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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Emanuele Fedele**

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**Student ID: DR994202**

**PhD Cycle: XXXV**

**PhD Cycle Chairman: Prof. Stefano Russo**

**PhD program student's start date: 01/12/2019**

**PhD program student's end date: 30/11/2022**

**Supervisor: Prof. Diego Iannuzzi**

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**Co-supervisor: Prof. Andrea Del Pizzo**

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**PhD scholarship funding entity:**

*Ministero dell'Università e della Ricerca (MUR), programma PON "Ricerca e Innovazione" 2014-2020, Azione I.1: "Dottorati Innovativi con Caratterizzazione Industriale".*

## General information

Emanuele Fedele received in year 2018 the Master of Science degree in Electrical Engineering from the University of Napoli Federico II. He attended a curriculum in Power Electronics, Electrical Machines and Drives within the PhD program in Information Technology and Electrical Engineering. He received a grant from the Italian Ministry of University and Research (MUR).

## Study activities

### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1 <sup>st</sup>	Intelligenza Artificiale ed Etica: La ricerca in IA alla prova delle sfide etiche	Ad hoc course	1.6	Roberto Prevete, Guglielmo Tamburrini	ITEE
1 <sup>st</sup>	Matlab Fundamentals	Ad hoc course	2.0	Agostino De Marco, Stefano Marrone	ITEE
1 <sup>st</sup>	Innovation management, entrepreneurship and intellectual property	Ad hoc course	5.0	Pierluigi Rippa	UNINA DII
1 <sup>st</sup>	Identificazione e Controllo Ottimo	MSc course	6.0	Francesco Garofalo	UNINA
1 <sup>st</sup>	Elaborazione Numerica dei Segnali	MSc course	6.0	Giuseppe Scarpa	UNINA
1 <sup>st</sup>	Machine Learning e Applicazioni (Mod. B)	MSc course	6.0	Roberto Prevete	UNINA
1 <sup>st</sup>	Machine Learning for Health	Ad hoc course	4.0	Marco Aiello, Anna Corazza, Diego Gragnaniello, Francesco Isgrò, Roberto Prevete, Francesco Raimondi, Carlo Sansone	ITEE/ICTH
1 <sup>st</sup>	Strategic Orientation for STEM Research & Writing	Ad hoc course	3.6	Chie Shin Frasier	ITEE
2 <sup>nd</sup>	Scientific Programming and Visualization with Python	Ad hoc course	2.0	Alessio Botta	UNINA DiSt
2 <sup>nd</sup>	Statistical Data Analysis for Science and Engineering	Ad hoc course	4.0	Roberto Pietrantuono	ITEE
2 <sup>nd</sup>	Reti Elettriche Complesse e Simulazione Circuitale	MSc course	9.0	Massimiliano de Magistris	UNINA
3 <sup>rd</sup>	Gate Drivers and Control Circuits for IGBTs and MOSFETs	External course	1.5	Prof. Martin Pfof (TU Dortmund)	European Center for Power Electronics
3 <sup>rd</sup>	EMC in Power Electronics	External course	1.5	Eckart Hoene (Fraunhofer IZM)	European Center for Power Electronics

3 <sup>rd</sup>	Sustainable Ship for the Energy Transition of Maritime Transport	Ad hoc course	4.0	Tommaso Coppola	ITEE
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## Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
2 <sup>nd</sup>	European PhD school on Power Electronics, Electrical Machines, Energy Control and Power Systems	Online	4.0	12-16/07/2021	University of Cassino, European Center for Power Electronics and Drives (ECPE), Associazione Nazionale Azionamenti Elettrici (ANAE)
3 <sup>rd</sup>	European PhD school on Power Electronics, Electrical Machines, Energy Control and Power Systems	Gaeta, Italy	4.0	23-27/05/2022	University of Cassino, European Center for Power Electronics and Drives (ECPE), Associazione Nazionale Azionamenti Elettrici (ANAE)

## Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1 <sup>st</sup>	How to get published with IEEE	0.4	Eszter Lukacs	IEEE	ITEE
1 <sup>st</sup>	Computational Biology: large scale data analysis to understand the molecular bases of human diseases	0.2	Michele Ceccarelli	DIETI UNINA	ITEE/ICTH
1 <sup>st</sup>	Large Scale Training of Deep Neural Networks	0.5	Giuseppe Fiameni	NVIDIA	ITEE
1 <sup>st</sup>	La programmazione europea e la ricerca. Nuovi scenari della programmazione europea dopo il 2020. La gestione di un progetto di ricerca.	0.4	Filippo Ammirati	ENEA	ENEA
1 <sup>st</sup>	Health 4.0 – La rapidità della medicina e la velocità del cambiamento del nostro mondo	0.4	Paolo Netti	UNINA	UNINA
1 <sup>st</sup>	Joint Design of Optics and Post-processing Algorithms Based on Deep Learning for Generating Advanced Imaging Features	0.4	Raja Giryes	University of Tel Aviv	IEEE Signal Processing Society

