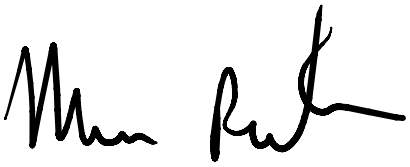
PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Marco Penta

Cycle: XXXIX

Training and Research Activities Report

Year: First



Tutor: prof. Andrea Del Pizzo

Co-Tutor: prof. Diego Iannuzzi

Date: November 6th, 2024

1. Information:

- **PhD student: Marco Penta**
- **DR number: DR997193**
- **Date of birth: 06/12/1998**
- **Master Science degree: Electrical Engineering**
- **University: Università degli Studi di Napoli Federico II**
- **Doctoral Cycle: XXXIX**
- **Scholarship type: PNRR**
- **Tutor: prof. Andrea Del Pizzo**
- **Co-tutor: prof. Diego Iannuzzi**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
How to Boost your PhD	Course	14	5	10/01/2024 - 07/02/2024	Prof. Antigone Marino (Fisica Unina)	Y
Strategic Orientation for STEM Research & Writing	Course	29	5	07/12/2023 - 04/04/2024	Prof. Chie Shin Fraser	Y
Statistical Data Analysis for Science and Engineering Research	Course	12	4	15/02/2024 - 29/02/2024	Prof. Roberto Pietrantuono (DIETI Unina)	Y
European PhD School 2024: Power Electronics, Electrical Machines, Energy Control and Power Systems	Doctoral School	-	4	27/05/2024 - 31/05/2024	European Center for Power Electronics – ECPE, Prof. Giuseppe Tomasso (UNICAS)	Y
Sistemi Elettrici per i Trasporti	Course	72	9	04/03/2024 - 05/06/2024	Prof. Mario Pagano (DIETI Unina)	Y
Using Deep Learning Properly	Course	12	4	23/01/2024 -	Dr. Andrea Apicella	Y

				08/02/2024	(DIETI Unina)	
Le nuove tendenze nel settore del fotovoltaico: bifaciale, agrisolare e storage	Seminar	4	0.8	09/11/2023	Prof. Mario Pagano (DIETI Unina)	Y
RIPE 87 Student Event: The Academic Corner of the RIPE Community	Seminar	1.5	0.3	14/11/2023	Jelena Ćosić (RIPE)	N
Impacts of Italian Infrastructure for railway high speed	Seminar	2	0.4	22/11/2023	Prof. Mario Pagano (DIETI Unina)	Y
MATLAB Expertise: Machine e Deep Learning	Seminar	2	0.4	22/11/2023	Salvatore Capuozzo, Vincenzo Scognamiglio (DIETI Unina)	Y
La qualità dell'energia elettrica: normative e applicazioni	Seminar	4	0.8	23/01/2024	Prof. Mario Pagano (DIETI Unina)	Y
HOMINIS	Seminar	5	1	21/02/2024	Prof. Carlo Sansone (DIETI Unina)	Y
ITECH Power Solutions Workshop	Seminar	6	1	16/04/2024	CalPower Srl	Y
GPT Unplugged: Raw, unfiltered discussions with our AI friend presented by Prasad Enjeti & Grant Pitel	Seminar	1	0.2	29/04/2024	IEEE Power Electronics Society - PELS	Y
High-Speed Rail Webinar Series: Policy Considerations for National High-Speed Rail Network Construction — Cases from Italy	Seminar	3	0.6	09/05/2024	Prof. Francesca Pagliara (DICEA Unina)	Y

Hitachi Rail Napoli: company presentation and technical seminar (DC and AC traction power supply)	**Seminar**	**7**	**1**	**20/05/2024**	**Prof. Luigi Pio Di Noia (DIETI Unina)**	**Y**
TA Springer Nature & CARE - CRUI: How to write a scientific paper	**Seminar**	**1**	**0.2**	**07/10/2024**	**Elisa Magistrelli (Springer Nature)**	**Y**
TA Springer Nature & CARE - CRUI: Research Integrity	**Seminar**	**1**	**0.2**	**08/10/2024**	**Elisa Magistrelli (Springer Nature)**	**Y**
Author Journey - Transformative Agreement Springer Nature & CARE – CRUI	**Seminar**	**1**	**0.2**	**09/10/2024**	**Elisa Magistrelli (Springer Nature)**	**Y**
IEEE Authorship & Open Access Symposium: Tips and Best Practices to Get Published from IEEE	**Seminar**	**1.5**	**0.3**	**24/10/2024**	**IEEE Xplore**	**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**	**1.9**	**6**	**0**	**7.9**
Bimonth 2	**5**	**1.8**	**4**	**0**	**10.8**
Bimonth 3	**5**	**1.2**	**6**	**0**	**12.2**
Bimonth 4	**17**	**1.6**	**2**	**0**	**20.6**
Bimonth 5	**4**	**0**	**4**	**0**	**8**
Bimonth 6	**0**	**0.9**	**7**	**0**	**7.9**
Total	**31**	**7.4**	**29**	**0**	**67.4**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The main topic of the PhD research activity is sustainable railway transportation and, particularly, rail vehicles with one or more onboard energy sources. Such onboard energy sources encompass both

traditional diesel units and alternative, non-emitting devices such as Fuel Cells (FCs) and Energy Storage Systems (ESSs), e.g. electrochemical batteries and supercapacitors.

