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UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

**DOTTORATO DI RICERCA / PhD PROGRAM IN  
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING**

## **Activities and Publications Report**

# PhD Student: **Federico Fiorenza**

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Student DR number: DR996968

**PhD Cycle: XXXVIII**

PhD Chairman: Prof. Stefano Russo

**PhD program student's start date: 01/01/2023**

**PhD program student's end date: 31/12/2025**

**Supervisor: Prof. Gianmaria De Tommasi**

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**PhD scholarship funding entity: Università Federico II**

### General information

Federico Fiorenza received in year 2022 the Master Science degree in Automation Engineering from the University of Napoli Federico II. Within the PhD program in Information Technology and Electrical Engineering, he attended a curriculum in Automation Engineering. He received a grant from Università Federico II.

### Study activities

#### Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organizer(s)
1 <sup>st</sup>	Title <b>Neural Networks and Deep Learning – Theoretical Foundations</b>	Ad hoc course	3	Prof. Giorgio Buttazzo, Università Sant’Anna di Pisa	Università Sant’Anna di Pisa
1 <sup>st</sup>	<b>The Linear Parameter Varying approach: theory and Application</b>	Ad hoc course	4	<b>Prof. Olivier Sename, University of Grenoble</b>	ITEE
1 <sup>st</sup>	<b>Advanced Course on Plasma Physics and Diagnostics</b>	External course	6		University of Padova, University of Naples Federico II
2 <sup>nd</sup>	Enterpreneurship and Innovation	External course	4	Prof. Pierluigi Ripa	ITEE

#### Attended PhD Schools

Year	School title	Location	Credits	Dates	Organizer(s)
1 <sup>st</sup>	<b>SIDRA 2023 PhD summer school</b>	Bertinoro, Italy	6	3-8/07/2023	SIDRA
2 <sup>nd</sup>	Japan International Fusion School	Naka, Japan	6	26/08-6/09/2024	EUROfusion

#### Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organizer(s)
1 <sup>st</sup>	<b>Is control a solved problem for aerial robotic research?</b>	0.2	Prof. Antonio Franchi	-	ITEE
1 <sup>st</sup>	Industry 4.0 Fundamentals in Bosch Applications	2	Eng. Bruno Martini	Politecnico di Bari	Politecnico di Bari
1 <sup>st</sup>	Series of seminars on “Design of the ITER Plasma	2.4	ITER PCS Design Team	ITER	ITER

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXVIII Cycle

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	Control System for the PFPO-1 phase”				
1 <sup>st</sup>	Using delays for control	0.2	Prof. Emilia Fridman	University of Tel-Aviv	Università della Tuscia
1 <sup>st</sup>	<b>Sistemi di intelligenza artificiale applicati al controllo dei plasmi nei tokamak</b>	0.8	Prof. Giuseppe Calabrò	Università della Tuscia	Università della Tuscia
1 <sup>st</sup>	<b>Ricerca e formazione nella società della transizione digitale</b>	1	Prof. Stefano Russo	Università di Napoli Federico II	ITEE
2 <sup>nd</sup>	<b>JT-60SA IC results and advances</b>	0.4	QST	QST	QST
2 <sup>nd</sup>	<b>Phase reduction for systems with higher-order interactions</b>	0.2	Dr. Riccardo Muolo	-	ITEE
2 <sup>nd</sup>	<b>MAXFEA: NON LINEAR PLASMA EVOLUTION CODE</b>	0.4	Dr. Mattia Scarpari	Università della Tuscia	Università della Tuscia
2 <sup>nd</sup>	<b>Oxford-Style debate: This house believes fusion energy will be ready in time for the energy transition</b>	0.2	Prof. Piero Martin	Università di Padova	Università di Padova
2 <sup>nd</sup>	<b>Fusion, a source of energy for the future</b>	0.2	Susana Clement-Lorenzo	F4E	Università di Federico II
2 <sup>nd</sup>	<b>JA strategies for DEMO reactor</b>	0.4	QST	QST	QST
2 <sup>nd</sup>	<b>Test facilities for Blanket engineering</b>	0.2	QST	QST	QST
2 <sup>nd</sup>	<b>Review of experimental fusion machines</b>	0.6	-	University of Tokyo	University of Tokyo
2 <sup>nd</sup>	<b>Divertor simulation experiments on GAMMA 10/PDX</b>	0.6		University of Tsukuba	University of Tsukuba
2 <sup>nd</sup>	<b>The Large Helical Device</b>	0.7		NIFS	NIFS
2 <sup>nd</sup>	<b>Overview of neutronics activities in the frame of EUROfusion WPPrIO project</b>	0.2		F4E	F4E
3 <sup>rd</sup>	<b>ITER CODAC online workshop</b>	1.2	Simroc Stefan	ITER	ITER

## Research activities

Federico Fiorenza contributed to several research areas spanning plasma control, system theory, and discrete-event system security.

