

INTERUNIVERSITY PH.D. PROGRAM BETWEEN  
POLITECNICO DI BARI AND UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO  
IN INDUSTRY 4.0

# **Towards Sustainable Future Generations of Communication Systems through Integration of Renewable Energy Sources with Online Predictive Scheduling**

## **PhD candidate**

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## **Cycle**

XXXVII

## **Tutors**

Gennaro Boggia

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## Description of the research program

As well known, the smart predictive load scheduling can be of great worth for an electrical communication system, in order to maximize the network infrastructure and minimize grid disturbances. In smart scheduling, by providing the desired parameters, the proposed system also has the ability to energize the communication infrastructure used by the industry for desired tasks (communication among devices, data processing, task offloading, execution of complex algorithms, such as path planning, routing, and so on). At the time of this writing, the interest to integrate advanced energy management schemes in future generations of communication systems is gaining momentum. Advanced and ubiquitous applications are even more requiring, in fact, self-organizing, energy-efficient and (when possible) self-sustainable communication networks. Indeed, the main goal of this research is to integrate different renewable energy sources and energy storage system with online predictive scheduling in order to develop an efficient energy management system that can use to support future generations of communication systems (for instance, B5G and 6G) exploited by industries.

The main objectives of the research program are as follows;

- A vigorous adaptive control system will be devised to answer the problems of independent energy supply to communication systems.
- The hybrid energy systems will be extended with harvesting and power transfer capabilities, thus supporting the design of novel energy-neutral edge networks architectures.
- To advocate the use of off-grid renewable energy sources, such as solar radiation, fuel cell and wind energy, as a means to reduce the environmental impact of modern Information and Communication Technology systems.
- To devise new online scheduling techniques that are green by design for future generations of communication systems (B5G and 6G).

The efficient utilization, control and exploration of various renewable energy sources have always been subjects of great concern to the communication infrastructures. Specifically, the energy-hybrid B5G and 6G networks will be considered in this research, where network nodes belonging to the fog/MEC/cloud continuum are co-powered by renewable energy sources and by the power grid as backup. In smart scheduling, by providing the desired parameters, renewable energy surplus can be either stored by using local energy storage devices or can be sold back to the grid or transferred to mobile nodes. The industry-academia also recently started to build real testbeds of hybrid-powered edge systems. In this work, the research methodology will consist of the following steps:

- Develop a hybrid novel adaptive Neuro-Fuzzy scheme to control solar and wind energy for maximum power tracking.
- Integration of all the renewable sources with an energy storage system (ultra-capacitor and battery banks) to ensure 24 hours power flow feeding the communication infrastructure.
- Executing and computing the jobs, by minimizing the amount of energy that is purchased from the power grid while meeting all deadlines.
- An online approach based on Model Predictive Control with lookahead capabilities will be devised to allocate computing resources.
- The external processes such as renewable energy and job arrivals are estimated within a prediction window, and their estimates will be used to drive the online optimization of job schedules, network configuration, and communication system performance.

Finally, the performance comparisons of proposed techniques with other existing techniques will be carried out in term of frequency deviation, fill factor, rise time, settling time, steady state error, efficiency, energy losses and cost analysis.

## Schedule of the research activities

Insert the research activities that you plan or you have completed for the three years, including any period abroad.

### First academic year

	Description	Period	Activity abroad
<b>Research Planning</b>	Selection of area and Identification of problem statement	M1-M4	
<b>Background Study</b>	Detailed literature review and Study of new methodologies. Preliminary formulation of problem and proposing solution	M5-M12	

### Second academic year

	Description	Period	Activity abroad
<b>Problems Statement</b>	Formulation of problem and proposing solution, Design of platforms and architectures of specific network	M13-M17	
<b>Simulations</b>	Development of experimental environments based on analytical or testbed models	M18-M24	

### Third academic year

	Description	Period	Activity abroad
<b>Abroad Experience</b>	In-depth study of the research topics addressed in previous years, with experience abroad.	M25-M29	Y
<b>Compiling the Results</b>	Dissemination of the results obtained from the activities of research dealt with in previous years.	M30-M33	
<b>Articles Submission</b>	Thesis writing, editing and submission	M34-M36	

## Provisional training and research activities plan

Specify with the related CFU (ECTS) the training activities that you plan to carry out or have completed in the three years (e.g., courses to attend, conferences, seminars, etc.). Please refer to the *Educational regulations of the Doctoral School of Politecnico di Bari*: <http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf>

Specify with the related CFU (ECTS) the research activities that you plan to carry out in the three years (e.g., individual research activity, supervision of students, integrative seminars to be given by the PhD student, activity of manuscript preparation for conferences or journals, activity of patents preparation, etc.).

