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

PhD Student: Pasquale Franzese

Cycle: XXXIV

Training and Research Activities Report

Year: Second

Pasquale Franzese

Tutor: prof. Diego Iannuzzi

Diego Iannuzzi

Co-Tutor:

Date: October 21, 2020

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXIV Author: Pasquale Franzese

1. Information:

- **PhD student:** Pasquale Franzese
- **DR number:** 993624
- **Date of birth:** 14/07/1994
- **Master Science degree:** Master's degree in Automation Engineering (cum laude)
  University: Università di Napoli Federico II
- **Doctoral Cycle:** XXXIV
- **Scholarship type:** No scholarship
- **Tutor:** Prof. Diego Ianuzzi

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Ingegneria del software	Courses	72	9	09/19-12/19	DIETI (UNINA) Prof. Anna Rita Fasolino	Y
Economia ed organizzazione aziendale I	Courses	48	6	09/19-12/19	DIETI (UNINA) Prof. Corrado Lo Storto	Y
Lo spazio cibernetico come dominio bellico	Seminar	2	0,2	15/11/19	DIETI (UNINA) Dott. Gian Piero Siroli	Y
Computational Biology: Large scale data analysis to understand the molecular bases of human diseases	Seminar	2	0,4	09/04/20	DIETI (UNINA) Prof. Michele Ceccarelli	N
Plasmonica: Metasurfaces	Seminar	4	0,8	30/04/20	Virtual Seminar Plasmonica & Nano-Ottica Working Group Michele Celebrano, Stefano D'Agostino, Carlo Forestiere	Y
How to get published with the IEEE?	Seminar	2	0,4	20/05/20	Biblioteca DIETI & IEEE Eszter Lukacs	N
SAS Analytics	Seminar	2	0,4	14/05/20	DIETI (UNINA) Dr. Cinzia Gianfiori, Dr. Costabile Santis, Dr. Daniele Goretti, Prof. Antonio Picariello	N
Planning 5G under EMF constraints: challenges and opportunities	Seminar	2	0,4	18/05/20	DIETI (UNINA) Prof. Luca Chiaraviglio	N
Plasmonica: Sensing	Seminar	4	0,8	20/05/20	Virtual Seminar Plasmonica & Nano-Ottica Working	Y

					Group Maria Caterina Giordano, Chiara Novara, Emiliano Descrovi, Riccardo Sapienza	
RETI 5G : IMPLEMENTAZIONE – CONSOLIDAMENTO – EVOLUZIONE VERSO IL 6G	Seminar	4	0,8	28/05/20	AEIT&DIETI (UNINA) Prof. Mario Pagano, Prof. Daniele Riccio, Prof. Nicola Pasquino e altri	N
Innovation management, entrepreneurship and intellectual property	Courses	14	5	05/20	DIETI (UNINA) Prof. Pierluigi Rippa	Y
ITEE/ICTH Module - Design and Implementation of Augmented Reality Software Systems	Courses	18	4	06/20	DIETI (UNINA) Dr. Domenico Amalfitano	Y
Economia ed organizzazione aziendale II	Courses	48	6	03/20-06/20	DIETI (UNINA) Prof. Corrado Lo Storto	Y
Seminario online STMicroelectronics	Courses	15	3	06/20	STMicroelectronics & DIETI (UNINA) Prof. Annalisa Liccardo, Dr. Francesco Bonavolontà	Y
IBM Quantum: i primi computer quantistici per la ricerca e la didattica	Seminar	3	0,6	9/10/20	Segreteria CRUI	N
Valutazione dei livelli di esposizione e del rispetto dei limiti. Il ruolo delle ARPA	Seminar	2	0,4	13/10/20	DIETI (UNINA) Prof.ssa Massa	N
Misure di segnali complessi nell''ambiente: Sistemi 4G	Seminar	2	0,4	13/10/20	DIETI (UNINA) Prof.ssa Massa	N
Interconfronto	Seminar	1	0,2	13/10/20	DIETI (UNINA) Prof.ssa Massa	N
Valutazione dei livelli di esposizione e del rispetto dei limiti Antenne e 5G	Seminar	2	0,4	20/10/20	DIETI (UNINA) Prof.ssa Massa	N
Misure di segnali complessi nell''ambiente: Sistemi 5G	Seminar	1	0,2	20/10/20	DIETI (UNINA) Prof.ssa Massa	N
Estrapolazioni su segnali 4G e 5G	Seminar	2	0,4	20/10/20	DIETI (UNINA) Prof.ssa Massa	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
First Year	24,2	6,6	42,5	0	73
Bimonth 1	0	0,2	5	0	5,2
Bimonth 2	15	0	5	0	21
Bimonth 3	0	1,6	7	0	8,6
Bimonth 4	18	2,4	6	0	26
Bimonth 5	0	0	5	0	5
Bimonth 6	0	2,6	6	0	8,6
Total	57,2	13,2	77,5	0	148
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

