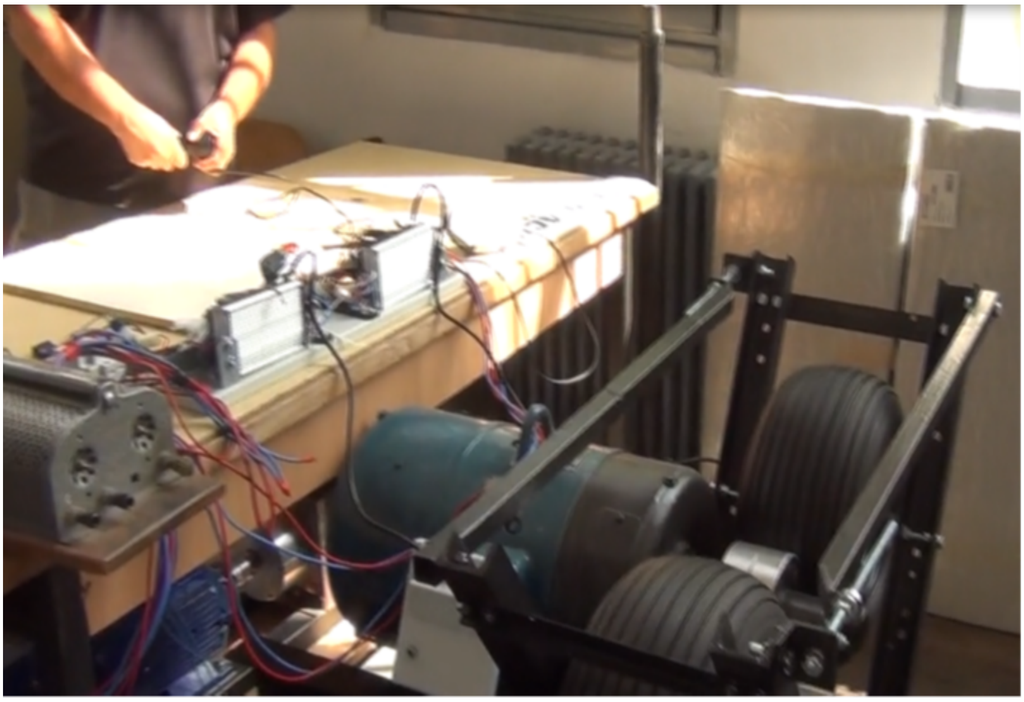

Fig. 14. Physical platform using in-wheel PM motors.

Additionally, the usage of green energy for vehicle energy storage, and a real-scale EV platform are in preparation for future extensions.

CONFIRMATION

The paper was presented at the Symposium on Electric Machines SME'23, the XIXth edition.

REFERENCES

1. M. Malschützky, A. Reher and A. Schröder, *Scholarship of Teaching and Learning - A way to identify inclusion opportunities and exclusion risks in digital learning scenarios*, 2021 World Engineering Education Forum/Global Engineering Deans Council (WEEF/GEDC), pp. 1-7, Madrid, Spain, 2021.
2. T. Kubica, T. Hara, I. Braun, F. Kapp and A. Schill, *Guided selection of IT-based education tools*, 2017 IEEE Frontiers in Education Conference (FIE), pp. 1-9, Indianapolis, IN, USA, 2017.
3. L. Popescu, *Electromobility topics entering a new decade*, in Electric machines, materials and drives present and trends (SME 2020), Bucureşti, November 2020.
4. C.L. Popescu, L.M. Dumitran, A. Stănescu *Simulation of Multi-Motor Propulsion System for Energy Efficiency in Electric Vehicles* in Annals of the University of Craiova, Electrical Engineering series**, 45**, *1*, pp 75-82, 2021, published the 21st of January 2022.
5. L. Popescu, L. Dumitran and A. Stănescu, *Multi-motor solutions for electric vehicles*, 2021 International Conference on Applied and Theoretical Electricity (ICATE), pp. 1-6, 2021.
6. L. Popescu, A. Stănescu, Şt. Vasiliu, *Didactical platform for multi-motor solutions*, in Electric machines, materials and drives present and trends (SME 2021), APME, **17***, 1*, pp. 172–181, ian. 2022.
7. T.B. Onofre, E. -E.P. da Silveira, W.W.A. G. Silva, A.L.N. Martins and G.L. Reis, *Implementation of a laboratory-based low-cost AC Chopper Soft-Starter*, 2016 17th International Conference on Harmonics and Quality of Power (ICHQP), pp. 885-889, Belo Horizonte, Brazil, 2016.
8. L. Popescu, L. Melcescu, L. Dumitran, A. Crăciunescu and A. Stanescu, *Control analysis of a bi-motor electric traction system for energy and performance optimization*, International Scientific Conference on Communications, Information, Electronic and Energy Systems (CIEES), 2021, AIP Conference Proceedings 2570, 040002, 2022.
9. L. Popescu, L. Melcescu, L. Dumitran, and A. Crăciunescu, *Analysis of the influence of wheel torque distribution on energy efficiency in the case of an electric vehicle with two motors* [abstract], in Proceeding book of 1st International Conference on Applied Engineering and Natural Sciences (ICAENS), Turkey pp. 300,1-3 November 2021, Konya.
10. L. Popescu, O. Craiu and L. Melcescu, *Analyzing the Torque Transfer between Two In-Wheel Motors of an Electric Vehicle*, 2023 13th International Symposium on Advanced Topics in Electrical Engineering (ATEE), pp. 1-6, Bucharest, Romania, 2023.
11. L. Popescu, A. Stănescu, *Efficiency maps for an EV BLDC motor using analytic calculation and simulation*, in Electric machines, materials and drives present and trends (SME 2022), APME, **18**, *1*, pp. 89-99, March. 2023.
12. L. Popescu, O. Craiu, *Energy Consumption Analysis for an EV Powertrain using Three BLDC Identical Motors*, Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **68**, *2*, pp. 152–157, Bucharest, 2023.