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

PhD Student: Emanuele Fedele

Cycle: XXXV

Training and Research Activities Report

Year: First

Emanuele Fedele

Tutor: prof. Diego Iannuzzi

Diego Iannuzzi

Co-Tutor: prof. Andrea Del Pizzo, Ph.D. Ing. Luigi Fratelli

Date: October 21, 2020

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXV **Author: Emanuele Fedele**

1. Information:

- **PhD student: Emanuele Fedele**
- **DR number: DR994202**
- **Date of birth: 24/05/1994**
- **Master Science degree: Electrical Engineering University: Università degli Studi di Napoli "Federico II"**
- **Doctoral Cycle: XXXV**
- **Scholarship type: MUR PON**
- **Tutor: prof. Diego Iannuzzi**
- **Co-tutor: prof. Andrea Del Pizzo, Ph.D. Ing. Luigi Fratelli**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Intelligenza Artificiale ed Etica: La ricerca in IA alla prova delle sfide etiche	Course	6	1.6	06/12/2019	Dr. Roberto Prevete (DIETI)	Y
Matlab Fundamentals	Course	20	2.0	20/02/2020 - 23/03/2020	Prof. Agostino De Marco (DII)	Y
Innovation management, entrepreneurship and intellectual property	Course	16	5.0	05/05/2020 - 06/06/2020	Prof. Pierluigi Rippa (DII)	Y
Identificazione e Controllo Ottimo	Course	48	6.0	09/03/2020 - 12/06/2020	Prof. Francesco Garofalo (DIETI)	Y
Elaborazione numerica dei segnali	Course	48	6.0	09/03/2020 - 12/06/2020	Prof. Giuseppe Scarpa (DIETI)	N
Machine learning e applicazioni (mod. B)	Course	48	6.0	09/03/2020 - 12/06/2020	Dr. Roberto Prevete (DIETI)	N
How to get published with IEEE	Seminar	2	0.4	20/04/2020	IEEE	Y

Computational biology: large scale data analysis to understand the molecular bases of human diseases	**Seminar**	**1**	**0.2**	**09/04/2020**	**Prof. Michele Ceccarelli (DIETI)**	**Y**
Large scale training of deep neural networks	**Seminar**	**2.5**	**0.5**	**06/05/2020**	**Prof. Carlo Sansone (DIETI)**	**Y**
La programmazione europea: nuovi scenari della programmazione europea dopo il 2020	**Seminar**	**2**	**0.4**	**13/05/2020**	**Università di Napoli "Federico II" e TecUp**	**N**
Health 4.0 – la rapidità della medicina e la velocità del cambiamento nel nostro mondo	**Seminar**	**2**	**0.4**	**14/05/2020**	**Università di Napoli "Federico II"**	**N**
Joint design of optics and post-processing algorithms based on deep-learning for generating advanced imaging features	**Seminar**	**2**	**0.4**	**19/05/2020**	**IEEE Signal Processing Society**	**N**
Virtual seminars on sensing	**Seminar**	**4**	**0.8**	**20/05/2020**	**Società Italiana di Ottica e Fotonica**	**Y**
Machine Learning	**Course**	**20**	**4.0**	**06-17/07/2020**	**Prof. Carlo Sansone (DIETI)**	**Y**
Strategic Orientation for STEM Research & Writing	**Course**	**18**	**3.6**	**16/07/2020 - 17/09/2020**	**Prof. Chie Shin Fraser**	**Y**
How to publish Open Access with IEEE to increase the exposure and impact of your research	**Seminar**	**1.5**	**0.3**	**23/09/2020**	**IEEE**	**Y**

IBM Quantum primi computer quantistici per la ricerca e la didattica	**Seminar**	**1.5**	**0.3**	**09/10/2020**	**CRUI**	**N**
Salute, algoritmi e Intelligenza Artificiale	**Seminar**	**2**	**0.4**	**22/10/2020**	**FUB fondazione Ugo Bordoni**	**N**
Proxima Safe	**Seminar**	**1.5**	**0.3**	**23/10/2020**	**CRUI e Oracle**	**N**

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	**1.6**		**2**		**3.6**
Bimonth 2			**3**		**3**
Bimonth 3	**2**	**0.6**	**4**		**6.6**
Bimonth 4	**5**	**2.5**	**4**		**11.5**
Bimonth 5	**10**		**4**		**14**
Bimonth 6	**3.6**	**1.3**	**5**		**9.9**
Total	**22.2**	**4.4**	**22**		**48.6**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 - 4.8**	

3. Research activity:

My research activity is related to railway vehicles with one or more onboard energy sources. Railway electrification requires significant investment and is usually not convenient on low and medium traffic routes, which are currently operated by diesel trains. However, diesel-based technologies produce polluting and noise emissions with considerable environmental impact [1]. Moreover, overhead electrification of tramways has a strong visual impact in historical city centres and can be difficult to extend in case of new routes. For these reasons, multimodal trains with onboard storage systems, which can operate without catenary, have gained increasing attention in the last twenty years in both academia and industry [2]. Research efforts in this field can be mainly related to: design and control of power converters and drives to increase performance and reduce operating costs, optimal control of energy sources to exploit regenerative braking and reduce overall energy demand, intelligent diagnostic algorithms to increase reliability and reduce maintenance costs, development of novel powertrain topologies.
During the first year I focused on two main topics, which are listed below.