My fellowship is associated with a project "*ELECTRIC ULTRA FAST CHARGING STATION (E-UFCS)*" presented for "POR FESR CAMPANIA 2014/2020- O.S. 1.1" that is a collaboration between *CRIAT (Centro di Ricerca Interuniversitario su Azionamenti per Trazione Aerea, Terrestre e Marittima) of Università di Napoli Federico II* and *Samso s.p.a*, so part of my research deals with charging stations for electrical vehicles.

The research project went through different steps of realization:

- Studying about state of the art of technology of the components for photovoltaic generation and the battery energy storage systems.
- Studying about state of the art of vehicles charge modes, in particular Ultrafast charge strategies.
- Sizing and design of the Ultrafast charge infrastructure.
- The development and the simulation of control strategies and advanced management for the integration between the photovoltaic generation, the battery energy storage system and the Ultrafast charge infrastructure.
- The implementation and installation of Ultrafast charge infrastructure.
- The testing of charge infrastructure and the experimentation of vehicle's Ultrafast charge services.

During my first year of PhD, I took care of the first two steps and the third step has started.

During this current year, the completed steps are the third one, the fourth one and the fifth one.

To explain briefly the path that lead me to size and design the Ultrafast charge infrastructure, I will display the project constraints.

The Mode 4 of electric vehicles charge, also called Ultrafast charge mode, is a defined standard in *CEI EN 61851-1:2019-09*. This type of charge is a dc charge, its definition provides an active connection between the vehicle and the charging system including grounding and control systems, the typical value of voltage is 600 V with a maximum current of 400 A.

There are not requirements that set a standard on the charge time, but typically the Ultrafast charge is intended as a charge of a medium size multi-purpose vehicle with the charge time ranging from 10 to 15 min. To provide these charging performances, the energy from the charging station to the vehicle needs to be transferred with a high level of power, as a consequence an Ultrafast charging station with multiple plug-in electric vehicle parking slots needs to have a great amount of installed power.

A project constraint requires that the charging station must be connected to the low voltage distribution network, so that the maximum installing power amounts to 100 kW, and it must have two charging slots.

The combination of these two power constraints led to the need to introduce a battery energy storage systems, it charges when no vehicles are requiring to be charged and discharges when the power demanded to the station is higher than that payable by the grid. It should be noted that the charge power of the BESS is the installed power of the grid, the discharge power depends on the charging requests by the vehicles. The scheme just described is shown in *Fig.1*.

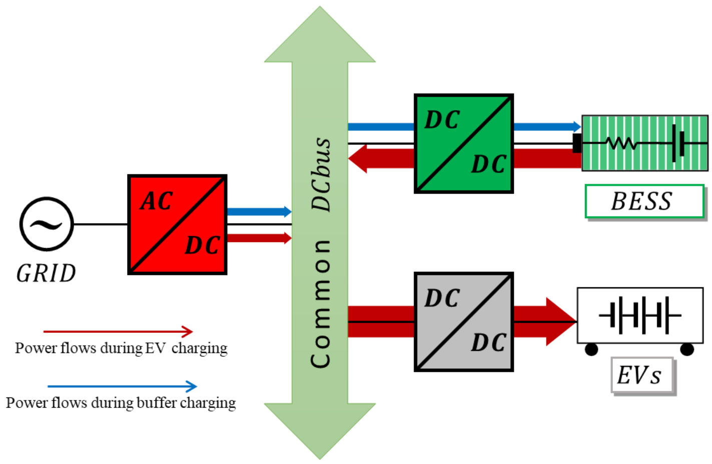

Fig.1 – Concept scheme of Ultrafast charging station

Three electrical structures have been identified to realize the Ultrafast charging station with the integration of the BESS, these structures are shown in *Fig.2*.

