



**PhD in Information Technology and Electrical Engineering**

**Università degli Studi di Napoli Federico II**

**PhD Student: Pasquale Natale**

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**XXX Cycle**

**Training and Research Activities Report – First Year**

**Tutor: Diego Iannuzzi**



Add the following items according to the meeting we had today.

Concerning the structure of the document, use the Section number as is. Use the sub-contents indicated with a letter only as a suggestion for your content (a free form text is preferable)

### 1. Information

My name is Pasquale Natale and I graduated cum laude in Electrical Engineering at University of Naples Federico II. I am a Ph.D student in Information technology and Electrical Engineering (XXX cycle) at the same University and my tutor is Prof. Diego Iannuzzi. My fellowship is financed by Ansaldo STS S.p.A for research in “methodologies and technologies for increasing energy efficiency in light railway systems.

### 2. Study and training activities

#### a) Courses

- “*Dinamica e controllo di macchine ed azionamenti elettrici (I modulo: Dinamica di macchine ed azionamenti elettrici)*”, M.Sc. course, held by Prof. Diego Iannuzzi (6 CFU)
- “*Dinamica e controllo di macchine ed azionamenti elettrici (II modulo: Controllo degli azionamenti elettrici)*”, M.Sc. course, held by Prof. Diego Iannuzzi (6 CFU)
- “*Identificazione e Controllo Ottimo*”, M.Sc. course, held by Prof. Franco Garofalo (0 CFU)
- “*Designing and writing scientific manuscripts for publication in english language scholarly journals, and related topics*”, Ad hoc module, held by Prof. Barnett Parker (3 CFU)
- “*Sistemi elettrici per i trasporti*”, M.Sc. course, held by Prof. Guido Carpinelli (0 CFU)

#### b) Seminars

- “*State of the art in power converters for high voltage DC transmission systems*”, Philippe Ladoux (0,4 CFU);
- “*Fundamentals of semiconductor power modules reliability*”, Alberto Castellazzi (0,4 CFU);
- “*Advanced power module thermal management and design for lifetime extension*”, Alberto Castellazzi (0,4 CFU);
- “*Power module on-board health monitoring*”, Alberto Castellazzi (0,4 CFU);
- “*Partial possibilistic regression path modelling*”, Rosaria Romano (0,4 CFU);
- “*Mathematical modelling of atomic force microscopes*”, Martin Homer (0,2 CFU);

- “*On Abel differential equations of the 2<sup>nd</sup> kind and exact inversion of boost DC/AC converters*”, Josep Olm (0,2 CFU);
  - “*Lagrangean relaxation and set covering*”, Manlio Gaudio (1 CFU)
- c) External courses
- *16<sup>th</sup> edition of the European PhD School: Power Electronics, Electrical Machines, Energy Control & Power Systems*, 25-29 May 2015, Gaeta (Italy) (3 CFU);

### 3. Research activity

My research activity refers to the methodologies for improving the energy efficiency in urban electrified railway transportation systems, in particular by means of supercap-based energy storage systems.

First of all my work focused on the state of the art about the different technologies used to implement energy storage systems in urban railway networks and on the different control strategies of this kind of systems reported in literature.

After this step I worked on the following topics :

- a) Analysis, numerical simulation and experimental test of wayside supercap-based energy storage system for urban railway applications: this activity has been performed in collaboration with Ansaldo STS and Ansaldo Breda in the context of the research project SFERE – “Sistemi Ferroviari: Eco-sostenibilità e Risparmio Energetico” (PON01\_00595). The final goal of this research activity is the study of the behaviour and the improvements in terms of energy saving, voltage drops and line losses with reference to a typical urban electrified railway system integrated with a supercap-based energy storage system installed along the track.
- The first step was the definition of a simple case study to be investigated and of the strategy for the sizing and control of the storage system. After some tests in Matlab/Simulink environment a real scale simulator of the system under investigation has been planned and set up in the laboratory of Ansaldo Breda. The tests carried out thanks to this simulator validated the goodness of the control strategy chosen and the improvement of system energy performances.
- b) Characterization on a test bench of LiC (Lithium-ion Capacitors) used as energy storage for tramway systems: this activity has been performed in collaboration with Ansaldo Breda in the context of the research project SFERE – “Sistemi Ferroviari: Eco-sostenibilità e Risparmio Energetico” (PON01\_00595). The first step of this activity has been the set up in the Transportation Laboratory of DIETI of a test bench in order to assess the behaviour and the performances of 4 LiC modules (69 F, 125V). The test bench implemented is made up of: a power section that is the DC supplied circuit used to achieve the charge/discharge cycles of LiC modules; a control

section to command the DC/DC converter that interfaces the modules with the power supply system and allows the setting of the reference current for charge/discharge operations; a measurements and acquisition data section.

The tests carried out have verified the effectiveness of internal protections of modules and the correct balancing of cell voltages after a single charge/discharge cycle and have made possible an analysis of thermal behaviour of modules after a sequence of charge discharge cycles.

