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WORKSHOP FOR PROFESSIONALS

Model-Based Digital Control of Three-Phase Drives

This three-day workshop provides a systematic introduction to the model-based digital torque control of converter-fed three-phase drives.

The principal concepts are developed using the permanent-magnet synchronous machine (PMSM) as a representative example, while their generalization to induction machines, electrically excited synchronous machines and other AC-machine types is discussed throughout.

Following mathematical preliminaries, inverter modulation and control-oriented machine modelling, participants develop two complete torque-control systems in MATLAB/Simulink: field-oriented control with current control, operating-point selection and modulation-level control; and direct torque control with flux and torque estimation, hysteresis control and direct inverter actuation. The workshop concludes with an outlook on advanced methods such model predictive control. Speed control and other outer-loop functions are deliberately excluded.

Short theoretical units alternate with model-based laboratory exercises covering simulation, automatic code generation, test-bench deployment and experimental validation.

Date
23–25 February 2027

Location
Hölderlin Campus
Hölderlinstr. 3, 57076 Siegen

Prerequisites
Basic knowledge of electrical machines, power electronics, feedback control and MATLAB/Simulink

Language
English

Course Fee
1.390,– EUR
Early Bird: 1.190,– EUR (until 15 January 2027)

Certificate
Certificate of Participation

Workshop focus

- Model-based development of a functioning torque-control setup
- Three-phase inverter modelling and modulation
- PMSM (discrete-time) modelling, experimental model validation
- Field-oriented torque control: current control, operating-point selection and modulation-level control
- Direct torque control: flux/torque estimation, hysteresis control and switching-table actuation
- Outlook on advanced control methods

Instructors

- **Prof. Dr.-Ing. Oliver Wallscheid,**
  Head of Chair of Interconnected Automation Systems (IAS)
- **Marvin Meyer,** Research Associate
- **Lukas Hölsch,** Research Associate

More about the Chair of Interconnected Automation Systems (IAS)

Registration

Workshop Details on our Website

Contact

Thomas Demmer

thomas.demmer@uni-siegen.de
+49 271 740-3649

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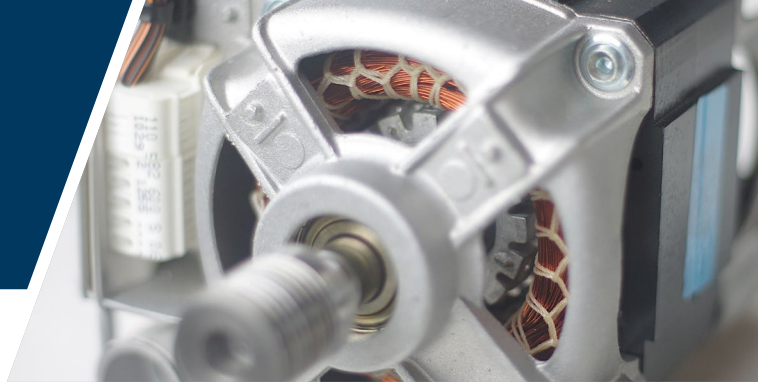

PROGRAMME

Model-Based Digital Control of Three-Phase Drives

Day 1 | Mathematical Foundations, Inverter Modulation and PMSM Modelling

Tuesday, 23 February 2027

09:15	Start of Registration & Welcome Coffee
09:45	**Welcome, Opening and Laboratory Safety Briefing**
10:00	**Structure of a Controlled Three-Phase Drive** Converter, electrical machine, sensors and digital controller; torque-control objective; direct versus indirect torque control; modulator-based versus modulator-free inverter actuation.
10:30	**Three-Phase Signals and Space-Vector Representation** Balanced three-phase systems, zero-sequence components, amplitude and power conventions, and geometrical interpretation of space vectors.
11:00	**Clarke and Park Transformations** Stationary alpha-beta and rotating d-q reference frames; forward and inverse transformations; interpretation of voltage, current and flux-linkage vectors.
11:45	**Two-Level Three-Phase Voltage-Source Inverter** Switching states, elementary voltage vectors, phase and line-to-line voltages, common-mode components and DC-link utilization.
12:30	Lunch
13:30	**Three-Phase Inverter Modulation** Carrier-based PWM, zero-sequence injection, space-vector modulation, linear modulation range, overmodulation, regular sampling and digital implementation effects.
14:15	***Laboratory Exercise 1: Inverter Modelling and Modulation*** Configure the inverter and modulation models in MATLAB/Simulink; compare modulation variants; generate and deploy real-time code; measure phase and line voltages; evaluate DC-link utilization, switching harmonics and dead-time effects.
15:30	Coffee Break
16:00	**Control-Oriented PMSM Modelling** Voltage and flux-linkage equations, permanent-magnet flux, electromagnetic torque, magnetic saliency and the distinction between surface-mounted and interior PMSMs.
16:30	***Laboratory Exercise 2: PMSM Modelling and Validation*** Parameterize the PMSM model; implement continuous- and discrete-time variants; calculate currents, flux linkages and electromagnetic torque; compare simulated responses with measured test-bench data.
17:20	**Results Review**
17:30	End of 1st Day

