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

Academic year: 2024-25 - PhD Year: Second

Tutors: Prof. Fabio Mottola

Prof. Daniela Proto

Co-Tutor: Eng. Antonio Ricca

Date: 10 November, 2025

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXIX **Author:** Massimiliano Ferrara

1. Information:

- **PhD student: Massimiliano Ferrara PhD Cycle: XXXIX**
- **DR number: DR997212**
- **Date of birth: 30/12/1997**
- **Master Science degree: Electrical Engineering**
  University: University of Naples Federico II
- **Scholarship type: company-funded by ENEA Research Centre (Portici)**
- **Tutors: Prof. Fabio Mottola, Prof. Daniela Proto**
- **Co-tutor: Eng. Antonio Ricca**
- **Period abroad:**
  Institution: Haute École d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD)
  2 months already spent, 2 more months to be spent (4 months in total)

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Solar cells: modelling and applications	Courses	15	4	10-14-17-24-28/01/2025	Dr. Ilaria Matacena (DIETI, UniNA)	Y
I pilastri della trasformazione digitale	Courses	12	3	2-3-4-14-15-16/04/2025, 16/05/2025	Prof. Nicola Mazzocca (DIETI, UniNA)	Y
Matrix Analysis for Signal Processing with MATLAB Examples	Courses	14	3	6-8-12-19-20-29/05/2025, 03/06/2025	Dr. Massimo Rosamilia (DIETI, UniNA)	Y
Hydrogen Summer School 2025 – ENEA – "Progetti sull'Idrogeno: Innovazione e Sostenibilità"	Doctoral School	21.5	4.3	27-28-29-30/05/2025	ENEA Casaccia (RM), AIDIC, University of Rome La Sapienza	Y
Modeling of Electrolysis Plants on Component and System Level	Seminar	2.5	0.5	14/11/2024	Dr. Mohammed Al-Saadi (DERlab)	Y
Dalla Tradizione all'Innovazione: Il Viaggio Digitale; Sfide e opportunità che la trasformazione digitale può offrire	Seminar	4	0.8	20/11/2024	Prof. Mario Pagano (DIETI, UniNA)	Y
Shaping robustly control	Seminar	1	0.2	05/12/2024	Prof. Ciro	Y

loop: look into stability margins & uncertainties					Visone (DIETI, UniNA)	
Time Window Assignment for Attended Home Delivery	Seminar	1	0.2	05/12/2024	Proff. Claudio Sterle, Maurizio Boccia, Adriano Masone (DIETI, UniNA)	Y
Kernel Search: a general-purpose method for MILP problems	Seminar	1	0.2	06/12/2024	Proff. Claudio Sterle, Maurizio Boccia, Adriano Masone (DIETI, UniNA)	Y
Solid State Transformers: Fundamentals, Insights and New Trends	Seminar	2	0.4	20/12/2024	Ing. Luigi Pio Di Noia (DIETI, UniNA)	Y
Opportunità e Prospettive dell'AI Generativa nel mondo del Lavoro e della Ricerca	Seminar	4	0.8	29/01/2025	ENEA Portici (NA)	N
Optimisation-based Control of Flexible Resources in Sustainable Energy Networks	Seminar	1	0.2	05/02/2025	Prof. Luigi Glielmo (DIETI, UniNA)	Y
Dynamic Risk Assessment in Industrial Applications: Leveraging Bayesian Inference for Enhanced Decision-Making	Seminar	1	0.2	04/03/2025	Dr. Francesco Vitale (DIETI, UniNA)	Y
Unlocking Surplus Interconnection Service. Colocating Renewable and Thermal Power Plants	Seminar	1	0.2	12/03/2025	Talgat Kopzhanov (IEEE)	Y
AI-driven: Decarbonization for Power Systems	Seminar	1	0.2	20/03/2025	Dawei Qiu, Zhu Han, Shengrong Bu (IEEE)	Y
Safety Assessment of Autonomous Vehicles: Approaches and Challenges	Seminar	1	0.2	24/03/2025	Proff. Stefano Russo, Roberto Pietrantuono (DIETI, UniNA)	Y
High Power Grounding: Changes to state-of-the-art over the past 150 years	Seminar	1	0.2	26/03/2025	Theo Laughner, Jeff Jordan (IEEE)	Y
Safety of highly automated driving systems	Seminar	1	0.2	23/04/2025	Prof. Marcello Cinque (DIETI, UniNA)	Y
Grid forming in Electrolysis Plants	Seminar	2	0.4	23/06/2025	Dr. Mohammed Al-Saadi	N