Finally the capacitance and the energy stored of each module have been evaluated and compared with respect to the values reported in the datasheet.

- c) Study and simulation of a “real time” control strategy for wayside energy storage systems in urban electrified transportation systems: in this activity the expression of the reference current for the storage system has been calculated in an analytical closed form starting from the resolution of an optimization problem aiming the minimization of line losses. The resulting optimal sizing of the storage system has been carried out by imposing an isoperimetric condition on the energy stored.
- In conclusion, at the end of this activity it has been evaluated a real time control law for the DC/DC converter of the storage system based on the knowledge of vehicle position and current profiles.
- Finally this control strategy has been verified on a case study by means of numerical simulation in Matlab/Simulink environment.

## 4. Products

- a) Published works
- *Iannuzzi D., Natale P., Nizza A., Pagano M., “An ‘on scale’ simulator for urban DC railway traction application”, AEIT International Annual Conference, Naples 14-16 October 2015*
- b) Works in preparations
- *Iannuzzi D., Lauria D., Natale P., “A real-time control strategy for supercapacitor-based energy storage systems in light electrical transportation networks”*

## 5. Conferences and Seminars

- Participation to the “*International Conference on Electrical Systems for Aircraft, Railway and Ship Propulsion (ESARS 2015)*”, Aachen (Germany) 03-05 March 2015 (**Topics**: T1 – Aircraft Electrical Applications; T2 – Shipboard Electrical Applications; T3 – Electrical Railway Traction Systems; T4 – Electrical Systems in Road Vehicles and Infrastructures in Transportation.)

- "Presentation of the paper *"An 'on scale' simulator for urban DC railway traction application"*, AEIT International Annual Conference, Naples 14-16 October 2015

## 6. Tutorship

I was involved in laboratory sessions on power electronics (total amount of 26 hours)

## 7. Credit summary

|                 | Credits year 1 |         |         |         |         |         |         |             |
|-----------------|----------------|---------|---------|---------|---------|---------|---------|-------------|
|                 | Estimated      | 1       | 2       | 3       | 4       | 5       | 6       | Summary     |
|                 |                | bimonth | bimonth | bimonth | bimonth | bimonth | bimonth |             |
| <b>Modules</b>  | <b>21</b>      | 0       | 0       | 0       | 6       | 12      | 0       | <b>18</b>   |
| <b>Seminars</b> | <b>5</b>       | 0       | 0,4     | 1,8     | 1,2     | 0       | 0       | <b>3,4</b>  |
| <b>Research</b> | <b>34</b>      | 6       | 6       | 6       | 8       | 4,6     | 8       | <b>38,6</b> |
|                 | <b>60</b>      | 6       | 6,4     | 7,8     | 15      | 17      | 8       | <b>60</b>   |

# Training and Research Activities Report – First Year

PhD in Information Technology and Electrical Engineering – XXX Cycle

Pasquale Natale

| Year | Lecture/Activity  | Type            | Credits | Certification | Notes                      |
|------|---|-----------------|---------|---------------|----------------------------|
| 1    | Dinamica e controllo di macchine ed azionamenti elettrici (I modulo: Dinamica di macchine ed azionamenti elettrici)"        | MS Module       | 6       | x             |                            |
| 1    | Dinamica e controllo di macchine ed azionamenti elettrici (II modulo: Controllo degli azionamenti elettrici)                | MS Module       | 6       | x             |                            |
| 1    | Identificazione e Controllo Ottimo  | MS Module       | 0       | \             | i only attended the course |
| 1    | Designing and writing scientific manuscripts for publication in english language scholarly journals, and related topics     | ad hoc module   | 3       | x             |                            |
| 1    | 16 <sup>th</sup> edition of the European PhD School: Power Electronics, Electrical Machines, Energy Control & Power Systems | Doctoral school | 3       | x             |                            |
| 1    | Sistemi elettrici per i trasporti   | MS Module       | 0       | \             | in progress                |
| 1    | State of the art in power converters for high voltage DC transmission systems   | Seminar         | 0,4     | x             |                            |
| 1    | Fundamentals of semiconductor power modules reliability   | Seminar         | 0,4     | x             |                            |
| 1    | Advanced power module thermal management and design for lifetime extention  | Seminar         | 0,4     | x             |                            |
| 1    | Power module on-board health monitoring   | Seminar         | 0,4     | x             |                            |
| 1    | Partial possibilistic regression path modelling   | Seminar         | 0,4     | x             |                            |
| 1    | Mathematical modelling of atomic force microscopes  | Seminar         | 0,2     | x             |                            |
| 1    | On Abel differential equations of the 2 <sup>nd</sup> kind and exact inversion of boost DC/AC converters                    | Seminar         | 0,2     | x             |                            |
| 1    | Lagrangian relaxation and set covering  | Seminar         | 1       | x             |                            |