- In all structures the grid is connected to the common bus through an AFE (active front end) type AC/DC converter. In structures *A* and *B* this converter is controlled to ensure constant voltage on the common bus and the power factor correction, in structure *C* is controlled to supply the BESS at constant power or constant current.
- In structure *C*, the BESS is directly connected to the common bus, in structures *A* and *B* the BESS is connected through an DC/DC converter built from an inverter interleaved.

- In structures A, B and C the vehicles slots (drawn in Fig.2 as Ultrafast connectors) are connected to the common bus with an DC/DC converter built from an inverter interleaved, a DAB (dual active bridge) type DC/DC converter and a SAB (single active bridge) type DC/DC converter respectively.

The sizing of inductive or conductive filters depended on the connectors requirements about the ripple of current (the target connectors are CHAdeMO and CCS2), the sizing of the BESS depended on the balance of the power and the energy between the sources and loads with the 'Load Levelling' strategy and on the transformation ratio of the different converters in the different structures.

The three structures have been sized to meet the constraints, the high-level and low-level control strategies are developed and simulated, the implementing structure C has been chosen from the analysis of the simulations.

The choice of structure C depended on the minor number of converters required and on the trade-off performances between the charge profile of vehicles and the charge/discharge profile of the BESS in order to preserve its state of health.

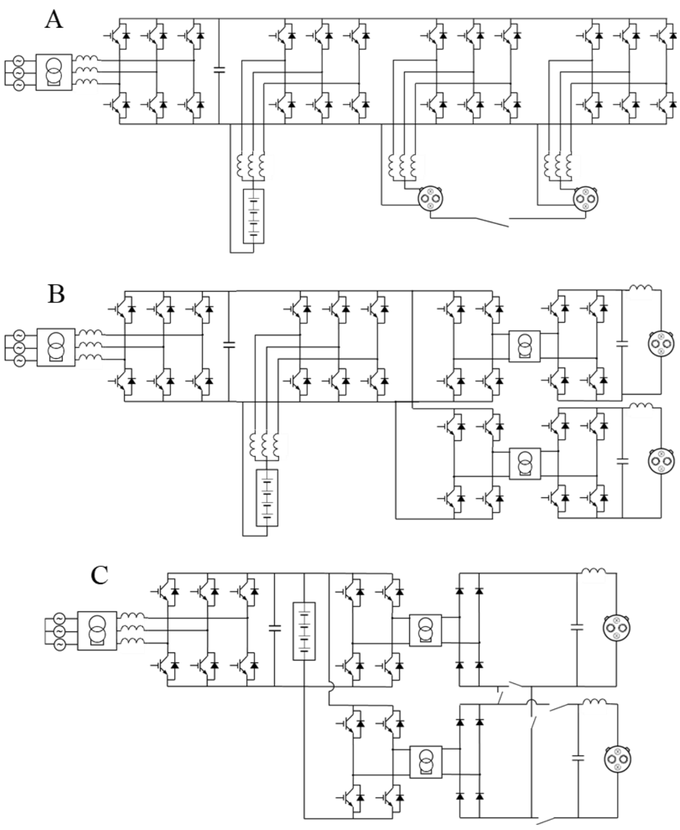

Fig.2 – Electrical solutions for Ultrafast charging station

The structure C has been implemented and installed in the laboratory of engines 'Perez de Vera' of the department and the next step will be the testing phase and the evaluation of charging performance with an electric vehicle or a test-bench simulator. In order to give an idea of about the expected performances, may be said: when the BESS is completely charged, the station can charge two vehicles of 40 kWh each simultaneously or one vehicle of 75 kWh in 10 minutes. After this described vehicles' charge happens, the BESS employs more or less 30 min to come back to the full charge.