					(DERlab), Dr. Norbert Henze (Fraunhofer IEE)	
System Technology and Grid Integration of Hydrogen Plants	**Seminar**	**3**	**0.6**	**26/09/2025**	**Dr. Philipp Strauss (Fraunhofer IEE), Dr. Norbert Henze (Fraunhofer IEE)**	**N**
Participation to the organization of "Porte Aperte 2025"	**Tutorship**	**13**	**0.5**	**11-12-13/02/2025**	**Prof. Mauro Alfonso William (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	2.3	7	0	9.3
Bimonth 2	4	1	8	0.5	13.5
Bimonth 3	0	1.2	9	0	10.2
Bimonth 4	10.3	0.4	6	0	16.7
Bimonth 5	0	0	6	0	6
Bimonth 6	0	0.6	9	0	9.6
Total	14.3	5.5	45	0.5	65.3
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

3. Research activity:

In recent years, hydrogen has been garnering more and more attention from both the research world and policymakers. In particular, green hydrogen – that is, hydrogen produced through the electrolysis process using energy provided by renewable sources – is recognized by international agencies as a key enabler for the next steps toward the decarbonization of the energy sector [1,2]. On this regard, hydrogen is a versatile energy vector, capable of contributing in different ways: from decarbonizing hard-to-abate industry sectors (such as chemical industry, refining, and steelmaking), to providing a clean alternative for the transport sector in those cases when electrification is costly, impractical, or outright unfeasible (heavy transport, shipping, rail transport in rural areas). With reference to the power sector in particular, seasonal energy storage appears to be the most promising application for green hydrogen [3]. In fact, despite having low round-trip efficiency, Power-to-Hydrogen-to-Power (P2H2P) technologies are characterized by great self-discharge characteristics, allowing them to outperform more common storage options over longer periods of time [4].

Despite the above-mentioned advantages and possibilities of green hydrogen, the development of a green hydrogen economy is suffering from setbacks, falling behind compared to previous growth estimates [2,3]. The main reasons for this are the slow-rising demand for hydrogen, the still high costs of the devices, and a general lack of regulation and experience with regard to hydrogen deployment in the energy system.

Moving within this context, my research activity for the second year explored cost-effective strategies for integrating green hydrogen technologies into the electrical system, focusing on the following three topics:

- Sizing of electrolyzers and batteries accounting for uncertainties
- Scheduling of distributed resources accounting for uncertainties and participation in voltage regulation
- Sizing, control, and performance evaluation of a P2H2P system with participation in frequency regulation

3.1. Sizing of electrolyzers and batteries accounting for uncertainties

While significant research efforts had already been dedicated to defining optimal sizing strategies for green hydrogen devices, most papers on this subject did not consider uncertainty elements in the planning problem. Even for those that did, they usually focused only on a few selected types of uncertainties. However, uncertainties in the planning phase are among the reasons currently slowing the deployment of hydrogen projects, and thus require careful consideration. In addition, incentive schemes were almost always neglected in papers dealing with optimal planning, despite them often being fundamental for the economic viability of hydrogen projects.

Therefore, part of my activity was dedicated to devising a planning strategy for an electrolyzer (EL) and a battery energy storage system (BESS), capable of dealing with multiple sources of uncertainty, namely variations in renewable energy generation, electricity demand, and electricity prices. Said strategy, defined as an economic optimization, was devised to be applied in the context of Renewable Energy Communities (RECs). On this note, three different connection configurations were also considered for the devices involved, in order to study how they would affect the performance of the system.

