PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Marco Penta

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-25 - PhD Year: Second

Tutor: prof. Andrea Del Pizzo

Co-Tutor: prof. Diego Iannuzzi

Date: November 6th, 2025

1. Information:

- ➢ **PhD student: Marco Penta**   **PhD Cycle: XXXIX**

- ➢ **DR number: DR997193**

- ➢ **Date of birth: 06/12/1998**

- ➢ **Master Science degree: Electrical Engineering**

- ➢ **University: Università degli Studi di Napoli Federico II**

- ➢ **Scholarship type: PNRR**

- ➢ **Tutor: prof. Andrea Del Pizzo**

- ➢ **Co-tutor: prof. Diego Iannuzzi**

- ➢ **Period abroad: at Delft University of Technology, The Netherlands. The period abroad in Delft started on October 1st, 2025 and is scheduled for a total duration of six months, until March 31st, 2026.**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
I pilastri della trasformazione digitale	Course	12	3	02/04/2025 - 16/04/2025	Dr. Francesco Tortorelli	Y
Methodologies and Tools for conducting Systematic Literature Reviews and Systematic Mapping Studies	Course	12	3	28/04/2025 - 14/05/2025	Prof. Domenico Amalfitano (DIETI Unina)	Y
DC Systems and EV Charging Summer School 2025	Doctoral School	40	5	30/06/2025 - 04/07/2025	Prof. Pavol Bauer (Delft University of Technology, The Netherlands)	Y
Dalla Tradizione all'Innovazione: Il Viaggio Digitale Sfide e opportunità	Seminar	4	0.8	20/11/2024	Prof. Mario Pagano (DIETI	Y

che la trasformazione digitale può offrire					**Unina)**	
Solid State Transformers: Fundamentals, Insights and New Trends	**Seminar**	**2**	**0.4**	**20/12/2024**	**Prof. Luigi Pio Di Noia (DIETI Unina)**	**Y**
Multi-Objective Design Optimization of Power Converters for Electric Aircraft Propulsion	**Seminar**	**1.5**	**0.3**	**30/01/2025**	**IEEE Power Electronics Society - PELS**	**Y**
Optimisation-based Control of Flexible Resources in Sustainable Energy Networks	**Seminar**	**1**	**0.2**	**05/02/2025**	**Prof. Luigi Glielmo (DIETI Unina)**	**Y**
Il computer quantistico a piattaforma superconduttiva a Federico II e il suo ecosistema	**Seminar**	**1**	**0.2**	**06/02/2025**	**Scuola Nazionale Dottorandi "F. Gasparini" – Prof. Francesco Tafuri (Fisica Unina)**	**Y**
Dynamic Risk Assessment in Industrial Applications: Leveraging Bayesian Inference for Enhanced Decision-Making	**Seminar**	**1**	**0.2**	**04/03/2025**	**Dr. Francesco Vitale (DIETI Unina)**	**Y**
PhD Survival Strategies	**Seminar**	**1.5**	**0.3**	**30/05/2025**	**Dr. Pietro Liguori (DIETI Unina)**	**Y**
Enabling the Grids of the Future - HVDC Technology Updates and Global Perspectives	**Seminar**	**1.5**	**0.3**	**18/06/2025**	**IEEE Power Electronics Society - PELS**	**Y**
Power Electronics-Based Products and	**Seminar**	**1.5**	**0.3**	**26/06/2025**	**IEEE Power**	**Y**

Systems for Grids and Power Quality Solutions					**Electronics Society - PELS**	
Advancing Power System Oscillation & Stability Analysis Based on the Concept of Interharmonics	**Seminar**	**1.5**	**0.3**	**10/07/2025**	**IEEE Power Electronics Society - PELS**	**Y**
MV Drives: Technologies, Challenges and Applications	**Seminar**	**1.5**	**0.3**	**24/07/2025**	**IEEE Power Electronics Society - PELS**	**Y**
Participation to the organization of the open day/orientation event *Porte Aperte Ingegneria 2025*	**Tutorship**	**8**	**0.3**	**12/02/2025 - 13/02/2025**	**Prof. Alfonso William Mauro (DII Unina)**	**Y**

