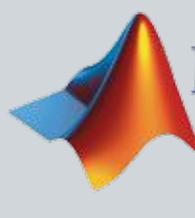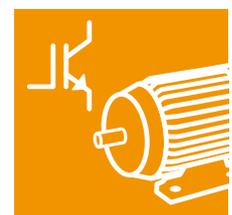# Training Systems
for Power Electronics

The Key Technology for Electrical Drives –
Multimedia Learning, Experimenting, Programming
and Researching

®

LUCAS-NÜLLE

MATLAB®
&SIMULINK®

*Connection via USB and
LN-Toolbox to Matlab®/Simulink®*

Making Power Electronics Understandable

The key role of power electronics

As part of the energy revolution, power electronics has assumed a key role as an interdisciplinary technology, with variable frequency drives capable of achieving enormous potential savings. Even more significant are the changes taking place in the field of automotive technology, as electric vehicles are poised to play an ever increasing role in shaping the future of road transport.

The deployment of power electronics must be competently prepared and implemented to ensure that potential efficiencies do not get ignored or anticipated savings remain untapped due to incorrect parameterization.

Industry is placing rising demands on the qualifications and know-how of electronics specialists, technicians and engineers – know-how which makes it possible to recognize potential efficiencies, create plans, as well as expertly handle, connect and parameterize power electronics systems and equipment. As a result, training that is both practical and project oriented is expected, covering the entire range of vocational needs right through to engineering level.

Modern development and analysis tools for electrical drive technology

To cope with technological change, the industry is looking for highly qualified and skilled engineers who not only possess the actual expertise required but are also familiar with contemporary, efficient tools and capable of using them too. The Matlab®/Simulink® programming language has established itself worldwide as a standard for scientific and engineering calculations and simulations.

This high-level language and its interactive environment for numerical computations, visualization and programming enables extremely fast development cycles for variable-speed drives which are currently experiencing tremendous demand thanks especially to the need for electric mobility.

Handling these tools is complex, and must be taught and learned in a practical manner, particularly in conjunction with test benches and "hardware in the loop". In this regard, the world's universities bear a major responsibility for training engineers in the skills required by industry.

Learning and understanding the basics of power electronics and drive technology

The modular, blended-learning training system for power electronics and drive technology makes learning and experimenting very simple and effective. Various basic and advanced equipment sets permit sophisticated, exciting experiments to be conducted and knowledge to be conveyed in a highly efficient manner leading to the acquisition of practical skills and competence. Starting with the transistor as a switch and progressing through modulation methods right up to variable-speed DC and three-phase drives, ILA interactive experiment manuals are available on all of the relevant subjects. Animations help understand complex theory, while proven guidelines and intrinsically safe devices make experimentation in project-oriented training a simple matter. Virtual instruments integrated into the course can be used to visualize actual measured values or to control the inverter.

Your benefits

- Compact, easily operable, intrinsically safe system
- Integrated measurement and time-based display of electrical variables
- Can be extended to fully operational drive systems with electrical machines of the 300W and 1kW classes

Expand the training system to a programmable, rapid prototyping system for drive technology


Your drive's control unit can be freely programmed via the programming interface. The LN-Toolbox can be used to rapidly simulate complex, variable-speed drives in Matlab®/Simulink®, and then program the control unit with automatically generated code. Under variable loads, the system can be subjected to complex analyses with the help of advanced tools. Matlab®/Simulink® is already being used by educational institutions around the world. Supplemented by the power electronics training system, this environment now also enables a comprehensive approach for training engineers in the areas of power electronics and drive technology.

Your benefits

- Fast prototyping system for power electronics
- A special Matlab®/Simulink® toolbox allows easy hardware access
- Data visualization in real time
- The same Matlab® model is employed for simulation and code generation for hardware

Components

Three-phase isolation transformer
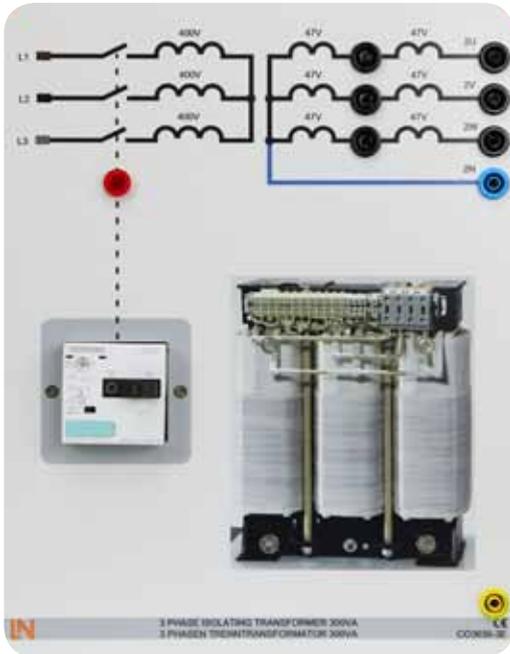
Serving as a power supply unit in all power electronics experiments, the isolation transformer optimizes protection during experiments by virtue of its galvanic isolation.

• Output voltage: 3x 94V with centre tap (47V)
• Power: 300VA/1000VA for operation with 300W/1kW machines
• Thermo-magnetic overload protection

Drive machines

All machines in the 300W and 1kW classes can be connected to the power electronics system. Thus, the following drives can be realized:

• Variable-speed DC drive
• Frequency converter drive with asynchronous motor
• Electronically commutated drive
• Servo-drive with synchronous servo-motor

The drives can be investigated and optimized conveniently by means of the servo-machine test stand.

Control unit: Self-commutated converter
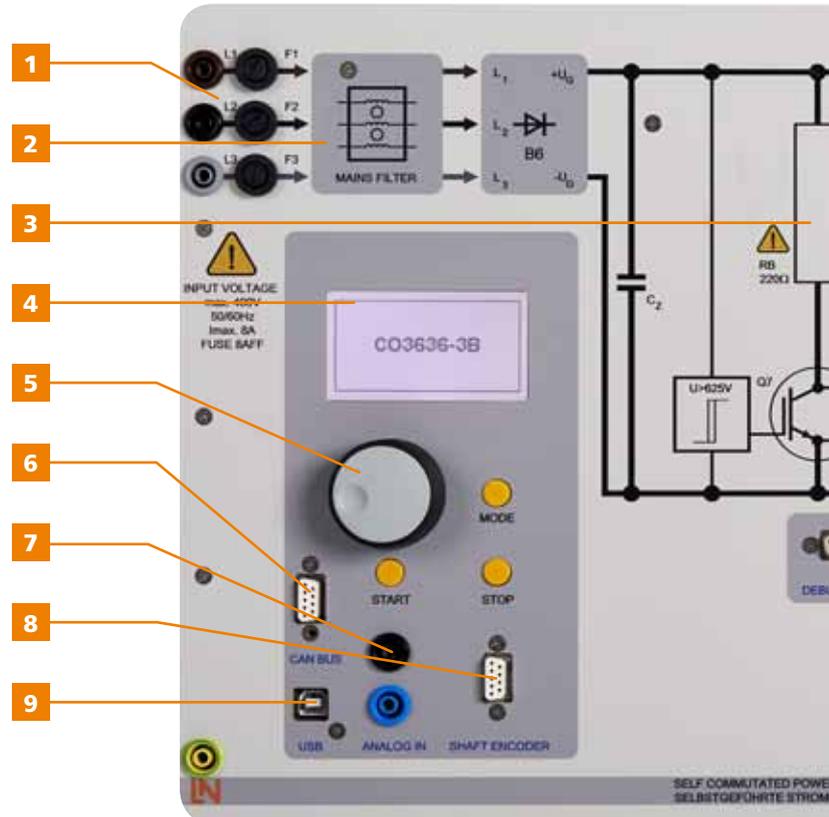
1 Input voltage range: 47 to 3x 230V