### Magnetic control and reconstruction in fusion devices

In tokamaks, a gas is heated until it becomes a plasma that carries induced currents. Because this plasma reaches extremely high temperatures, its shape and position must be precisely controlled using externally applied magnetic fields. His work includes testing ITER magnetic–reconstruction algorithms in scenarios with reduced sensor availability, developing a fast neural-network-based method for real-time plasma boundary reconstruction, and designing an efficient control architecture capable of stabilising elongated plasmas even in the absence of dedicated in-vessel actuators. He also contributed to the development of an MPC-based magnetic control scheme for the upgraded RFX-mod2 device.

### Finite-Time Stability

Finite-Time Stability (FTS) is a control-theoretic concept ensuring that system trajectories remain within predefined bounds over a finite time horizon. He extended FTS results to linear descriptor systems, with ongoing research aimed at generalising these findings to nonlinear dynamics.

### Opacity verification in Petri Nets

Opacity is a security property of discrete-event systems, ensuring that an external observer cannot infer secret states or behaviours. He contributed to verification algorithms for assessing Current-State Opacity in both labelled and unlabelled bounded Petri Nets.

## Tutoring and supplementary teaching activities

*6 hours lesson Automation & Robotics - Industrial Automation – “The IEC 611131-3 standard”, master MEIM 16/10/2025*

*6 hours lesson Automation & Robotics - Industrial Automation – “SCADA and Human Machine Interface”, master MEIM 17/10/2025*

*6 hours lesson Automation & Robotics - Industrial Automation – “The IEC 611131-3 standard”, master MEIM 14/10/2024*

*6 hours lesson Automation & Robotics - Industrial Automation – “SCADA and Human Machine Interface”, master MEIM 16/10/2024*

## Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1 <sup>st</sup>	19	6.6	24	0
2 <sup>nd</sup>	10	4.1	41	3.2
3 <sup>rd</sup>	0	1.2	68.5	2.4

## Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1 <sup>st</sup>	QST	Ide Shunsuke, Director	30/10/2023- 1/12/2023	Experiment analysis on magnetic reconstruction and control during JT60SA Integrated Commissioning
2 <sup>nd</sup>	F4E	Filippo Sartori, I&C Unit Leader	01/11/2024- 14/12/2024	Design of the Instrumentation and Control system of the Bolometers Diagnostic, focusing on the development of a transmission line compensation scheme and on the testing of the latest diagnostic electronics prototypes
3	F4E	Filippo Sartori, I&C Unit Leader	03/01/2025- 31/07/2025	Design of the Instrumentation and Control system of the Bolometers Diagnostic, focusing on the development of a transmission line compensation scheme and on the testing of the latest diagnostic electronics prototypes

## PhD Thesis

The ITER tokamak, currently under construction, is expected to be the first magnetic confinement device capable of producing a net surplus of fusion energy. While awaiting its completion, several satellite projects have been launched to support ITER's mission. Among them are the EU–Japan joint project JT-60SA—presently the world's largest operating fusion device—and the Divertor Tokamak Test (DTT) facility in Italy, which will investigate heat exhaust solutions for next-generation reactors. These satellite tokamaks play a crucial role in developing and validating technologies and control strategies for ITER. In this framework, the initial commissioning phases of tokamak devices pose significant challenges for plasma magnetic control, particularly due to the temporary absence of

critical subsystems, such as in-vessel stabilization coils and the full suite of magnetic diagnostics. This thesis tackles the challenges of early-stage tokamak operations while also proposing advanced control and magnetic reconstruction algorithms for the effective operation of next-generation tokamaks. In particular, the contributions are the following:

- Validation of ITER's magnetic reconstruction tools under reduced sensor availability and the development of a fast boundary reconstruction algorithm.
- The design of advanced control strategies for plasma stabilization in early operational scenarios or in the presence of strict actuator constraints.

On the magnetic reconstruction side, this work leverages data from the JT-60SA Integrated Commissioning campaign to preliminarily validate ITER's real-time magnetic reconstruction algorithms, testing the algorithms' reconstruction capability with reduced diagnostics. In fact, during the JT-60SA IC, only a limited number of magnetic sensors were available. Furthermore, an alternative fast boundary reconstruction algorithm is proposed, based on Extreme Learning Machines — a class of neural networks characterized by fast training and inference times. Its performance is first evaluated in the same reduced-sensors scenario and then benchmarked against the XLOC algorithm, which has been used for decades at JET to reconstruct the plasma boundary in real time, with DTT serving as a case study.