3.1 Analysis of multimodal railway vehicles in current or recent operation

The focus of this activity was a broad investigation on commercial and prototype realizations of railway vehicles with one or more onboard energy sources from the early 2000s to present date. The route

typology (regional or national railway, city metro, etc..), rated traction power and off-wire autonomy of the multi-modal vehicles were catalogued. Their storage systems were analyzed in relation to the type (batteries, supercapacitors, fuel-cells, hybrid systems) and technology. When available, weight, volume and electrical data were collected and processed to calculate the power and energy density of the different sources, in order to allow a comparison at system level. A number of publicly available powertrain architectures were inspected to understand the onboard integration of the storage devices in terms of modular distribution along the vehicle and interface to the common DC bus through proper power conversion stages [3]. The investigation was complemented with the reported information on energy management strategies: typical rule-based power-split strategies during each phase of a standard driving cycle were found to be implemented. The result of this investigation is a broad overview of the state of the art of multimodal trains, where state of the art refers to implemented prototypes or commercial vehicles that are or have recently been in operation. This is the starting point for a forthcoming analysis of the state of the research in this field, with a particular focus on novel topologies of power converters and traction drives, optimal energy management strategies and techno-economic criteria for their critical evaluation.

3.2 Study on techniques for the monitoring and early detection of mechanical faults in traction drives

The focus of this activity was to study the most acknowledged techniques for the condition monitoring and early fault detection of bearings in traction motors. Indeed, bearings represent one of the most critical elements in a drive chain and account for more than 40% of the possible faults in an electric motor. In this context, condition monitoring and early diagnosis can reduce unexpected downtimes and maintenance costs and increase the usable lifetime of the components [4]. Traditionally, bearing condition monitoring is accomplished through the analysis of vibration signals. For this reason, diagnostic techniques that make use of vibration signals were firstly investigated, with a deep focus on time-frequency algorithms that exploit the ciclo-stationarity of vibration signals [5]. Then, non-invasive algorithms based on electrical signals were also analyzed: from the traditional motor current signature analysis to more recent solutions that have been historically inspired by vibration analysis [6]. The advantages and drawbacks of these methods were evaluated. As the proposed techniques are mostly data-driven, a thorough electromechanical model of the induction motor with a faulty bearing was developed. The model considers generic airgap length variations and can simulate both eccentricity and localized bearing defects. It will serve as starting point for the development of a model-based algorithm that can enhance the presence of a bearing fault signature in the electrical signals and improve its early detection.

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[1] D. Murray-Smith, “A Review of Developments in Electrical Battery, Fuel Cell and Energy Recovery Systems for Railway Applications: A Report for the Scottish Association for Public Transport,” Scottish Association for Public Transport, Glasgow, Scotland, 2019.

[2] T. Ratniyomchai, S. Hillmansen and P. Tricoli, "Recent developments and applications of energy storage devices in electrified railways," in IET Electrical Systems in Transportation, vol. 4, no. 1, pp. 9-20, March 2014.

[3] Becker, Frank, and André Dämmig. "Catenary free operation of light rail vehicles—Topology and operational concept." 2016 18th European Conference on Power Electronics and Applications (EPE'16 ECCE Europe). IEEE, 2016.

[4] Y. Gritli, A. Bellini, C. Rossi, D. Casadei, F. Filippetti and G. Capolino, "Condition monitoring of mechanical faults in induction machines from electrical signatures: Review of different techniques," 2017 IEEE 11th International Symposium on Diagnostics for Electrical Machines, Power Electronics and Drives (SDEMPED), Tinos, 2017, pp. 77-84.

[5] Randall, Robert B., and Jerome Antoni. "Rolling element bearing diagnostics—A tutorial." Mechanical systems and signal processing 25.2 (2011): 485-520.

[6] Schoen, Randy R., et al. "Motor bearing damage detection using stator current monitoring." IEEE transactions on industry applications 31.6 (1995): 1274-1279.

4. Research products:

Del Pizzo, A.; Di Noia, L.P.; Fedele, E.
"*A Simple Analytical Model of Static Eccentricity for PM Brushless Motors and Validation through FEM Analysis*"
Energies 2020, 13(13), 3420 (published).

Del Pizzo, A.; Di Noia, L.P.; Fedele, E.
"*An analytical evaluation of rotor eccentricity effects on synchronous drives with surface mounted permanent magnet brushless motors*"
20th IEEE Mediterranean Electrotechnical Conference, MELECON 2020- Proceedings, 2020 (published)

Dannier, A.; Fedele, E.; Coppola, M.
"*Sizing Approach of high torque density motors for aircraft application*"
2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2020, 2020 (published)

Fedele, E.; Iannuzzi, D.
"*Onboard storage systems in urban and regional railway vehicles: a review"*
Undergoing submission to the journal IET Electrical Systems in Transportation.

5. Conferences and seminars attended

Conferences:

- 2020 IEEE 20th Mediterranean Electrotechnical Conference (MELECON), Palermo, Italy, 16-18 June 2020 (virtual).
  I attended this conference as presenting author.

- 2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2020, Sorrento, Italy, 24-26 June 2020 (virtual).

Workshops:
- AI4Rails 2020, Munich, Germany, 7th September 2020 (virtual).

6. Activity abroad:

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7. Tutorship

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