2 Integrated input filter

3 Integrated brake chopper with a powerful 300W resistor

4 DSP-controlled driving and measuring unit, integrated measurement of 6 voltages and 3 currents, display of operating states

5 Intuitive user operation by means of a control dial and pushbuttons

6 CAN-bus port for networking drive systems

7 Analog input: +/- 10V
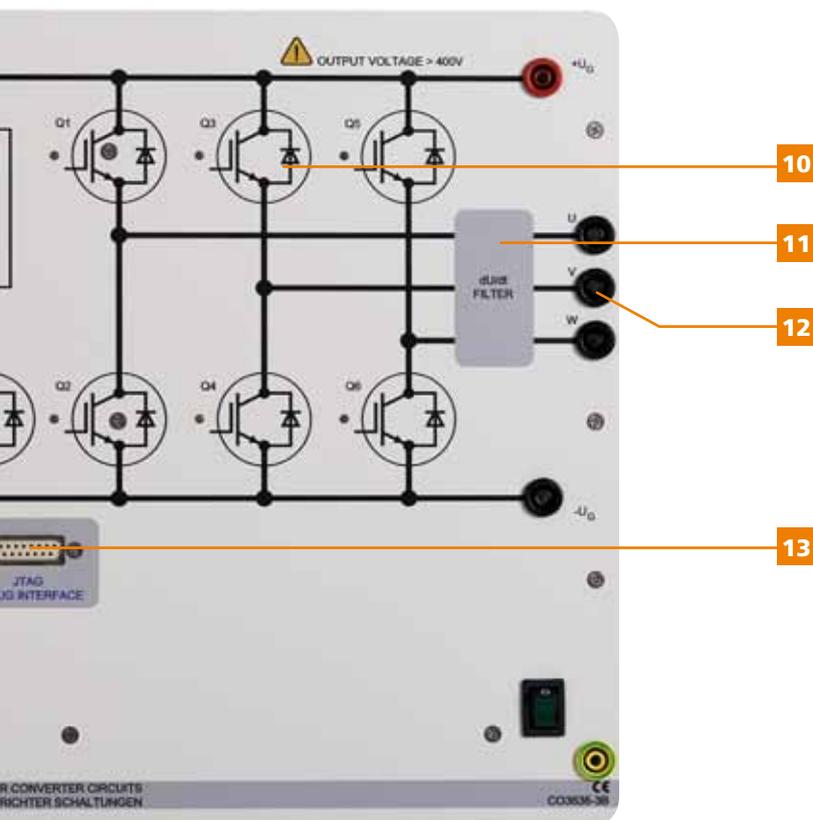
Intelligent load unit
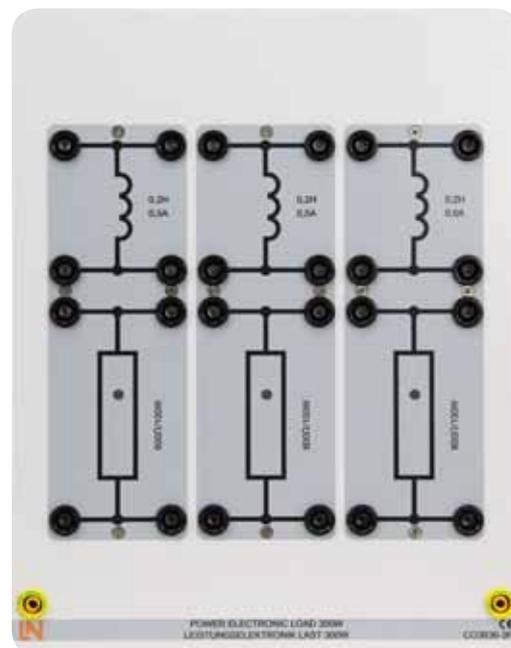
This unit is suitable as a load for all experiments on power electronics.

- Resistive load (600Ω, 3x 100W)
- Inductive load (3x 0.2H, 0.5A)
- LEDs for indicating the current's direction and intensity
- Auto-reset overload protection

8 Galvanically isolated input for incremental encoder with a resolution of 1024 increments/revolution

9 PC connection via a galvanically isolated USB port

10 6-fold IGBT with display of operating states

11 Output filter for improving electromagnetic compatibility

12 A high output current of max. 10A allows operation of machines in the 300W and 1kW classes

13 Programming interface for running applications created in Matlab®

Lucas-Nülle

Self-Commutated Converter Circuits

Training System

The widespread proliferation of power electronic equipment requires electronics specialists and engineers alike to command in-depth knowledge enabling them as users to handle such devices competently and in a resource-saving manner or to put them in a position to systematically explore the subject in research and development.

For that reason power converters are a fundamental constituent in curricula for students studying electronics and electrical engineering. The "Self-commutated converter circuits" training system comprises sophisticated experiments to convey the basics in hands-on exercises and project-oriented work. Circuitry, modulation and rotary-field generation are the key topics rendered easily comprehensible thanks to theoretical sections and, especially, graphic animations, thus rapidly leading to the next level of competence.

Training system: "Self-commutated power converter with a passive R-L load"

Training objectives

- Pulse-width modulation
- DC chopper in single- and 4-quadrant operation
- AC power switch
- Three-phase converter with block/sine commutation and space-vector modulation
- Resistive and inductive loads
- Suppressor circuits, link circuits, free-wheeling
- Control characteristics and operating graphs
- Interpolation, clock frequency, ripple
- Frequency analysis and examination of harmonics

Interactive Learning Environment

How do the various control methods function in modern power electronics?

Learn about various control methods and techniques in modern power electronics. Determine system response at different loads and clock frequencies; examine various control methods; analyze signals in the time and frequency domains.

The ILA course guides you step-by-step through the experiments.
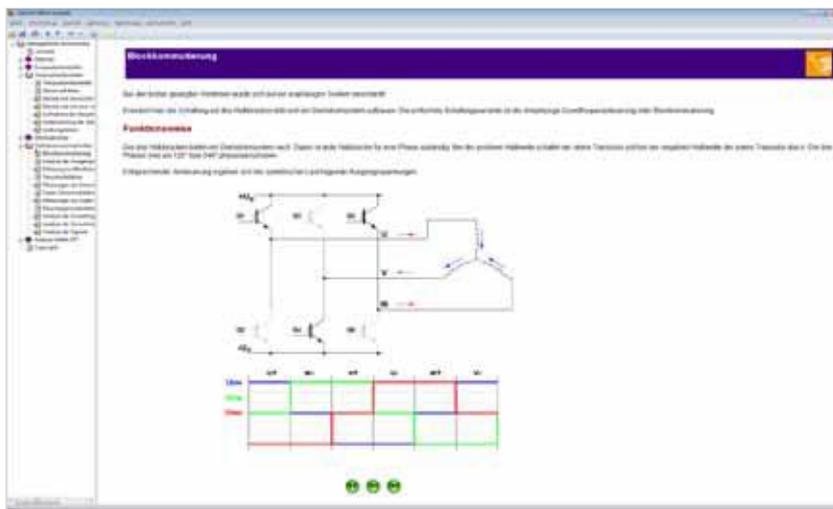
Switching sequence of power semiconductors with block commutation in the ILA course titled "Self-commutated power converters"

Harmonics analysis in the case of block commutation

What effects do the various control methods have?

Operate different loads with various clock frequencies and control techniques; analyze the signal characteristics and the response in the frequency domain. Customized virtual instruments allow selection of different operating modes and recording of measured signals. Measured values can be dragged and dropped into the ILA course.

Frequency Converter Drives

Training System

A modern frequency converter can transform any standard three-phase motor into a variable-speed drive. The standard three-phase motor's robustness and widespread use have significantly contributed to the tremendous success of electronic drive technology incorporating frequency converters. Today, frequency converters are found in numerous applications in the textile industry and in packaging machinery, lifting equipment and even washing machines. The interplay between power electronics and motor operation can be studied and learned with the "Frequency converter drives" training system.