On the control side, the thesis provides a twofold contribution. First, it introduces an ITER-like, model-based magnetic control technique tailored for early operation scenarios lacking in-vessel actuators. This architecture enables the use of external superconducting coils for multiple tasks, including vertical stabilization, and its effectiveness is demonstrated through nonlinear simulations of JT-60SA plasmas. Second, the thesis develops a Model Predictive Control (MPC)–based scheme for the upgraded RFX-mod2 device. Following the removal of the Inconel vessel and the introduction of a conductive cage, a new electromagnetic model is derived, and consequently an MPC control system is designed. Importantly, the proposed approach explicitly accounts for hardware constraints on the actuators, such as the use of the already existing one-quadrant converters, thereby ensuring reliable tracking of desired plasma shape and current in RFX-mod2 operations.

Together, these developments contribute to the creation of flexible and resilient magnetic reconstruction and control strategies, crucial for the safe and efficient operation of next-generation tokamak devices.

### Research products

Research results appear in 6 papers published in international journals, 4 contributions to international conferences.

## List of scientific publications

### International journal papers

Romanelli Francesco, ..., **Fiorenza Federico**, et al

Divertor Tokamak Test facility project: status of design and implementation,  
*Nuclear Fusion*

64.11 (2024): 112015, DOI: 10.1088/1741-4326/ad5740

Gianmaria De Tommasi, ..., **Fiorenza Federico**, et al

Control of elongated plasmas in superconductive tokamaks in the absence of in-vessel coils,  
*Nuclear Fusion*

64.7 (2024): 076005, DOI: 10.1088/1741-4326/ad4895

Dubbioso Sara, **Fiorenza Federico**, et al

Rapid prototyping of control modules for the DTT Plasma Control System,  
*Fusion Engineering and Design*

218 (2025): 115167, DOI: 10.1016/j.fusengdes.2025.115167

Basile Francesco, Dubbioso Sara, De Tommasi Gianmaria, **Fiorenza Federico**

Verification of K-step Non-Interference for Live Bounded and Reversible Discrete Event Systems Modeled with Petri Nets,

*IEEE Control Systems Letters*

9 (2025): 865 - 870, DOI: 10.1109/LCSYS.2025.3575358

**Federico Fiorenza**, et al

Preliminary validation of ITER magnetic diagnostic algorithms by using JT-60SA magnetic measurements,  
*Fusion Engineering and Design*

222 (2025): 115486, DOI: 10.1016/j.fusengdes.2025.115486

Szepesi, Tamas, **Fiorenza Federico**, et al

Analysis of the first plasmas of JT-60SA using the EDICAM visible video diagnostic,  
*Fusion Engineering and Design*

222, 2026, 115530, ISSN 0920-3796, DOI: 10.1016/j.fusengdes.2025.115530

### International conference papers

Basile Francesco, Dubbioso Sara, De Tommasi Gianmaria, **Fiorenza Federico**

An Optimization Approach to Current State Opacity Assessment,  
*2024 IEEE 63rd Conference on Decision and Control (CDC)*,

Milan, Italy, Dec. 2024, IEEE, DOI 10.1109/CDC56724.2024.10886766.

Basile Francesco, Dubbioso Sara, De Tommasi Gianmaria, **Fiorenza Federico**

Sequence-based Vs Observer-based Approaches to Verify Current-State Opacity: A Benchmark Case,  
*2025 IEEE Conference on Control Technology and Applications (CCTA)*,

San Diego, USA, Aug. 2025, IEEE, DOI 10.1109/CCTA53793.2025.11151370.

## Activities and Publications – Final Report

UNINA PhD in Information Technology and Electrical Engineering – XXXVIII Cycle

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Abate Domenico, ..., **Fiorenza Federico** et al.,  
A Model Predictive Control Approach for the active coil currents in the RFX-mod2 device,  
*2nd IFAC Workshop on Control of Complex Systems COSY 2025*  
Gif-sur-Yvette, France, July, 2025, ELSEVIER, DOI 10.1016/j.ifacol.2025.09.552

Amato Francesco, ..., **Fiorenza Federico**, et al.,  
Finite-time stability and stabilization for linear time-varying descriptors systems,  
*2nd IFAC Workshop on Control of Complex Systems COSY 2025*  
Gif-sur-Yvette, France, July, 2025, ELSEVIER, DOI 10.1016/j.ifacol.2025.09.525

**Date 9/12/2025**

**PhD student signature**

*Federico Fiorenza*  

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**Supervisor signature**

*Gianni D'Amico*  

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