1)   Courses, Seminar, Doctoral School, Research, Tutorship
2)   Choose: Y or N

2.1. Study and training activities - credits earned

	Courses	**Seminars**	**Research**	**Tutorship**	**Total**
Bimonth 1	**0**	**1.2**	**7**	**0**	**8.2**
Bimonth 2	**0**	**0.7**	**7**	**0.3**	**8**
Bimonth 3	**0**	**0.2**	**10**	**0**	**10.2**
Bimonth 4	**6**	**0.9**	**7**	**0**	**13.9**
Bimonth 5	**5**	**0.6**	**5**	**0**	**10.6**
Bimonth 6	**0**	**0**	**12**	**0**	**12**
Total	**11**	**3.6**	**48**	**0.3**	**62.9**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

During the second PhD year, the research activity has continued and expanded the work done during the first year on the energy management of multi-source powertrains, with a focus on the railway sector.

3.1. Experimental work on railway powertrain laboratory demonstrator

The PhD research activity is funded through the National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza - PNRR) within the framework of the National Sustainable Mobility Center (Centro Nazionale per la Mobilità Sostenibile - MOST). The Electrical Machines, Converters and Drives research group in the DIETI Department is involved in a number of tasks within the MOST,

one of them being the design and set up of an experimental demonstrator of a multimode rail propulsion system. This is why my overarching activity throughout the second year has been contributing to the setup of such demonstrator in the Electrical Machines and Drives laboratory (Sala Macchine) at DIETI, as well as to several subsequent experimental tests that have been performed with it.

The current layout of the demonstrator (i.e. the layout at the time of writing this document) is reported in **Figure 1** and essentially represents the powertrain of a fuel cell/battery-powered train which is not connected to any overhead catenary. Indeed, as shown in the figure, two power sources, namely an electrochemical battery and a hydrogen fuel cell (FC), are emulated through two bidirectional programmable DC power supplies. Naturally, a battery is also an energy storage device, resulting in the need of a bidirectional power supply for enabling both charging and discharging capabilities. Both power supplies are equipped with a programmable interface which allows to model the electrical behaviour of FCs and batteries (e.g. FC output voltage vs current curve or battery open-circuit-voltage vs state of charge curve). Additionally, they can be interfaced with proprietary software for greater programming flexibility. The battery emulator is connected directly to a common DC-link, while the FC emulator is interfaced with it through a dedicated power electronic DC/DC converter, which allows controlling the output of the FC. On the other end of the demonstrator, the train's traction drive is represented by a three-phase drive composed of a power electronic inverter and an asynchronous motor with added external inertia. The two converters included in the demonstrator are controlled by means of microprocessor control boards, interfaced with each other and with a host computer through a CAN-based network. Naturally, the demonstrator also includes several devices such as current and voltage transducers, oscilloscopes, computers and other additional equipment, which are not reported in the figure for the sake of simplicity. A picture of the demonstrator is shown in **Figure 2**.
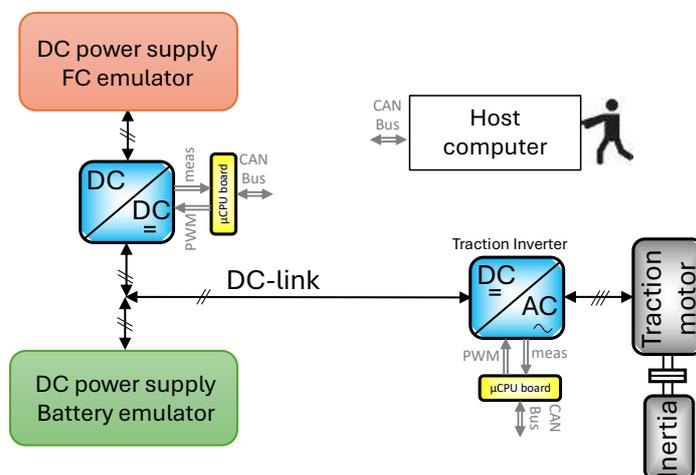

Figure 1. Current layout of PNRR-MOST multi-source rail powertrain demonstrator.