Training system: "Frequency converter drive with servo-machine test stand"

Training objectives

- Differentiating between various converter types
- Design of modern frequency converters
- Link circuits
- Brake choppers
- Control methods (U/f-characteristic, U/f2-characteristic, vector control)
- Speed adjustment and ramps
- Optimization methods
- Analysis of voltage and frequency relationships

Interactive Learning Environment

How are various operating points set?

Learn how a frequency converter's frequency and output voltage influence speed, torque, power and efficiency.

Determine the various operating points with the help of the servo-machine test stand and ActiveServo software. Lucid representations make it possible to directly determine operating behaviour.

The ILA course provides the necessary information and guidelines to perform the hands-on experiments.
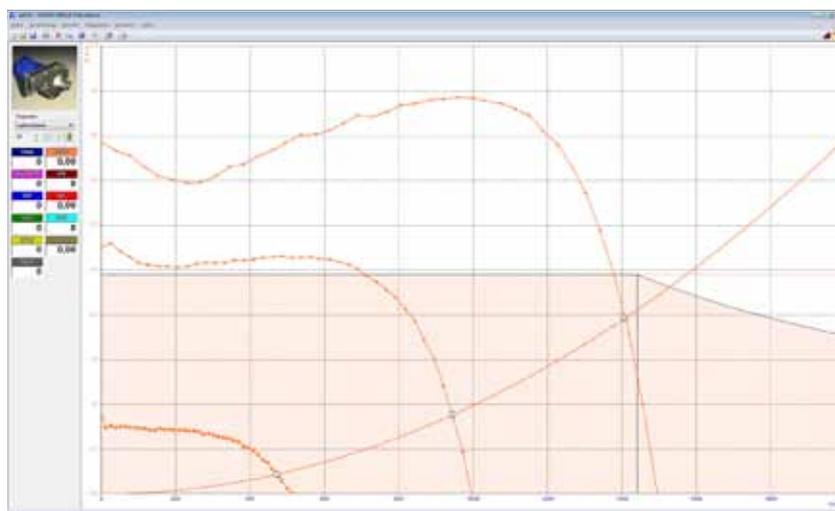
Variable-speed pump drive
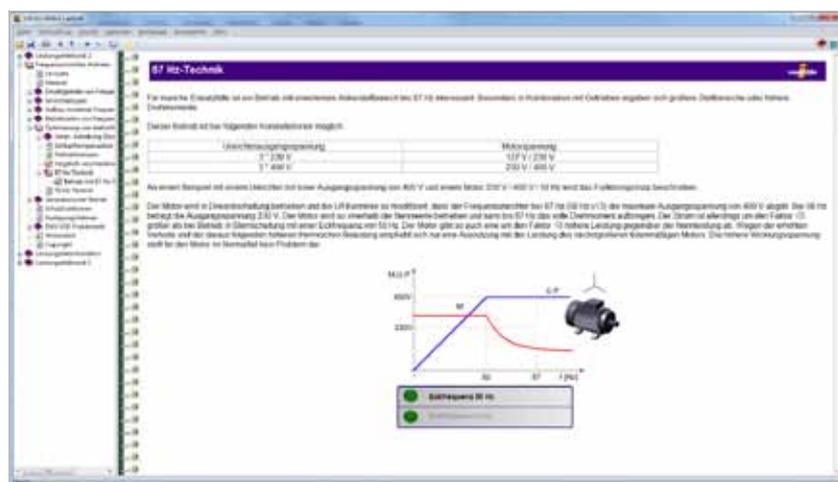
87Hz technology in the ILA course on frequency converter drives

What does 87Hz technology mean?

Drives with an extended control range are important for certain applications. Thanks to the converter's design it is possible to use what is known as 87Hz technology. In this case, the converter's control range is increased by a combination of intelligent motor circuitry and appropriate parameterization, without resulting in any torque losses.

Servo-Drives

Training System

Servo-drives are variable-speed units designed to meet high dynamic response and overload demands. They are often used in automation solutions involving significant changes in speed and torque, such as in machine tools or robot systems. The training system for servo-drives clearly demonstrates the functionality of a variable-speed servo-system with a permanent magnet.

Training system: "Servo-drives with a servo-machine test stand"

Training objectives

- Design of a servo-drive
- Investigation of coordinate and encoder systems
- Operating principle of a servo-motor with electronic commutation
- Analysis of modulation
- Design of control loop structures
- Analyses of variable-speed drives

Interactive Learning Environment

How is a synchronous servo-motor designed?

The ILA course shows how modern servo-motors are designed, how the various position measurement systems function, and what controller architecture is employed. Informative illustrations and animations help investigate functionality and mode of operation.

Layout of a synchronous servo-motor in the ILA course on servo-drives
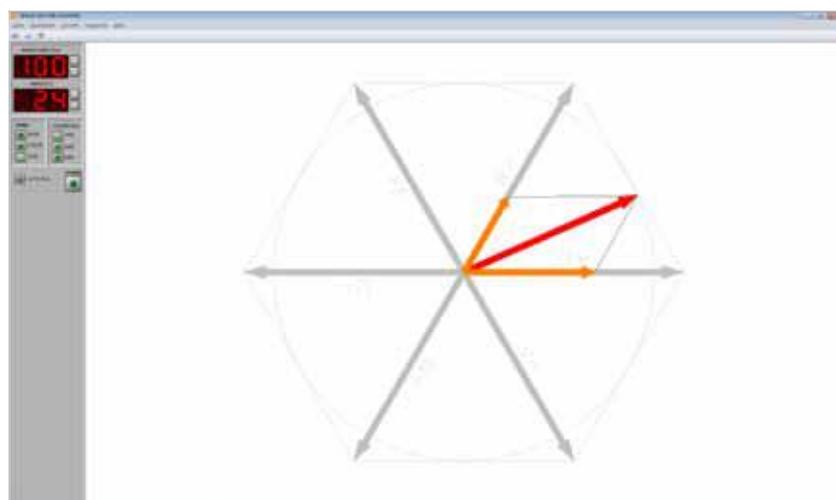
Space-vector control of the servo-motor

What is load commutation?

Control power semiconductors via rotor position, and learn how various parameters influence speed and torque.

Optimize the drive's properties using virtual instruments, and examine the drive's behaviour using the servo-machine test stand.