Given a set of possible design alternatives, meaning combinations of EL and BESS sizes, and a set of potential future scenarios, the optimal planning revolves around the use of Decision Theory (DT) criteria to elaborate the results of life cycle simulations of the system's behavior. For any design alternative and scenario, those simulations resulted from the solution of Mixed Integer Linear Programming (MILP) problems aimed at maximizing the daily revenues from energy sharing within the REC, as well as hydrogen and electricity selling. The use of DT approaches, namely *expected cost minimization*, *min-max weighted regret*, and the *stability areas* criterion, allows the defined sizing approach to serve as a flexible tool for decision makers. Depending on the information available with respect to uncertainty sources and scenario probabilities, it can be used not only to find the optimal solution, but also to evaluate the differences between riskier and more risk-averse solutions, and to analyze how probabilities affect the final decision.

3.2. Scheduling of distributed resources accounting for uncertainties and participation in voltage regulation

As the process of decarbonization continues, the increasing penetration of Renewable Energy Sources (RESs) is creating stability and capacity issues for power systems. One of the solutions that can contribute to addressing such issues is the participation of Distributed Energy Resources (DERs) in ancillary grid services. With respect to hydrogen devices, this topic is currently being discussed in literature, but most of the works focus on frequency regulation services. Fewer instead consider the use of hydrogen devices to provide voltage regulation through reactive power support.

Relating to this topic, I developed a probabilistic management application for a case study REC featuring several kinds of DERs: photovoltaic (PV) generators, controllable loads, BESSs, and finally an EL working in a Power-to-Gas configuration. The REC is part of a larger MV network featuring non-controllable loads with both active and reactive power consumption profiles. Aside from the controllable loads, which leverage their active power flexibility, all the DERs listed above, including the EL, participate in the reactive power support service.

The application is based on the solution of an optimal scheduling of both active and reactive powers of the DERs. Defined as a MILP problem, it aims at maximizing revenues while satisfying fundamental grid and device constraints, including capability curves for the devices, which determine the extent to which they can provide reactive power. Two versions of the scheduling strategy were defined, in order to compare the results of the two different reactive power procurement approaches: centralized control, where reactive power setpoint signals are determined by a central controller, and decentralized control, where DERs adjust their reactive power autonomously, based on local control functions (e.g., a $Q(V)$ characteristic). Uncertainties related to PV generation and load demand were addressed using Monte Carlo simulations. This allowed obtaining probabilistic distributions of the results in terms of revenue, hydrogen production, and reactive power provision. The work demonstrated that reactive power procurement through centralized control is more efficient compared to the distributed approach, requiring significantly less reactive power from distributed resources. Moreover, for the chosen case study, increasing the penetration of RESs led to opposite trends in terms of reactive power provision. While the decentralized strategy required more participation by the DERs, with the centralized one, less and less reactive power was needed to satisfy the power system voltage constraints.

3.3. Sizing, control, and performance evaluation of a P2H2P system with participation in frequency regulation

As mentioned above, the scientific literature already features a significant number of works related to the participation of green hydrogen devices in frequency regulation services. This topic is of particular interest, as using an EL or a Fuel Cell (FC) to provide such services not only helps maintain the stability of the power system, but also provides an additional form of revenue for hydrogen devices, as frequency regulation is remunerated in practice. Therefore, participation in frequency regulation can be leveraged to increase the economic viability of ELs and FCs.

Following this line of research, my latest activity has been focused on developing an optimal planning strategy for a multi-vector hydrogen-electrical system featuring all three elements of the green hydrogen cycle (i.e., EL, hydrogen storage, and FC), in a P2H2P configuration. A particular feature of this work would be the analysis of the performance of a system in which hydrogen devices are used to contemporarily provide frequency regulation and seasonal storage, an aspect currently absent in the available literature, despite seasonal storage being among the most promising applications for green hydrogen [4].

This work is ongoing and is the focus of my research abroad period.