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Emanuele Fedele

1 <sup>st</sup>	Virtual Seminars on Sensing	0.8	Jerome Wenger, Carsten Rockstuhl, Leonetta Baldassarre and Monika Fleischer	University of Aix Marseille, Karlsruhe Institute of Technology, Università di Roma La Sapienza, University of Tubingen	Società Italiana di Ottica e Fotonica - Plasmonics and Nano-Optics Working Group
1 <sup>st</sup>	How to publish Open Access with IEEE to increase the exposure and impact of your research	0.3	Derek Abbott, Lajos Hanzo, Andrew Popper	University of Adelaide, University of Southampton, IEEE	IEEE
1 <sup>st</sup>	IBM Quantum: i primi computer quantistici per la ricerca e la didattica	0.3	Federico Mattei	IBM	CRUI
1 <sup>st</sup>	Salute, Algoritmi e Intelligenza Artificiale	0.5	Giovanni Arcuri, Pasquale Avella, Amedeo Cesta, Arturo Chiti, Tommaso Di Noia, Marco Marsella	Policlino Gemelli, Università del Sannio, CNR, Università Humanitas, Politecnico di Bari, Commissione Europea	Fondazione Ugo Bordoni
2 <sup>nd</sup>	Reliability of Modern Power Electronic Based Power Systems	0.2	Saeed Peyghami	Aalborg University	IEEE Power Electronics Society
2 <sup>nd</sup>	Towards Sustainable and Reliable Automated Design of Power Electronics Systems	0.2	Ivana Kovacevic	ETH Zurich	IEEE Power Electronics Society
2 <sup>nd</sup>	Patent Searching Best Practices with IEEE Xplore	0.2	Eszter Lukacs	IEEE	ITEE
2 <sup>nd</sup>	Advances in Machine Learning for Modelling and Understanding in Earth Sciences	0.2	Gustau Camps-Valls	University of Valencia	IEEE Geoscience and Remote Sensing South Italy Chapter
2 <sup>nd</sup>	Designing a Socially Assistive Robot for adaptive and personalized assistance to patients with dementia	0.2	Antonio Andriella	Pal Robotics	PRISCA Lab DIETI

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UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

PhD candidate: Emanuele Fedele

2 <sup>nd</sup>	Introduction of a State-of-the-Art Power Electronics Design Automation Tool in Hitachi ABB Powergrids – Challenges and Best Practices	0.2	Ralph Burkart	Hitachi ABB	IEEE Power Electronics Society
2 <sup>nd</sup>	Emotions in Reinforcement Learning Agents	0.2	Joost Broekens	University of Leiden	Prof. Silvia Rossi (DIETI)
2 <sup>nd</sup>	High Performance Heat Sink Design for WBG Power Modules using Genetic Algorithms	0.2	Burak Ozpineci, Emre Gurpinar	Oak Ridge National Laboratory, Sikorsky Aircraft	IEEE Power Electronics Society
2 <sup>nd</sup>	High-density Motor Drive Design for Electric Aircraft Propulsion: what we might know and what we don't	0.2	Fang Luo	Stony Brook University	IEEE Power Electronics Society
2 <sup>nd</sup>	EMI Reduction Techniques for Automotive Power Conversion Systems	0.2	Pradeep Shenoy	Kilby Laboratories TX	IEEE Power Electronics Society
2 <sup>nd</sup>	Opportunities, challenges and Potential Solutions in High-frequency WBG Motor Drives	0.2	Xibo Yuan	University of Bristol	IEEE Power Electronics Society
2 <sup>nd</sup>	Short and ultrashort, high voltage electric pulses for biological and medical applications	0.3	Stefania Romeo	CNR	ICTH
2 <sup>nd</sup>	L'avvincente storia degli acceleratori	0.3	Giorgio Vaccaro	UNINA	Prof. Rita Massa (UNINA)
2 <sup>nd</sup>	A stochastic first-order trust-region method with inexact restoration for nonconvex optimization	0.2	Natasa Krejic	University of Novi Sad	Prof. Daniela di Serafino (UNINA)
2 <sup>nd</sup>	Power Electronics for Precision Farming with Sustainable and Cleaner Environment	0.2	Brij N. Singh	Tulane University	IEEE Power Electronics Society
2 <sup>nd</sup>	Introduction to legged robots and examples of IIT's dynamic legged systems Lab	0.4	Claudio Semini, Michele Focchi	Istituto Italiano di Tecnologia	Prof. Fabio Ruggiero (UNINA)
2 <sup>nd</sup>	A Mission-profile-based Reliability Assessment Software Tool for the Design of Power Electronics	0.2	Ionut Vernica	Aalborg University	IEEE Power Electronics Society