### First academic year

	Description	Period	Duration	CFU
<b>PhD courses</b>	SCUDO course - Application of MATLAB		20 hours	2
	SCUDO course - Industry 4.0: optimization, control and security		20 hours	2
	SCUDO course - Reasoning on the Web of Data		20 hours	2
<b>Master's degree courses</b>	Network Security and Mobile Radio Networks	Second cycle of semester	120 hours	12
<b>Participation to seminars and international congresses or workshops</b>	5G International PhD School 2022	1/12–3/12	20.5 hours	3
	International Conference on Energy Conservation and Efficiency (ICECE)	March 2022	3 days	3
<b>Presentation of research products at international congresses or workshops</b>	IEEE International Conference on Communications	June 2022	6 days	6
	<b>TOTAL OF CFU FOR TRAINING ACTIVITIES</b>			30
<b>Individual research activity</b>	Simulations and experimental work at the laboratory			16
<b>Students' supervision</b>	Study and research activities under the tutor's guidance			14
<b>Integrative didactic activities</b>				
<b>Preparation of manuscripts for conferences or journals</b>				
	<b>TOTAL OF CFU FOR RESEARCH ACTIVITIES</b>			30
	<b>TOTAL OF CFU FOR YEAR I</b>			<b>60</b>

## Second academic year

	<b>Description</b>	<b>Period</b>	<b>Duration</b>	<b>CFU</b>
<b>PhD courses</b>	Doctoral School Course - Programming with Python for Data Science		16 hours	2
	5G International PhD School 2023	1/12–3/12	20.5 hours	3
<b>Master's degree courses</b>	Internet of Things		60 hours	6
<b>Participation to seminars and international congresses or workshops</b>	Lipari School 2023	7/7-13/7	6 days	6
	International Conference on Computing, Electronic and Electrical Engineering (ICE Cube)	October 2023	3 days	3
<b>Presentation of research products at international congresses or workshops</b>	IEEE Global Communications Conference (GLOBECOM)	November 2023	5 Days	5
	IEEE International Conference on Computer Communications	December 2023	5 days	5
	<b>TOTAL OF CFU FOR TRAINING ACTIVITIES</b>			<b>30</b>
<b>Individual research activity</b>	Simulations and experimental work at the laboratory			14
<b>Students' supervision</b>	Study and research activities under the tutor's guidance			6
<b>Integrative didactic activities</b>				
<b>Preparation of manuscripts for conferences or journals</b>	Research Articles writing and submission			10
	<b>TOTAL OF CFU FOR RESEARCH ACTIVITIES</b>			<b>30</b>
	<b>TOTAL OF CFU FOR YEAR II</b>			<b>60</b>

## Third academic year

	<b>Description</b>	<b>Period</b>	<b>Duration</b>	<b>CFU</b>
<b>PhD courses</b>	Summer School of Information Engineering		5 days	5
	5G International PhD School 2023	1/12–3/12	20.5 hours	3
<b>Master's degree courses</b>				

<b>Participation to seminars and international congresses or workshops</b>	International Conference on Energy Conservation and Efficiency (ICECE)	January 2024	5 days	5
	IEEE Wireless Communications and Networking Conference (WCNC)	April 2024	6 days	6
<b>Presentation of research products at international congresses or workshops</b>	International Conference on Computing, Electronic and Electrical Engineering (ICE Cube)	June 2024	5 days	5
	IEEE Consumer Communications & Networking Conference		6 days	6
	<b>TOTAL OF CFU FOR TRAINING ACTIVITIES</b>			<b>30</b>
<b>Individual research activity</b>	Simulations and experiments at the laboratory		40 hours	10
<b>Students' supervision</b>	Study and research activities under the tutor's guidance		60 hours	6
<b>Integrative didactic activities</b>				
<b>Preparation of manuscripts for conferences or journals</b>	Research articles writing and submission			14
	<b>TOTAL OF CFU FOR RESEARCH ACTIVITIES</b>			<b>30</b>
	<b>TOTAL OF CFU FOR YEAR III</b>			<b>60</b>
	<b>TOTAL OF CFU FOR THE WHOLE PHD COURSE</b>			<b>180</b>