Converter Drives with a DC Motor

Training System

Thanks to their simple control structure, converter drives with a DC motor are particularly suitable for an introduction to the subject of variable-speed drives. A separate consideration of closed-loop current and speed control enables the student to put the controller parameters into initial operation and then to optimise them step-by-step. The training system, in effect, provides a vivid and graphic demonstration of how a variable-speed drive system operates.
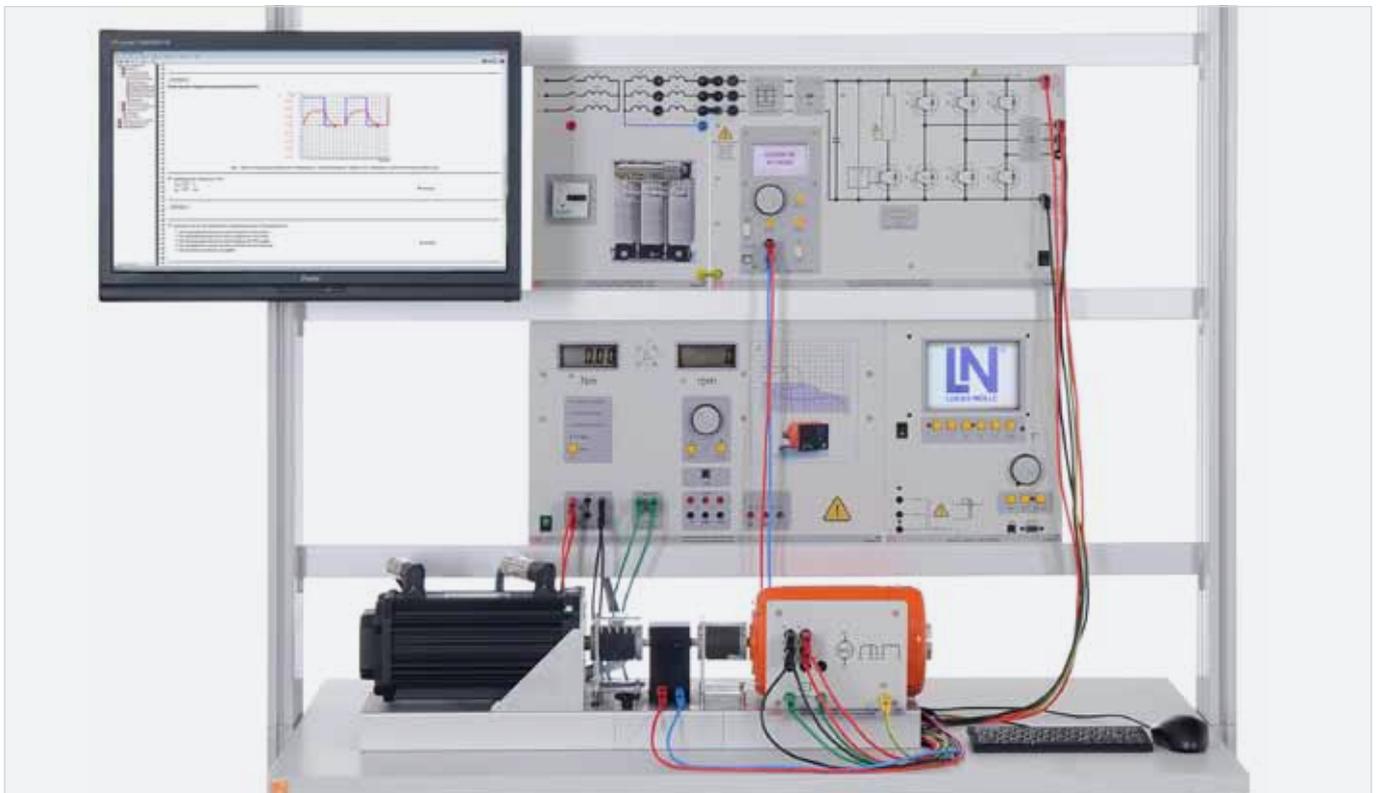
Training system: "Converter drives with a DC motor and servo-machine test stand"

Training objectives

- Open-loop speed control in single-quadrant operation
- Open-loop speed control in 4-quadrant operation
- Closed-loop speed control in general
- Closed-loop current control
- Cascade control
- Computer-aided analyses of controlled systems and their controllers
- P-, PI-controller parameterization
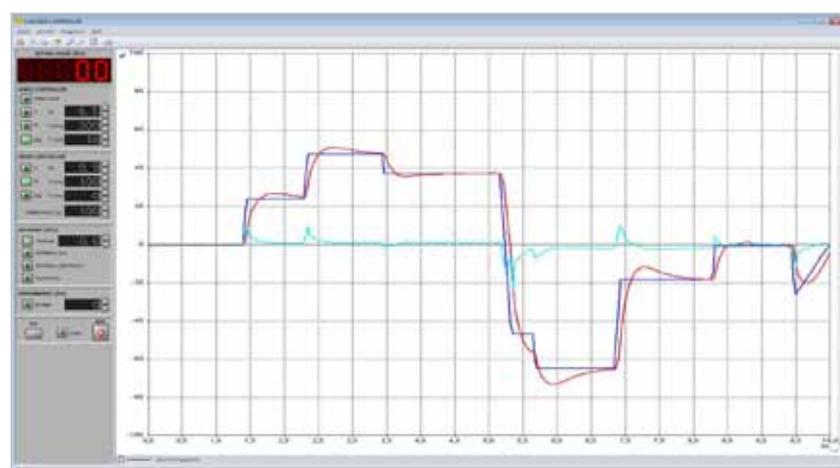- Controller optimization

Interactive Learning Environment

What is cascade control?

In the case of dynamic DC drives, both the current and the speed have to be subjected to closed-loop control. To do this, cascade controllers are a classic solution where two control loops are integrated into each other. The inner loop is used for current control, the outer loop for speed control.

This ILA course shows how to perform calculations and controller optimization in individual steps.
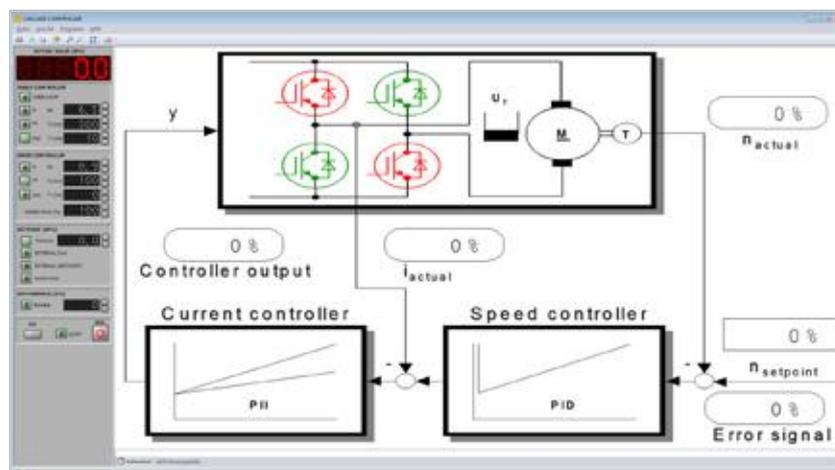
Design of a drive system with a DC motor

Partly optimized operation of the DC drive

Which controller works best with a DC drive?

Use the DC drive with different controller configurations, and learn about their advantages and disadvantages. Optimize the controllers, and use the software to analyze the transient responses of the speed and motor power. Ascertain measures to further optimize the drive.

Model-Based Development of Drives with Matlab® / Simulink®

Expand the Training System to a Programmable, Rapid Prototyping System for Drive Technology

Nearly all electrical drives such as those used in industrial plants and electric vehicles incorporate three-phase technology. The automatic control of such drives, for instance, to ensure smooth start-up or measured acceleration, entails mathematically complex and elaborate programming. Implementation is therefore often characterized by very long development times.

A newly created toolbox will in future make it possible to simulate complex controller structures for three-phase drives with Matlab®/ Simulink® in advance, and subsequently test them on a real converter with a motor and load by means of automatically generated code.

