NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Smart control and optimization of electrical smart grids

Ph.D. candidate

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Cycle

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Tutors

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1. Description of the research program

Managing, using and manipulating large amounts of data is one of the most important challenges in modern science: the now pervasive presence of “big data,” coupled with the growing development of disciplines such as artificial intelligence and machine learning, has attracted the attention of numerous researchers from different disciplines, who seek to harness the power of these methods to apply them to their specific context. Automatic scholars are no exception, who have been looking with strong interest for decades at the world of machine learning and, in recent years, especially at reinforcement learning techniques: a branch of artificial intelligence that, although born in a different context and with a different formalism, has several similarities and substantially similar goals to those of machine control. These techniques are part of that broader strand called “data-driven control.” Automatic and control theory have always made use of data-driven techniques for the realization of controllers, either through indirect techniques (identification processes) or direct synthesis.

The reason for interest in these issues is obvious: although classical model-based methodologies guarantee strong results in terms of stability and performance, their practical use requires knowing with some accuracy the model of the system to be controlled: when this is not possible, nominal performance degrades and even stability may no longer be guaranteed. The use of tools that do not require modeling of the system is therefore attractive, but it presents several problems: first, it is not easy to formulate, and thus guarantee, a system's stability requirement; second, many of these techniques, require large amounts of data to ensure good performance, and it is not always possible to conduct lengthy, and potentially dangerous, experiments on the processes to be controlled. An interesting approach to data-driven control is shown in , in which some of these difficulties are overcome with strategies that allow sufficient data to be collected with a single experiment and, more importantly, to synthesize the controller with an off-line iterative process. These strategies, which make use of a theoretical result that first appeared in, have led to numerous results in recent years, especially in the area of linear systems. The extension of these strategies to nonlinear systems is a largely open problem. Another strategy concerns the use of reinforcement learning techniques. The latter presents some additional difficulties, as mentioned above: the research interest in this area is to ensure that the strategies adopted meet stringent requirements in terms of stability and safety.
Their use is extremely promising and the applications numerous: from robotics, to autonomous driving, to power electronics. The application of these techniques to the control of smart grids is a topic of great interest: the latter are complex and highly distributed systems and require appropriate control strategies to achieve satisfactory performance. Learning techniques can be vertically integrated on smart grids architectures at every level: power generation, transmission and distribution. On the control (operational control) plane, large microgrids are difficult to model, and therefore data-driven algorithms can be effective in making up for the inability to adequately model the grid; in addition, control requirements often include safe zones for current and voltage values, which must not be violated: learning techniques are extremely well suited to these needs. On the transmission (optimal dispatch) side, interest in microgrids is also on their specific configuration: since they are highly distributed and highly flexible systems: reinforcement learning algorithms can also be used to derive the optimal topology of the distribution network.

Finally, destruction systems of this type are subject to security issues, which in this context can take on two different meanings: on the one hand, security related to the correct operational regimes of electrical quantities (a requirement that in some ways can be part of the aforementioned operational control); on the other hand, network security (cyber-security): knowledge of cyber-physical systems security, integrated with recent developments in cybersecurity policies based on machine learning could be applied to the smart grids context.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Background study	Individual Research and literature review on data-driven and reinforcement learning oriented algorithms	24/25 T1-T6	NO
Problem Statement	Problem formulation and evaluation of the methodologies, techniques, and theoretical tools to be adopted and developed for future research activities	24/25 T7-T12	NO

Second academic year (planned)

	Description	Period	Activity abroad
Further background study and proposed solutions.	Individual Research and literature review on data-driven control aimed at applications such as microgrid control. Development of novel control algorithm based on data.	25/26 T1-T6	NO
Simulation and experimental tests	Abroad research period at the Institute for Aerospace Technology of the University of Nottingham (UK). Design of simulation environment. Experimental tests and validation of the theoretical results.	25/26 T7-T12	YES

Third academic year (planned)

	Description	Period	Activity abroad
Simulation and experimental data evaluation	Evaluation of the obtained simulation and experimental results. Participation in conferences and seminars.	26/27 T1-T6	NO
Thesis writing	Drafting of conference and journal articles. Drafting of the Ph.D. thesis.	26/27 T7-T12	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	EECI Course	TBD	No	3
	EECI Course	TBD	No	3
	SIDRA Summer School	July 2025	Yes	3
	Partner Universities Course	TBD	Yes	3
	Partner Universities Course	TBD	Yes	3
	Partner Universities Course	TBD	No	3
	Dausy Course	TBD	Yes	2

B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	Conference participation	TBD		3
F. Presentation of research products at international congresses or workshops	Conference presentation	TBD		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			25
G. Individual research activity	Individual Research and literature review on Machine Learning techniques and data-driven control			25
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for conferences or journals			10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			35
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses	EECI Course	TBD	Yes	3
	Dausy Course	TBD	Yes	1
	SIDRA Summer School	July 2026	No	3
	Partner Universities Course	TBD	Yes	3
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	Conference participation			3
F. Presentation of research products at international congresses or workshops	Conference presentation			2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			15
G. Individual research activity	Individual Research and literature review on data-driven control aimed at applications such as microgrid control. Development of novel control algorithm based on data.			35
H. Supervision of students				

I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for conferences or journals			10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			45
	TOTAL OF ECTS			**60**

Third academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses	SIDRA Summer School		No	3
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	Conference participation			6
F. Presentation of research products at international congresses or workshops	Conference presentation			4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			13
G. Individual research activity	Individual Research and literature review on data-driven control aimed at applications such as microgrid control. Development of novel control algorithm based on data. Drafting of the Ph.D. thesis.			30
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for conferences or journals			17
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			47
	TOTAL OF ECTS			**60**

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