3.1. Background and motivation

The transportation sector is responsible for a considerable share of both global energy demand and global polluting emissions. Despite rail transport being arguably the cleanest among the several different means of transportation, its environmental footprint is still significant. In fact, according to the International Energy Agency (IEA) less than half of railway lines in the world is electrified (45% in 2022), while the remainder still run on diesel, thus contributing to polluting emissions and greenhouse effect [1, 2]. Therefore, with the aim of tackling climate change, efforts are being made to improve rolling stock in terms of efficiency and sustainability. While complete electrification of lines appears as the most obvious solution to reduce emissions, it is often accompanied by drawbacks including complexity, high costs and regulatory issues in delicate areas such as historical city centres. Multimodal-powered rail vehicles (i.e. rolling stock powered by more than one energy source) can therefore represent an effective solution to potentially mitigate these issues [3,4]. Compared with traditional rolling stock, multimodal rail vehicles come with several advantages such as:

- Flexibility (capability of using different energy sources);
- Potential improvement of reliability;
- Where complete electrification is unfeasible, they are the only way of replacing or revamping old rolling stock to reduce/eliminate emissions.

On the other hand, multimodal rail vehicles are accompanied by several challenges that need to be addressed, such as the low energy densities of ESSs and the safety measures required to store and use hydrogen on board of vehicles. Furthermore, multiple energy sources powering a traction drive must be properly operated and controlled through efficient management strategies [5], which have been the focus of the research activity so far.

3.2. Energy management of multimodal powertrains

Within the area of multimodal-powered rail vehicles, the first-year PhD research activity has been focused on the energy management of the onboard power sources. Indeed, multiple sources and/or ESSs (such as hydrogen FCs, batteries, supercapacitors) powering the same onboard loads (traction loads and auxiliary loads) bring about a certain degree of complexity that needs to be properly addressed. Therefore, efficient energy management strategies (EMSs) are essential to the functioning of the powertrain and are the key to unlocking the full potential of multimodal vehicles.

In a powertrain with multiple energy sources, the EMS acts as a supervisory, high-level control whose aim is providing the appropriate electrical references – 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.

The combination of energy sources and/or ESSs, interface converters, loads and common electrical buses establishes, in fact, an electrical microgrid, generally operated in direct current (DC). Thus, the onboard energy management policies must also account for optimal energy and power flows between nodes as well as voltage and current regulation at all nodes.

After a broad literature review in the field, different EMSs have been studied and then tested in simulations. The focus has been given to a technique known as Equivalent Consumption Minimization Strategy (ECMS). Such strategy consists in providing appropriate references to the low-level control of the single sources by minimizing an "equivalent fuel" cost index [5]. For instance, in a scenario where the powertrain is powered by a FC and a battery, the equivalent fuel is calculated as the sum between the real fuel (hydrogen) consumed by the FC and a "virtual fuel" associated with the energy absorbed and/or delivered by the battery. Studies on the ECMS have led to the research products listed in Section 4.

3.3. PNRR Sustainable Mobility Center (MOST) and related project in the DIETI Department

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 MOST encompasses several projects and tasks, one of them involving the Electrical Machines, Converters and Drives research group in the DIETI Department. Such task, related to the PhD activity as well, is the design and set up of a laboratory demonstrator of a multimodal rail propulsion system. The demonstrator, which is going to be housed in the electrical machines and drives laboratory in the DIETI building, will comprise a traction unit and several emulated sources and storage systems (electric catenary, FC, battery and supercapacitor). All sources will be connected to a common DC-link through dedicated power electronics converters. Currently, my research activity refers to studying efficient energy management strategies for the lab demonstrator, leveraging the concepts presented in the previous subsection.

References

[1] "Transport," International Energy Agency (IEA). [Online]. Available: https://www.iea.org/energy-system/transport.
[2] "Greenhouse gas emissions from transport in Europe," European Environment Agency (EEA). [Online]. Available: https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport.
[3] E. Fedele, D. Iannuzzi, and A. Del Pizzo, "Onboard energy storage in rail transport: Review of real applications and techno-economic assessments", *IET Electrical Systems in Transportation*, vol. 11, no. 4, pp. 279–309, 12 2021.
[4] A. Ajanovic and R. Haas, "Prospects and impediments for hydrogen and fuel cell vehicles in the transport sector", *International journal of hydrogen energy*, vol. 46, no. 16, pp. 10 049–10 058, 2021.
[5] S. Onori, L. Serrao, and G. Rizzoni, *Hybrid Electric Vehicles: Energy Management Strategies*, 1st ed. Springer, 2016.

4. Research products:

- Del Pizzo, A.; Fedele, E.; Iannuzzi, D.; **Penta, M**.; & Spina, I., *"Energy Management of a Fuel Cell Train through an Equivalent Consumption Minimization Strategy",* 2024 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), Ischia, Italy, 2024 **(published)**.
- **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 **(accepted)**.

5. Conferences and seminars attended:

- **Conference:** *2024 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*. Ischia, Italy, 19-21 June 2024.
  Attended this conference as presenting author (see "Research products").
- **Tutorial:** *Model Predictive Control for Power Electronics, Drives and Power Grid Applications*. Pilsen, Czech Republic, 8-9 July 2024.

6. Activity abroad:

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7. Activity in partner companies:

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8. Tutorship:

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