Currently, the demonstrator is fully operational and several tests have already been performed with it. However, this configuration may not be final as other power sources - or emulators thereof - may be added in order to account for more complex powertrains, such as tri-mode propulsion systems (e.g. including fuel cell, battery and supercapacitor or catenary, battery and supercapacitor). Additional converters may also be added to enable controlling of the power sources and, thus, allowing for more complex energy management strategies.

Figure 2. PNRR-MOST demonstrator in the Electrical Machines and Drives laboratory, DIETI Unina.

During the second PhD year, my activity related to the laboratory demonstrator has consisted in:

- Contributing to assembling and setting up the devices and components;
- Testing the programmable DC power supplies and their related software;
- Contributing to testing the communication between the host computer and the converters' control boards;
- Implementing simple energy management strategies on the setup (see also **Section 3.2**).

3.2. Energy management of multi-source powertrains in different transportation domains

The main theme of the research activity during the second year has been, just like the previous year, the energy management of multimode powertrains. Indeed, multiple sources and/or energy storage systems powering the same onboard loads (traction loads and auxiliary loads) bring about a certain degree of complexity that needs to be properly addressed through the application of effective energy management strategies (EMSs). In a powertrain with multiple energy sources, the EMS acts as a supervisory, high-level control providing the appropriate electrical setpoints – in terms of power, voltage and/or current – to the low-level control systems of the single sources. The low-level control is generally performed by means of power electronics converters, which provide the necessary interface between the different sources and the common traction and auxiliary loads.

While this framework has been mainly developed in the simulation domain during this year, it has also been applied on an experimental level, by performing simple energy management tests on the aforementioned laboratory demonstrator.

The EMS which has been given focus has been the Equivalent Consumption Minimization Strategy (ECMS), which provides current and/or power setpoints to the low-level control of the controllable power sources by minimizing an "equivalent fuel" variable obtained by combining several factors. For instance, in a FC/battery powertrain, the equivalent fuel is calculated as the sum between the real fuel (in most cases, hydrogen) used by the FC and a "virtual" fuel representing the energy gained or lost by the battery during its charging and discharging events.

Being a high-level, supervisory control strategy, the ECMS is not necessarily tied to railway powertrains only. Indeed, the idea behind it can easily be transferred and applied to different transportation scenarios, such as airborne and naval transportation. This has been done, at least on a simulation level, during this PhD year. In the field of airborne transportation, the idea of the ECMS has been studied on a simulated FC/battery light aircraft prototype through a collaboration with Leonardo S.p.A. On the other hand, a collaboration with the marine engineering group of the Industrial Engineering Department (DII) at Unina has led to studies on the application of the ECMS on a methanol FC/battery-powered light Unmanned Surface Vehicle (USV) for water quality monitoring purposes. These two collaborations have led to the research products which are reported in **Section 4** of this document.

Finally, the research on energy management has also been applied in the domain of road Electric Vehicles (EVs). More specifically, possibilities for energy management strategies have been studied for the Ultra-Fast Charging Station (UFCS) for EVs installed in the Electric Machines laboratory (Sala Macchine) at the DIETI department. Such UFCS is composed of an active front-end AC/DC converter interfaced with the distribution grid, two DC/DC converters interfacing with the EVs and two in-between battery energy storage systems. The two batteries have been placed with the goal of providing flexibility to the system, as they can store a certain amount of energy e.g. when the grid energy price is lower, and using it afterwards for charging the vehicles. Currently, new EMSs are being investigated with the aim of minimizing system's losses during typical EV charging scenarios.