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UNINA PhD in Information Technology and Electrical Engineering – XXXV Cycle

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	Systems					
2 <sup>nd</sup>	5G: l'architettura, le applicazioni e la rete di accesso radio	0.4	Francesco Mollica	Vodafone S.p.A.	Italia	Prof. Nicola Pasquino (DIETI)
2 <sup>nd</sup>	Advanced Health-Conscious Fast Charging Schemes and Battery Management Systems for Autonomous E-mobility	0.3	Sheldon Williamson	Ontario University	Tech	IEEE Power Electronics Society
2 <sup>nd</sup>	Testing Inverters using Electric Motor Emulators: Benefits, Challenges	0.4	Uday Deshpande	D&V Electronics USA		IEEE Power Electronics Society
2 <sup>nd</sup>	L'esposizione ai campi elettromagnetici generati dal sistema 5G - Metodologie scalari e vettoriali di misura dell'esposizione e tecniche di estrapolazione	0.8	Sara Adda, Daniele Franci, Settimio Pavoncello	ARPA Piemonte, ARPA Lazio		Prof. Nicola Pasquino (DIETI)
2 <sup>nd</sup>	Adaptive EMC design for wide bandgap power converters in aviation applications	0.2	Cong Li	Global Research Center USA		IEEE Power Electronics Society
2 <sup>nd</sup>	Passives in Power Electronics: Magnetic Components Design and Simulation	2.2	Gerard Hurley	National University of Ireland		European Center for Power Electronics
3 <sup>rd</sup>	Design Principles of Finite Control Set Model Predictive Control for Power Converters	0.2	Naki Güler	Gazi University of Technology		IEEE Industrial Electronics Society
3 <sup>rd</sup>	IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	0.3	Josep Guerrero, Eszter Lukacs, Paul Canning	Aalborg University, IEEE,		IEEE
3 <sup>rd</sup>	High-Performance Cascaded Multi-Resonant Switched-Capacitor Converter for Datacenter Power Delivery	0.2	Ting Ge	UC Berkeley		IEEE Power Electronics Society
3 <sup>rd</sup>	Springer Nature Author Workshop: Open Access and Trasformative Agreements in Italy	0.3		Springer Nature – Account Development Europe		Springer Nature – Account Development Europe

3 <sup>rd</sup>	Litz Wire and Magnetic Loss Calculation in Power Electronic Design Process	0.2	S. Ehrlich and A. Roskopf	Fraunhofer IISB	IEEE Power Electronics Society
3 <sup>rd</sup>	Design of a Robust Cyber Shield for a Grid-Connected PV System via Digital Watermarking Principle	0.2	Prasad Enjeti	Texas A&M University	IEEE Power Electronics Society
3 <sup>rd</sup>	La sostenibilità del trasporto pubblico locale su ferro: elementi di efficientamento	0.7	Mario Cuoco et al.	DIETI et al.	DIETI and AEIT Sezione Napoli
3 <sup>rd</sup>	REACT-EU, Dottorati e contratti di ricerca: ipotesi di soluzione per casi di sospensione e ritardo di avvio attività	0.4			MUR
3 <sup>rd</sup>	Advanced Insulation and Wire Wrap Systems for 800V+ Next Gen E-Motors	0.2	Benjamin Gaussens, Martino Bailoni and Shafiqh Nategh	Polestar	IEEE Industrial Electronics Society
3 <sup>rd</sup>	Power Electronics for NetZero Aviation	0.2	Pat Wheeler	University of Nottingham	IEEE Power Electronics Society

### Research activities

Emanuele Fedele has put his main contribution into the research on the integration and control of NPC Multi-Source Inverters in the traction systems of multimode rail vehicles by proposing and validating a novel modulation technique of the power converter and evaluating its potential with reference to real-case studies by means of circuit and magnetic/thermal FEM simulations. He has also taken part to the research on modeling and diagnostic of induction and PM brushless traction motors in presence of mechanical unbalances, eccentricities, and bearing faults and defects with the aim to assess the robustness of current-based diagnostic methods and benchmark them against the state-of-art vibration analysis. He has also contributed to some research work about: contribution of wayside energy storage systems to the short-circuit currents in a dc railway system; Doubly Fed Induction Generators for wind energy systems; experimental evaluation of carrier-based PWM techniques for Modular Multilevel Converter fed by distributed battery cells for transport applications; modeling and dynamic and steady-state analysis of power converters and energy storage systems for electrified aircrafts; modeling and efficiency assessment of an Ultra-Fast charging infrastructure for battery-electric vehicles; hairpin winding technology.

