



COURSE DESCRIPTION CARD - SYLLABUS

Course name

Model Based Design [N1Eltech2>PO12-MBD]

Course

Field of study

Electrical Engineering

Year/Semester

5/9

Area of study (specialization)

–

Profile of study

general academic

Level of study

first-cycle

Course offered in

Polish

Form of study

part-time

Requirements

elective

Number of hours

Lecture

10

Laboratory classes

10

Other

0

Tutorials

0

Projects/seminars

10

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

The student is expected to have knowledge and skills at a level that allows them to work independently with models and basic control algorithms. In particular, mastery of the basics of engineering mathematics (analysis and linear algebra), elements of control theory and system dynamics, and the ability to program at a basic level are required. In the laboratory, awareness of the principles of safe work with equipment and test stands is required.

Course objective

The aim of the course is to teach the practical approach of Model-Based Design (MBD) from the engineering of requirements and acceptance criteria, through modeling and implementation, to verification and validation in the MIL/SIL/PIL/HIL chain. Students will learn how to build coherent artifacts (requirements-model-tests-results) and conduct integration tests using HIL, where DUT (Device Under Test) cooperates with an object running in real time. The course emphasizes industrial practice: iterative development (Agile) and quality and safety requirements characteristic of automotive projects (e.g. ASPICE, ASIL).

Course-related learning outcomes

Knowledge:

The student is familiar with the fundamentals of MBD tools and flow and understands the roles of the MIL/SIL/PIL/HIL stages in software development and testing. The student understands the basics of control and implementation of controllers for power electronics and drive systems (e.g. PMSM+inverter, BMS, RES converters) and the limitations of real-time operation. Knows the basic principles of requirements engineering.

Skills:

The student is able to prepare and verify a solution in the MIL→SIL→PIL→HIL chain, including selecting test scenarios resulting from the requirements and evaluating the results. Can run a HIL experiment: configure a real-time model, connect it to DUT (Device Under Test), and perform measurements, tests, and basic diagnostics. Can use ICT/CAX tools to automate tests and develop a report, as well as plan team work and project schedule.

Social competences:

The student is ready to constantly supplement their competencies in the area of MBD tools and testing methods. The student is also ready to responsibly perform roles in the project team, adhere to the principles of professional ethics and take responsibility for jointly performed tasks.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

The knowledge acquired during the lecture is verified during the final exam in the form of open questions with equal scores in the scope described in the curriculum content of the subject. Passing the lecture is obtained after reaching the threshold of at least 50% of points.

The skills acquired in the laboratory are verified on the basis of performing HIL exercises, including station configuration, running real-time models, integration with a DUT (Device Under Test - object, e.g. controller, inverter, BMS controller or converter control system), conducting scenario tests and interpreting the results. The correctness and repeatability of the procedure, the quality of logging and data analysis, as well as the completeness of laboratory documentation are evaluated. A laboratory is considered to have been passed after obtaining at least 50% of points in the laboratory part.

The design part is verified on the basis of a team task, in which students go through a coherent fragment of the development process: from behavior specification (including acceptance criteria), through modeling and testing (MIL/SIL), to commissioning and validation in the HIL configuration. The quality of the project artifacts is evaluated, in particular the consistency of the model and tests, documented results and reasoned conclusions, as well as the organization of the team's work and timeliness. A project is considered to have been passed after obtaining at least 50% of points.

Programme content

The course covers requirements engineering (including acceptance criteria and tracing), software design in the Model-Based Design approach, and verification and validation in the MIL/SIL/PIL/HIL chain in automotive, electromobility and RES applications, with reference to quality practices (ASPICE, Agile) and functional safety fundamentals (ASIL).

Course topics

Lecture: Model-Based Design methodology as a process of development software from requirements engineering (requirements, acceptance criteria, tracing) to V&V evidence; review of MIL/SIL/PIL/HIL stages and typical artifacts (model, tests, results, reports) in an iterative approach (Agile) and with reference to quality expectations in automotive (ASPICE) and basics of functional safety (ASIL); modeling of objects and controllers for PMSM drives with inverter, BMS systems and RES converters (PV/wind, grid inverters, microgrids); real-time operation (discretization step, latency, deterministic, I/O synchronization), scenario and edge test planning, result analysis, and safe boot policies.

Laboratory (HIL): Preparing the object model for real-time operation and its instrumentation; configuration of I/O and communication interfaces and integration with DUT (Device Under Test) in the control loop; performing tests in accordance with the requirements (scenario tests, edge testing, basic diagnostics and fault injection elements) and recording and interpreting the results; comparison of behaviour at the MIL/SIL and HIL levels (consistency, regression), preparation of documentation of

results and conclusions, taking into account health and safety principles.

Project: Team development of a mini-control system in the area of automotive/e-mobility/RES in the MBD approach, including the definition of requirements and acceptance criteria, preparation of the MIL/SIL model and tests, and subsequent validation at the HIL station; iterative work in short cycles (Agile) with artifact reviews (requirements-model-tests-results) and tracing; The result is a project report containing a description of the solution, a set of tests and their results, analysis and recommendations for changes, ending with a demonstration of operation.

Teaching methods

The lecture is conducted in the form of a presentation illustrated with examples and short case studies with an emphasis on the transition from requirements to testing in the MIL/SIL/HIL chain. The laboratory is based on work on the HIL workstation, where students independently configure the system, perform tests and analyze the results under the supervision of the instructor. The project is carried out as a team and iteratively, with reviews of requirements, test results and report quality.

Bibliography

Basic:

1. Nicolescu, G.; Mosterman, P. J. (red.) Model-Based Design for Embedded Systems. CRC Press, 2010
2. Wiegers, K.; Beatty, J. Software Requirements. 3rd Edition. Microsoft Press, 2013
3. Tripathi, S. M.; Gonzalez-Longatt, F. M. (eds.) Real-Time Simulation and Hardware-in-the-Loop Testing Using Typhoon HIL. Springer, 2023
4. Schlager, M. Hardware-in-the-Loop Simulation: A Scalable, Component-based, Time-triggered Hardware-in-the-loop Simulation Framework. VDM Verlag, 2008
5. Aarenstrup, R. Managing Model-Based Design. The MathWorks, 2015

Additional:

1. Pietrowski, W.; Puskarczyk, M.; Szymenderski, J. Fault Detection Methods for Electric Power Steering System Using Hardware in the Loop Simulation. *Energies*, 2024, 17(14), 3486. DOI: 10.3390/en17143486
2. von Jouanne, A.; Agamloh, E.; Yokochi, A. Power Hardware-in-the-Loop (PHIL): A Review to Advance Smart Inverter-Based Grid-Edge Solutions. *Energies*, 2023, 16(2), 916. DOI: 10.3390/en16020916
3. VDA QMC. Automotive SPICE® 4.0 - Process Reference Model / Process Assessment Model (PRM/PAM), Publications (December 2023)
4. Patankar, P.; Kulkarni, S. MATLAB and Simulink In-Depth: Model-based Design with Simulink and Stateflow, User Interface, Scripting, Simulation, Visualization and Debugging. BPB Publications, 2022
5. MathWorks. What Is Hardware-in-the-Loop (HIL)?

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	32	1,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	68	2,50