UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Model-based Design of Advanced Control and Monitoring Algorithms for Power Electronics"

Dr. Pierpaolo Dini

Department of Information Engineering, University of Pisa – Pisa, Italy

pierpaolo.dini@unipi.it

Short Abstract:

The increasing complexity of automotive and industrial systems demands innovative methods for designing and verifying control and monitoring algorithms. In this context, the Model-Based Design (MBD) approach emerges as a crucial solution to tackle these challenges. The unprecedented availability of computational power and data—both real and synthetic—opens up new possibilities for improving time-to-market and reducing validation costs. This course offers a comprehensive overview of modern control and monitoring architectures for power converters and drives, highlighting the importance of MBD.

Students will gain practical and theoretical skills to design, verify, and test advanced control and monitoring algorithms. The MBD approach, with its ability to leverage computational power and available data, provides a robust and effective methodology to address the challenges posed by the increasing complexity of modern power electronics systems.

Course Contents in brief:

- **Lecture 1**: Introduction to advanced control and monitoring architectures, including adaptive and predictive controllers, Kalman filters, and health state estimation algorithms. The theoretical foundations of the MBD approach and its impact on system quality and reliability will also be covered.
- **Lecture 2**: Utilization of algorithm verification tools through MIL/SIL (Model/Software-In-the-Loop) approaches, computational analysis and optimizations, automatic C/C++ code generation, and timed sequential logic coverage analysis. Special emphasis will be placed on code and model coverage analysis to ensure all parts of the system are adequately tested and verified.
- **Lecture 3**: Hands-on session using a specific toolbox for the NXP embedded platform (based on Cortex-M4, typical for automotive/automation applications) for SIL and PIL (Processor-In-the-Loop) testing for real-time verification. Techniques for designing test sequences from specifications will be addressed, ensuring the developed algorithms meet the stringent requirements of industrial applications.

- **Lecture 4**: Demonstration of a simple test bench using the GPIO of the NXP evaluation board to connect an inverter and a low-voltage/power synchronous motor, allowing for prototype HIL (Hardware-In-the-Loop) testing, interacting with runtime simulation. This practical example will show how MBD can be applied to create efficient and reliable control and monitoring solutions.

Total # of hours of lecture: 16 hours

References:

1. Dini, P., Ariaudo, G., Botto, G., Greca, F. L., & Saponara, S. (2023). Real-time electro-thermal modelling and predictive control design of resonant power converter in full electric vehicle applications. IET Power Electronics, 16(12), 2045-2064.
2. Dini, P., & Saponara, S. (2022). Processor-in-the-loop validation of a gradient descent-based model predictive control for assisted driving and obstacles avoidance applications. IEEE Access, 10, 67958-67975.
3. Dini, P., Basso, G., Saponara, S., & Romano, C. (2024). Real-time monitoring and ageing detection algorithm design with application on SiC-based automotive power drive system. IET Power Electronics, 17(6), 690-710.
4. Dini, P., Saponara, S., Chakraborty, S., Hosseinabadi, F., & Hegazy, O. (2023). Experimental Characterization & Electro-Thermal Modeling of Double Side Cooled SiC MOSFETs for Accurate and Rapid Power Converter Simulations. IEEE Access.

CV of the Teacher

Pierpaolo Dini received his Master's Degree in Automation Engineering in 2016 and his PhD in Smart Industry, with full marks, in 2022, with a thesis entitled “Model-Based Design of Embedded Control & Monitoring Systems for Industrial Mechatronics”.

He currently holds the role of Researcher (RTD-A) in the ING-INF/01 area at the Department of Information Engineering (DII) of the University of Pisa.

He carries out advanced research in the field of electronic systems on board modern vehicles and for industrial automation systems. He is an expert in real-time development and integration on embedded platforms of advanced control and monitoring algorithms for electronic systems and devices on board vehicles and in automation systems.

He is involved in several advanced research activities in which he actively collaborates with national and international partners, in the context of European Projects (including EPI, HiEFFICIENT, AERO, TEXTAROSSA), National (CN1 Spoke 6, HARDNESS), and Regional (IR-ACCESS, SURFACE, MICAELA).

He is currently involved in the testing activities of predictive control and monitoring algorithms of the HiEFFICIENT project: (i) in Use Case 2a, on validation of a monitoring and aging estimation algorithm for a three-phase traction inverter based on SiC technology for operating range 400V/50kW) in close collaboration with project partner Ideas & Motion (Cuneo); (ii) in Use Case 5c, on validation of a predictive control algorithm of the electro-thermal dynamics of an isolated CLLLC converter for OBC based on SiC/GaN technology 900V/21kW, in close collaboration with project partner FLAG-MS (Turin). He is also involved in collaborative activities with the research center VUB (Vrije Universiteit Brussel) and Politecnico di Torino in the development of compact and real-time models of high-frequency converters for electric drives.

It carries out collaboration and technology transfer activities with various local companies of national and international importance in the industrial and automotive sectors, including VITESCO Technologies, MAGNA Mechatronics, TOYOTA Industries, MBDA Italy and MARELLI Technology Innovation.

He is also co-inventor of two patents (with U.S. validity) on Cybersecurity of communication networks based on CAN/CAN-FD protocol, resulting from R&D activities in collaboration with MARELLI.

He is the author of 36 publications (24 Journals and 12 Conferences) of which 25 as first author, with an H-index of 16 and 500 citations (Scopus).

He also teaches “Vehicle Electronics” for the Master’s Degree in Vehicle Engineering and “Electronic Laboratory” for the Bachelor’s Degree with a Professional Orientation in “Mechanical and Production Techniques” at the University of Pisa. He also teaches the 1st Level University Master’s Degree in “Highly Specialized Science and Technology in Rehabilitation” at the University of Pisa, for the courses “Sensors and Acquisition Systems” and “Statistics and Data Processing with MATLAB”.

Final Exam: oral discussion/presentation.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell’Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

Day1 – Monday, January 20, h. 9:00-13:00

Day2 – Tuesday, January 21, h. 9:00-13:00

Day3 – Wednesday, January 22, h. 9:00-13:00

Day4 – Thursday, January 23, h. 9:00-13:00