## Tutoring and supplementary teaching activities

### Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	22.2	4.4	22	0
2 <sup>nd</sup>	19	8.3	40	0
3 <sup>rd</sup>	7	2.9	60	0

## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2 <sup>nd</sup>	University of Birmingham	Prof. Pietro Tricoli	1/12/2020- 31/05/2021 (remote)	Preliminary analysis of the Multi-Source Inverter (MSI) concept and its application to railway traction systems; study, simulation and experimental validation of the state-of-literature MSI modulation; development and experimental validation of a stationary-recharge modulation technique.
3 <sup>rd</sup>	Hitachi Rail S.p.A.	Dr. Ing. Luigi Fratelli	1/6/2021 – 31/8/2022 (blended: remote and in-presence)	Methodologies for the diagnosis of distributed bearing faults in asynchronous traction motors through measurements of vibrations and electrical quantities (currents and voltages); experimental measurements on a traction motor with healthy and faulty bearings in Hitachi S.p.A. laboratory; post-processing for assessment/rejection of the envisioned diagnostic routines.  Simulation and experimental activities on the MSI: novel modulation technique, system-level simulations for two case-studies and benchmarking with standard traction circuit topologies, experimental validation.

## PhD Thesis

In the PhD Thesis, Emanuele Fedele investigates the potential of the Neutral-Point-Clamped (NPC) Multi-Source Inverter (MSI) as main traction converter in rail vehicles equipped with onboard energy storage devices and alternative power sources. In the effort to reduce fuel consumption, improve energy efficiency, and limit overhead infrastructures, rolling-stock manufacturers have been increasingly developing new



propulsion systems with alternative energy sources (hydrogen fuel cells) and energy storage devices (batteries, supercapacitors) in combination or replacement with traditional supplies (overhead or ground-level power lines, diesel generators). Multimode rail vehicles can benefit from high energy savings due to braking energy recuperation, lower current absorption and voltage swings on the external supply, and null local emissions when operating in absence of electrified infrastructure. Laying at the heart of multimode traction architectures, power electronic converters interconnect and control the energy flows among power sources, traction motors, and auxiliary loads. Conventionally, all power converters are connected to a common dc-bus, whose rated voltage level depends on the type of network on which the vehicle is operated. The traction and auxiliary loads are supplied through dc/ac Voltage-Source Inverters, while the onboard and external power sources are interfaced by means of unidirectional and bidirectional dc/dc converters. Employing several dc/dc converters enables the highest versatility in the design and management of the onboard sources. However, they result in increased cost and complexity of the multimode powertrain, and their size is usually constrained by the volume occupied by fuel cells and storage elements. To cope with the low energy densities of the primary sources and storage devices, compact power electronics have to be developed. To pursue this goal, alternative powertrain architectures that make use of non-conventional converter topologies or interconnections can be investigated. This thesis aims at exploring the adoption of NPC MSI as traction converters of multimode rail vehicles. MSIs allow a single-stage interconnection of two independent dc sources to the same ac load without magnetic elements through a conventional NPC circuit. When the MSI is properly integrated in a semi-active architecture of a bimode traction system, a semi-two-stage topology arises. In this configuration, a direct connection path between the low-voltage onboard source and the traction motors is provided. By adequately controlling and coordinating the main MSI traction converter with the onboard chopper, a significative reduction in the peak power rating of the dc/dc converter is achieved, with benefits in terms of power losses, weights, and volumes of the traction equipment. The envisioned control and coordination of the semi-two-stage architecture is assessed experimentally through extensive tests on a bimode traction drive prototype for a standard driving cycle and under common energy management strategies. Furthermore, comprehensive system and component-level circuit and FEM analyses carried out for two real-case studies show reductions of up to 60% in the power losses and 35% in the volume of passive filters and heatsinks in the onboard dc/dc converter, at the expenses of increased circuit complexity and higher VA rating of the traction inverter.

