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Technology, components and methods for MVDC grids

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BACKGROUND – RELEVANCE

As the demand for reliable and efficient power conversion increases, the power grid faces significant challenges in controlling power flow, maintaining stability, and managing the integration of renewable energy sources. Medium Voltage (MV) AC-DC and DC-DC converters are pivotal technologies for this future grid, acting as power interfaces between conventional AC grids and emerging DC grids, as well as enabling high-power applications like traction inverters. Furthermore, the complexity of control strategies for these converters is growing to ensure robustness and fast dynamic response. To address this, Control-Hardware-in-the-Loop (CHIL) testing has emerged as a crucial methodology, allowing for the validation of control systems without the risks and costs associated with full-scale prototypes.

ABSTRACT

This course provides a comprehensive theoretical and practical exploration of Medium Voltage (MV) power converters and their control development workflows. It covers the topology and modulation of MV AC-DC converters, including multilevel voltage source converters and current source converters. It further explores MV DC-DC converter topologies, focusing on soft-switching principles, modular configurations, and waveform analysis. Beyond topology, the course bridges the gap between simulation and deployment by introducing Control-Hardware-in-the-Loop (CHIL) testing. Participants will learn generalized testing methods, code development workflows, and how to utilize Real-Time Simulation (RTS) to safely validate and verify power electronics control software before it touches real hardware. The theoretical foundation is supported by exercises, simulations, and laboratory sessions focused on debugging and commissioning. The course will also introduce guidelines based on field expertise gained from the MVDC research grid at RWTH Aachen University.

KEYWORDS - HASHTAGS

DC-DC Converters, Medium Voltage DC Grids, AC-DC Converters, Multilevel Converter, Power Converter Control, PWM Modulation, Control-Hardware-in-the-Loop, Real-Time Simulation.

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FOCUS ON …	Knowledge	Application		Implementation	
CDIO		Conceive	Design	Implement	Operate
DIFFICULTY LEVEL	Basic	Intermediate		Advanced	
EQF LEVEL	7 (Master's level)	**CREDITS**	4	**LANGUAGE**	English

LEARNING OUTCOMES

After completing this course, the participant will be able to:

1. Analyze Converter Topologies: Analyze Current Source Converters and multilevel Voltage Source Converters (NPC, MMC, Cascaded H-Bridge) and explain their waveforms and suitability for MV applications.
2. Understand Switching Behaviors: Classify between hard and soft switching and analyze current waveforms to check for soft-switching conditions.
3. Design Control Systems: Design control structures (PI/PR, cascaded loops, dq-frame control, PLL) for MV AC-DC and DC-DC converters, including ISOP connected configurations.
4. Apply Modulation Strategies: Explain and compare modulation strategies such as multilevel Sine-Triangle PWM and Space Vector Modulation (SVM).
5. Utilize CHIL Methodology: Understand the workflow of Control-Hardware-in-the-Loop (CHIL) testing and its role in validating control systems without full-scale prototypes.
6. Verify and Validate Code: Apply efficient workflows to debug firmware and validate power electronics control software using Real-Time Simulation
7. Apply practical design guidelines and operational insights derived from the RWTH MVDC research grid to address real-world challenges in converter development and grid integration.

PRIOR KNOWLEDGE REQUIRED

1. Power Electronics Fundamentals: Knowledge of semiconductor devices (IGBTs, MOSFETs, diodes), principles of efficient power conversion, and basic rectifier/inverter topologies.
2. Converter Operation: Fundamental knowledge of DC-DC converter operation, PWM modulation, and steady-state analysis.
3. Control Theory: Feedback control principles (PI controllers), frequency domain analysis (Bode plots, stability), and system modeling using block diagrams.
4. AC Systems: Basic AC circuit theory (power factor) and Park's transformation (abc to dq).

PRACTICAL ORGANISATION - follow up on line for eventual changes		
	Theoretical part/simulations/exercises	**Hands on part**
ORGANISER/ISSUER	**RWTH Aachen University** Institute for Power Generation and Storage Systems	
ERASMUS CODE	(TBD / Specific to RWTH EON-ERC)	
WHEN	TBD	Spring 2027
WHERE	**RWTH Aachen University (Aachen, Germany)**	**RWTH Aachen University (Aachen, Germany)**
TEACHER(s) INSTRUCTOR(s)	Lars Hagemann Julius Kleutgens	tbd
COURSE MATERIAL	available in **www.Xdemia.com**	Available in **www.Xdemia.com**
SOFTWARE USED	Plecs	Plecs
OTHER MATERIAL		
MAX ATTENDEES	16	16
REGISTRATION	link	Link
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EXAM		

COURSE PROGRAM			
	DATE	**LOCATION**	**TOPIC**
1	tbd	RWTH	Topology and control of MV multilevel AC-DC converters
2	tbd	RWTH	Topology and control of MV DC-DC converters
3	tbd	RWTH	RT-Simulation and ChiL testing of high-power DC-dc converters
4	tbd	RWTH	LVDC Systems
5	tbd	RWTH	MVDC Systems
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