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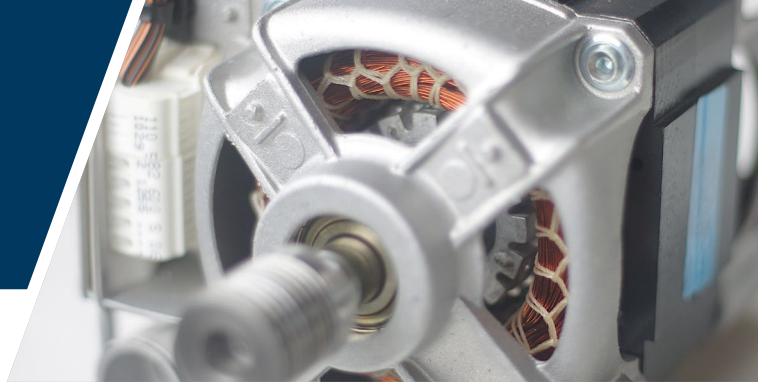

PROGRAMME

Model-Based Digital Control of Three-Phase Drives

Day 2 | Field-Oriented Torque Control

Wednesday, 24 February 2027

09:00	Start of 2nd Day
09:00	**Discrete-Time PMSM Models for Digital Control** Sampling, zero-order-held inverter voltages, computational delay and discrete-time formulations for controller design and implementation.
09:45	**Field-Oriented Control Structure** Indirect torque control, rotor-oriented coordinates, separation of flux- and torque-forming current components, and integration with inverter modulation.
10:30	Coffee Break
11:00	**Digital Current-Control Design** PI current controllers, bandwidth and pole selection, d-q-axis coupling, induced-voltage feedforward, voltage-vector limitation and anti-reset wind-up.
11:45	***Laboratory Exercise 3: FOC Current Control*** Implement and tune the d- and q-axis current controllers; compare feedback-only, decoupled and feedforward-supported structures; generate and deploy real-time code; evaluate reference tracking, disturbance rejection and voltage saturation.
13:00	Lunch
14:00	**Operating-Point Selection for PMSM Torque Control** Map torque references to d-q current references; current and voltage constraints; maximum torque per current; field weakening; maximum torque per voltage and torque limitation.
14:45	**Modulation-Level Control** Closed-loop regulation of inverter-voltage utilization; coordination of operating-point selection, current control and modulation; compensation of model uncertainty and inverter nonlinearities.
15:30	Coffee Break
16:00	***Laboratory Exercise 4: FOC Operating-Point Selection and Modulation-Level Control*** Integrate the operating-point selection and modulation-level controller with the commissioned current loops; test current-limited and voltage-limited operation; investigate the transition into field weakening; evaluate torque-reference tracking across the feasible operating range.
17:15	**FOC Results Review and Generalization to Other Machine Types** Transfer of the modelling, current-control and operating-point concepts to induction-machine and electrically excited synchronous-machine drives.
17:30	End of 2nd Day

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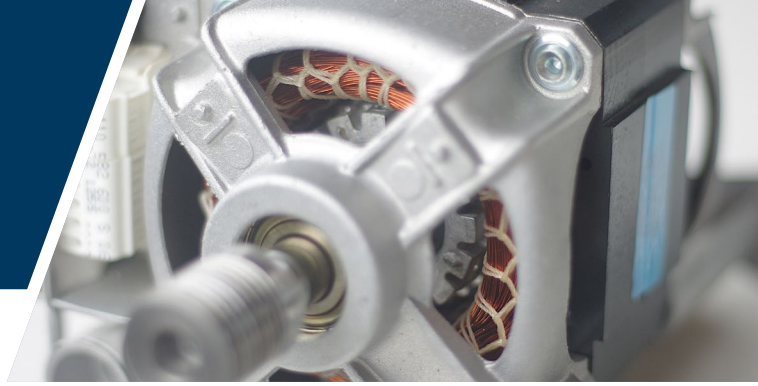

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Model-Based Digital Control of Three-Phase Drives

Day 3 | Direct Torque Control and Advanced Control Outlook Thursday, 25 February 2027	
09:00	Start of 3rd Day
09:00	**Direct Torque Control: Fundamental Principles** Direct versus indirect torque control; stator-flux and torque dynamics; influence of elementary inverter voltage vectors.
09:45	**Flux-Linkage and Torque Estimation** Voltage- and current-model flux estimation, torque reconstruction, parameter sensitivity, measurement offsets and low-speed limitations.
10:30	***Laboratory Exercise 5: Flux-Linkage and Torque Estimation*** Implement the estimators in MATLAB/Simulink; validate their behaviour in simulation and on the test bench; investigate parameter mismatch, voltage offsets and numerical integration drift.
11:45	Coffee Break
12:15	**Hysteresis-Based Torque and Flux Control** Torque and flux hysteresis comparators, flux-vector sector identification, switching-table design and variable switching-frequency behaviour.
13:00	Lunch
14:00	**Operating-Point and Modulation-Level Management for DTC** Generation of feasible torque and stator-flux references; current and voltage constraints; coordination of flux level, voltage utilization and switching behaviour.
14:45	Coffee Break
15:15	***Laboratory Exercise 6: Complete DTC Torque Controller*** Integrate the estimators, hysteresis controllers, operating-point logic and switching table; generate and deploy real-time code; tune the hysteresis bands; perform torque-reference tests; compare torque ripple, flux trajectories and switching behaviour with FOC.
16:45	**FOC and DTC in Comparison** Dynamic torque response, current limitation, torque ripple, switching-frequency characteristics, robustness, modularity and implementation effort.
17:00	**Outlook: Model Predictive Control of Three-Phase Drives** Prediction models, optimal-control formulation, continuous- and finite-control-set MPC, explicit constraint handling and computational trade-offs.
17:20	**Wrap-Up and Final Discussion**
17:30	End of Workshop

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