### **Publications**

Research results appear in 5 papers published in international journals, 7 contributions to international conferences.

## List of scientific publications

### International journal papers

A. Del Pizzo, L.P. Di Noia, E. Fedele,

A Simple Analytical Model of Static Eccentricity for PM Brushless Motors and Validation through FEM Analysis,

*Energies*,

vol. 13 (13), pp. 3420-3437, 2020, DOI: 10.3390/EN13133420.

E. Fedele, D. Iannuzzi, A. Del Pizzo,

Onboard Energy Storage in Rail Transport: Review of Real Applications and Techno-Economic Assessments, *IET Electrical Systems in Transportation*,

vol. 11 (4), pp. 279-309, 2021, DOI: 10.1049/ELS2.12026.

E. Fedele, D. Iannuzzi, P. Tricoli, A. Del Pizzo,

NPC-based Multi-Source Inverters for Multimode DC Rail Traction Systems, *IEEE Transactions on Transportation Electrification*,

Early Access, 2022, DOI: 10.1109/TTE.2022.3175097.

E. Fedele, A. Cervone, I. Spina, D. Iannuzzi, A. Del Pizzo,

Multi-Objective Vector Modulation for Improved Control of NPC-based Multi-Source Inverters in Hybrid Traction Systems,

*IEEE Journal on Emerging and Selected Topics in Power Electronics*,

Early Access, 2022, DOI: 10.1109/JESTPE.2022.3181515.

A. Dannier, E. Fedele, I. Spina, G. Brando,

Doubly-Fed Induction Generator (DFIG) in Connected or Weak Grids for Turbine-Based Wind Energy Conversion Systems

*Energies*,

vol. 15 (17), p.p. 6402-6406, 2022, DOI: 10.1109/JESTPE.2022.3181515.

### International conference papers

A. Del Pizzo, L.P. Di Noia, E. Fedele,

An analytical evaluation of rotor eccentricity effects on synchronous drives with surface mounted permanent magnet brushless motors,

*2020 IEEE 20th Mediterranean Electrotechnical Conference (MELECON)*,

Palermo, Italy, Jun. 2020, pp. 35-40, IEEE, DOI: 10.1109/MELECON48756.2020.9140521.

A. Dannier, E. Fedele, M. Coppola,

Sizing approach of high torque density motors for aircraft application,

*2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*,

Sorrento, Italy, Jun. 2020, pp. 497-501, IEEE, DOI: 10.1109/SPEEDAM48782.2020.9161871.

A. Di Pasquale, E. Fedele, D. Iannuzzi, M. Pagano

Contribution of Wayside Energy Storage Systems to Short Circuit Currents in DC Railway Traction Power Systems,

*2022 International Power Electronics Conference (IPEC-Himeji 2022- ECCE Asia)*,

Himeji, Japan, May 2022, pp. 1101-1106, IEEE, DOI: 10.23919/IPEC-Himeji2022-ECCE53331.2022.9807030.

E. Fedele, A. Di Pasquale, D. Iannuzzi, M. Pagano

Integration of Onboard Batteries and Supercapacitors Based on the Multi-Source Inverter for Light Rail Vehicles,

*2022 International Power Electronics Conference (IPEC-Himeji 2022- ECCE Asia)*,

Himeji, Japan, May 2022, pp. 698-704, IEEE, DOI: 10.23919/IPEC-Himeji2022-ECCE53331.2022.9807195.

E. Fedele, D. Iannuzzi, I. Spina,

Semi-Two-Stage Traction System based on the NPC Multisource Inverter for Tram Vehicles with Onboard Supercapacitors,

*2022 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*,

Sorrento, Italy, June 2022, pp. 277-282, IEEE, DOI: 10.1109/SPEEDAM53979.2022.9842209.

I. Spina, E. Fedele, A. Cervone,

Simplified low-cost experimental setup for battery loss evaluation in MMC converters,

*2022 International Symposium on Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM)*,

Sorrento, Italy, June 2022, pp. 534-540, IEEE, DOI: 10.1109/SPEEDAM53979.2022.9842092.

A. Dannier, F. Di Bruno, F. Fiume, E. Fedele, G. Brando,

Hairpin Winding Technology for Electric Traction Motors: Design, Prototyping, and Connection Rules,

*2022 International Conference on Electrical Machines (ICEM)*,

Valencia, Spain, Sept. 2022, pp. 1170-1175, IEEE, DOI: 10.1109/ICEM51905.2022.9910851.

**Date** 25/10/2022

**PhD student signature**

Emanuele Fedele

**Supervisor signature**

Diego Iannuzzi