Training system: "Field-oriented control of asynchronous motors with Matlab®/ Simulink®"

Your benefits

- Safe handling thanks to intrinsically safe hardware (all protective functions are implemented independently of software)

- Promotion of a deeper understanding of a complex subject, e.g. in education and training, or through use of the toolbox in laboratory programs accompanying theory

- Very rapid, model-based, parameterizable software generation for own controllers in conjunction with industrial applications

- Pursuit of new methods of research on rotary-field drives, e.g. control using state-space methods, condition monitoring for errors, sensorless automatic speed control using new observational techniques

- Impressive design possibilities for closed-loop control of three-phase drives

- Creation of complex algorithms using fast control cycles of 125 µs

- P-, PI-controller parameterization

- Controller optimization

Quicker results with the Matlab® toolbox

A toolbox adapted to the power electronics hardware enables rapid implementation of one's own applications. Special templates allow simple introduction by configuring the system so that only a few adjustments still need to be made by the user. The toolbox provides users with all the necessary modules for controlling hardware-related functions, as well as blocks for fast transformations and controllers. The system can be extended at will by adding one's own library elements to those of the Matlab®/Simulink®.
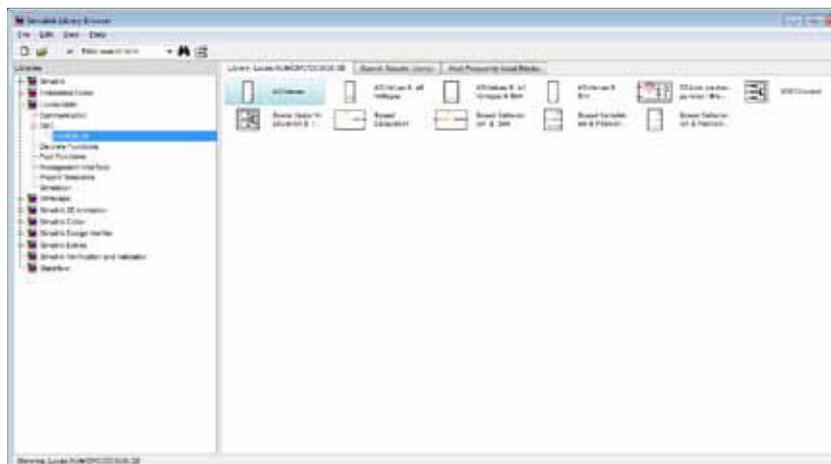
Special toolbox for the training system
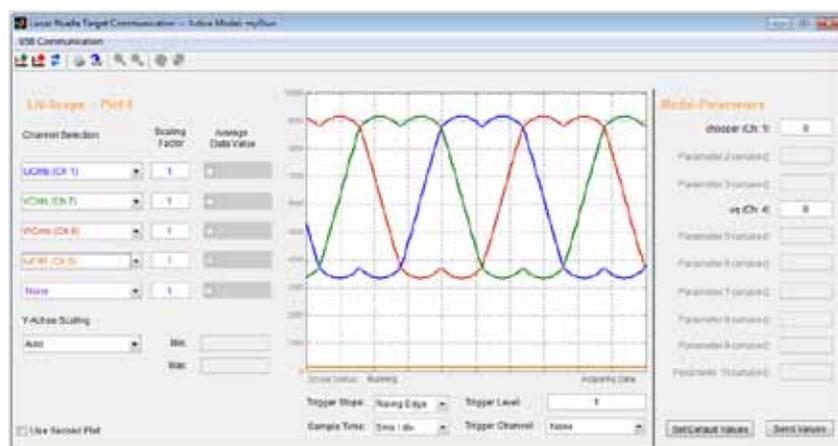
Graphic user interface in the Matlab® environment

Hardware connection via Matlab® Scope

A special graphic dialog serves to establish the connection between Matlab® and hardware via a USB interface. The time characteristics of all internal variables can be visualized during runtime. A number of different time resolutions and trigger options are available here. The signals can be displayed in the time domain as well as the frequency domain. The display can be divided into two units, making it possible to visualize up to ten signals simultaneously. Parameters such as those related to the controller can be uploaded conveniently from the PC to the hardware during runtime.

Field-Oriented Control of Asynchronous Motors with Matlab® / Simulink®

Training System

Three-phase drives are used in almost all electrical drives today. The automatic control of such drives is a mathematically complex and costly undertaking. With the help of a special toolbox for Matlab®/Simulink®, the training system makes it possible to simulate complex control algorithms, and subsequently test them by means of automatically generated code on authentic, intrinsically safe hardware incorporating a motor and load.

Training system: "Field-oriented control of asynchronous motors with Matlab® / Simulink® and a servo-machine test stand"

Training objectives

- Creation of an HIL system (hardware in the loop) under real-time conditions
- Modeling and design of field-oriented control on a continuous design level
- Discretization of control for operation on a DSP (digital signal processor)
- Creation and optimization of current and speed controllers
- Park and Clarke transformation
- Integration of space-vector modulation for optimal control of IGBTs
- Decoupling of field-oriented currents and voltages
- Speed detection via an incremental encoder
- Comparison of simulation results with real measurements

Interactive Learning Environment

How does field-oriented control work?

Drives with field-oriented control are today found in many machines. The high dynamics and ample torque reserves characterize these drive systems.

This ILA course guides you step by step through the topic of field-oriented control. In addition to the creation of the process control models, the course also covers the testing and optimization of the control loop.
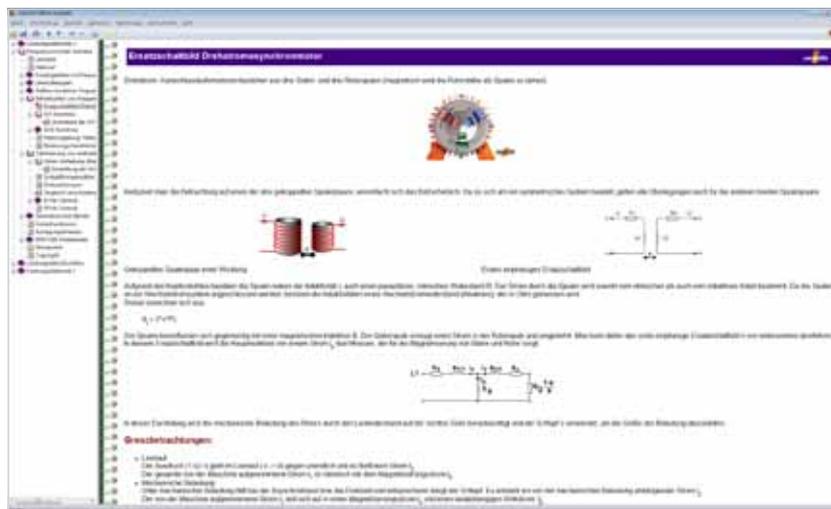
ILA course: "Field-oriented control of asynchronous motors"
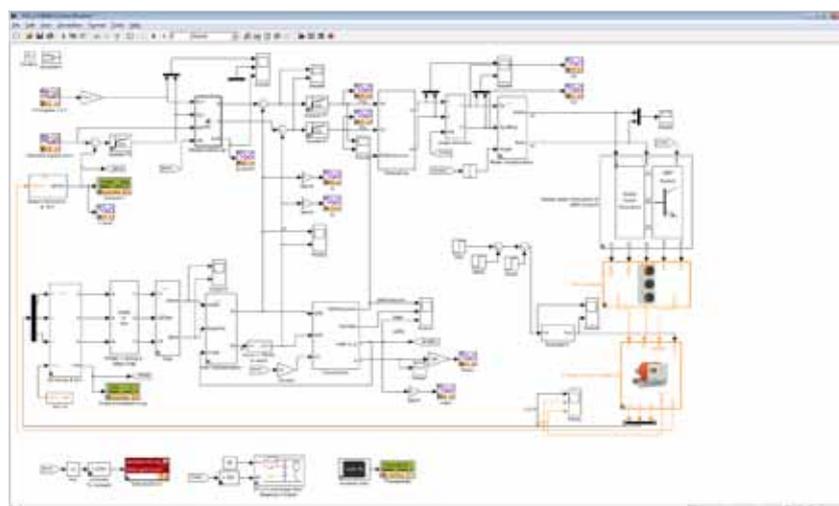

Field-oriented control of a three-phase motor

**Simulation or real control?
Decide for yourself.**

A single Simulink® model forms the foundation for simulation or functions as the program for the actual hardware. It is only after completion that the user chooses between simulation or application in the real system. Accordingly, it is possible during simulation to test and optimize the control loop and then use the model to put the actual hardware into operation. This procedure guarantees rapid learning success. At the same time the distinction between simulation and real systems is clearly recognised.

