



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

PhD Student: Massimiliano Ferrara

Cycle: XXXIX

Training and Research Activities Report

Year: First

Tutors: prof. Fabio Mottola

prof. Daniela Proto

Co-Tutor: Eng. Antonio Ricca

Date: November 7, 2024

Training and Research Activities Report

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Author:

1. Information:

- **PhD student:** Massimiliano Ferrara
- **DR number:** DR997212
- **Date of birth:** 30/12/1997
- **Master Science degree:** Electrical Engineering
University: University of Naples Federico II
- **Doctoral Cycle:** XXXIX
- **Scholarship type:** company-funded by ENEA Research Centre (Portici)
- **Tutors:** Prof. Fabio Mottola, Prof. Daniela Proto
- **Co-tutor:** Eng. Antonio Ricca

2. Study and training activities:

Activity	Type ¹	Hours	Credits	Dates	Organizer	Certificate ²
How to boost your PhD	Course	14	5	10-17-24-31/01/2024, 07/02/2024	Prof. Antigone Marino (Physics Department - Unina)	Y
Strategic Orientation for STEM Research & Writing	Course	24	5	07-15/12/2023, 12-19/01/2024, 09-23/02/2024, 04/04/2024	Sig.ra Adriana D'Auria (DIETI - Unina)	Y
Using Deep Learning Properly	Course	12	4	23-25-30/01/2024, 1-6-8/02/2024	Dr. Andrea Apicella (DIETI - ITEE PhD)	Y
Statistical Data Analysis for Science and Engineering Research	Course	12	4	15-19-23-26-27-29/02/2024	Prof. Roberto Pietrantuono (DIETI - ITEE PhD)	Y
Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems	Course	12	4	2-16-18-23-25/07/2024, 08/10/2024	Prof. Adriano Masone (DIETI - Unina)	Y
Summer School On Smart Grid, 9th Edition, "The Role of Grid Operational Flexibility in Power System Decarbonization"	Doctoral School	30	5	08-09-10-11/07/2024	Proff. Vincenzo Galdi, Vito Calderaro (Unisa)	Y

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Ensuring Electronic Reliability Against CERN's Radiation Environment	Seminar	2	0.4	01/12/2023	Prof. Francesco Fienga (DIETI - Unina)	Y
Energy-Efficient Data Science	Seminar	1	0.2	13/12/2023	Prof. Elio Masciari (DIETI - Unina)	Y
HOMINIS	Seminar	5	1	21/02/2024	Prof. Carlo Sansone (DIETI - Unina), Eng. Stefano Marrone (DIETI - Unina)	Y
Evolution of Short Term Unit Scheduling Solutions in Power Systems Operations	Seminar	1	0.2	17/04/2024	Dr. Khaled Abdul-Rahman (IEEE)	Y
Power Electronics Role in Future Hydrogen Systems	Seminar	1	0.2	25/04/2024	Dr. Francisco Canales (IEEE), Dr. Ahmed Abdelhakim (IEEE)	Y
Solar Design and Installation Training: 101-7 Solar System Design Guidelines	Seminar	1	0.2	29/04/2024	Dr. Shuhui Li (IEEE)	N
Intelligenza artificiale e regole del mercato	Seminar	2	0.4	14/05/2024	Prof. Antonia Maria Tulino (Unina)	Y
Machine Deception	Seminar	1	0.2	23/05/2024	Prof. Alessandra Rossi (Unina)	Y
Sustainable IT: Strategies and Best Practices for a Green Engineering Future	Seminar	5	1	27/05/2024	Prof. Antonia Maria Tulino (Unina)	Y
Generative AI for Software Engineering: Strategies, Impacts, and Practical Applications	Seminar	5	1	29/05/2024	Prof. Antonia Maria Tulino (Unina)	Y
Social Network Analysis: Methods and Applications	Seminar	2	0.4	07/06/2024	Prof. Giancarlo Sperli (DIETI - Unina)	Y
Introduction to Large Language Models: Evolution and the current state	Seminar	2	0.4	10/06/2024	Prof. Giancarlo Sperli (DIETI - Unina)	Y
On the Single Allocation hub location problems:	Seminar	1	0.2	26/06/2024	Proff. Claudio Sterle, Maurizio	Y

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New formulations and Solving Methods					Boccia, Adriano Masone (DIETI - Unina)	
Using support vector machines for feature selection and outlier detection	Seminar	1	0.2	26/06/2024	Proff. Claudio Sterle, Maurizio Boccia, Adriano Masone (DIETI - Unina)	Y
Real-time Resource Management for Adaptive Embedded Systems and Applications	Seminar	1	0.2	26/06/2024	Prof. Marcello Cinque (DIETI - Unina)	Y
Resource management and orchestration for mixed-criticality cloud/distributed systems	Seminar	1	0.2	27/06/2024	Prof. Marcello Cinque (DIETI - Unina)	Y
Including elastic demand in the hub line location problem	Seminar	1	0.2	28/06/2024	Proff. Claudio Sterle, Maurizio Boccia, Adriano Masone (DIETI - Unina)	Y
The maximal covering location problem with edge downgrades	Seminar	1	0.2	28/06/2024	Proff. Claudio Sterle, Maurizio Boccia, Adriano Masone (DIETI - Unina)	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	0.2	9	0	9.2
Bimonth 2	5	1.4	2	0	8.4
Bimonth 3	5	0.6	7	0	12.6
Bimonth 4	4	4.6	6	0	14.6
Bimonth 5	9	0	4	0	13
Bimonth 6	4	0	7	0	11
Total	27	6.8	35	0	68.8
Expected	30 - 70	10 - 30	80 - 140	0 - 4.8	