References

[1] 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

[2] IEA (2025), Global Hydrogen Review 2025, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2025 , Licence: CC BY 4.0

[3] Johnson, N., Liebreich, M., Kammen, D. M., Ekins, P., McKenna, R., & Staffell, I. (2025). Realistic roles for hydrogen in the future energy transition. *Nature Reviews Clean Technology*, *1*(5), 351–371. https://doi.org/10.1038/s44359-025-00050-4

[4] Petkov, I., & Gabrielli, P. (2020). Power-to-hydrogen as seasonal energy storage: an uncertainty analysis for optimal design of low-carbon multi-energy systems. *Applied Energy*, *274*. https://doi.org/10.1016/j.apenergy.2020.115197

4. Research products:

- Ferrara, M., Mottola, F., Proto, D., Ricca, A., Valenti, M. Integrating Green Hydrogen Production and Electrical Energy Storage in Energy Communities Under Uncertainty. Applied Energy (Appl. Energy), indexed in Scopus and ISI Web of Science, submitted.
- Ferrara, M., Mottola, F., Proto, D. Enhancing Voltage Regulation through Renewable Energy Communities under Uncertainty. IEEE Transactions on Industry Applications (IEEE Trans. Ind. Appl), indexed in Scopus and ISI Web of Science, submitted.

5. Conferences and seminars attended

- Hydrogen Summer School 2025 – ENEA – “Progetti sull'Idrogeno: Innovazione e Sostenibilità”, ENEA Research Centre Casaccia (Rome, Italy), 27-30 May 2025.
- ENEA PhD day – Giornata dei Giovani Dottorandi, ENEA Research Centre Casaccia (Rome, Italy), 1 July 2025.
  Invited for poster presentation. Title of the poster: “Dimensionamento di un sistema PEMEL-BESS basato sulla teoria delle decisioni per la gestione delle incertezze.”

6. Periods abroad and/or in international research institutions

Toward the end of this academic year (2024-2025) I have begun my research period abroad, at the Haute École d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD), in Yverdon-les-Bains,

Switzerland. My activities started on the 25th August 2025 and have continued to the present day. As per defined in the learning agreement with the HEIG-VD, they will continue, uninterrupted, until the 23rd December 2025.
My work is supervised by Prof. Mauro Carpita, Director of the Institute d'Énergie (Energy Institute) at HEIG-VD, and Prof. Mokhtar Bozorg, Associate Professor in energy and power systems. Based on the former's extensive research experience and the latter's expertise in both electrical system modelling and optimization frameworks, my research has been led toward the definition of an optimal management strategy for a multi-vector system featuring hydrogen seasonal storage and frequency regulation service provision to the grid. The activities carried out since the beginning of the collaboration are:

- Background research and literature study on planning and scheduling applications for multi-vector hydrogen-electrical systems;
- Identification of a significant literature gap for the assessment of hydrogen's potential as a distributed resource of the electrical system, and definition of a relevant case study;
- Mathematical modelling of the optimal management problem, including the modelling of devices behaviour, interactions, and normative and contractual constraints.

The activities will continue toward software implementation and later expansion of the problem from the optimal management to the optimal planning scope.
I spent a total period of about 2 months abroad during this academic year.

7. Tutorship

- Participation in the organization of the event "Porte Aperte 2025" of University of Naples Federico II, 11-12-13 February 2025. Number of hours: 12.

8. Plan for year three

The activities planned for the third year are as follows:

- Completing my research period at the Haute École d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD): as mentioned above, this activity will continue toward the software implementation (in the Python/Pyomo environment) of the already defined optimal management strategy. Then, the scope of the problem will be extended from optimal scheduling to optimal planning.
- Deepening the study of P2H2P systems and their participation in ancillary services: guided by the results of the previous activity, further research efforts will be devoted to this topic. The objective of this research is to assess the value that frequency regulation – and, generally, ancillary services – can bring to multi-vector hydrogen-electrical systems.
- Laboratory activities at ENEA Research Centre (Portici): depending on the availability of the equipment, one or both of the following activities will be performed: testing of the developed control strategies on an electrical grid emulation system and tests on electrolyzers and metal-hydride storage tanks, to assess their dynamic performance and compatibility with the developed control strategies.

- PhD thesis writing: based on the research activities performed during the first two years, and on the work foreseen for the next one, a tentative title for my thesis is "Integration of hydrogen technologies in distribution grids: cost-effective approaches for the planning and operation of hydrogen-electrical systems". Accordingly, the core topic of this thesis will be the definition of optimal planning and scheduling strategies for realistic hydrogen deployment scenarios, with the consequent assessment of the value that advanced control can provide to multi-vector hydrogen-electrical systems.