Variable-Speed Permanent-Magnet Servo-Drives with Matlab® / Simulink®

Training System

Synchronous servo-motors are now used in many modern drives. In addition to dynamic response, energy efficiency is also playing a major role. The training system permits in-depth investigations of existing control loop concepts thanks to the open programming feature Matlab®/Simulink® and permits new approaches to be safely tested. For instance, the system can be used to create drives typically employed in industry and the automotive sector.
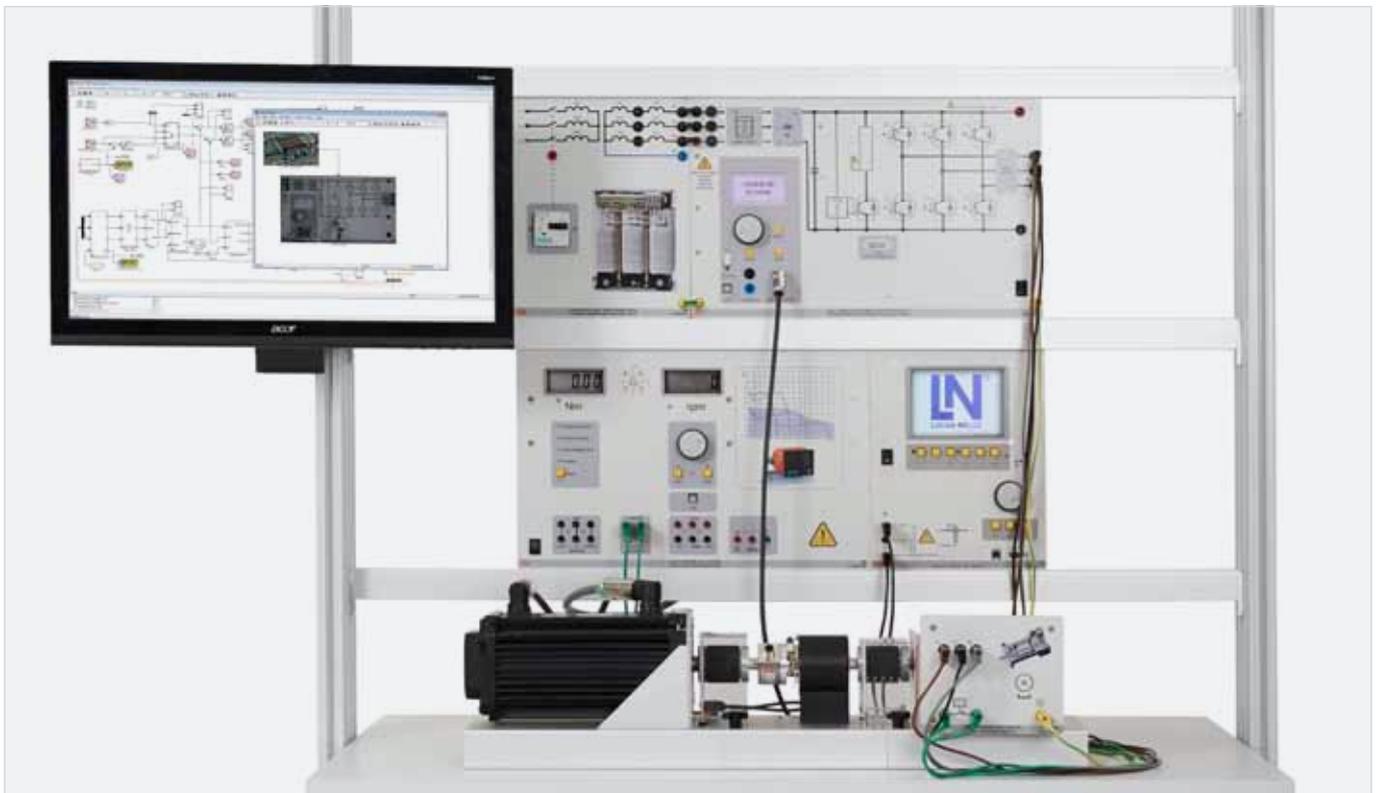
Training system: "Variable-speed permanent-magnet servo-drives with Matlab® / Simulink® and the servo-machine test stand"

Training objectives

- Creation of a HIL system under real-time conditions
- Modelling and design of an automatic servo control on a continuous design level
- Discretization of a closed-loop control for operation on a DSP
- Creation and optimization of current and speed controllers
- Park and Clarke transformation
- Integration of space-vector modulation for optimal control of IGBTs
- Decoupling of field-oriented currents and voltages
- Speed and position detection via an incremental encoder
- Comparison of simulation results with real measurements

Interactive Learning Environment

How does a drive with a synchronous servo-motor operate?

Permanently-excited synchronous motors do not work without corresponding control electronics. Create a synchronous servo-drive and work your way through this topic, starting with open-loop control all the way to closed-loop control.

The ILA course guides you step by step, the open system making it easy to implement progressive concepts so that the drive can be expanded according to your own ideas.

Function of the feedback system in the ILA course
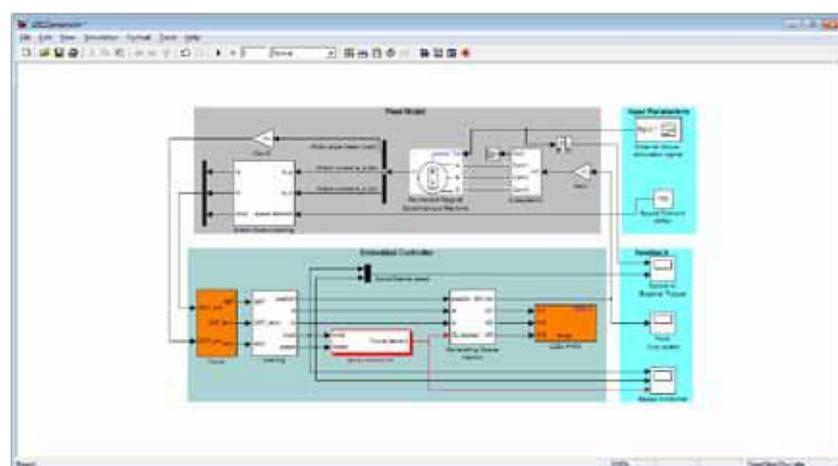
*Model-based design of a servo-drive system*

What is my drive's dynamic response?

Use the servo-machine test stand to examine the drive. Different load emulations such as use of a variable flywheel make it possible to investigate the drive's control response under real-life conditions. Optimize controller parameters and make independent decisions on the performance of your drive.