3. Research activity:

Several institutions and international agencies have recognized “clean hydrogen”, meaning hydrogen produced through electrolysis using renewable energy (“green hydrogen”) or by Steam Methane

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Reforming (SMR) with the addition of Carbon Capture and Storage (“blue hydrogen”), as one of the key enablers in the upcoming energy transition toward a decarbonized future [1,2,3]. In fact, clean hydrogen has the potential to serve many purposes. Among the most important ones, it can facilitate the decarbonization of those sectors and activities that electrification struggles to reach (steel, heavy transport, shipment, rail transport in some rural areas, etc.). Also, it can fill the gap in short-to-medium term energy storage, in which batteries are not ideal because of their self-discharge performance. More generally, proper integration of hydrogen – especially green hydrogen – in the energy mix would fall very much in line with the current trend toward sector coupling and enhancing grid flexibility, as it would open new Power-to-X pathways while also offering an additional way to mitigate the strain that the ever-increasing penetration of aleatory Renewable Energy Sources (RESs) puts on the electrical grid.

Despite all the advantages that green hydrogen can theoretically bring, low-emission hydrogen currently accounts for less than 1% of all hydrogen demand worldwide [4]. This is due to several reasons, from a slow growth in demand to the lack of unified regulation. Most importantly, without incentives, this technology is not yet economically competitive, in most cases, compared to traditional fossil-based solutions like SMR. As a result, large investments in green hydrogen technologies are still deemed too risky by a significant share of potential stakeholders and the green hydrogen space is growing at a slower pace than anticipated. This has contributed to creating a knowledge gap when it comes to practical experience in green hydrogen device management. More specifically, laboratory-tested advanced control strategies for the effective integration of hydrogen devices in the grid, accounting for all three parts of the green hydrogen cycle (production from electrolyzers, storage, and usage, for example by re-electrification through fuel cells), are lacking in the literature and are the main focus of my doctoral research.

The very first part of my research activity was dedicated to deepening my knowledge of hydrogen devices, especially Proton Exchange Membrane (PEM) electrolyzers, understanding their working principles and implementing some static linear and non-linear models in both Matlab and Python simulation environments. Using those models, an optimal strategy was developed for the scheduling of the controllable elements of a microgrid featuring active and passive loads, distributed resources, and an electrolyzer working in a Power-to-Gas configuration. Said strategy was applied to a first case study in which, by hypothesis, the resources were able to provide flexibility services and were organized, together with the electrolyzer, to form a Renewable Energy Community (REC). The optimal management of all resources was achieved by defining a Mixed Integer Linear Programming (MILP) problem. As a result of the case study, the economic contribution of the electrolyzer to the community’s revenue was estimated and significant synergies between reactive power control and daily hydrogen production capability were identified.

Later on, I worked on a sensitivity and statistical analysis regarding the sizing of photovoltaic generators and battery storage systems to be used together with an electrolyzer. Once again, RECs were used as context for the study, as incentive strategies are necessary for the economic viability of green hydrogen production. A single case sensitivity analysis with various sizing combinations was performed, followed by Montecarlo simulations varying the load demand and PV production (main inputs of the problem). The results were analysed to understand the trends in hydrogen production, shared energy, total revenue of the REC, and reactive power provision.

Recently I have been working on a more extensive evaluation of the sizing and economic viability of electrolyzers directly powered by PV systems. Simulating power flows for the whole life cycle of the system under study and employing decision theory criteria, the aim is to identify guidelines for electrolyzer sizing accounting for uncertainties in prices, RES generation, and load demand. Also, it

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should be possible to identify techno-economic thresholds for the viability of green hydrogen. This work is ongoing.

Regarding the laboratory side of my research, which was developed in parallel with the above-mentioned research activities, I participated in the still ongoing setup of the laboratory equipment at ENEA Research Center. Also, I reviewed the scientific literature regarding empirical and semi-empirical electrolyzer and fuel cell models, identifying suitable models for the future characterization of the hydrogen devices in the laboratory.

References

- [1] European Commission, Directorate-General for Energy, ‘COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A hydrogen strategy for a climate-neutral Europe’, COM(2020)301 final.
- [2] IEA (2024), Global Energy and Climate Model, IEA, Paris <https://www.iea.org/reports/global-energy-and-climate-model>, Licence: CC BY 4.0.
- [3] IRENA (2023), World Energy Transitions Outlook 2023: 1.5°C Pathway, Volume 1, International Renewable Energy Agency, Abu Dhabi, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2023/Jun/IRENA_World_energy_transitions_outlook_2023.pdf
- [4] IEA (2024), Global Hydrogen Review 2024, IEA, Paris <https://www.iea.org/reports/global-hydrogen-review-2024>, Licence: CC BY 4.0.

4. Research products:

- Ferrara, M., Mottola, F., Proto, D., Ricca, A., Valenti, M. Local Energy Community to Support Hydrogen Production and Network Flexibility. *Energies* (MDPI), published, 2024.
- Ferrara, M., Mottola, F., Proto. Contribution of Renewable Energy Communities to Grid Operation: Sensitivity and Statistical Analyses. 2024 IEEE International Humanitarian Technologies Conference (IEEE IHTC), accepted.

5. Conferences and seminars attended

- Summer School On Smart Grid, 9th Edition, “The Role of Grid Operational Flexibility in Power System Decarbonization”, University of Salerno (Salerno, Italy), 8-11 July 2024.
- 2024 IEEE International Humanitarian Technologies Conference (IEEE IHTC), Polytechnic of Bari (Bari, Italy), 27-30 November 2024.
Designated as presenting author of the paper “Contribution of Renewable Energy Communities to Grid Operation: Sensitivity and Statistical Analyses” (presenting on November 29, 2024).

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6. Activity abroad:

None.

7. Tutorship

None.