The EV domain has been the starting point for my research activity abroad, which has started on October 1st, 2025 and has thus taken the final month of my second PhD year. The activity abroad is hosted at the Delft University of Technology, The Netherlands, and is expected to last for six consecutive months, i.e. until March 31st, 2026. More details can be found in **Section 6** of this document.

4. Research products:

- **Penta, M**.; Fedele, E.; Manrique, C.; Iannuzzi, D.; & Accardo, G., *"Analysis of an Equivalent Consumption Minimization Strategy for a Fuel Cell Electric Aircraft",* 2024 Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles and International Transportation Electrification Conference (ESARS-ITEC), Naples, Italy, 2024 **(published)**.
- Scamardella, F.; **Penta, M.**; Acanfora, M.; Altosole, M.; Balsamo, F.; Del Pizzo, A.; Ianniello, N.; Iannuzzi, D.; Marsilia, P.; Rufino, G.; Sorrentino, V.; Vitiello, L., *"Design and Energy Management of an Electric Marine Eco Unmanned Surface Vehicle",* 2025 International Conference on Clean Electrical Power (ICCEP), Villasimius, Italy, 2025 **(published)**.

5. Conferences and seminars attended

- **Conference:** 2024 Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles and International Transportation Electrification Conference (ESARS-ITEC). Naples, Italy, 26-29 November 2024. Attended this conference as presenting author (see "Research products" in **Section 4**).

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6. Periods abroad and/or in international research institutions

- **Hosting institution abroad:** Delft University of Technology, The Netherlands
- **Research group, department and faculty:** DC Systems, Energy Conversion & Storage (*DCE&S*) group, department of Electrical Sustainable Energy (*ESE*), Faculty of Electrical Engineering, Mathematics and Computer Science (*EEMCS*).
  Address: Mekelweg 4, 2628 CD Delft, The Netherlands.
- **Supervisor abroad:** Dr. Gautham Ram Chandra Mouli.
  Contact: G.R.ChandraMouli@tudelft.nl
- **Period abroad start date:** 01/10/2025
- **Period abroad expected end date:** 31/03/2026 (six months)

As mentioned in **Section 4**, the research activity at TU Delft will be focused on Electric Vehicles (EVs) and, more specifically, on the development of smart charging algorithms including Vehicle-to-Grid (V2G), i.e. bidirectional power flow between the EVs and the distribution grid. Such algorithms will be tested and validated through a Power Hardware-In-the-Loop (PHIL) setup, where the distribution grid is simulated through a Digital Real Time Simulator (DRTS) while the V2G-equipped charger is physical hardware. The DRTS chosen for this activity is OPAL-RT, with its proprietary software RT-LAB.

Since the start of the activity abroad (01/10/2025) up to the end of the second PhD year, a pre-existing PHIL setup for EVs, equipped with a standard unidirectional charger, has been reassembled in the TU Delft laboratories, and several tests have been executed to validate the performance of all the equipment involved, with a focus on the OPAL-RT DRTS itself. The RT-LAB software has been interfaced with MATLAB/Simulink-based models in order to explore the real-time capabilities of such equipment and its behaviour within the PHIL setup.

In the immediate future, the activity abroad will continue with the aim of replacing the traditional charger with a bidirectional/V2G one, while at the same time studying potential smart charging algorithms to be implemented in the setup.

7. Tutorship

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8. Plan for year three

The activity abroad at the Delft University of Technology is continuing into the third PhD year and is expected to last until March 31st, 2026. In the coming months, the new V2G EV charger will be integrated into the Power Hardware-In-the-Loop (PHIL) setup. The research on smart EV charging algorithms will continue, with the aim of testing a number of algorithms through the PHIL setup itself.

Upon returning to Italy, the experimental activity on the PNRR-MOST multi-source powertrain demonstrator will be resumed, with the final testing of the energy management strategies previously studied. The combination of simulation and experimental activities performed at Unina and abroad at TU Delft is expected to converge into the final PhD thesis.