DC Drives with Cascade Control Using Matlab®/Simulink®

Training System

Thanks to their clearly arranged control structure, power converters with DC motors are particularly suitable for programming one's own initial, own control algorithms. This training system permits implementation, optimization and operation of the student's own control configurations. Not only conventional approaches, but also new ideas and extensions can be tried out safely in the open system.
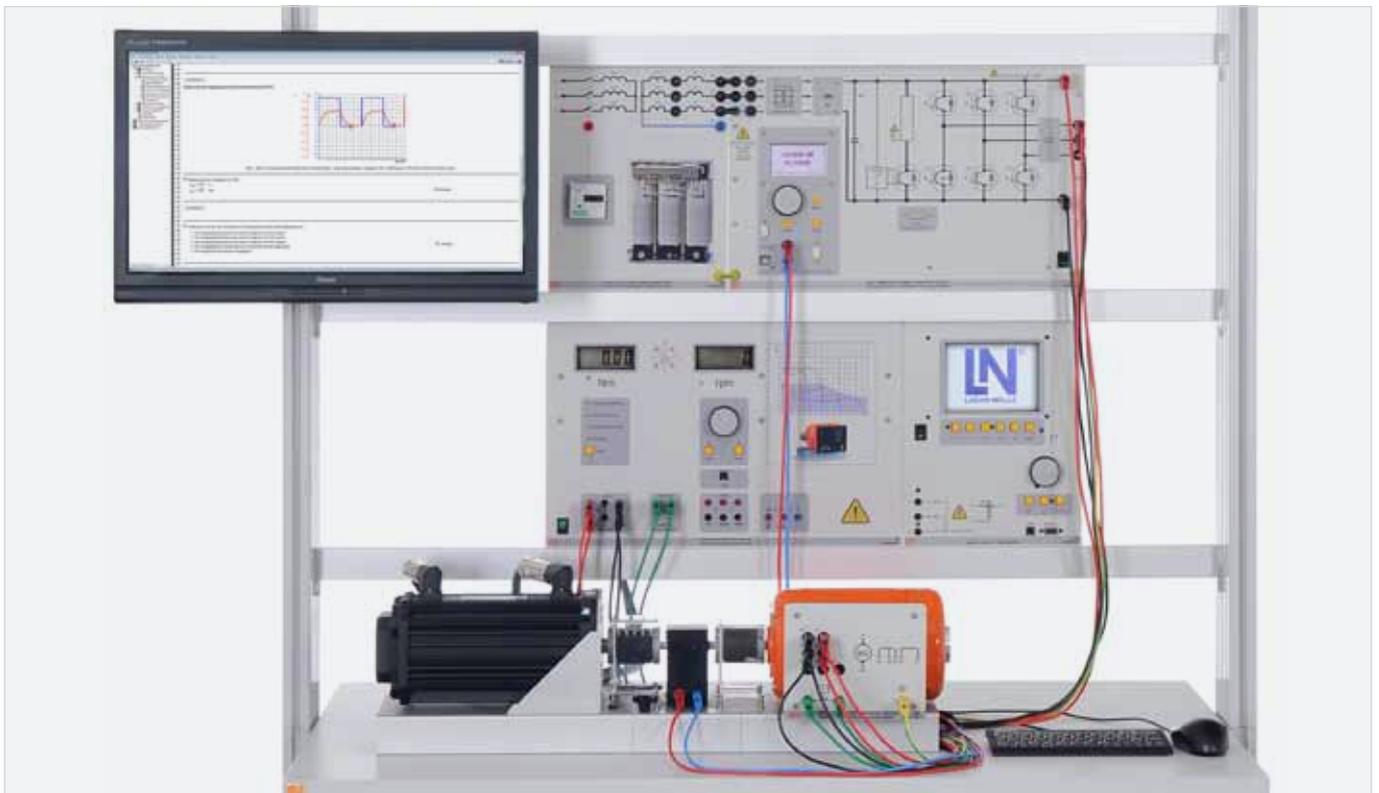
Training system: "DC drives with cascaded control using Matlab®/Simulink® and a servo-machine test stand"

Training objectives

- Creation of a HIL system under real-time conditions
- Modelling and design of cascade control loop for DC motors at the continuous design level
- Discretization of the control loop for operation on a DSP
- Creation and optimization of current and speed controllers
- Speed detection via an incremental encoder
- Comparison of simulation results with real measurements

Interactive Learning Environment

How does a variable-speed DC drive work?

This ILA course provides practical examples to demonstrate the design, configuration and commissioning of DC drives. Current and speed controllers are implemented and optimized step by step. Direct application in control enginee-ring models and work with real systems ensure successful learning on a lasting basis.

Fundamentals of DC motors in the ILA course
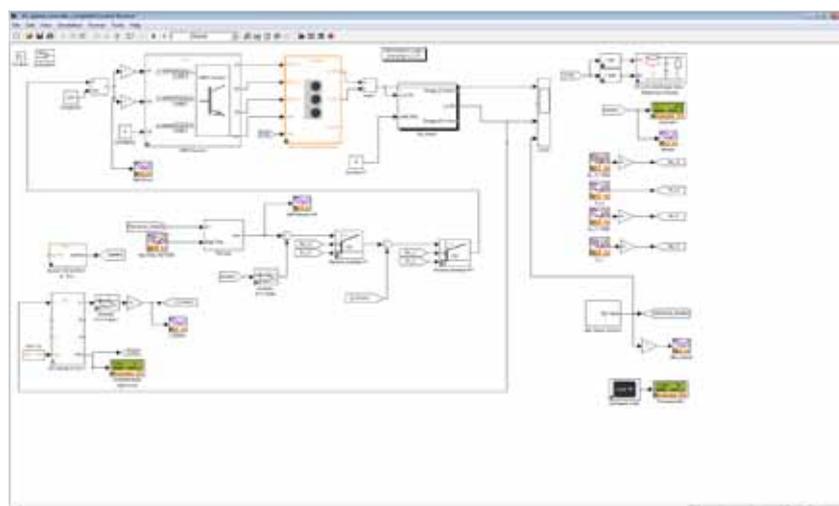
Optimization of controller settings

How are controllers designed?

The training system can be used to test controller design as part of simulations as well as real environments. A graphic user interface optimizes access to the control variables' dynamic signals and thus permits rapid adjustments to settings as well as their testing.

Computer-Assisted Learning Environment

Interactive Lab Assistant (ILA)

An Interactive Lab Assistant (ILA) supports you while you conduct the experiments. Besides serving as a guide through the experiment procedures, this assistant provides valuable theoretical information and records readings. The necessary laboratory documentation is created as printed matter or PDF files automatically in the background.

If you want to customize the manuals, simply use the LabSoft Classroom Manager to revise or supplement the contents.
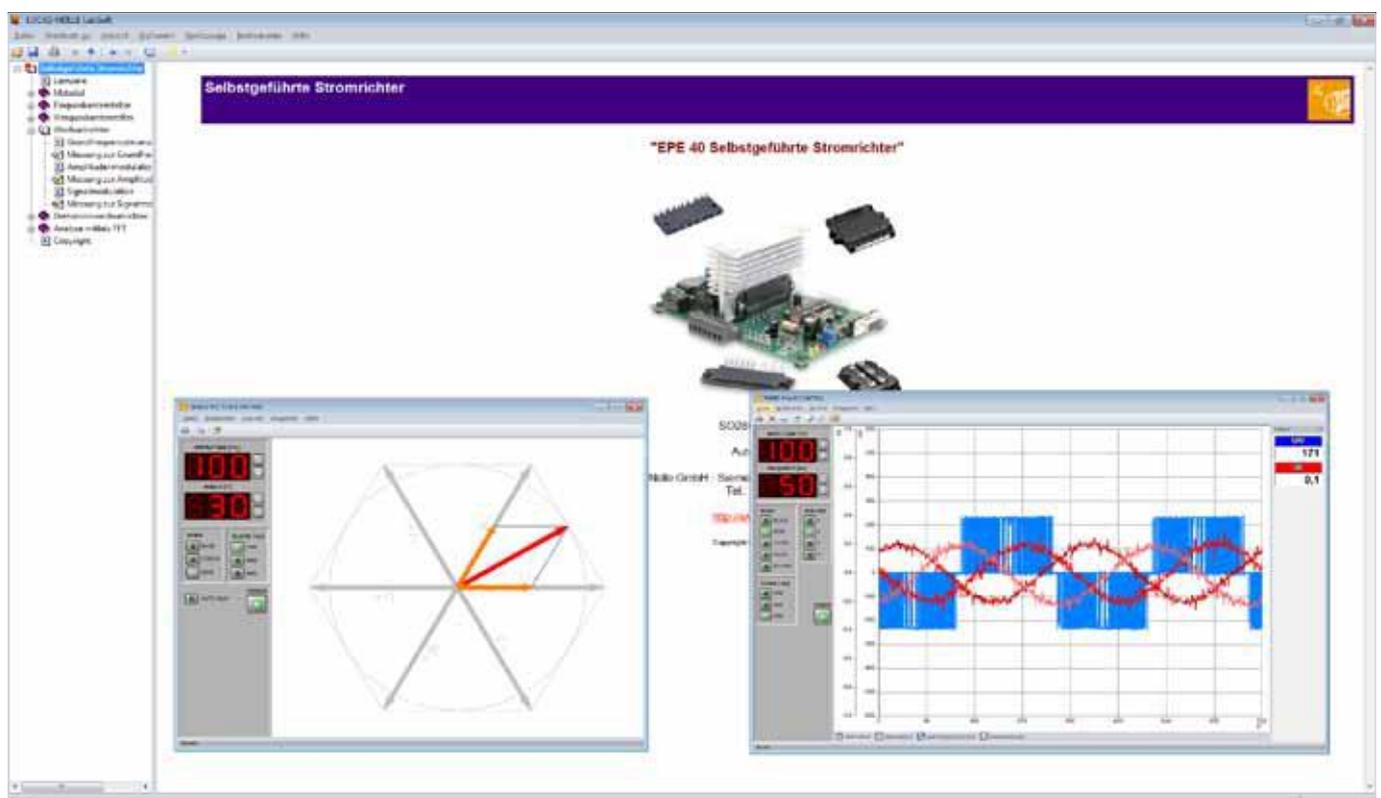