A strategy to manage a real Ultrafast charging service, taking into account the various operative conditions in which the vehicles and the station can found and the chance that a queue occur, has already been developed.

In order to explain the scheduling algorithm used in this management strategy, the charging procedure is analyzed:

- The first vehicle arrives at the station and provides its status information: State of Charge, Capacity of the battery and maximum value of the charging power or current.
- The system processes this information together with the BESS status and the energy and the power constraints and results the charging profile.
- The customer receives the receipt with the charging profile and pays on the basis of the charging time: a faster charge is a more expensive charge.
- The same procedure is applied to the second vehicle, but the energy and the power constraints depend on the charging profile assigned to the first vehicle in this case.

The choices on the first vehicle affect the charging profile planning for the second one, but not vice versa. Because the first customer has already accepted the charging profile for his vehicle and he has paid for it. For this reason, the planning for the second vehicle is more constrained, so the performances of the charge are less than that of the first vehicle.

The charging profile's planning of a vehicle is chosen to minimize its charging time under power and energy constraints. This choice not only guarantee the maximum charging performances to each vehicle, but also tries to leave at least one slot free for a vehicle to come, in order to avoid a queue.

Another topic of my research activity during this academic year is the Wireless Power Charge for the e-bike sharing service implemented at the department as a part of a few years ago project. The goal of this activity has been to renew the custom wireless battery charging system realized for the project and to implement a secondary side sensorless control.

The wireless battery charging system consists of two ferromagnetic coils, that are part of a series-series resonant converter, that exchanges power through electromagnetic induction. On the primary side the system is connected to the grid, on the secondary side the battery of the e-bike is connected to be charged. The sensorless control strategy intends to manage the charge of the battery, identifying the secondary coil current of resonant transformer and the battery voltage without measuring them, but estimating them with a Fourier frequency domain methodology.

The methodology proposed consist of Fourier transformation in frequency domain of the primary coil current and voltage to find the secondary coil current and voltage. The components of current and voltage on secondary side for each multiplier of main frequency result from the resolution of a nonlinear system of algebraic equations dependent on the components of current and voltage on primary side, the secondary side electrical values are obtained from the superposition of components of each frequency. This identification strategy needs to know the initial condition, so, before starting the control, the physical system is supplied in open loop in order to estimate the initial value of battery current and voltage.

The results show that this strategy is strictly dependent on the accuracy of the battery model and on the alignment of coils, but it works fairly both in continuous current mode and in discontinuous current mode.

4. Research products:

Pubblications:

- **Published:** Diego Iannuzzi, Pasquale Franzese. "Ultrafast Charging Station for Electrical Vehicles: Dynamic Modelling, Design and Control Strategy", *Mathematics and Computers in Simulation 2020*
- **Published:** Diego Iannuzzi, Mario Pagano, Pasquale Franzese, Cristina Roscia. "On-board Energy Storage Systems based on Lithium Ion Capacitors for LRT Energy Saving: Optimization Design Procedure", *Proceedings of the IEEE International Conference on Industrial Technology, 2020, 2020-February*
- **Published:** Brando Gianluca, Cervone Andrea, Franzese Pasquale, Meo Santolo, Toscano Luisa. "Gain scheduling control with minimum-norm pole-placement design of a dual-active-bridge dc-dc converter", *2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2020*
- **Published:** Pasquale Franzese, Diego Iannuzzi, Fabio Mottola, Mario Pagano, Daniela Proto. "Charging Strategies for Ultra-Fast Stations with Multiple Plug-in Electric Vehicle Parking Slots", *2020 International Annual Conference, AEIT 2020*

5. Conferences and seminars attended

I attended following conferences where I presented papers:

- *IEEE International Conference on Industrial Technology, ICIT 2020, Buenos Aires, Agentina, 26-28 February 2020*
- *2020 International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2020, Napoli, Italia, 24-26 June 2020*
- *2020 International Annual Conference, AEIT 2020, Virtual Conference, 22-25 September 2020*

6. Tutorship

The only experiences are support to master thesis students and teaching support for the course of "Macchine ed azionamenti elettrici" of my tutor prof. Diego Iannuzzi.