NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Control methods for smart networks

Ph.D. candidate

Simone Gentile

Cycle

XXXIX

Tutors

Prof. Alessandro Di Giorgio

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1. Description of the research program

A Smart Network is a communication network or system that leverages advanced technologies to enhance the efficiency, management, and security of network operations. These advanced technologies often encompass the use of computing, automation, and artificial intelligence to optimize network functioning. Smart networks are capable of automating many network management operations, reducing reliance on human intervention and improving overall efficiency.

The research programme, starting from the analysis of the requirements deriving from real needs of Smart Network end users, will concern both the derivation of abstract/theoretical optimization and Smart Network control strategies which, in compliance with the identified requirements, allow to maximize the efficiency of the entire Smart Network control system, and the concrete and personalized engineering of said strategies. The Smart Network application areas in which these services will be identified include, for example, cellular networks, space networks, energy distribution networks, transport infrastructures, health systems and critical infrastructures.

One promising Smart Network application area is in energy distribution networks, i.e., the so-called Smart Grids. This application area will not be necessarily the only one which will be explored in the framework of the research programme. Nevertheless, for the sake of concreteness, this description of the research programme will just focus on Smart Grids. As a matter of fact, mutatis mutandis, many of the concepts related to Smart Grid control, can be applied even to other Smart Network/System application areas.

About that Smart Grids represent a crucial element in the transformation of the energy sector towards a more sustainable and reliable future. These networks are designed to enable more efficient and dynamic energy management by integrating renewable energy sources and energy management technologies. However, to maximize the potential of Smart Grids, it is essential to continue developing strategies and technologies that optimize their integration.

With the proliferation of digital technologies in Smart Grids, cybersecurity is of paramount importance. Protecting the grid against cyber threats is essential to ensure its reliability and safety. Smart Grids employ robust cybersecurity measures to safeguard against potential attacks. These measures include encryption, intrusion detection systems, and continuous monitoring of network traffic. As Smart Grids continue to evolve, staying ahead the cybersecurity remains a priority to protect critical infrastructure.

One of the key areas of development is grid resilience. Smart Grids are designed to be more adaptable and capable of self-healing. They can automatically reroute power during outages, minimizing the impact on consumers. Additionally, advancements in energy storage technologies are enhancing grid stability. Large-scale energy storage solutions, such as grid-scale batteries, will play a pivotal role in storing excess renewable energy and releasing it when needed, ensuring a steady and reliable energy supply. The integration of renewable energy sources into the grid will continue to grow, with innovations like grid-scale wind and solar farms contributing to a sustainable energy mix. The future prospects for Smart Grids aim to greater energy efficiency and reliability, reduced environmental impact, and enhanced grid resilience.

Smart Grids have seen remarkable technological advancements in recent years. Advanced sensor technology, the Internet of Things (IoT), and learning algorithms have played a pivotal role in optimizing energy distribution. These technologies enable real-time monitoring of grid performance, allowing for rapid detection and response to disruptions.

This research proposal aims to explore and optimize the integration of renewable energies and energy management technologies in Smart Grids. The specific research objectives include developing advanced control and management strategies for Smart Grids to optimize the utilization of renewable energy sources and ensure network stability, analyzing the impact of emerging technologies, such as energy storage and electric vehicles, on Smart Grids and evaluating their potential contributions to optimization, including benefits for users.

The research will be conducted through a combination of theoretical analysis, computational simulations, and empirical case studies. Simulations will allow for the evaluation of various implementation scenarios and comparisons with current network infrastructures. The results of this research will significantly enhance our understanding of the challenges and opportunities associated with optimizing Smart Grids. This research will have practical implications for policymakers, energy companies, and end-users by providing guidance for the development of more intelligent and sustainable electrical networks.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Literature Review and Selection Application Areas	Review of literature for Smart Networks and selection of two Smart Network application areas in the set including cellular networks, space networks, energy distribution networks, transport infrastructures, health systems and critical infrastructures.	November 2023 – January 2024	NO
Preliminary Design	Preliminary design of model-based and model-free control/AI methodologies for Smart Network Control.	January 2024 – October 2024	NO

Second academic year (planned)

	Description	Period	Activity abroad
Methodology Selection and Final Design Area1	Selection of the candidate methodologies and their final design with respect to the selected application area 1	November 2024 - October 2025	TBD
Methodology Selection and Final Design Area2	Selection of the candidate methodologies and their final design with respect to the selected application area 2	November 2024 – October 2025	TBD

Third academic year (planned)

	Description	Period	Activity abroad
Methodology Engineering and Performance Evaluation Area1	With respect to the selected application area 1, engineering of the selected methodologies and evaluation of the performance and consequent design refinements	November 2025 – October 2026	TBD
Methodology Engineering and Performance Evaluation Area2	With respect to the selected application area 2, engineering of the selected methodologies and evaluation of the performance and consequent design refinements	November 2025 – October 2026	TBD

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Game Theory for Controlling Autonomous Systems	June-July 2024	Yes	2
	Model Predictive Control (IMT Lucca)	3–22 April 2024	Yes	2
	From Least Squares to Subspace Identification	(February-March) 2024	Yes	2
	EECI International Graduate School on Control: Data-Driven Operation of Autonomous Power Systems (Barcelona)	6/5/2024-10/5/2024	Yes	3
B. Master's degree courses	Intelligent and Hybrid Control	March-June 2024	Yes	6
C. Soft skill courses				
D. Participation to seminars	2-3 Dausy Seminars	TBD	No	6
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops	Convegno Automatica SIDRA			5
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			26
G. Individual research activity	Literature review			18
H. Supervision of students	Supervision of students attending tutors' courses			5
I. Integrative teaching activities	Integrative teaching activities on the tutors' courses			5
J. Preparation of manuscripts for conferences or journals	Preparation of a manuscript			6
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			34
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	2-3 Dausy Courses	1st Semester	Yes	6
	SIDRA Summer school	June-July 2025		2
B. Master's degree courses	Smart Grid Analysis and Design	September-December 2024	Yes	9
	Domotics and Building Automation Laboratory	September-December 2024	Yes	3
C. Soft skill courses				
D. Participation to seminars	2-3 Dausy Seminars	TBD		6
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained by research activity to international congresses/workshops (SIDRA/MED/ECC/CDC)			
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			26
G. Individual research activity	Research work (including period abroad)			19
H. Supervision of students	Supervision of students attending tutors' courses			5
I. Integrative teaching activities	Integrative teaching activities on the tutors' courses			5
J. Preparation of manuscripts for conferences or journals	Preparation of a manuscript			6
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			34
	TOTAL OF ECTS			**60**

Third academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	Participation to congresses or workshop according to availability			4
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained by research activity to international congresses/workshops (SIDRA/MED/ECC/CDC)			4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			8
G. Individual research activity				32
H. Supervision of students	Supervision of students attending tutors' courses			6
I. Integrative teaching activities	Integrative teaching activities on the tutors' courses			6
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts			8
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			52
	TOTAL OF ECTS			**60**

4. List of the publications written by the candidate in the triennium

Simone Gentile

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Alessandro Di Giorgio, professor

Alessandro Di Giorgio

Francesco Delli Priscoli, professor