Your benefits

- Theoretical reference material
- Support in conducting experiments
- Clear representation of experiment setups
- Access to real instrumentation
- Integrated operating manuals
- Documentation of experiment results (creation of experiment reports)
- Knowledge test and feedback

LabSoft Classroom Manager

The LabSoft Classroom Manager is a comprehensive administration software with which practical teaching and learning processes can be conveniently organized and managed. Suitable for all LabSoft-based educational programs such as ILA, UniTrain-I, InsTrain and CarTrain, the Classroom Manager comprises five program sections mentioned below.
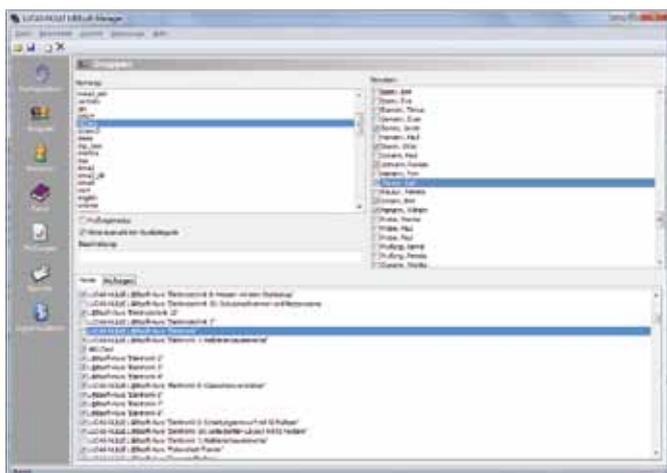

LabSoft Manager: Manage your LabSoft courses, students and whole classrooms with the LabSoft Manager to make the appropriate educational content available to students at all times.
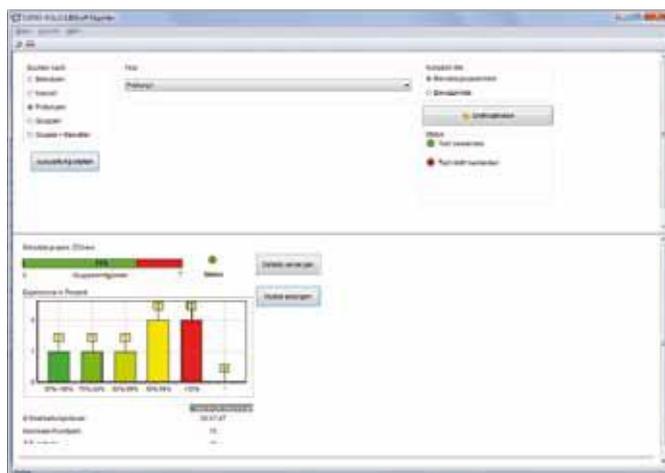

LabSoft Reporter: Learning progress and test results are presented by the LabSoft Reporter. Numerous evaluations of results achieved individually or collectively in courses and tests permit selective monitoring.
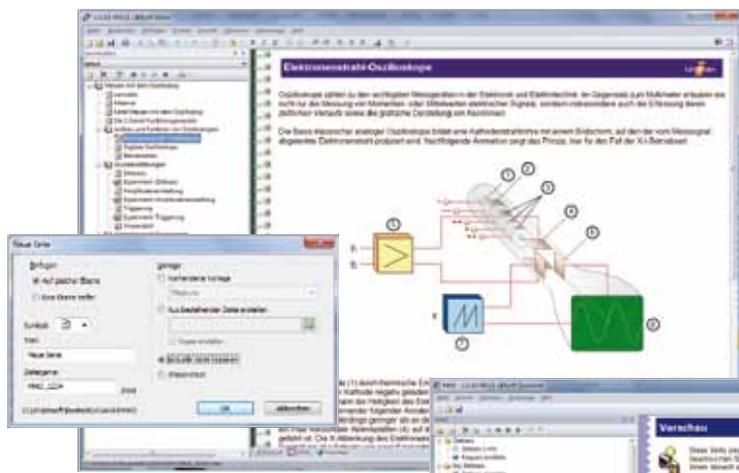
LabSoft Editor: This editor can be used to create new courses and revise existing ones. Numerous wizards guide the user step by step through the necessary details.
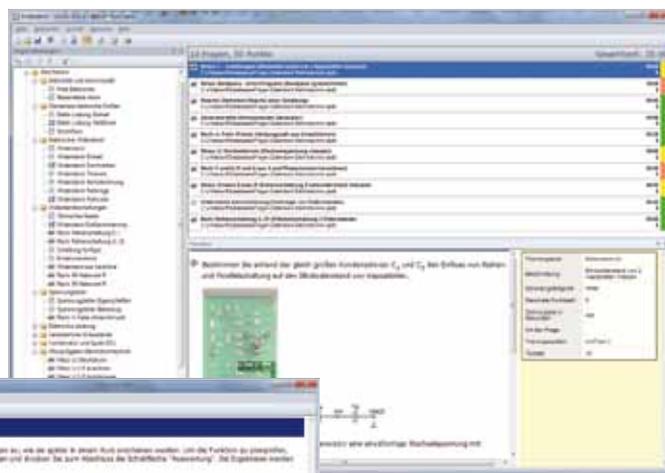
LabSoft TestCreator: The LabSoft TestCreator can be used to create tests for examining acquired knowledge and practical competence simultaneously.
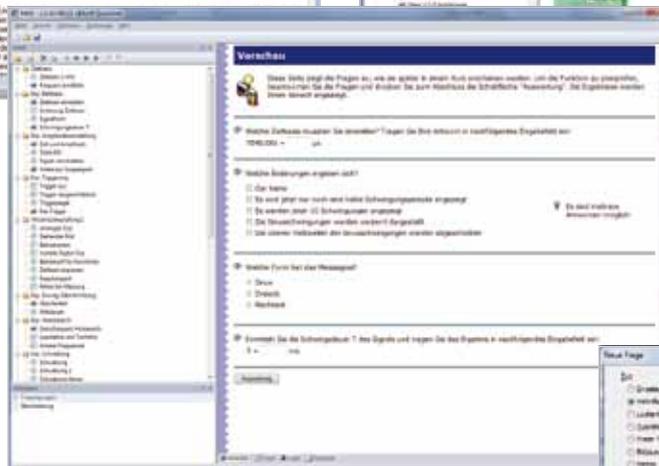
LabSoft Questioner: The LabSoft Questioner provides many prototypes for creating questions, measurement exercises and exam problems. The exercises and questions can be added to courses and tests.

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*Further information is provided in
our catalogue on drive technology.*

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